SOFC Testing in Cathode Air with Quantified Cr Concentration

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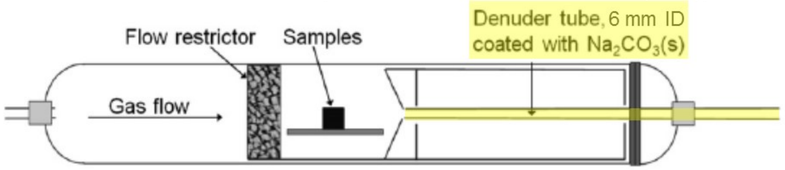
PRIOR WORK

Cr quantification technique was inspired by work by Jan Froitzhiem, et al.

- *ECS Trans.*, **25**(2) 1423-8 (2009).
- *J. of the Electrochem. Soc.*, **157**(9) B1295-300 (2010).
- *J of Power Sources*, **220** 217-27 (2012).
- *ECS Trans.*, **50**(44) 43-9 (2013).
- *J. of the Electrochem. Soc.*, **161**(9) C373-81 (2014).

They used a single denuder tube as illustrated in their publication on Cr volatility from metallic SOFC interconnects [*J of Power Sources*, **220** 217-27 (2012)]:



95+/-5% Cr collection efficiency was achieved independent of flow-rate

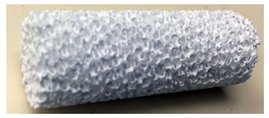
The denuder tube is coated with Na_2CO_3 which reacts with Cr-species to form water soluble Na_2CrO_4

$$CrO_3(g) + Na_2CO_3(s) \rightarrow Na_2CrO_4(s) + CO_2(g)$$
$$CrO_2(OH)_2(g) + Na_2CO_3(s) \rightarrow Na_2CrO_4(s) + CO_2(g) + H_2O(g)$$

IMPLEMENTATION AT PNNL

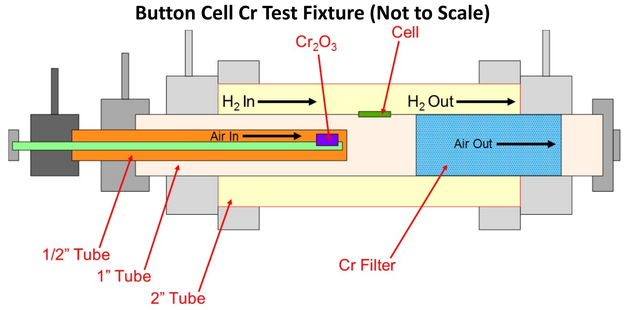
Na_2CO_3 was coated on reticulated alumina filters for increased capacity relative to a single tube.

The alumina filters have 30 pores per inch and a spec of 3 ppm Cr or less



The filters are inserted into the test fixture downstream from the button cell

Button Cell Cr Test Fixture (Not to Scale)



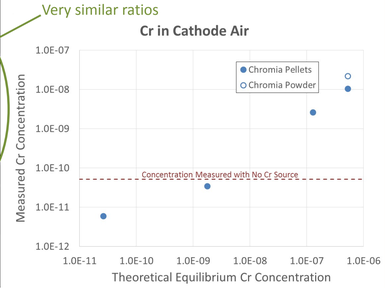
Cr FIXTURE TEST PLAN

1) Validation tests at 850ºC before drilling cell ports ***(Complete)***

Parameters	Cr Mass (µg)	Measured mol% Cr in Air	Theoretical Eqm. mol% Cr	Meas/Theo
Cr2O3 Powder at 800C 3% Water	306.17	2.22E-08	5.33E-07	4.17E-02
Cr2O3 pellet at 800C 3% Water	143.21	1.06E-08	5.33E-07	1.99E-02
Cr2O3 pellet at 600C 3% Water	35.83	2.62E-09	1.28E-07	2.05E-02
Cr2O3 pellet at 800C Dry Air	0.46	3.44E-11	1.78E-09	1.93E-02
Cr2O3 pellet at 600C Dry Air	0.08	6.01E-12	2.62E-11	2.30E-01
No Cr Dry Air	0.70	5.18E-11	0	N/A

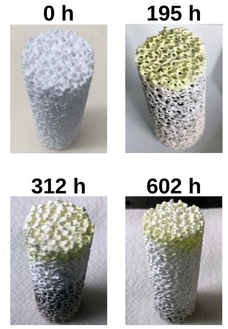
Chromia appeared to have blown out of the container

Very similar ratios



2) Preliminary tests of time-to-saturation at high Cr exposure ***(In Progress)***

Time (h)	mol% Cr in Air	Meas/Theo mol% Cr
195	7.08E-09	1.33E-02
312	7.17E-09	1.34E-02
602	1.15E-08	2.16E-02
~800	Test in Progess	
~1000	Test in Progess	



