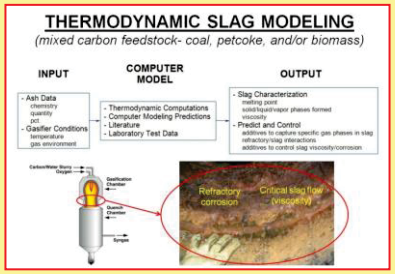
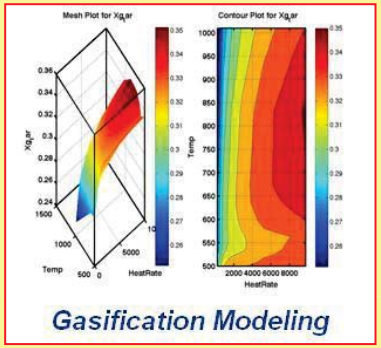
GTC 2013, Colorado Springs, CO – Oct 13-16, 2013

NATIONAL ENERGY TECHNOLOGY LABORATORY





CSC Fouling

Refractory/TC Wear

RSC Fouling

Research Efforts at NETL to Improve Gasifier Performance

James Bennett

National Energy Technology Laboratory – USDOE

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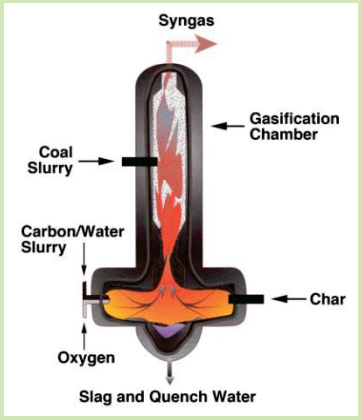
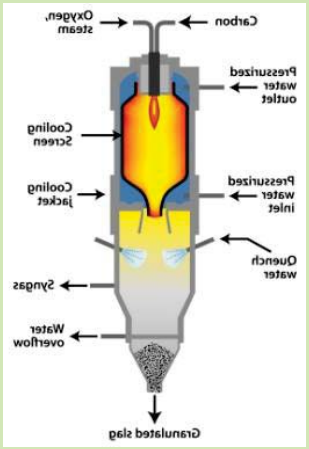
Phone: 541-967-5983

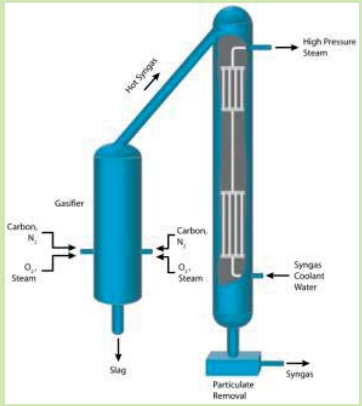
U.S. DEPARTMENT OF ENERGY

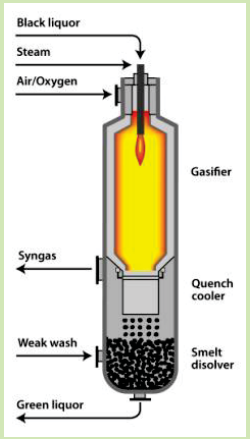


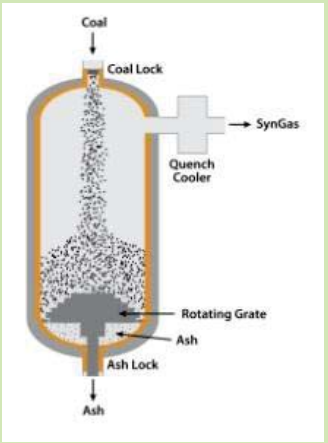


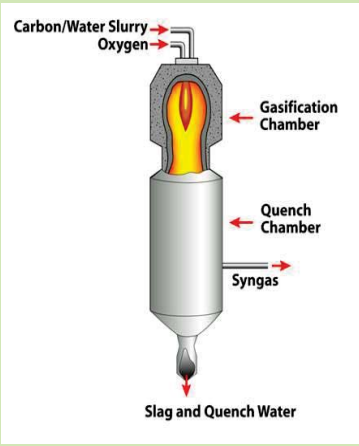
OUTLINE

- Research Objectives
- Program Overview
- Materials Research Focus (Refractories)
  - *Scope of work*
  - *Impact to date*
  - *Long range goals*
- Industrial Involvement
- Summary/Disclaimer







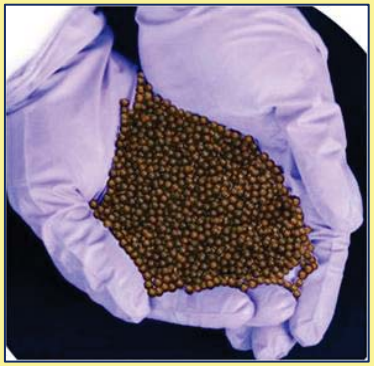


Advanced Gasification

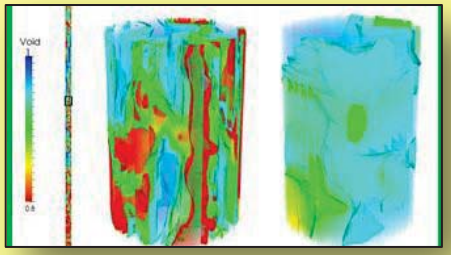
Goals: *increase gasifier efficiency, reduce capital and operational costs, reduce cost of electricity, develop predictive gasifier models, meet/exceed EPA emission targets, and increase carbon feedstock flexibility (including U.S. low rank coals)*

