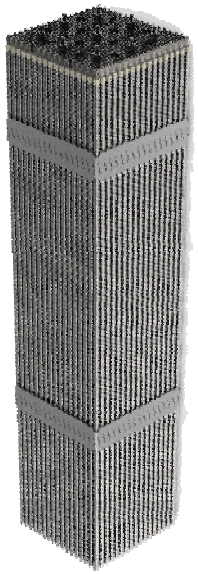
SAND2010-3229P



PWR Rodlet Ballooning Tests

Shea R. Loges

Sandia National Laboratories

Sandia Fuel Project

Funded by Nuclear Regulatory Commission (NRC) and the Organization for Economic Cooperation and Development (OECD)

Sandia National Laboratories

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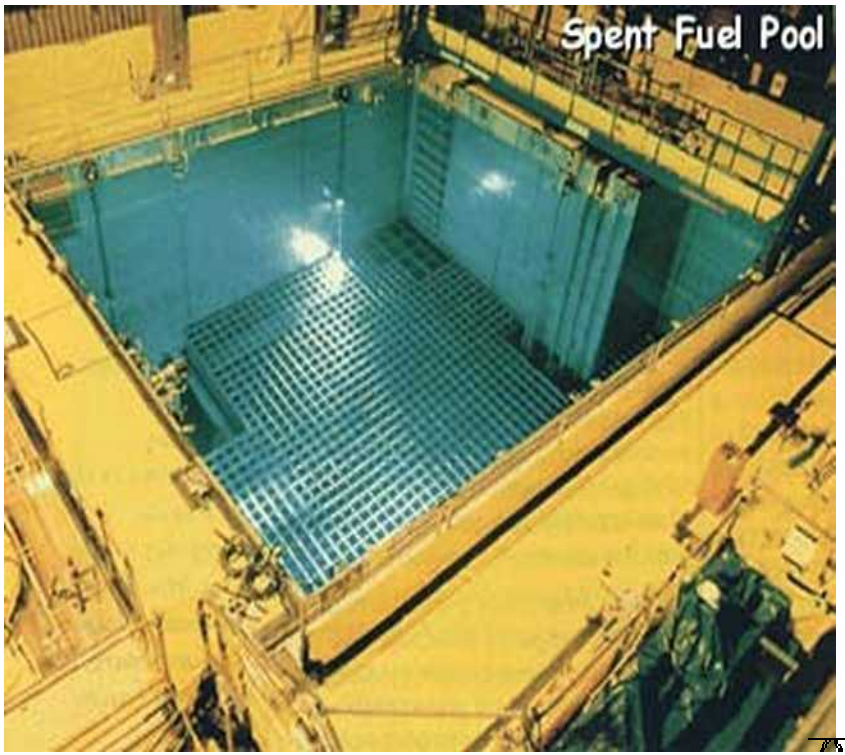
- Land of Acronyms
- NEWC – Nuclear and Energy Work Complex
- CYBL – Cylindrical Boiling
- PPE – Personal Protective Equipment
- PPA – Property Protection Area
- PRCS – Permit Required Confined Space
- ILMS – Integrated Laboratory Management System

TEDS

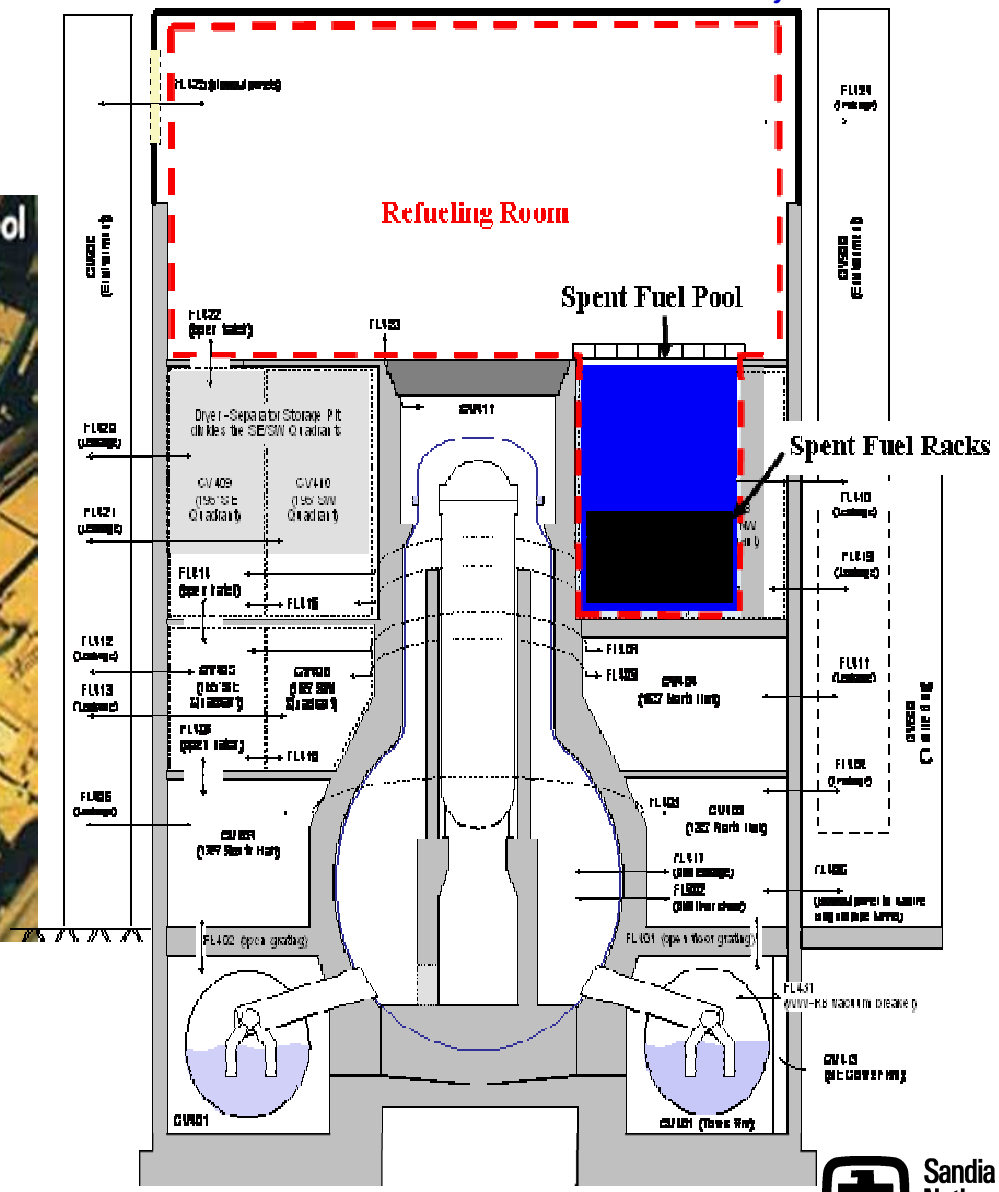
- TEDS – Because online corporate training is the only proof of competence
- In order to be eligible to do almost anything you must first pass the related TEDS course
- Ladder Safety – for anyone who climbs ladders
- Hand Tool training – to prove competence with wrenches and hammers
- Slips, Trips, and Falls – to prevent employees from losing their footing

MELCOR and Spent Fuel Pools



BWR Spent Fuel Pool

MELCOR Model for Plant Analysis



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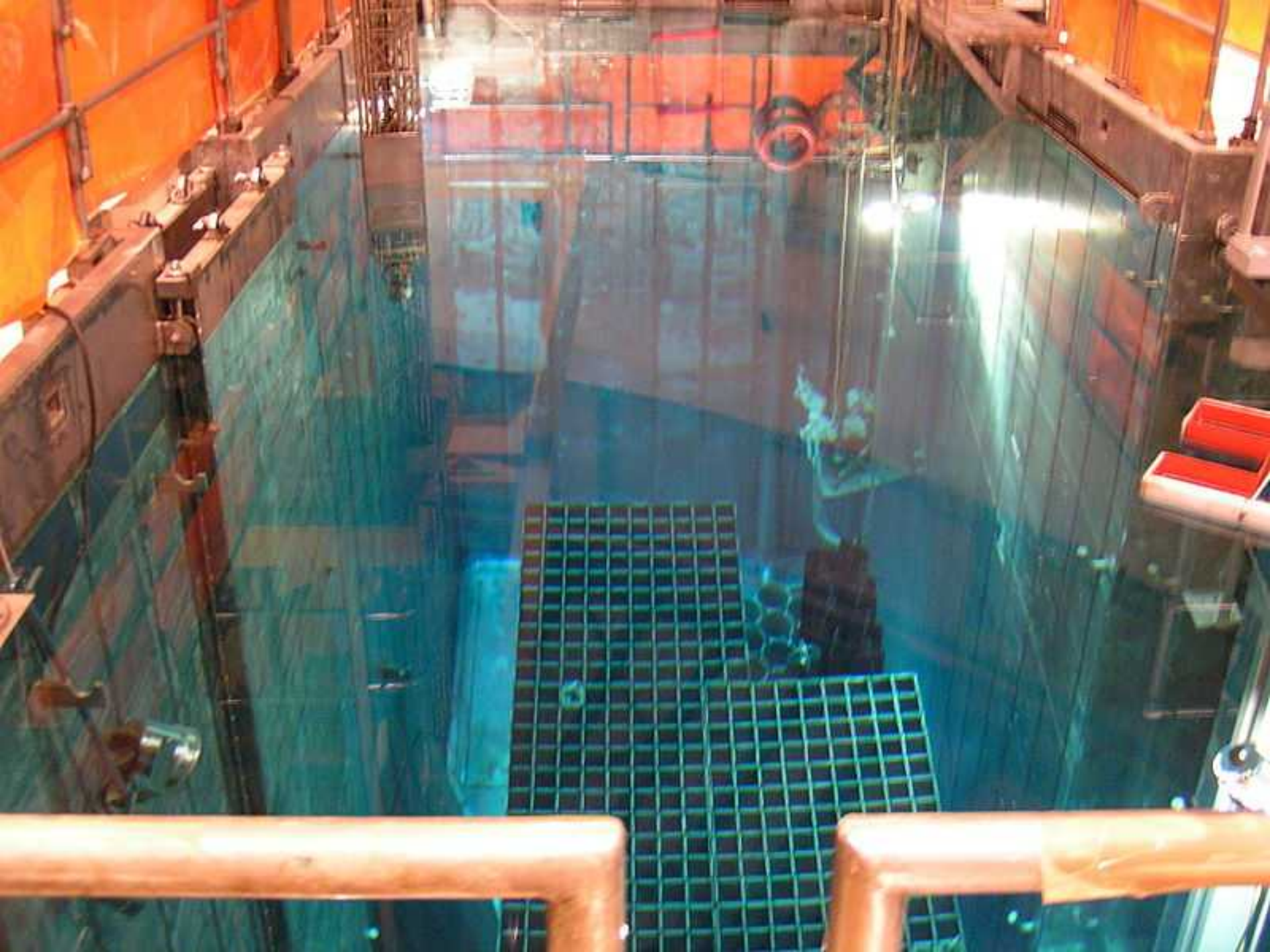
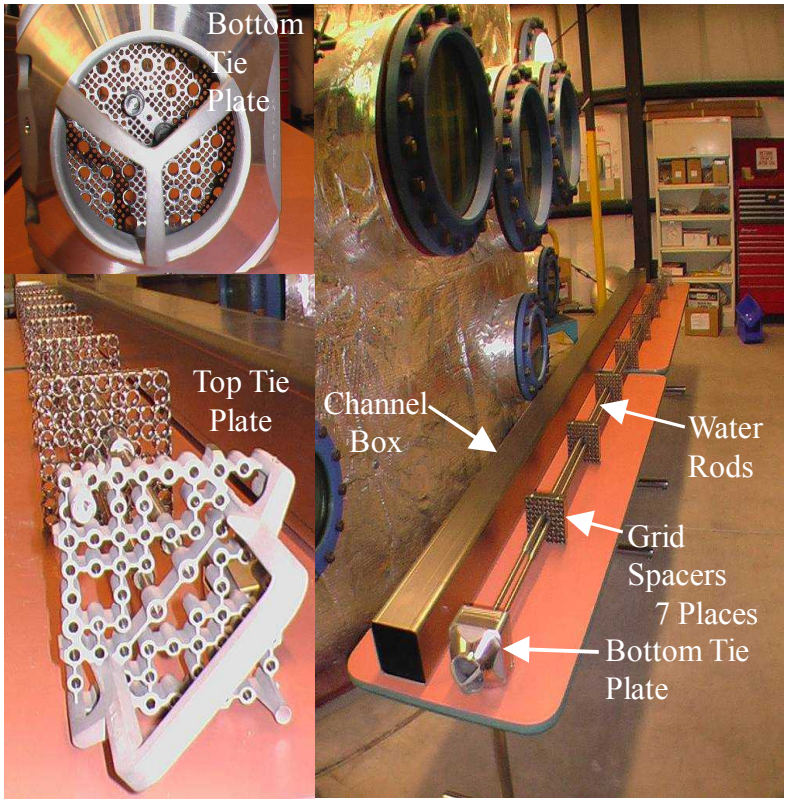
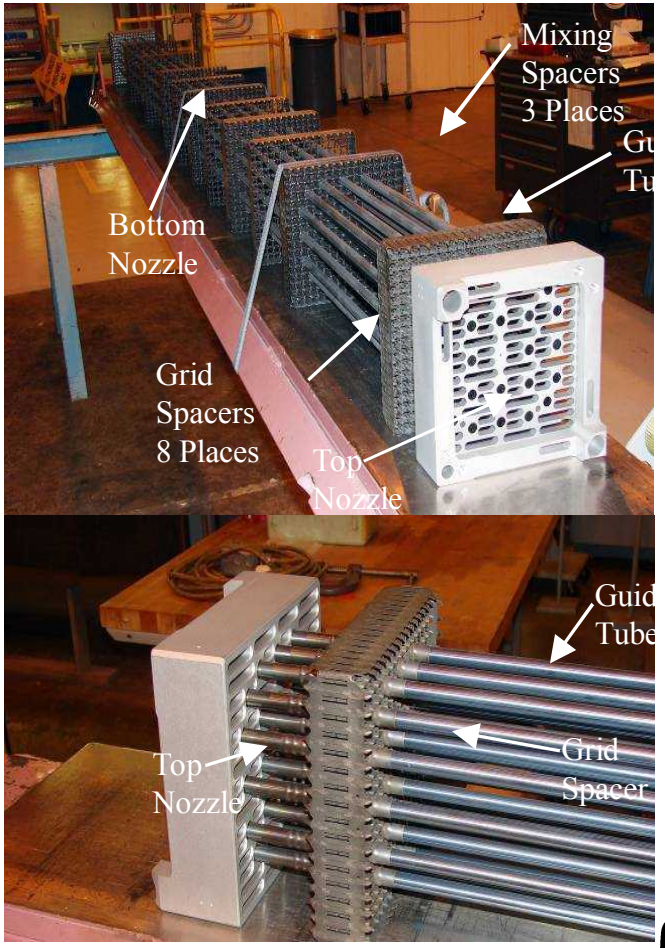


Prototypic Hardware

GNF 9×9 BWR



Westinghouse 17×17 PWR



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Spacer Grids

Nuclear Fuel Pellet

Cladding

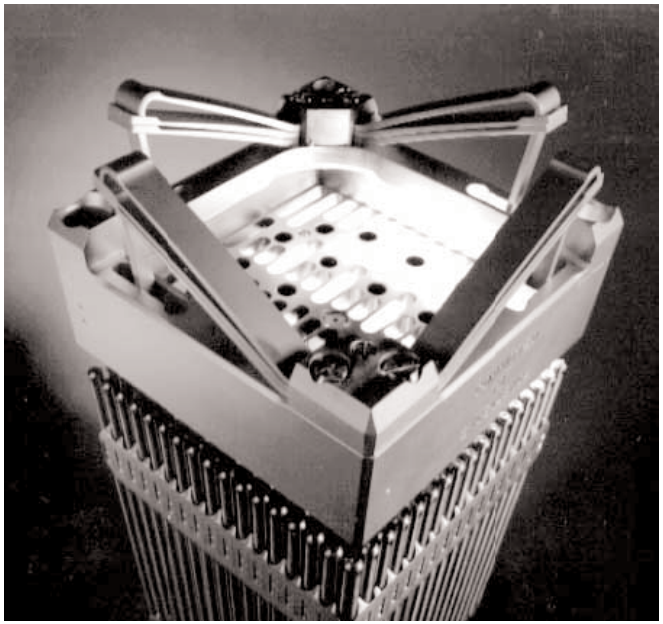
Fuel Rod

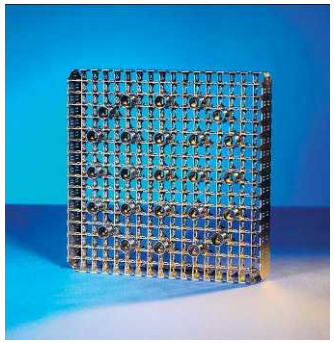
Guide Tube

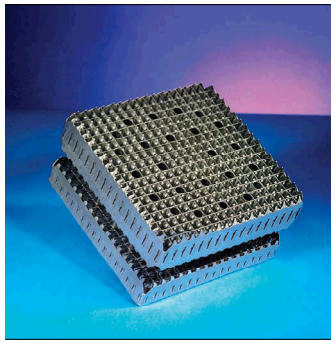
Instrument Tube

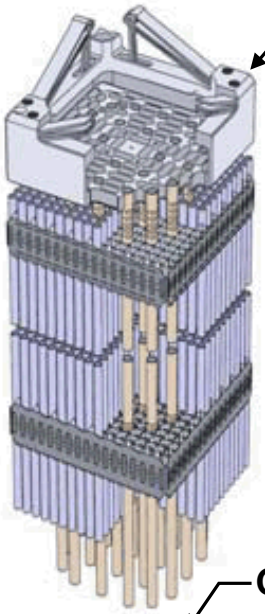
Drawing Not To Scale
00022DC_ATP_Z1S30-04a.ai

