Heavy Gas Čerenkov Detector January 2011 Update

Garth Huber,
Wenliang Li & Lee Sichello
University of Regina

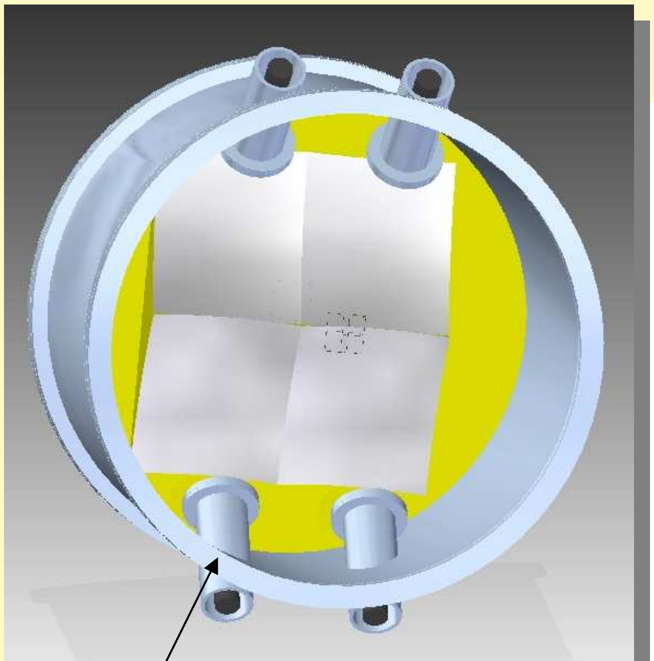
SHMS Detector Working Group Meeting. January 13, 2011.

Outline

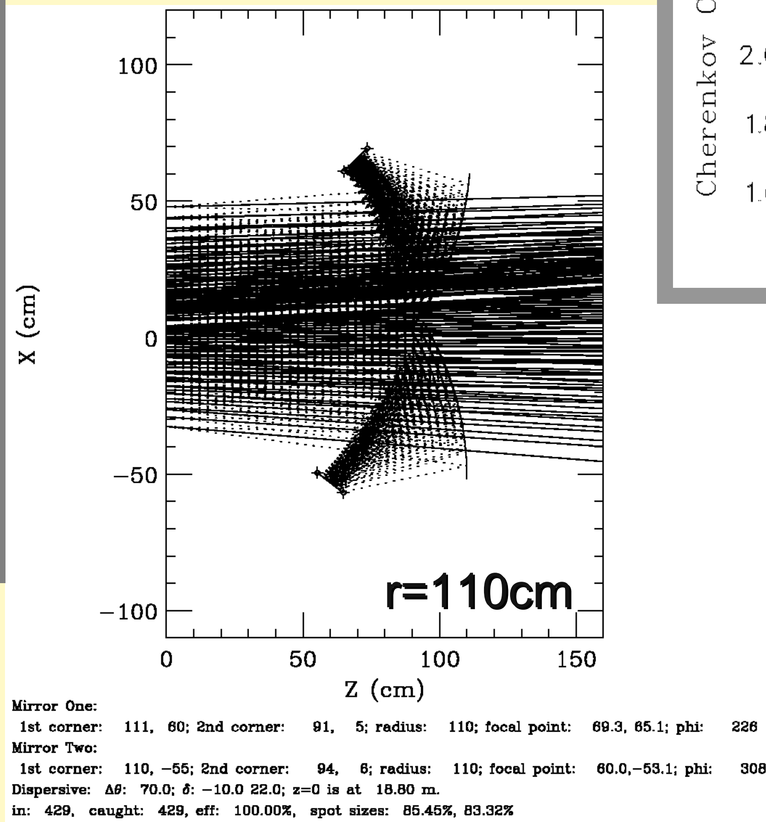
- Brief Overview.
- **Tests of sample mirror from Sinclair Glass.**
- Our plans for next ~6 months.
- **New FEA calculations of Pressure Vessel entrance window from University of Alberta.**
  - Aluminum alloy used is now 2024-T3, in conformance with JLab Safety Requirements.
  - Two hydroformed depths and window curvature radii considered.

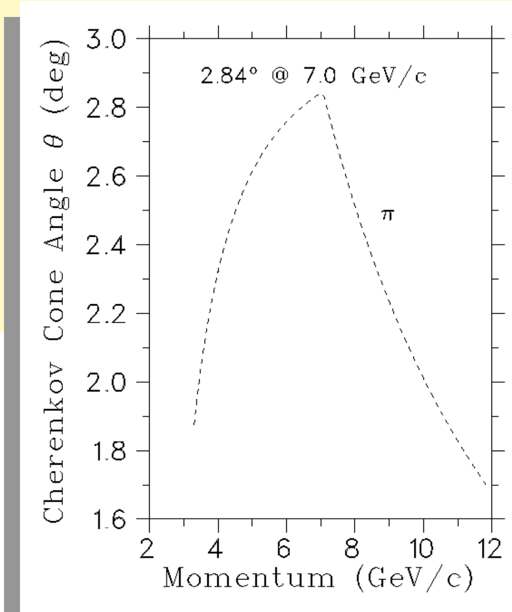
Heavy Gas Čerenkov Overview

Cylindrical aluminum vessel similar to HMS Gas Čerenkov (rated to 1 atm underpressure).



170cm inner diameter.





Hardest to collect all light at 7 GeV/c.

Dr. Garth Huber, Dept. of Physics, Univ. of Regina, Regina, SK S4S0A2, Canada.

Test Mirror from Sinclair Glass

- Sinclair Glass recently purchased Europtec's mirror works (the previous vendor who supplied quotes).
- Because we require mirrors with square corners, instead of their usual 2" corner radius, Sinclair made a test mirror for us, which arrived in early-December.
- Sinclair used a mold made for a different client, similar to our requirements with 40" mirror radius of curvature.

Nov. 12. 2010 4:34PM SINCLAIR GLASS No. 9249 P. 1

SINCLAIR GLASS

A Division of Middletown Enterprises, Inc.
105 North Wabash Avenue • P.O. Box 527
HARTFORD CITY, INDIANA 47348

Phone: 765-348-3100
Fax: 765-348-3823

November 12, 2010

University of Regina – Dept. of Physics
Attn: Dr. Garth Huber
Regina, SK S4S-0A2
Canada

Dear Dr. Huber,

The following is our quote you requested.

21.654" x 23.622" x 1/8" clear glass – bent to a spherical outside radius of 43.425" – swiped edges – bulk packed
The piece price based on 10 pieces is $350.00 each.
The tooling charge is $5150.00.

Please note the tooling charge is subject to change based on material costs after 30 days.

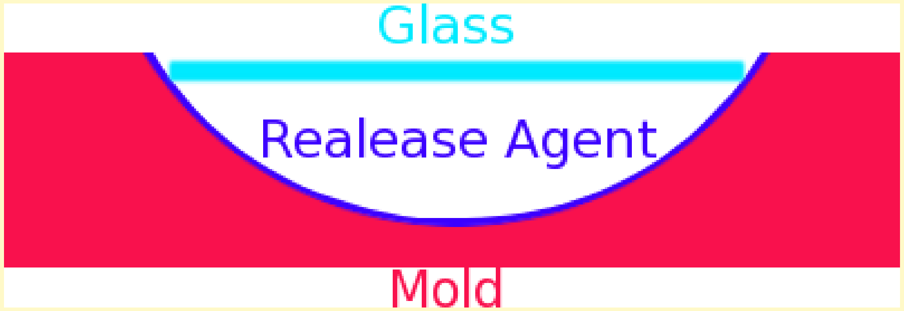
There is currently a 10% additional surcharge in effect. The above items are quoted F.O.B. Hartford City, IN. Our payment terms are 1% discount on the 10th and 25th, net 30 days.

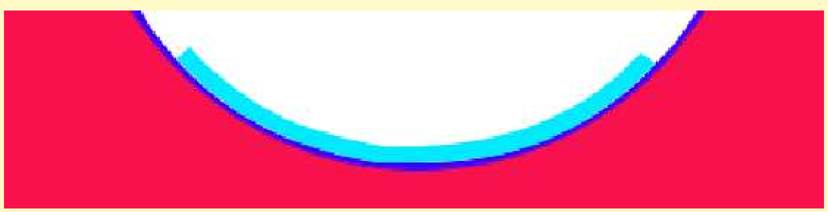
Thank you for the opportunity to quote your specialty glass requirements. If you have any questions, please feel free to contact me directly at 765-348-3100.

Sincerely,

Andrew Mair
President

How the Mirrors are Made





It will be helpful to understand how the mirrors are made:

Stage 1

- Spread release agent onto the mold.
- Place flat glass onto the mold.

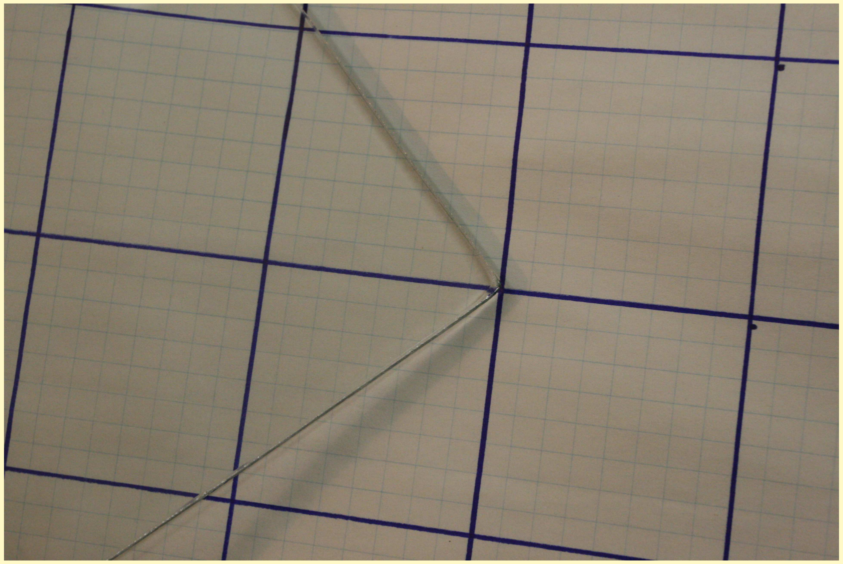
Stage 2

- Place mold into the oven.
- Glass slumps toward the mold.

