



ADIT Electron Tubes





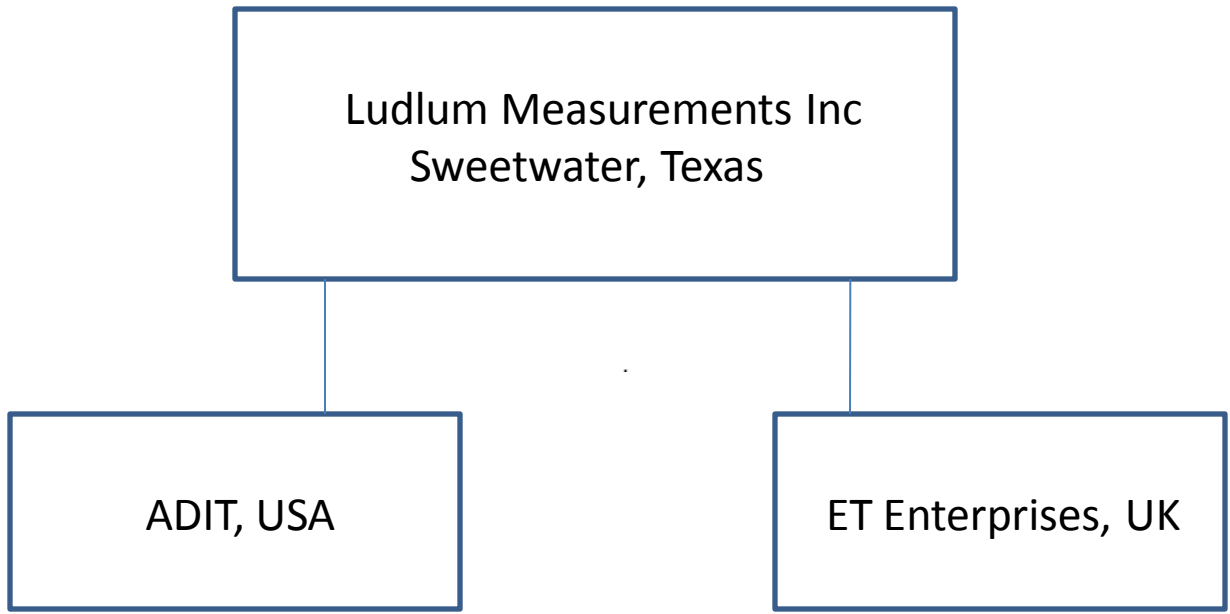
ADIT
Electron Tubes



- Introduction - About ADIT Electron Tubes
- Our Large Area Photomultipliers
- The Design of an 11" Diameter PMT for LBNE
- Questions



ADIT Electron Tubes



Ludlum Measurements Inc
Sweetwater, Texas

ADIT, USA

ET Enterprises, UK

PMT manufacturer, USA

- General purpose PMTs
- Very large batch Manufacture

PMT manufacturer, UK

- Research and development PMTs
- High performance PMTs
- Small to medium batch production

Ludlum Company Overview

In Business since 1962

500 Employees

Engineering Excellence

Vertical Manufacturing



Sweetwater, Texas

Committed to:

- Reliability
- Durability
- Affordability



Don Ludlum – Founder & President



ADIT Electron Tubes



ADIT

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ADIT
Electron Tubes



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Our Hemispherical Photomultipliers

- 5" diameter 9372
 - Designed for G. Grata at Palo Verde
- 8" diameter range
 - 14 stage 9350 designed for MACRO
 - 6 stage 9352 designed for Air Cerenkov Telescopes
 - 12 stage 9354 designed for BOREXINO
 - 12 stage 9357 designed for cryogenic temperature
- 11" diameter latest design for LBNE



Summary of Performance



Parameter	9372	9350	9352	9354	9357	D type
Diameter (in)	5	8	8	8	8	11
No. of stages	6	14	6	12	12	12
Typical operating gain	10 ⁷	10 ⁸	10 ⁴	10 ⁷	10 ⁷	10 ⁷
Typical QE% at peak	28	30	30	30	18	30
Surface area (in ²)	25	66	66	66	66	124
Typical dark cps at 20C	1500	4000	-	4000	4000	8000
Typical SER ratio	1.5	1.5	-	2	2	2
Typical 1e TTJ fwhm(ns)	2.7	8	-	2.7	2.7	3
Minimum Temperature	-30C	-30C	-30C	-30C	-196C	-30C
Weight (grams)	380	700	700	700	700	2000

Design of 11" PMT Envelope for LBNE



Specifications:

- External water pressure of 11 bar
- Long life in pure water
- Glass with low content of radioactive isotopes
- Shape for good photoelectron collection
- Shape for good timing (TTJ)

Electron Optics Design



Electron-optic software

LORENTZ-E Three-dimensional Particle Trajectory Solver (Electric)

Integrated Engineering Software

Version 9.0 x64

Release Date: July 2011

Advanced Charged Particle Design Suite (Professional)

