# AN UPDATE ON FIELD TEST RESULTS FOR AN ENGINEERED REFRACTORY FOR SLAGGING GASIFIERS

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## ABSTRACT

The widespread commercial adaptation of slagging gasifier technology to produce power, fuel, and/or chemicals from coal will depend in large measure on the technology's ability to prove itself both economic and reliable. Improvements in gasifier reliability, availability, and maintainability will in part depend on the development of improved performance structural materials with longer service life in this application. Current generation refractory materials used to line the air-cooled, slagging gasifier vessel, and contain the gasification reaction, often last no more than three to 18 months in commercial applications. The downtime required for tear-out and replacement of these critical materials contributes to gasifier on-line availabilities that fall short of targeted goals. In this talk we will discuss the development of an improved refractory material engineered by the NETL for longer service life in this application, and provide an update on recent field test results.

## INTRODUCTION

Gasification is one of several technologies expected to see increased utilization in the Advanced Fossil Fuel Power Systems of the future; however, while the technology has proven itself to be an efficient and relatively clean way to produce electricity, liquid fuels, and chemicals, questions still remain regarding the level of reliability, availability, and maintainability that can be obtained in existing commercial systems. For air-cooled, slagging, gasifiers, the lack of reliable and affordable structural materials that can effectively contain the gasification reaction for long periods of continuous operation is a source of some of these questions. The harshest operating conditions within the gasifier island occur inside the gasifier itself, where the environment includes elevated temperature and pressure, as well as the presence of corrosive slags and gases. Attempts to enhance gasifier output and economics by operating at higher temperatures, with higher throughputs, and/or with variable feedstocks, put additional stresses on the materials exposed to the operating environment, and typically result in a corresponding decrease in their useful service life. Because of the extreme operating conditions, research has shown that refractory ceramic materials, consisting primarily of chromium oxide, are the only workable option for lining an air-cooled, slagging coal gasifier [1-7]. Current generation high chromium-oxide refractories typically last between three and 18 months at the hotface of the gasifier, depending on the operating conditions of the specific system. As gasification technology matures, the need for new and improved refractory materials will increase as the time between required maintenance shutdowns, and hence the economics and reliability of operation, are defined more and more by the service life of the materials from which the system is built. To address this need for improved materials, the National Energy Technology Laboratory has developed and patented a phosphate-modified chromium oxide refractory designed specifically for longer service life in air-cooled, slagging coal gasifiers [8], and adapted the material for commercial production in collaboration with Harbison-Walker Refractories Company. In this paper, we discuss the development of this material, and present the results of a recent 14-month field trial of the refractory in a commercial coal gasifier.

## DEVELOPMENT OF AN IMPROVED REFRACTORY

Materials performance in any application is defined by the inherent ability of the material to withstand the physical conditions created by the operating environment, combined with its ability to withstand the specific stresses imposed by the design and operation of the system. This concept is outlined specifically for refractory materials in air-cooled, slagging gasifiers in Figure 1. Conversations with gasifier manufacturers and operators about their experience, combined with extensive laboratory studies of refractories removed from commercial slagging gasifiers, indicate that while all of these pathways