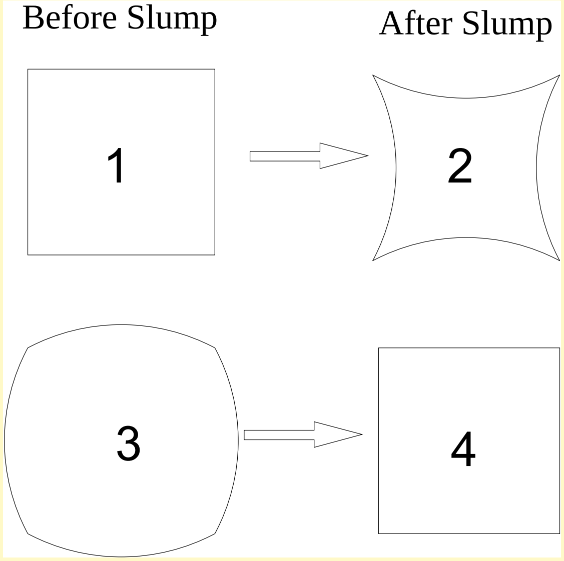
Stage 3 (Important)

- **Sinclair Glass usually does not let the glass slump all the way to the mold.**
- **To assure the test mirror is exactly spherical, they allowed the glass to slump all the way into the mold.**

Test Mirror Corner & Edge



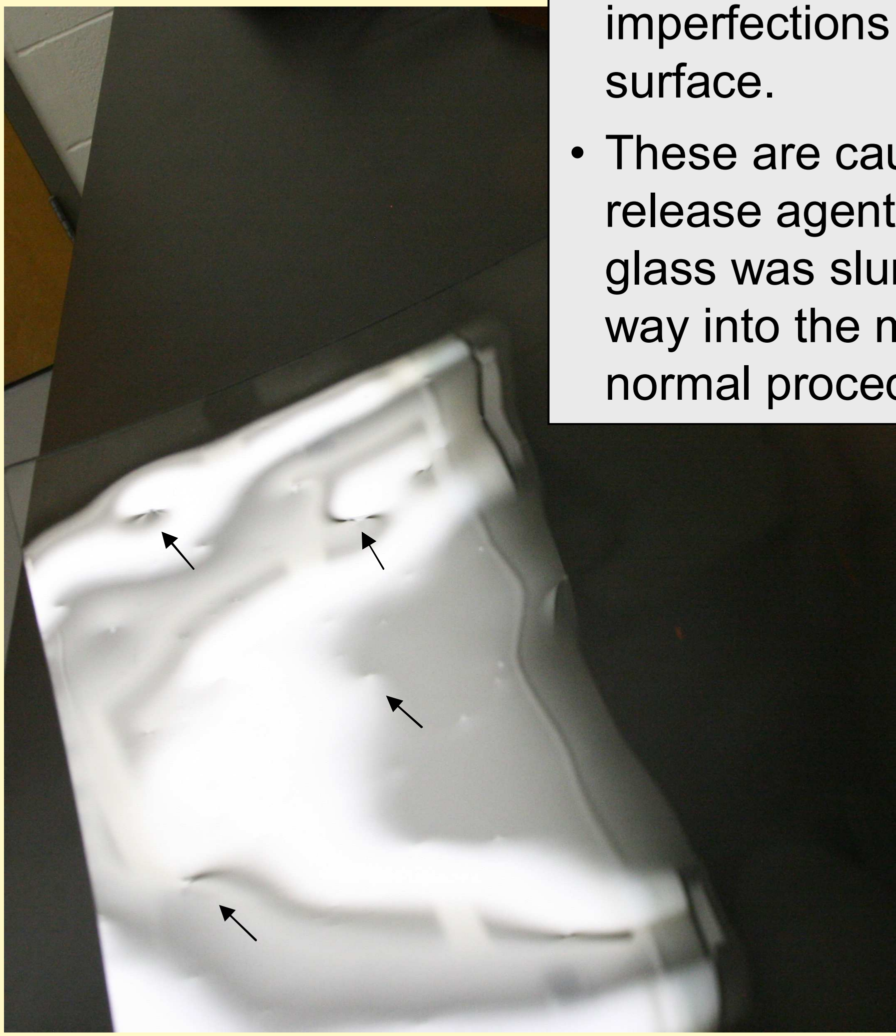
- The test mirror was a simple square blank (1→2).
- We are happy with the quality of the test mirror corner and edges.

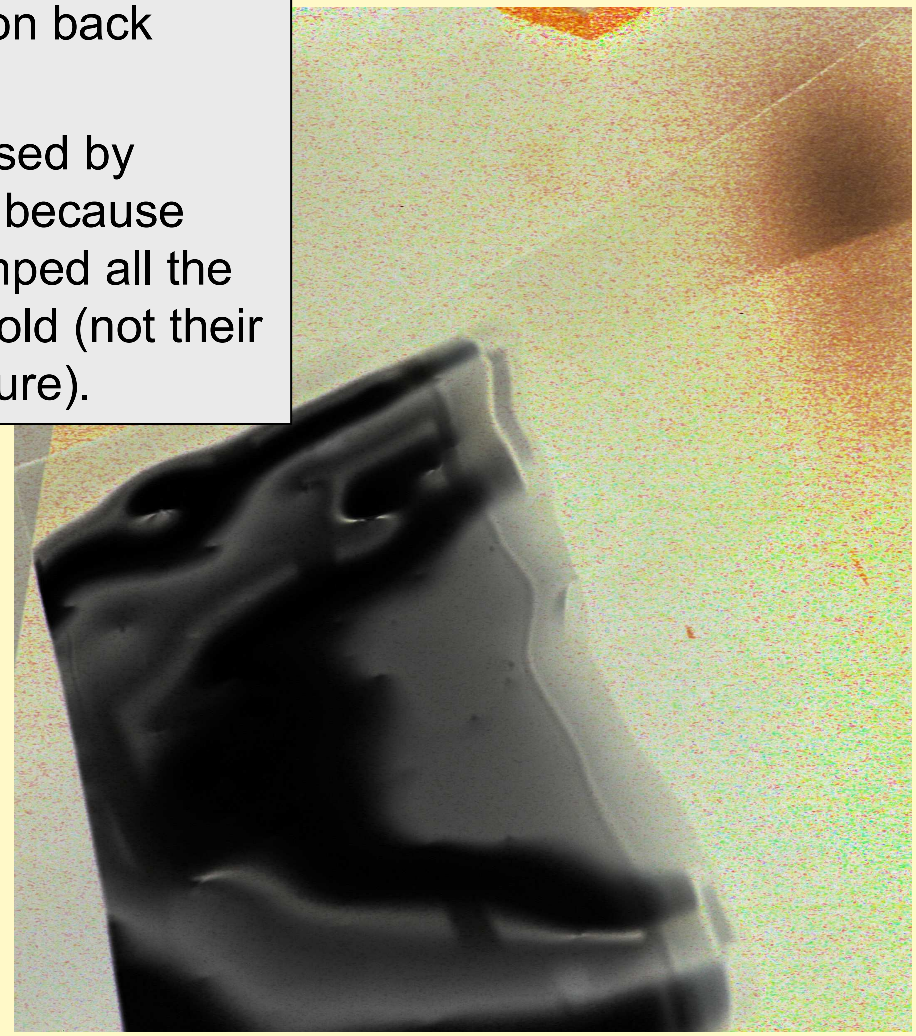


- For the actual mirrors, Sinclair will precut the glass to shape 3→4, to give even more square corners.

Test Mirror Surface Imperfections

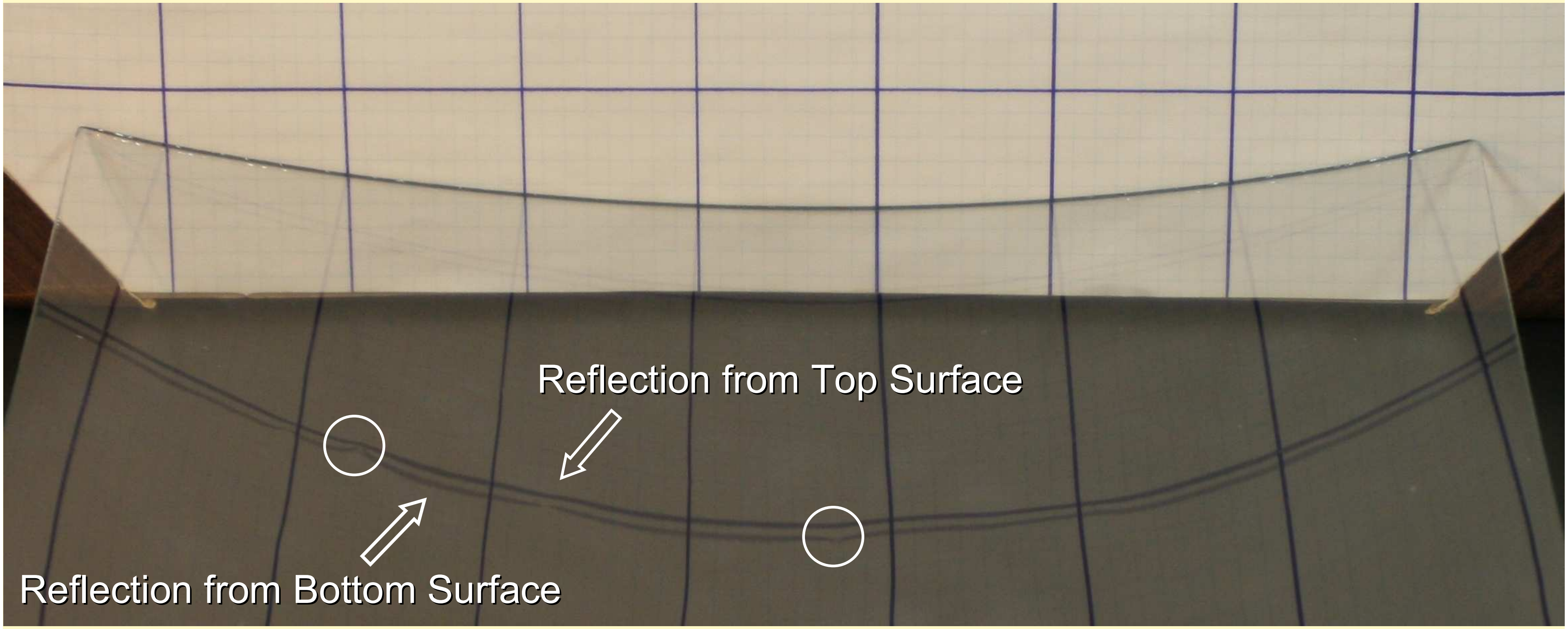
- Black arrows indicate large imperfections on back surface.
- These are caused by release agent, because glass was slumped all the way into the mold (not their normal procedure).





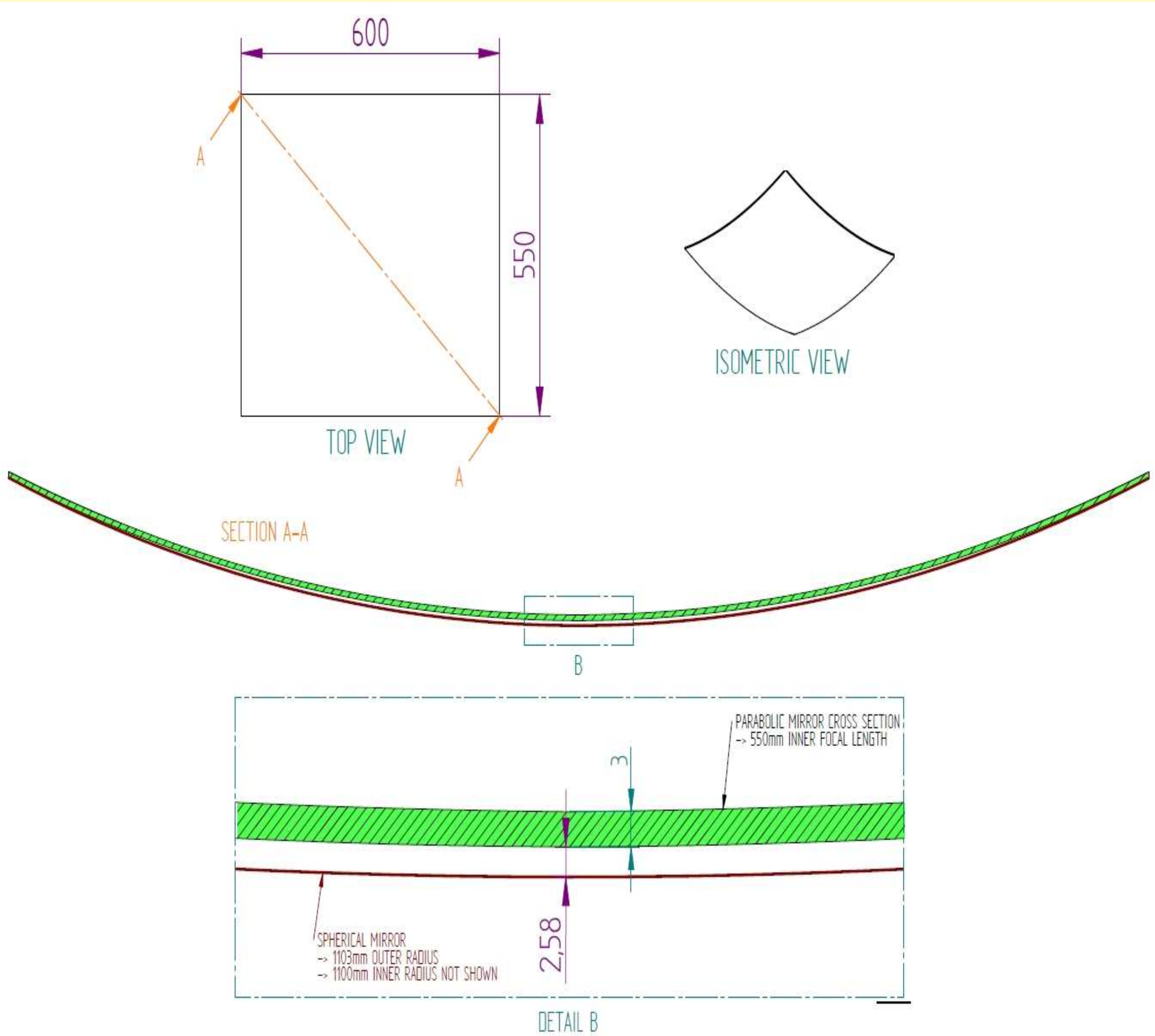
Reverse video of photo at left.

