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# Lawrence Livermore Laboratory

THE LLL GEOTHERMAL INDUSTRIAL SUPPORT PROGRAM IN  
CHEMISTRY AND MATERIALS FOR FY76T AND FY77

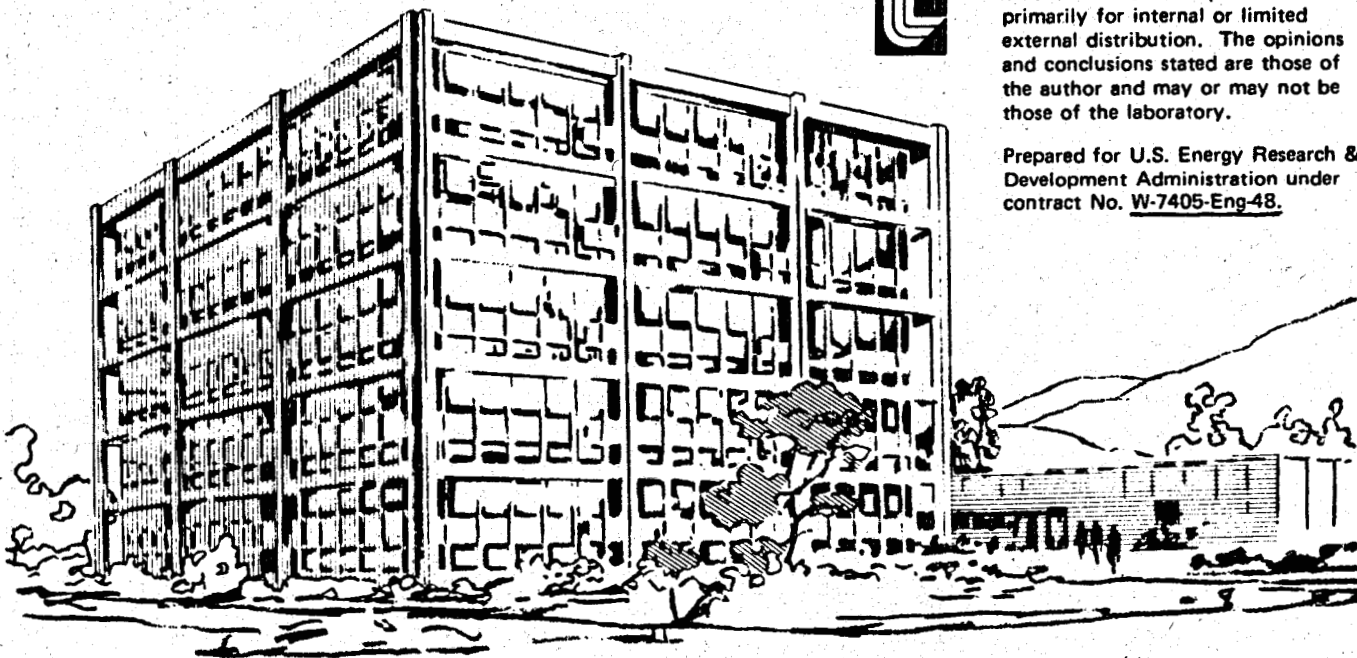
ROLAND QUONG

JULY 29, 1976



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FOREWORD

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THE LLL GEOTHERMAL INDUSTRIAL SUPPORT  
PROGRAM IN CHEMISTRY AND MATERIALS  
FOR FY76T AND FY77

INTRODUCTION

In response to ERDA/DGE\*, LLL has initiated an Industrial Support Program (ISP) to provide technical assistance to joint ERDA/industry projects. The basic purpose is to:

- Carry out relevant research investigations in potential problem areas in order to broaden opportunities for solutions, and to provide alternate approaches where needed.
- Provide ad hoc technical assistance to help solve critical problems that may arise during the operations of joint ERDA/industry projects.

Much of the ongoing work at LLL to develop the Total Flow concept will find application, and the ISP will provide a mechanism for effective, timely use of the diverse talents at LLL and transfer of its geothermal expertise. This support program was established by ERDA/DGE in January, 1976, and currently is directed only toward the jointly funded project carried out by San Diego Gas and Electric (SDG&E) to construct and operate the Geothermal Loop Experimental Facility (GLEF) at Niland, California. It is expected that the ISP will eventually include assistance to other joint projects as they are developed.

Based on our experience in working with SDG&E on the GLEF since January, 1976, we have outlined a program plan in Chemistry and Materials for FY76T and FY77. This plan encompasses technical support in existing problem areas as well as suspected problem areas which have been identified during the initial operating phase of the GLEF.

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\* U.S. Energy Research and Development Administration, Division of Geothermal Energy

It should be recognized that the size of the ISP and, more specifically, the number of tasks and the level of activity in each task, will depend solely on the progress of the joint ERDA/industry projects and the level of funding. Clearly, if the GLEF encounters severe technical difficulties, or if more projects are added, the planned level of funding, already extremely constraining, will be inadequate to support a coherent program. The important point, however, is that the ISP will provide insurance in terms of a contingency plan for action against unforeseen problems. In this sense, the development of the Total Flow process is itself an alternate approach and is, in effect, a contingency plan. Hence, the ISP will be another important bridge to transfer the advanced technology developments from LLL to industry.

## I. SCALE CONTROL AND BRINE HANDLING

### 1. Scale Characterization and Control

a. Field Tests: Surveillance of Scaling Rates in the SDG&E, GLEF.

Objective: To measure, in-situ, the rate of scale buildup in critical components and piping in the SDG&E test facility during operation.

Scope: Radiographs of critical components of the GLEF will be made during operation as a means of surveillance for scale deposition and growth. The temperature of the brine in the formation is approximately 500°F. It is flashed in the well casing to approximately 350°F and continues to undergo temperature and pressure drops through the GLEF process, before being reinjected at approximately 200°F. The large temperature and pressure drops which these HT/HS brines undergo are near optimum conditions for promoting solids precipitation, a precursor to scale deposition and growth. This could lead to reduced operation if not total curtailment. Because of the uncertainty in the rate at which scale forms, surveillance of scale buildup

during facility operation becomes important, not only from an operational necessity, but from the standpoint of a need to understand how scaling rates vary with time during the period of operation. The ability to monitor scale buildup and to relate this to plant operation is important in enhancing the operator's ability to assess and, if necessary, safely curtail operation.

Radiographic surveillance will be made at frequent intervals during GLEF operation. As the operation progresses into a steady-state condition, radiographs every two weeks to a month will be taken at critical sites. Approximately 20 critical sites have already been radiographed. This was done before operation to obtain baseline information, and also during the initial operational phase of the GLEF at 50% flow capacity. With this field experience on the GLEF, we have developed an operating procedure and field capability to provide essentially on-the-spot radiographs showing scale deposition on the walls of pipes up to 12 in. diameter, pipe fittings, and valves. Change in scale thickness of 1 mm can be resolved by this method. Radiography is a completely external means of scale surveillance. Internal methods such as probes, depth gauges, etc. would, in themselves, promote local scaling and not give a true scaling rate on GLEF components.

b. Field tests: Effect of brine modification on scaling rates.

Objective: Determine through field tests whether chemical modification of the brine is an effective method for scale control.

Scope: Analyses of scales produced by HT/HS brines found in the Imperial Valley show principal constituents to be heavy metal sulfides and silica. The solubility of both phases is, of course, temperature dependent, but in addition, also strongly pH dependent. Furthermore, there is evidence

that the rate of silical deposition as a scale constituent is dependent on the degree of polymerization of the precipitated monomer, and that the rate of polymerization is also pH dependent. Field experiments will be conducted on the flowing brine to test these theories. Oxidation experiments will also be conducted to attempt to convert sulfide ions to relatively innocuous free sulfur. The temperature dependence of these chemical modification tests must also be known in order to determine the effectiveness of this technique when applied to the successively lower temperature steps in the GLEF process. We will conduct scaling rate experiments using nozzle expansion tubes where the temperature drops in the nozzle expander from wellhead temperatures of  $\sim 230^{\circ}\text{C}$  to  $100^{\circ}\text{C}$  at the nozzle exit. Our experiences with these nozzles have shown that controlled scaling rate experiments at variable, but known temperatures, are executable in the field and that they provide valuable scaling data. Acidification of the brine will be accomplished by injecting inorganic acids such as  $\text{HCl}$  and  $\text{HNO}_3$ . Modification of brine  $E_h$  will be accomplished by injecting  $\text{FeCl}_3$ ,  $\text{Cl}_2$  and  $\text{O}_2$ . Both the amount and rate of chemical addition will be carefully controlled to determine the optimum quantities required to reduce scaling rates.

#### c. Scale Characterization

Objective: Determine the mineralogical and chemical composition of scale deposits as they are formed in the various stages and components in the GLEF and relate their composition to the changes in the chemical and thermodynamic properties of the brine at the same locations in the GLEF.

Scope: During periods of suspended operation when inspection and maintenance take place in the GLEF, and at other opportune times, scale samples will be collected at various locations in the GLEF. Thickness, coloration,



texture, hardness, layering, and other physical characteristics will be recorded. Mineralogical and chemical analyses of these samples will be made. The type and number of different analyses to be made on a particular sample will depend on the nature and location in the GLEF of the scale sample. The samples are expected to be highly variable in composition because of the wide range of operating conditions in the GLEF. Analytical methods which will be used for scale inspection and analysis include: optical microscopy, transmission electron microscopy, electron microprobe spectrometry, scanning electron microscopy, instrumental and neutron activation, x-ray diffraction, x-ray fluorescence, emission spectroscopy, and atomic absorption spectroscopy. In addition, specific surface area analysis and particle size characterization will be made on selected samples.

The results of these scale analyses will be correlated with the chemical and thermodynamic properties of the brine and with the operating conditions in the GLEF in order to understand scaling parameters and what effect scaling will have on GLEF operation.

## 2. Brine and Effluent Characterization

### a. Analysis of samples taken during GLEF operation.

Objective: Sample and analyze the various multiphase process streams in the GLEF in order to understand the change in chemical and thermodynamic properties of the brine in the GLEF process.

Scope: Samples of brine, steam, suspended solids, and non-condensable gases will be taken from about 40 locations during GLEF operation. Initially, the brine, steam and suspended solids will each be analyzed semi-quantitatively for about 75 elements. They will be analyzed quantitatively

for approximately 30 constituents (cation, anions, and gases) of special interest. In addition, density, pH,  $E_h$  (oxidation potential), and total dissolved solids will be determined in brine and steam samples. Noncondensable gases will be given a multicomponent analysis by mass spectrometry and microwave spectrometry. They will be analyzed quantitatively for  $H_2S$ . The concentration, particle size distribution, mineralogical composition and surface area of suspended solids will also be determined. (Described in task 3a).

The frequency of sampling at any given location and the exact analysis to be made will depend on the rate of change in composition and the nature of the sample. GLEF operating conditions will also affect the sampling requirements. The 40 or so sampling points include points along the production and reinjection lines, and also the input and output streams of each stage for evaluation of stage efficiency. These samples are also required to properly interpret scaling phenomena, solids formation, and the relationship of brine chemistry to corrosion. By analyzing the brine for changes in silica, sulfides, and salt content we will be able to maintain a reasonable inventory of solids accumulation along points in the GLEF. In instances when the quantity and distribution of unreacted sulfides are required, special nonreactive sample bottles will be used. Where stratified and multiphasic flow prevails, a specially designed pitot-like sampling probe which traverses the full diameter of the pipe will be used to sample different points within the stream. The noncondensable gas stream entering the stack is a critical point in the GLEF for sampling. This stream is the source of ejected material into the environment and also the point where noncondensable gases leave the GLEF process. We will have analytical capability for analyzing this stream.

### 3. Suspended Solids Characterization and Control

#### a. Sampling and Characterization of Suspended Solids

Objective: Sample and characterize the suspended solids formed in the various brine streams during GLEF operation.

Scope: Part of this task involves the development of apparatus and techniques for sampling so that the properties of the solids can be preserved for subsequent characterization. It will be necessary to separate the solids from the brine in-situ in high temperature stages of the process because solids will separate continuously as the brine cools. For this work, a filtration apparatus was designed to operate at temperatures up to 300°C and pressures up to 600 psi.

If the particles are of a colloidal size and too small to collect on filters, in-situ analysis may have to be considered for the high temperature stages. It may be possible to obtain information on concentration and particle size distribution with a light-scattering spectrometer modified to operate at high temperatures and pressures. However, the technology for in-situ chemical and mineralogical analysis at high temperatures and pressures does not exist, and the time and effort for development of this technology may be prohibitively long and expensive.

The concentration of the solids in the brine will be obtained by weighing the solids collected on filters from a measured volume of brine. In addition, chemical composition by x-ray fluorescence or atomic absorption, mineralogical composition by x-ray diffraction or electron microprobe and surface area will be determined. A more accurate particle size distribution could be obtained with an electron microscope. Characterization of the solids which form at GLEF conditions is, of course, fundamental to the understanding of

scale formation and control. But of equal importance is the role of suspended solids in causing erosion and hold up problems in the GLEF, and potential plugging in the reinjection well.

b. Solids Mass Balance for the GLEF

Objective: To provide stage by stage and overall mass inventory of the GLEF process in order to fully evaluate stage efficiency, solids deposition, solids accumulation, and the distribution of the chemical components of the brine as a function of position and time.

Scope: Based on chemical analyses of brine, steam and non-condensable gas samples taken periodically at approximately 40 points in the GLEF during operation and from the recorded mass flow rates of the process streams, a mass balance will be made across each stage, and across the entire process. The amount of solids accumulation, scale formation, and suspended solids will be compared with data and analysis from sampling to provide a means of understanding the interaction of brine chemistry and process variables on solids production and scale formation.

The rate of produced solids will be small by comparison with the brine mass flow rates, and may be difficult to resolve over short times within the precision of the sample analysis. The severity of this problem will be variable, depending on the chemical species being followed. In addition, solids may deposit in one location and then migrate downstream over time, again to an extent depending on the particular species involved. This movement of material after deposition introduces a variable which adds another dimension to the inventory problem.

There are no viable alternative approaches to doing a material balance on the process except through period sampling and analysis. Therefore, this subtask will be dependent on results of other subtasks such as 1c, 2a and 3a.

There will be a small number of on-stream analyses, but these will be limited to the noncondensable gas streams.

c. Thermochemical Analysis of Solids Production and Control

Objective: The objective of this task is to develop the means of applying thermochemical principles and existing data to the solutions of severe solids management problems.

Scope: Scale and sludge formation in the GLEF are the result of chemical precipitation reactions. These can in principle be described in terms of kinetics and equilibrium solubilities. Preventive measures can be taken if the conditions under which precipitation will take place are known. However, the chemical complexity of natural brines, the extreme conditions and short time scale of processing make such interpretations difficult.

Our approach to obtaining a quantitative description of the process chemistry in a plant is to estimate activity products of scale forming species in the brine, and compare them with computed solubility products of scale solids. This is possible because data are available from the chemical literature which takes into account the effects of pH, temperature, and degree of chloride complexing on activity coefficients. Many individual chemical reactions can be evaluated in this way, although the method does not permit a complete description of the system, and requires some discretion and interaction with the investigator.

In the GLEF process each of the multiple stages of steam separation can be considered as a quasi-equilibrium situation. At these points, the residence time and reduced stream velocity are expected to allow solids to form and accumulate. The removal of noncondensable gases along with the steam also

affects the brine chemistry, and makes it important to be able to estimate their distribution.

Because of the considerable variability in operating parameters and the number of chemical reactions that must be considered, an essential feature of this task is in the development of a computer code which treats specified precipitation equilibria for any set of physical conditions existing in the GLEF. Input to the code includes the original chemical composition of the fluid, pressure and steam quality as function of temperature, solubility and dissociation of hydrogen sulfide, and effective activity coefficients for ionic species.

This code was first used to study the precipitation behavior of PbS. This is a material that preliminary experimental studies showed to be a pervasive solid even at the relatively high temperatures in the brine at the wellhead. The computed solubilities agree with this observation and indicate that PbS results primarily from a pH increase caused by the loss of CO<sub>2</sub> from the liquid phase.

Since pH change appears to be an important factor controlling precipitation, the effect of CO<sub>2</sub> evolution on pH will be introduced. The effects of imposed pH reduction (chemical modification) will be added as an option.

Additional chemical data will be obtained and added to the code to permit computations for other sulfides and for classes of compounds other than sulfides, such as oxides, hydroxides, sulfates and carbonates. Solids removal by pre-precipitation from hot brine before the fluid enters a plant, and post-treatment of spent brine before reinjection may eventually become necessary. A study will be made of the effects of potential additives for these purposes. Such processes would involve reactions at higher pH and oxidation states than are normally encountered. A mechanism will be added to

the code for specifying the oxidation state of the system. Extrapolations of activity coefficient data will be necessary to allow computations in alkaline solutions.

d. Assessment of Solids Control Methods

Objective: Define chemical methods for reducing solids production and the physical techniques for solids handling and/or removal in the GLEF process.

Scope: At the temperatures and pressures at which the GLEF operates, and examination of the thermodynamic equilibria of constituents such as silica and heavy metal sulfides, indicates that the quantity of scale that can be cemented on equipment surfaces is but a small fraction of the total solids which exceed equilibrium solubility. Those solids which are not immobilized as scale could potentially 1) cause plugging at points in the piping network, 2) separate and settle in the process vessels reducing their effective volume, brine residence time and hence stage efficiency, and 3) pass through the plant and into the reinjection wells causing a serious flow problem by reducing formation permeability. Potential solids production rate can be computed based on equilibrium solubility and brine composition as described in subtask 3c.

The actual production rate within the GLEF will be affected by kinetic factors, the dynamics of the flowing brine, partition of  $\text{CO}_2$  and  $\text{H}_2\text{S}$  in the gas and liquid phases, and the chemistry of the hypersaline brine.

Selection of promising chemical and physical methods for solids control will be dependent on results of the brine and solids sampling and characterization phases of the field program. Whatever method is selected, it must be compatible with the total process including reinjection of the spent brine.

In conjunction with chemical modification techniques, the use of conventional solids processing methods in the GLEF process will be assessed as a means of controlling the flow of excess solids through the facility and the amount which is ultimately reinjected.

#### 4. Effluent Conditioning for Reinjection

##### a. Assessment of Effluent Conditioning Procedures

**Objective:** Assess the chemical and engineering procedures involved in processing the spent brine stream containing suspended solids in the GLEF in order to prevent potential plugging of the formation during reinjection.

**Scope:** The assessment of procedures for solids handling depends on results of the other subtasks on solids characterization and control. A major distinction is made in that whatever procedure is selected, concern over energy degradation is no longer a primary factor in the spent brine stream. The main consideration is the prevention of solids from plugging the formation.

We will survey existing technology for separating solids from liquid streams. Promising methods will be evaluated along with an assessment of chemical and equipment design problems for GLEF application. We will make process design calculations for the selected separation process using input conditions and properties anticipated in the operation of the GLEF.

The main problem areas in processing the effluent stream for suspended solids are 1) exposure to oxygen which would increase the corrosive potential of the reinjected brine and 2) submicron particles sizes and low density solids constituents, making settling times long and separation difficult, and 3) continuing precipitation of solids in the brine even after separation.



Several techniques which may prove fruitful include 1) ponding the brine, settling and separation, followed by oxygen treatment, 2) filtration, and 3) inertial separation techniques. In addition, chemical seeding will be evaluated to co/pre-precipitate species that may come out of solution when reinjected.

b. Field Tests: Effluent Condition and Handling Methods

Objective: Conduct field tests of methods defined in subtask 4a for conditioning and handling of spent brine effluent for reinjection.

Scope: Based on the field program plan defined in subtask 4a, small scale field tests will be conducted on the most promising methods for conditioning and handling spent brine effluent. Equipment will be ordered and field installed.

Most of the tests will be designed toward use of commercially available process equipment in anticipation of the potential need for available, larger versions of equipment should an acceptable process be found. Atmospheric settling ponds may be a near-term practical solution. Following chemical treatment and settling, chemical or mechanical flocculation may be required to agglomerate the remaining fine grained particles. High efficiency, inertial type separators could then be used as the next stage to remove the relatively low density solids from the heavily salted spent brine. Because of the relatively low solids concentration in the spent brine and small density difference between the solid agglomerates and the brine it may be necessary to use equipment capable of producing very high centrifugal forces in which case equipment power consumption would be considerably increased. The effectiveness of the effluent conditioning and handling methods will be tested by passing samples of the treated effluent through core samples of the reinjection formation and observing the change in permeability at simulated in-situ conditions.

## II. MATERIALS

### 1. Corrosion Surveillance and GLEF Support

#### a. Nondestructive Surveillance

Objective: To measure the rate of corrosion of piping and components during GLEF operation. Correlate the data with operating parameters and brine properties.

Scope: Approximately 30 sites on the GLEF have been selected for periodic measurement of wall thinning by ultrasonic techniques. The extent of corrosion will be evaluated with respect to the variation of process conditions, such as temperature, pressure, fluid velocity, pH, and the specific location of the corrosion site.

The technique utilizes a transducer coupled externally to the pipe or component wall for transmitting and receipt of an ultrasonic signal. The signal is displayed and interpreted to give a measure of wall thickness. We expect to resolve changes of 10 mils. thickness in typical pipe walls.

Difficulties may arise in transducer compatibility with the hot surfaces encountered in the upstream portions of the facility. Good surface contact is required between the transducer and the surface of the specimen. It may be necessary to use thermal standoffs which will degrade signal transmission to some extent, but not enough to negate the usefulness of the technique. If there is appreciable and rapid corrosion, then ultrasonics should detect this without great expense or without interruption of the process.

The radiographs at various sites on the GLEF for monitoring scale buildup will also provide information on wall thinning and localized corrosion. An interpretation of these radiographs will be made for corrosion and the data will be assembled and evaluated with other corrosion studies described elsewhere

in the LLL program. Radiographs of critical sites other than those for detailing scale buildup will also be made, especially elbows and regions downstream of control valves where large temperature and pressure drops occur.

b. Analysis of Materials Related Failures

Objective: Provide SDG&E with metallographic analytical support during operation of the GLEF. Inspect and analyze materials related failures of facility piping, fittings, and components. Recommend replacement materials, parts, and/or process modifications.

Scope: Because LLL has the facility and trained personnel for comprehensive and detailed metallographic analysis, LLL will provide support to SDG&E during operation of the GLEF. Inspection and analysis of materials related failures will be made, followed by recommendations for substitute materials and/or parts. We plan to do this on a timely basis, in order to impact on ongoing GLEF activities. Generally the parts will be sent to the laboratory for full analyses, although some capability will be available in the field, e.g., radiography and dye penetrant application. Materials related failures have already occurred in the operation of the GLEF in critical components. Elbows, the first stage control valve, and the tubing in the production and reinjection wells to monitor downhole pressure have already failed through a combination of erosion and corrosion. LLL is, at the present time, inspecting and analyzing these parts and have made recommendations for both provisional and long-term solutions. We anticipate that similar problems will occur in the ensuing operating phases of the GLEF. Should they occur, we will be prepared to provide support. Other parts of our industrial support program in materials addresses the problem of prevention of corrosion related failures.

## 2. Materials Test and Evaluation

### a. Corrosion Tests of Substitute Plant Materials

Objective: The purpose of this task is to expose, to the raw brine, materials which can be substituted for currently used plant materials that may undergo excessive corrosion. Three categories of materials will be tested: 1) steels that are readily available as large diameter pipes and fittings, 2) materials that may be expected to exhibit better corrosion resistance than these pipe steels but are presently available only in other shapes, and 3) compositions which will provide important information as a data base for the long-range development of low-cost, corrosion-resistant alloys.

Scope: During the short period of operation of the SDG&E Test Facility, unacceptable corrosion rates of some plant components have become evident. Replacement materials will have to be selected. To assure that the proper substitute materials are specified, a knowledge of the relative corrosion behavior of readily available structural materials in the corresponding brines will be required.

Pipe materials will be exposed in the form of corrosion spools directly in the production line of the GLEF. Spools containing corrosion coupons will also be exposed in bypass lines. The structural materials at the test facility are mainly plain carbon steels, typically ASTM A-53, Grade B. The corrosion spools will be made out of readily available steel pipe such as S00-90, L-80, and others used in the petroleum industry. They will measure 0.61 M (2 ft) in length by 0.27 M (10-3/4 in.) in diameter. To obtain a measure of susceptibility to crevice corrosion, a crevice specimen of the material used for the spool will be inserted through and welded on to the wall of the spool. These samples will also contain a weld bead. Coupons of a large number of other materials will be exposed in the spools placed in bypass lines to expand our

data base on corrosion of materials in geothermal brines. This will provide information for potential long-range substitute materials and for the development of new alloys. In addition, this information will be useful for considering the substitution of materials for components which cannot tolerate excessive corrosion such as in valves and pumps. With respect to developing a data base for understanding the role of composition, we will include (1) low carbon steels with varying amounts of Cr and Mo and possibly Ni and Si, (2) austenitic stainless steels with varying amounts of Ni, Cr, and Mo, and (3) ferritic stainless steels with varying amounts of Cr and Mo and possibly Ni.

The corrosion spools will be examined radiographically and, at appropriate intervals, will be removed so that they can be checked metallographically. Corrosion coupons will be designed so that information on general corrosion, crevice corrosion, and pitting corrosion will be obtained. Duplicate samples will contain weld beads to simulate weldments. Weight and thickness measurements and metallographic analysis will be made. An analysis of initial and replacement costs will be made for these materials.

#### b. Electrochemical Corrosion Tests

**Objective:** This work will involve experiments using several electrochemical testing techniques in the field for the purpose of screening alloys for their corrosion resistance in high-temperature, high-salinity geothermal brines.

**Scope:** Three basic types of measurements will be carried out: (a) "instantaneous" corrosion-rate (also known as linear-polarization resistance, LPR) measurements; (b) open-circuit corrosion potential measurements; and (c) polarization curve measurements. The LPR measurements can, in theory, be conducted entirely with commercially available equipment. Measurements (b) and

(c) require a stable reference-electrode assembly suitable for use at  $\sim 220^{\circ}\text{C}$  and 200 psi. Initially, measurements will be made with the hot, high-pressure unmodified, flowing brine and various prospective alloy materials will be tested. These materials include low carbon steels with varying amounts of Cr and Mo such as A36, S00-90, A387; stainless steels such as MP35N, 410, and Ti alloys such as Ti-6Al-4V, and Ti-38A Code 12. If chemical modification of the brine proves successful in abating scale formation, corrosion rate tests will also be conducted in the modified brines.

In addition to the field testing, a chemical laboratory facility will be maintained at LLL for concomitant, laboratory electrochemical measurements, and for checkout of the field equipment. This laboratory will be devoted primarily to short-term applied research or semi-routine tests.

Provided a reliable reference-electrode assembly can be developed, the principal problem area in the electrochemical measurements is the effect of scaling. All measurements will be carried out as a function of time, and this should yield some information on its influence. The inhibition of corrosion by scaling does not necessarily preclude obtaining meaningful electrochemical corrosion-rate measurements on the various materials.

Eventually, if LPR measurements prove to be valuable sensors of corrosion activity, permanent installations of this type will be considered at various locations in the GLEF. By sensing corrosion activity at several locations, the direct effect of changes in brine chemistry on corrosion activity can be determined.

#### c. Corrosion Tests in Modified Brines

Objective: Test corrosive effects of chemically modified brines on substitute plant materials.

Scope: This task will be closely coupled with subtask 1b under scale control and brine handling, where the brine will be modified chemically in attempts to control scale formation. These tests will be conducted using expansion tubes (nozzles). For corrosion tests, these tubes will be fabricated out of low and medium carbon steels, low and medium alloy steels, and stainless steels. These tests will enable us to determine the corrosive nature of these chemically modified brines. Two methods of brine modification anticipated in subtask 1b (scale control and brine handling) will be acidification and oxidation. Following each test, the expansion tubes will be sectioned and will undergo metallographic analysis. Corrosion rates on various materials in geothermal brines as a function of pH,  $E_H$ , and temperature will add significantly to our understanding of corrosion.

d. Test and Evaluation of Polymeric Materials

Objective: Test and evaluate polymeric liners, coatings, and platings on metallic surfaces as a means of preventing scaling and corrosion in low velocity components.

Scope: Samples of polymeric coating bonded to metal substrates will be exposed in bypass spools to low velocity brine flow. The amount of scaling and wear of the coating will be examined by several means - usually by weight, dimensional, and hardness changes and also by microscopic examination. Temperature, type and amount of suspended solids in the brine, and velocity are the primary parameters affecting the resistance of polymer coatings and liners. Methods of polymer application to metal substrates will also be evaluated. Some screening of materials and methods will be made in the laboratory prior to the field tests to assure that only prime candidate materials are tested in the field. Polymeric coatings may prove to be effective in preventing scale and corrosion in components where erosion is minimal.

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