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**Session Th5-BC - Materials Degradation**  
*License Renewal Issues & Irradiation Assisted Stress Corrosion Cracking*

*Studies on Irradiation Assisted Stress Corrosion Cracking  
of Austenitic Stainless Steels in LWR Environments*

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## *U.S. Nuclear Power Plants*

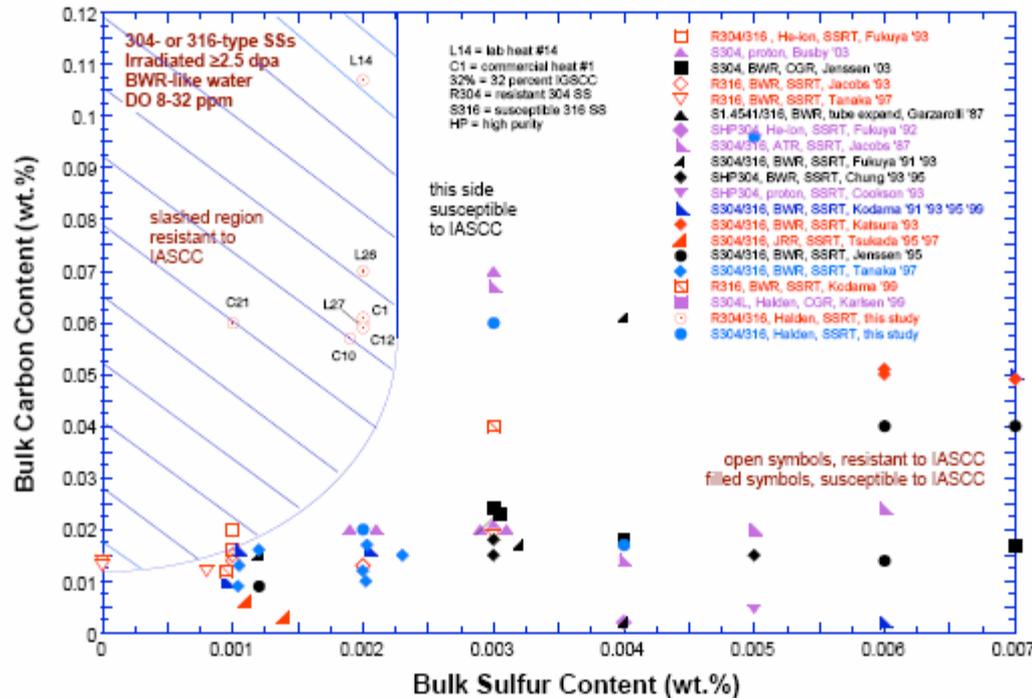
- **Regulatory Issue:** Integrity of reactor components is subjected to **Environmentally Assisted Cracking (EAC)**. Need to
  - develop technical information needed to assure that selected inspection intervals are adequate to assure structural integrity
  - identify susceptible materials and conditions, &
  - verify effectiveness of industry–proposed mitigating measures
- **Current concerns** focused on
  - cracking of core internals,
  - cracking of nickel alloys & welds,
  - aging and license renewal issue, &
  - wastage of PV head



# Cracking of Core Internals

- **Technical Issue:** High irradiation levels in reactor core can increase susceptibility to stress corrosion cracking (i.e., IASCC) by affecting both material & environment
- **Program Activity:**
  - Understand mechanisms of various types of cracking; material selection & identify solutions
  - Develop technical information such as
    - *crack growth rates*  
*to determine inspection intervals & disposition components*
    - *fracture toughness*  
*also to disposition components*

