# CORROSION MITIGATION AT THE GEYSERS

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## KEY WORDS

corrosion protection, polymers, composites, pre-ceramics, piping, well casing, cooling towers, acid condensate

## PROJECT BACKGROUND AND STATUS

Corrosion problems at The Geysers have increased as steam pressures decline. These have contributed to decreases in electric power generation, increased operating costs, and safety and environmental concerns. In FY 1990, BNL initiated cost-shared work with geothermal companies active at The Geysers which focuses on low cost solutions to these difficult materials problems. The R&D approach is to select and then optimize previously developed and, in some cases industrially utilized, organic and inorganic polymer formulations for specific end-use applications at The Geysers. The identification of needs, performance of prototype and full-scale field evaluations, and subsequent economic studies are performed as cost-shared activities with firms active at The Geysers.

As of October 1995, a series of field tests of coating systems for well casing had been completed with the Central California Power Agency (CCPA), and evaluations of pipeline and dry cooling tower coatings were ongoing with the Northern California Power Agency (NCPA) and Pacific Gas and Electric (PG&E), respectively. In addition, laboratory work directed towards other components, such as rotor housings, was underway.

## PROJECT OBJECTIVES

Increased HCl concentrations in the steam condensate produced from geothermal wells in some portions of The Geysers have resulted in severe corrosion problems in the upper regions of the well casing where condensation may occur, in steam collection piping, and on turbine blades and rotors. Geothermal fields in other countries have reported HCl production after many years of operation, and it is expected that HCl will cause problems in other U.S. fields. In addition, before dry cooling towers can economically be used as a means of conserving water needed for reinjection, low cost corrosion protective systems for use on structural components must be identified. Solving these materials problems is the objective of this project.

*Technical Objectives*

- Decrease the operating costs of steam production, transmission and utilization at The Geysers by the identification and subsequent demonstration of low cost materials of construction which will withstand the highly corrosive acidic environments being encountered in some areas of the geothermal field.

*Expected Outcomes*

Attainment of the project objectives will result in the following:

- Wells that presently cannot be operated due to excessive maintenance costs or environmental/safety concerns may be restarted.
- Service life expectancies of fluid production, transmission and electric generation components will be increased.
- Cost-effective methods for water conservation will be available, thereby resulting in reservoir life extensions due to increased fluid reinjection.

## APPROACH

The approach is to optimize polymer, polymer cement composite and pre-ceramic formulations, previously developed under Geothermal Division sponsorship, for specific end-use applications at The Geysers. The identification of needs, performance of prototype and full-scale field evaluations, and subsequent economic studies are performed as cost-shared activities with firms active at The Geysers.

The Project consists of three phases:

Phase 1 consists of the identification of specific materials problems, elucidation of the fluid environments, and the selection of candidate materials systems. Laboratory testing under simulated process conditions is then conducted to establish technical feasibility. Based upon these results, modifications to the systems are made to maximize corrosion resistance.

Phase 2 consists of small-scale field testing, and contingent upon the results, prototype component testing.

Phase 3 consists of design studies to incorporate the technology into components, cost estimates, documentation, and the identification of potential commercial suppliers of the new technology.

## RESEARCH RESULTS

Laboratory and field testing efforts being performed as cost-shared activities with geothermal companies active at The Geysers were continued. Current industrial participants are the Pacific Gas and Electric Company (PG&E) and the Northern California Power Agency (NCPA). Of interest to PG&E are corrosion protective coatings for turbine components, and dry cooling towers. Polymer-matrix composite-lined steam transmission piping tees are being evaluated for NCPA. Details of these activities are summarized below.

### *Turbine Components*

Flame spray-applied coatings on five metal substrates of compositions representing those currently used in turbines by PG&E at The Geysers are being evaluated. Components of interest are wheel pieces, buckets, diaphragm bodies and diaphragm partitions. New materials and specimens cut from parts removed from turbines used at The Geysers are included in the test matrix. Data from the latter will yield insight regarding the performance that may be expected when coatings are field applied to the components during routine maintenance operations.

