ABSTRACT

Coal preparation is one of several applications where high-chlorine coal causes corrosion problems. The most straightforward approach to solving such problems is to upgrade materials of construction. The objective of this project was to evaluate two ideas for improving the durability of materials used in piping, chutes, screening equipment, and other materials of construction. One was to evaluate alloys like cupronickels which are known to perform well in high chloride marine applications. The second idea was to cathodically protect wear resistant alloys like Hadfield steel to withstand the effects of corrosion and erosion in coal slurry piping.

The first series of tests was conducted in process water, make-up water, and the atmosphere at Freeman United and Arch of Illinois coal preparation plants. Two cupronickel alloys performed much better than 1018 carbon steel, but not as well as 304 stainless steel. No evidence for pitting attack on 304 specimens was observed, and it offers the best compromise between cost and performance of the alloys tested.

The second series of tests was conducted in a coal slurry line at the Arch of Illinois plant. Success was achieved in cathodically protecting a specialty cast iron and Hadfield steel against the combined effects of corrosion and erosion. The cathodically protected, specialty cast iron had the lowest metal wastage rate of all the materials tested. An unprotected specialty stainless steel, AL6X-N, also performed well.
EXECUTIVE SUMMARY

Last year, an assessment was made of the number and severity of corrosion problems attributed to chlorine in the processing and utilization of Illinois coal. This year's project addressed the problems identified in coal preparation plants which process coal containing more than 0.2% Cl. The objective was to evaluate materials and methods which could lead to cost-effective solutions to corrosion and corrosion-erosion problems now being faced. In-plant tests were conducted to measure the corrosion rates of alloys known to perform well in high chloride marine environments. Examples are cupronickel alloys and a new type of stainless steel developed specifically for marine applications.

A second approach was taken for materials which must withstand the severe conditions of chloride corrosion in combination with coal slurry erosion. Hard, wear-resistant alloys, such as special grades of cast iron and Hadfield steel, were cathodically protected by connecting specimens to low voltage DC power supplies.

After exposure, metal wastage in the test specimens was determined from weight and dimensional changes. The structure and composition of corrosion product layers on the materials were determined by microscopic observations, Auger spectroscopy, and other characterization methods.

The first set of tests was completed in December at two coal preparation plants. One plant serves Freeman United Orient No.6 mine and processes coal containing approximately 0.4% Cl. The other plant serves the Arch of Illinois Captain Mine, where the coal contains only 0.04% Cl. The chlorine concentrations in the process water at the plants are 1400 versus 100 ppm. Metal wastage rates for the test specimens were determined after chemically removing corrosion products from their surfaces. The results showed that the two cupronickel alloys corroded much slower than 1018 steel but more rapidly than 304 stainless steel. No evidence of pitting attack on 304 specimens was found, and at present metals prices, 304 is not as expensive as cupronickel alloys. Therefore, 304 stainless steel offers the best compromise between cost and performance of the alloys evaluated in this set of tests.

The surprising result was that, without exception, the metal wastage rates were higher at the plant which processes low chlorine coal. This result proves that another factor or factors other than chlorine content have a dominant effect on corrosion rates. Follow-on laboratory experiments have been planned to obtain a better understanding of water chemistry effects. One possible explanation for the observed results lies in an oxygen solubility effect, and another lies in a passivating effect of sulfate ions in the process water.

The second series of tests consisted in evaluating another series of alloys in a coal slurry refuse line at the Arch of Illinois plant. The solids content of the water was approximately 25 percent, so the combined corrosion-erosion environment was severe. Two alloys with very good wear properties but fair to poor corrosion resistance were cathodically protected against corrosion (a specialty cast iron and Hadfield steel). A factor of 10 to 30 improvement in metal wastage was
realized with the cathodically protected specimens. The performance of the specialty cast iron was exceptionally good, the best of all the alloys tested. An unprotected, specialty stainless steel alloy (AL6X-N) also performed well. These data are the first obtained on this alloy in an erosion environment.

Two presentations on this year's project will be given at the Annual Meeting of the American Institute of Mining, Metallurgical and Petroleum Engineers (AIME) in Anaheim, CA in February 1990. A paper based on the study completed a year ago and entitled "A Review of Chlorine-Induced Corrosion in Underground Mines and Coal Preparation Plants" will appear soon in *Fuel Processing Technology*. 
OBJECTIVES

The general objective of the project was to obtain data from in-plant tests in two coal preparation plants for identifying better materials and methods for solving chlorine-induced corrosion problems. During the current year, coupons of various alloys were evaluated in three plant environments: (1) process water with little or no suspended coal, (2) coal-water slurries, and (3) areas in the plants where the air is extremely humid. The types of alloys evaluated were believed to show promise either because they are known to perform well under high chloride marine conditions, or because cathodic protection is expected to provide good resistance to conditions for which synergistic corrosion and erosion damage occurs.

INTRODUCTION AND BACKGROUND

For decades, corrosion under high chloride conditions has provided challenges to engineers and materials specialists in virtually all applications where the conditions exist. Last year, an assessment was conducted by our project team of the types and severity of chlorine-induced corrosion experienced in coal mining, processing, and utilization. One of the conclusions of the study was that coal containing more than approximately 0.2% chlorine causes unacceptably high rates of corrosion in coal preparation, flue gas desulfurization, and coke-making plants. The same may be true in fluidized bed combustion of high-chlorine coal, but data available at present are inadequate for drawing a reliable conclusion.

There are several approaches that can be taken to alleviate chlorine-induced corrosion problems. These include: (1) upgrading of materials of construction, (2) cathodic protection, (3) redesign of processes and equipment, and (4) dechlorination of the coal. Upgrading of materials of construction is the most common approach to solving corrosion problems, and industry is favoring this approach for existing problems. Ordinary steels are being replaced with specialty steels, plastics, and ceramics to resist general corrosion and the combined effects of corrosion by chlorides and erosion by coal slurries. All such substitutions involve higher materials cost, but hopefully lower maintenance costs and operating down time. While these materials upgrading steps seem to be resulting in improvements, experience to date is limited; and there are still some plant areas and processing conditions for which it is not clear what structural materials should be used.

For this project, it was decided to focus attention on corrosion and corrosion/erosion problems in coal preparation plants. In last year's assessment, two ideas evolved which are now being investigated. One is to evaluate alloys which are known to perform well in marine applica- tions where the chloride concentration is even higher than in coal processing. The second idea is to investigate the feasibility of using cathodic protection of moderately priced steels and cast iron. Cathodic protection is a proven technology used for minimizing corrosion in natural gas pipelines, oil drilling equipment, and ships. Encouragement and good cooperation from coal companies was received in conducting the tests described in the following sections.