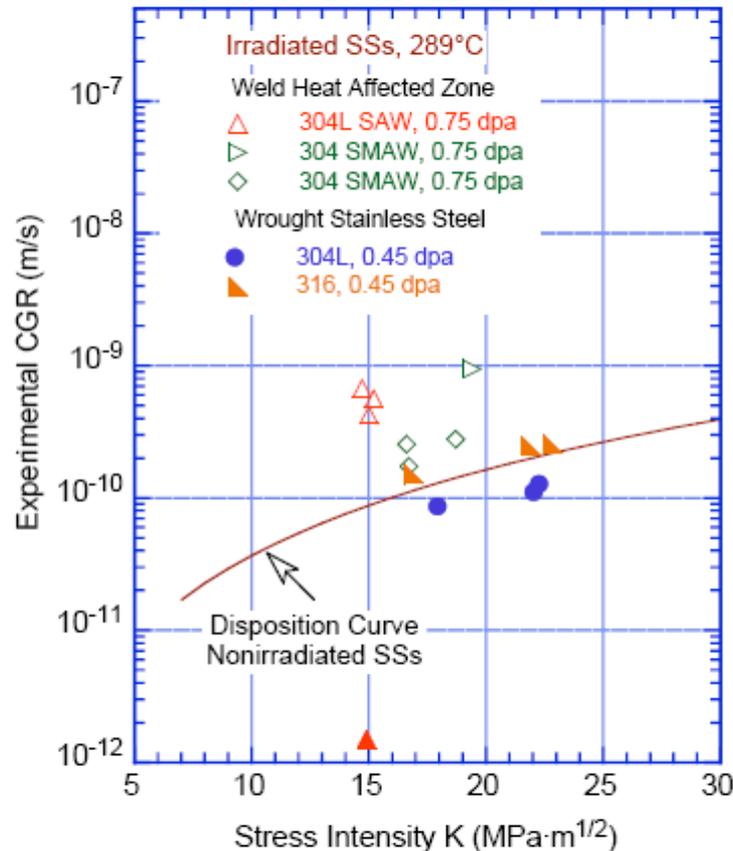
# IASCC Susceptibility - Effect of Sulfur & Carbon Content



- Stainless steels with  $\leq 0.002$  wt.% sulfur are resistant to IASCC; low carbon steels must have very low sulfur to minimize susceptibility

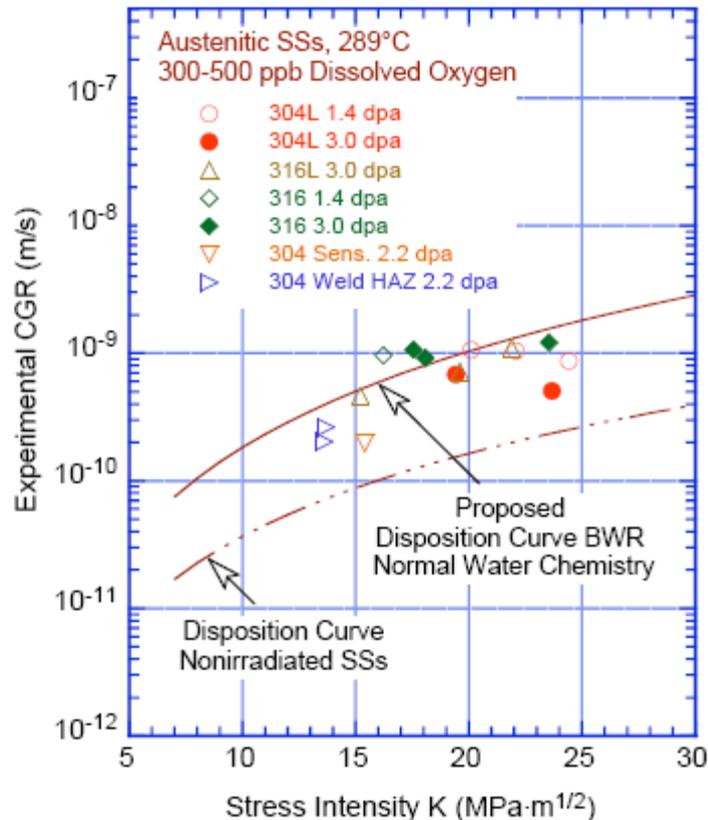
\* 1 dpa  $\approx 7 \times 10^{20}$  n/cm<sup>2</sup> (E > 1 MeV), or  $\approx 7$  y service for BWR Top Guide