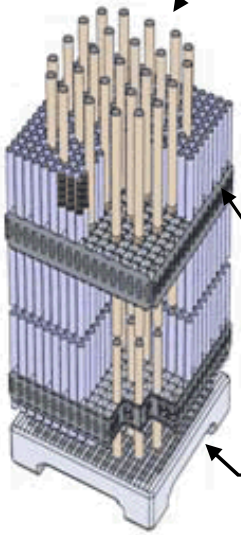
PWR Fuel Assembly





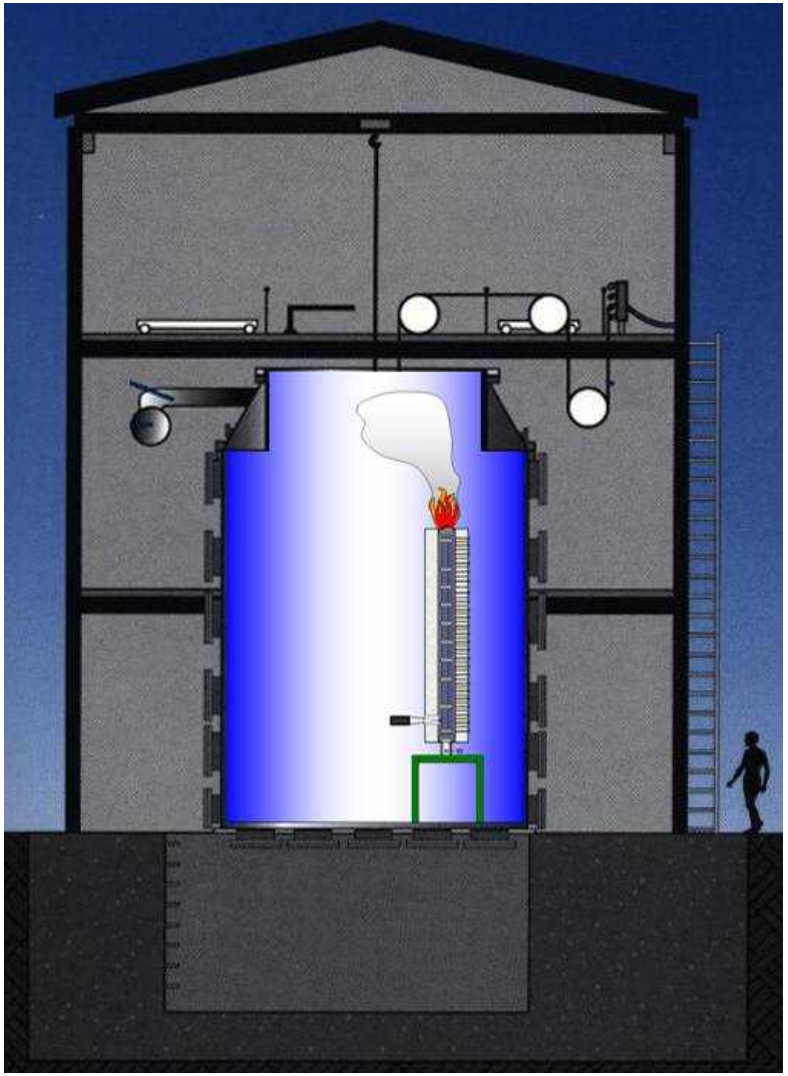






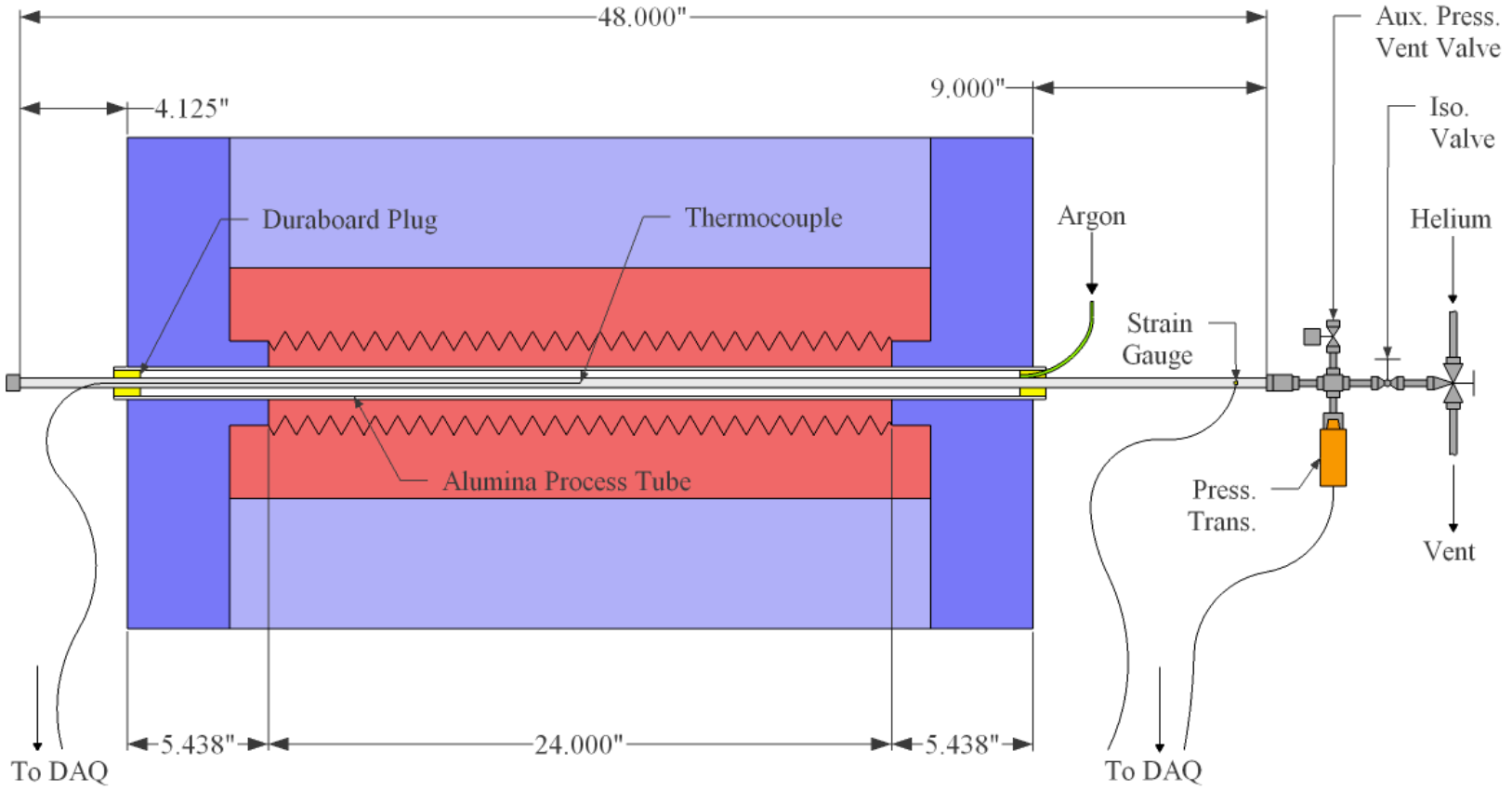
- Westinghouse 17×17 RFA PWR
- Components
  - 264 fuel rods
  - 24 guide tubes
  - 1 instrumentation tube
  - 8 grid spacers
  - 3 flow mixers
  - 1 debris catcher

Test Facility

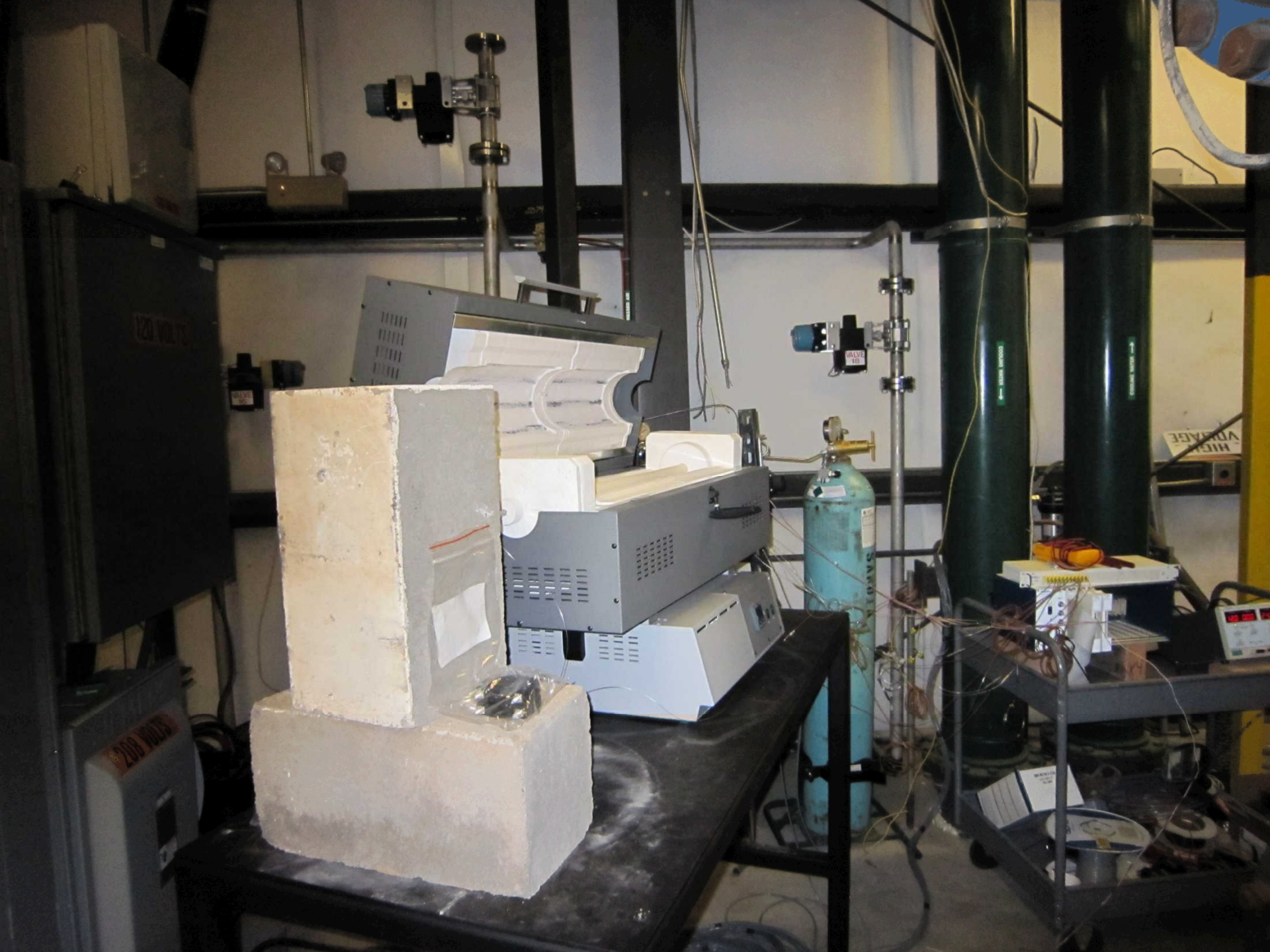


- Cylindrical Boiling (CYBL) Facility
  - Stainless steel vessel
    - Inner diameter 5.1 m
    - Height 8.4 m
  - Provides well defined exclusion zone
  - Large view ports
  - Can accommodate argon flood to extinguish Zr fire

Test Setup

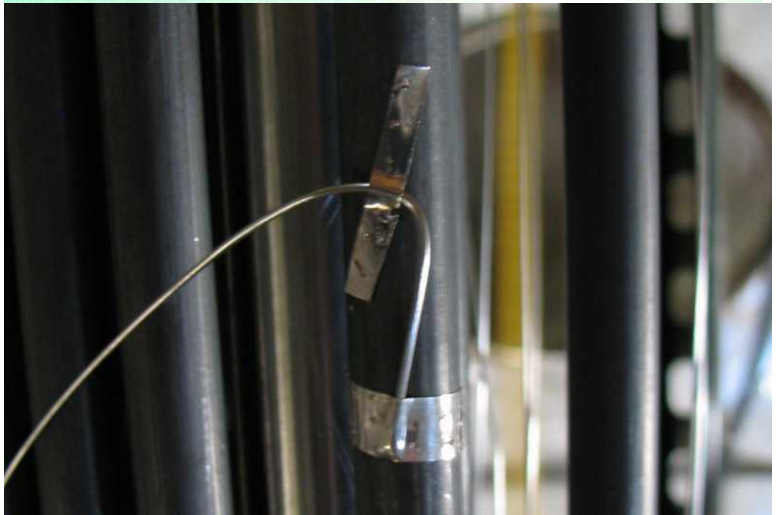


- Electric tube furnace
  - Heated length 61 cm
  - Furnace length 91 cm
- Zr-4 rodlet loaded in alumina process tube
  - Pressurized to 2 – 3.5 MPa (300 – 500 psi)
  - Filled with MgO and SS plenum spring