More Detail on Surface Imperfections



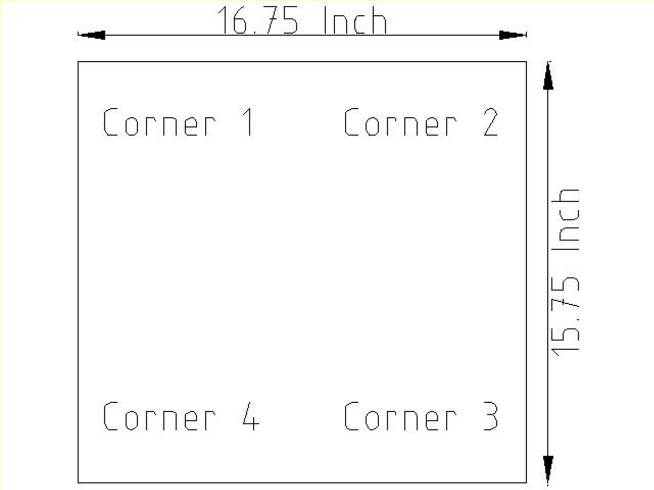
- **Double Reflection of line provides useful check of top vs. bottom surface quality.**
- Circled dips in bottom line confirm Sinclair's claim that imperfections are primarily on the bottom surface.
- Top reflected line is also not smooth, so some imperfections have made their way through to the top surface.

Our suggestion to reduce surface imperfections

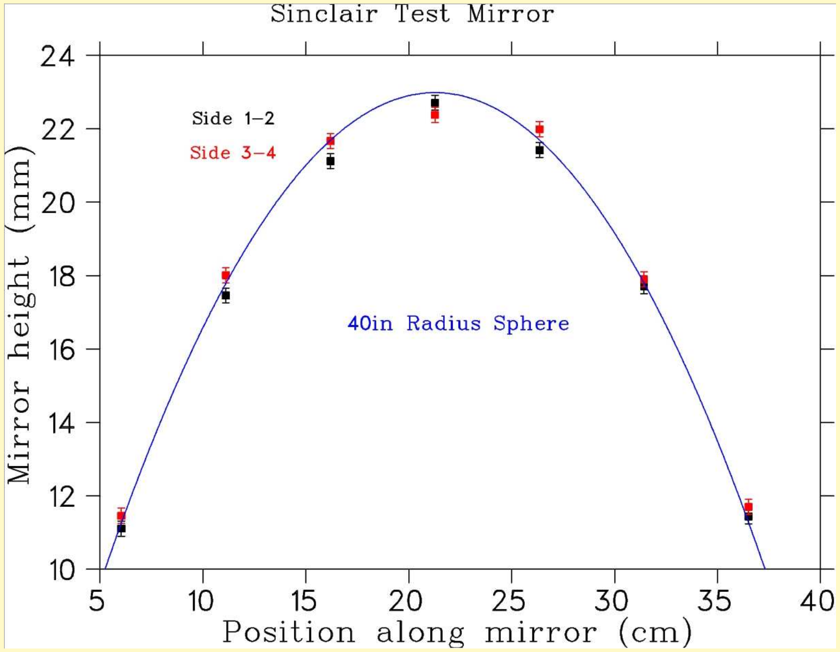


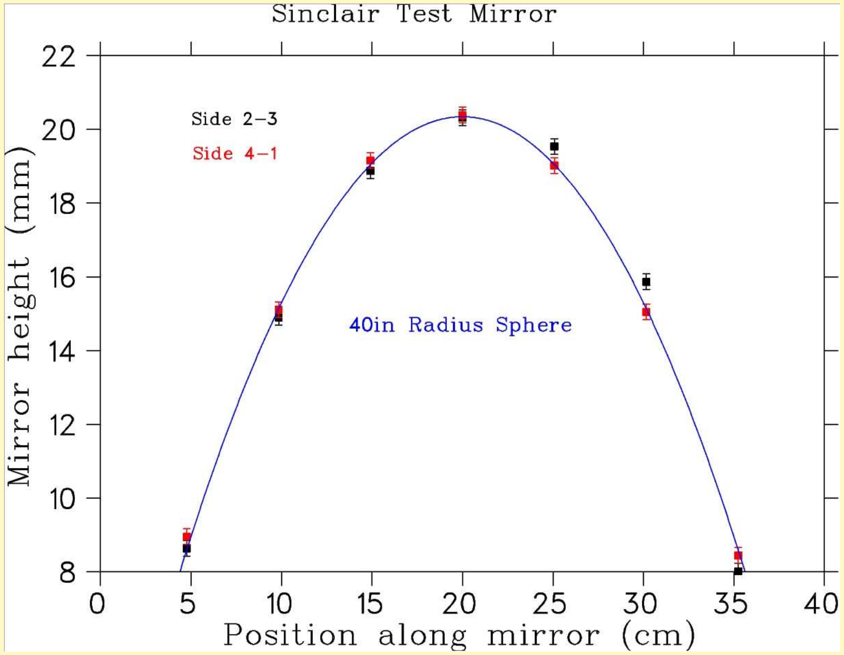
- Sinclair Glass typically leaves a small gap between the glass and mold when slumping.
- We can tolerate (in fact prefer) a slightly non-spherical mirror.
- A parabolic mirror of the same focal f=55.0cm length will provide better focusing for our application.
- The bottom of the parabolic mirror is 2.58mm shallower than the spherical mirror at the center.
- Sinclair agrees a gap makes things easier from their viewpoint, but there will be a ~1/16” gap variation from mirror to mirror.

Test Mirror Radius of Curvature Check



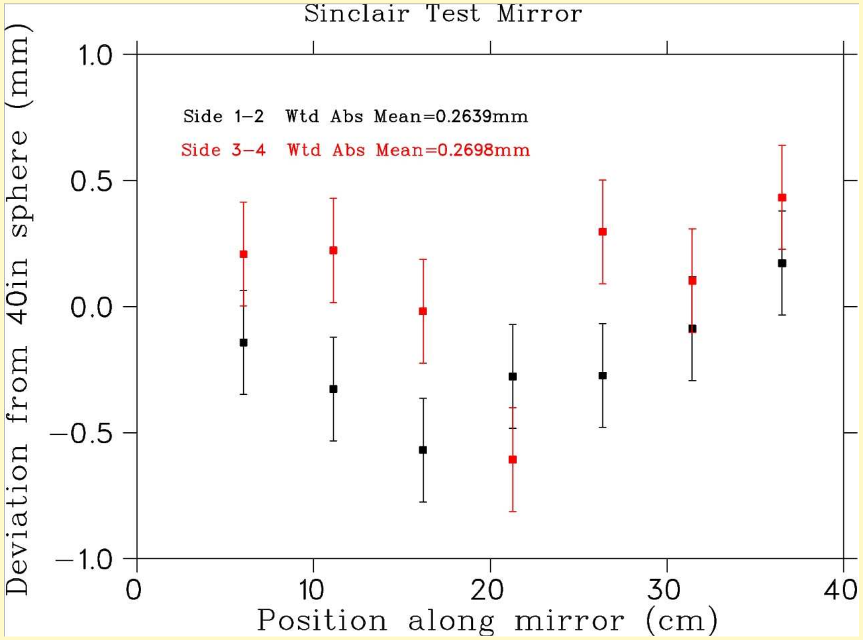
- We measured the mirror height at 7 locations along each edge, and compared with Sinclair's specified 40" radius of curvature.

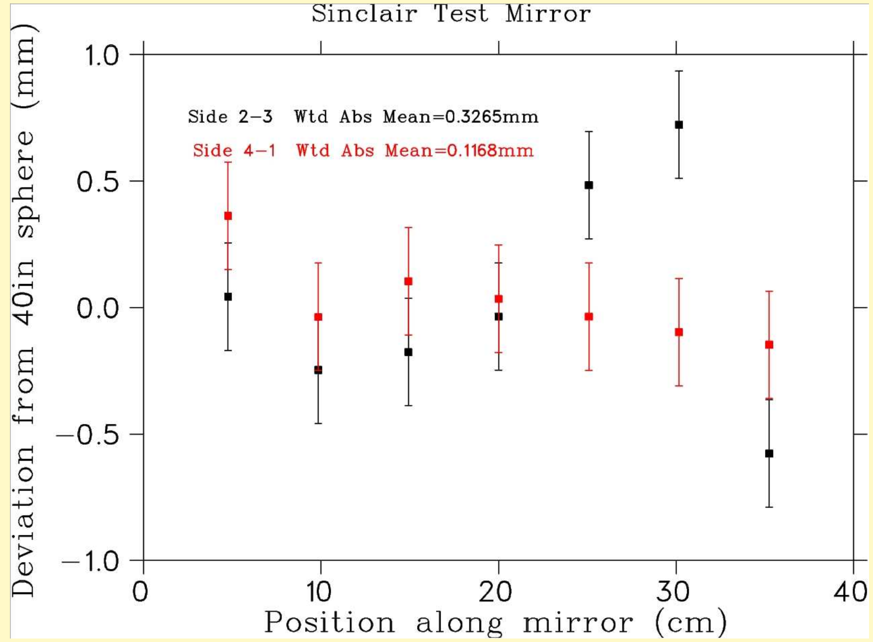




Dr. Garth Huber, Dept. of Physics, Univ. of Regina, Regina, SK S4S0A2, Canada.

Curvature Deviation from 40" Sphere





- Our measurements confirm the glass curvature is close to a 40" sphere along the 4 outer edges.
- Curvature measurements on interior of mirror are planned but not yet completed.

Summary of Sinclair Glass Test Mirror

- **Good**
  - Edges and Corners are very good.
  - Radius of curvature seems close to Sinclair's stated 40".
- **Bad**
  - Surface imperfections (caused by release agent and mold surface).
- **Possible Solution**
  - Glass does not have to be slumped all the way into the mold.