## Crack Growth Rates for SSs Irradiated to <0.75 dpa



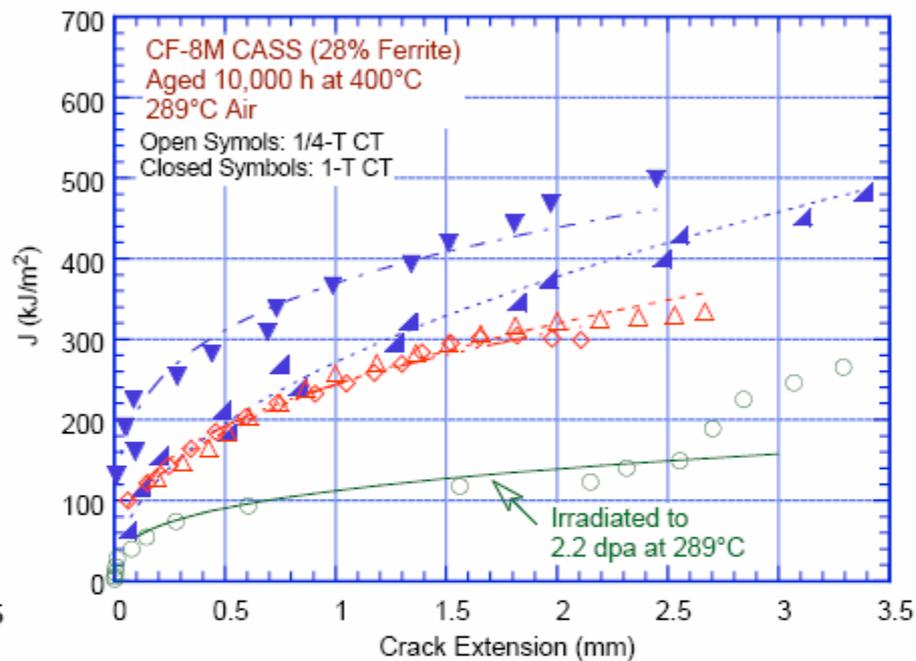
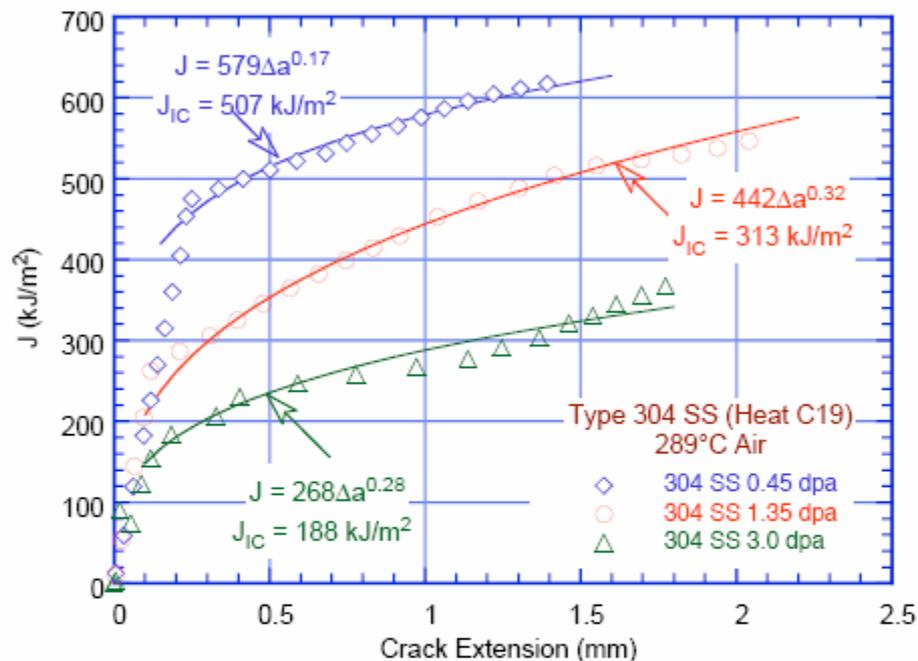
- For BWR normal water chemistry, crack growth rates of steels irradiated to 0.45 dpa are consistent with the disposition curve for nonirradiated steels
- Disposition curve for nonirradiated steel may not be adequate for weld heat affected zones, e.g., crack growth rates of HAZ material irradiated to  $\approx 0.75$  dpa are factor of  $\approx 5$  higher