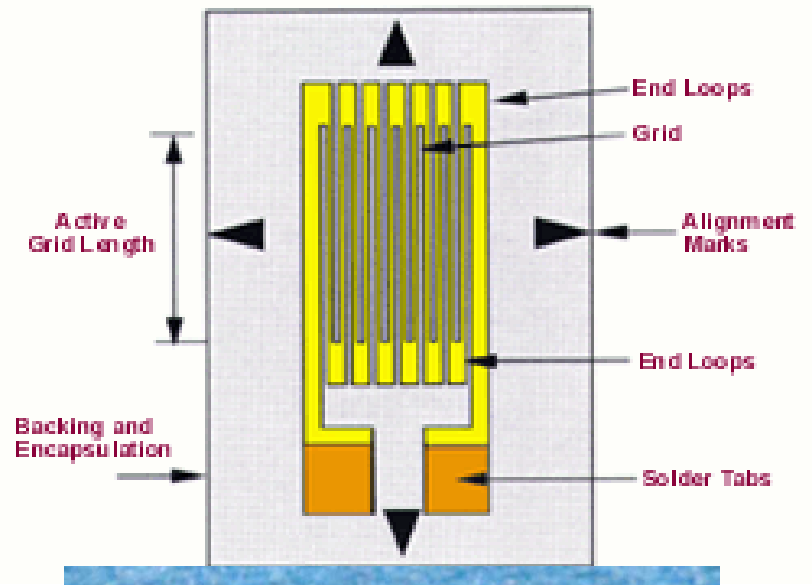


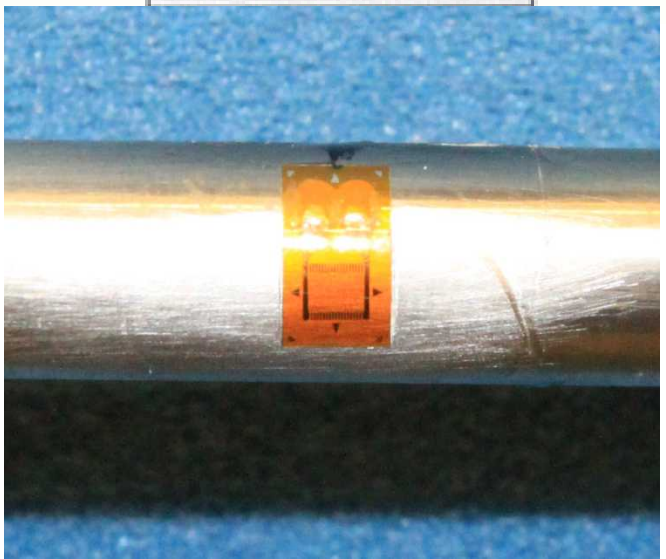
Tools of the Trade

Thermocouples (TCs)



Strain Gauges





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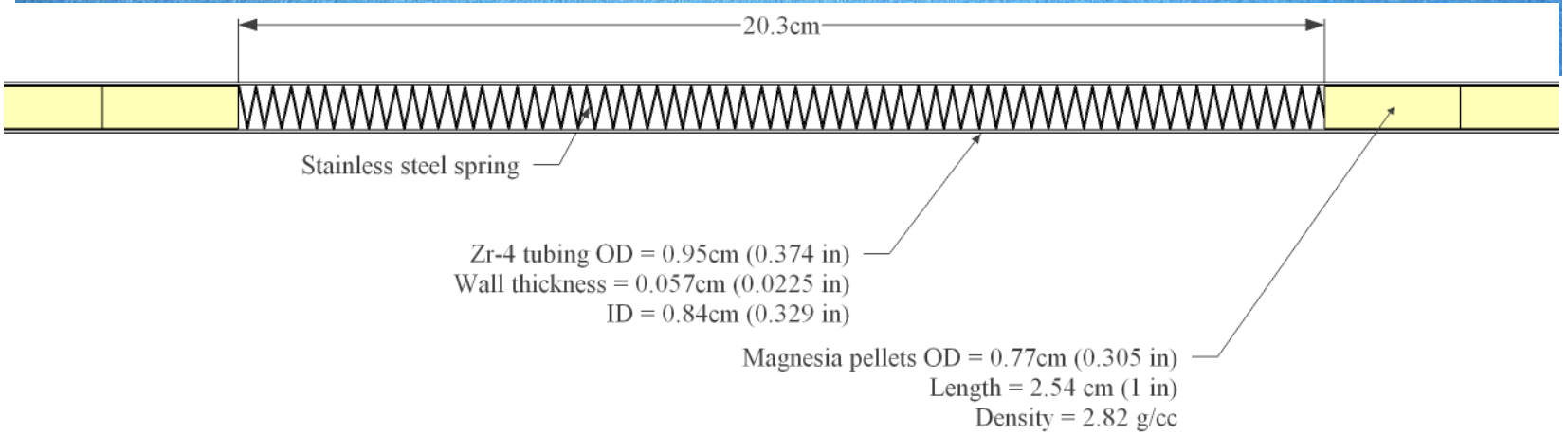
US : 5020
HT TE

Ballooning



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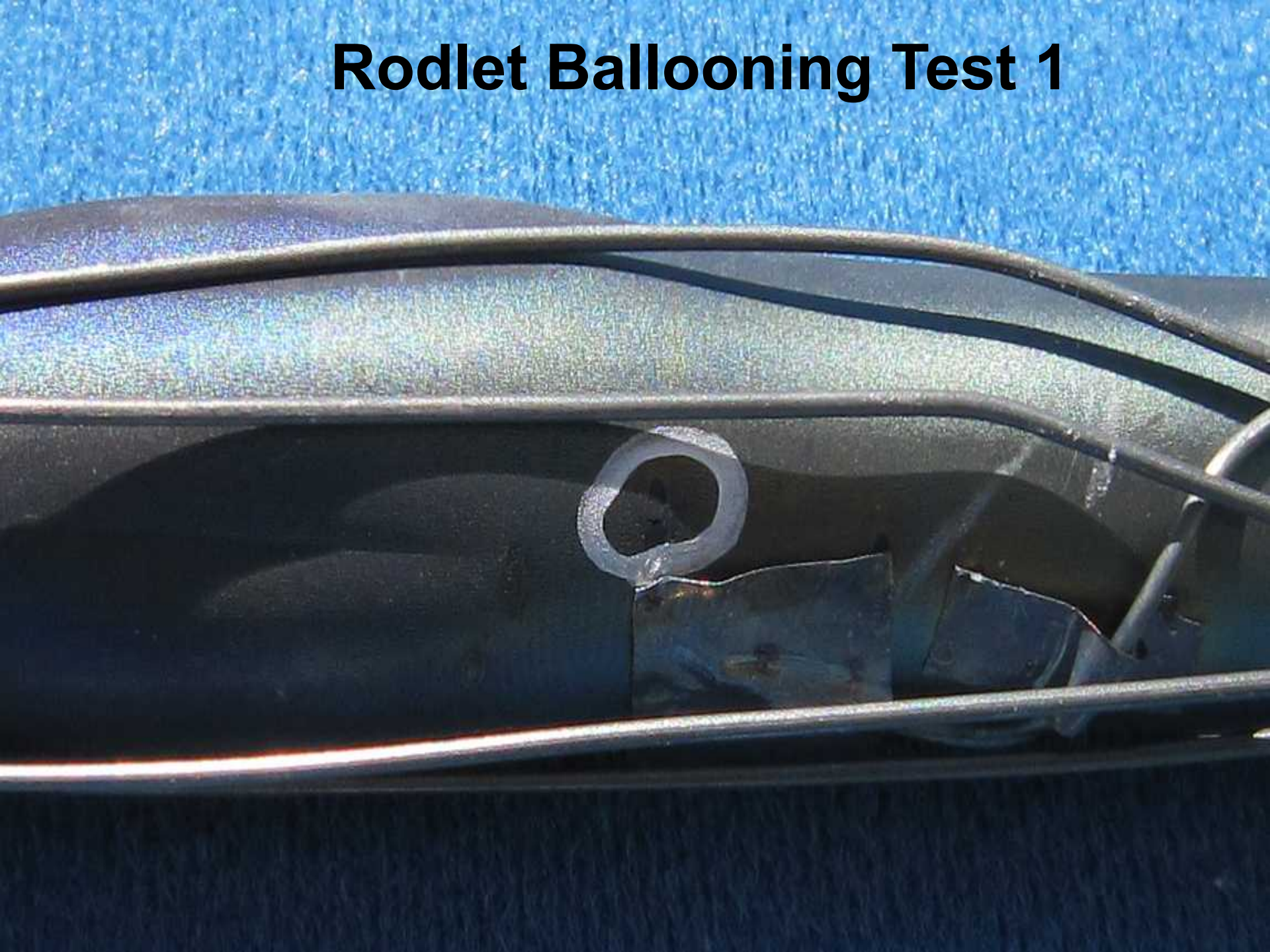
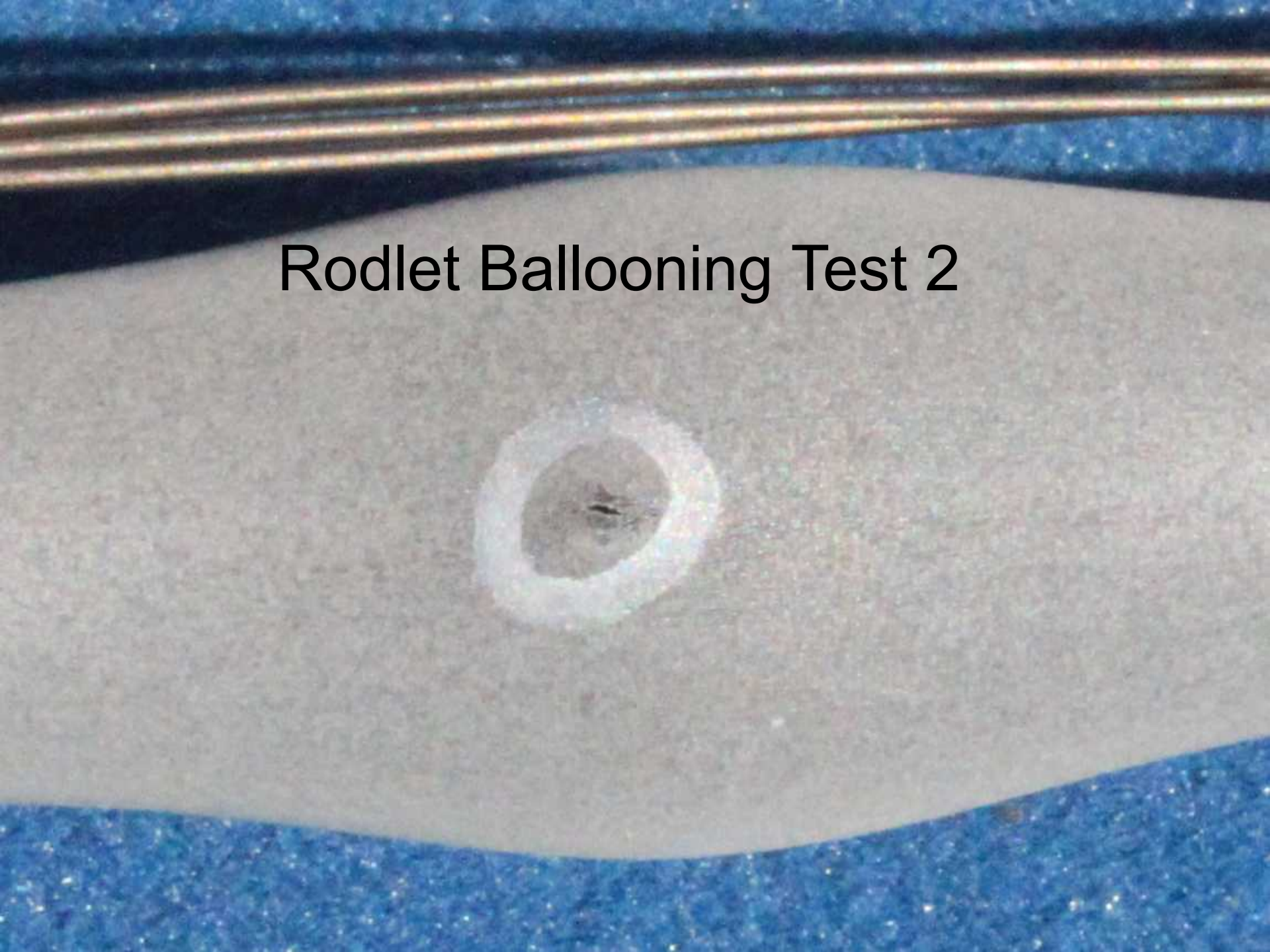
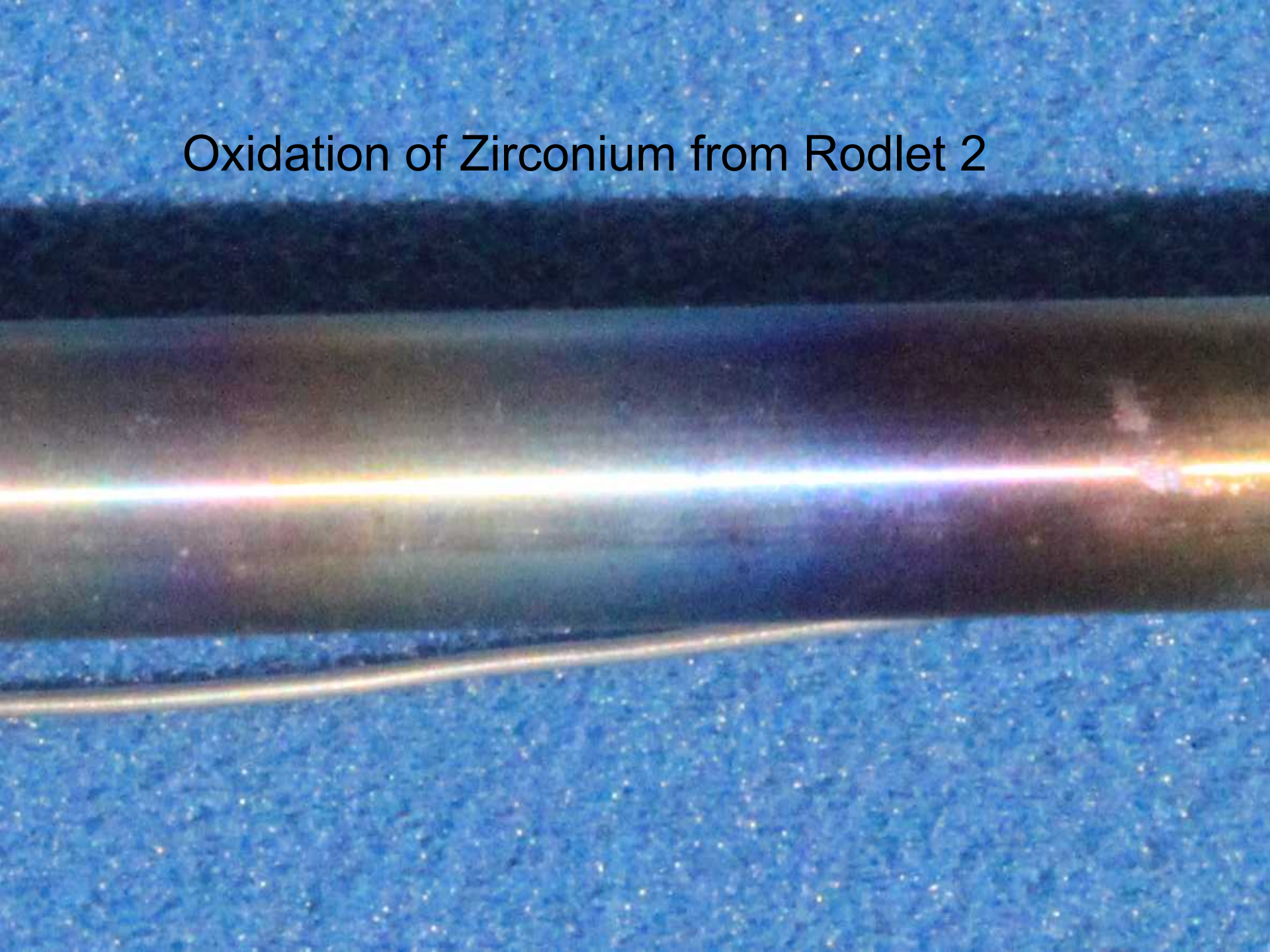
Rodlet Ballooning Test 1



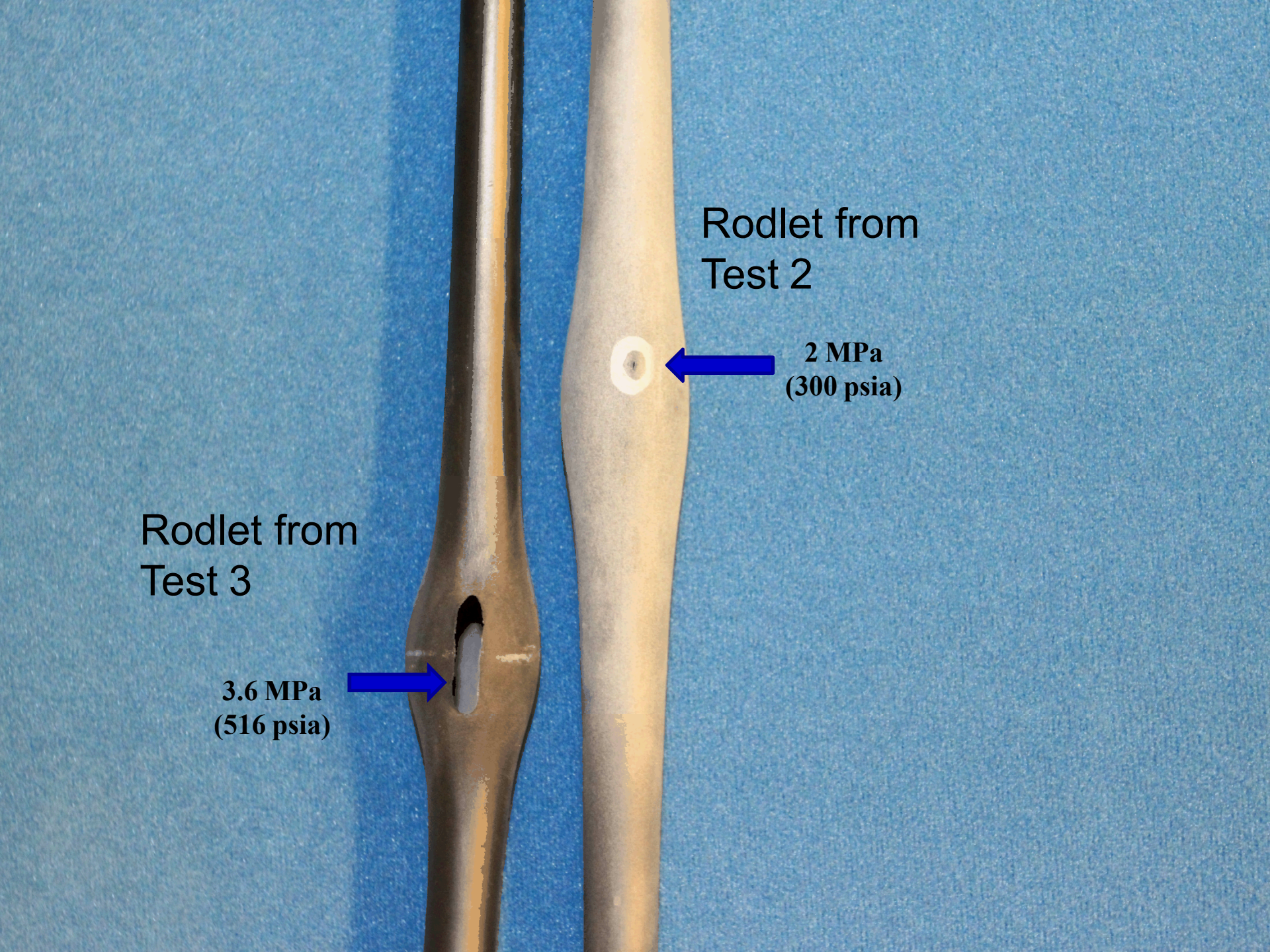
Rodlet Ballooning Test 2



Oxidation of Zirconium from Rodlet 2



Rodlet Ballooning Test 3


Rodlet from
Test 2
2 MPa
(300 psia)
Rodlet from
Test 3
3.6 MPa
(516 psia)

Thanks to

- Ken Sorenson
- Samuel Durbin
- Eric Lindgren
- Robert Wauneka
- Greg Koenig
- Shane Adee
- Brandon Cervantes

Extra Slides

Advanced Nuclear Fuel Cycle Technologies – Org 6774

- Part of the Energy, Security, and Defense Technologies Division for SNL as part of the Nuclear Energy and Global Security Center
- Conducts research and development and applied technology development to find solutions for technical and safety issues associated with the use of nuclear materials in nuclear fuel cycles and space applications
- I worked on the Sandia Fuel Project (SFP) testing for the US Nuclear Regulatory Commission (NRC) and the Organization for Economic Cooperation and Development (OECD)
- Experimental work conducted primarily at the NEWC site comprised of Surtsey and CYBL

Objective

- Provide prototypic thermal hydraulic and zirc-fire data for accident code validation under air flow conditions associated with:
  - Spent fuel pool complete LOCA
    - Arrangement of high density fuel racks for mitigation strategy
  - Late phase core melt progression
  - Complete loss of water during refueling
  - Dry cask storage (thermal-hydraulic data)
- Data is needed to assess:
  - Cladding ballooning
  - Flow correlation (Pressure drop vs. Velocity) under low Reynolds numbers (not available)
  - Initiation of zirc fire
  - Assess potential for propagation of zirc fire
  - Mitigation strategies concerning fuel assembly management
- Pre-test (Blind) and Post-test simulation-to-data comparison to ensure code adequacy
- **Use test results to validate or correct MELCOR along with other severe accident codes**

