IEEE NPEC SC-2 Meeting: April 2010

Designing Mechanical Seals for Nuclear Instrumentation

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ROSEMOUNT® Nuclear

EMERSON™ Process Management

Agenda

- **Overview of Pressure Transmitter Applications**
- **General Design Concepts for Static Seals**
- **Theory to Practice**
  - 3150 Process Seal Design
- **New Qualification Requirements**
  - 3150 Housing Seal Design

Pressure Transmitter Applications

Nuclear Island/ Containment

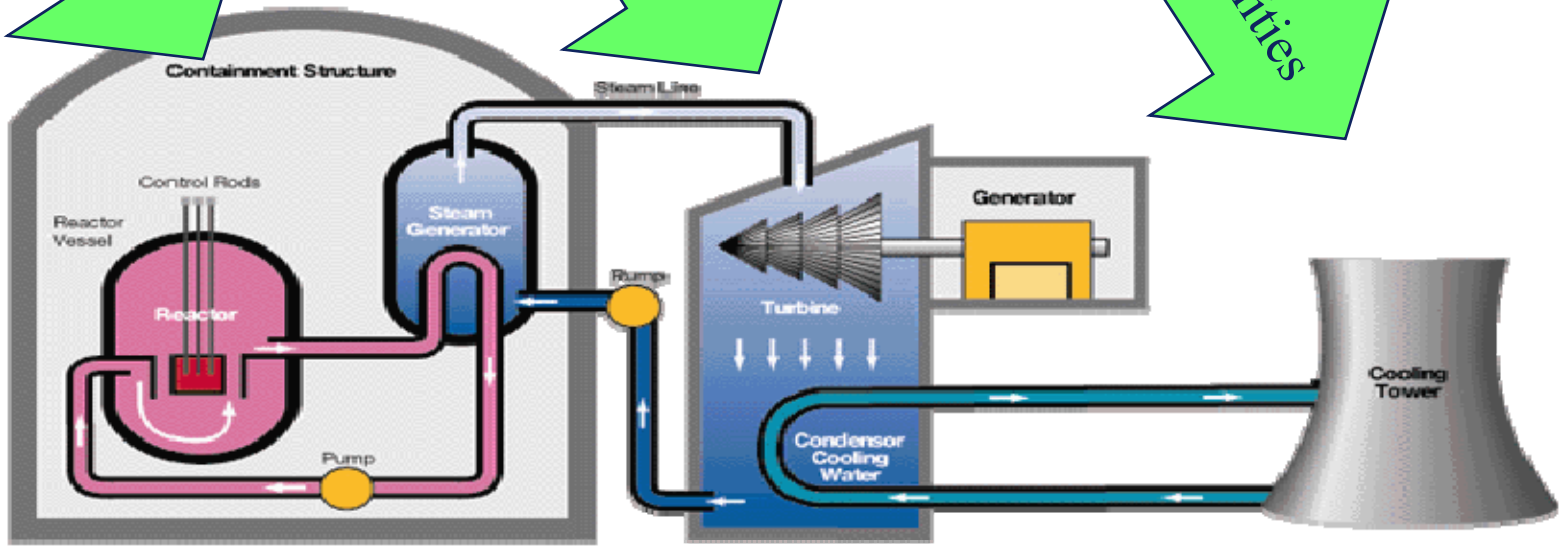
100-400 transmitters per reactor

Balance of Plant/ (BOP)

300-500 transmitters per reactor

Auxiliary Facilities

300-500 transmitters per reactor



Safety Related | Non-Safety

Balance of Plant (BOP)

Nuclear Island

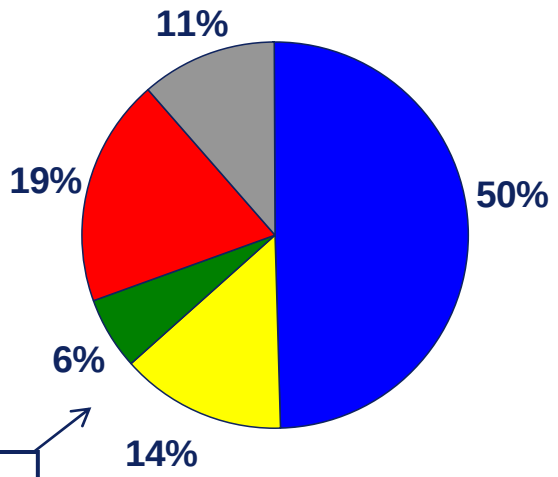
Safety Related | Non-Safety

3150 Series Qualification Efforts

KTA 3505 Standard
(In Progress)

RCC-E Standard K2/K3
(Complete)

IEEE Standards
(In progress)

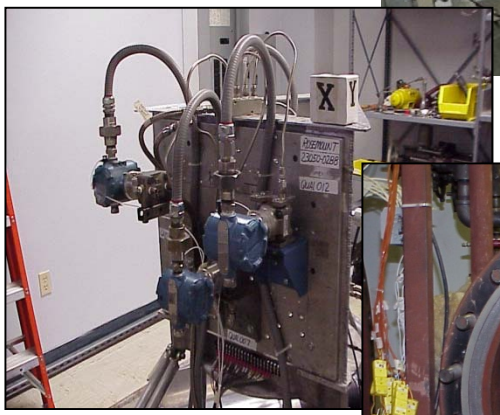


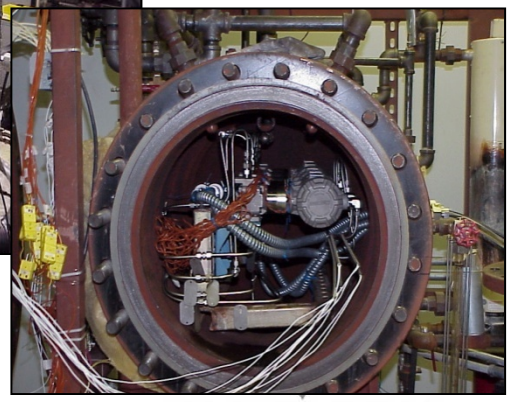
Market Breakdown by
Typical Standard Specified

ROSEMOUNT®
Nuclear

Nuclear Requirements Highlights

- **20-year Qualified Life at 120°F**
  - Aging (Thermal, Mechanical, Electrical)
- **Up to One Million Pressure Cycles**
- **200 Mrad Total Radiation Dose**
- **Tri-axial Seismic Tests (8.5g ZPA)**
- **Airplane Crash Test (8g sine sweep)**
- **435°F and 110 psig LOCA**
- **Post Accident and Submergence**
  - Up to 4 months duration
  - Steam and boric acid exposure