- **Mirror order will be placed shortly.**
- **Need to prepay Sinclair's tooling charges, with balance due upon delivery.**
- **Expect mirrors to be delivered ~8 weeks after order.**

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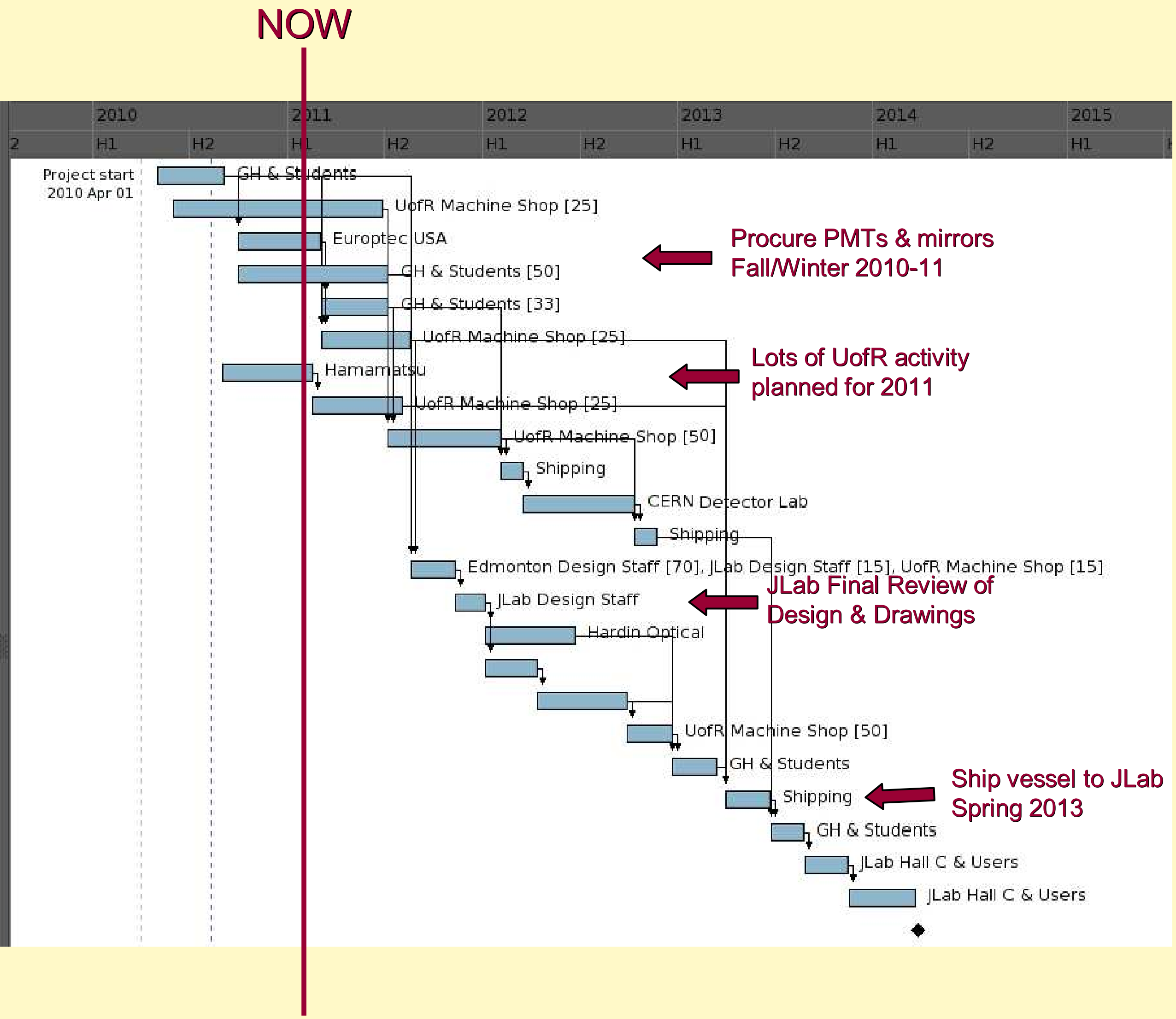
Geant4 studies planned for next ~6 mo.

- Ongoing bug checking and documenting of Geant4 code.
- **Implement Donal Day's PMT position sensitivity measurements in SensitiveDetector analysis to produce more accurate simulated photoelectron distributions.**
- **Continue double-checks of optimized PMT-mirror locations and angles before finalizing vessel design later this summer:**
  - **Determine sensitivity to misalignments.**
  - **Once mirrors arrive, can refine MC to more closely approximate actual mirror geometry.**
  - **Need to be sure all engineering constraints in mirror mounts, beam envelope, etc. have been taken into account.**

Project Timeline Plans *(updated Aug 11/10)*

WBS	Name
1	Finalize mirror selection via Geant4 Simulations
2	Prototype Mirror Stiffening Brackets
3	Mirror Procure
4	Finalize PMT and Mirror Placement via Geant4 Sim
5	Mirror Optical Testing
6	Mirror Mount Assemblies
7	PMTs, mu-Shields, Bases Procure
8	PMT Mount Assemblies
9	Mirror Stiffening Brackets
10	Ship Mirrors from Regina to CERN
11	Mirror Aluminization @ CERN
12	Ship Mirrors from CERN to JLab
13	Pressure Vessel Detailed Drawings
14	Pressure Vessel Final Design Review
15	PMT Adapters and Spectrosil Windows Procure
16	Pressure Vessel Vendor Bids
17	Pressure Vessel Procure
18	Window Hydroforming
19	Pressure Vessel Vacuum Test
20	Ship Vessel & Parts from Regina to JLab
21	Assembly of Detector in Test Lab @ JLab
22	Cosmic Tests at JLab
23	Install on SHMS
24	Completion of Project



FEA STUDY OF A HYDROFORMED ALUMINUM SHEET WINDOW FOR THE HEAVY GAS CERENKOV DETECTOR WITH THE IMPLEMENTATION OF A CONTACT MODELING FEATURE

Jan Soukup
University of Alberta
janskp0@gmail.com

- **2024-T3 aluminum alloy material analysed.**
- **Window hydro-formed to be initially spherical with studies made for a center depth of 53.4 mm and 146.9mm repectively.**
- **Window thicknesses analysed were 1mm for the 53.4mm center depth and 1mm and 2mm for the 146.9mm center depth.**
- **Bonded joint was assumed between the sheet and the window flange up to the R 12.5mm lip.**
- **Contact modeling was applied between the sheet and the rounded lip of the flange.**
- **The complexity of the analysis model was reduced by studying a quarter-symmetry segment.**

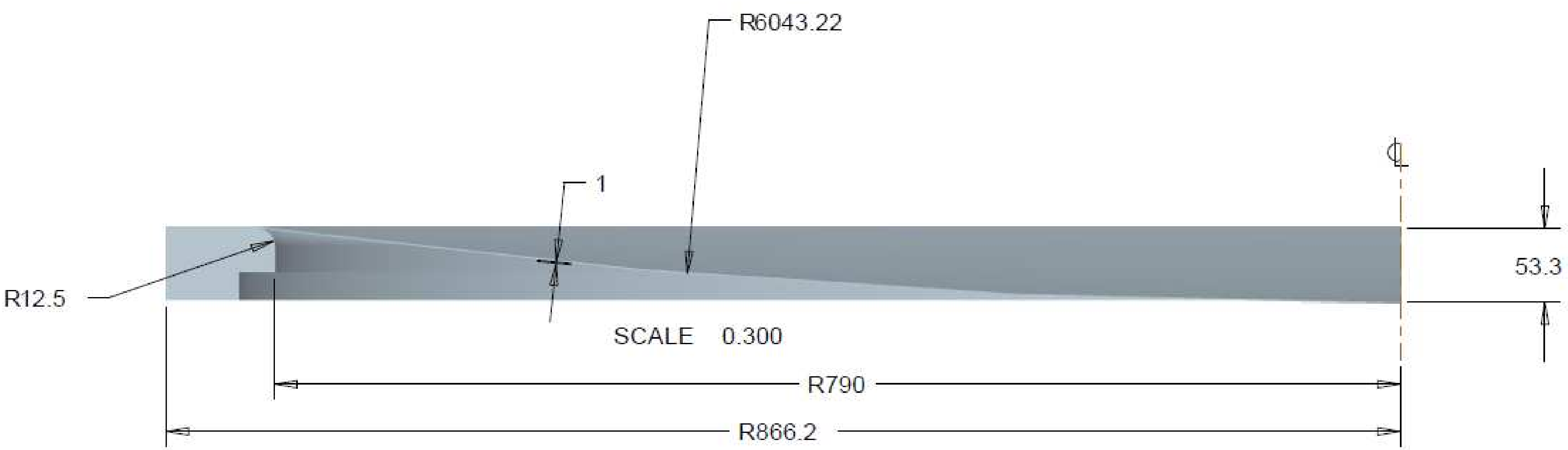
SELECTED PROPERTIES OF 2024-T3 ALUMINUM ALLOY

Density	2.78 g/cc	0.1 lb/in³	AA; Typical
Mechanical Properties			
Hardness, Brinell	120	120	AA; Typical; 500 g load; 10 mm ball
Hardness, Knoop	150	150	Converted from Brinell Hardness Value
Hardness, Rockwell A	46.8	46.8	Converted from Brinell Hardness Value
Hardness, Rockwell B	75	75	Converted from Brinell Hardness Value
Hardness, Vickers	137	137	Converted from Brinell Hardness Value
Ultimate Tensile Strength	483 MPa	70000 psi	AA; Typical
Tensile Yield Strength	345 MPa	50000 psi	AA; Typical
Elongation at Break	18 %	18 %	AA; Typical; 1/16 in. (1.6 mm) Thickness
Modulus of Elasticity	73.1 GPa	10600 ksi	AA; Typical; Average of tension and compression. Compression modulus is about 2% greater than tensile modulus.
Poisson's Ratio	0.33	0.33	
Fatigue Strength	138 MPa	20000 psi	AA; 500,000,000 cycles completely reversed stress; RR Moore machine/specimen
Machinability	70 %	70 %	0-100 Scale of Aluminum Alloys
Shear Modulus	28 GPa	4060 ksi	
Shear Strength	283 MPa	41000 psi	AA; Typical

For more 2024-T3 properties information visit:
http://asm.matweb.com/search/SpecificMaterial.asp?bassnum=MA2024T3