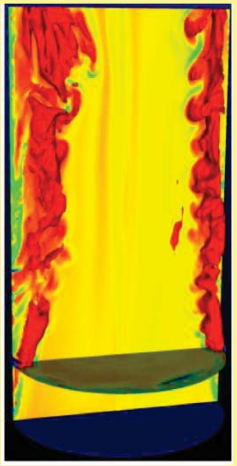
Target*: work with industry to increase gasifier availability by 10 pct*

Program Approach: *1) materials, 2) modeling, and 3) emissions*



C3M™
Carbonaceous Chemistry for Computational Modeling



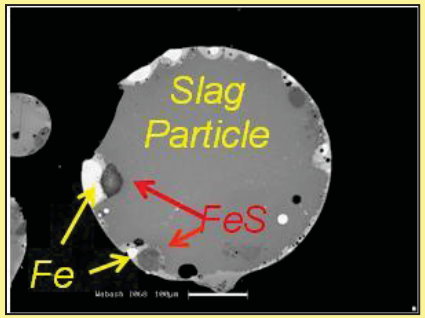


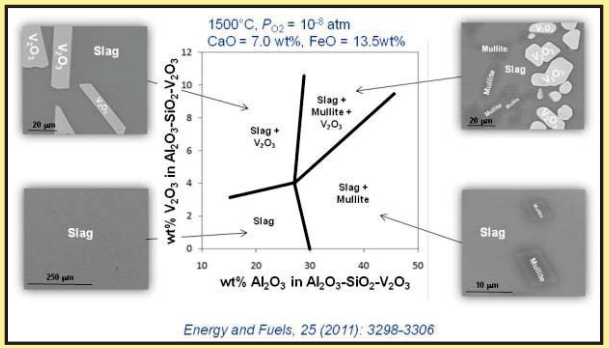
1) Materials

Research Objective: *Improve the performance of existing materials/develop improved performance materials used in gasification systems - with the goal of increasing gasifier reliability, availability, and maintainability (decrease system downtime).*

Ongoing Research:

- *high temperature molten ash phase study/thermodynamic determination*
- *slag management for control of slag viscosity and refractory/slag interactions*
- *study material wear/failure, develop improved performance materials/processes (gasifier liners, thermocouple sensors, syngas coolers)*





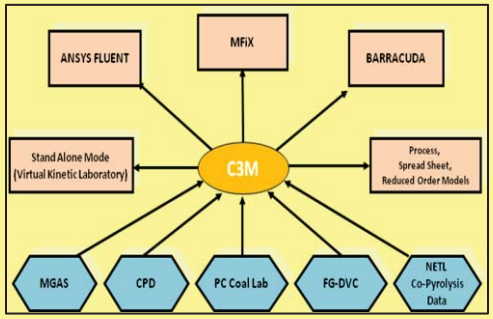
Contact: James Bennett, NETL, james.bennett@netl.doe.gov 541-967-5983

2) Modeling/Simulations

Research Objective: *develop physics-based simulation models for conducting applied research on gasification systems. Models are based on kinetic software and real world data of carbon feedstock gasification.*

Ongoing Research:

- *provide a user friendly, comprehensive interface between reliable sources of kinetic data and reacting, multi-phase CFD models*
- *TARGETS: modeling a gasifier to a high degree of confidence and accuracy, modeling mixed carbon feedstock properties and behavior to assist in feedstock selection, and developing computer software in C3M and MFIX to provide significant insight in feedstock properties.*



MFiX – NETL developed open source software for gasification system prediction ≈ 3100 registered users

MFiX/C3M – available at: https://mfix.netl.doe.gov

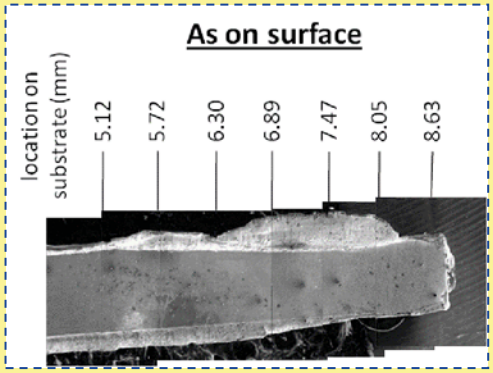
Contact: Bill Rogers, NETL, william.rogers@netl.doe.gov, 304-285-4272

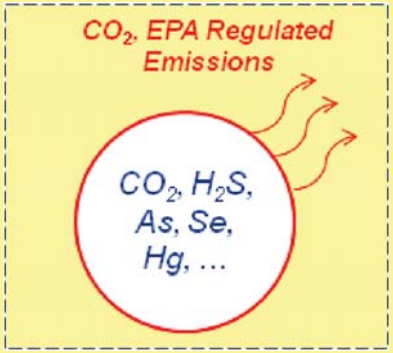
3) Emissions

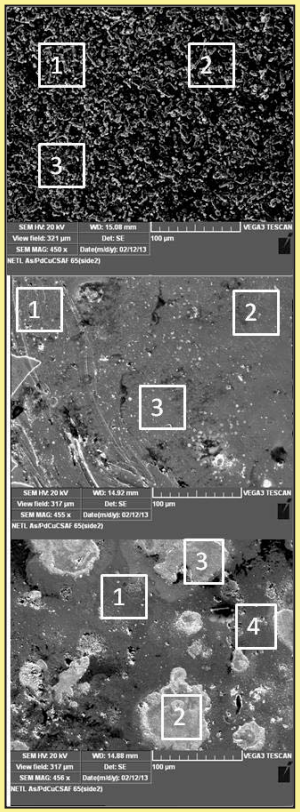
Research Objective: *synthesis gas requires cleaning before use, must meet or exceed EPA regulations associated with toxic emissions from gasification processes by a cost effective process.*

Ongoing Research:

- *field trails evaluated the use of Pd to remove Hg, As, Se, S from warm gases. Evaluating the rate of impurity removal, quantity of material removed, process cost*
- *researching lower cost alternative materials for selective ion removal*

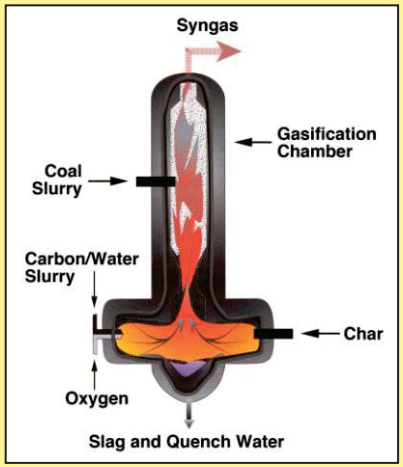


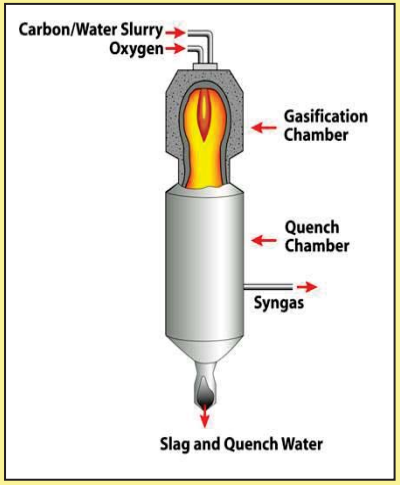




Contact: Evan Granite, NETL, evan.granite@netl.doe.gov 412-386-4607

Objectives - Refractory Material Development

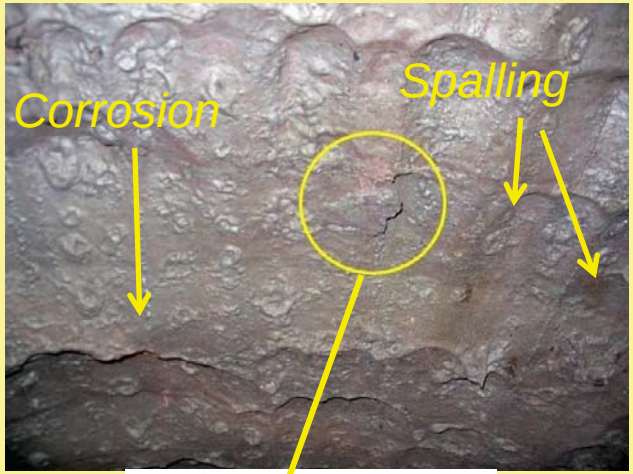


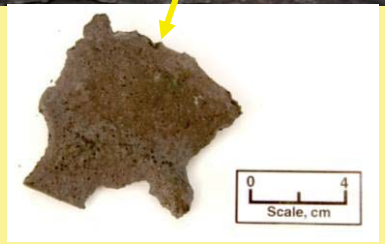


- Develop refractories with improved performance *(longer and predictable service life)*
- Develop refractories that are environmentally friendly and cost effective *(Cr+6)*
- Develop refractories with carbon feedstock flexibility
  - *characterize gasifier slag (chemistry, viscosity, slag phases)*
  - *control slag/refractory interactions and slag viscosity*
- Develop reliable sensors *that accurately monitor gasification temperature*
- Model gasifier slag and refractory wear *(maximize refractory service life, correct slag fluidity, determine additives to control slag properties and refractory wear)*

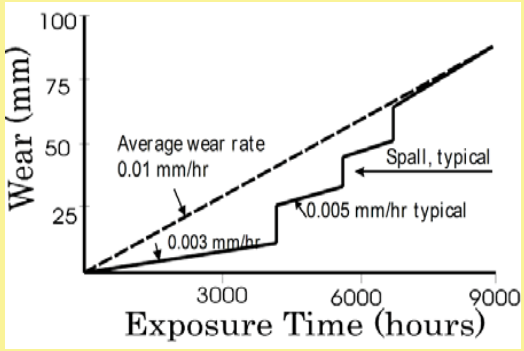
Current Wear Mechanisms

(Corrosion and Spalling – refractory service life = 3-36 months)