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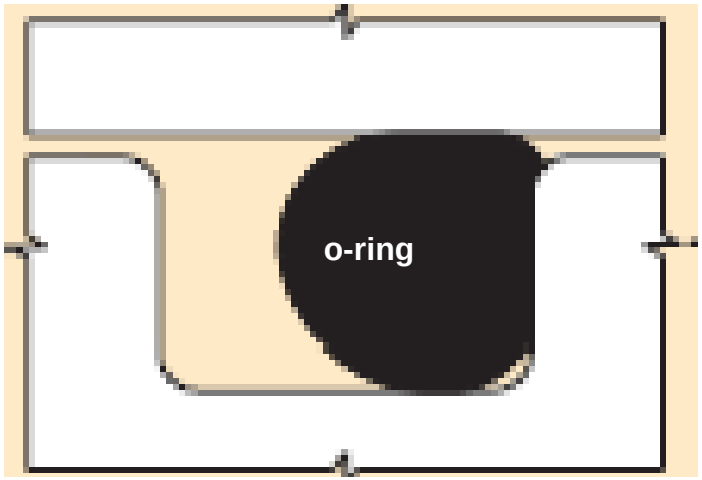
Elastomer O-rings

- **ASTM Criteria for the Definition of an Elastomer**
  - Must not break when stretched approximately 100%
  - After being held for five minutes at 100% stretch, must return to within 10% of original length within five minutes after release *- Parker Hannifin Corporation*

- **Typical Elastomers**
  - EPDM, Butyl, Nitrile, Fluorocarbon, Aflas, Neoprene, Silicone

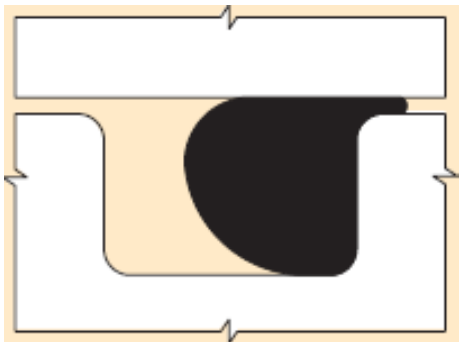
Elastomer O-rings

- **Popular choice of seal**
  - Seals over a wide range of surface irregularities
  - Large bolt load not required
  - Ease of service
  - Inexpensive
  - Design concept of self-help utilized

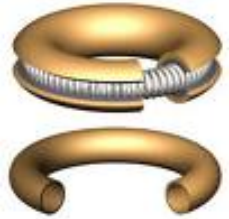


Design Considerations for Elastomer O-rings

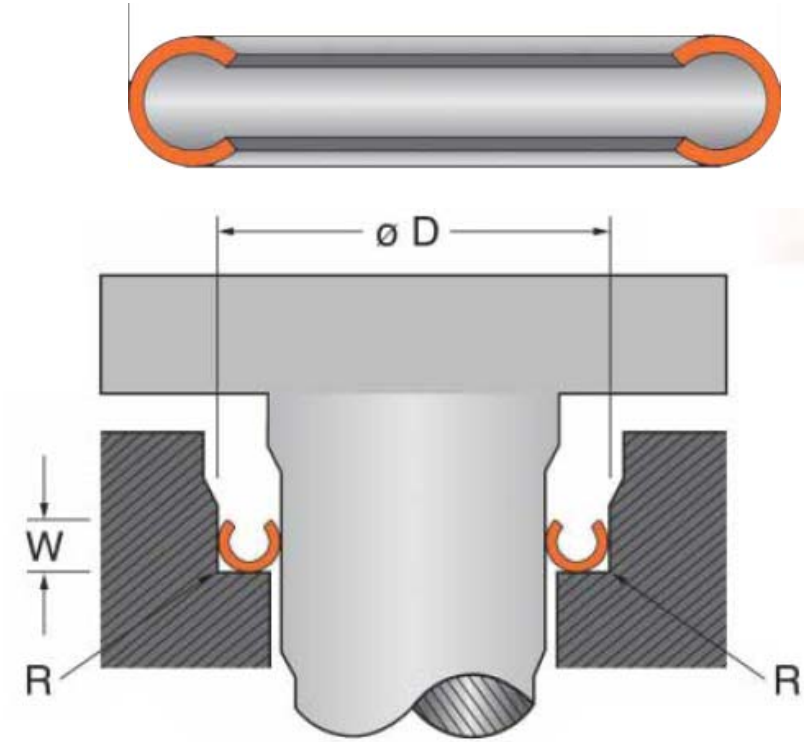
- **Dimensioning**
  - Correct amount of compression
- **Surface Finish**
- **Extrusion**
  - Durometer, Differential Pressure and Gap Size
- **Compression Set**
- **Process Material Compatibility**
- **Temperature and Radiation Resistance**
- **Permeability**
  - O-ring material, Gas, O-ring size
  - Temperature, Differential Pressure, and Time



Metal O-rings and C-rings

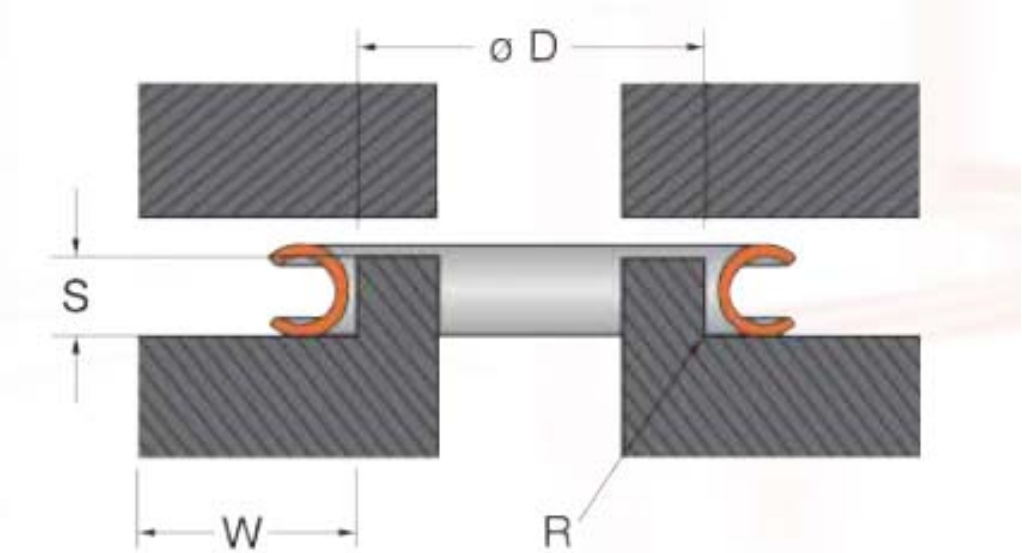


- **Offers many advantages**
  - Suitable for extreme operating conditions
  - High pressure and vacuum applications
  - Insensitive to radiation
  - Insensitive to thermal aging
  - Non permeable



