# DA VINCH -- ASME Code Rules for CWD Vessels

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# Presentation Outline

- Principal DA VINCH Vessel Design Features
- The CWD Vessel Detonation Loading
  - Pressure – Time History Evaluation
  - Impulse Distribution
- ASME Section VIII, Division 3 Design Requirements
  - Single Application of Detonation Impulsive Load
  - Multiple Detonations (Fatigue)
- CWD Vessel Response to a Single Detonation
- Crack Growth for Sequential Detonations
- Satisfaction of Leak-Before-Burst Criteria
- Conclusions

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# DA VINCH Vessel Design Features

- Two close-fitting vessels to provide containment
- Inner vessel removable, high-strength, low alloy steel
- Outer vessel fixed, laminated carbon steel cylindrical wall welded to carbon steel top and bottom ellipsoidal heads
- Complete circumferential gap in inner vessel provides a measure of overpressure protection for the inner vessel, and obviates the need for an expansion chamber
- Combined vessel system has vacuum capability, enabling the detonation pressures in the inner vessel to be substantially reduced

# External View of DAVINCH Vessel

# Vessel with Top Heads Removed

# DA VINCH Inner Vessel

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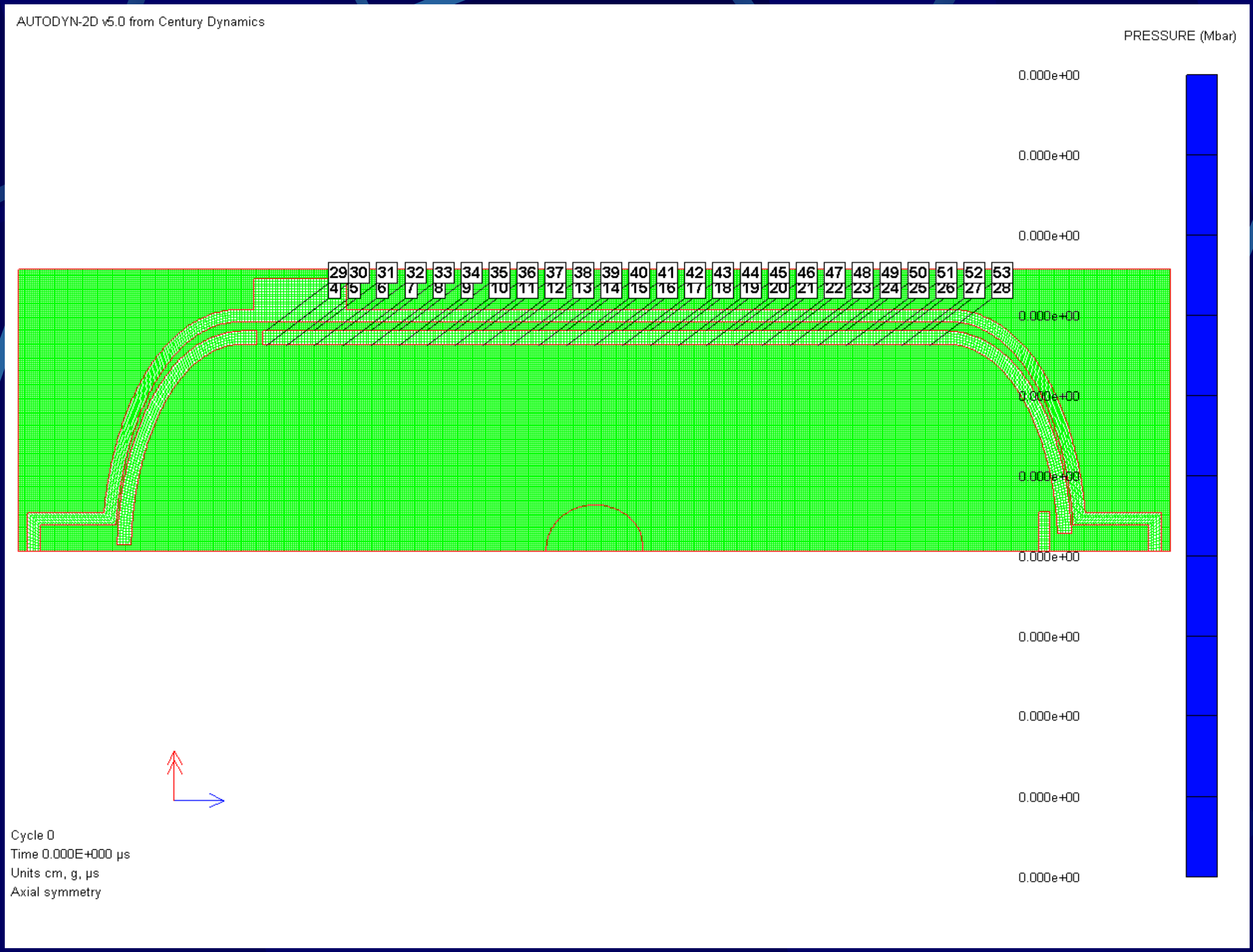
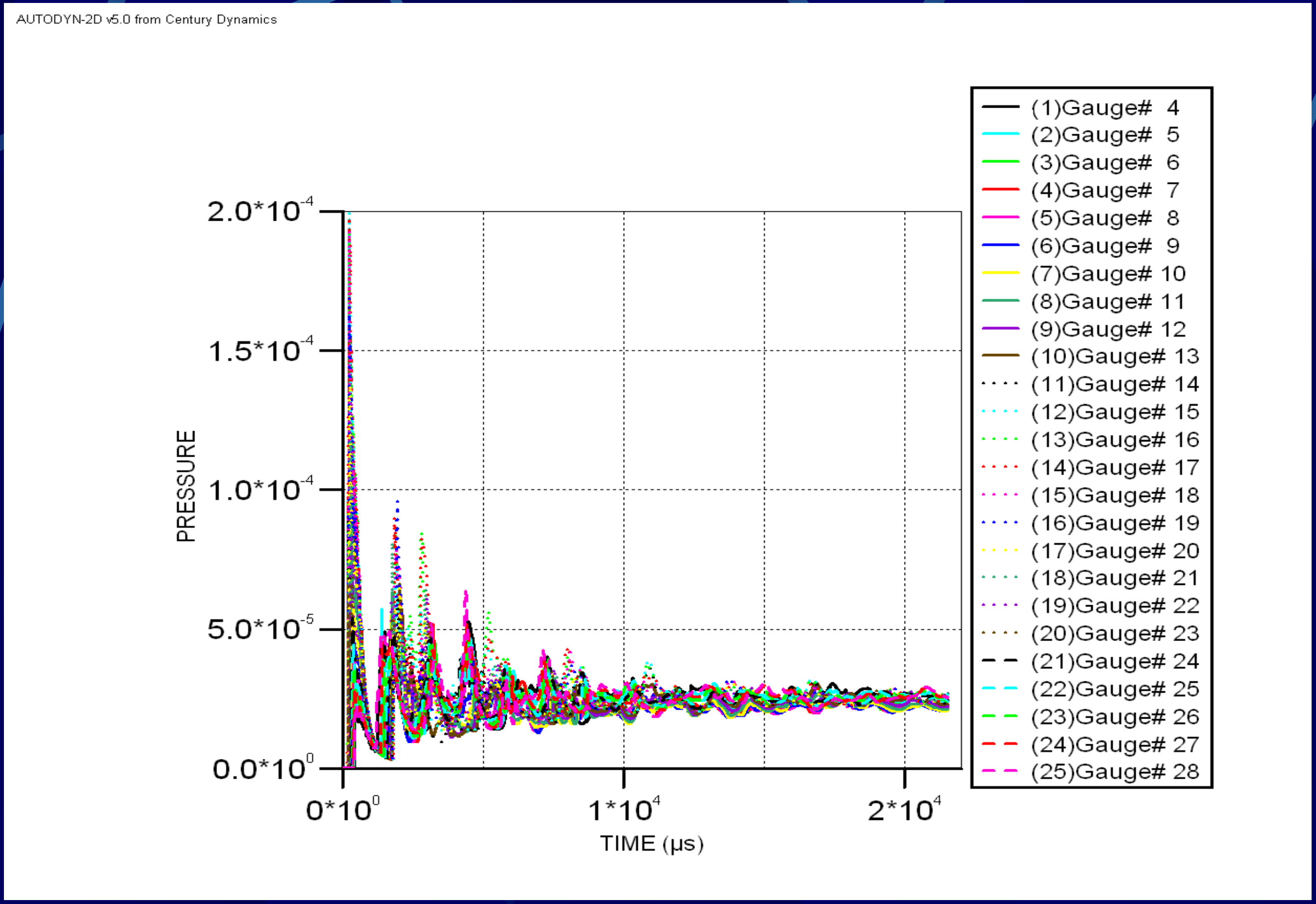
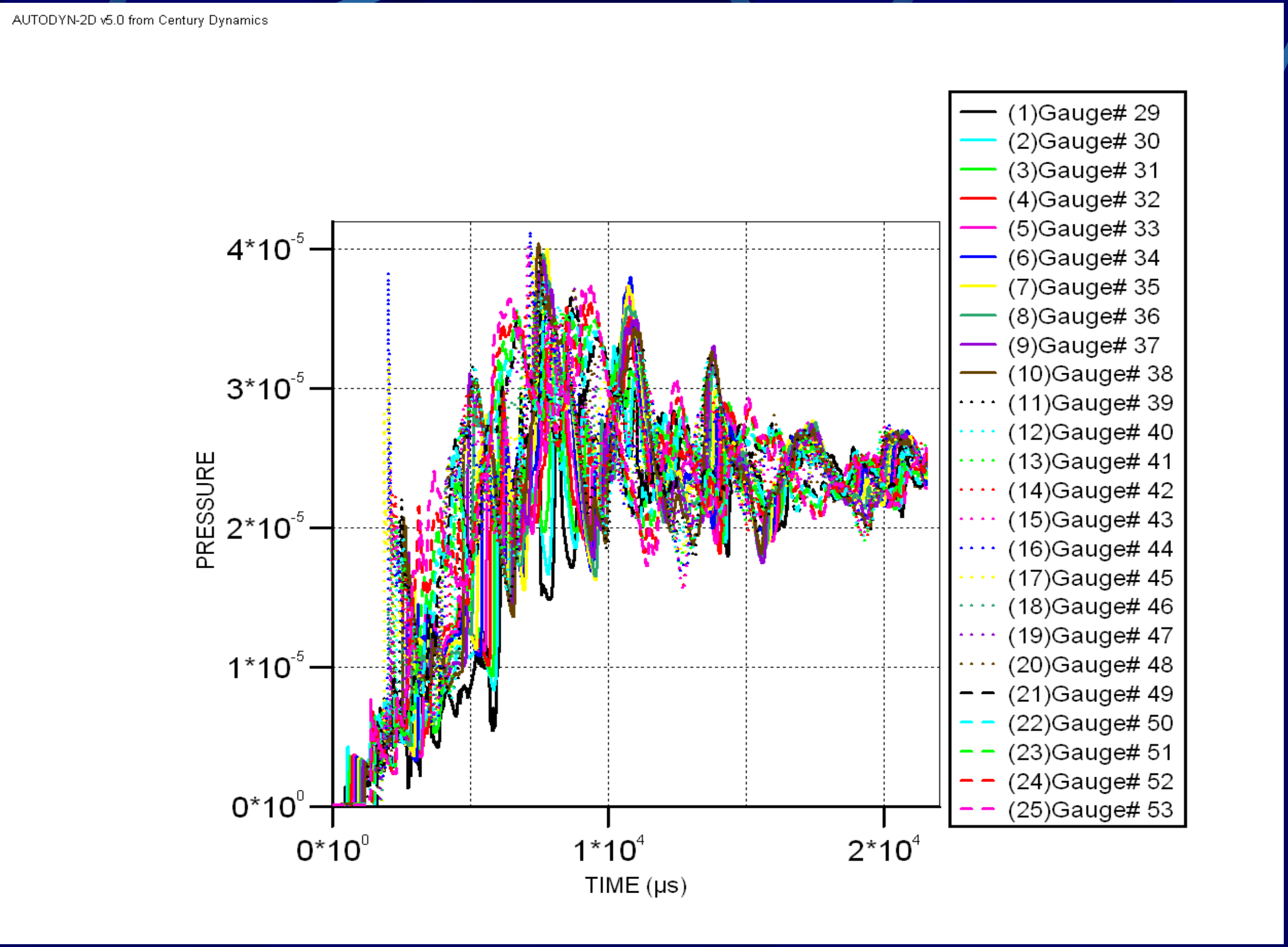
# Detonation Pressures Points