Work to evaluate flame spray variables for polyphenylene sulfide (PPS) and other high temperature polymeric coatings is being conducted as part of a cost-shared effort with the Materials Sciences Department at The State University of New York at Stony Brook. Experiments to determine the optimum PPS particle size for spraying and to evaluate application techniques are underway. The work to date has shown that PPS can be sprayed with a butane torch, flame spray torch, and plasma. Parameters such as substrate preheat temperature, flame temperature and particle size are being evaluated. Based on the results obtained, it appears that high quality coatings suitable for demonstration are achievable. One major stumbling block has been the particle size of the PPS feedstock. A size distribution between 50 and 100 microns appears necessary, and this has been obtained by laboriously grinding larger particles. A major supplier of PPS resins is cooperating with us in our attempt to obtain larger quantities of properly sized material. Once received, coating of the PG&E turbine component samples will commence.

Laboratory evaluations of PPS coatings dip-applied to cold rolled steel and aluminum substrates were started. It was determined that coating thicknesses of >0.12 mm are needed to achieve long-term corrosion protection. With steel, it was determined that the formation of water insoluble FeS and ZnS reaction products at the PPS/steel interface enhances bonding and durability. These compounds are produced by interactions during the application process between S originating from the PPS and Fe in the steel.

A moderate rate of oxidation of the sulfide in PPS was found to play a key role in ensuing that PPS coatings protect aluminum in wet, low pH environments. The formation of a discontinuous, intermediate layer of $Al_2(SO_4)_3$ as the interfacial reaction product between $Al_2O_3$ at the top surface of aluminum and the oxidized PPS enhances the bond strength at this interface.

### *Dry Cooling Tower Components*

Prototype sections of polymer coated finned-tube heat exchanger tubing were placed into test by PG&E at The Geysers in June 1994. In the test environment, the corrosion rate of carbon steel is approximately 15 mpy. Aluminum corrodes at a lesser but unacceptable rate. Two metal systems, aluminum fins on stainless steel tubing and electrogalvanized steel on carbon steel tubing are being evaluated. Polyphenylene sulfide (PPS) and vinyl ester resin - trimethylolpropane trimethacrylate applied to surface modified and "as-received" metal surfaces were used for corrosion protection. Visual inspections were made after approximately 2, 5, and 10 mo, and no signs of blistering, chalking or delamination were apparent on any of the coated samples. All of the samples were reported to be in an "as new" condition. These tests are continuing.

### *Piping Systems*

In March 1992, two polymer cement (PC) lined 30-cm diameter pipe tees were installed by NCPA in a steam transmission line where the conditions are as follows: flow rate 13,640 kg/hr, temperature 173°C and pressure 0.83 MPa. Both tees were visually inspected after approximately 12 mo exposure. At that time, some fine cracks and small regions of disbondment of the liner were noted, but in general both tees were in good condition. Therefore, the test was resumed and it has continued without interruption for a total exposure time of 44 mo as of December 1995. Since filters located downstream of the tees which are monitored routinely have not collected any pieces of the PC liner, it is expected that no gross erosion or delamination has occurred. At the next plant shutdown, both tees will be removed for examination.

## FUTURE PLANS

Field testing at NCPA and PG&E will be continued. Laboratory work to select promising systems for possible use on turbine blades and rotor housings will be completed. Contingent upon these results, larger-scale tests for these applications will be initiated at PG&E. Other corrosion-related projects will be started as their needs are identified by the DOE/Industry Geysers Working Group.

## INDUSTRY INTEREST AND TECHNOLOGY TRANSFER

| Organizations | Type and Extent of Interest |
|---|---|
| NCPA | Research collaborators for corrosion protection for transmission piping. Potential user of technology. |
| PG&E | Research collaborators for corrosion protection of dry cooling tower components, turbine blades, rotor housings. Potential user of technology. |

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