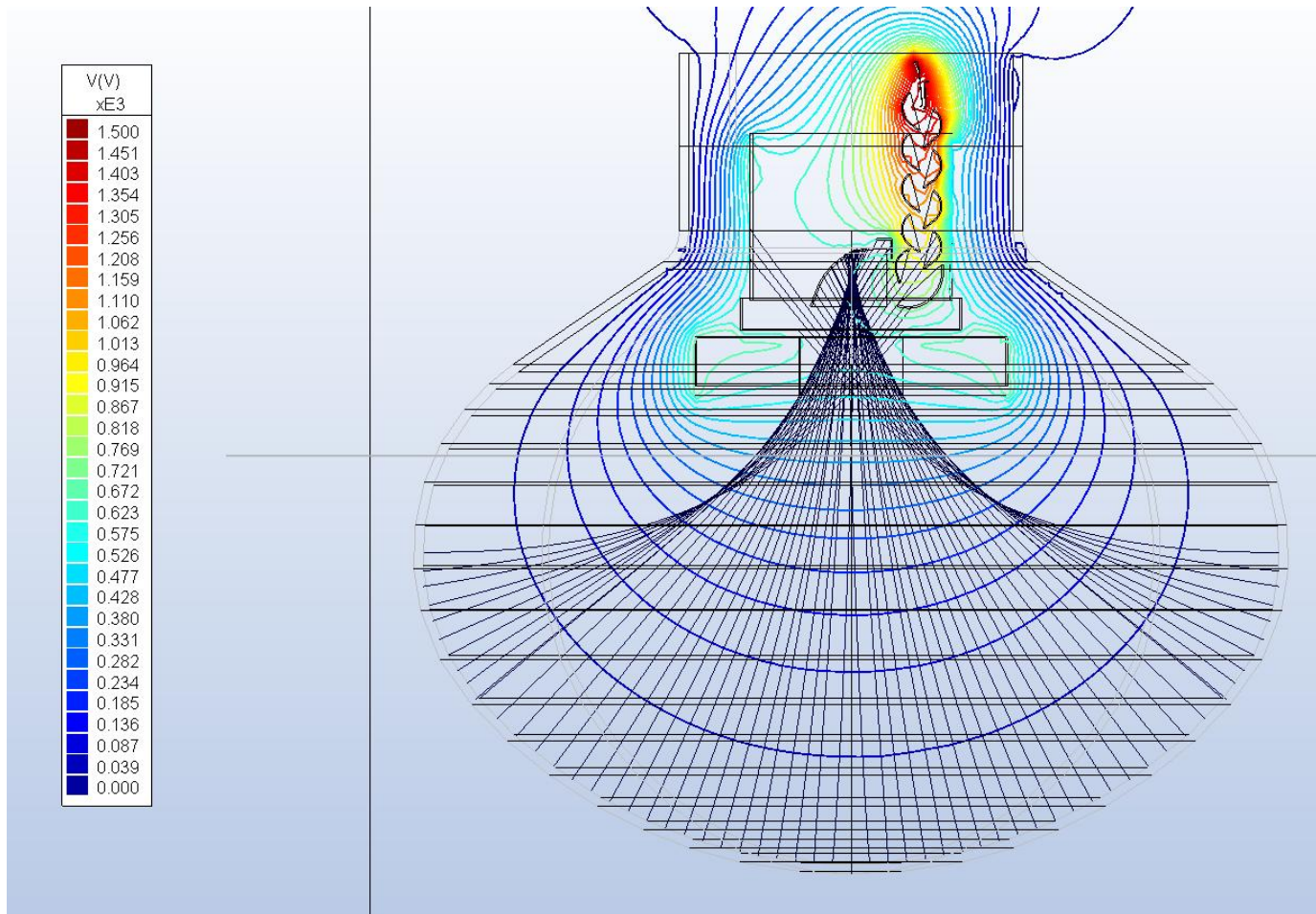
Geometer, MetaMesh, HiPhi, Magnum, OmniTrak, Phiview, Magview, Omniview

Field Precision LLC

64-Bit Edition

Release Date: 2011

Shape for good photoelectron collection and timing



Photoelectron Collection Area



Collection Area k-d1	Predicted Area (cm²)	Predicted Area (in²)
Projected photocathode area	568	88
Photocathode curved surface area	749	116
Outer bulb curved surface area	800	124

Transit time walk center to edge



Launch distance \perp to tube axis (inches)	Launch distance \perp to tube axis (mm)	k-d1 transit time (ns)
0	0	36.1
0.47	12	36.1
0.96	24	36.0
1.42	36	36.0
1.89	48	35.9
2.36	60	35.7
2.80	71	35.7
3.27	83	35.4
3.74	95	35.2
4.21	107	35.2
4.69	119	35.6
5.39	137	34.9

Finite Element Analysis for 11 bar External Pressure



FEA Software:

