FIELD TESTING OF THERMALLY-CONDUCTIVE, CORROSION-RESISTANT LINERS

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KEY WORDS

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PROJECT BACKGROUND AND STATUS

A major concern in the utilization of geothermal resources for producing low cost electricity is the scaling and fouling of the heat exchanger surfaces used in binary power cycles. Scale formation can accelerate the corrosion rate of the heat exchanger surfaces and drastically reduce the heat transfer effectiveness. The Brookhaven National Laboratory (BNL) has developed a low cost polymer concrete (PC) material that can protect carbon steel from corrosion and may also reduce the fouling rate as compared to bare metal surfaces.

A collaborative effort which began in 1993 between the National Renewable Energy Laboratory (NREL) and an industry partner sought to quantify the heat transfer, anti-corrosion, and anti-scaling properties of a set of Polymer Concrete Lined (PCL) heat exchanger tubes provided by BNL. Field tests of the PCL and AL-6XN control tubes were concluded in November 1994 after a total of 75 days in brine service. The test results indicated that under similar operating conditions the overall heat transfer coefficient for the PCL tubes was about 9% lower than for the AL-6XN tubes. Similar pressure drops along both sets of heat exchanger tubes indicate that comparable rates of fouling and scale buildup existed on the PC lining and the metal tubes. Post field test analysis at BNL proved that the PC liner fully protected the carbon steel surfaces from the corrosive brine. However, because the scale to PC liner bond strength was the same order of magnitude as the liner to tube wall bond strength, the PCL tubes could not be reliably hydroblasted clean without damage to the liner surface.

An economic analysis was conducted to ascertain the cost savings potential of PC-lined heat exchangers. Significant capital cost savings can be realized if all the wetted heat exchanger surfaces are constructed of carbon steel and then coated with a protective liner. Increased attention is, therefore, being paid to the details of constructing such a lined heat exchanger. In particular, methods for attaching lined tubes to the heat exchanger tubesheets is receiving close attention.

PROJECT OBJECTIVES

This project's objective is to reduce the cost of electricity generation from moderate temperature geothermal resources by improving the performance and economic viability of binary power cycles. To meet this goal, NREL conducts field experiments to quantify the heat transfer, anti-corrosion, and anti-scaling properties of tube liner materials—BNL's polymer concrete to date—in geothermal brine service. This task is important to the geothermal industry because it may provide an alternative to the high cost of heat exchangers, currently in service, made from corrosion resistant metals (e.g., titanium and AL-6XN). In addition, it has the potential to reduce operational and maintenance costs of general process piping in geothermal brine service.

Technical Objectives

- Characterize the heat transfer, anti-corrosion, and anti-scaling properties of industrial polymer coatings, such as the polymer concrete lining developed at BNL, in relation to the currently available, corrosion-resistant metal alternatives.
- Identify potential difficulties arising from normal operations with a lined heat exchanger.
- Identify the significant manufacturing issues raised in the commercial production of lined heat exchangers; propose and test possible remedies and solutions.
- Assess the economic advantages of lined heat exchangers over conventional heat exchangers for geothermal brine service.

Expected Outcomes

- Thermal and mechanical data for use in designing full-scale, lined heat exchangers for binary geothermal cycles.
- Manufacturing techniques and processes for constructing lined heat exchangers in a commercial production environment.
- General cost data which can be used to estimate the capital costs associated with the fabrication of lined heat exchangers as well as any O&M cost savings.
- New heat exchanger lining materials that will lower the cost of electricity generation and extend the life of the primary heat exchangers as well as significantly reduce the operational and maintenance costs associated with power plant components wetted with geothermal brines.

APPROACH

Working closely with industry partners and BNL, NREL field tests and analyzes polymer liner systems that may provide viable alternatives to expensive, corrosion-resistant metals for geothermal heat exchanger tubing and service piping. BNL investigates and develops liner materials and coats appropriate lengths of heat exchanger tubing for the field tests. NREL installs the tubes in its heat exchanger test skid located at a geothermal power plant operated by the industrial partner. Temperature, pressure, and mass flow data are recorded at the site and downloaded via a modem for analysis at NREL's offices. Test skid maintenance may be performed by plant personnel or by a person under subcontract to NREL.

NREL works with industrial heat exchanger manufacturing firms to determine methods by which pre-lined heat exchanger tubes can be assembled into shell and tube heat exchangers using standard industrial processes. These manufacturing firms also conduct analysis to help quantify the potential cost savings of using corrosion-resistant liners for carbon steel components in place of using corrosion-resistant metal components or overlays.

RESEARCH RESULTS

Previous heat exchanger design studies indicated that the lined tubes were to be 1 inch (2.54 cm) OD and approximately 40 foot (12.2 meter) long. Given the nature of the coatings currently under study, the tubes must be lined prior to their assembly into a shell and tube heat exchanger. This situation presents difficulties in attaching the tubes to the tubesheets using standard methods such as face welding, and roller or hydro expansion. Studies have shown that the ends of the tubes can be welded safely if the PC liner covers all but the last ½" on each end of the tube. The liners currently under study will not reliably survive a normal roller or hydro expansion process. Thus for all the standard attachment methods, a second manufacturing step is needed to protect the bare ends from corrosion after the tubes have been attached to the tubesheets. NREL is examining various methods by which this manufacturing step may be carried out.

FUTURE PLANS

BNL has reformulated its PC material in an attempt to reduce the fouling rate of the liner surface and decrease the scale-to-liner bond strength. Tubes employing this new liner formulation and a new tube wall precoat designed to increase the liner to tube bond strength will be tested in NREL's test skid at an industrial partner's facility during FY97.

A new heat exchanger test skid similar to the existing unit but more compact and transportable is currently under design. This unit will be used to evaluate the performance of lined heat exchanger tubes at geothermal wells with differing brine chemistries.

Determine materials and methods to coat the ends of the tubes, the tubesheets, and channels. Studies relating to the manufacturing of lined heat exchangers will continue. Emphasis will be placed on identifying and testing methods and materials for protecting the tube ends, tubesheets, and channels in shell and tube heat exchangers.

INDUSTRY INTEREST AND TECHNOLOGY TRANSFER

Organization	Type and Extent of Interest
CalEnergy	Industry partner where previous pcl brine tests were conducted.
Oxbow Power Services	Geothermal power producer who may be first company to receive the new portable heat exchanger test skid.
Hughes-Anderson Heat Exchangers	Has conducted design and economic studies of polymer concrete lined heat exchangers.

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