# Calculated Detonation Pressures Inner Vessel, Inner Surface



# Calculated Detonation Pressures Inner Vessel, Outer Surface



# Detonation Pressure Calculations

- AUTODYN® used for the calculations
- Pressure-time histories and integrated impulse agree well with spherical vessel detonation experiments (20 lb to 120 lb HE equivalent) carried out at Los Alamos National Laboratory
- Circumferential gap in inner vessel enables pressure to equilibrate on inside and outside surfaces of inner vessel, reducing dynamic stresses to relatively low values
- Outer vessel is subject to pressure-time ramp, not impulsive pressure

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# ASME Code Section VIII, Division 3

- Alternative rules for the design of vessels subjected to high pressure
- Two methods permitted – one based on elastic stress analysis, one based on elastic-plastic analysis
- Includes requirements for demonstrating leak-before-burst
  - If leak-before-burst demonstrated, standard fatigue methods for cyclic loading
  - If leak-before-burst cannot be demonstrated, fracture mechanics and crack growth methods

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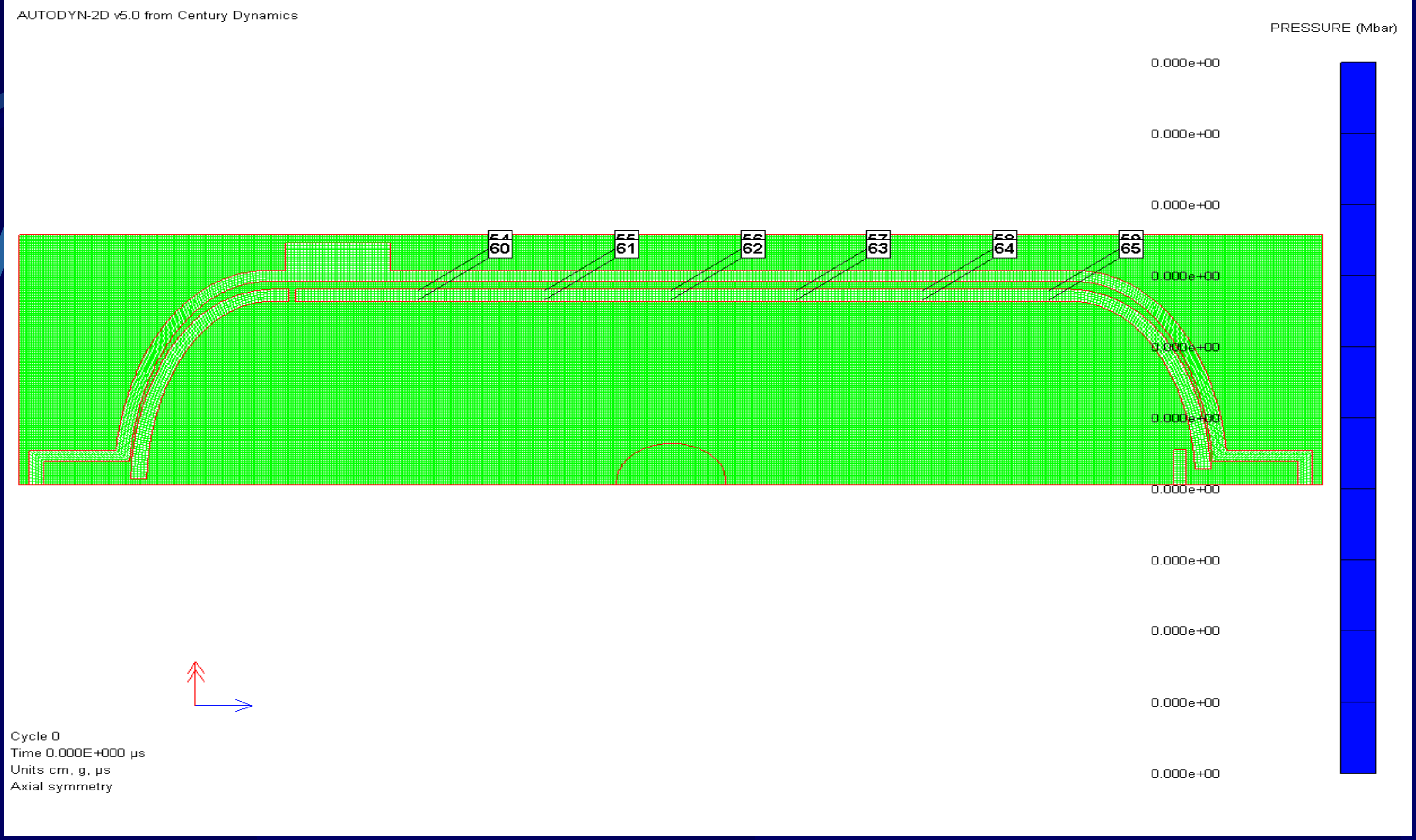
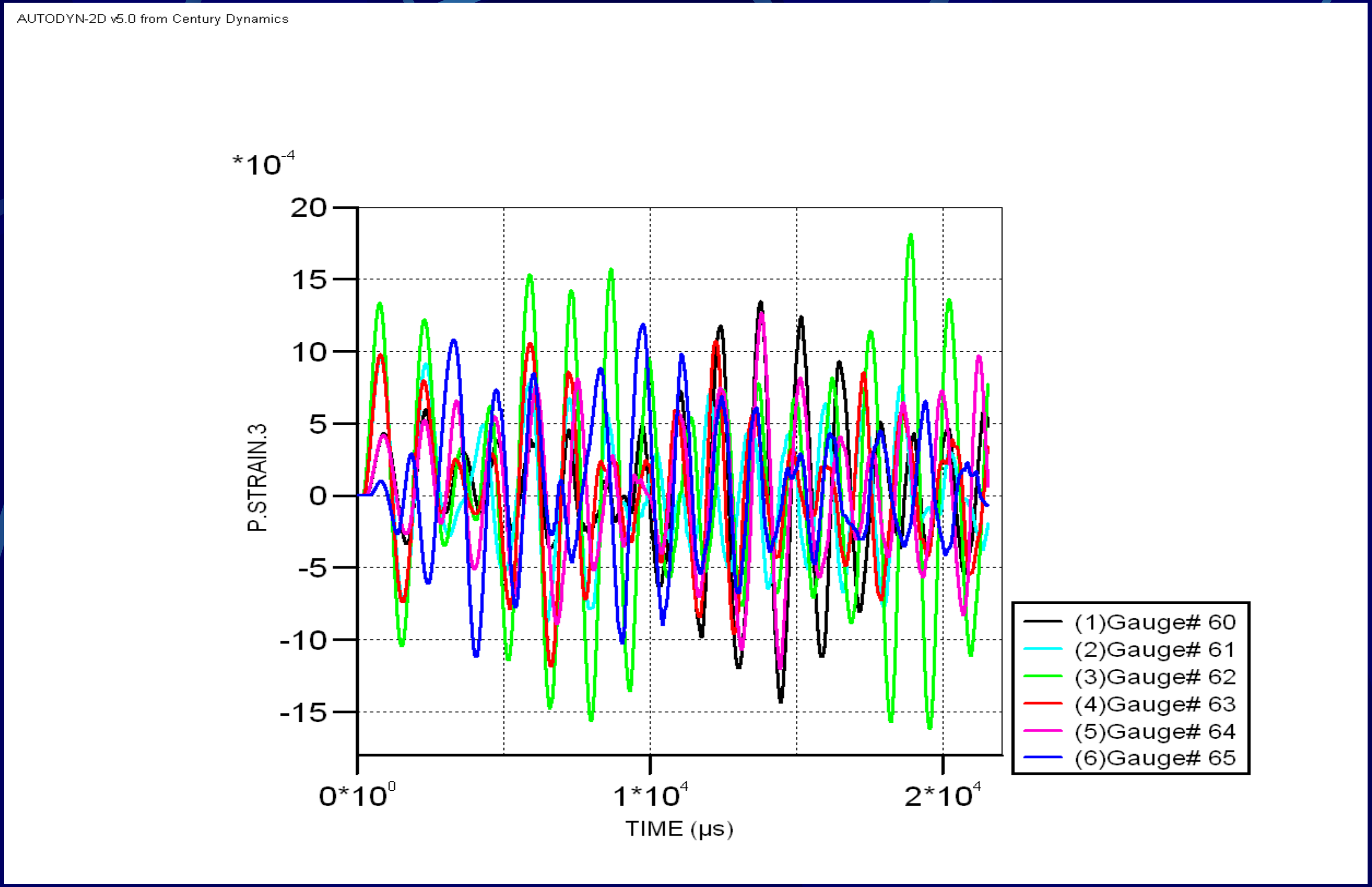
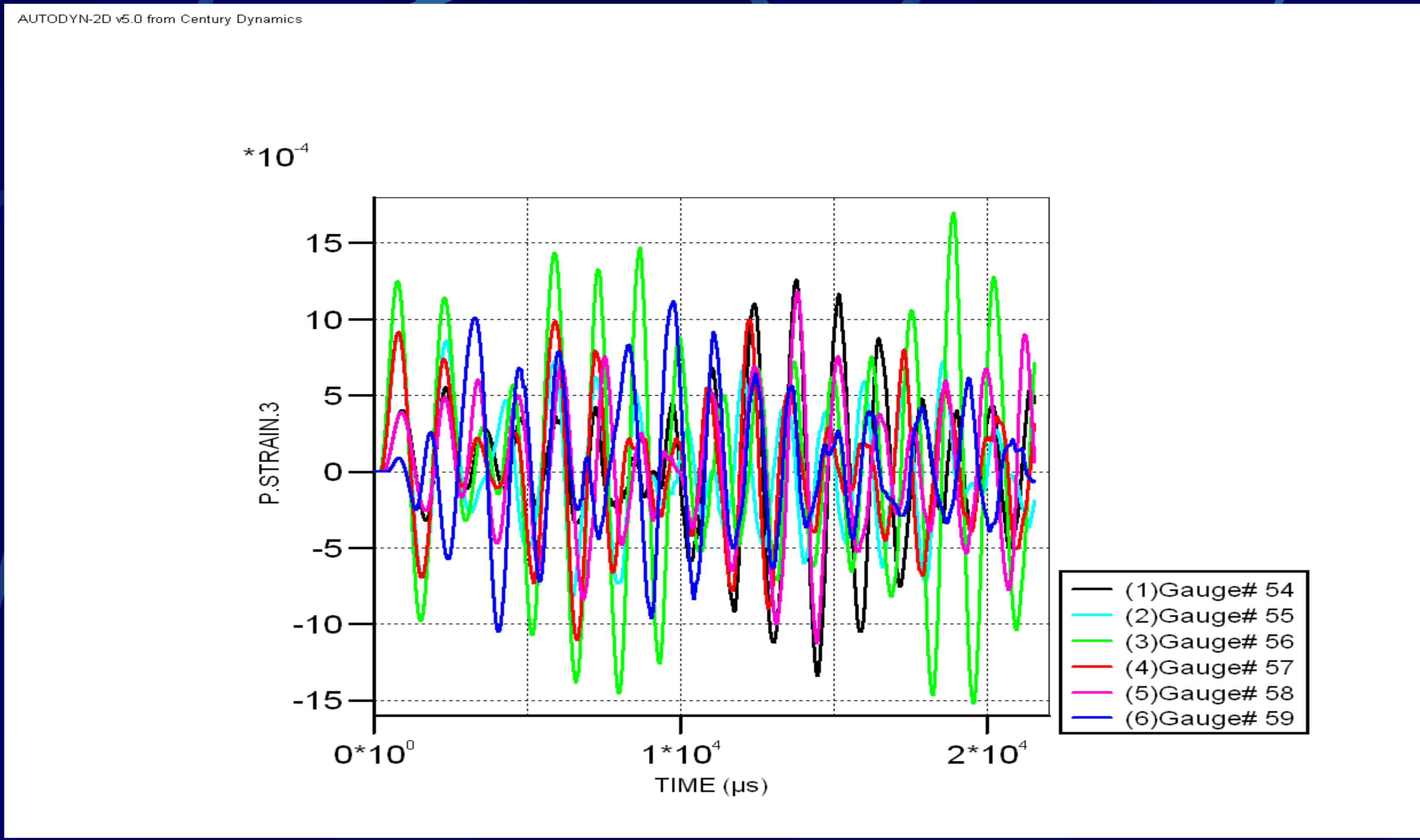
# Circumferential Strain Points
# Inner Vessel, Inner/Outer Surface



# Calculated Circumferential Strain Inner Vessel, Inner Surface



# Calculated Circumferential Strain Inner Vessel, Outer Surface



# Single Detonation Response

- Multiple strain cycles with gradually decreasing peak amplitude
- Two significant modes of dynamic response with frequencies that are far apart
  - Radial “breathing” mode of moderately high frequency
  - Axial “push-pull” mode, heads pushing and pulling on cylindrical section
- In-phase “beating” and out-of-phase “nullification” taken into account for cyclic crack growth calculations
- Number of cycles per detonation doubled to account for response from 20 msec to 40 msec

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# Multiple Detonation Response

- Initial flaws of various depths postulated at inner surface of inner vessel, based on pre-service inspection capability (1.5 mm to 25 mm)
- Crack propagation calculated for single detonation, with new crack depth calculated and crack growth during subsequent detonations accumulated
- Calculations continued and propagated flaw compared after each sequential detonation to critical flaw size
- In-service inspection schedule for inner vessel determined (200 to 650 detonations)

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# Conclusions

- All three ASME Section VIII, Division 3 leak-before-burst criteria are met
- Critical axial flaw depth is larger than the vessel thickness
- Applied fracture mechanics stress intensity factor at worst location is less than fracture toughness
- Remaining ligament is much less than the square of fracture toughness/yield strength
- Results confirm Kobe Steel experience with other DA VINCH inner vessels