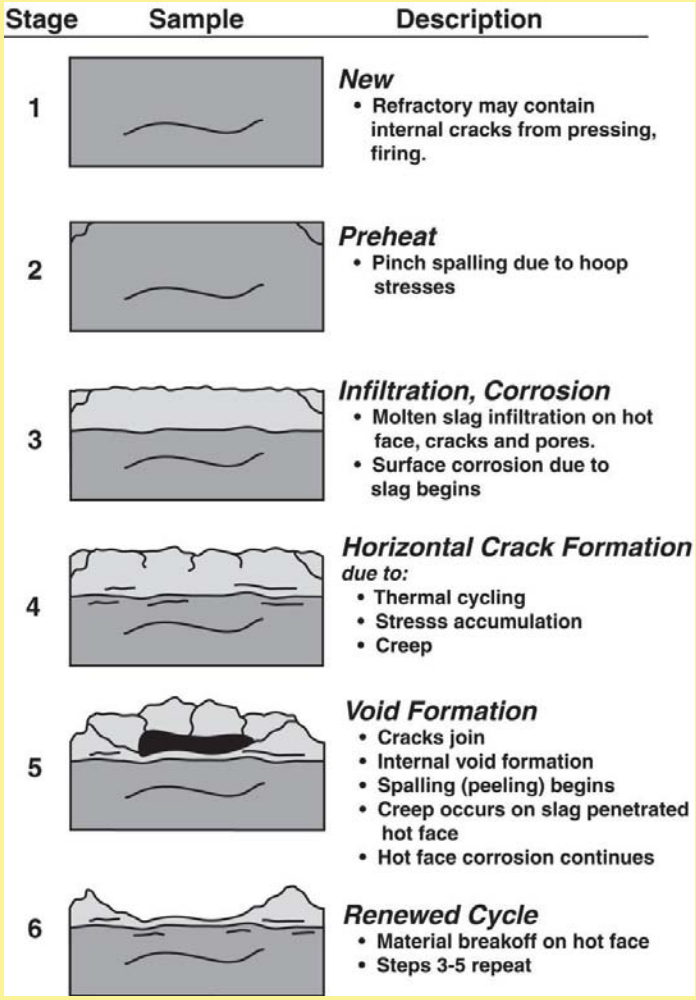




Spalled Material



Impact of Spalling



Repeative Cycle of Spalling

W.T. Bakker, "Refractories for Present and Future Electric Power Plants," Key Engineering Materials, Trans Tech Publications, (1993), Vol. 88, pp. 41-70..

NETL-Refractory Research for Improving the Reliability and Performance of Gasification

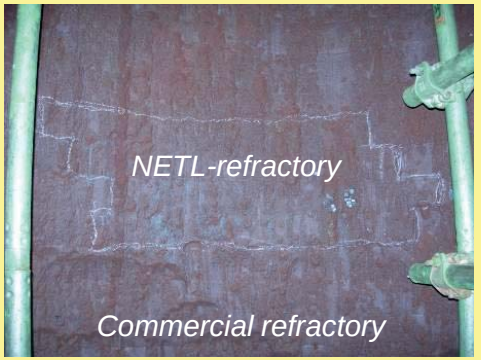
Failure mechanisms Identified

Spent refractory from commercial gasifier

Chromium-Oxide based Composition Developed at NETL

NETL-develops and patents chromium-oxide refractory in laboratory tests resists failure mechanism

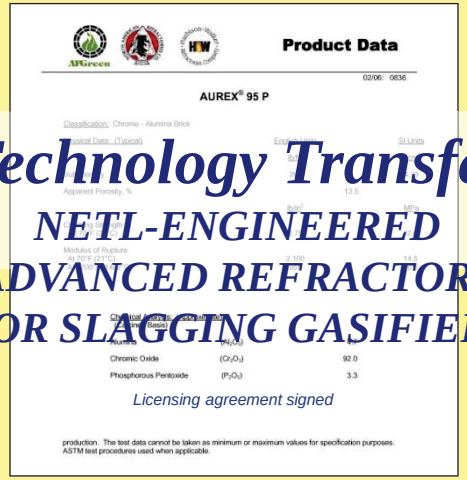
NETL Refractory Scales up for Field Trials in Comm. Gasifiers