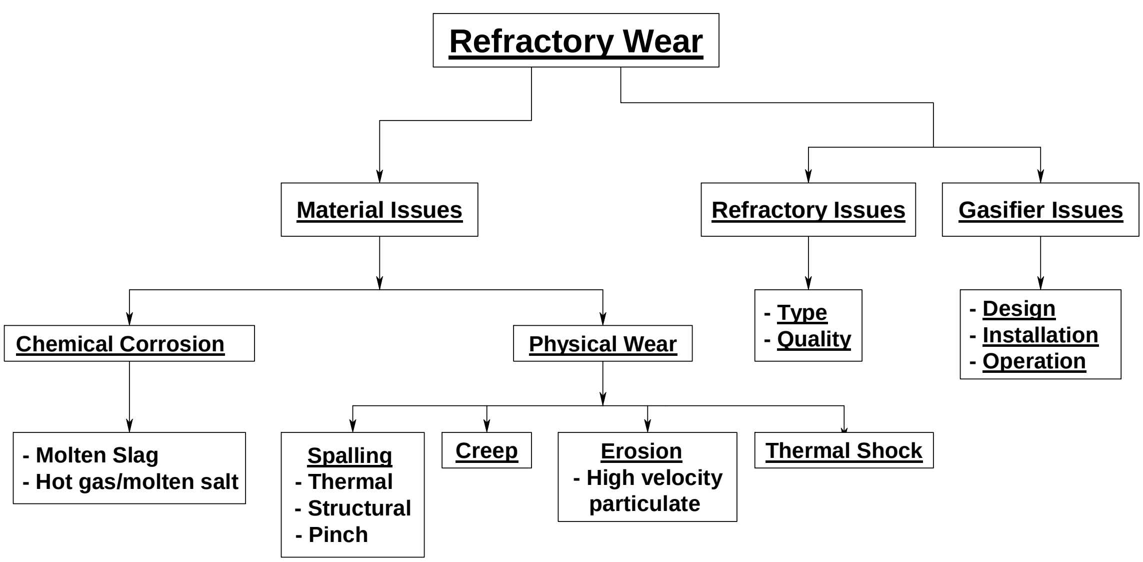


**Figure 1. Potential refractory wear mechanisms in an air-cooled, slagging gasifier.**

can contribute to material loss, the key to designing an improved performance refractory lies in reducing the potential for chemical corrosion (dissolution in the flowing slag) and spalling (physical removal of large chunks of material). Thus the goal in designing an improved refractory for this application should be to engineer a material with a stronger bond that can better resist slag attack and fracture.

Adopting this thesis, scientists at NETL developed a phosphate-modified high chromium oxide refractory material that proved to be more resistant to slag penetration and attack in initial laboratory exposure tests, when compared with refractory materials currently used by the gasifier industry [9-12]. In collaboration with Harbison-Walker Refractories Company, NETL expanded laboratory testing of its refractory to further prove the concept. The more aggressive rotary slag exposure tests also predicted improved performance by the NETL-developed brick, as illustrated in Figures 2. Post-test evaluation of the refractory materials indicated little or no cracking in the NETL material during exposure to slag and temperature in the rotary kiln (Figure 2-top), as compared to extensive fracture in the commercial material (Figure 2-bottom). Slag penetration was also minimized in the NETL material, to less than 20% that observed in commercial refractories. Tests of the physical and thermal properties of the NETL-developed refractory showed comparable, or in many cases superior, properties when compared to several commercially-available high chromium oxide refractory materials. Collected together, these promising laboratory test results indicated that the NETL refractory was ready for field trials in a full-sized slagging gasifier.

**Figure 2. NETL-developed refractory (top) and commercial refractory (bottom) following exposure in the rotary slag test.**

## FIELD TEST RESULTS

A test lot of 24 of the NETL-developed refractory brick were produced for field trial by Harbison-Walker at its Vandialia, MO, production facility, and installed in the sidewall hotface of a commercial slagging coal gasifier in November, 2004. Pictures of the brick as they arrived at the facility, and during installation in the gasifier, are found in Figures 3. Installation of the test panel was in conjunction with a full hot-face refractory reline of the gasifier. Following completion of the refractory installation and other gasifier-island repairs, the gasifier was put into stand-by mode at elevated temperature, but with no slag flowing, to await service.

**Figure 3. Installation of refractory test panel: arriving at the site (top), and during installation in the side wall of the gasifier (bottom). Test refractory are marked with red dots.**

Over the course of the subsequent 14 months, the refractory test panel was exposed to 237 equivalent days of service (5688 hours) at a gasifier operating temperature of at least 1350º C, and with a feed rate of approximately 1200 tons of bituminous coal per day. The gasifier was cycled to room temperature on several occasions during this time period, providing opportunity to examine the test panel for relative performance compared to other refractories in the gasfier. In addition, regular thermal imaging of the gasifier shell insured that premature refractory failure was not causing problems with the system. Throughout the 14 months, there was no indication of any issues with the test panel, and visual inspections continued to indicate that the test refractory was performing as well, or better, than its commercial counterparts. Removal of the test refractory panel occurred early in 2006, during a scheduled maintenance shutdown of the gasifier. Again, visual inspection of the test panel prior to removal from the gasifier suggested that the NETL-developed refractory out-performed the surrounding commercially-available brick, with less spalling-induced material loss (Figure 4).