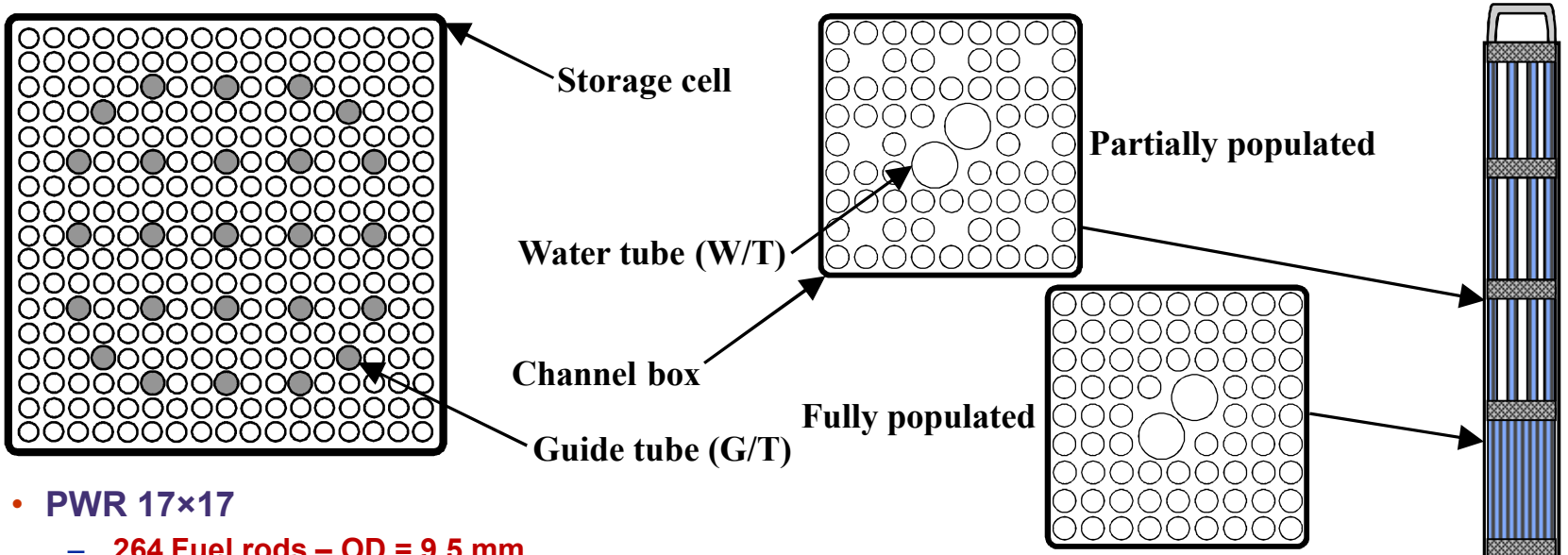
Transition from BWR to PWR tests

An analogous PWR study is required

- PWR and BWR geometries differs significantly
  - Previous BWR results not applicable
    - More rods, larger footprint
    - No water rods
    - No partial length rods

Assembly Geometries

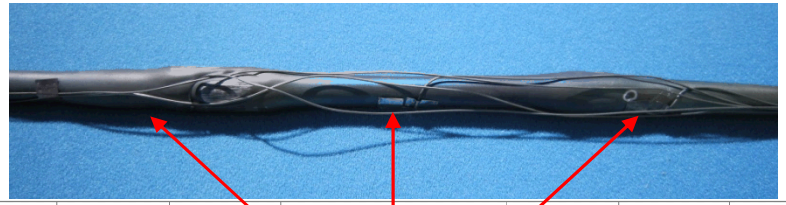
PWR and BWR comparison

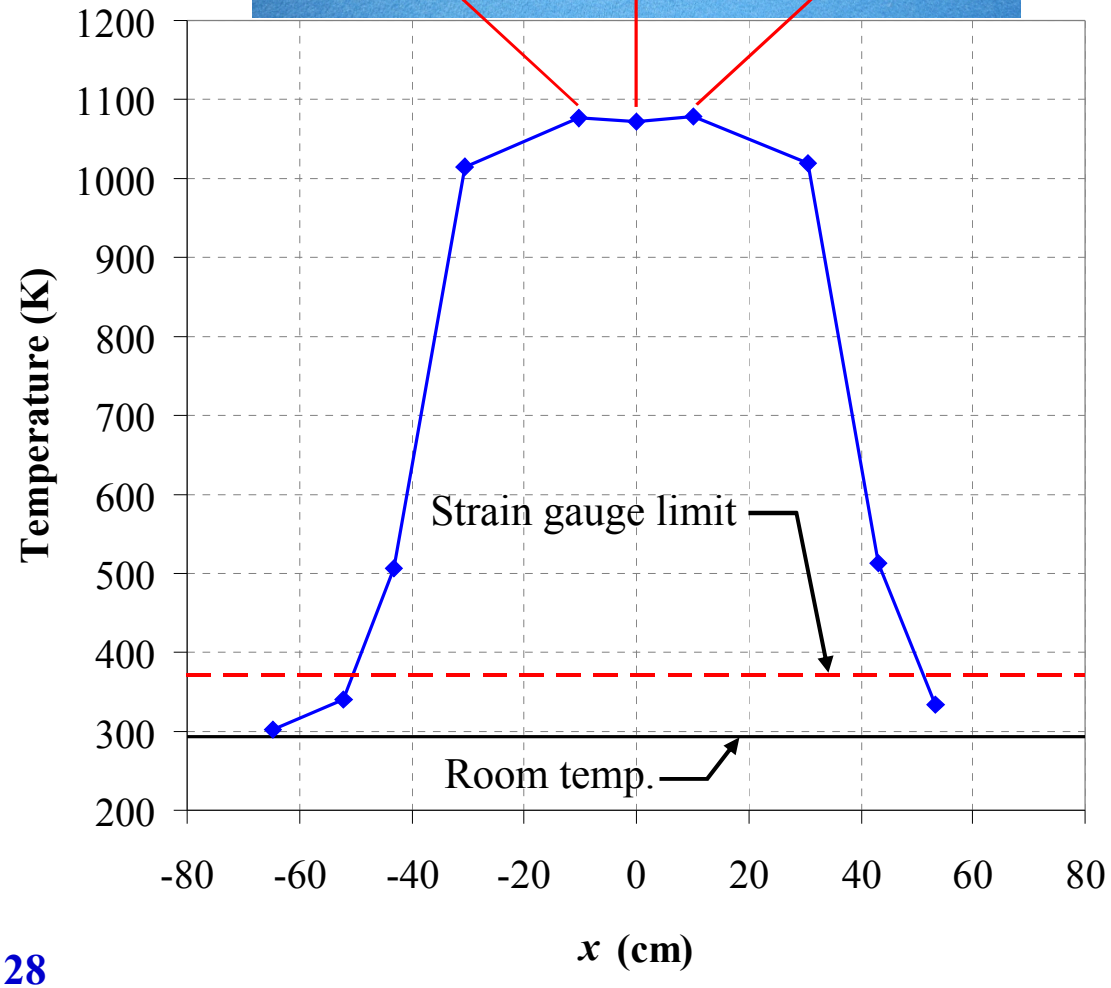


- PWR 17×17
  - 264 Fuel rods – OD = 9.5 mm
  - 24 Guide tubes / 1 Instrument tube – OD = 12.2 mm
  - 11 spacers
- Three storage cells tested
  - Close fitting (Bundle flow)
    - ID = 217.5 mm
    - D_h = 10.8 mm
  - Typical industry sizes
    - ID = 221.6 and 226.6 mm
    - D_h = 11.2 and 12.1 mm, respectively

- BWR 9×9
  - 74 Fuel rods – OD = 11.2 mm
    - 8 partial length
  - 2 Water tubes – OD = 24.9 mm
  - 7 spacers
- Channel box – ID = 134.0 mm
  - Fully populated (Blocked W/T)
    - D_h = 11.9 mm
  - Partially populated (Blocked W/T)
    - D_h = 14.1 mm

Rodlet Temperature Profile





- Nearly uniform temp. in center 20.3 cm (8 in)
  - 61 cm (24”) active heating
  - Origin (x = 0) defined in middle of furnace
  - Ballooning at transition between plenum and fuel surrogate
- Rodlet temp. falls quickly outside of furnace
  - Swagelok and strain gauge near room temp.