STUDY #1: HYDROFORMED 2024-T3 1mm THICK ALUMINUM SHEET WINDOW

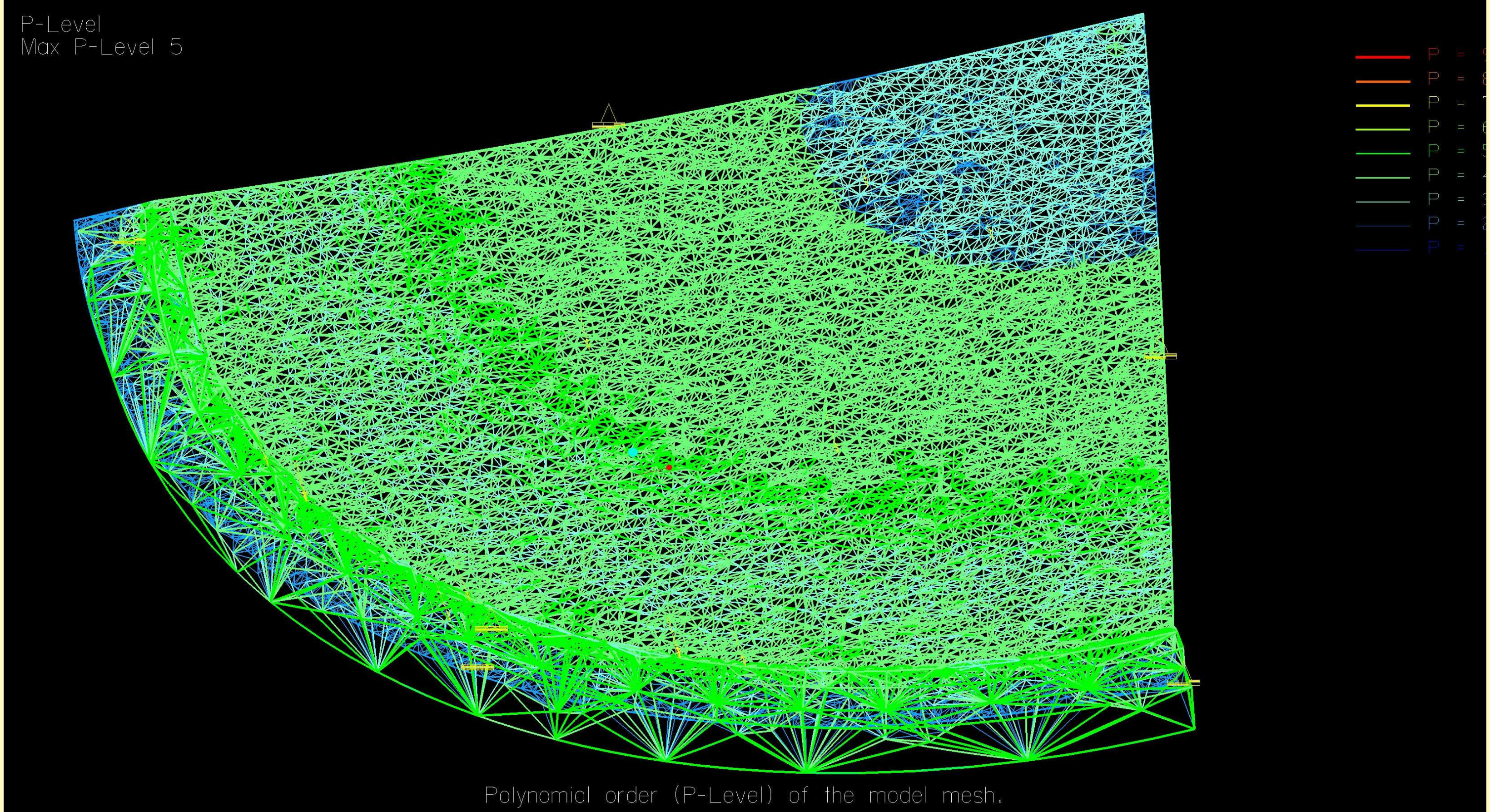
With a pre-hydro-formed dish radius of R = 6043.22 mm, dish depth of 53.3 mm.



Dr. Garth Huber, Dept. of Physics, Univ. of Regina, Regina, SK S4S0A2, Canada.

FEA STUDY OF A HYDROFORMED 2024-T3 ALUMINUM SHEET WINDOW

t = 1mm,   R = 6043.22 mm,   d = 53.3mm



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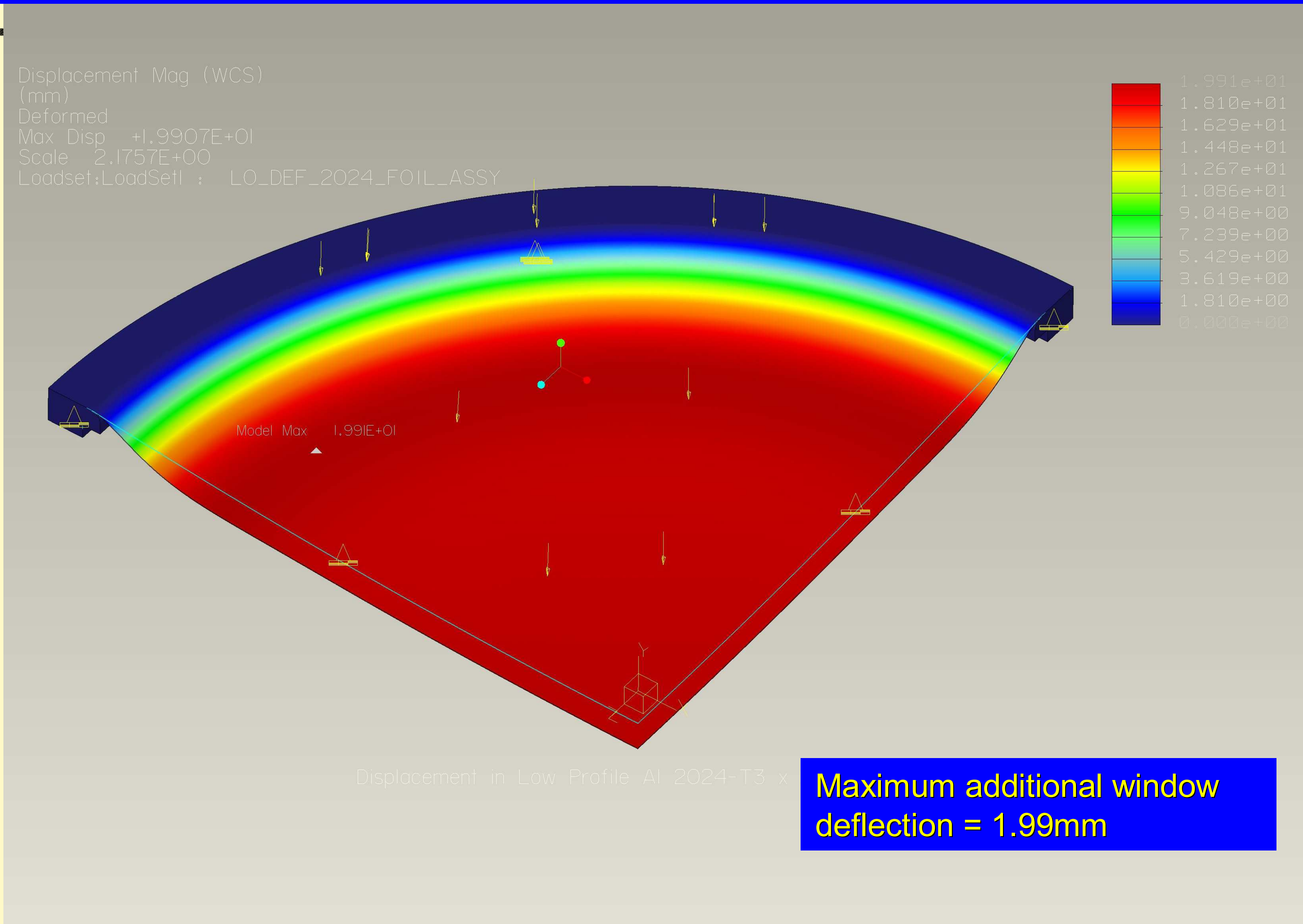
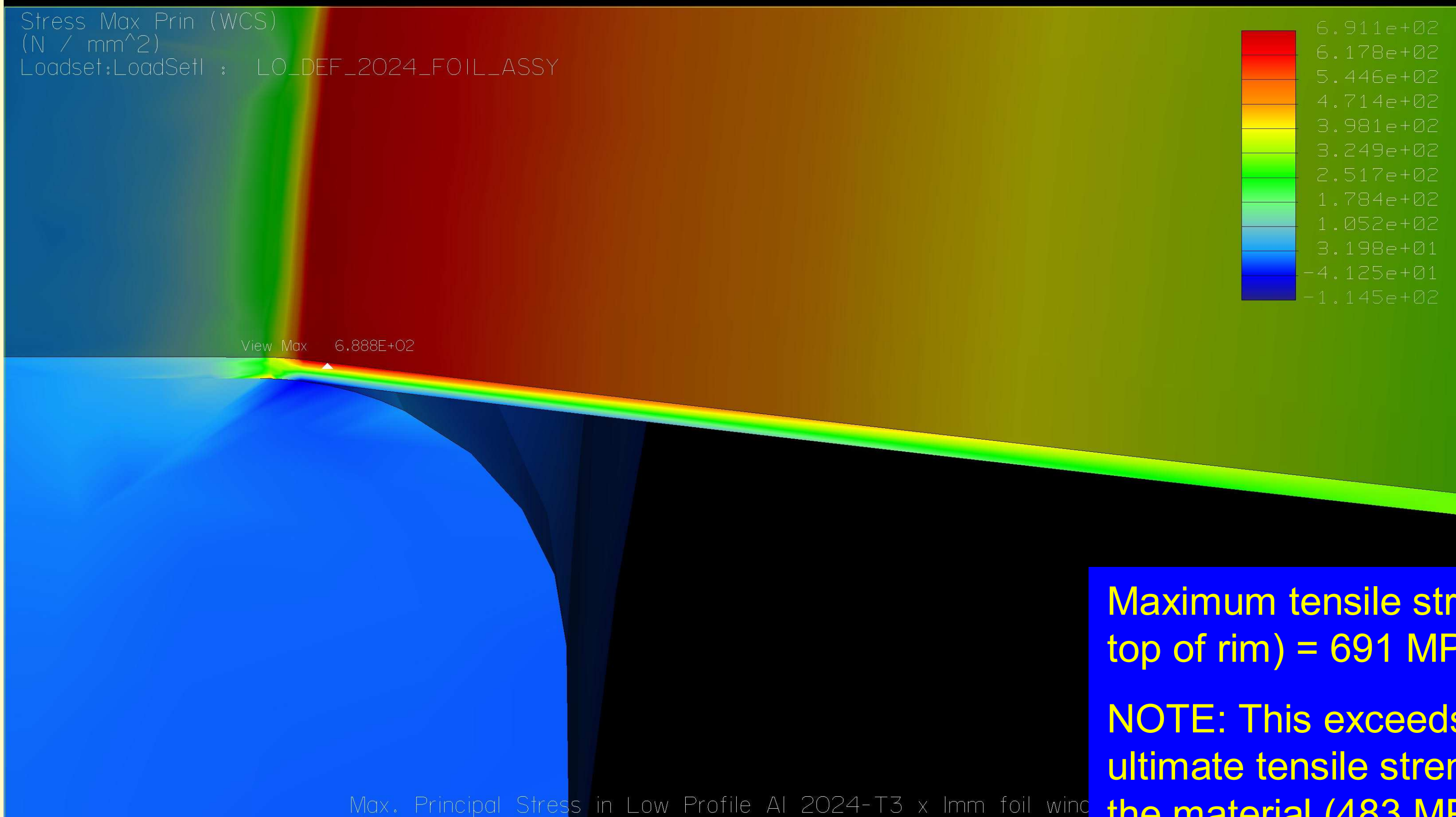
FEA STUDY OF A HYDROFORMED 2024-T3 1mm THICK ALUMINUM SHEET WINDOW
With a pre-hydro-formed depth of 53.4mm.