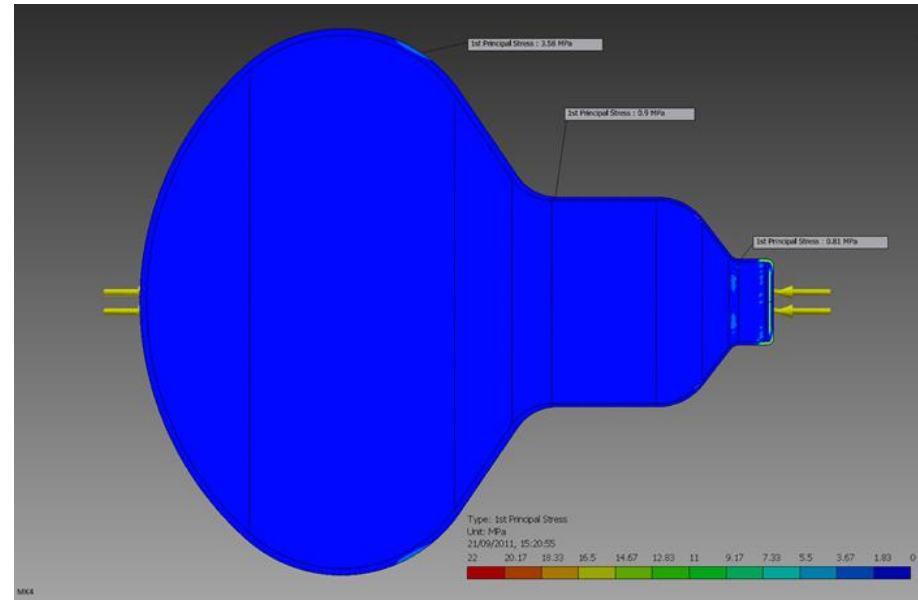
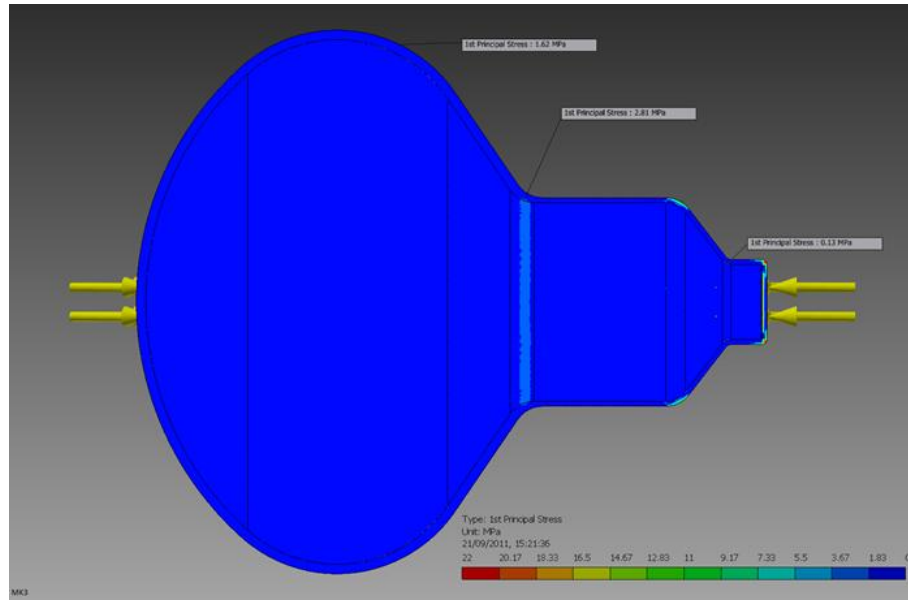
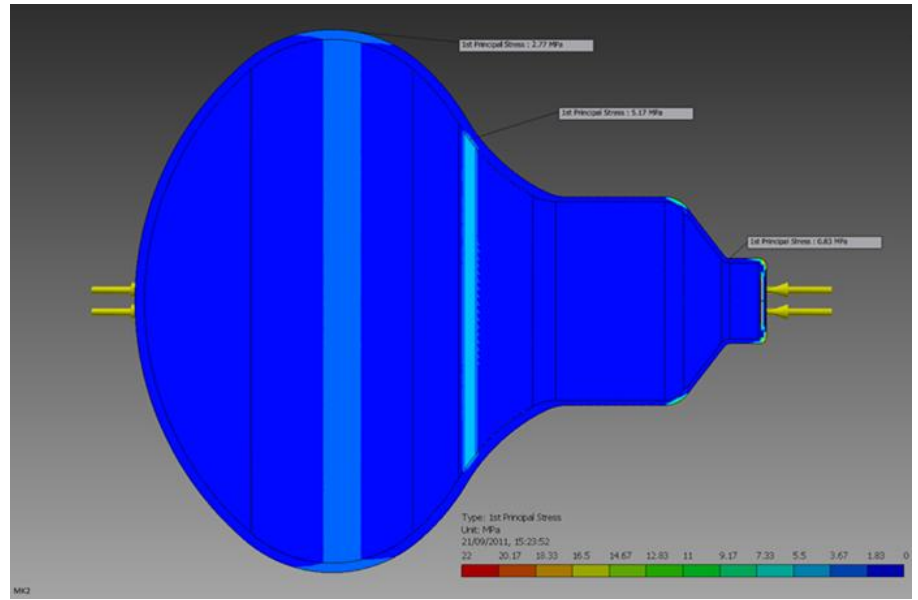
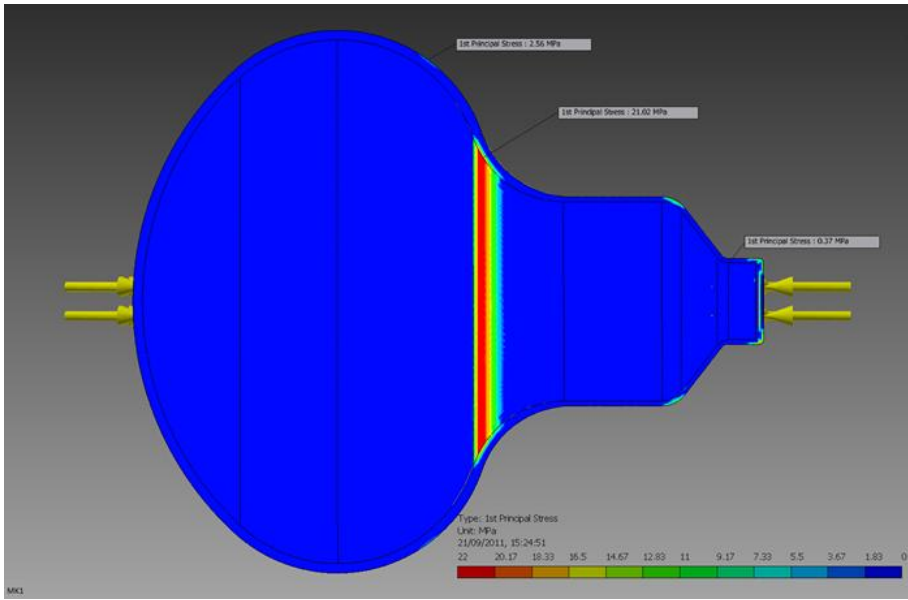
Autodesk Inventor Product Design Suite Ultimate 2012

64-Bit Edition

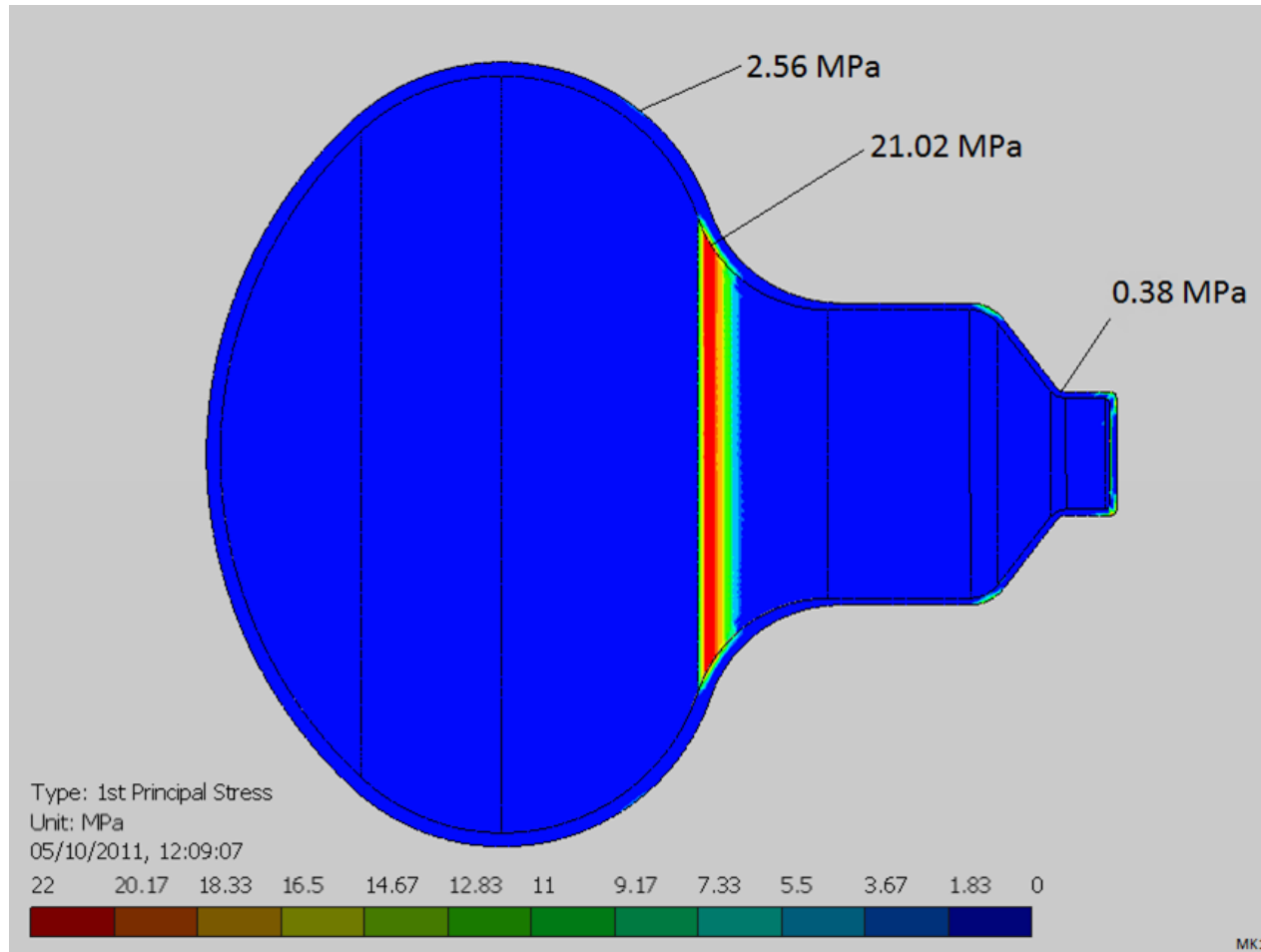
Release Date: January 2011

Data Inputs:

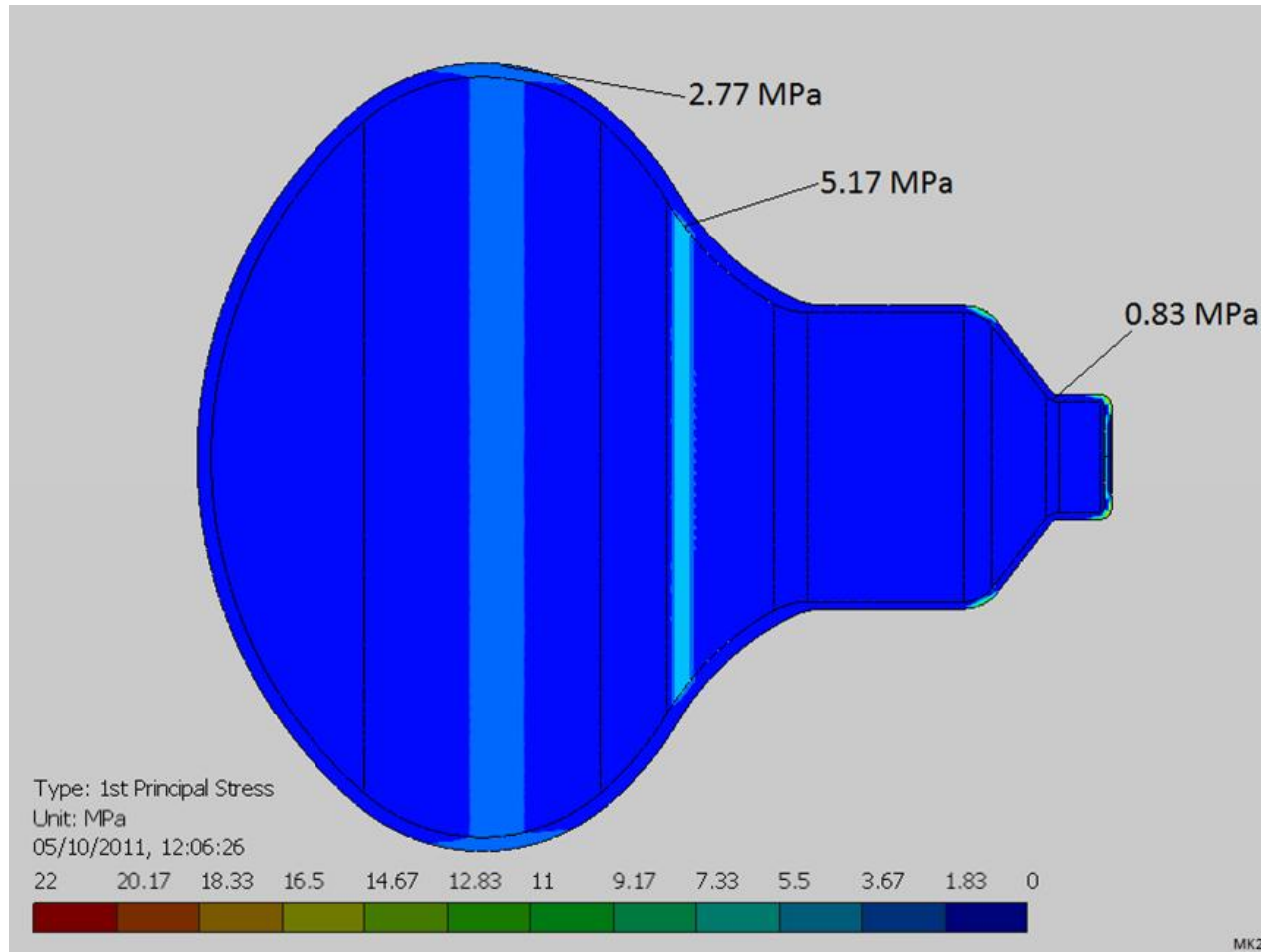
Glass	Schott 8246
Young's Modulus	70 GPa
Poisson's ratio	0.21
Pressure Difference Inside / Outside	11 bar



