THE GEOSCALE COMPUTER MODEL FOR GEOTHERMAL PLANT SCALING AND CORROSION ANALYSES

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It is generally recognized that corrosion and scaling problems could seriously affect the operation and electric power production from a geothermal power plant. The Electric Power Research Institute (EPRI) has sponsored a study at Battelle-Northwest (BNW) to develop a brine chemistry data base and analytical tools to analyze how corrosion and scaling affect the degradation of the power output of a geothermal plant.

The GEOSCALE computer model is a steady-state thermal hydraulics code that describes the process parameters of the power plant. At present the multistage flash and binary cycle plants are being analyzed. Initially the code computes the power output from a given geothermal brine flow and provides flow rates, temperature, velocities at points from the bottom of the production wells through the plant to the waste injection system. Based on the starting brine chemistry and these process parameters, corrosion and scaling rates will be estimated at points throughout the system. The amount of scale formation in a time interval will be calculated and the impact on brine flows and heat transfer calculated, resulting in a new set of plant process parameters for the next iteration. The iterations continue until some portion of the plant is degraded to a process limit or a plant life of 20 to 30 years is reached.

Obviously the most difficult part of this analysis is the lack of valid analytical expressions and supporting rate data to calculate scaling. The general approach to the scaling rate equations is that the rate of buildup is proportional to the degree of insolubility of a mineral minus the rate of mechanical removal. We are very interested in all current scaling work that could help in providing scaling kinetics data related to process parameters so we can test these analytical expressions. Our program includes a computer subroutine for calculating mineral insolubilities as brines cool, a chemical and structural analysis of several actual scale samples and a laboratory experimental program to examine scaling kinetics.

DISCLAIMER

ELECTRIC POWER RESEARCH INSTITUTE

PROGRAM NO. EPRI 653-1

SCOPE

INVESTIGATE BRINE CHEMISTRY AND COMBINED HEAT/MASS TRANSFER, SCALING KINETICS, AND DEVELOP MODELS TO PREDICT GEOTHERMAL PLANT DEGRADATION

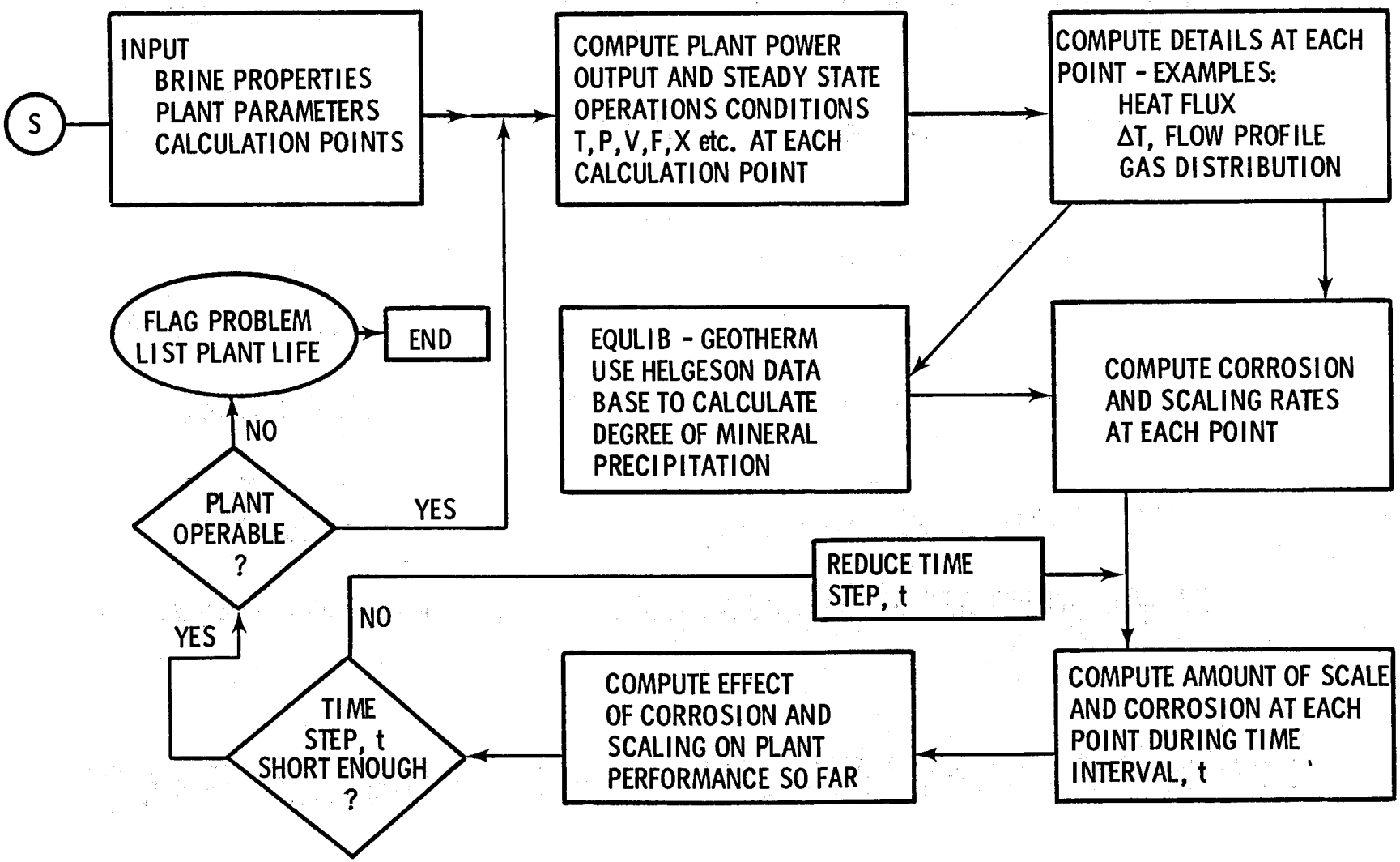
BATTELLE'S APPROACH TO THE EPRI GEOSCALE MODEL

- ANALYTICAL TOOLS BADLY NEEDED BY ENGINEERS DESIGNING PLANTS
- COMPUTER ANALYSIS IS A STRAIGHT FORWARD EXTENSION OF OUR WORK ON GEOCOST
- MODEL DEVELOPMENT NOW CAN FOCUS R&D NEEDS
- MAJOR PROBLEM