Bricks after 237 of operation

Technology Transfer

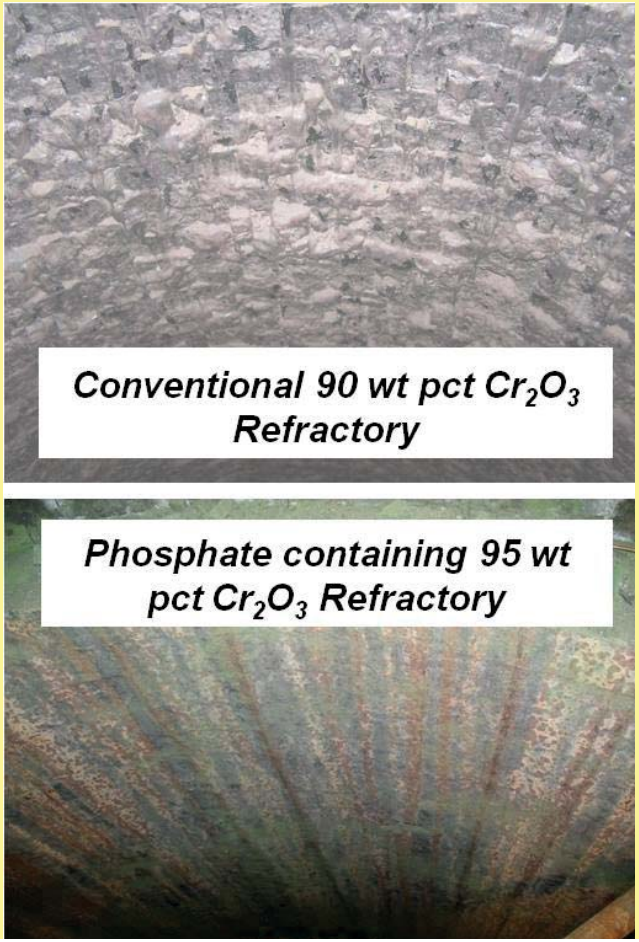
NETL-ENGINEERED ADVANCED REFRACTORY FOR SLAGGING GASIFIERS



Licensing agreement signed

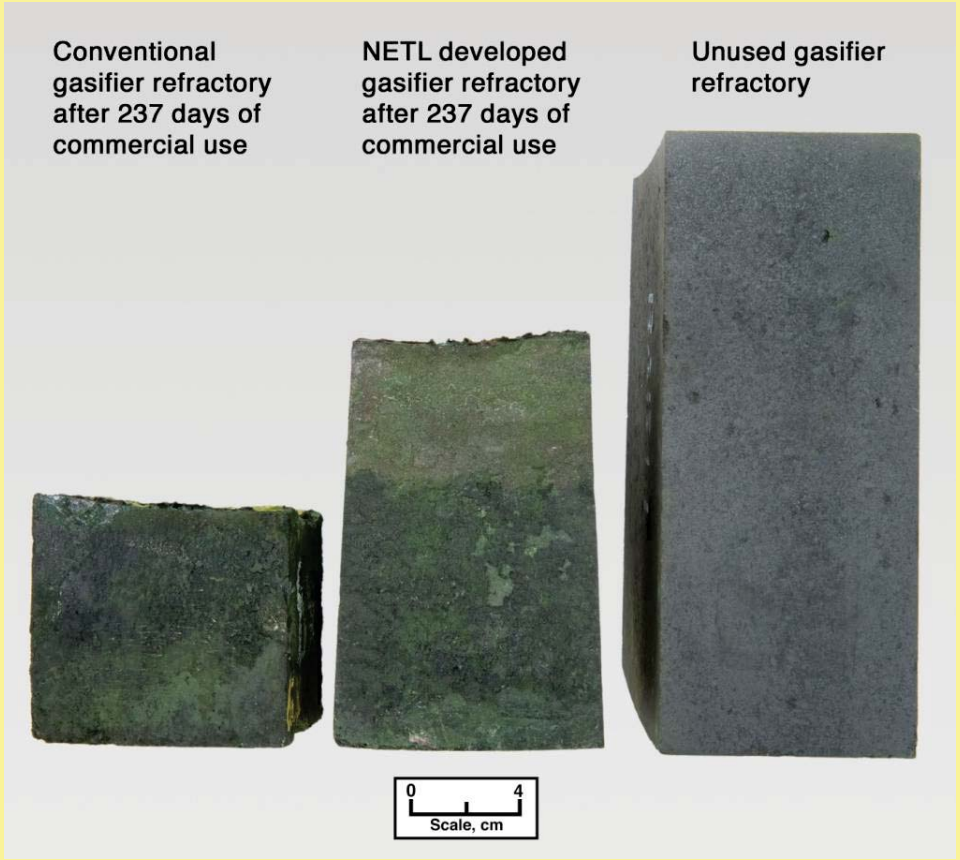
NETL developed phosphate containing high Cr_2O_3 refractory marketed by Harbison and Walker Refractory Co. under the product name Aurex 95P.

Commercial Performance of Phosphate Containing High Cr_2O_3 Refractory



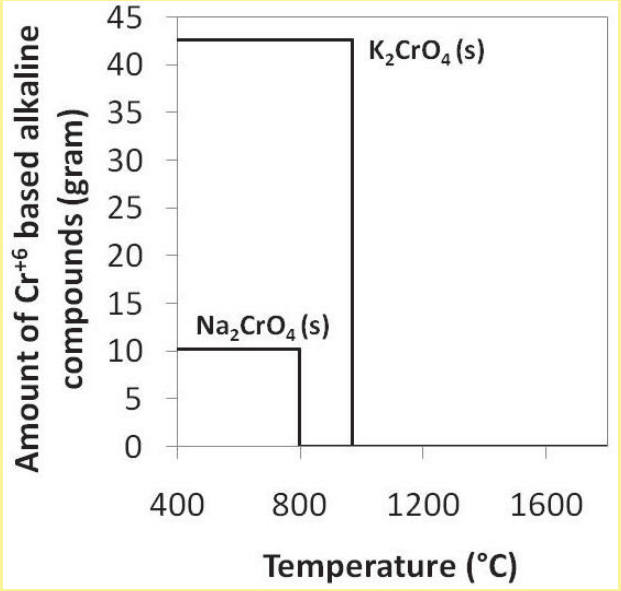
Gasifier Refractory Lining

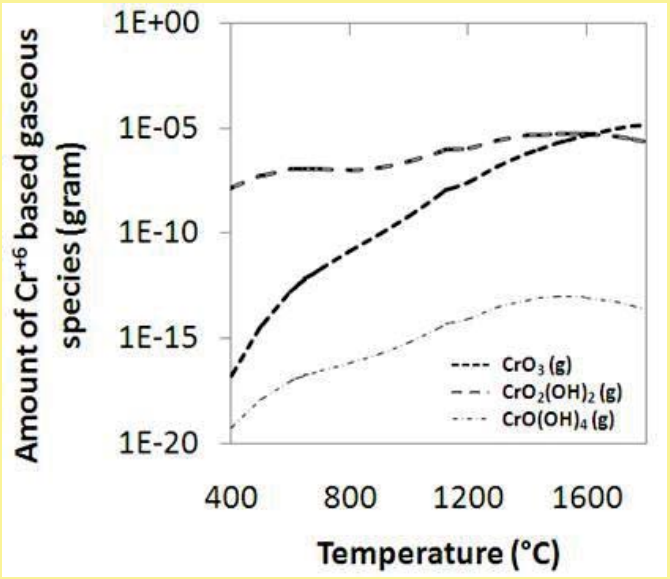
(3 Years Service)



Chrome Oxide Refractory Research (Cr^{+6})

