Impact of Oxygen/Nitrogen Oxide Partial Gas Pressures on 310 N Stainless Steel Corrosion in Solar Salt at 600 °C

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Motivation and State-of-the-art

Molten salt based thermal energy storage (TES) systems are a well suited energy storage option:

- Molten **Solar Salt (60 wt% $NaNO_3$/40 wt% KNO_3)** is a proven storage/heat transfer medium; operating >565 °C enhances storage density, but promotes salt decomposition to nitrite and oxide ions, causing faster corrosion [1].
- At 600 °C, **oxide ion concentration >0.25 mol%** is a critical threshold, beyond which stainless steel corrosion rises sharply [2].
- Recent advances show that **gas management (high O_2 + ppm-level NO)** stabilizes salt by controlling oxide ion concentration, reducing steel corrosion up to ~620–650 °C and enabling higher-temperature TES [3].

Fig.1: Top: Concentrated solar power (CSP) plant with a power tower configuration. Bottom: Molten salt storage tanks

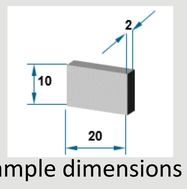
Objective

1. **Salt Chemistry with gas atmosphere** – Test O_2 (5–80 vol%) + NO (400–600 ppm) impact on nitrate/nitrite/oxide/chromate at 600 °C.
2. **Impact on corrosion** – Measure 310N SS weight change, rates, and layer structure under varied gas atmospheres.
3. **Correlation** – Identifying time dependent nitrate, nitrite ions impact on corrosion?

Fig.2: Schematics of objective

Materials & Methods

Material Used:
Salt: 60 wt.% $NaNO_3$/ 40 wt% KNO_3
Alloy: 310N

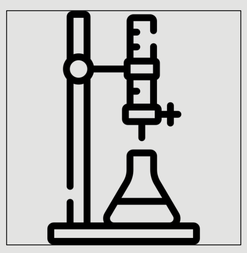


Steel sample dimensions (mm)

Salt analysis

(a)

Fig.3 (a) Ion chromatography(IC)

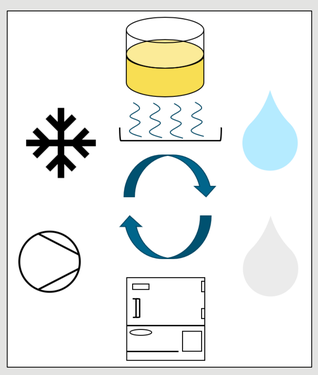


(b)

(b) Acid-base titration

- Fig.3 (a), **IC** for nitrate, nitrite, chromate analysis
- Fig.3 (b), **Acid-base titration** used to detect corrosive oxide ions for post analysis

Alloy analysis



(a)

(b)

Fig.4: (a) Macrostructure analysis using acid wash descaling (b) Microstructure analysis using Scanning Electron Microscopy with Energy Dispersive X-ray Spectroscopy (SEM-EDS)

Experimental Setup

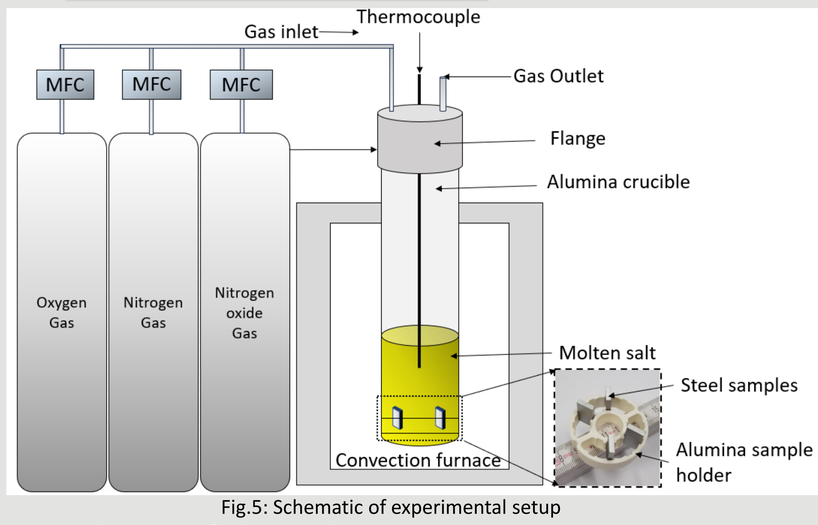
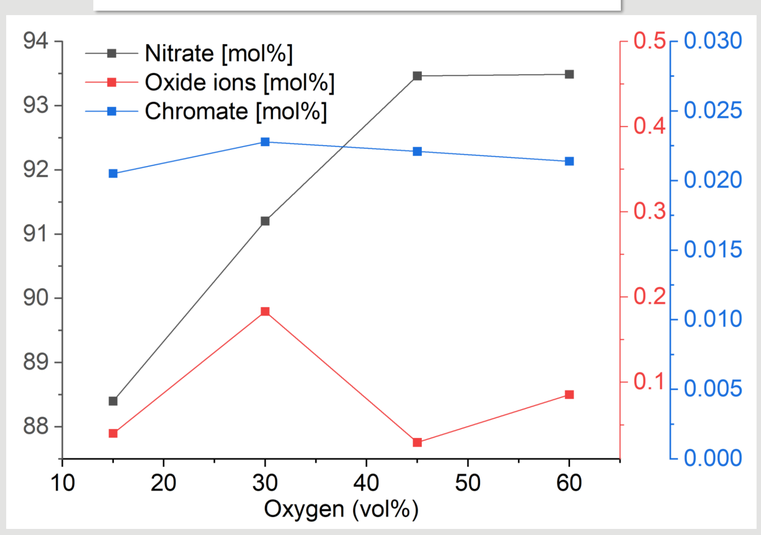