A full *post-mortem* evaluation of the test brick has not yet been completed; however, initial results confirm *in-situ* observations that the NETL-developed refractory outperforms its commercial counterparts in this application. A side-by-side comparison of the test brick with a commercial high-chromia brick removed from a similar location in the gasifier indicates less material loss over the 14-month service period (Figure 5). Examination of the cross sections of these brick shows far less subsurface fracture in the test brick, suggesting better thermal shock resistance, as well as a better ability to withstand changes induced in the refractory as a result of slag attack. How much of a service life extension the NETL-developed refractory will provide the gasifier operator, and its versatility in terms of fuel tolerance, will be better understood when additional field trials are concluded later this year and next, and when the subsequent *post-mortem* evaluations are completed.

**Figure 4. Refractory test panel (approximately outlined with chalk) prior to tear-out following 14 months of service.**

## SUMMARY

A phosphate-modified, high chromium oxide refractory engineered for longer service life in air-cooled, slagging gasifiers has been developed by the NETL and adapted for commercial production in collaboration with Harbison-Walker Refractories Company. A recently-concluded 14-month field trial of the brick in the sidewall of a commercial, coal-fed slagging gasifier confirms that the NETL refractory can outperform its commercial

counterparts in this application. Additional field trials of this material are in process and planned, which should confirm its performance in this application, as well as its versatility in terms of fuel flexibility.


**Figure 5. Refractory brick following 14-months in service in a coal-fired slagging gasifier. The NETL-developed refractory, on the right, has clearly experienced less material loss during service (original dimensions were identical in the two brick).**

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## REFERENCES

[1] Bonar, J.A., Kennedy, C.R., and Swaroop, R.B., *Am. Ceram. Soc. Bull.* **59** 473-478 (1980).

[2] Bakker, W.T., Darling, S.L., and Coons, W.C., *Am. Ceram. Soc. Bull.* **62** 1359-1363 (1983).

[3] Bakker, W.T., *Key Engineering Materials* **88** 41-70 (1993).

[4] Fahrion, M.E., *Materials at High Temperatures* **11** 107-112 (1993).

[5] Bakker, W.T., *EPRI Report TR-110507*, Palo Alto, CA.(1999).

[6] Guo, Z-Q, Han, B-Q, and Dong, H, *Ceramics International* **23** 489-496 (1997).

[7] Guo, Z-Q and Zhang, H., *J. European Ceramic Soc.* **19** 113-117 (1999).

[8] Kwong, K-S, Powell, C.A., Bennett, J.P., Chinn, R.E., and Petty, A.V., "Use of Phosphates to Reduce Slag Penetration in $Cr_2O_3$-based Refractories," U.S. Patent # 6,815,386 (2004).

[9] Dogan, C.P, Kwong, K-S, Bennett, J.P., and Chinn, R.E., *Proceedings from the 18th International Pittsburgh Coal Conference*, Newcastle, New South Wales, Australia, 2001.

[10] Dogan, C.P., Kwong, K-S, Bennett, J.P., Chinn, R.E., and Dahlin, C.L., *Proceedings of the Gasification Technologies 2002 Conference*, San Francisco, CA, October, 2002.

[11] Powell, C.A., Kwong, K-S, Bennett, J.P., Chinn, R.E., and Krabbe, E., in *Proceedings from the 29th International Technical Conference on Coal Utilization and Fuel Systems*, Clearwater, FL (2004).

[12] Bennett, J.P., Kwong, K-S., Powell, C.A., Thomas, H., and Krabbe, E., *Proceedings from the 9th Bienneial Unified International Technical Conference on Refractories*, Orlando, FL (2005).