Atmospheric O_2 Partial Pressure

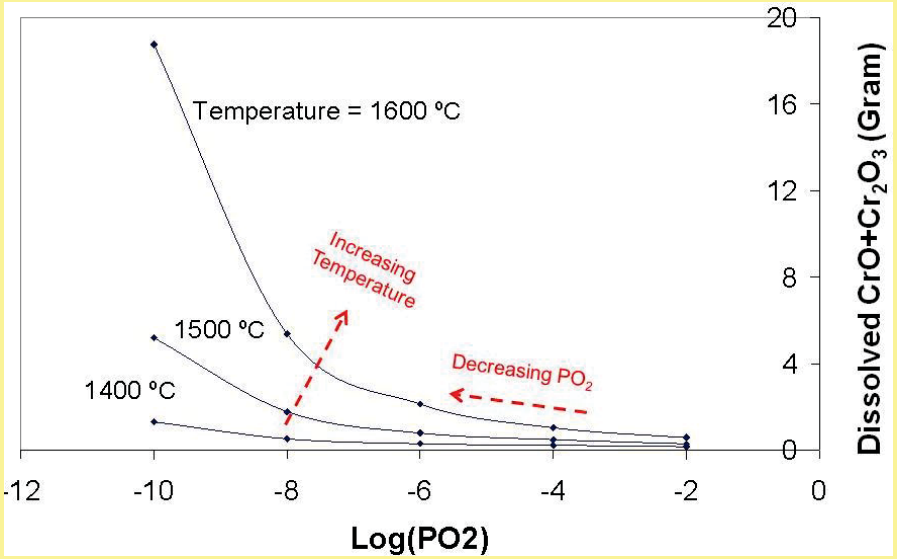




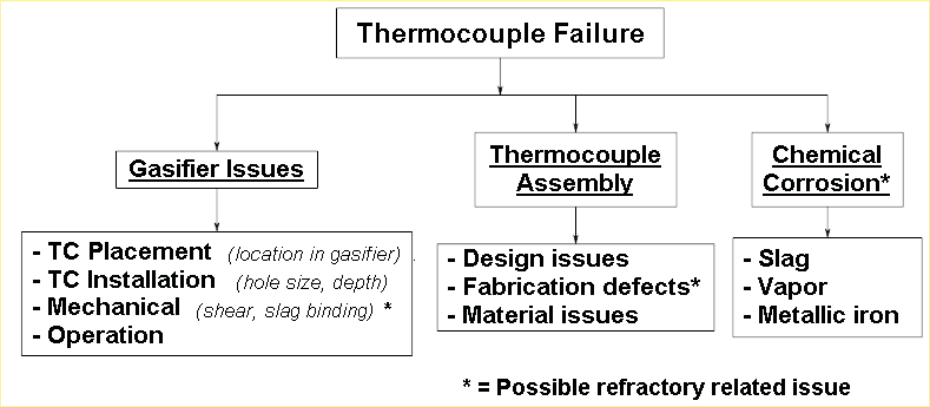
10^{-8} O_2 Partial Pressure (Gasifier Condition)

Cr^{+6} formation not an issue with current carbon feedstock

90 Wt % Cr_2O_3 – 10 wt pct Al_2O_3 // Slag, Temperature, and Oxygen Partial Pressure Interactions



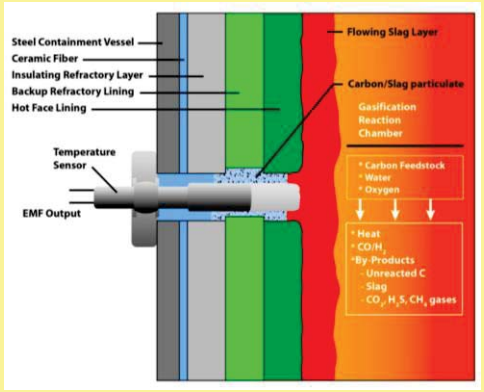
Sensor Research – Refractory Filler



Causes of thermocouple failure

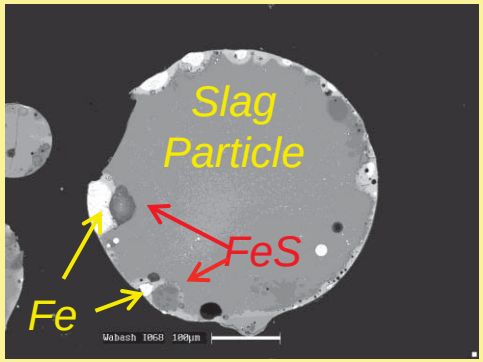
- **Determine causes of failure – evaluate TC assemblies from several gasifier sites.**
- **Evaluating interaction of gasifier environment with thermocouple assembly and components**

Thermocouple shear, slag/refractory corrosion



Thermocouple assembly

Syngas, Slag, Char, and Fe interact with Pt



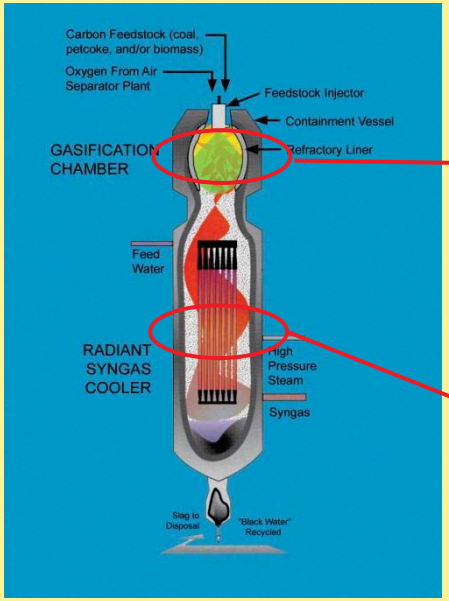
Current Program Emphasis – Slag Management

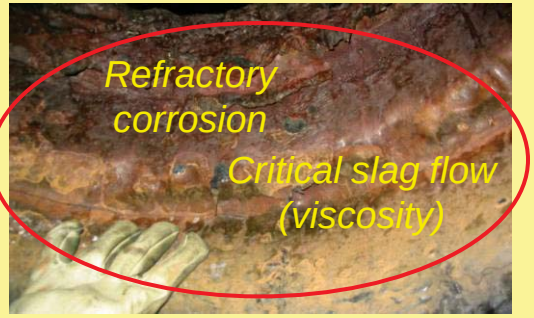
(mixed carbon feedstock- coal, lower grade western coal, petcoke)