Fig.5: Schematic of experimental setup

Operating conditions, Fig 5:

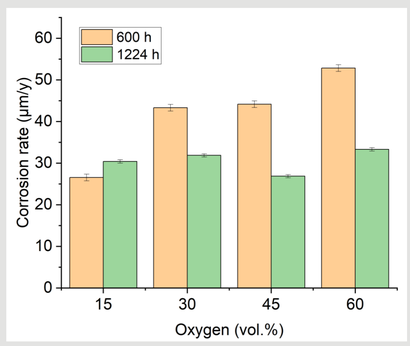
- **Temperature** : Isothermal 600°C, static conditions
- **Time:** 600 and 1224 h
- **Total gas flow**: 100 mL/min (Mass Flow Controllers)
- **Atmosphere**: O_2 (5 to 80 vol%), N_2, NO (400 and 600 ppm)

Results and Discussion

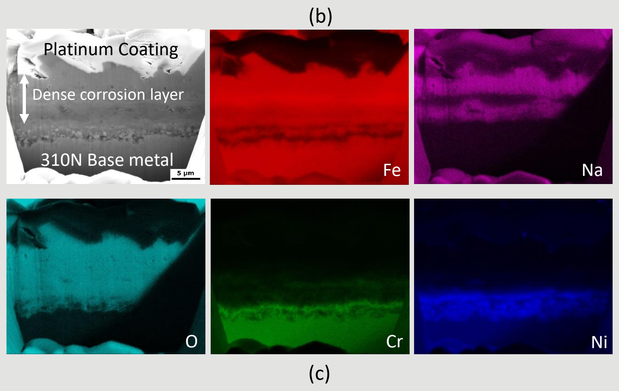


(a)

Fig 6: (a) Variation in nitrate, chromate, and oxide ion concentrations at 600 °C after 1224 h exposure with 600 ppm NO with varying oxygen vol% (b) Corrosion rate analysis results (c) Cross-section FIB-EDX mappings for SS 310N sample in Solar Salt at 600 °C and 15 vol% O_2, 600 ppm NO after 1224 h



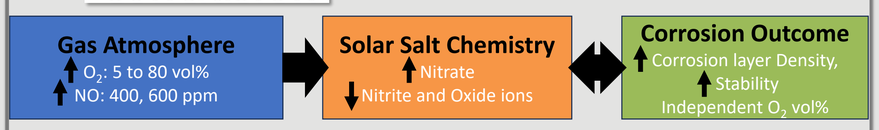
(b)



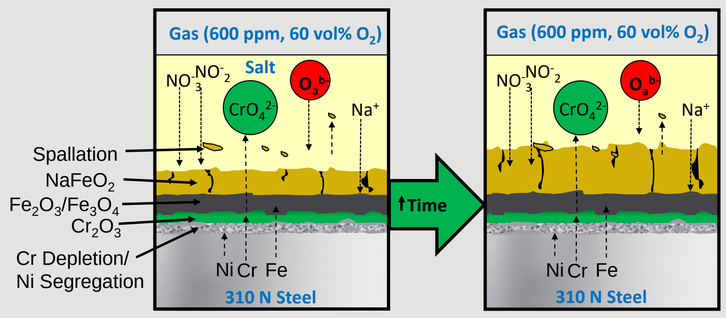
(c)

- **At 600 °C (400 & 600 ppm NO): Fig 6 (a),** increasing nitrate, chromate ion stable, oxide < 0.20 mol% with increasing O_2 vol%.
- **At 600 °C (400 and 600 ppm NO): Fig 6 (b),** corrosion rate increases with O_2 vol% at 600 h, but stable at 1224 h.
- Dense and less porous corrosion layer formed at both 600 and 1224 h at 400 and 600 ppm NO above 5 vol% oxygen, **Fig 6 (c).**
- Corrosion layer thickness increase with increasing time, with low chromium depletion and dense sodium iron oxide, and iron oxide layer, **Fig 6 (c).**

Conclusion



(a)



(b)

Figure 7. Summary of gas–salt–corrosion interaction at 600 °C.(a) O_2 (5–80 vol%) + NO (400–600 ppm) stabilizes salt chemistry by increase nitrate and suppressing nitrite/oxide ions.
(b) Under optimal gas, 310N steel forms dense $NaFeO_2$/Fe–oxide/Cr_2O_3 scales with dense and low long-term corrosion layer growth(left 600 h and right 1224 h corroded steel).

- **O_2 + NO Synergy Stabilizes Salt Chemistry** –Fig 7 (a), ≥5 vol% O_2+≥400 ppm NO effectively suppress nitrite/oxide ion formation, with oxide <0.20 mol% at 600 °C.
- **Long-Term Corrosion Independence from O_2** – Fig 7 (b), after 1224 h, corrosion rates and layer thickness are stable across 5–80 vol% O_2 for both 400 and 600 ppm NO.
- **Dense, Protective Corrosion Layers Form** – Fig 7 (b), ≥5 vol% O_2+ ≥400 ppm NO atmosphere produce compact Na–Fe–O / Fe–oxide / Cr_2O_3 scales, reducing dissolution and extending steel lifetime.

Reference: [1] Kumar et al. (2024) Heliyon — http://doi.org/10.1016/j.heliyon.2024.e25966
[2] Kumar et al. (2025) Corros. Sci. — http://doi.org/10.1016/j.corsci.2025.112849
[3] Bonk et al. (2024) Corros. Sci. — http://doi.org/10.1016/j.corsci.2023.111700

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