Metal O-rings and C-rings

- **Design Considerations**
  - Appropriate Groove Surface Finish with Concentric Tool Paths
  - Adequate Seating Load
  - Tightly-Controlled Compression
  - Compatibility Between O-ring Material and Flange Material
  - Appropriate Plating Material and Thickness



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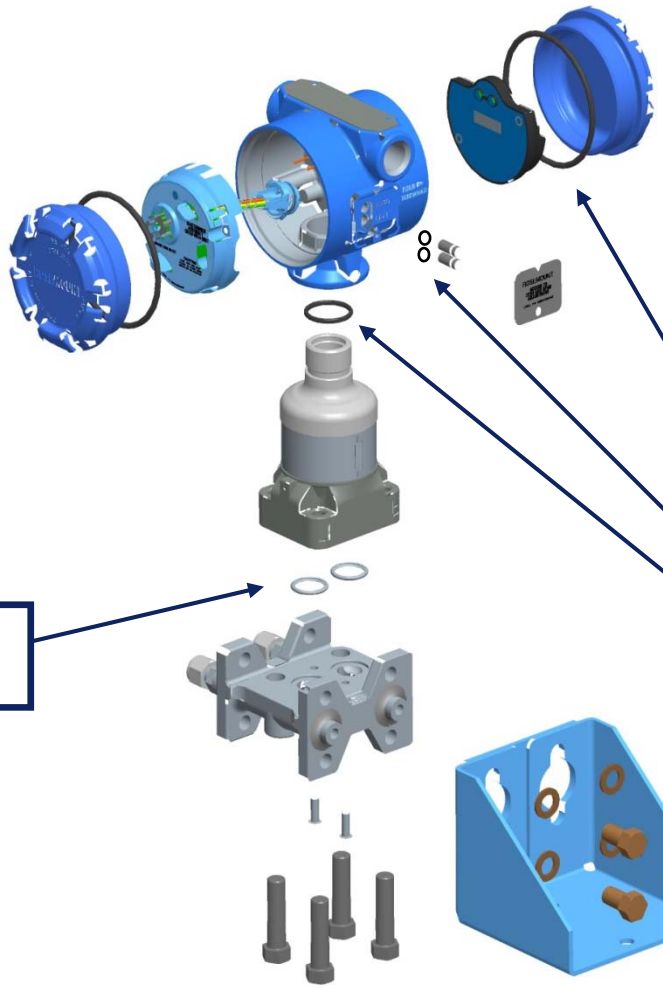
Pressure Transmitter Mechanical Seals

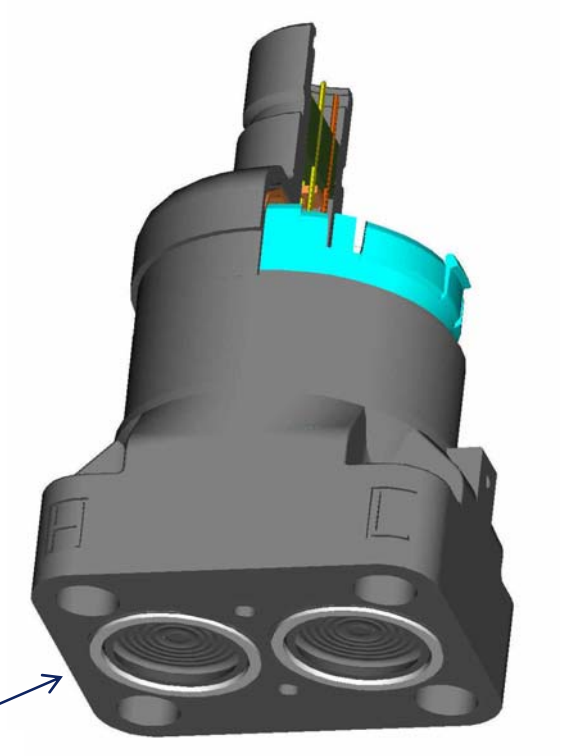


Process Seals

Environmental Seals

3150 Series Process Seal
- Primary Objectives

- High Reliability in Nuclear Environments
- Hydrostatic Pressure to 6,000psi
- Burst Pressure >10,000 psi
- Minimize “Dead Zones” for Process Fluid Entrapment
- Clamping Stress Does Not Affect Transmitter Performance
- Can be Manufactured with High Yields
- Low Risk of Part Obsolescence



Process Seals

3150 Series Process Seal

Multiple Designs Evaluated

- Elastomer o-rings
- ETFE gaskets
- Spring-energized ETFE and PEEK o-rings
- Graphite gaskets
- All-welded configuration
- Redundant seals

General Shortcomings

- Sealing performance after aging and/or accident testing
- Complexities in manufacturing or field maintenance

