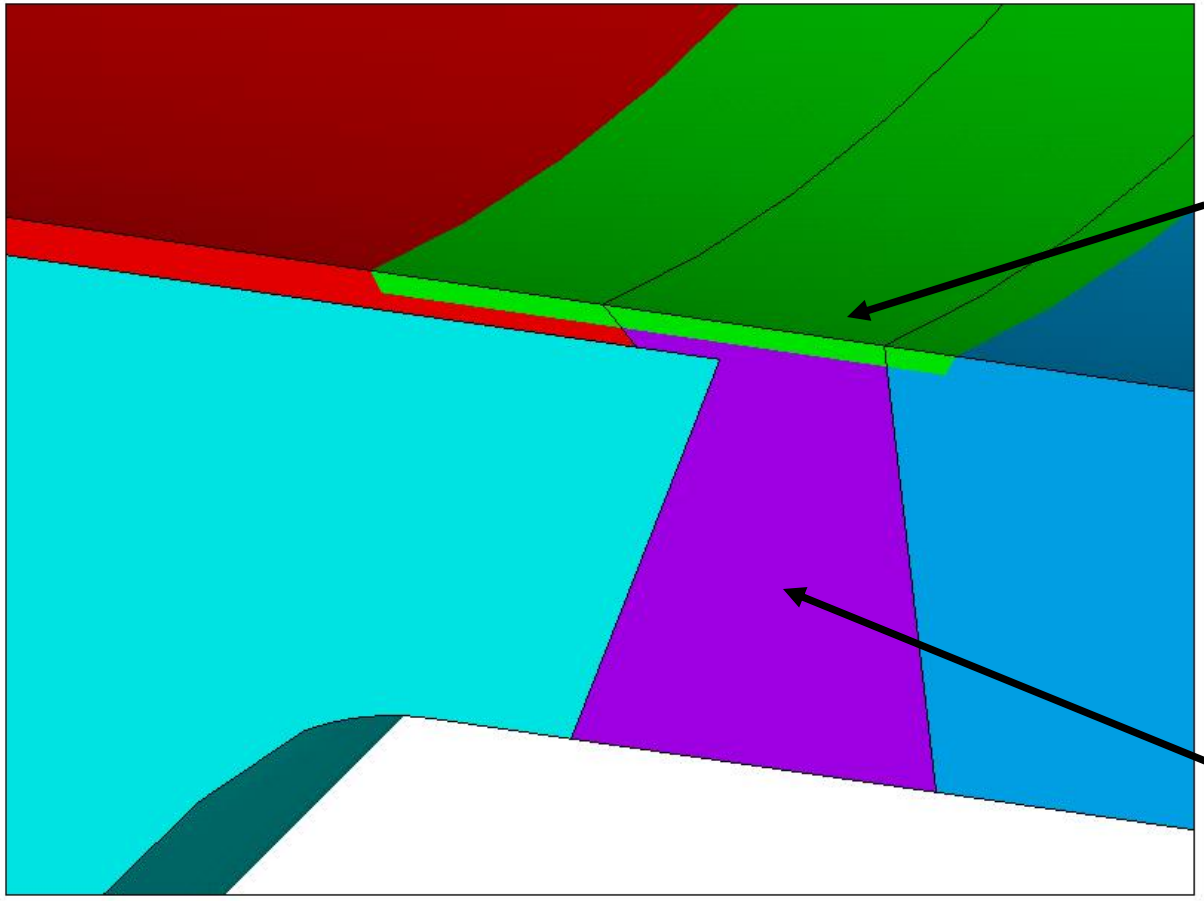

# *AEGIS Weld Inlay™: Isolation of PWSCC Susceptible Material*

**NRC/EPRI Workshop on LBB in PWSCC Systems**

**Ben Grambau, AREVA NP Inc.**

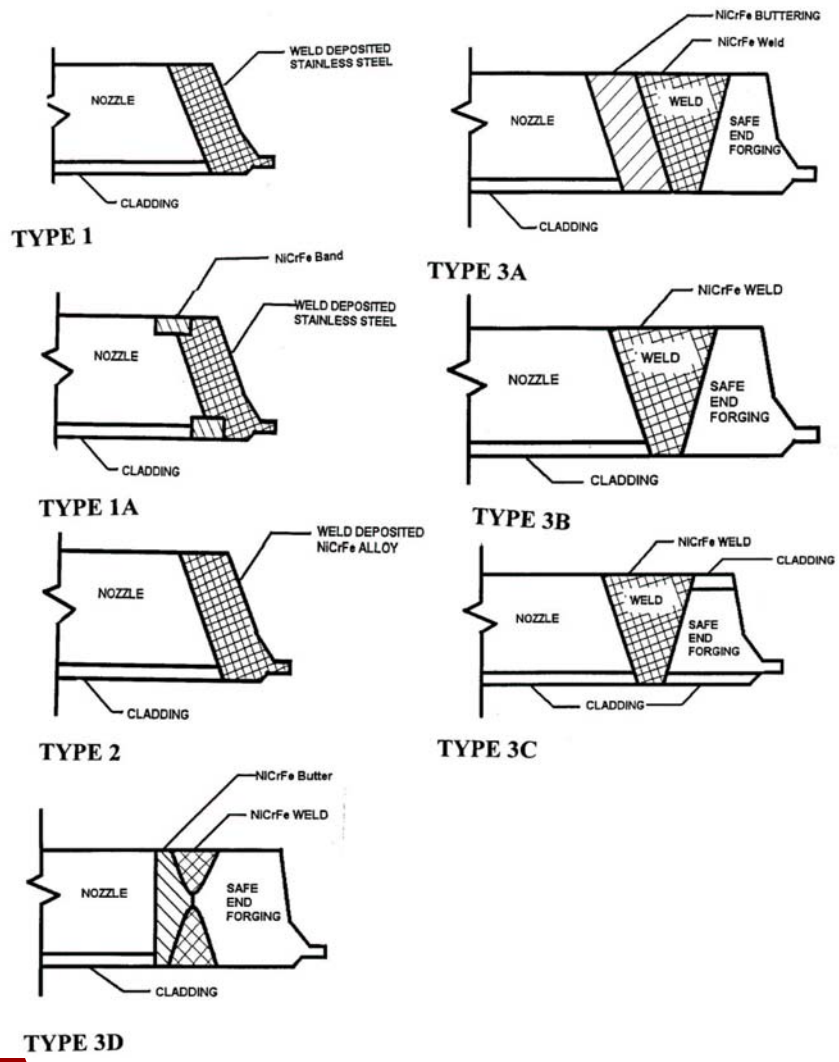
# What Is Inlay?



# Inlay Definition

- **From Technical Basis:**
  - **Weld inlay is defined as PWSCC-resistant material (Alloy 52/52M) applied to the inside diameter of a DMW that completely isolates the PWSCC-susceptible material (Alloy 82/182) from the primary reactor coolant.**
- **From Draft Code Case:**
  - **Barrier Weld:**
    - **A corrosion resistant barrier (weld inlay) applied between the DMW and the reactor coolant requiring excavation using mechanical methods of some portion of the DMW thickness and associated cladding and/or base material thickness for the full circumference, prior to welding.**
    - **A corrosion resistant barrier (corrosion resistant cladding onlay) applied between the DMW and the reactor coolant that does not require excavation other than mechanical removal of surface contaminants to shiny bright metal prior to welding.**