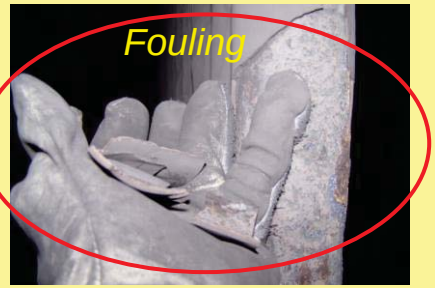
INPUT	COMPUTER MODEL	OUTPUT
- Ash Data chemistry quantity pct. - Gasifier Conditions temperature gas environment	- Thermodynamic Computations - Computer Modeling Predictions - Literature - Laboratory Test Data	- Slag Characterization melting point solid/liquid/vapor phases formed viscosity - Predict and Control additives to capture specific gas phases in slag refractory/slag interactions additives to control slag viscosity/corrosion

GOALS

- ***Primary*** *– control refractory wear and slag flow*
- ***Secondary*** - minimize syngas cooler fouling

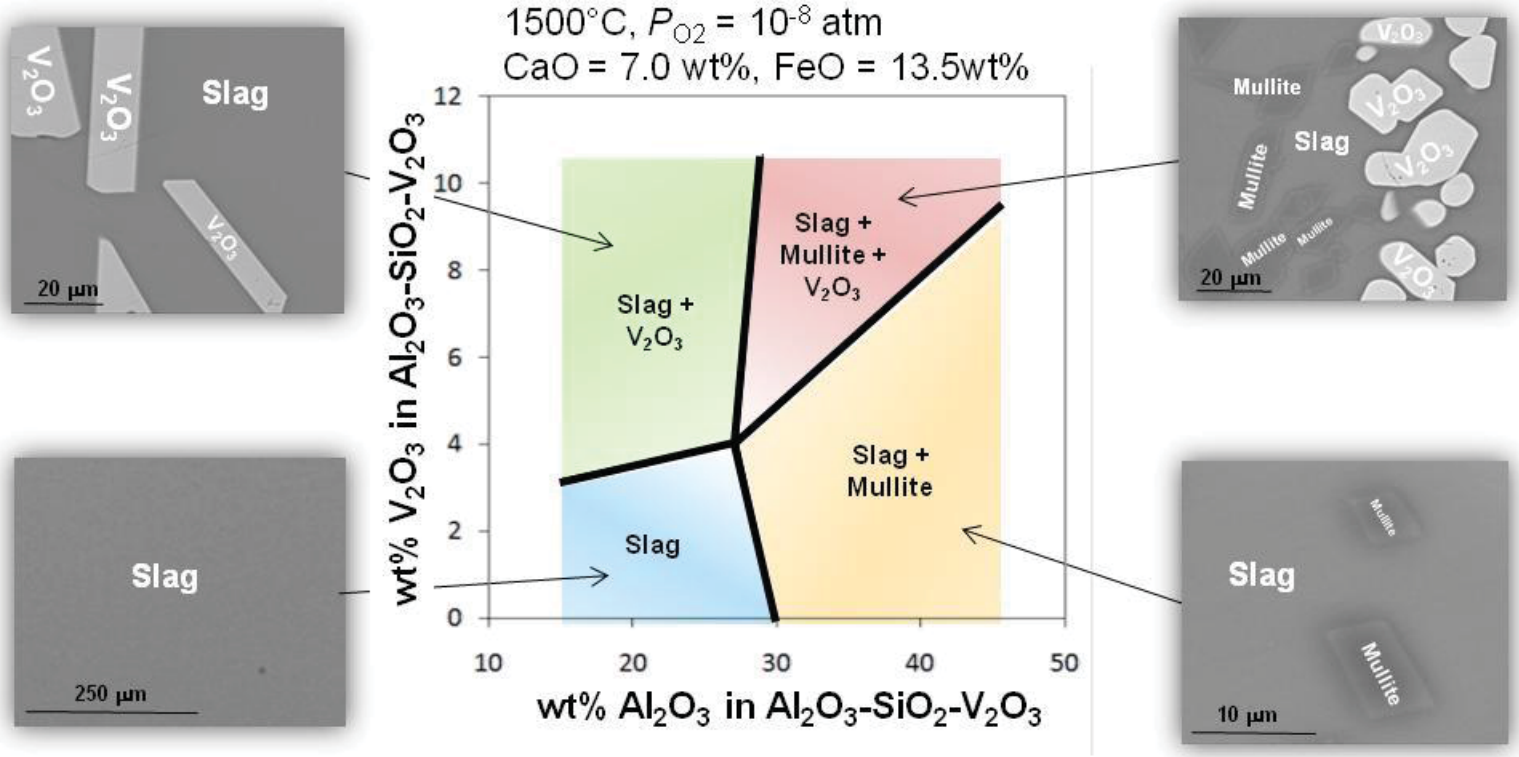






Phase Diagram/Thermodynamic Research

(vanadium oxide phase study)



Energy and Fuels, 25 (2011): 3298-3306

American Ceramic Society Spriggs Award

Slag

- **Impacts gasifiecation temperature**
- **Refractory wear**
- **Lack of vanadium thermo data for predictive modeling**

PARTNERSHIPS/AGREEMENTS

(Refractory Program)

- **NDA's – 2 gasifier sites**
- **Confidentiality – one gasifier site**
- **Academia – CMU, WVU, McGill Univ. Penn State, University of Tokyo, Chiba Institute of Technology**
- **Commercial – FactSage™, ExxonMobile, BP**
- **Government Agencies – CanmetENERGY, Canadian Light Source**

Industrial cooperation in all aspects of the Advanced Gasification Program is encouraged and welcomed. Confidentiality agreements, cooperative research and development agreements, non-disclosure agreements, or other forms of joint research can be arranged.