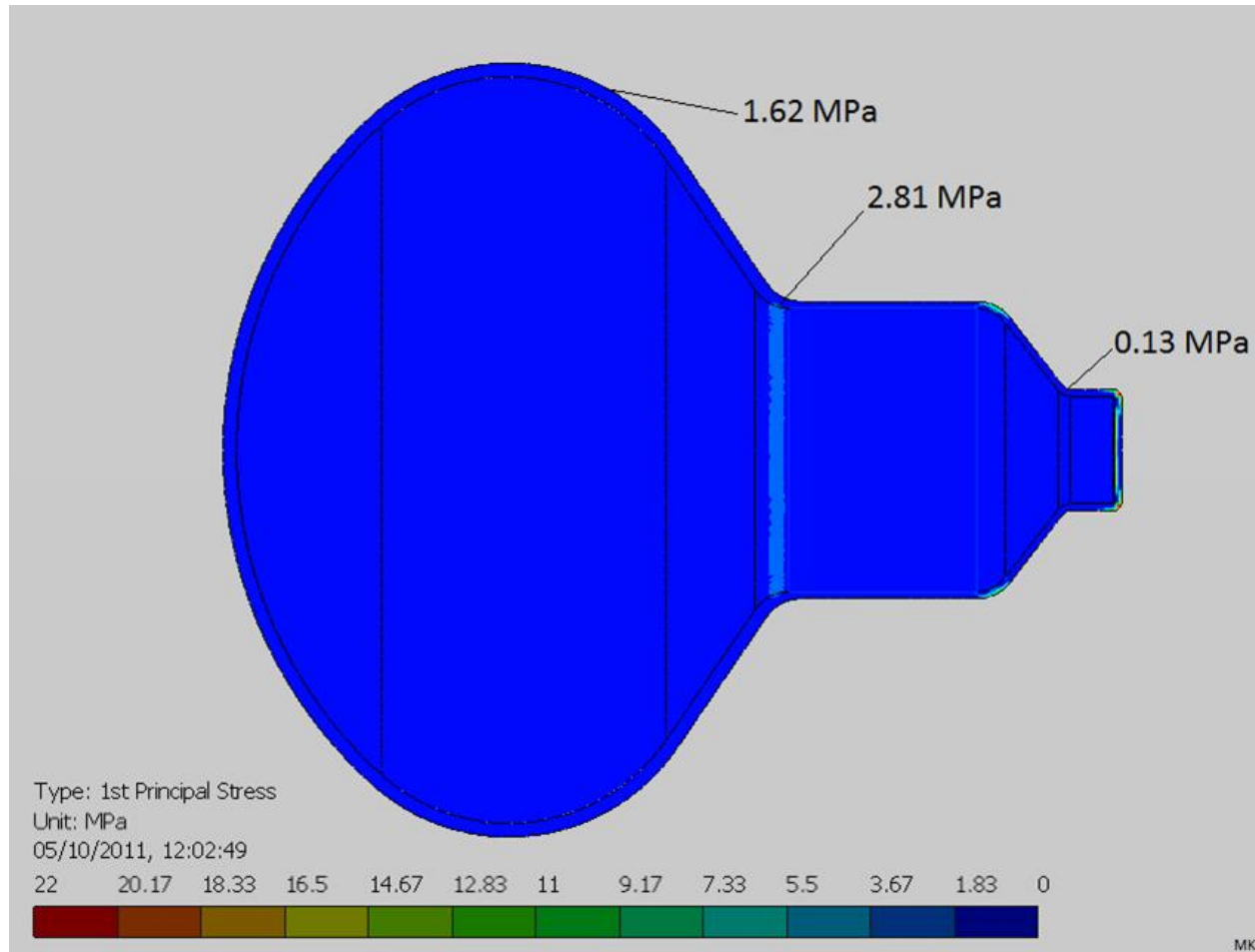
11 inch diameter envelope Mk1



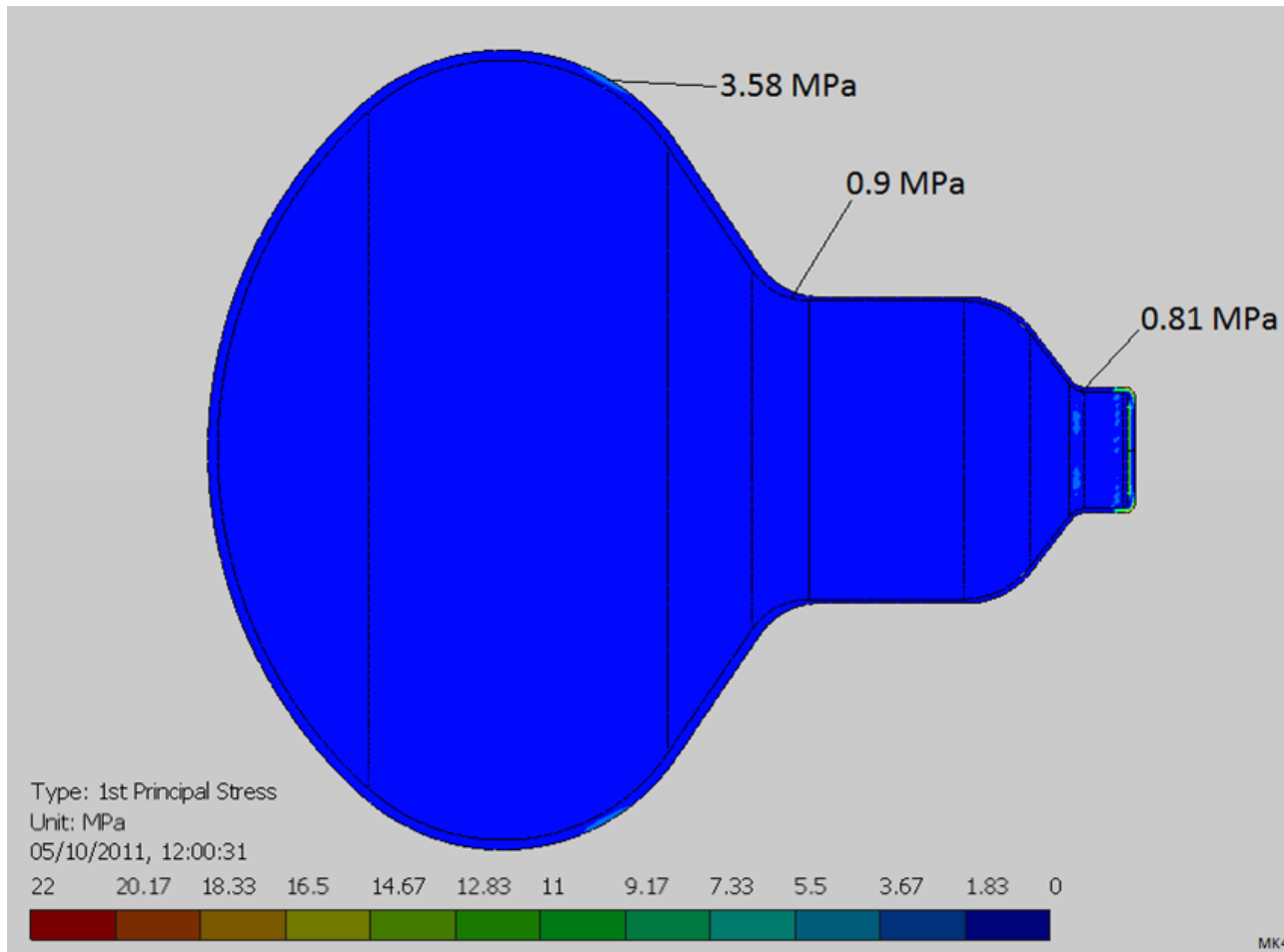
11 inch diameter envelope Mk2



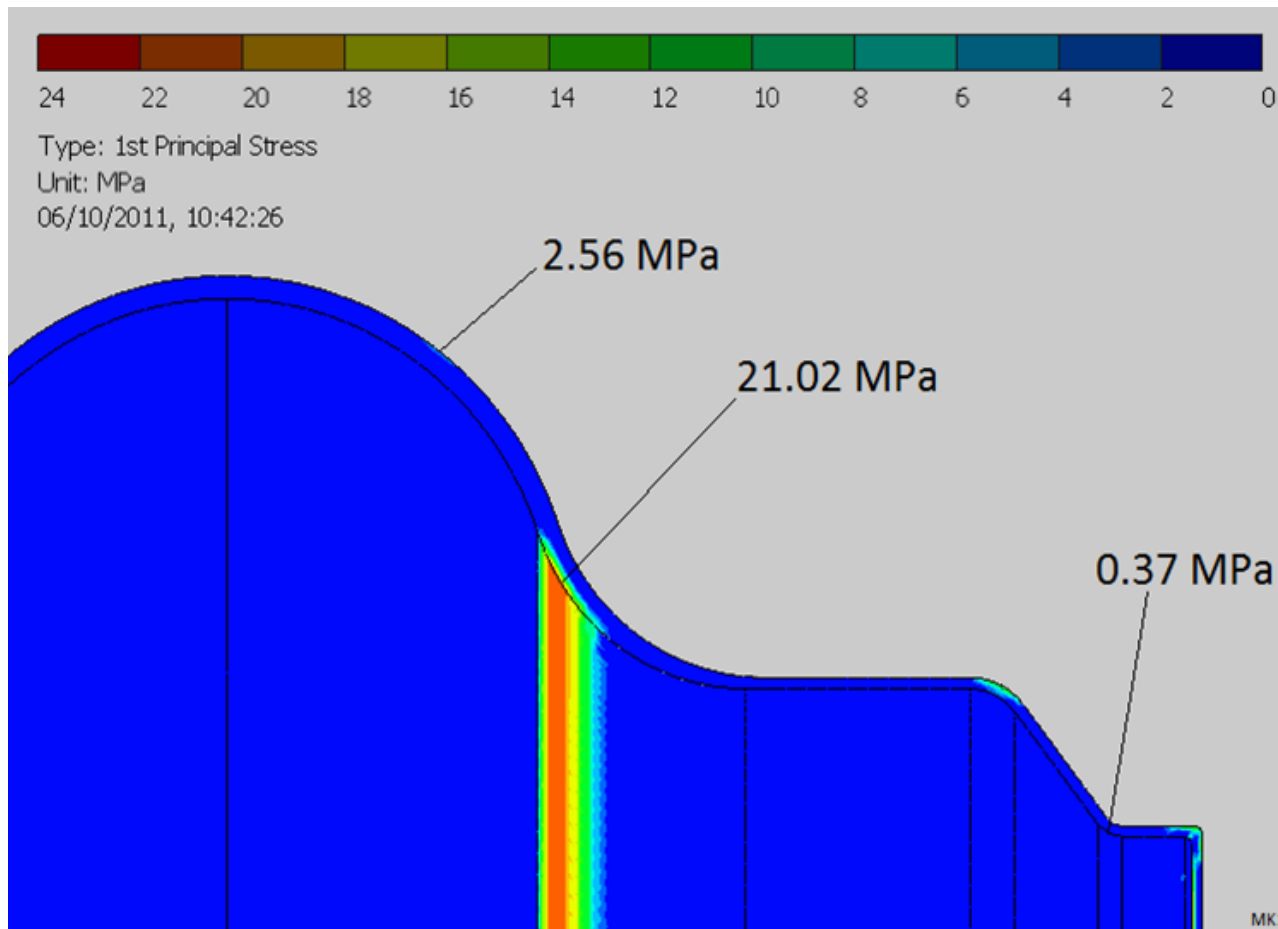
11 inch diameter envelope Mk3



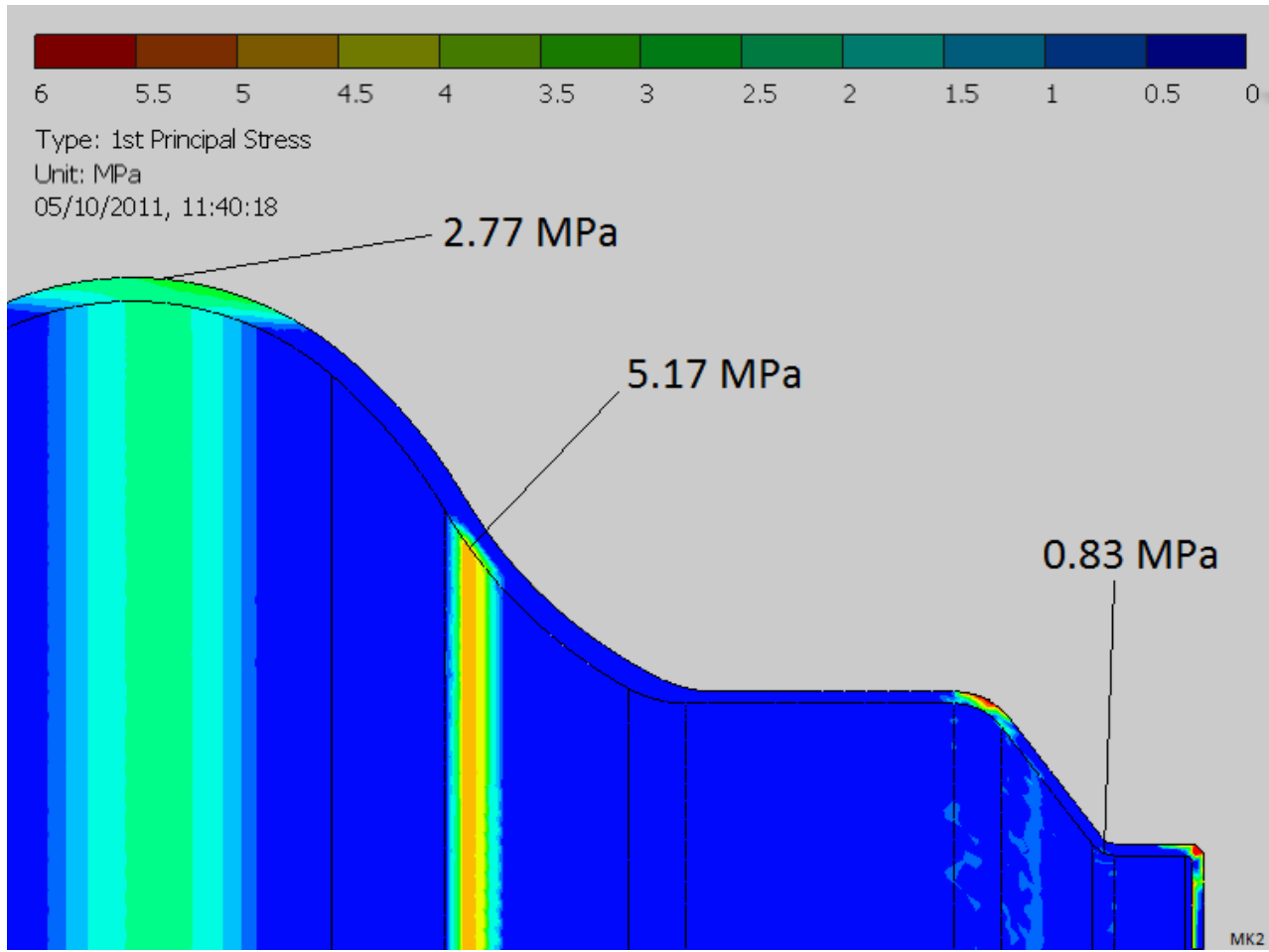
11 inch diameter envelope Mk4