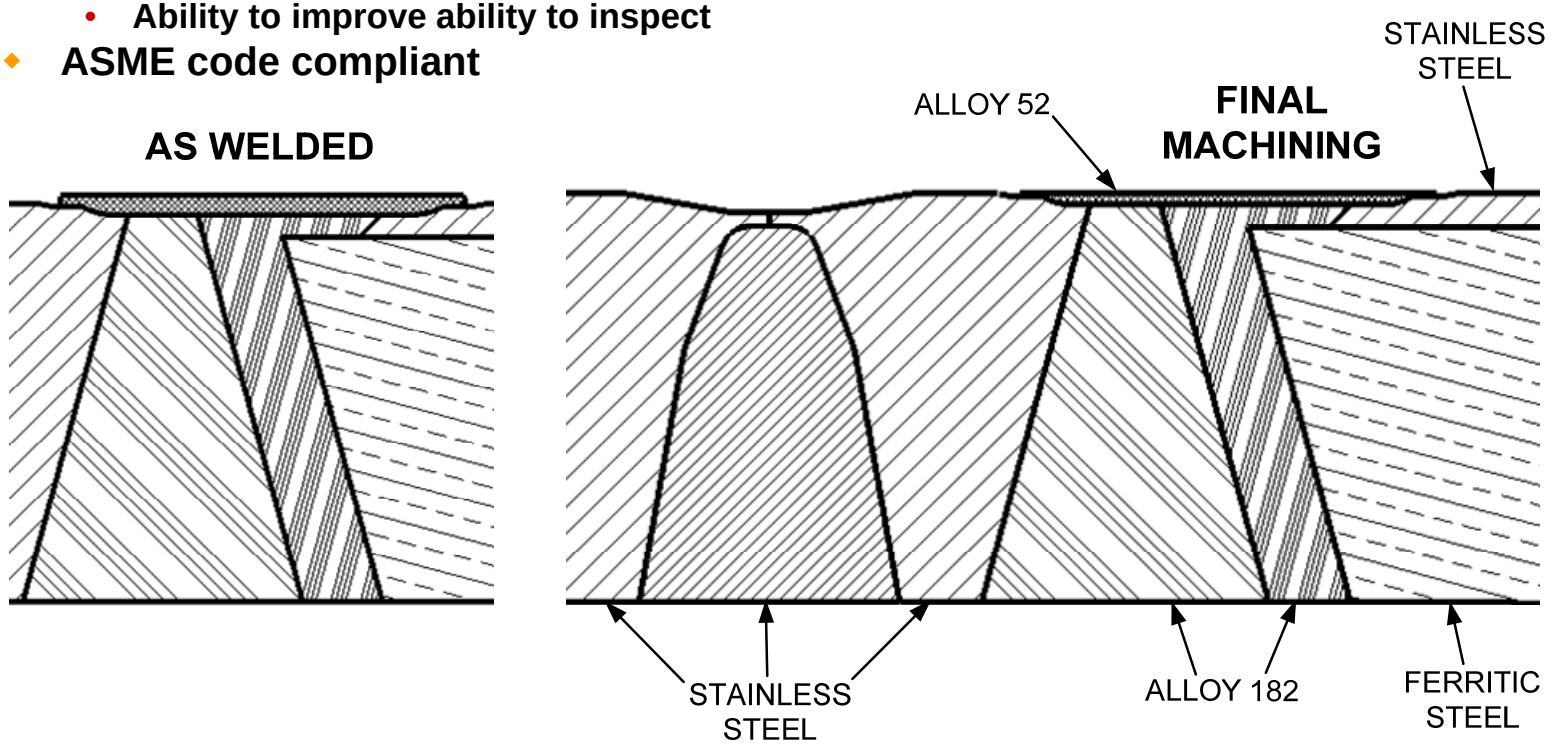
# MRP-139 RV Nozzle Configurations



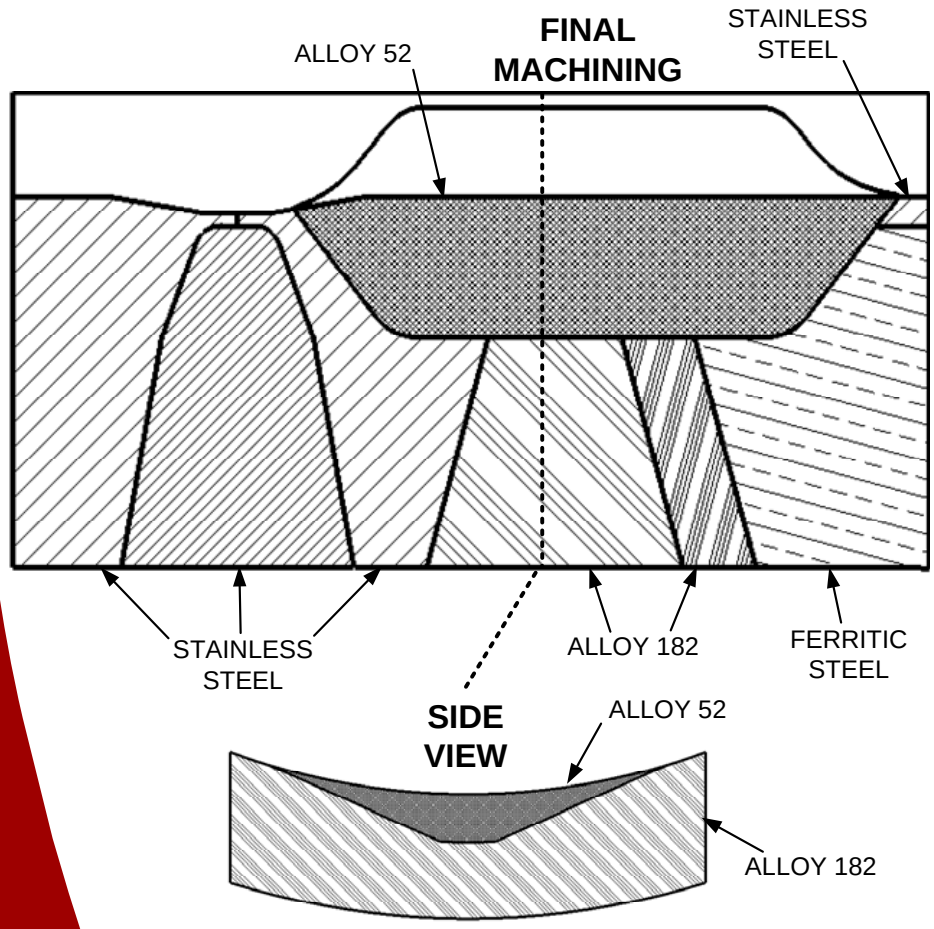

- Type 3A Weld Geometry is Prevalent in 4-Loop PWRs
- A600 DMW Configuration (U.S. Plants)
  - **22 units with Type 3A**
  - **2 units with Type 3B**
  - **4 units with Type 3C**
  - **2 units with Type 2**
- At least 14 European plants with similar DMW configurations

# RV Nozzle Inlay
# Mitigation Design Considerations

- **Type 3A mitigative inlay**
  - **No existing cracks**
  - **ID restored to original geometry**
  - **Inlay acceptance criteria per Section III**
  - **Post repair classification**
    - **Category A, MRP-139**
    - **Future ISI inspections use existing PDI qualification and equipment**
    - **Ability to improve ability to inspect**
  - **ASME code compliant**



# RV Nozzle Inlay - Repair Design




- Post repair classification
  - **Category A, MRP-139**
- Localized excavation referenced to NDE data through common tooling coordinate system
- Ambient temperature temperbead weld contingency
  - **PSI acceptance criteria in accordance with CC638**
- Balance of weld is mitigative geometry and acceptance criteria
  - **Proposed above standard PSI**

# Inlay Mitigation - MRP-139

- **PWSCC risk mitigation by inlay**
  - **MRP-139 RV primary nozzle DM weld inspection implementation schedule:**
    - **By 12/31/09 – Perform first PDI volumetric inspection of the hot leg.**
    - **By 12/31/10 – Perform first PDI volumetric inspection of the cold leg.**
  - **MRP-139 categorizes DM welds by inspectability, presence of flaws and mitigation applied**
  - **Post inlay – Category A, no susceptible material**
    - **Current 10 year ISI inspection requirements**