Maximum additional window deflection = 1.99mm

FEA STUDY OF A HYDROFORMED 2024-T3 ALUMINUM SHEET WINDOW (Detail)

t = 1mm, R = 6043.22 mm, d = 53.3mm

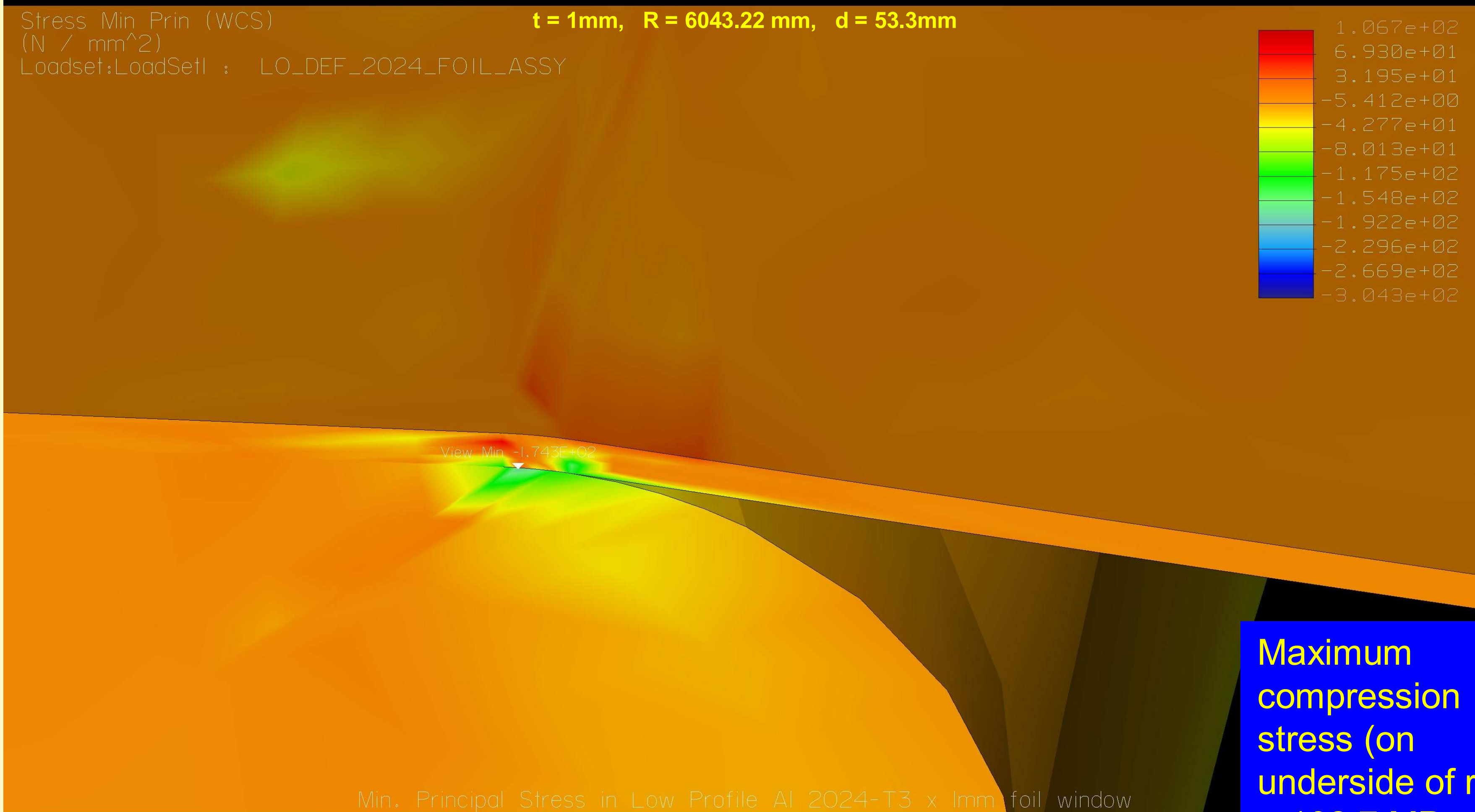


Maximum tensile stress (on top of rim) = 691 MPa.

NOTE: This exceeds the ultimate tensile strength of the material (483 MPa).

MAXIMUM PRINCIPLE STRESS (MAXIMUM TENSILE STRESS)

FEA STUDY OF A HYDROFORMED 2024-T3 ALUMINUM SHEET WINDOW (detail)

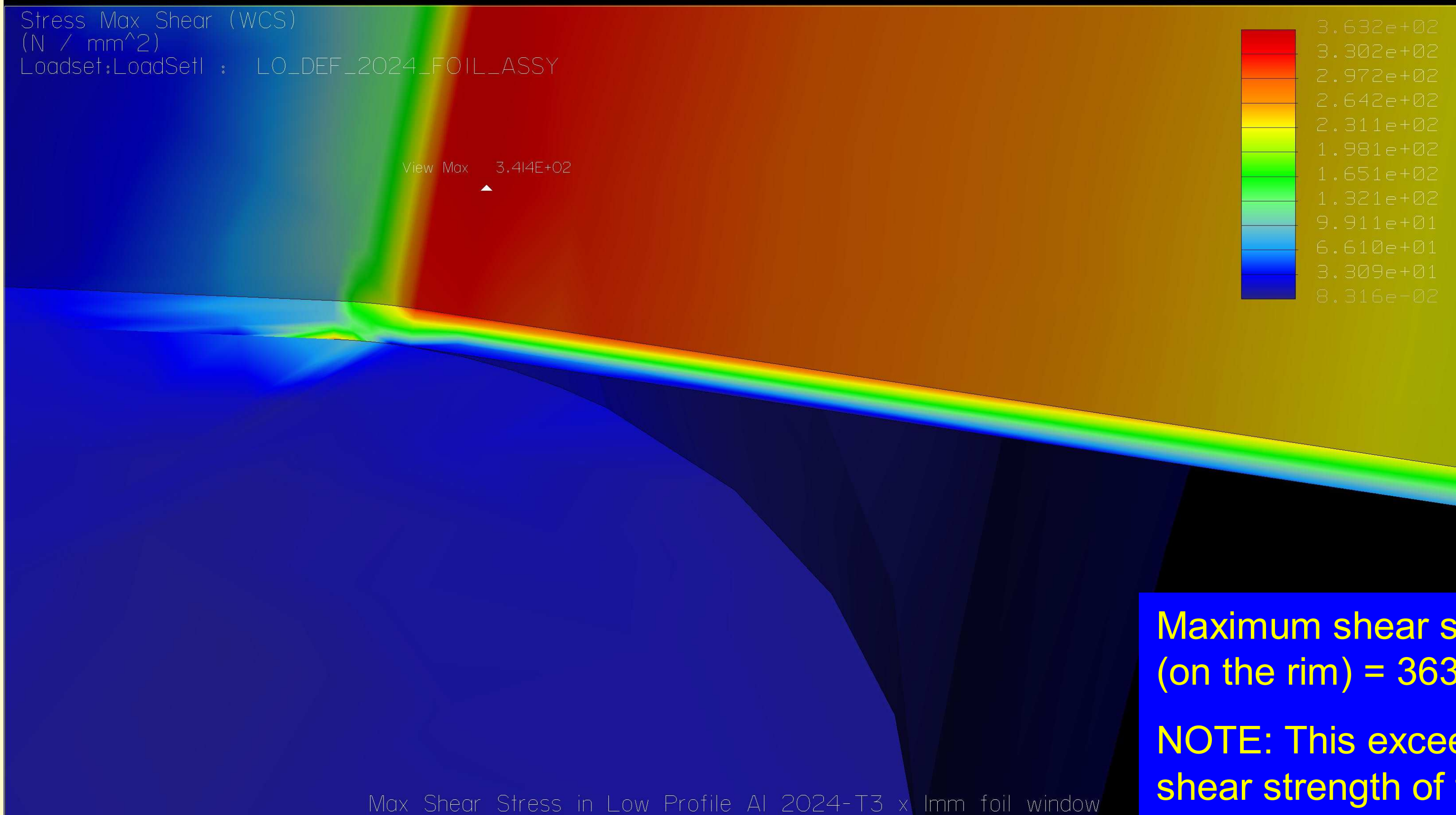


Maximum compression stress (on underside of rim) = 102.7 MPa

MINIMUM PRINCIPLE STRESS (MAXIMUM COMPRESSIVE STRESS)

FEA STUDY OF A HYDROFORMED 2024-T3 ALUMINUM SHEET WINDOW

t = 1mm, R = 6043.22 mm, d = 53.3mm



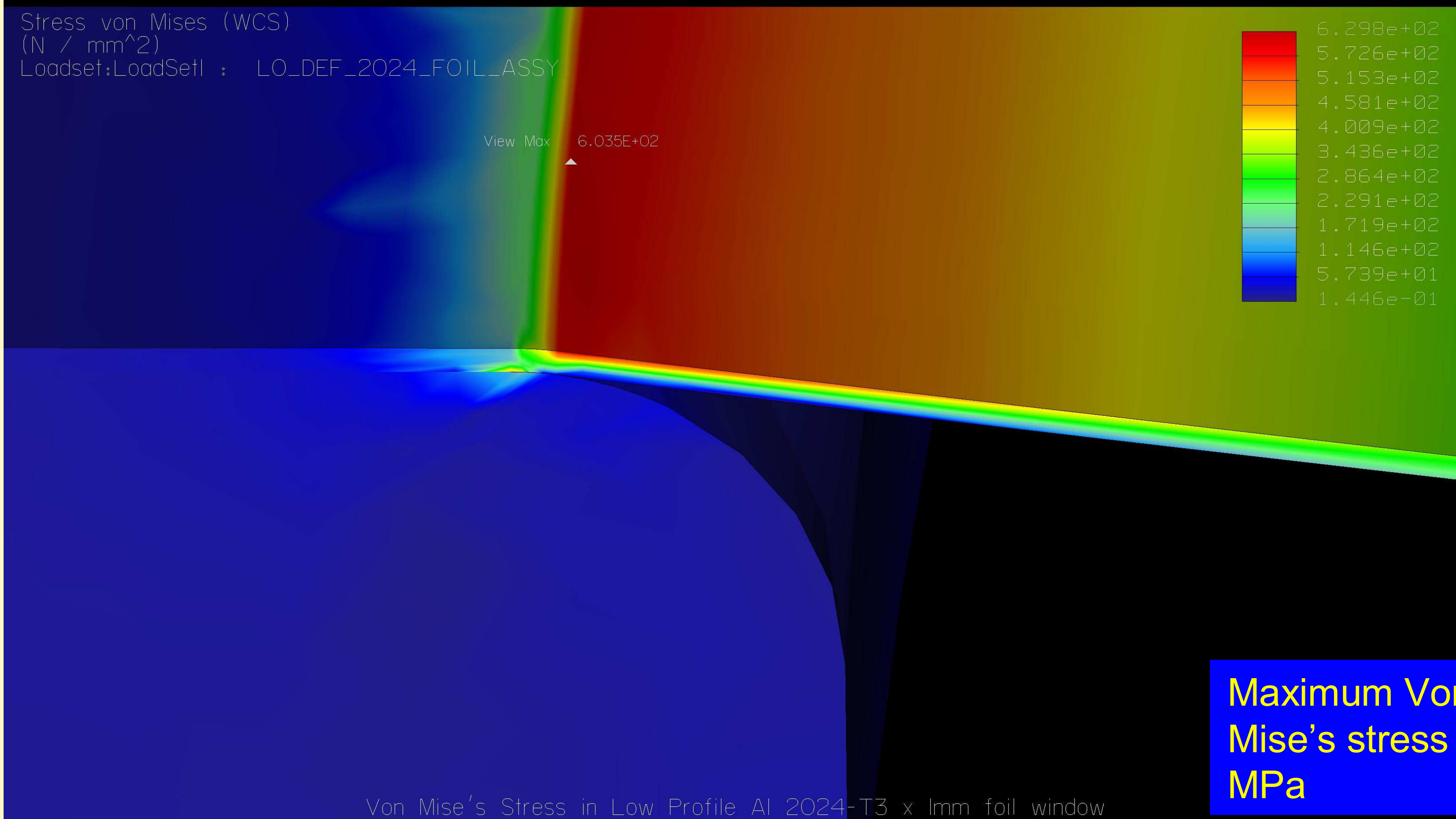
Maximum shear stress (on the rim) = 363 MPa

NOTE: This exceeds the shear strength of the material (283 MPa)

MAXIMUM SHEAR STRESS (detail)