## Crack Growth Rates for SSs Irradiated to >0.75 dpa



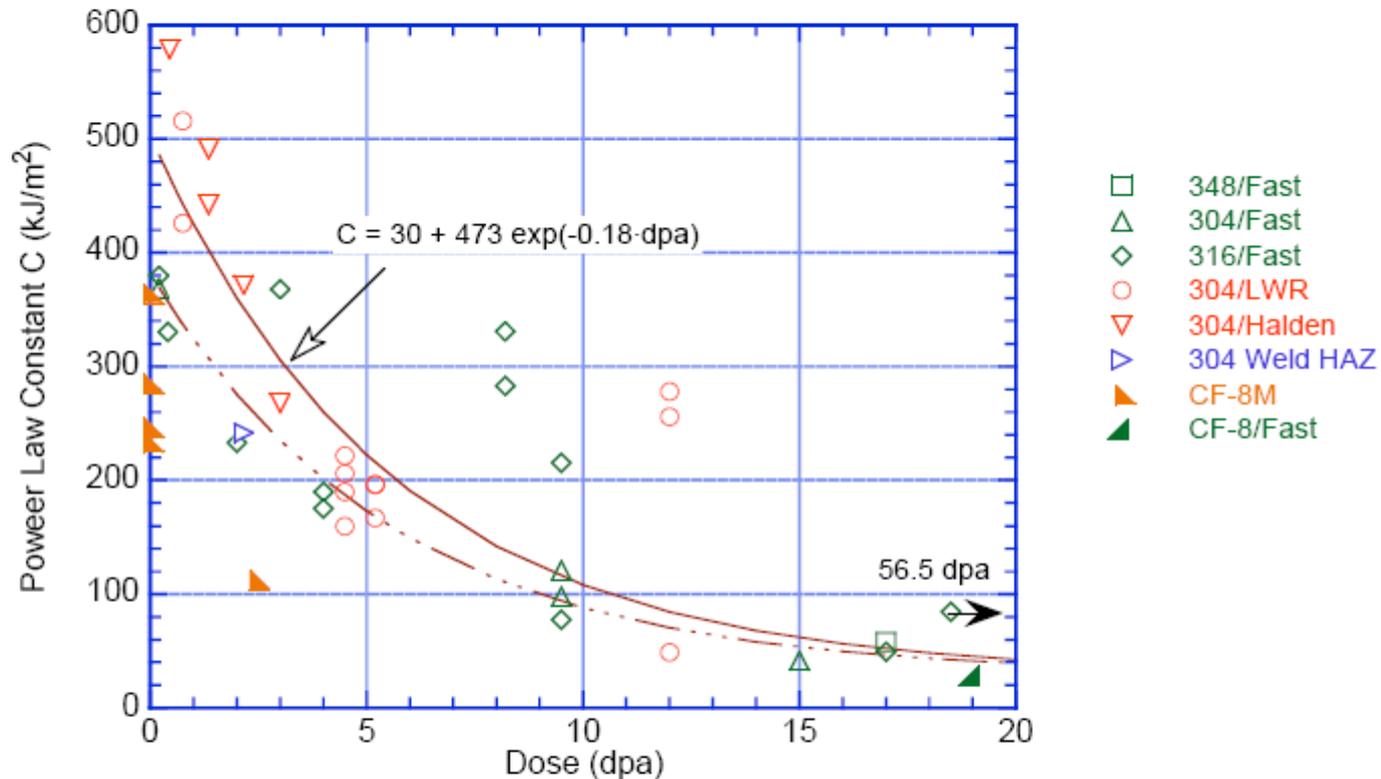
- For BWR normal water chemistry, crack growth rates of steels irradiated between 0.75 and 3.0 dpa are a factor of  $\approx 5$  higher than the current disposition curve for nonirradiated stainless steels
- For BWR hydrogen water chemistry, growth rates decrease more than an order of magnitude

# Fracture Toughness of Irradiated Stainless Steels



- Neutron irradiation decreases the fracture toughness of wrought & cast austenitic stainless steels
- For cast stainless steels, thermal aging embrittles the ferrite phase, neutron irradiation embrittles also the austenite phase

# Estimating Change in Toughness with Neutron Irradiation



- For irradiated wrought & cast austenitic SSs the change in toughness may be represented by a correlation between coefficient C of the power-law J-R curve & neutron dose

## Summary

- **IASCC susceptibility** of irradiated SSs is being investigated as a function of material chemistry & irradiation level (NUREG/CR-5608, -6687, -6892)
  - Sulfur & carbon content in steel effect susceptibility
- **Crack growth rates** are being determined as a function of fluence, water chemistry, & material composition (NUREG/CR-6826, -6891)
  - In BWR normal water chemistry, crack growth rates of SSs irradiated to 0.75–3.0 dpa are factor of 5 higher than the disposition curve for nonirradiated SSs
  - In BWR hydrogen water chemistry, growth rates are order of magnitude lower than in normal water chemistry
- **Fracture toughness** of wrought & cast SSs is decreased by neutron irradiation
  - Effect of irradiation on cast SS is greater than on wrought SS
  - Correlation are being developed to estimate fracture toughness as a function of fluence and material type, including synergistic effect of thermal & neutron irradiation for cast SSs