# *Inlay ASME Code Activity*

- **AREVA is developing code cases in order to address the requirements for application of inlay in Alloy 600 DM butt welds. There are two code cases under development:**
  - **1) Mitigative inlay – current effort**
  - **2) Repair inlay – future effort**

# Mitigative Inlay Acceptance Examination

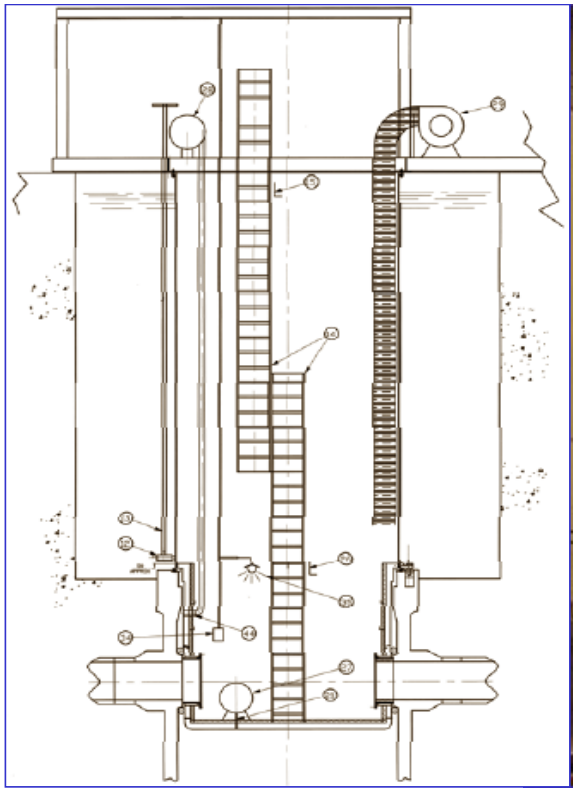
- Proposed above standard mitigative inlay acceptance criteria
  - **The inlay surface, including at least 1/2 in. (13 mm) from each edge thereof, shall be examined using the liquid penetrant or eddy current examination method. Acceptance criteria shall be in accordance with Section III, NB-5352 except rounded indications with major dimension greater than 1/16 in. (1.5 mm) shall not be permitted**
  - **The inlay weld volume including the fusion zone (and ferritic steel heat-affected zone, when temper bead welding is used) shall be ultrasonically examined in accordance with Section V, Article 4, using Cladding Technique One. The acceptance criteria of Section III, NB-5330 shall apply.**
- Post inlay classification
  - **Category A, MRP-139**
  - **Return to current ISI inspection frequency**
    - **Examination Case pending**
  - **Future ISI inspections use existing PDI qualification and equipment**

# Reactor Vessel Primary Nozzle Inlay Application History

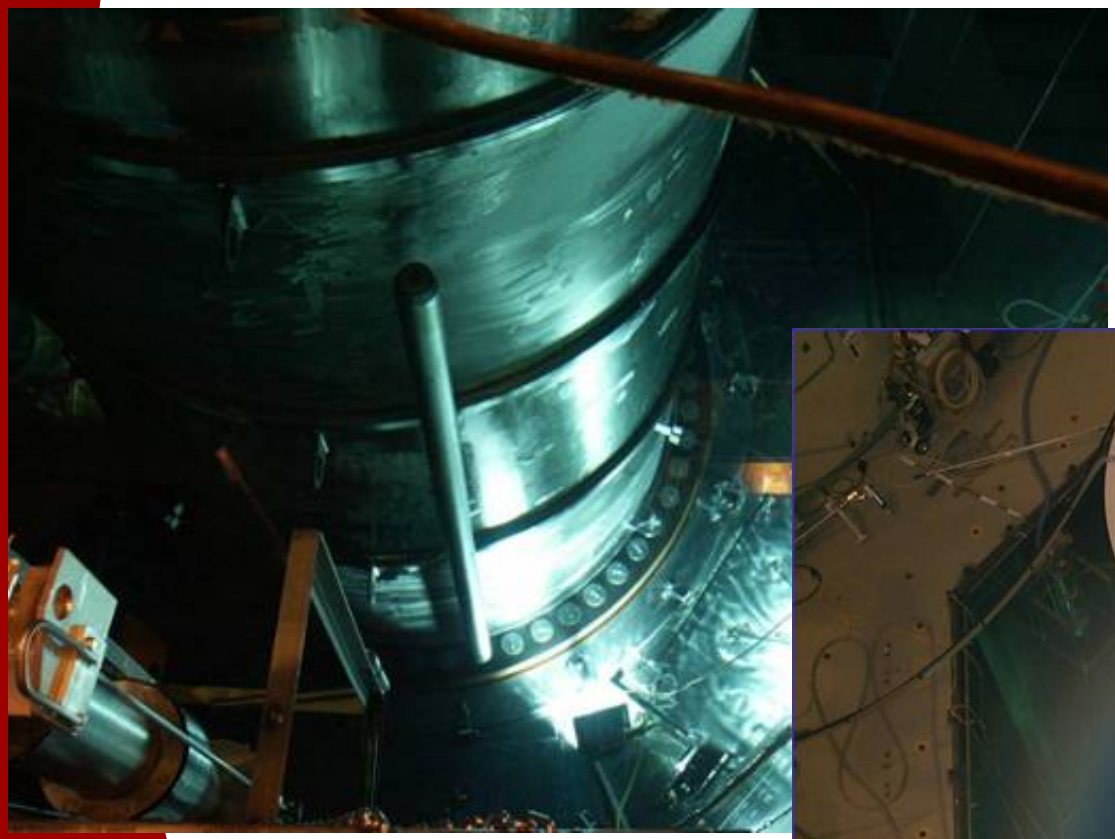
- Cold leg spool piece replacement performed at Fessenheim with ID machining/PT using robotics delivered through RC pump
  - ID operations later qualified for delivery through RV nozzle with lower internals removed in a dry cavity
  - Unlike in France, US and other European plants with Alloy 600 DM welds do not have provision to drain loops with the lower internals removed
    - Would require significant cavity shielding
- Inlay application at Ringhals with flooded cavity
  - ~3-5 week schedule for 3 hot legs per unit
  - Included welding of boat sample excavations
  - High personnel exposure with semi-remote delivery
  - Hat and barrel not easily transported LSA