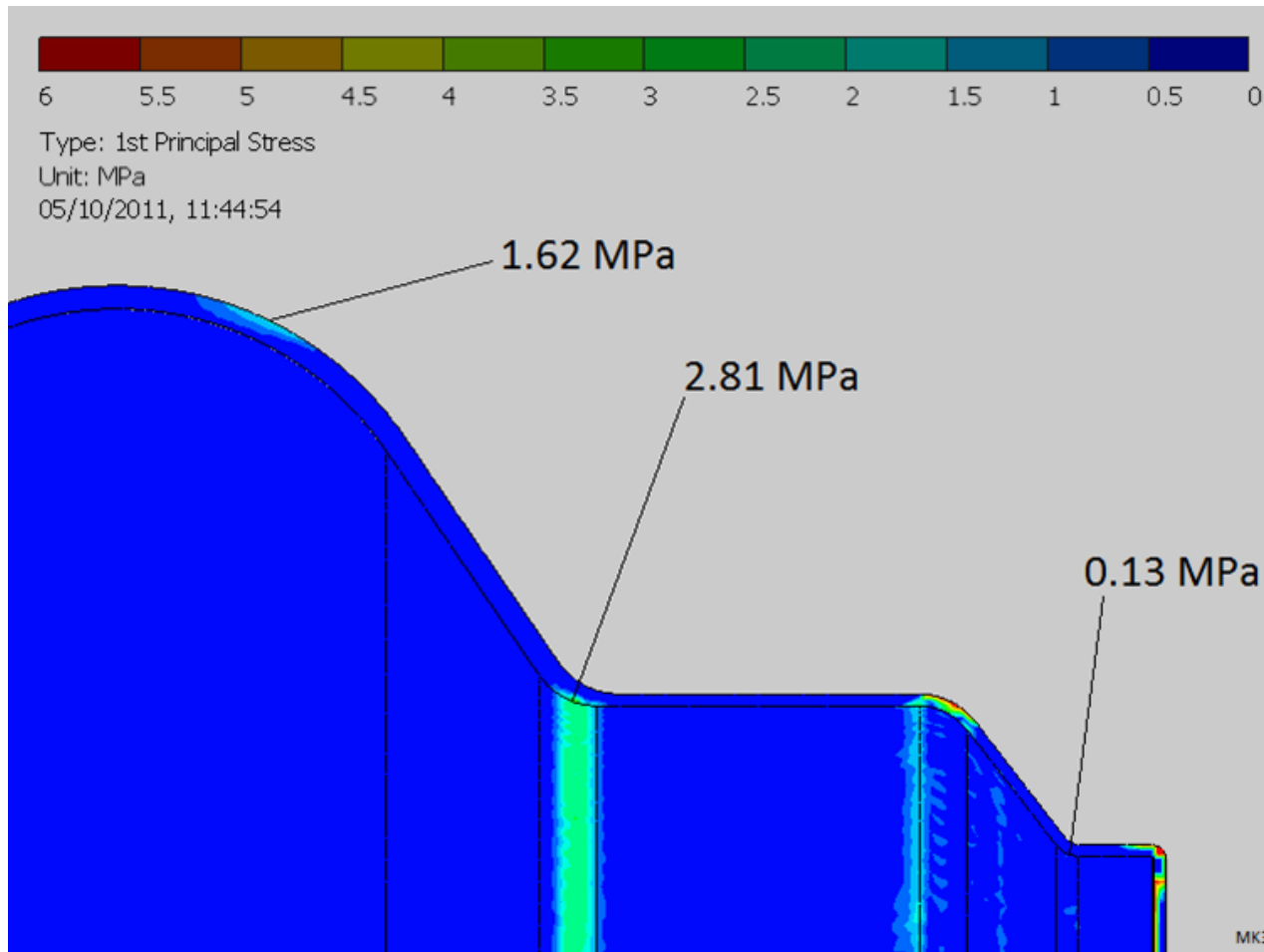
11 inch diameter envelope Mk1



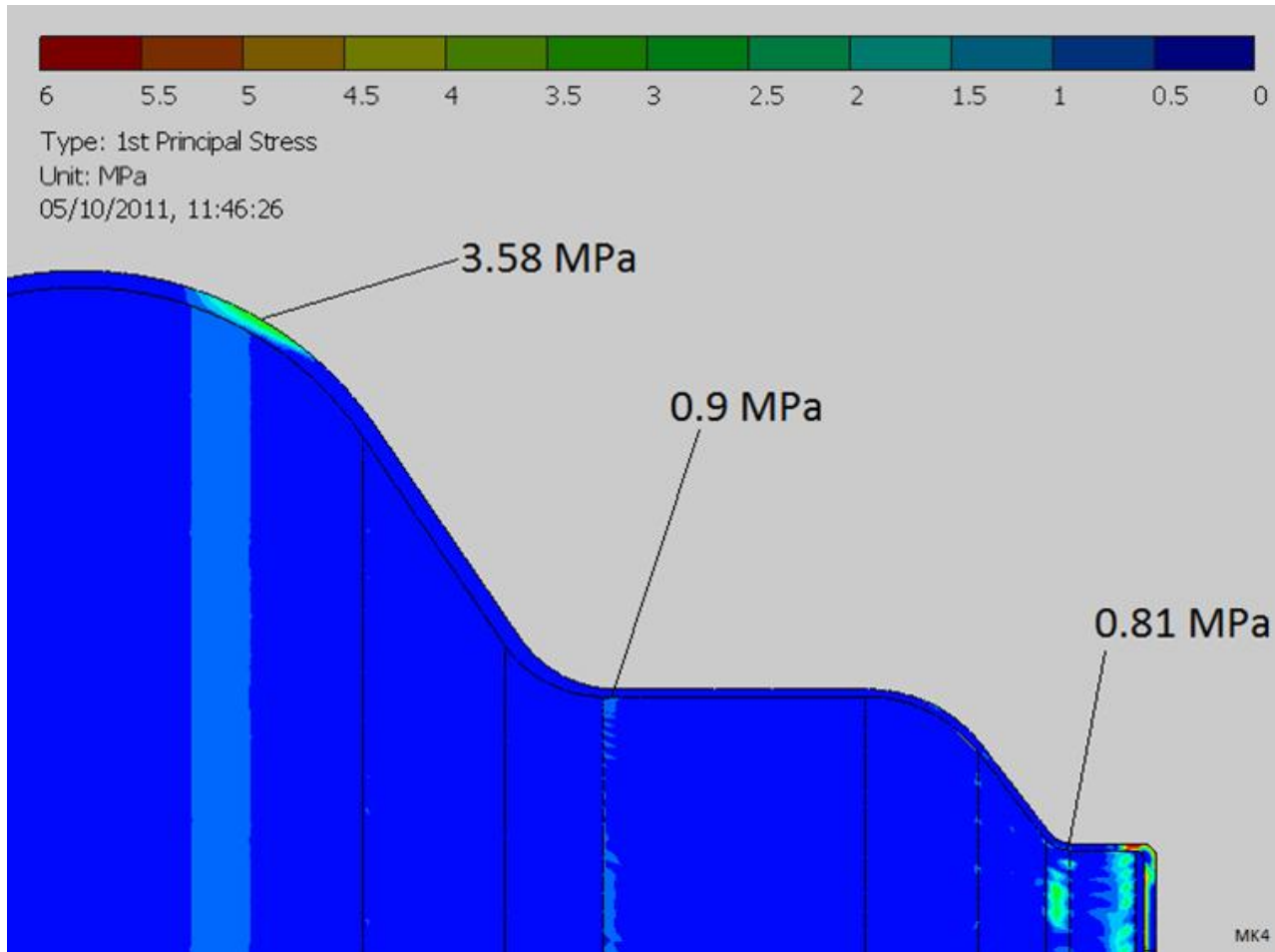
11 inch diameter envelope Mk2



11 inch diameter envelope Mk3



11 inch diameter envelope Mk4



11 inch diameter envelopes



Glass Thickness

M K	Bulb (mm)	Bulb (in)	Neck (mm)	Neck (in)
1	5	0.2	2.5	0.1
2	5	0.2	2.5	0.1
3	5	0.2	2.5	0.1
4	3.5	0.14	1.5	0.06

11 inch diameter envelopes



Glass Activity Mk4

Glass thickness	Expected mass (g)	Gamma rate (Bq)* (60ppm K, 30ppb Th, 30ppb U)
Maximum	2,218	3.2 ± 1.7
Minimum	1,482	2.2 ± 1.1

*Estimated Gamma emission > 0.1 MeV

Schott 8246	Concentration
Natural potassium	60 ppm
Thorium	30 ppb
Uranium	30 ppb

Flexible Operations



- **Two locations; one in USA and one in Europe**
- Many sales teams worldwide
- Two design teams
- Two manufacturing plants
- **One focus; our customers.**



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