3) Preliminary tests of time-to-detection at low Cr exposure ***(In Progress)***

# of Tests	Cr2O3 Source	Cr2O3 Temperature (C)	Humidity Level	Time (h)
1	None	N/A	<5 ppm	1000
1	Pellet	600	<5 ppm	1000
1	Pellet	800	<5 ppm	1000
1	None	N/A	<5 ppm	2000
1	Pellet	600	<5 ppm	2000
1	Pellet	800	<5 ppm	2000

4) Baseline Cr-contamination tests on LSM/YSZ button cells ***(Upcoming)***

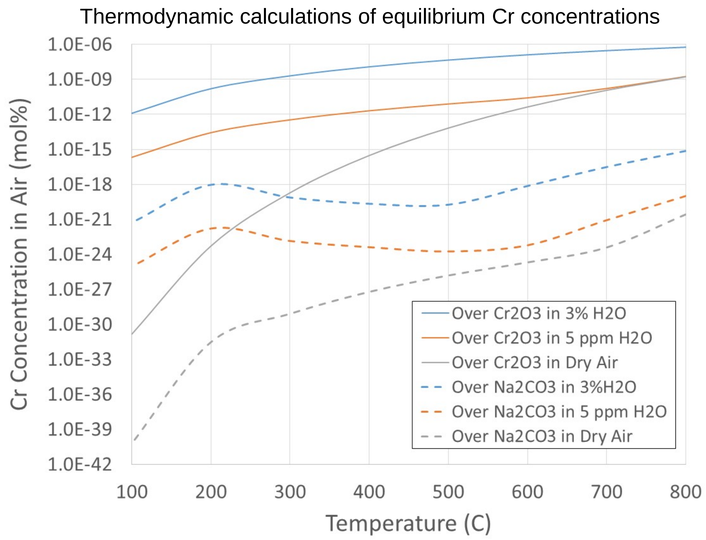
# of Tests	Cr2O3 Source	Cr2O3 Temperature (C)	Humidity Level
3	No	N/A	<5 ppm
3	Yes	800	<5 ppm

5) LSM/YSZ button cell tests with variable Cr dosing ***(Upcoming)***

# of Tests	Cr2O3 Source	Cr2O3 Temperature (C)	Humidity Level
3	Yes	800	~3%
3	Yes	600	<5 ppm

6) LSM/YSZ button cell tests seeking Cr concentration threshold below which cell performance is not significantly affected ***(Upcoming)***
   - 3 progressively lower Cr source temperatures in <5 ppm water

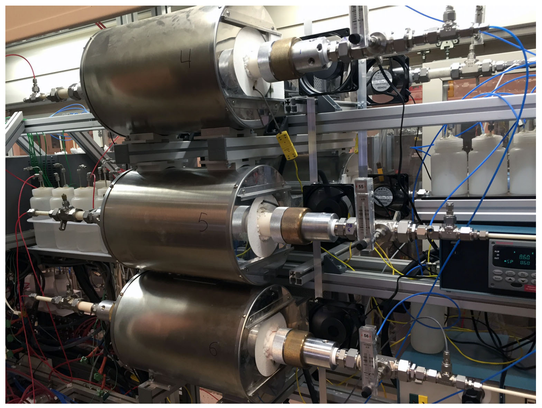
THEORETICAL EFFECTIVENESS OF CARBONATE COATING



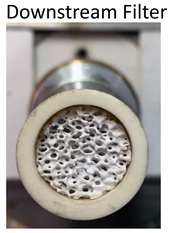
Sodium carbonate could reduce the concentration of Cr-species in the air by more than 8 orders of magnitude

This would mean capture of all but less than 10 ppb of the Cr released by the chromia source.

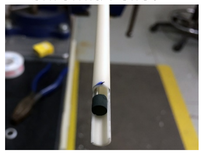
SIX TEST FIXTURES HAVE BEEN ASSEMBLED



Downstream Filter



Chromia Pellet



SUMMARY

- A method of quantifying Cr in the cathode air has been implemented and validated.
- Theoretical calculations and prior experimental work have shown sodium carbonate coatings to be highly effective for Cr capture.
- The Cr is captured as sodium chromate which is water soluble for easy dissolution.
- Validation tests show Cr captured by filters to be ~1-2% of the equilibrium concentration for the humidity and temperature conditions surrounding the chromia source.
- Powder chromia sources become entrained in gas stream causing uncertainty in whether captured Cr was a vapor species.
- Visual inspection of filters indicate Cr is captured at leading edge.
- Filters are not yet saturated after 600 h of testing at highest anticipated Cr concentration in air

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