Elastomer O-rings

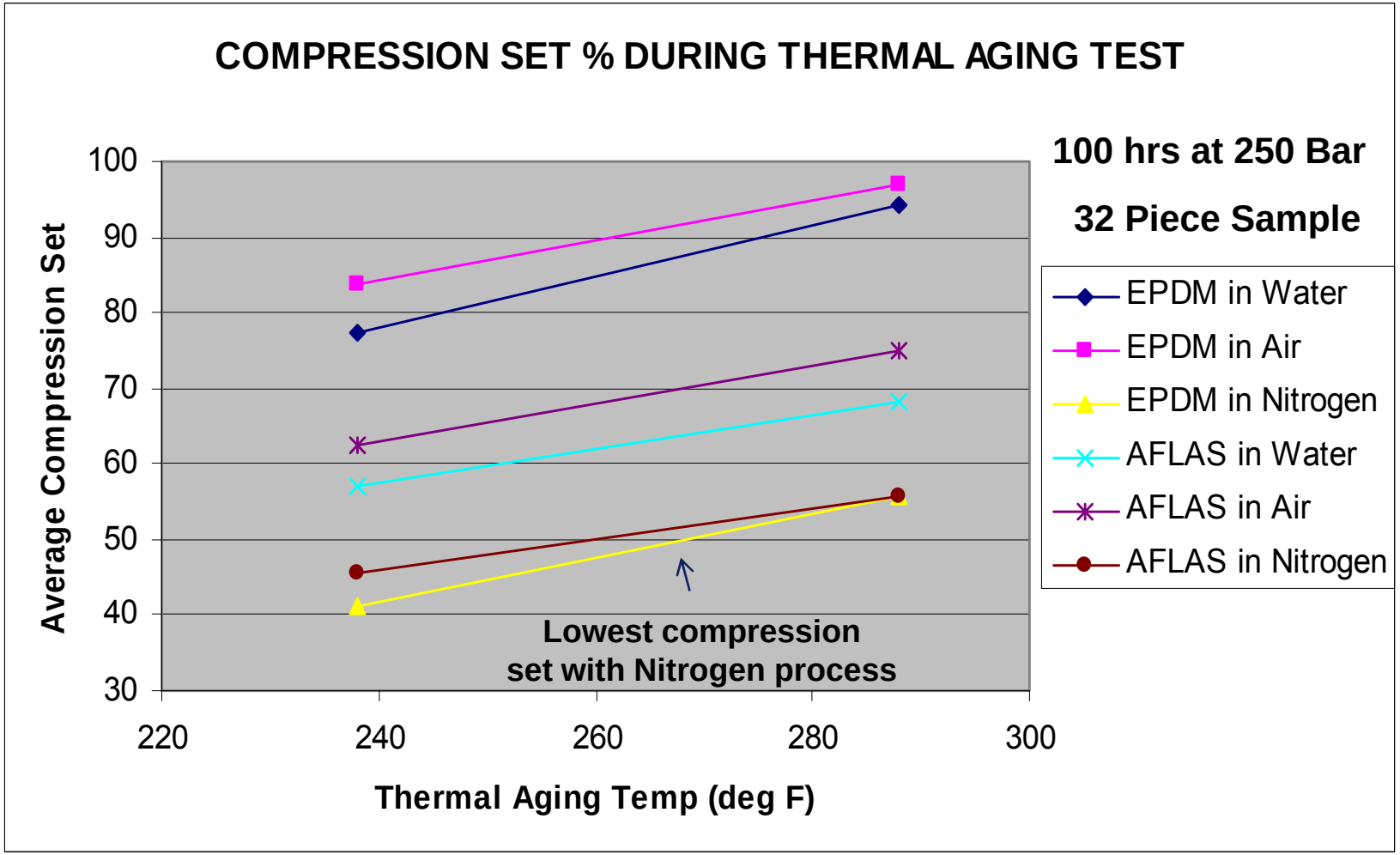
Advantages

- Simple for manufacturing
- Prior use of EPDM and Aflas in other applications
- Readily available
- Low cost

Concerns

- High pressure sealing
- Compression set and extrusion of o-ring after aging
- Formulation sensitivity

Elastomer O-rings: Compression Set



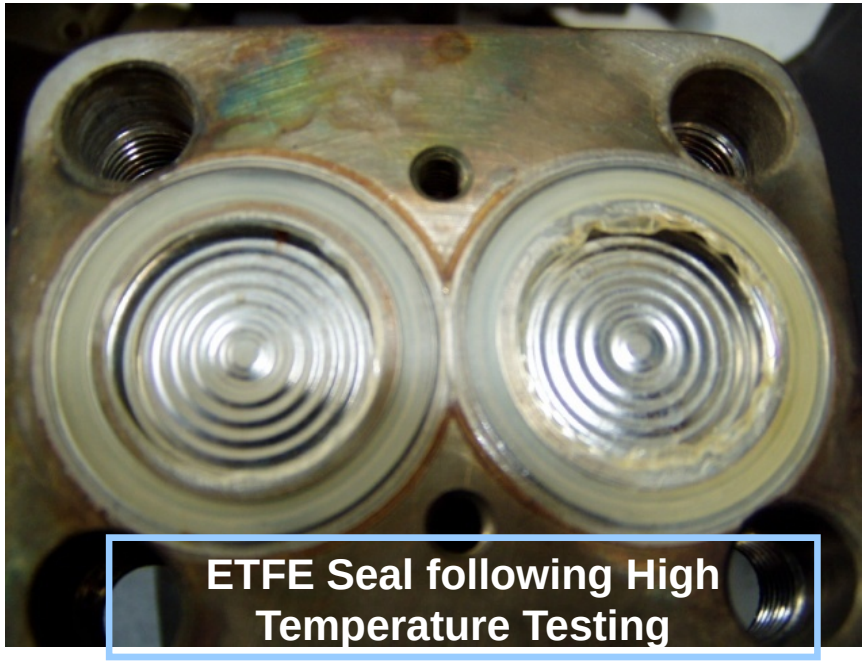
ETFE o-rings

Advantages

- **Similare to Teflon Seal**
  - Teflon used extensively for high volume commercial pressure transmitters
- **Temperature resistance**
  - 300°F (100,000 hours)
  - 350°F (10,000 hours)
- **Significant tensile strength and elongation remain after 120 Mrad**