FEA STUDY OF A HYDROFORMED 2024-T3 ALUMINUM SHEET WINDOW

t = 1mm,   R = 6043.22 mm,   d = 53.3mm

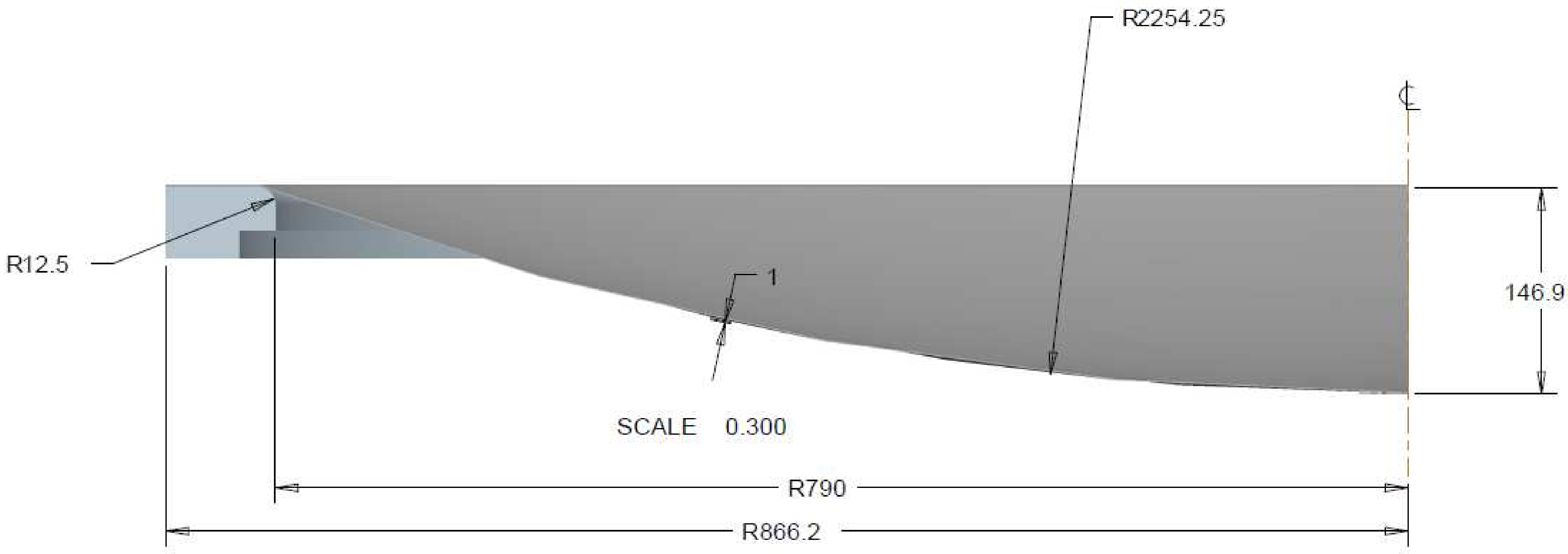


Maximum Von Mise's stress = 573 MPa

VON MISE'S STRESS (detail)

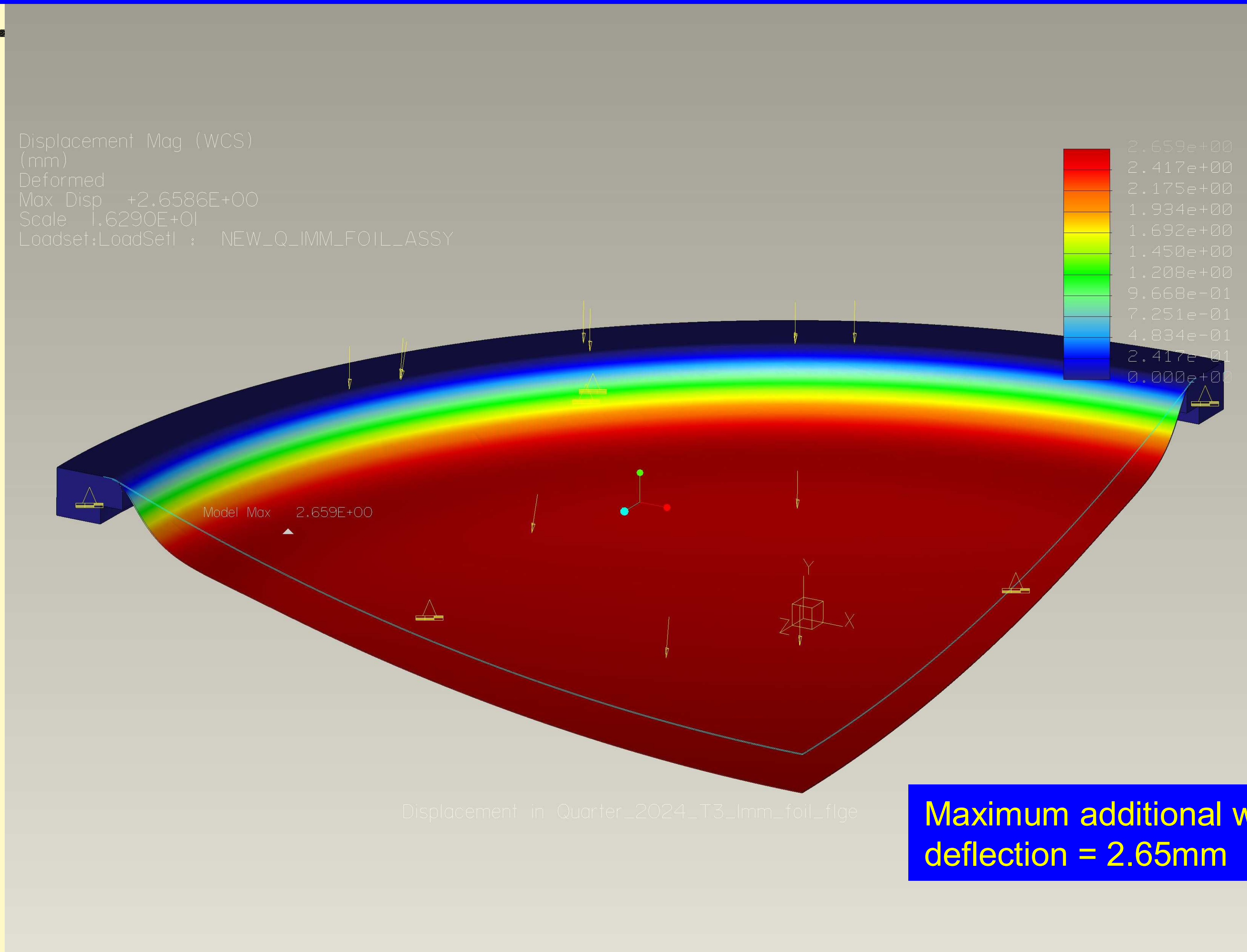
STUDY #2: HYDROFORMED 2024-T3 1mm THICK ALUMINUM SHEET WINDOW

With a pre-hydro-formed dish radius of R = 2254.25 mm, Dish depth of 146.9 mm.



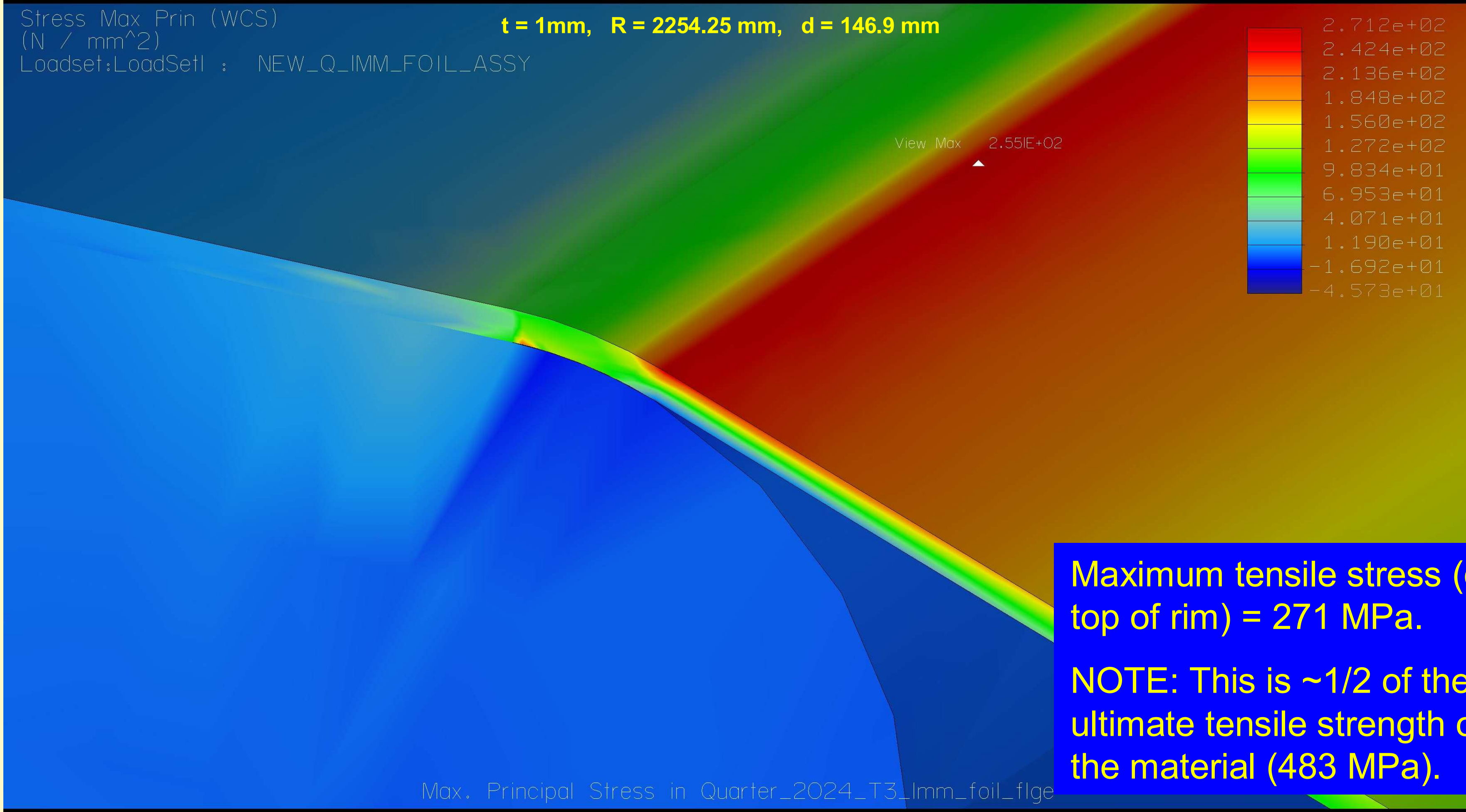
Dr. Garth Huber, Dept. of Physics, Univ. of Regina, Regina, SK S4S0A2, Canada.

FEA STUDY OF A HYDROFORMED 2024-T3 1mm THICK ALUMINUM SHEET WINDOW
With a pre-hydro-formed dish radius of R = 4508.5 mm.



Maximum additional window deflection = 2.65mm

FEA STUDY OF A HYDROFORMED 2024-T3 ALUMINUM SHEET WINDOW (Detail)

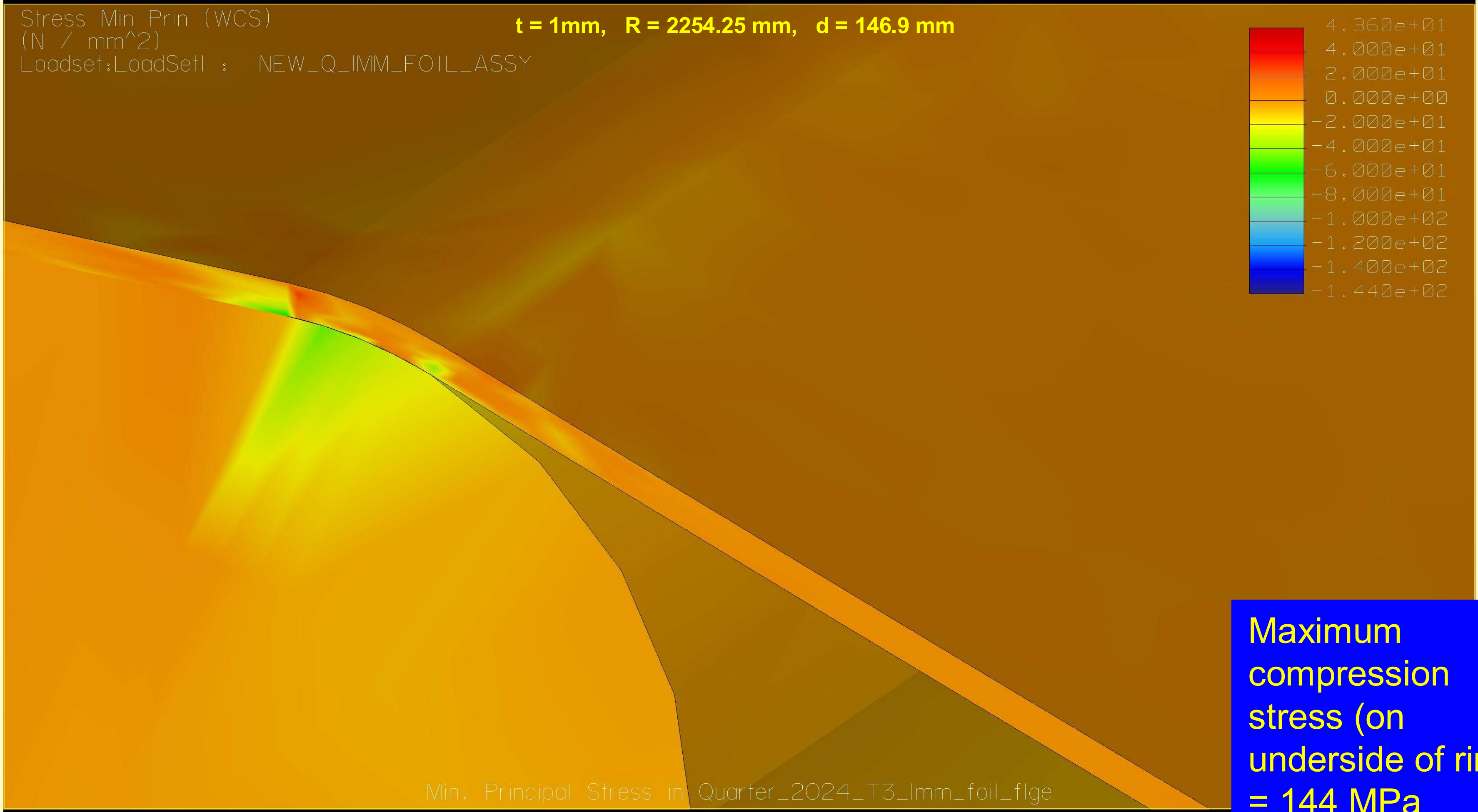


Maximum tensile stress (on top of rim) = 271 MPa.

NOTE: This is ~1/2 of the ultimate tensile strength of the material (483 MPa).

MAXIMUM PRINCIPLE STRESS (MAXIMUM TENSILE STRESS)

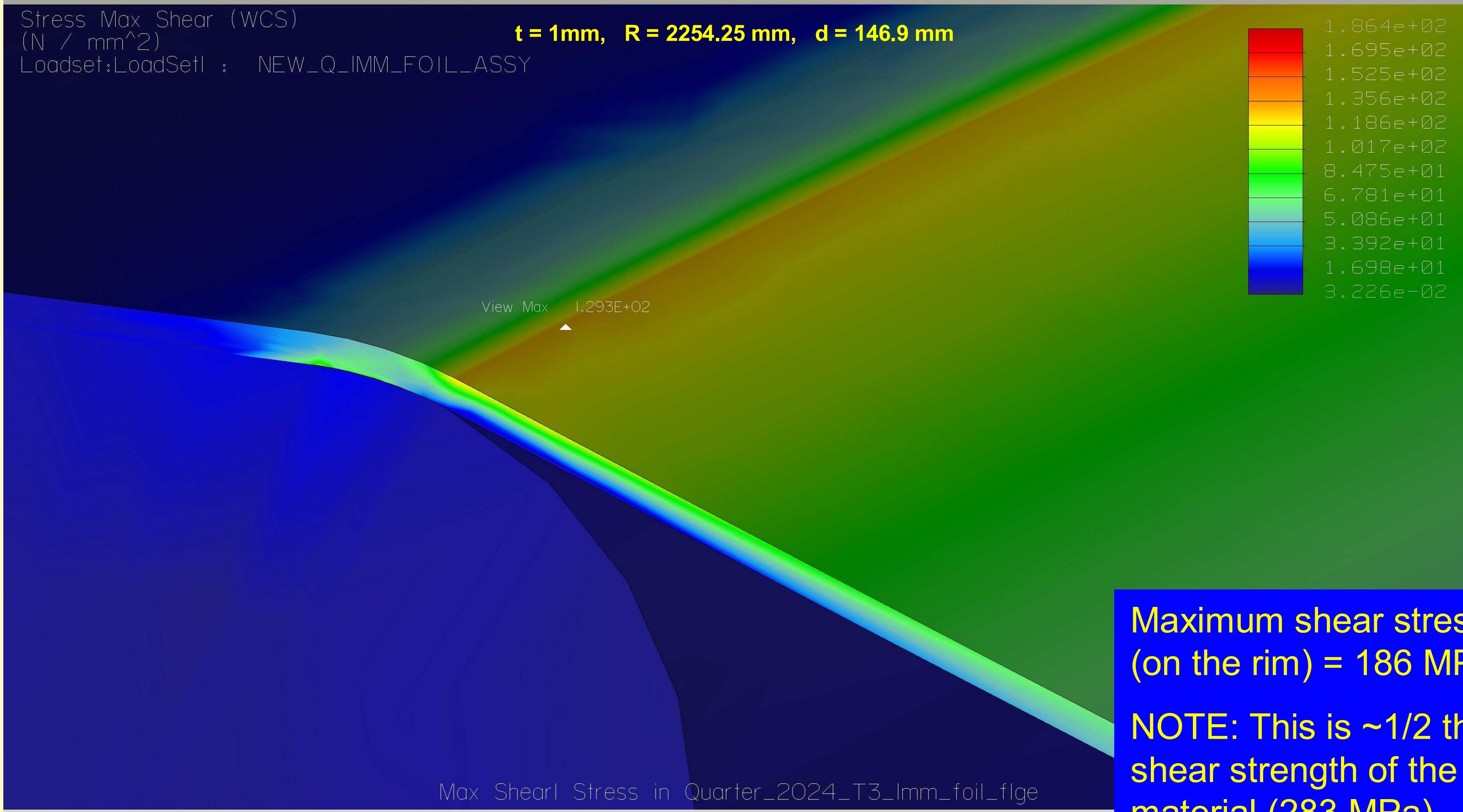
FEA STUDY OF A HYDROFORMED 2024-T3 ALUMINUM SHEET WINDOW (detail)



Maximum compression stress (on underside of rim) = 144 MPa

MINIMUM PRINCIPLE STRESS (MAXIMUM COMPRESSIVE STRESS)

FEA STUDY OF A HYDROFORMED 2024-T3 ALUMINUM SHEET WINDOW

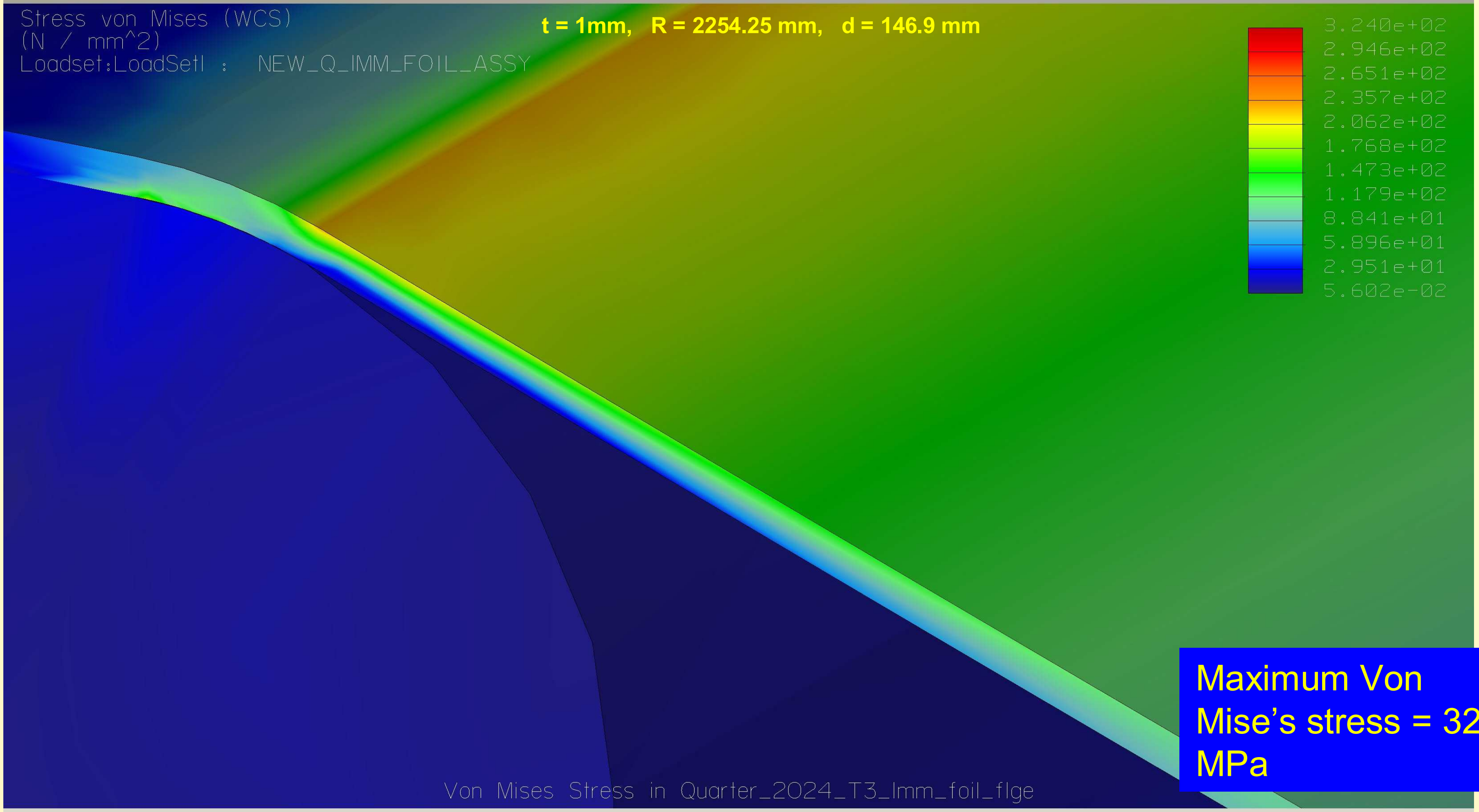


Maximum shear stress (on the rim) = 186 MPa

NOTE: This is ~1/2 the shear strength of the material (283 MPa)

MAXIMUM SHEAR STRESS (detail)

FEA STUDY OF A HYDROFORMED 2024-T3 ALUMINUM SHEET WINDOW



Maximum Von Mise's stress = 324 MPa

VON MISE'S STRESS (detail)

Window FEA Summary

- Study #1 results with 53.4mm hydroform depth (suggested by Steve Lassiter) seem to indicate that (prior to possible yielding and stretching) the tensile stress on the window exceeds the posted strength of 2024-T3 aluminum.
- Study #2 results with 146.9mm hydroform depth seem to conform to the material strength.
- Further studies with intermediate hydroform depths planned.
- Comments & suggestions from Hall C engineering staff are needed.