# Safe End Repair Project (SERP)

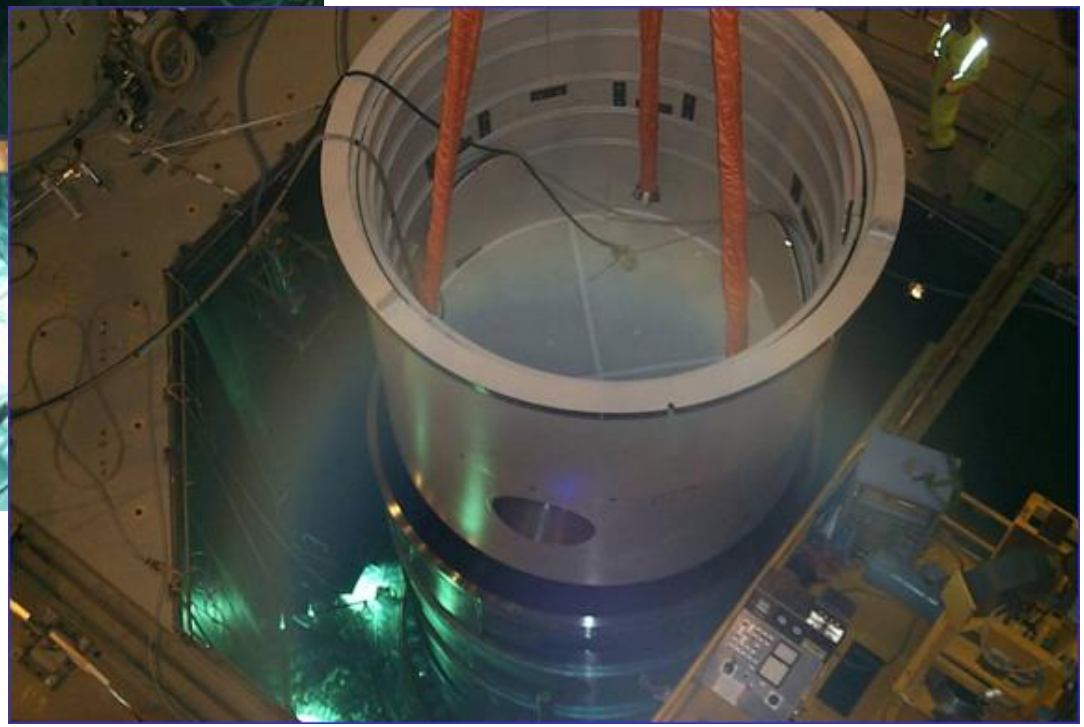
- Ringhals 4 (2002)
- Ringhals 3 (2003)
- Performed by Westinghouse and Uddcomb Engineering (now an AREVA subsidiary)



# Safe End Repair Project (SERP)



- Hat and barrel approach

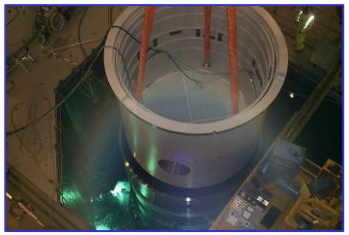


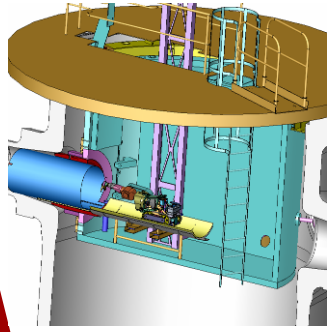
# *Reactor Vessel Primary Nozzle Inlay Next Generation*

- AREVA NP design criteria for next generation Aegis Inlay™ methodology is:
  - **Flooded cavity**
  - **Ability to handle any flaw scenario**
  - **Parallel operations and schedule optimization**
  - **Delivery system transportable LSA via normal shipment containers**
  - **High production rate with low dose**

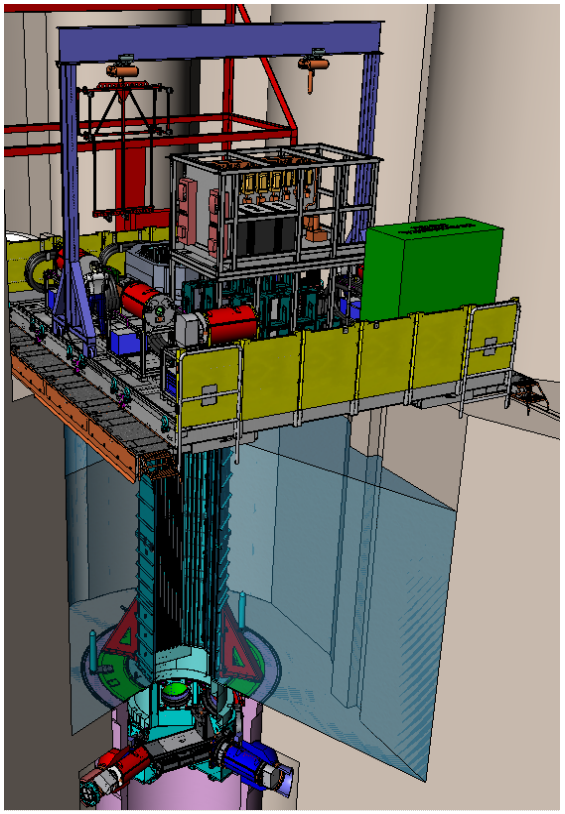
# Aegis Inlay™ Approach

- Next generation system built on global technologies
  - Low dose
  - Fully remote
  - Parallel activities

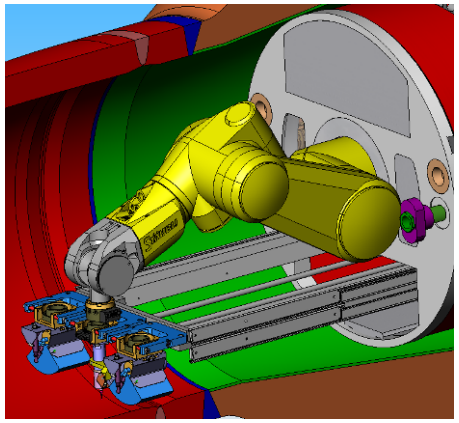




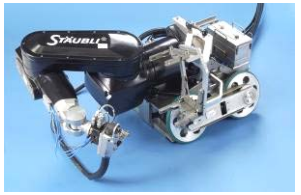
PREVIOUS GENERATION HAT & BARREL CONCEPTS

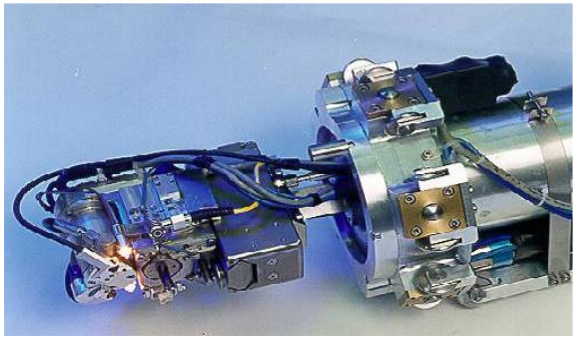


FLOODED CAVITY DELIVERY SYSTEM

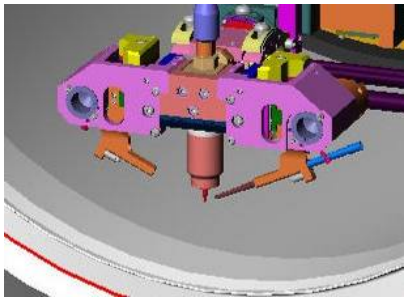


SFC ARTUR TECHNOLOGY





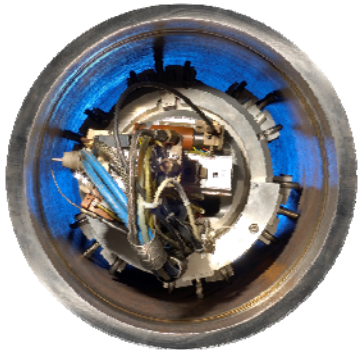
SGA IN-PIPE MANIPULATOR MACHINING TECHNOLOGY

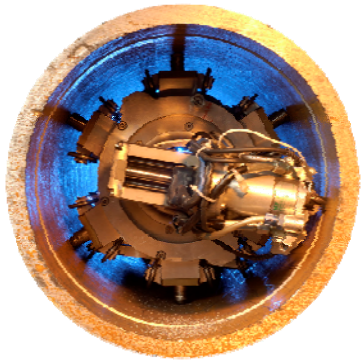


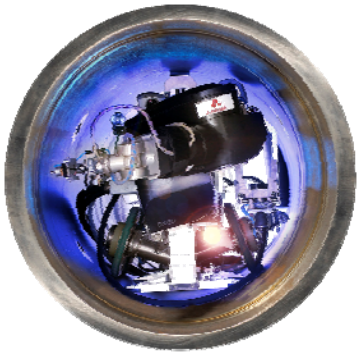
SAC REMOTE WELDING TECHNOLOGY

# Adaptation of Proven Technologies

- Welding, machining, NDE and FOSAR processes based on proven global system technologies
  - **French ARTUR system – utilized at Fessenheim for CL spool replacement**
  - **German In-Pipe Manipulator – developed to machine BWR piping weld roots for improved UT**
  - **US remote orbital welding**
  - **AREVA NP, Uddcomb Engineering experience @ Ringhals**
  - **TWS RV ISI transducer/NDE technology**

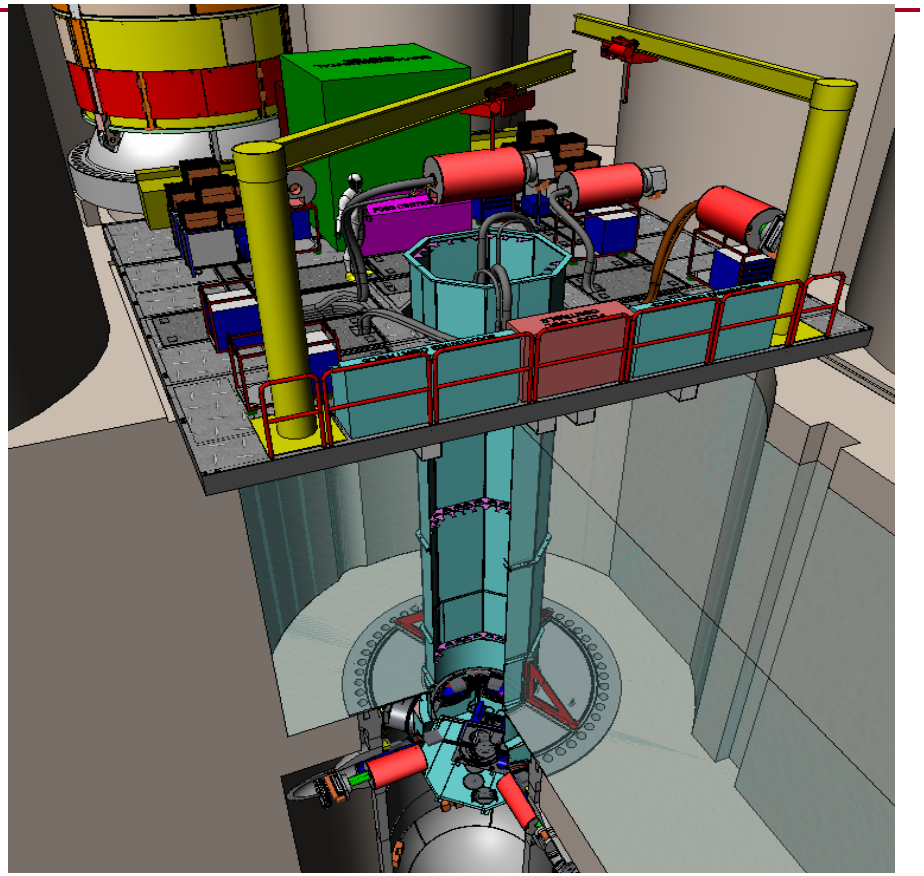






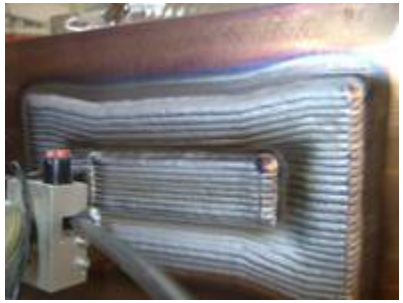
# AREVA NP Flooded Cavity Delivery System

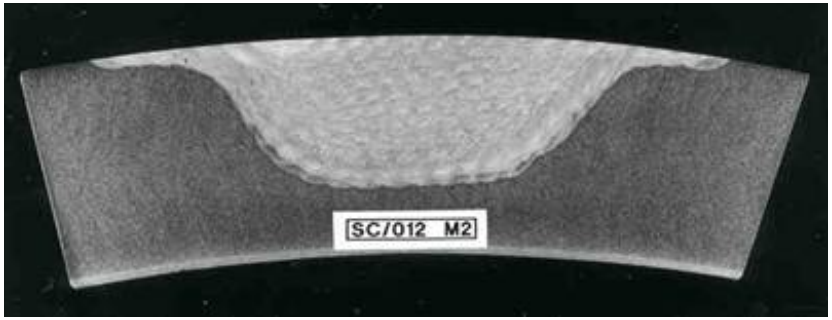
- Fully remote parallel operations
  - **Facilitated by remote failure recovery and redundant system design**
  - **Engineered cable management**
- All delivery activities from refuel floor
  - **Machining, cleaning and NDE data acquisition controlled at work platform**
  - **Welding and NDE Data analysis operations controlled from outside containment**
- Primary and secondary FME confinement
- Integrated environmental control system to rapidly dry nozzles after draining and after immersion UT operations
  - **Contamination control by maintaining negative pressure within delivery system**
  - **Also maintains low humidity during welding without disturbing gas coverage**



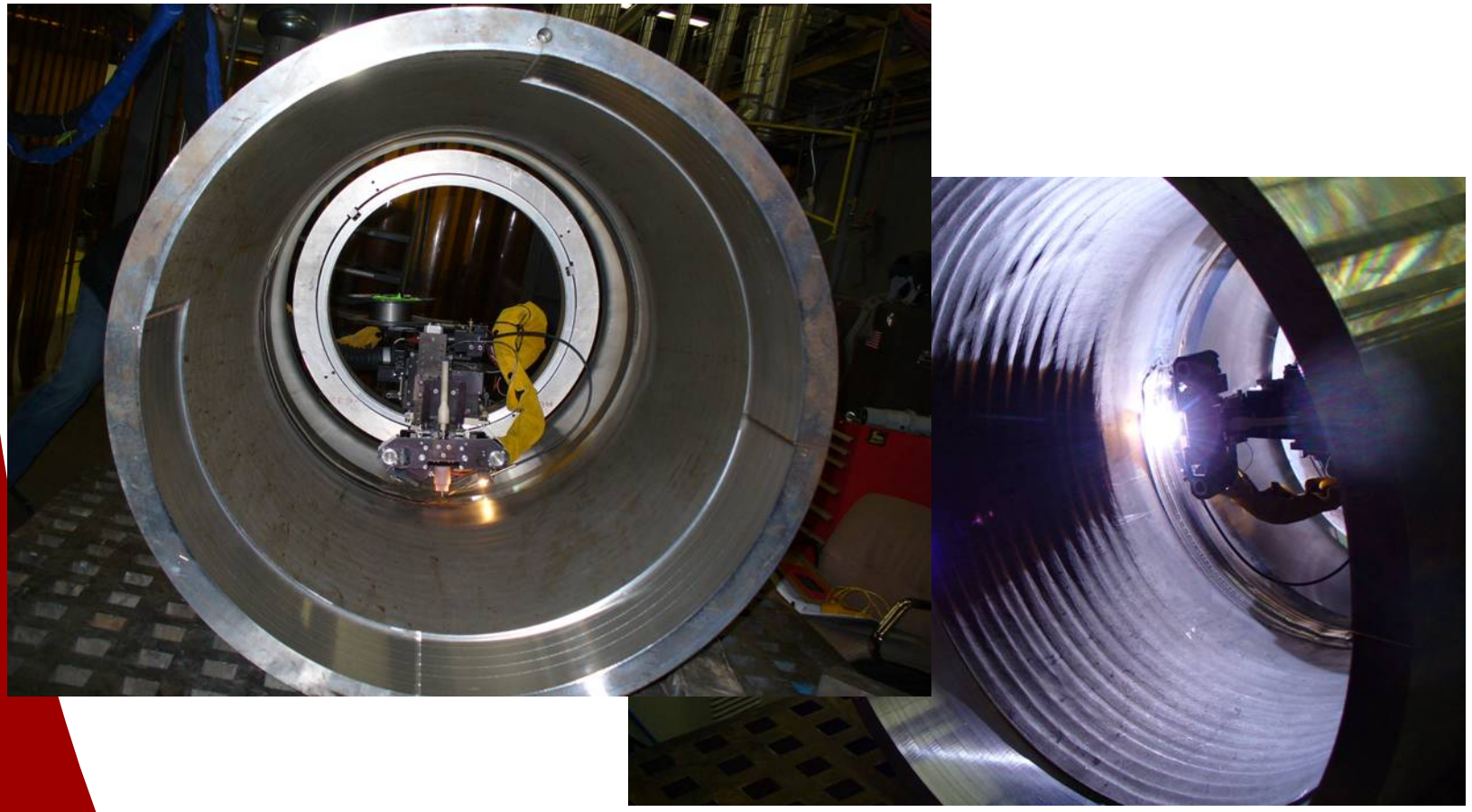
# Inlay Welding

- Remote GTAW w/ dual wire feed
  - **Option of double-up or bi-directional welding progression**
- Existing orbital equipment
  - **Large experience base**
- Local cavity ambient temperature temperbead contingency



# AREVA NP / PWROG Mockup Fabrication



# PWROG Participation

- **The PWROG has committed to the development of RV primary nozzle inlay via a Project Authorization for PDI equivalency testing and integrated system qualification and demonstration.**
- **AREVA is making a substantial capital investment in Aegis Inlay™ for design, fabrication, and qualification for one field deployable system by fall 2008.**

# LBB Considerations for Weld Inlays

- Alloy 52/52M corrosion resistant layer removes PWSCC as an “active degradation mechanism” from the Alloy 82/182 butt weld location.
- Original geometry and loads are not modified by the weld inlay installation
- Weld Inlay material is applied using Gas Tungsten Arc Welding (GTAW) process which exhibits higher fracture toughness than shielded metal arc welding (SMAW) which is typically the process used for the dissimilar metal butt welds at these locations.
- A qualitative materials reconciliation can be performed to demonstrate that LBB remains applicable at the location

# Conclusions

- Weld inlay is application of a PWSCC-resistant layer that completely isolates PWSCC susceptible Alloy 82/182 from the environment.
- LBB is preserved by removing PWSCC as an active degradation mechanism from the location.
- Tooling and delivery systems are based on adaptations to proven technology.
- Inlay designs for both preemptive mitigation and repair of in-service flaws.