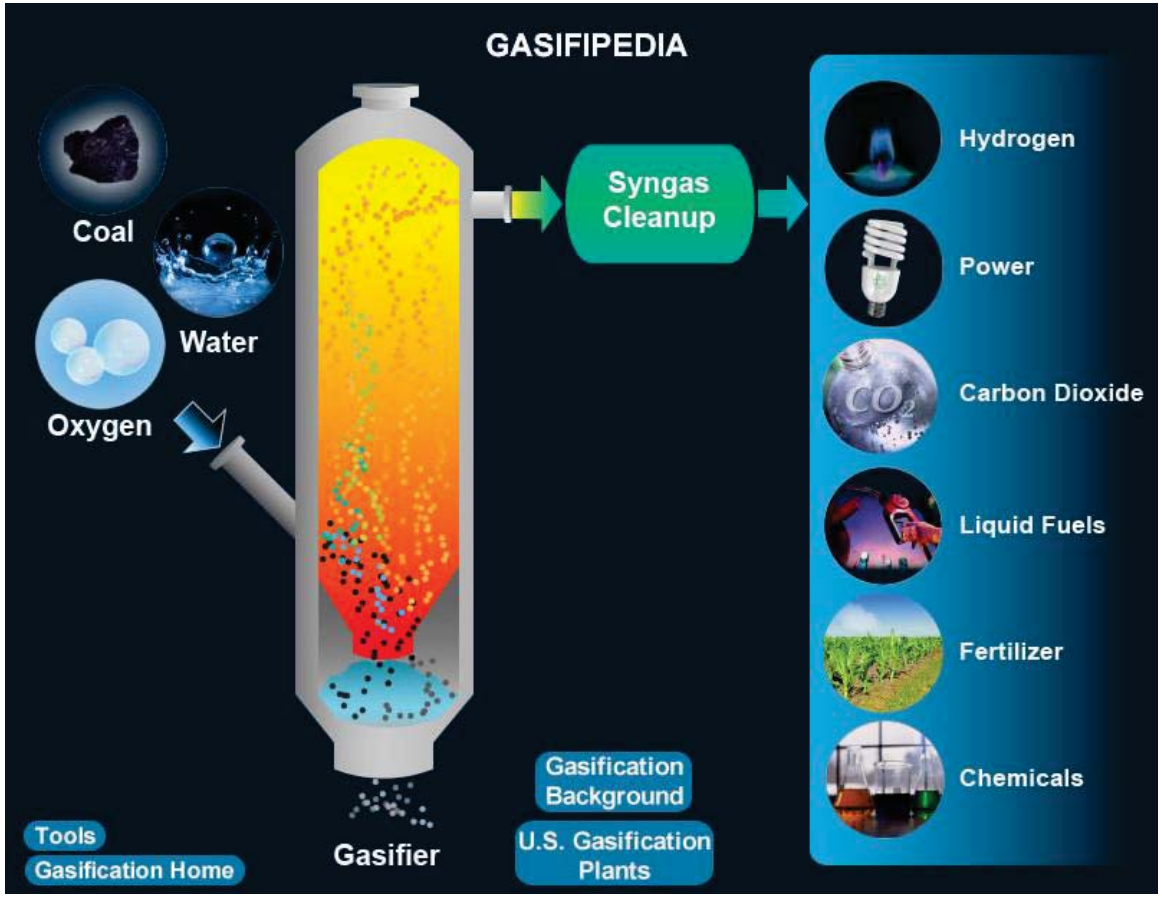
Summary

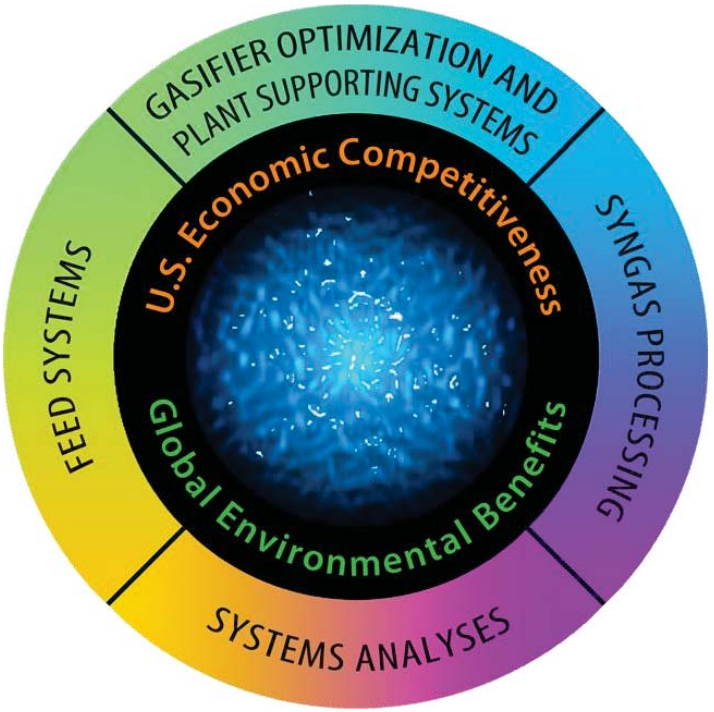
- Overview given of the Advanced Gasification Research Program within NETL related to
  - materials
  - modeling
  - emissions
- Refractory research success and future direction described (liner material development, sensor protection, and slag modeling for wear and corrosion, Cr+6)
- Industrial involvement welcomed – need for more producers/users in program research
- Contact information: James Bennett; National Energy Technology Laboratory; james.bennett@netl.doe.gov; 541-967-5983

Visit NETL Gasification Website

www.netl.doe.gov/gasification-portal.html

Google the term "Gasifipedia"





DISCLAIMER: