Modeling Effect of Fragment Impact Orientation and Shape on Explosive Response

Abstract #22173

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Agenda

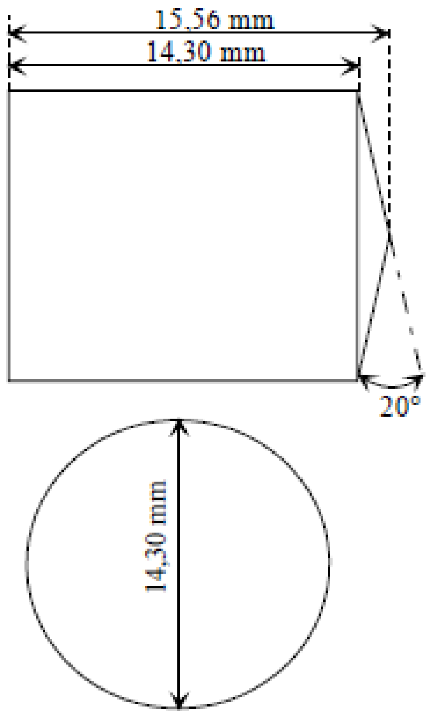
- ***Fragment Impact Test Background***
- ***Technical Approach***
- ***Results – Standard Fragment***
- ***Results – Spherical Fragment***
- ***Summary and Conclusions***

Background

- ***The Fragment Impact Test is conducted to assess the violence of reaction of a munition subjected to high-velocity impact of a fragment meant to simulate an aerial bomb or artillery projectile fragment***

- ***Due to asymmetry of fragment design future tests may include costly efforts to measure the orientation of the fragment at impact***
  - ***Measurement currently not required by test standard***

- ***What is effect of fragment impact orientation on the response of a munitions' high explosive fill, and is this effect significant enough to invalidate a test?***



Standard Fragment Design

NATO Standardization Agreement (STANAG) 4496, Edition 1, *Fragment Impact, Munitions Test Procedure*, 13 December 2006.

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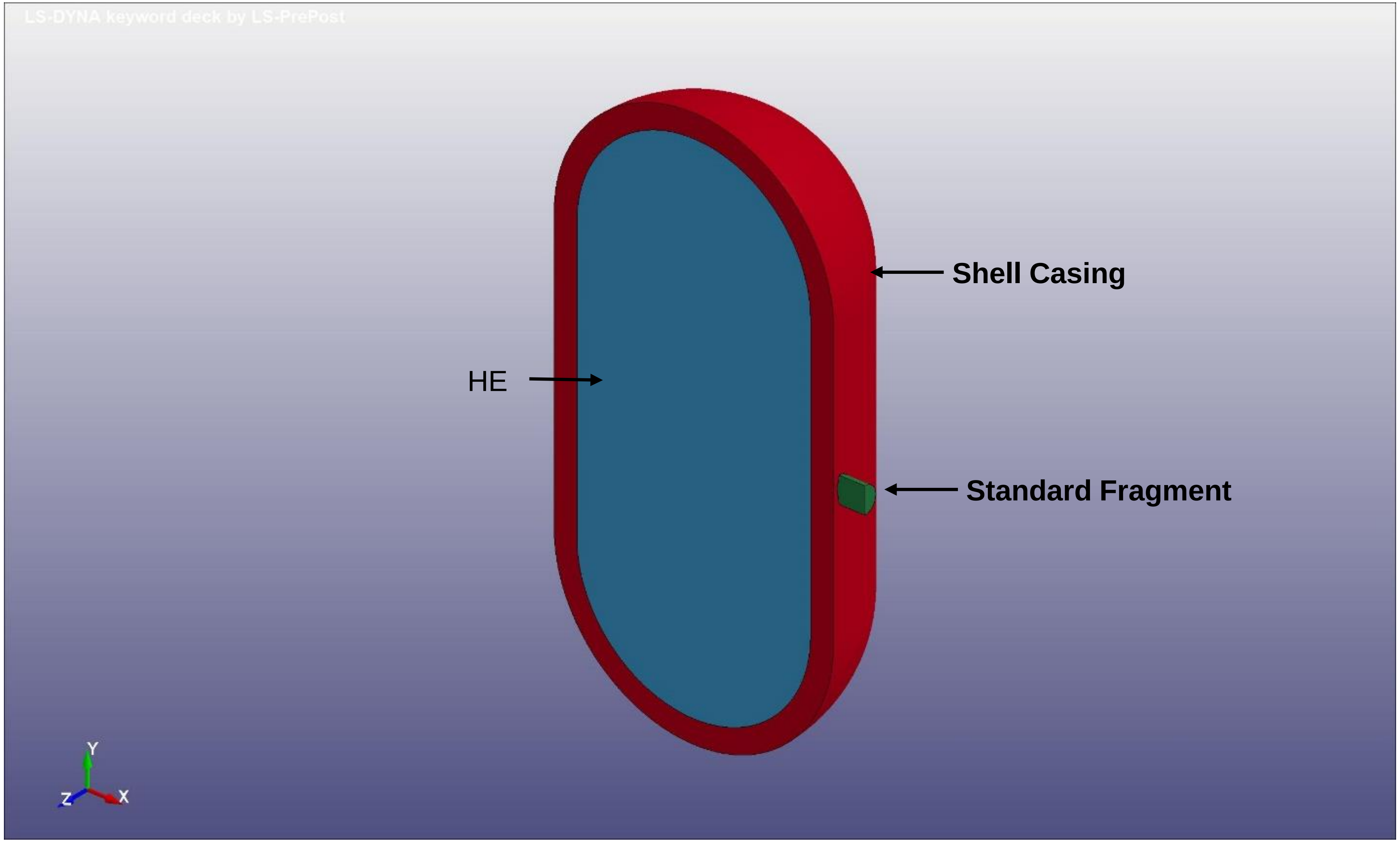
Technical Approach

- ***Three continuum mechanics finite element models developed to simulate the effects of fragment impact orientation on the initial transient pressure in a high explosive fill just beneath the shell casing wall following impact***
  - ***Models simulate notional 155 mm diameter munition with 2:1 length to diameter aspect ratio with 4340 steel casing thicknesses of 0.5", 0.25", and 0.125"***
  - ***All simulations run explicit Lagrangian using 3D, half-symmetry finite element models***
- ***High Explosive material selected was Composition B***
  - ***Mixture of TNT and RDX***
  - ***Modeled using a reactive flow Ignition and Growth Model with a constitutive Elastic/Plastic strength model for the unreacted material.***
- ***4340 Steel casing and mild steel fragment modeled using Johnson-Cook constitutive material model with a Mie-Gruneisen Equation of State***

Technical Approach (cont.)

- ***All models run with fragment impacting at five different orientations***
  - ***Fragment angles of 0°, 2°, 5°,10°, 20° were simulated***
    - *0° defined as fragment oriented with its cylindrical axis perpendicular to munition shell body axis of symmetry*
  - ***Fragment impact velocity modeled at 8300 ft/s***
- ***Models were also run using a spherical fragment of same mass as standard conical fragment***
  - ***Results were compared to standard fragment at 0° to assess feasibility of spherical fragment as a replacement for standard fragment***
- ***All models have a mesh zoning of 20 zones/cm***
- ***All models were run using LS-DYNA, developed and marketed by Livermore Software Technology Corporation (LSTC)***

3D Half-Symmetry Model of Fragment Impact Test



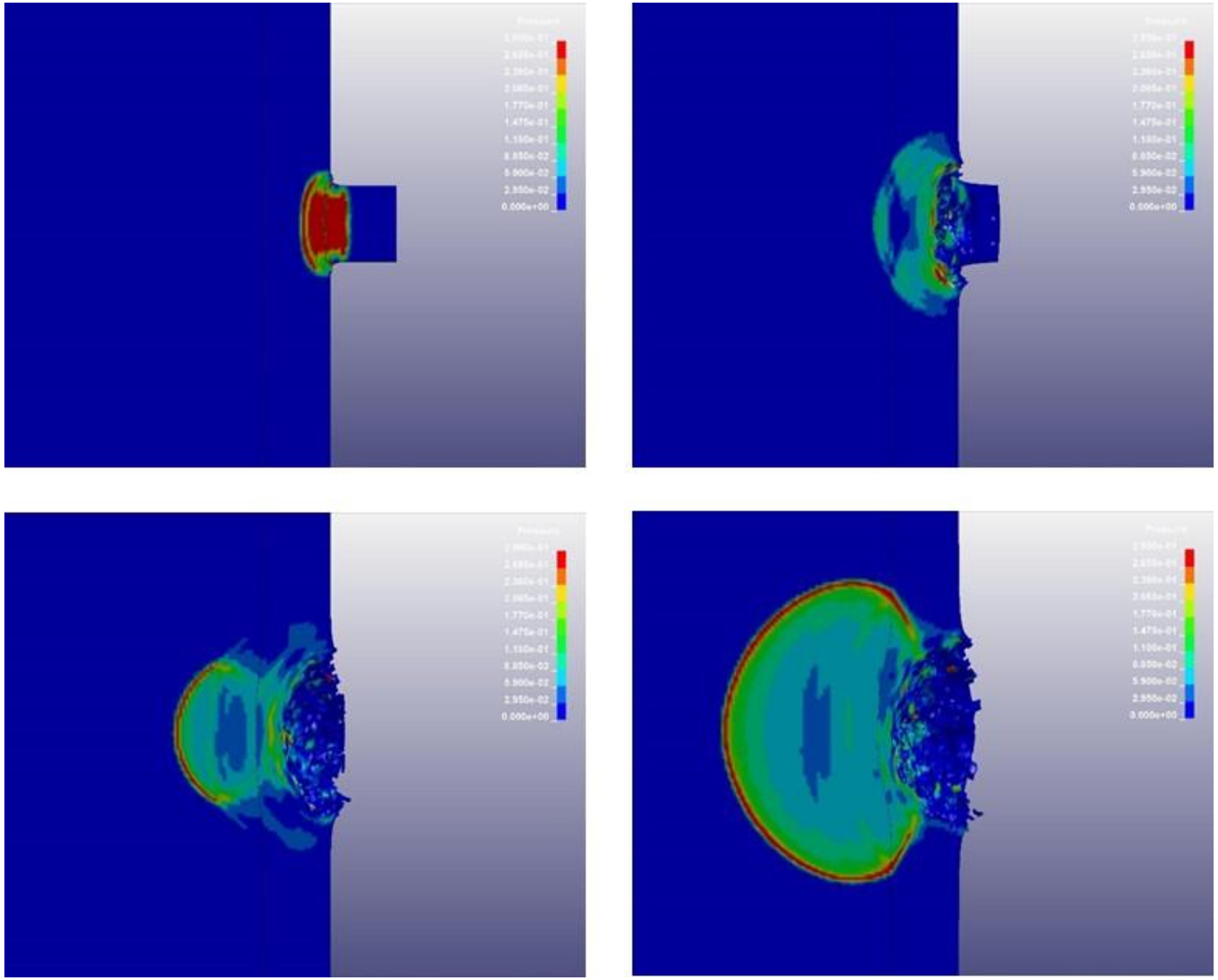
Technical Results – Standard Fragment

- ***All simulations were run for a total of 8 µsec***

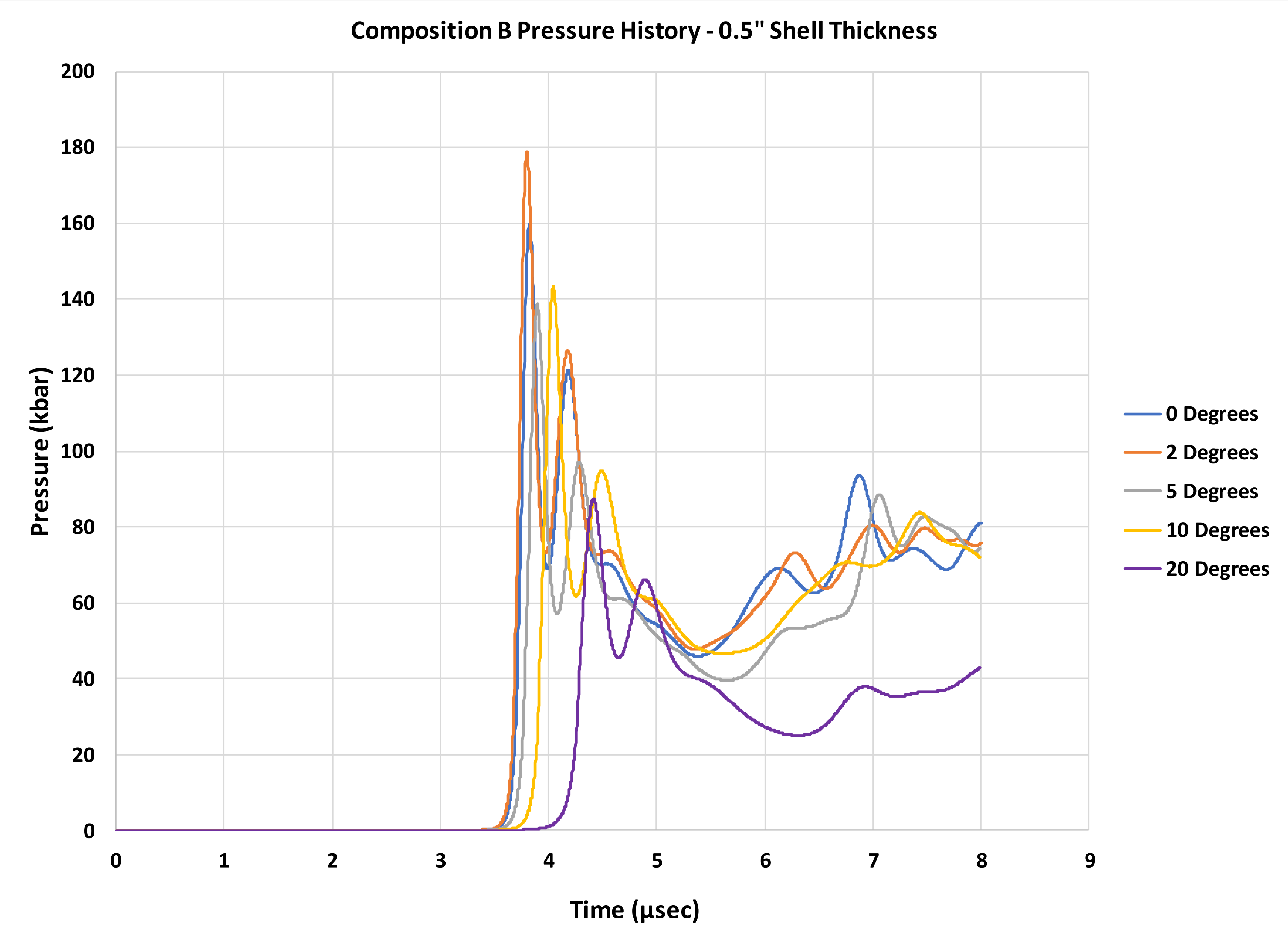
- ***For each simulation, a pressure-time history was recorded for an element in the HE closest to the HE/shell casing interface that experienced the highest initial pressure after fragment impact***
  - ***Pressure history was recorded for selected element every 0.001 µsec***

- ***Following slides show:***
  - ***Pressure contour of the 0.5" shell model at 2, 4, 6, and 8 µsec after fragment impact for a fragment orientation of 0°, illustrating the shock to detonation transition occurring in the Composition B high explosive material***
    - *Detonation occurred with all fragment orientations and shell thicknesses*
  - ***Pressure vs. time history plot at the selected elements for the five different fragment impact orientations. Also provided is a summary table of the peak pressure experienced in the HE immediately after impact.***

Pressure Contours – Standard Fragment at 0° 2, 4, 6, and 8 μsec

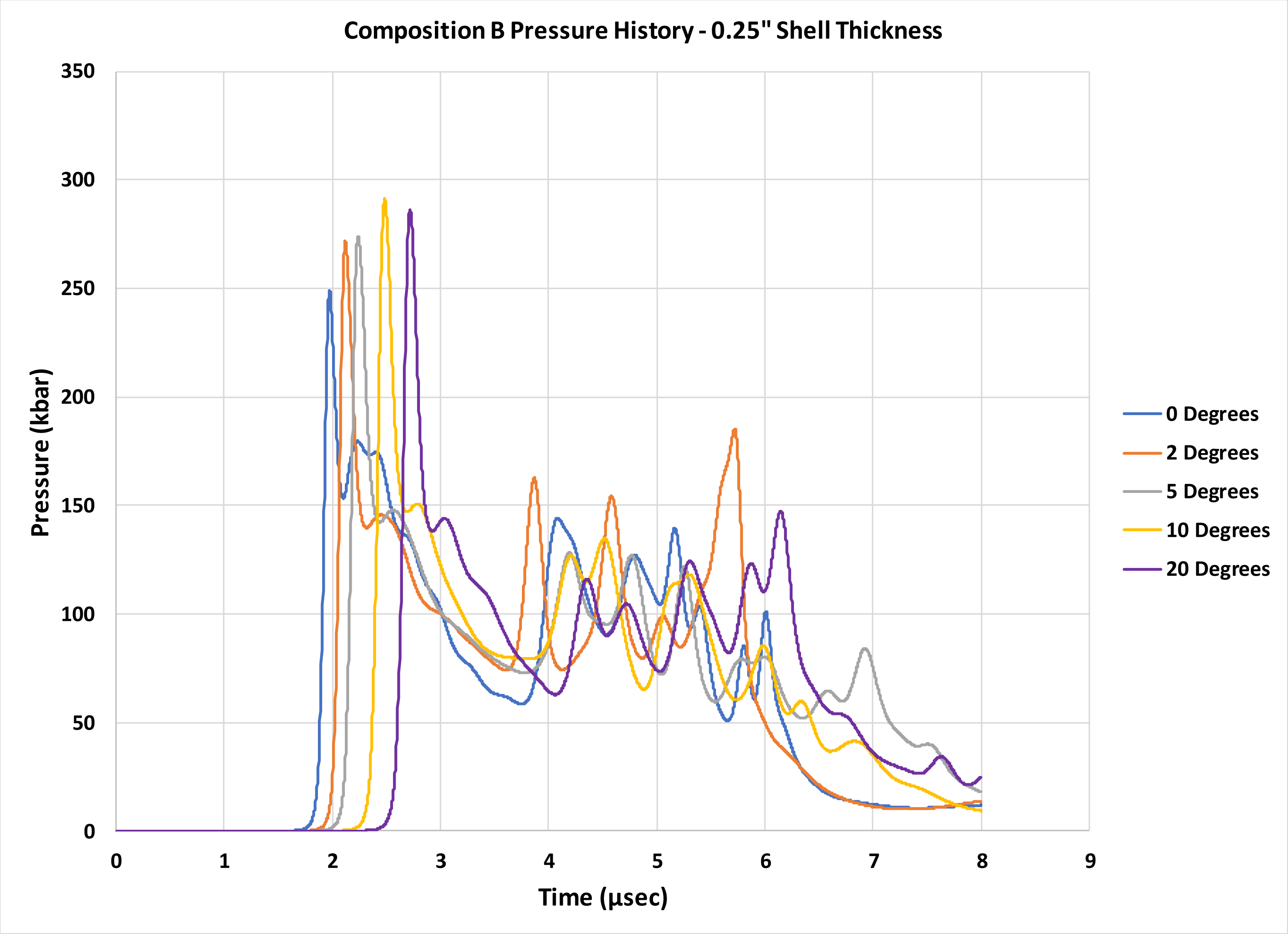


Technical Results – 0.5” Thick Steel Shell Casing



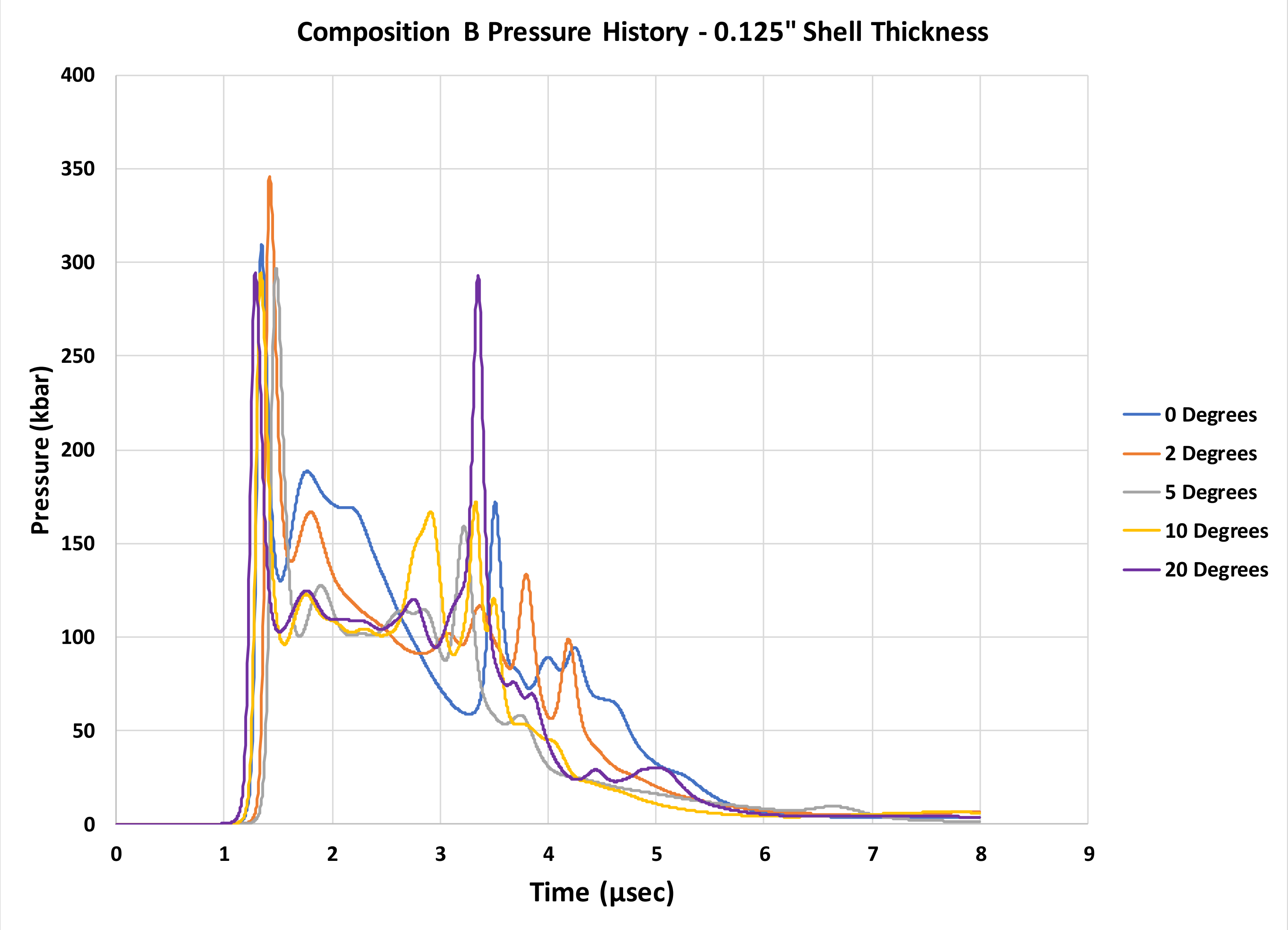
Fragment Orientation (°)	Peak Pressure (kbar)	Change from 0° (%)
0	160	-
2	179	+12
5	139	-13
10	143	-10
20	88	-45

Technical Results – 0.25” Thick Steel Shell Casing



Fragment Orientation (°)	Peak Pressure (kbar)	Change from 0° (%)
0	249	-
2	272	+9
5	274	+10
10	291	+17
20	286	+15

Technical Results – 0.125” Thick Steel Shell Casing



Fragment Orientation (°)	Peak Pressure (kbar)	Change from 0° (%)
0	310	-
2	346	+12
5	297	-4
10	294	-5
20	295	-5

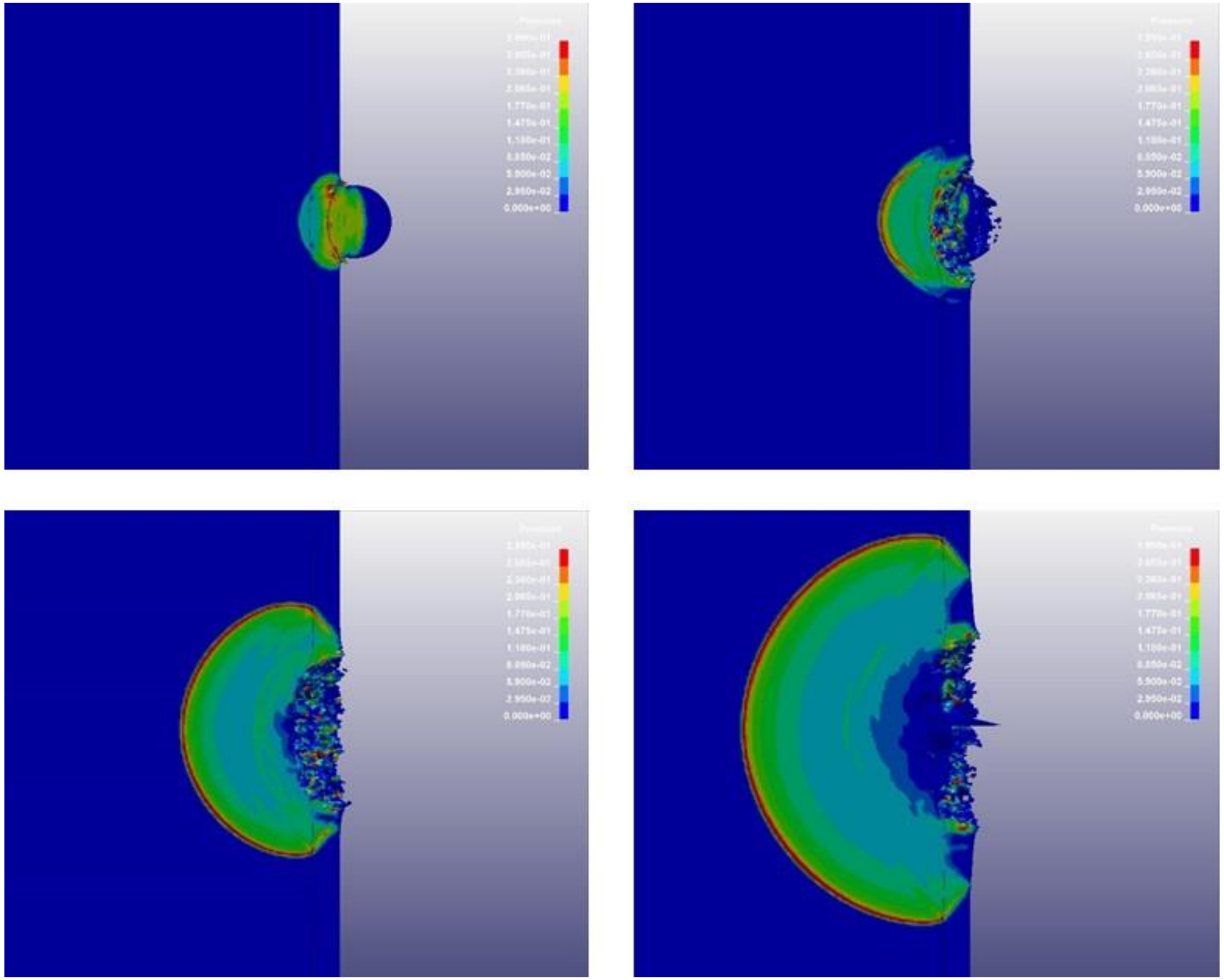
Technical Results – Spherical Fragment

- ***One possible solution for alleviating the need to measure fragment impact angle is to replace the current conical fragment with fully symmetrical spherical fragment***

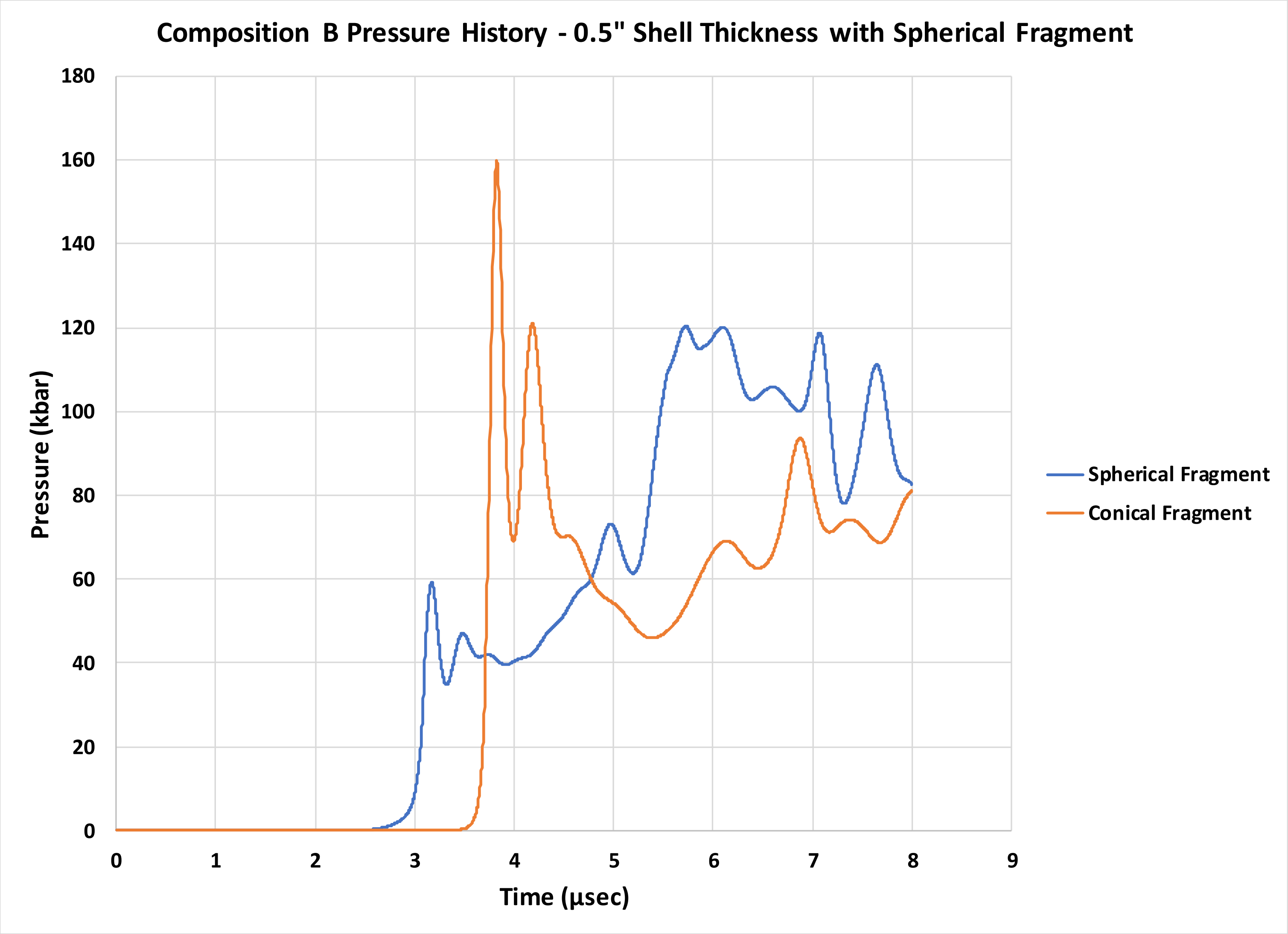
- ***To investigate this solution, the same 3D, half-symmetry, explicit Lagrangian models of varying shell thickness used for the standard fragment were utilized***
  - ***Conical fragment was replaced with spherical fragment of the same mass***
  - ***All materials and material properties remained as previously described***
  - ***Fragment impact velocity modeled remained at 8300 ft/sec***

- ***Following slides show:***
  - ***Pressure contour of the 0.25" shell model at 2, 4, 6, and 8 μsec after fragment impact, illustrating the shock to detonation occurring in the Composition B high explosive material***
    - *Detonation occurred with all shell thicknesses*
  - ***Pressure vs. time history plot comparing standard fragment with the spherical fragment. Also provided is a summary table of the peak pressure experienced in the HE immediately after impact***

Pressure Contours – Spherical Fragment
2, 4, 6, and 8 μsec



Technical Results – 0.5” Thick Steel Shell Casing



Fragment Type	Peak Pressure (kbar)	% Change from Conical Fragment
Conical	160	-
Spherical	59	-63

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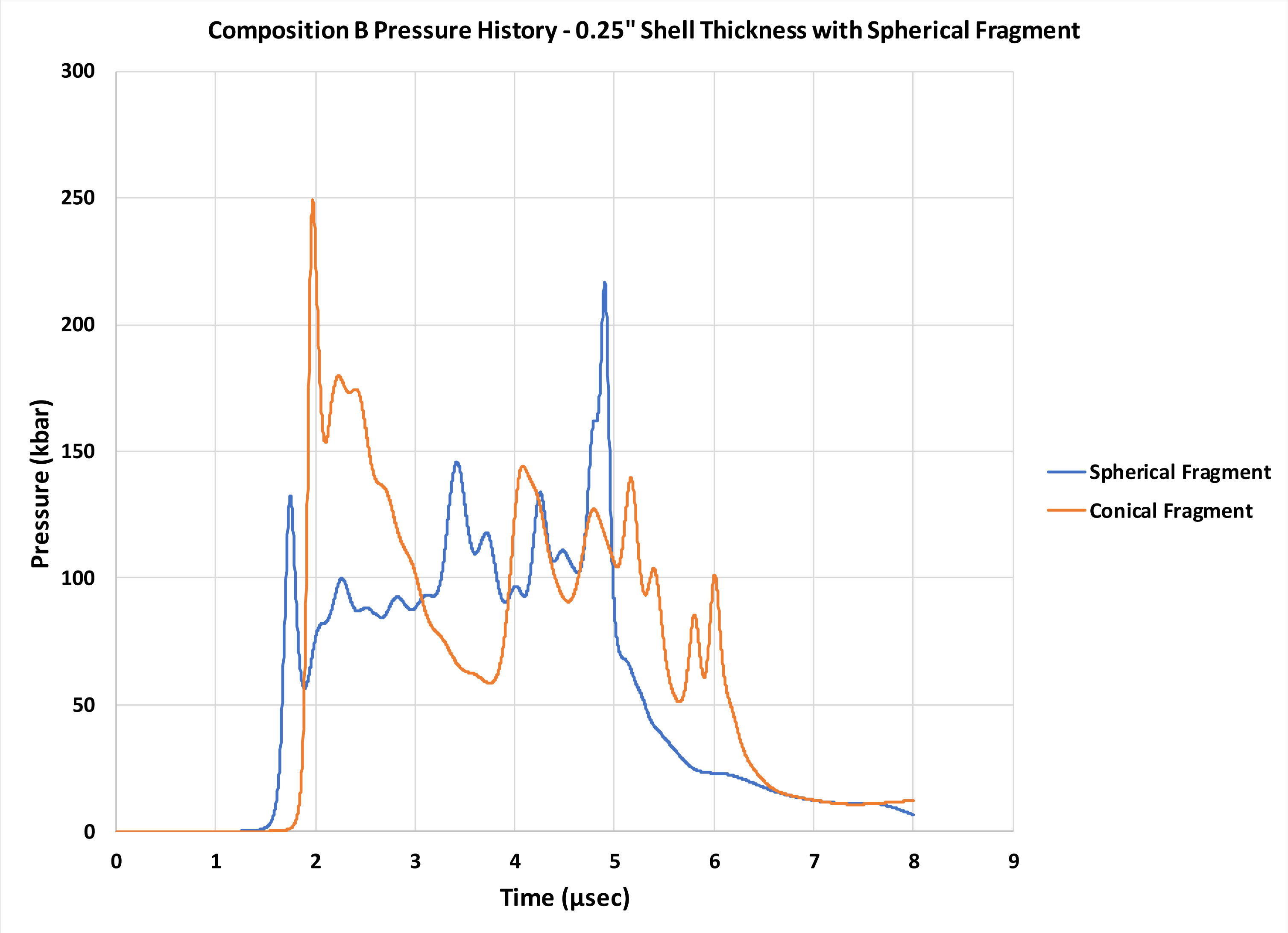
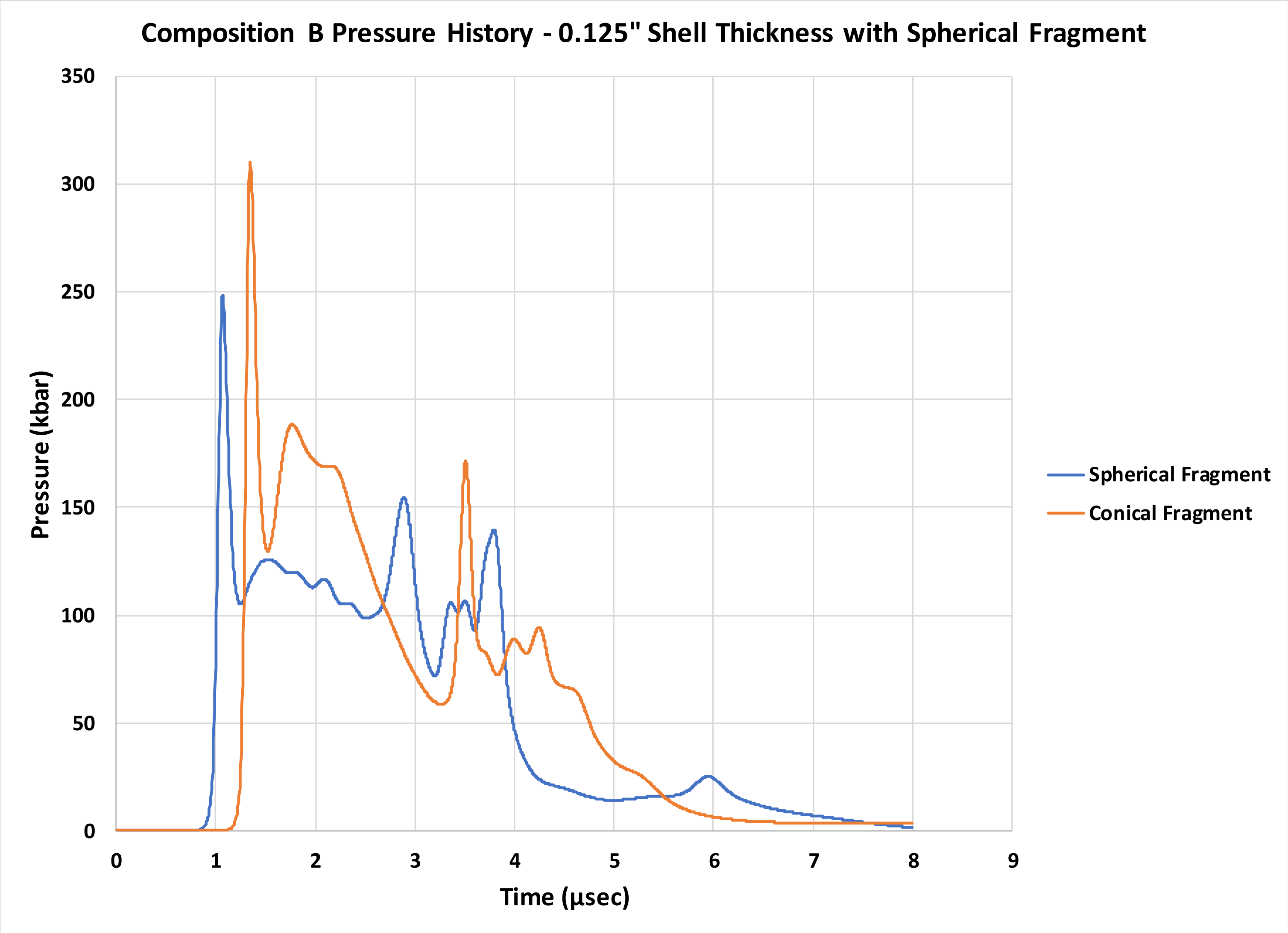
Technical Results – 0.25” Thick Steel Shell Casing



Fragment Type	Peak Pressure (kbar)	% Change from Conical Fragment
Conical	249	-
Spherical	132	-47

Technical Results – 0.125” Thick Steel Shell Casing



Fragment Type	Peak Pressure (kbar)	% Change from Conical Fragment
Conical	310	-
Spherical	249	-20

Summary and Conclusions – Standard Fragment

- ***Modeling results showed that minor deviations in fragment impact orientation have significant effects on the peak pressure and pressure-time history experienced by the explosive fill for a range of shell casing thicknesses - all resulted in prompt detonation of Comp B explosive fill***
  - ***0.5" thickness steel shell casing***
    - *2° impact orientation resulted in 12% increase in peak pressure*
    - *5° and 10° impact orientations resulted in decreases in peak pressures of 13% and 10%, respectively*
    - *20° impact orientation resulted in a decrease in peak pressure of 45%*
  - ***0.25" thickness steel shell casing***
    - *All deviations from 0° resulted in decreases in peak pressures, ranging from 9-17%*
  - ***0.125" thickness steel shell casing***
    - *2° impact orientation resulted in increase of 12% in peak pressure*
    - *All other deviations from 0° resulted in decreases in peak pressures of 4-5%*

Summary and Conclusions – Spherical Fragment

- A spherically shaped fragment of the same mass/material was also modeled to assess viability as a replacement for the conical fragment

- Unfortunately, spherical fragment impact models showed significant drops in peak pressure experienced by the explosive fill at all shell thicknesses modeled in comparison to the conical fragment impact models at 0°

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