23rd Annual Conference on Fossil Energy Materials
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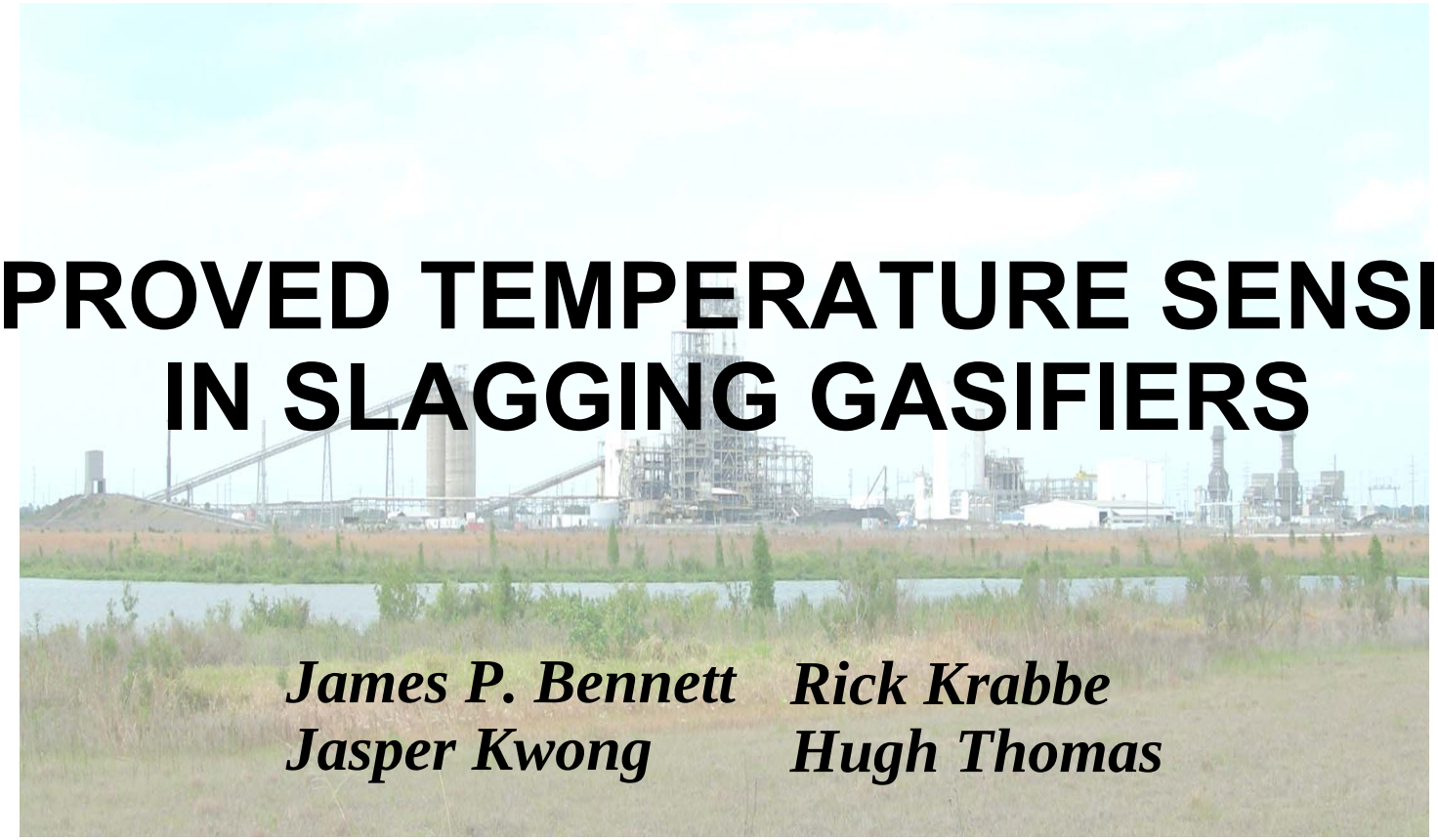

IMPROVED TEMPERATURE SENSING IN SLAGGING GASIFIERS

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Outline

- **Program goals**
- **Need for accurate temperature measurement**
- **Causes of sensor failure (thermocouples)**
  - post mortem analysis of gasifier thermocouples
  - laboratory simulations
- **Current research direction**
  - Redesign of current sensors and how used
  - New approaches to signal transfer
- **Conclusions**
- **Acknowledgement**

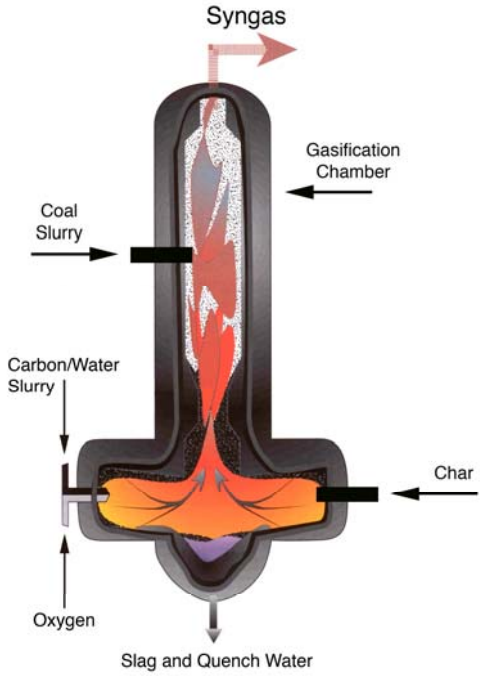
Program Goals

Develop reliable sensors that will accurately monitor gasification temperature. Research to achieve this goal is being conducted by:

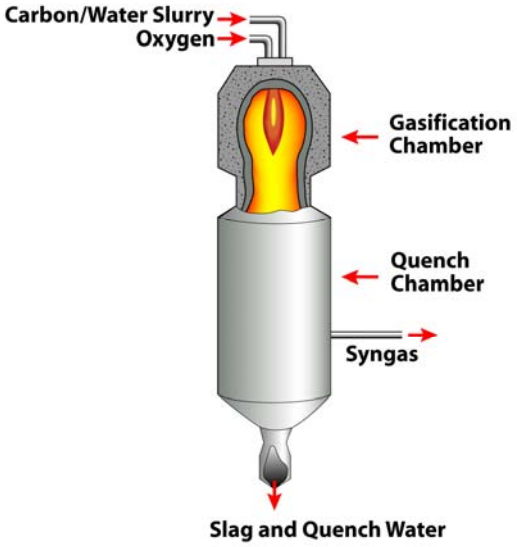
1) evaluating the causes of thermocouple failure
2) developing improved thermocouple designs
3) evaluating new sensors and/or communication devices

Need for Accurate Temperature Measurement in a Gasifier

Gasification Temperature
≈ 1325° to 1575°C



- Temperature control is critical during heating, idling, or cooling
- High gasification temperature accelerates slag/refractory liner wear – shorter campaign
- Low gasification temperature causes poor slag flow - can lead to gasifier shutdown
- Impacts thermal cycling - refractory spalling wear



Direct impact on gasifier operation/on-line availability

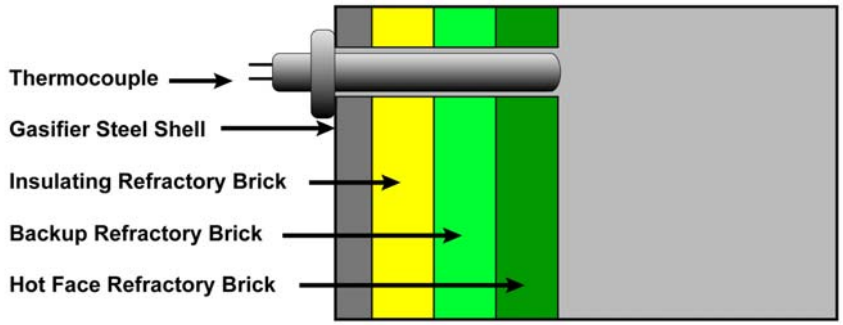
Thermocouple Failure

(typical life is less than 120 days)

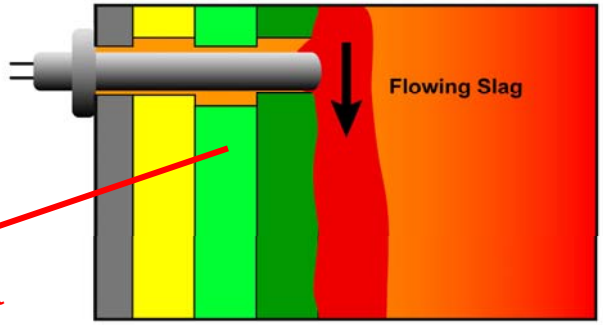
Failure rates can be up to 50 % within 15 days, 75 % within 30 days

Causes of Thermocouple Failure

- Slag corrosion
- Mechanical shear
- Design/assembly/ installation flaws
- Refractory liner



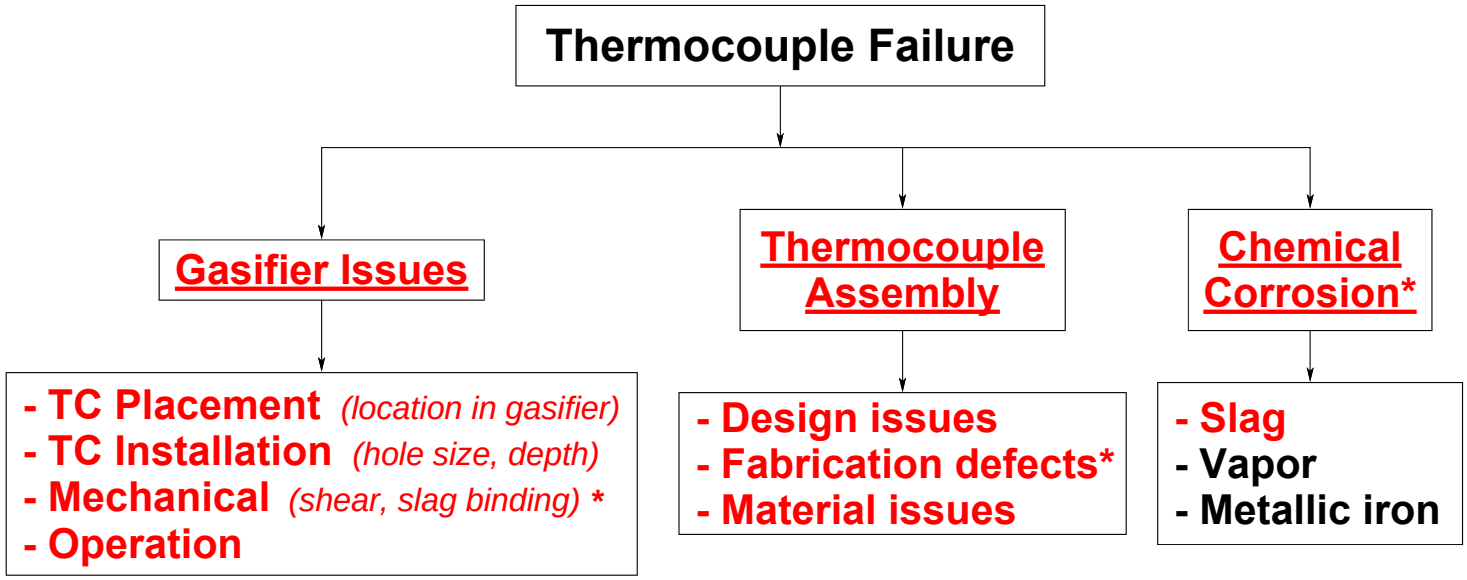
Initial Installation



During Gasification

Different Lining Movement

Causes of Thermocouple Failure



* = Possible refractory related issue

Range of Chemistry Found in Over 300 U.S. Coal Slags Due to Mineral Impurities

Material	Weight Percent			
	Max.	Min.	Avg.	Std. dev.
SiO_2	68.5	7.1	43.6	16.4
Al_2O_3	38.6	4.1	25.2	10.2
Fe_2O_3	69.7	2.1	17.0	11.2
CaO	45.1	0.5	5.8	6.6
MgO	8.0	0.1	1.2	1.1
K_2O	3.5	0.2	1.4	0.7
Na_2O	6.5	0.3	0.9	0.6
TiO_2	3.7	0.4	1.4	0.8

