A Brief Overview of Current State of Knowledge of HT Corrosion in sCO$_2$

Ian G. Wright (WrightHT, Inc) and Steve C. Kung (EPRI)

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Prior Experience of Corrosion in sCO₂

**Significant research in support of UK gas-cooled reactors:**

- Tests at 40 bar, ≤550°C (ferritics); 650-850°C (austenitics)
- Ferritics: ‘breakaway oxidation’ (exposures to 95kh)
  - attributed to effects of C
- Austenitics: potential problems only with ≤18Cr-8Ni
  - C pickup when duplex scales formed
  - for higher-Cr alloys, C pick-up only in initial stages, or after exfoliation; sigma phase?
  - expected to meet requirements (250kh)
  - test exposures to 25kh
- Key contributions from additions of CH₄ and H₂O
Recent Results

- Higher $T$ and $P$, but shorter $t$ than earlier UK studies
- No systematic reports of effects of impurities in sCO$_2$
- Kinetics appear ±consistent
Oxidation Kinetics of Austenitics in sCO₂

![Graph showing oxidation kinetics of austenitics in sCO₂](image-url)
Similar Kinetics in sCO₂ & HP Steam

Steam data (lab) suggest no change in mechanism ≤4kh at 650-800°C
Scale Morphologies Compared to HP Steam?

- Steam oxidation: different scale morphologies than in air
  - $H_2O = O^+ + OH^-$: mobility of all 3(?) in scales
  - typically 2-layered scales: Fe-Cr spinel (inner, L1), magnetite (outer, L2)

Schematic representation:
cross section of fully-developed scale on T91 in HP steam (EPRI Atlas)

- sCO$_2$ involves: CO$_2 = O^+ +$ CO$^-$
  - similar oxidation process (i.e. similar scale morphologies)
  - and, carburization expected
Actual Scale Morphologies

Ferritics

T91, 64kh at 566°C & 138 bar steam (EPRI Atlas)

T91, 155kh at 538°C & 17 bar steam (EPRI Atlas)

T91, ≈300h at 550°C & 250 bar CO₂ (Rouillard, 2010)

Fe-9Cr, ≤9kh at 550°C & 40 bar CO₂ (Harrison, 1974)
Actual Scale Morphologies
Austenitics

Main features of scale in HP steam
(Wright & Dooley, 2011)

TP347HFG, 11kh at 670°C & 251 bar steam
(EPRI Atlas)

TP347HFG, 500h at 700°C & 200 bar CO₂ (Pint & Keiser, 2014)
Summary: Immediate Needs

• Longer-term exposures (10kh+?)
  – onset of failure
  – kinetics for thin sections

• Morphological characterization
  – departure from expectations (HP steam)
    o fate of C?
    o influence of brazing elements?