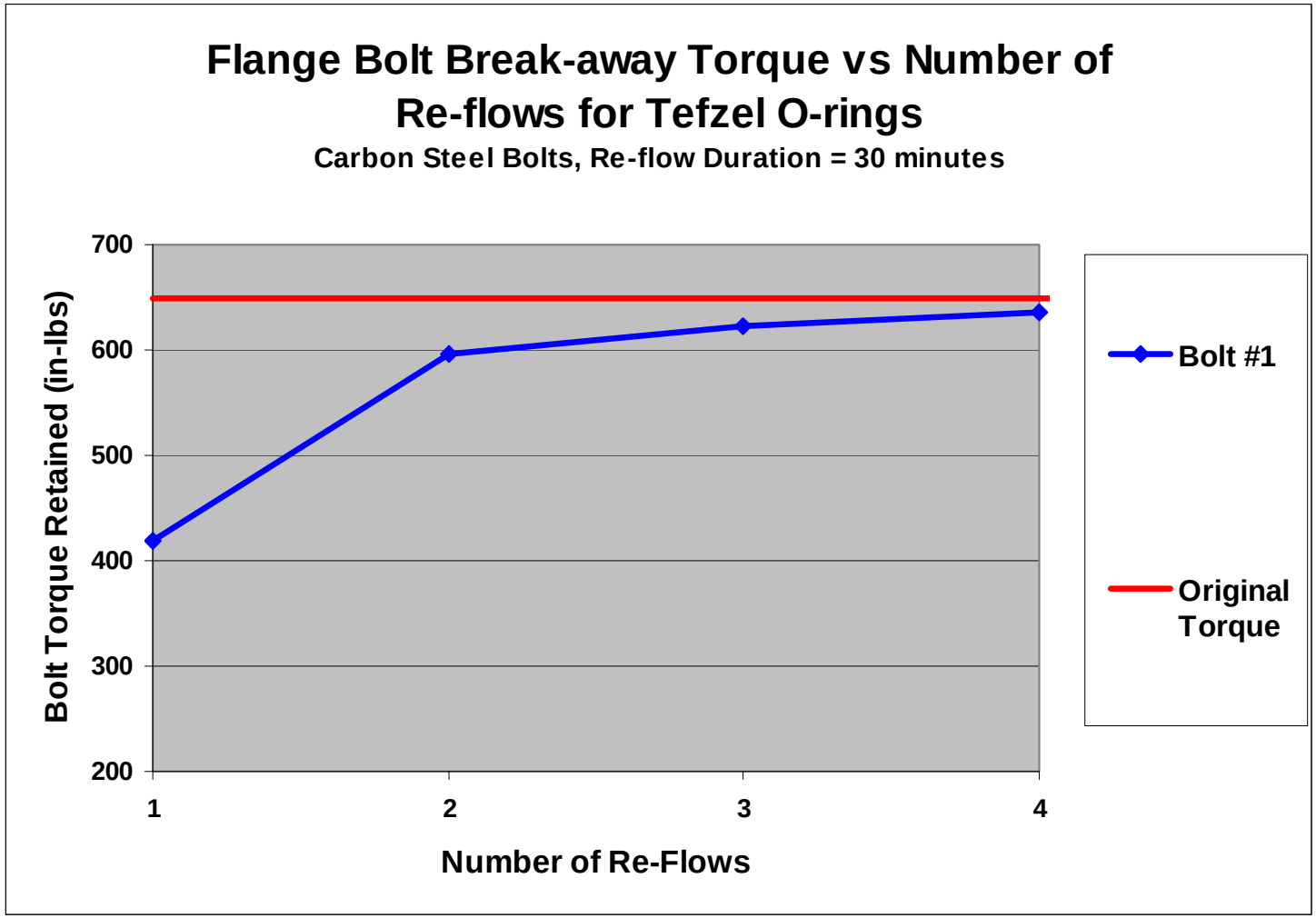
Concerns

- **Relaxation at temperature**
  - Loss of bolt load
- **Temperature Cycling Reliability**