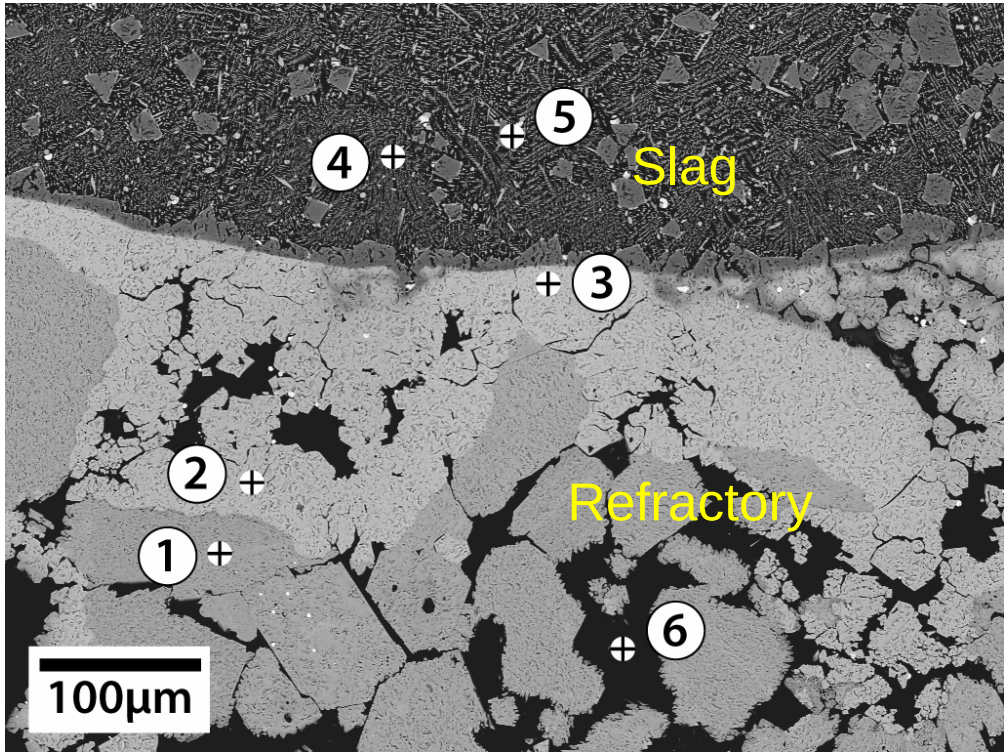
Source: W.A. Selvig and F.H. Gibson; Analysis of Ash from United States Coals; USBM Bulletin, Pub. 567; 1956, 33 pp.

Note: Petcoke slags contain V and Ni

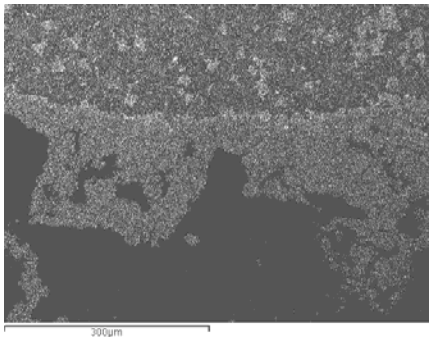
Chemical Composition and Physical Properties of High Chrome Oxide Refractory Materials

	Brick Type	
	A	B
Chemistry (wt pct) - Cr_2O_3	90.3	87.3
- Al_2O_3	7.0	2.5
- ZrO_2	0.01	5.2
Bulk Density (gms/cc)	4.21	4.07
Porosity (pct)	16.7	16.5
CCS (MPa)	48.3	66.9

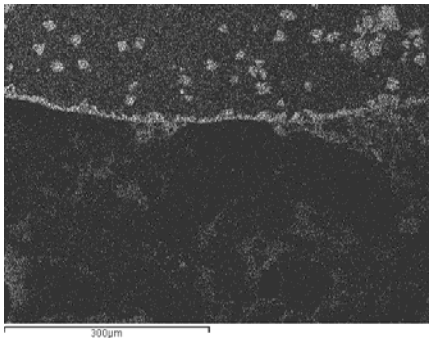
Slag/Refractory Interactions – Chemical Spalling and Corrosion of the Cr_2O_3-Al_2O_3 Refractory



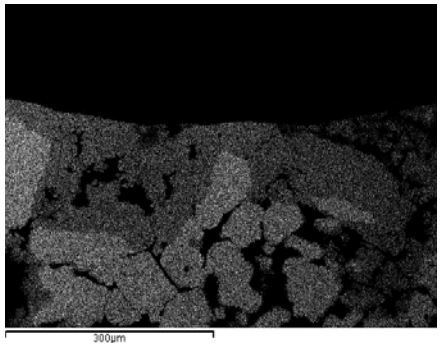
Slag diffusion, corrosion, chemical spalling



Fe



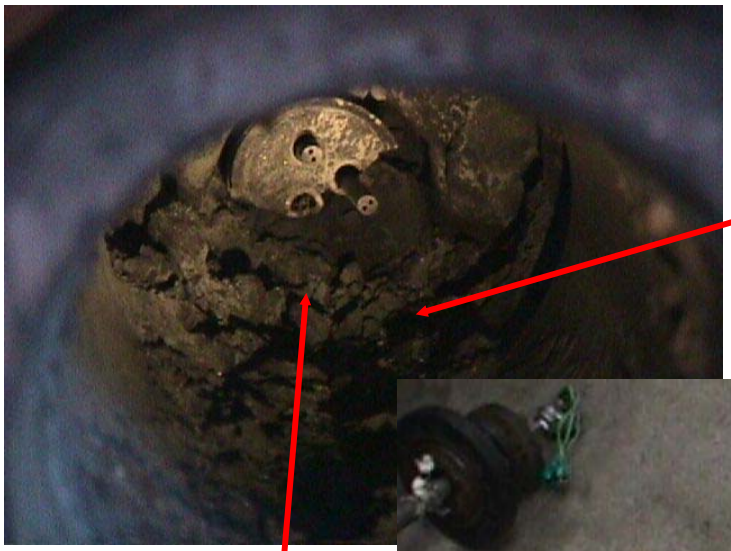
Al



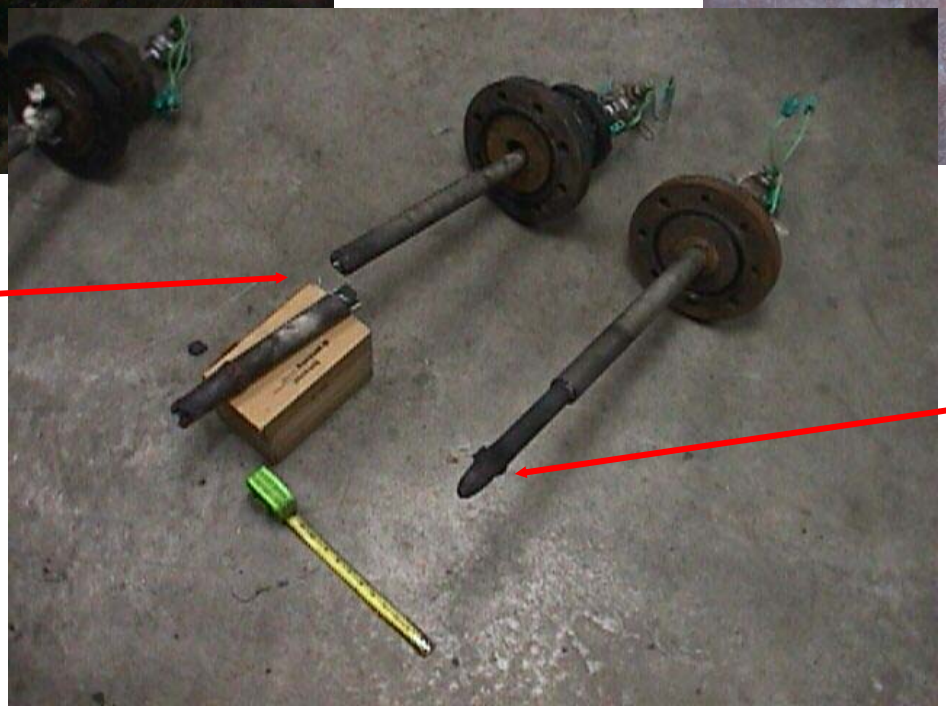
Cr

Failed Thermocouples

(shear, corrosion, slag and char penetration)



Slag,
char

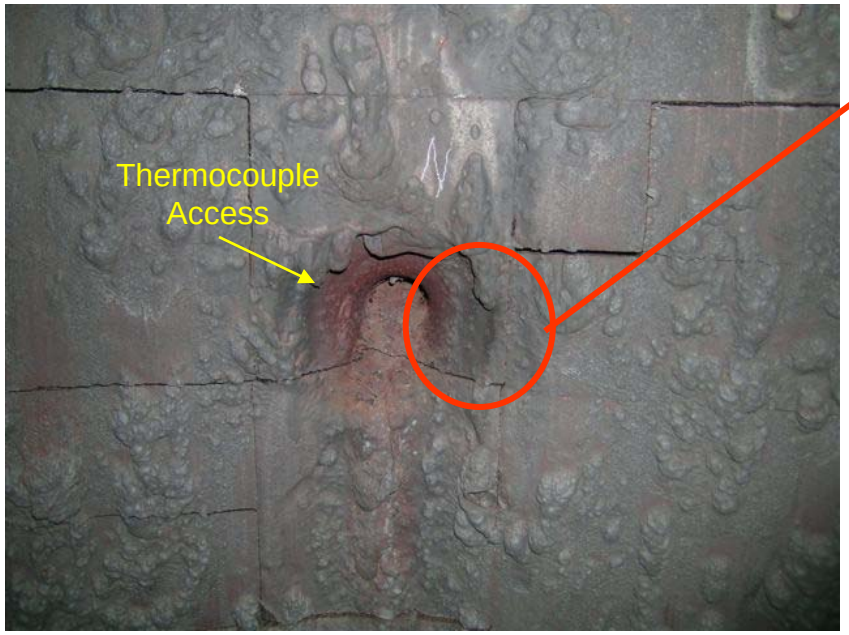


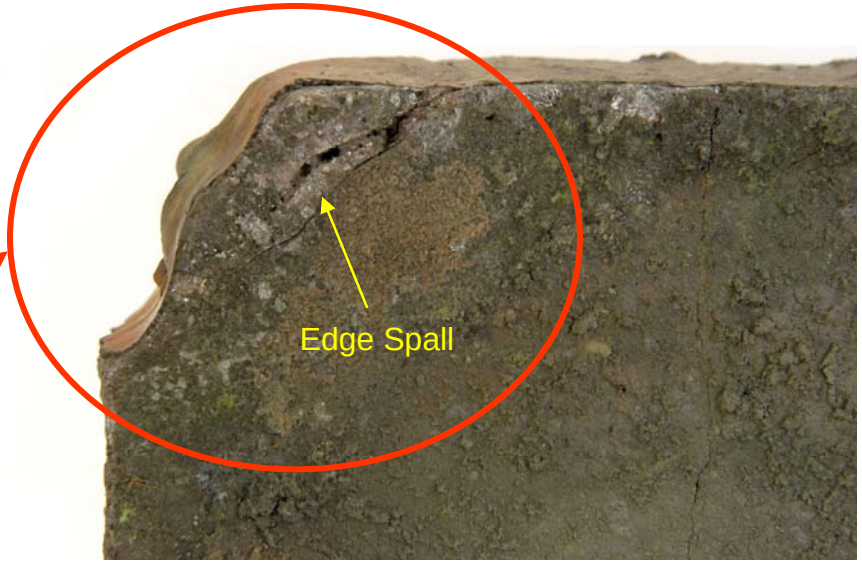
Shear

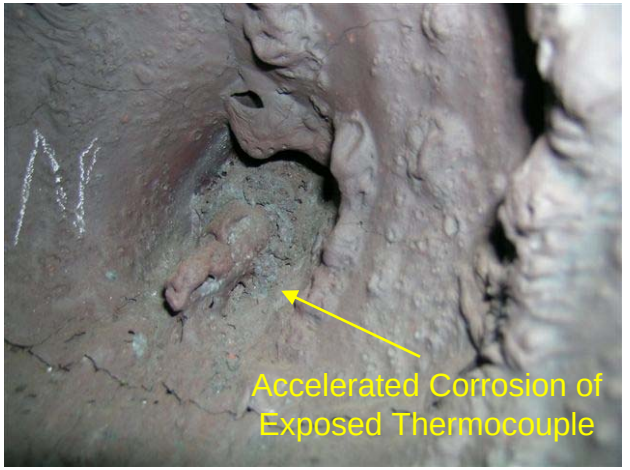
Corrosion

(refractory block
and
thermocouple)

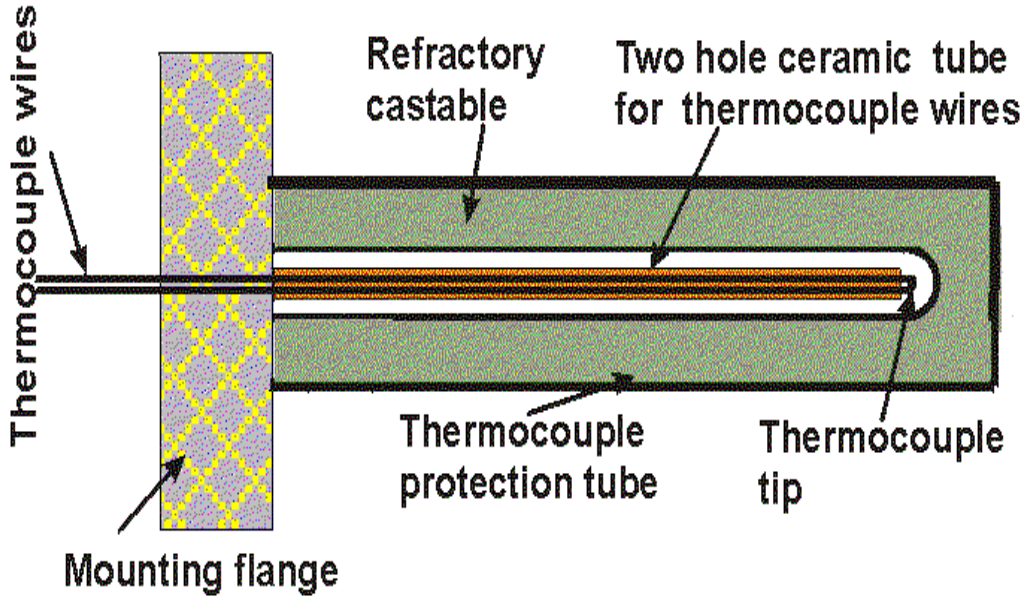
Edge Spalling/Corrosion of Refractory Where the Thermocouple Enters the Gasifier





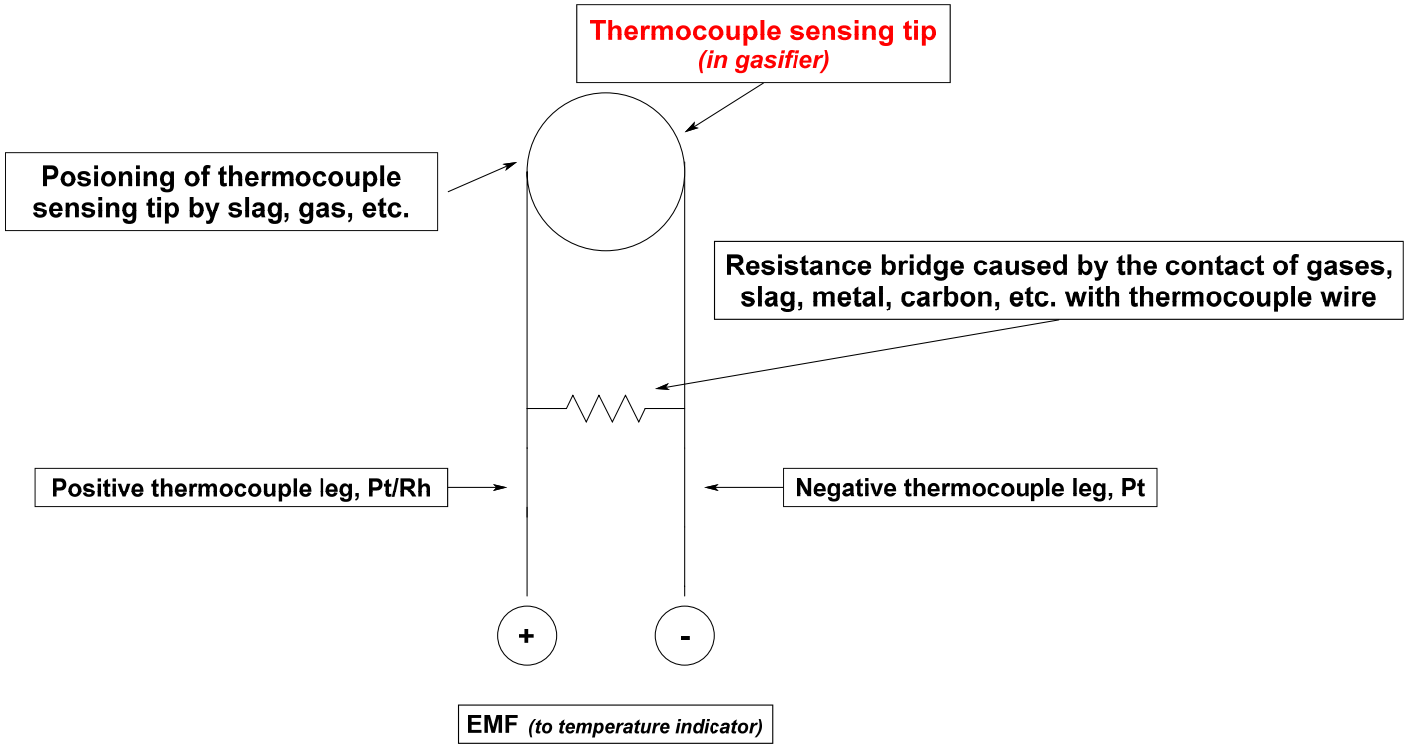


Generalized Thermocouple Assembly



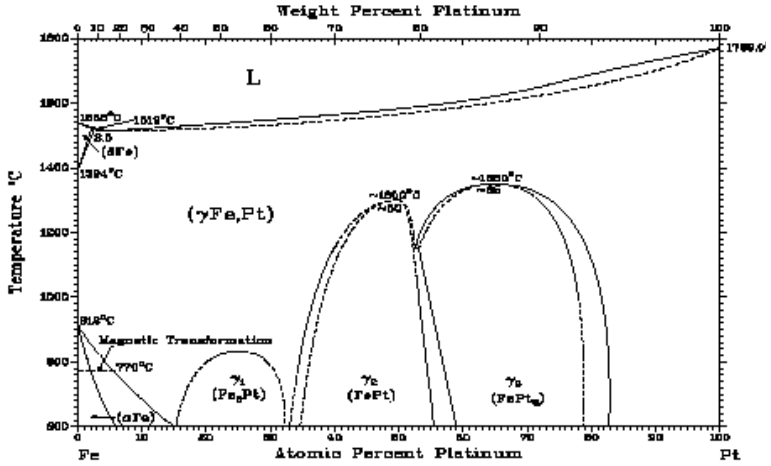
Metallic Thermocouple

(Pt/Rh – type R, S, or B)



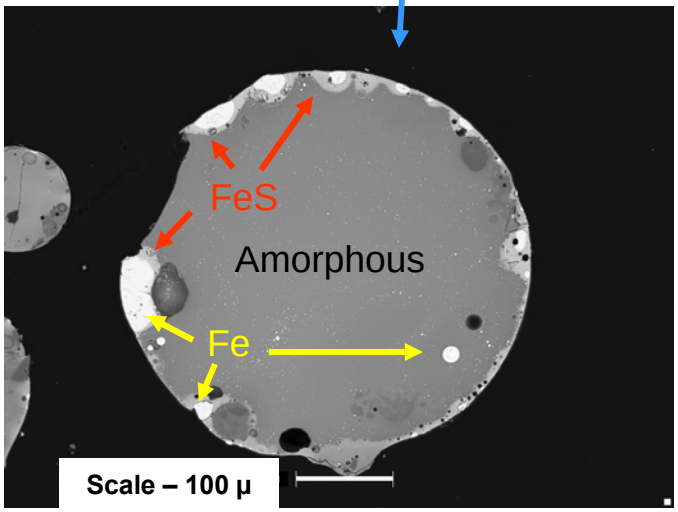
Possible Slag/Pt Thermocouple Wire Interactions

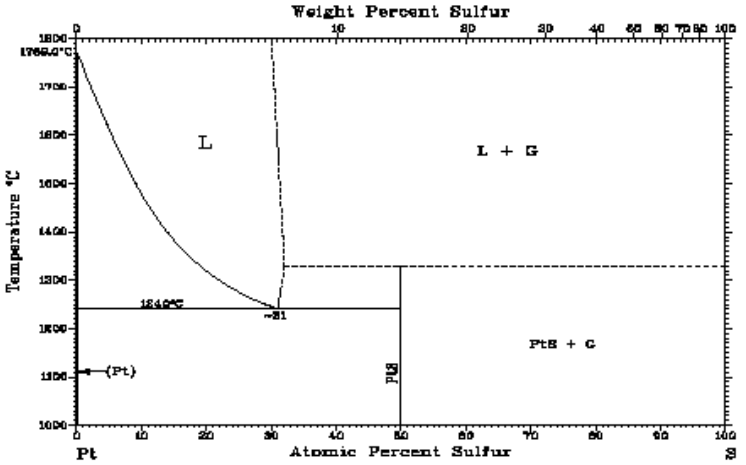
Gasifier Slag



Fe – Pt Phase Diagram

SEM Micrograph Showing FeS and Fe in Slag Particle

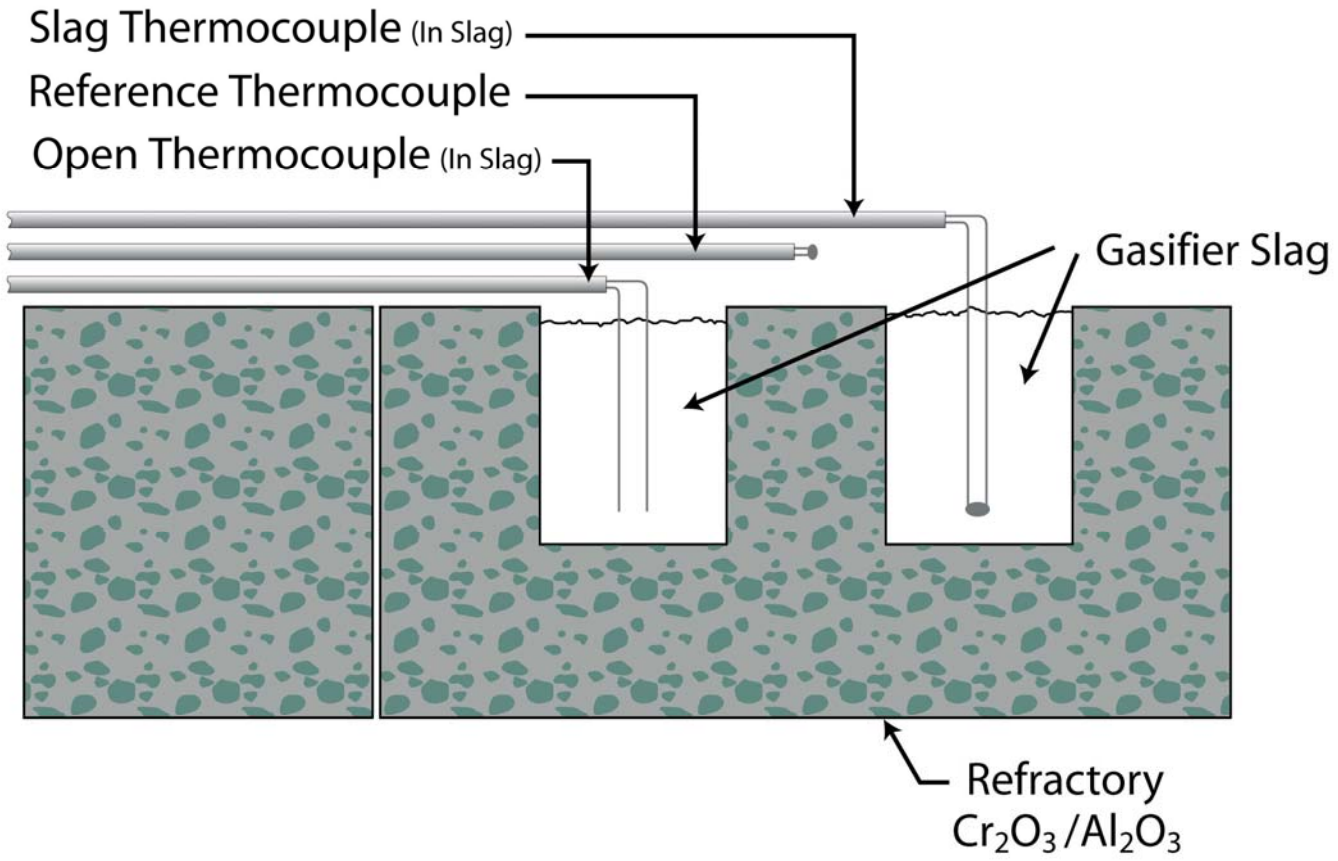




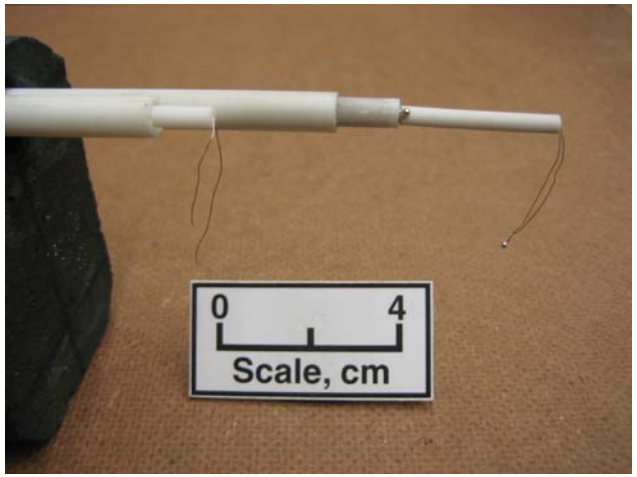
Pt - S Phase Diagram

Binary Alloy Phase Diagrams, 2nd Ed., Editor T.B. Massalski, ASM International, 1990

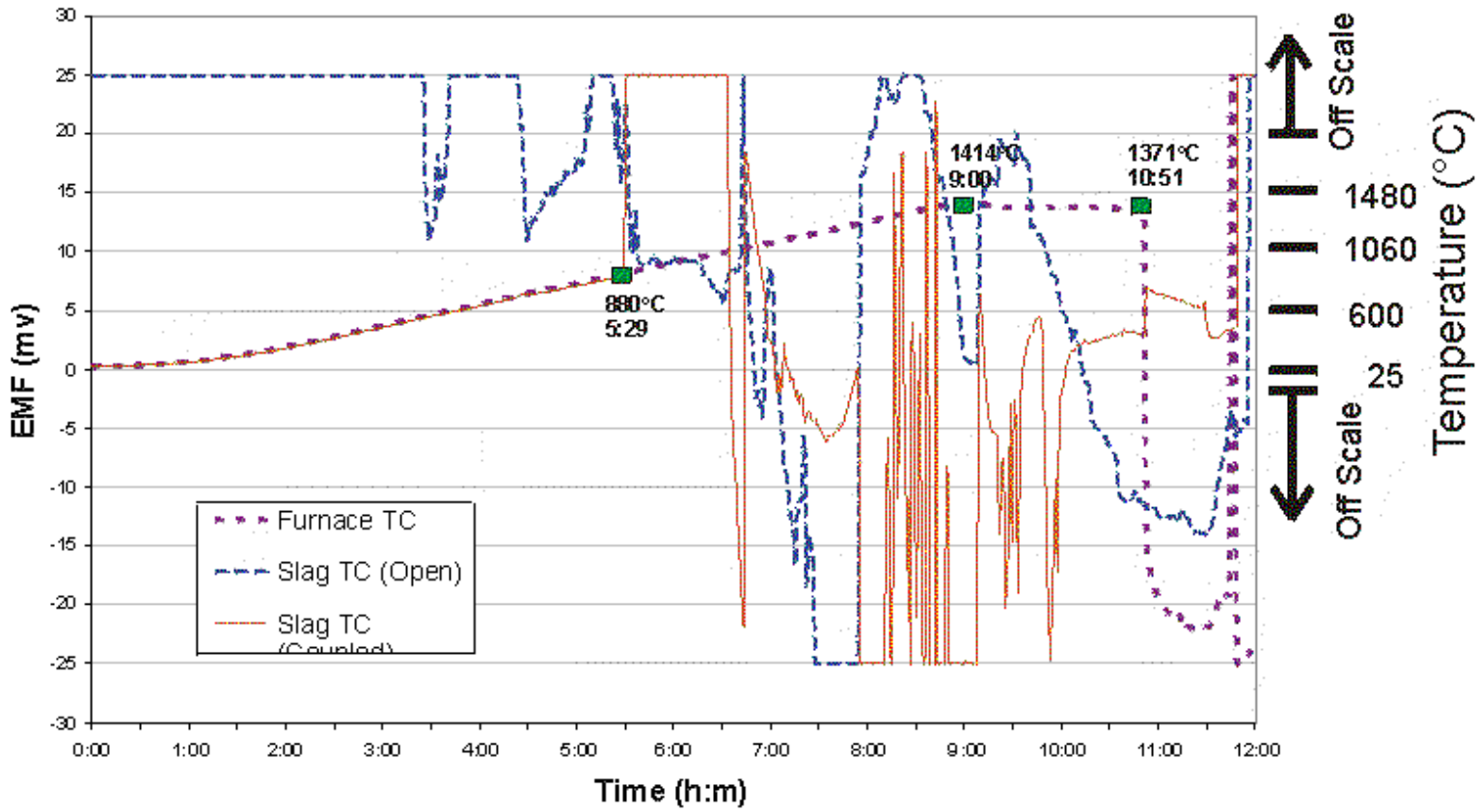
Coal Slag Attack on Thermocouple Wire



Test Assembly – Type “S” Thermocouple, 1500°C (goal), Ar

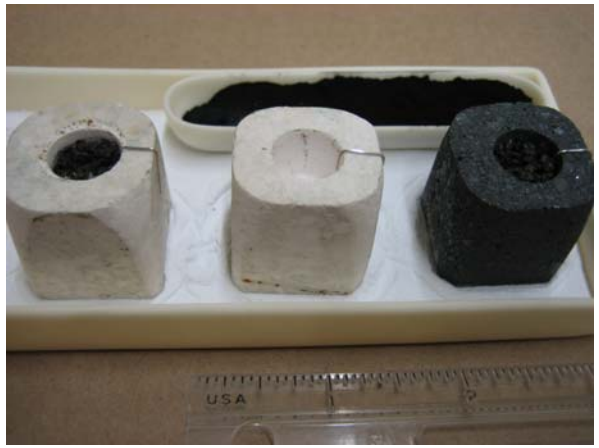


EMF Output – 1500°C, Ar



Thermocouple Wire Sample Exposure Test Conditions

(Preliminary Data)



Exposure Conditions

- **1450°C, 8 Hours hold at temperature**
- **100 % Pt wire**
- **Ultra high purity Ar with C and Ti metal getters**
- **Samples covered with high purity alumina crucible caps and set on high purity alumina setter powder**
- **Test Slag: Coal ash**
- **Test Samples:**
  - 99 % Al_2O_3
  - 90 % Cr_2O_3 - A
  - 90 % Cr_2O_3 - B

Cup – Top View, After Exposure

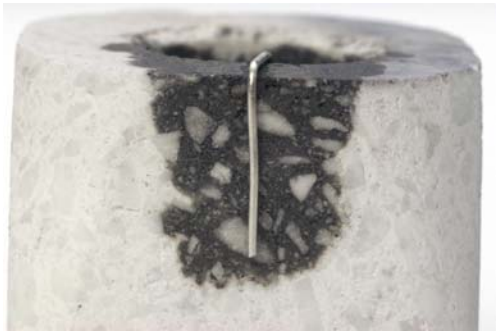
	With Slag	Without Slag
Al_2O_3		
Cr_2O_3 - A		
Cr_2O_3 - B		

Cup – Side View, After Exposure

With Slag

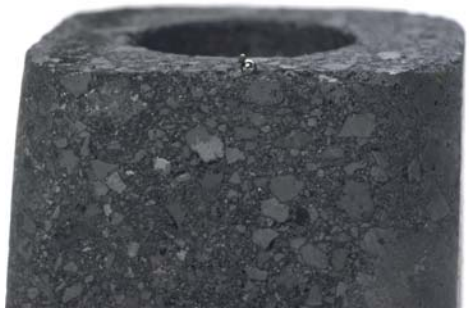
Without Slag

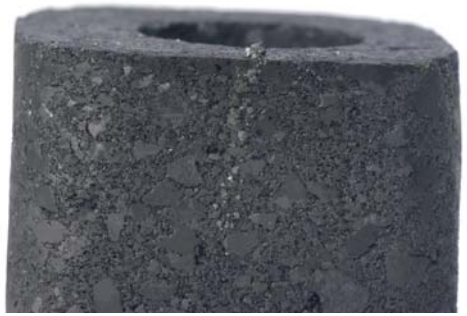
Al_2O_3



Cr_2O_3 - A

Cr_2O_3 - B





Current Research Direction

- **Modifications in traditional thermocouple assembly**
- **New approaches to temperature sensing**
  - Evaluating redesign of thermocouple sensors and how utilized in gasifiers
  - Exploring different approaches to thermocouple assemblies
  - Evaluating different ways to transfer signal information from the gasifier

Conclusions

- Current temperature sensors in gasifiers fail by a number of means (shear, material corrosion, sidewall spalling, contact with slag, ….). Post-mortem analysis difficult/impossible.
- Preliminary thermocouple data indicates contact with slag/refractory/or gasifier environment can lead to thermocouple failure or false temperature readings
- Currently evaluating thermocouple redesign and how thermocouples are used in a gasifier
- Evaluating ways to transfer signal information from the gasifier

ACKNOWLEDGEMENT

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USDOE – NETL; Advanced Research - Materials