ETFE Seal following High Temperature Testing

ETFE O-rings - Bolt Torque Loss



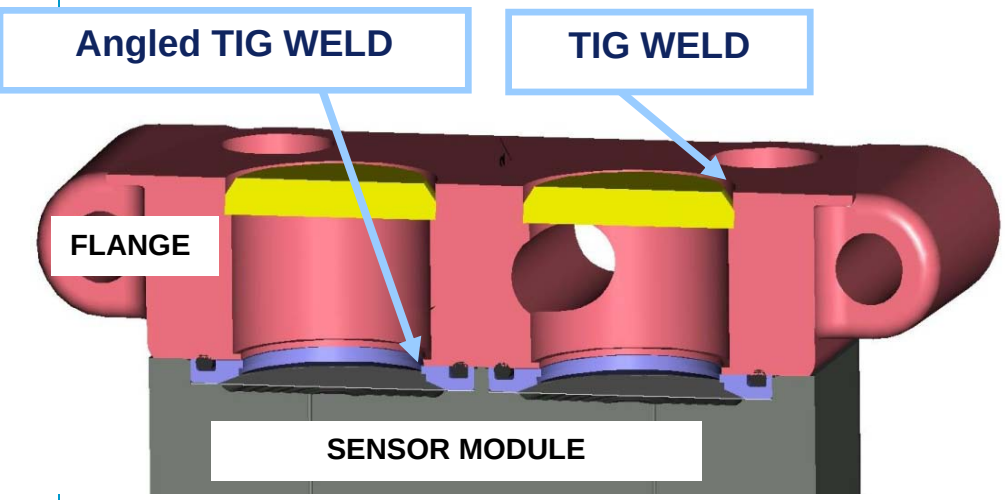
All-Welded Configurations

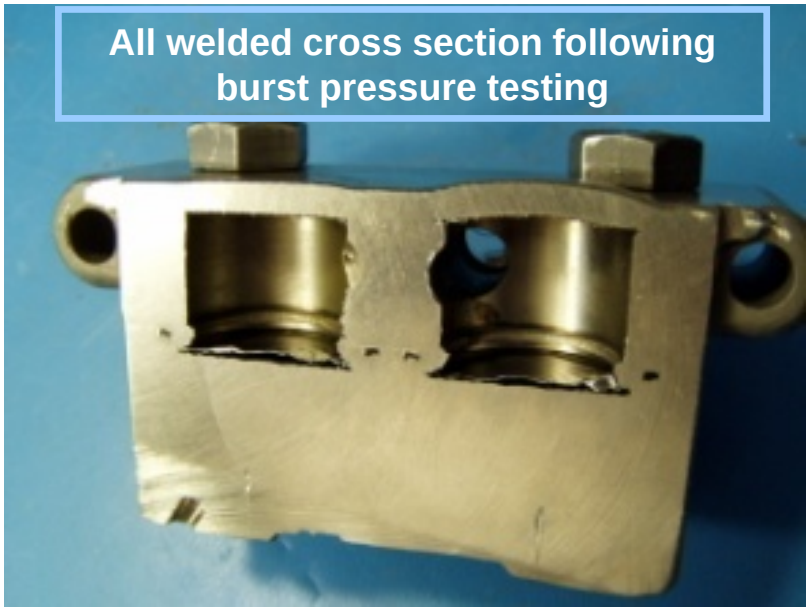
Advantages

- All metallic construction
  - Age insensitive
- Hermetic

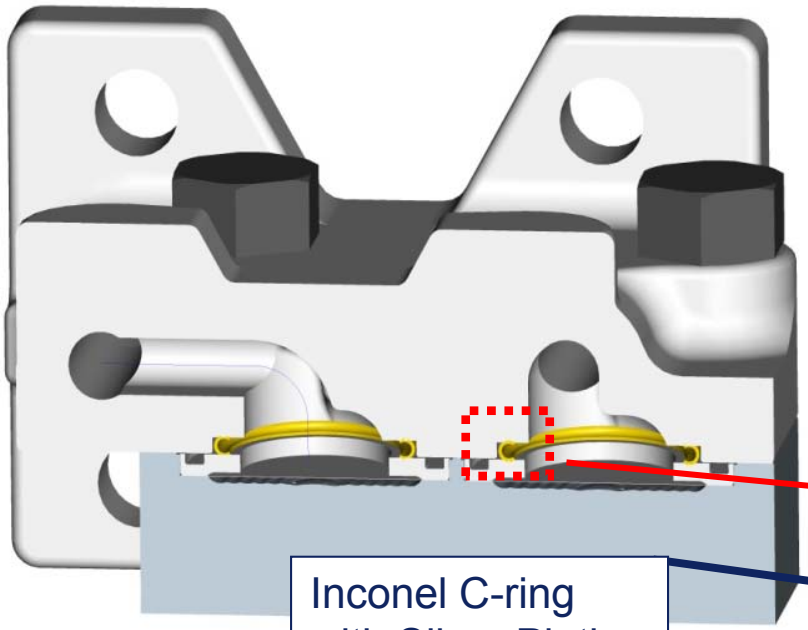
Concerns

- Difficult to manufacture
- Proximity of angled weld to isolator





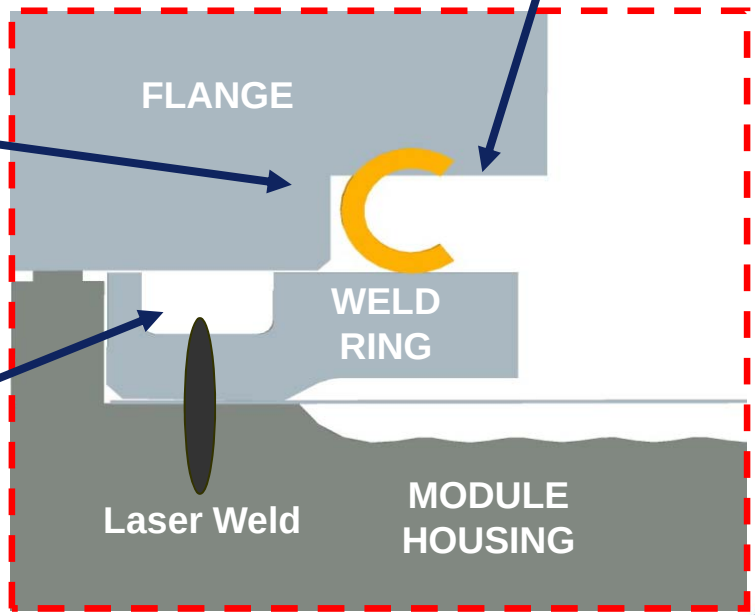
3150 Series Process Seal Design



Groove in Flange Allows for Larger C-ring:

- Rigid Weld Ring <0.001” deflection
- Larger Dimensional Tolerances

Inconel C-ring
with Silver Plating

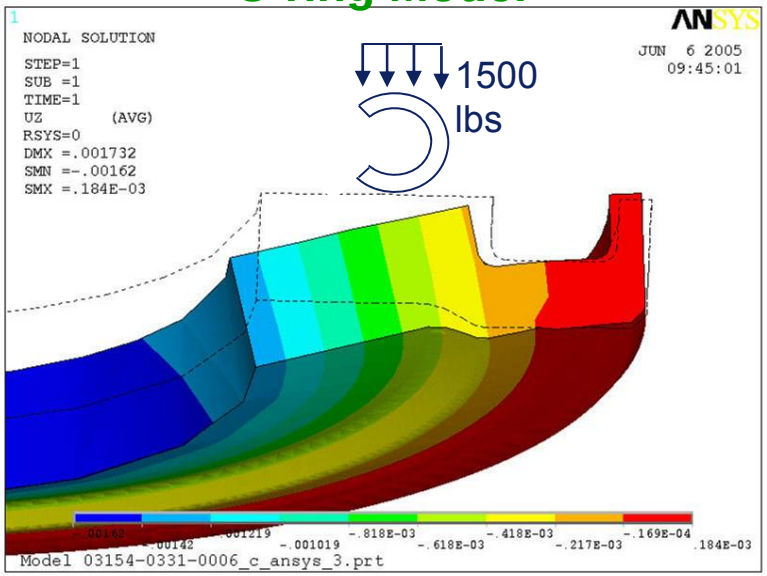


O-ring Groove for Rubber O-ring

- Used for preliminary manufacturing testing

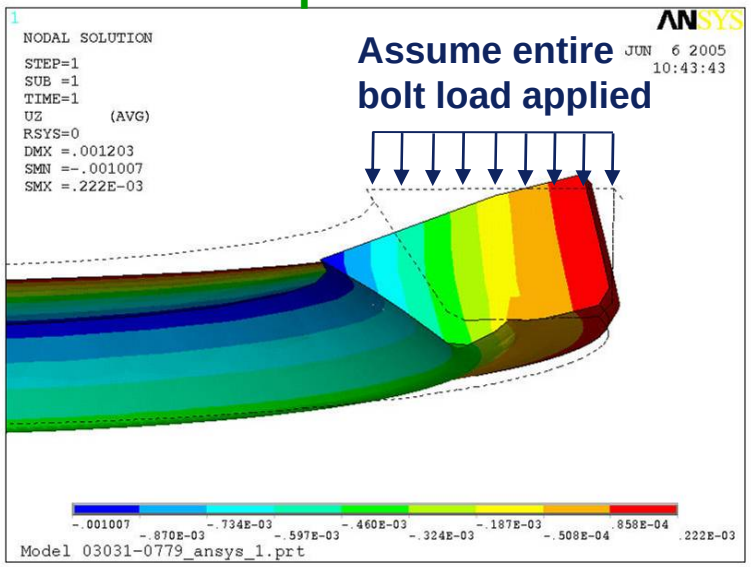
Loading on Weld Ring

C-ring Model



~.2 x 10^{-3} deflection at edge due to c-ring load

Simplified 3051 Model



~.35 x 10^{-3} deflection at edge due to c-ring load

- → Less “Free” Deflection than Previous Designs
- → Force Neutralization: Deflection Upward Due to 4000 psi Process Pressure is About Half the Downward Deflection Due to C-ring Load

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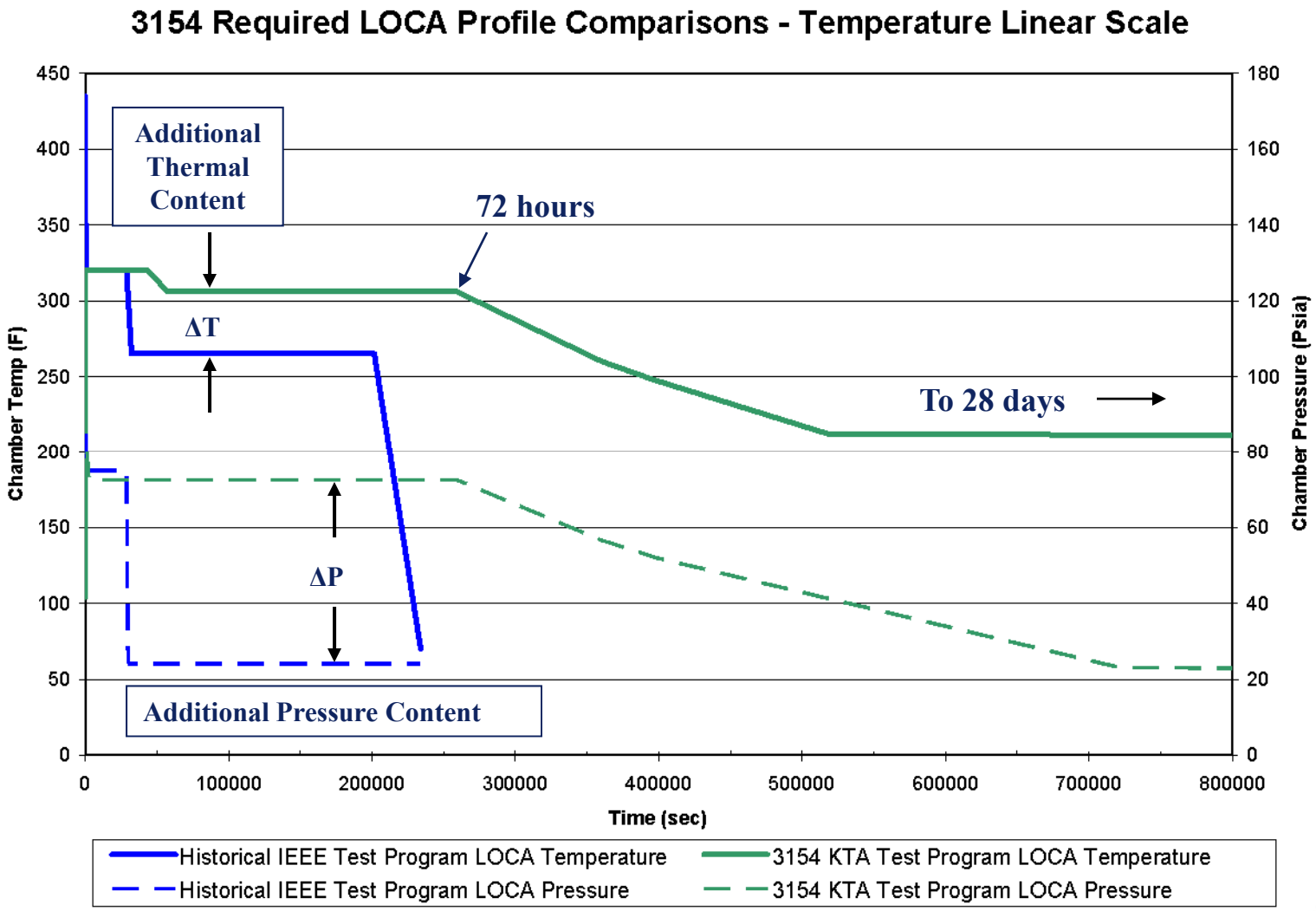
New Qualification Requirements

- **Challenging LOCA and Post Accident Requirements for New Reactor Designs**
  - Extended time at higher LOCA temperatures (>320F)
  - Extended post accident (PAMS) conditions
- **Multiple World Areas**
- **Rosemount Nuclear Lessons Learned**
  - Metal C-ring process seal robust in these environments
  - Elastomeric environmental seals require careful evaluation and potential re-design for reliable operation

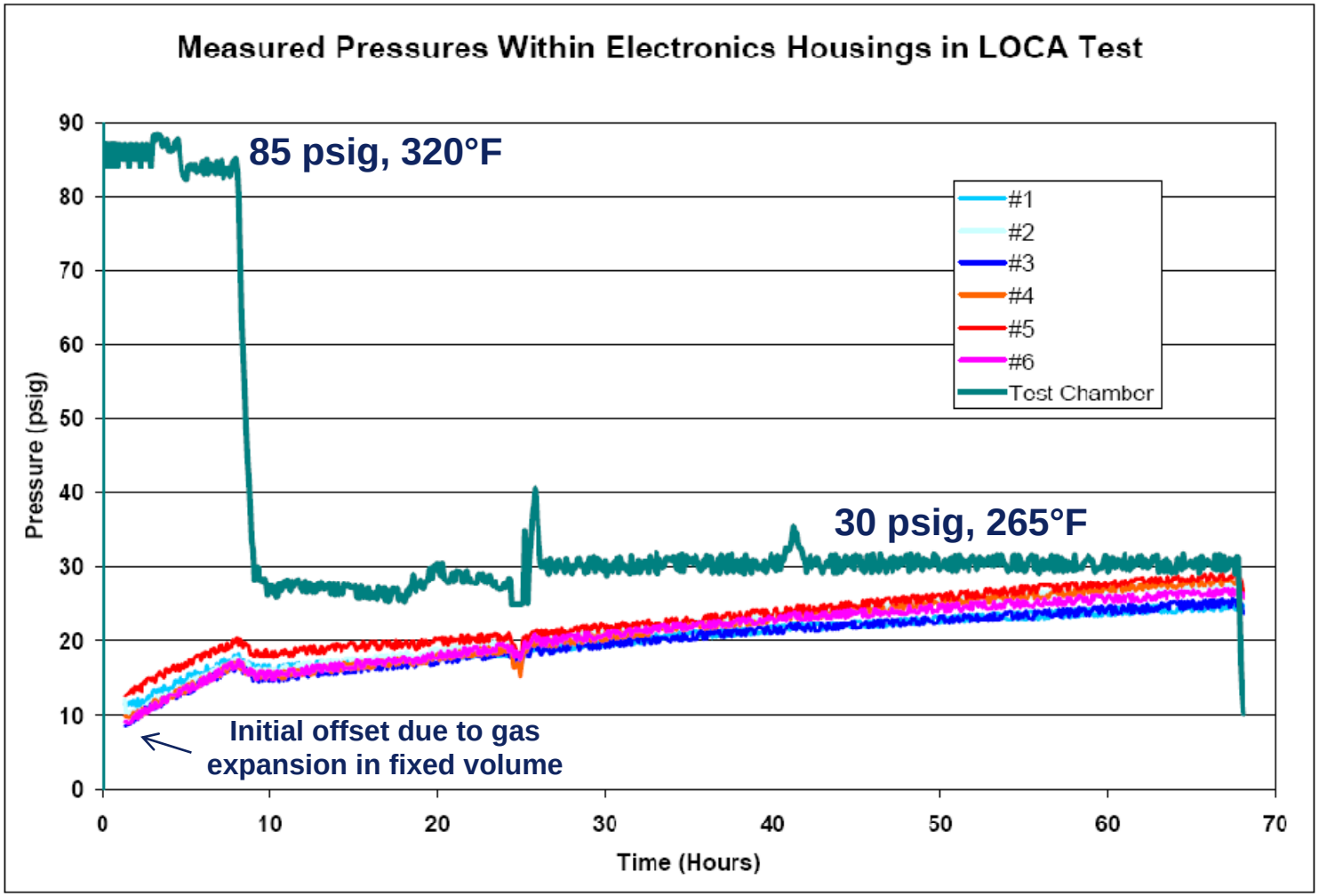
New Qualification Requirements
- Recent Example on Linear Scale



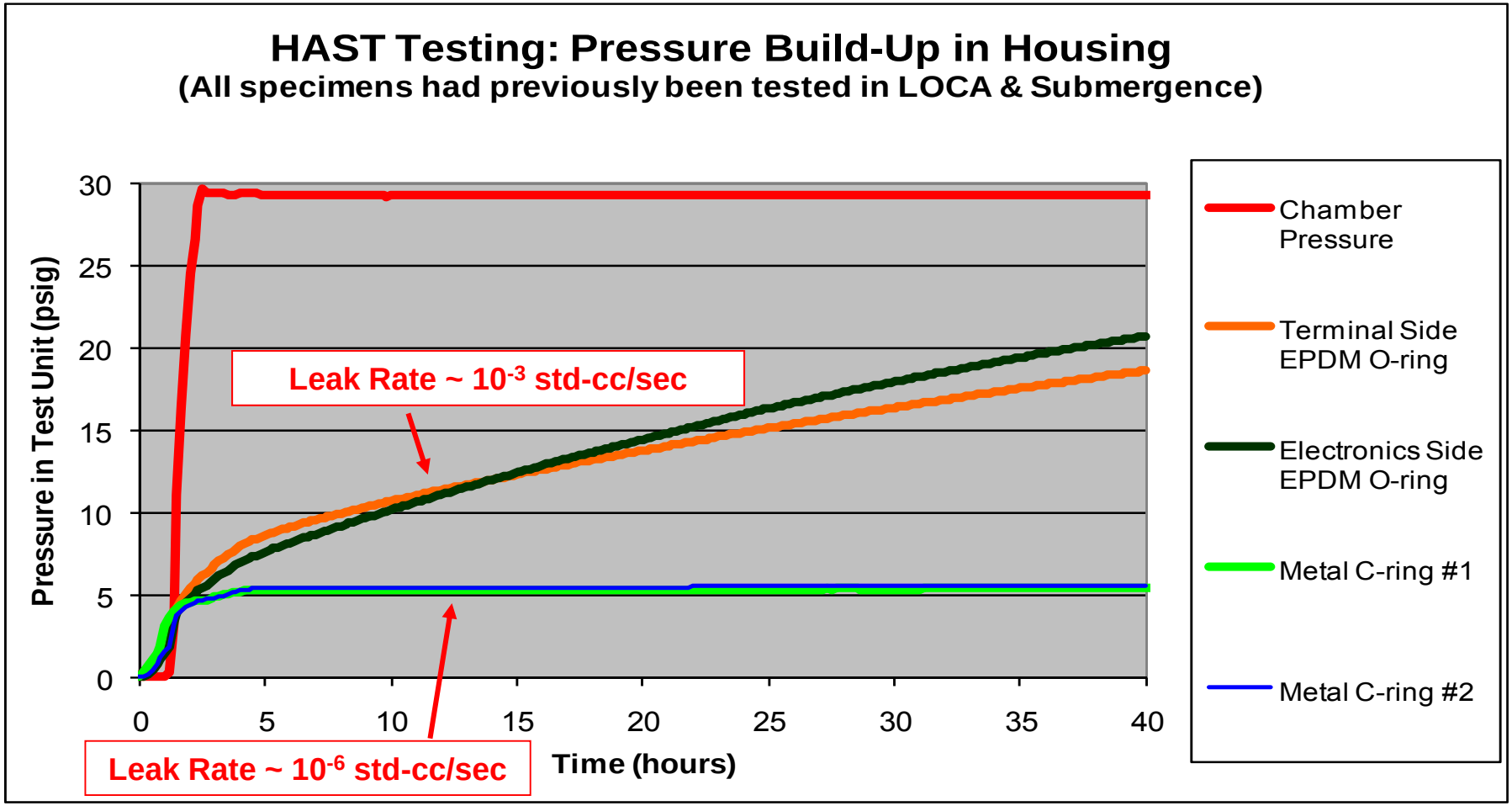
Housing Seal Designed Experimentation

- **Evaluate housing seals in various LOCA environments**
  - Welds, Metal seals, Elastomers
- **Monitored pressure build up inside housing**
- **Each seal evaluated independently**

Internal Housing Pressure vs. Time – Legacy PWR LOCA



Internal Housing Pressure vs. Time – C-rings vs. EPDM Seals



Summary

- **Elastomeric o-rings and metal seals (c-rings / o-rings) are common instrumentation pressure seals**
- **Applications exists for these types of seals in new instrumentation designs**
- **New reactor EQ requirements present new challenges for pressure seals**
  - Welds and metal c-rings have performed well in design testing
  - Elastomeric seals require detailed evaluation for suitability in extended post accident environments