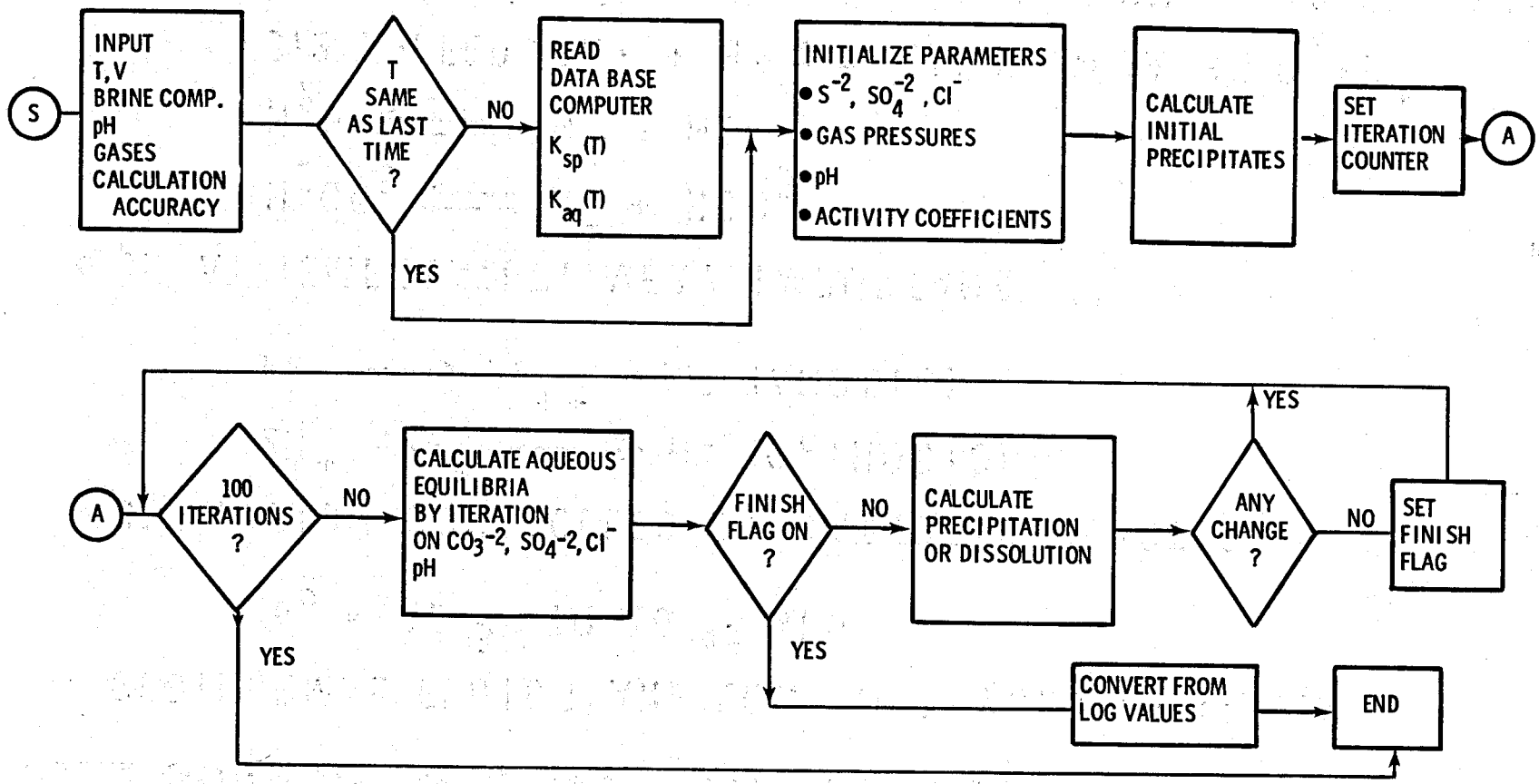
  LACK OF RATE DATA TO WRITE EQUATIONS TO CALCULATE CORROSION AND SCALING

- EXPERIMENTAL EMPHASIS SHOULD BE ON OBTAINING SCALING KENETICS DATA
- OTHER GEOTHERMAL PROGRAMS WILL PROVIDE MUCH NEEDED CORROSION RATE DATA AND SCALING DATA

THE GEOSCALE MODEL FOR GEOTHERMAL PLANT SCALING & CORROSION ANALYSES



EQUILIB - GEOTHERM
CALCULATE MINERAL SOLUBILITIES AT 0 TO 300 C



IMPORTANT FACTORS AFFECTING CARBON STEEL CORROSION IN GEOTHERMAL BRINES

- GEOTHERMAL FLUIDS ARE LOW IN OXYGEN INITIALLY

  $fo_2 = 10^{-30}$ TO 10^{-45} atm

- CORROSION CONTROLLED BY CATHODIC REACTION

  $2H^+ + 2e^- \longrightarrow H_2$ (CATHODIC)

  $Fe \longrightarrow Fe^{++} + 2e^-$ (ANODIC)

- pH AT TEMPERATURE VERY IMPORTANT

  $H_2CO_3 \rightleftharpoons H^+ + HCO_3^-$

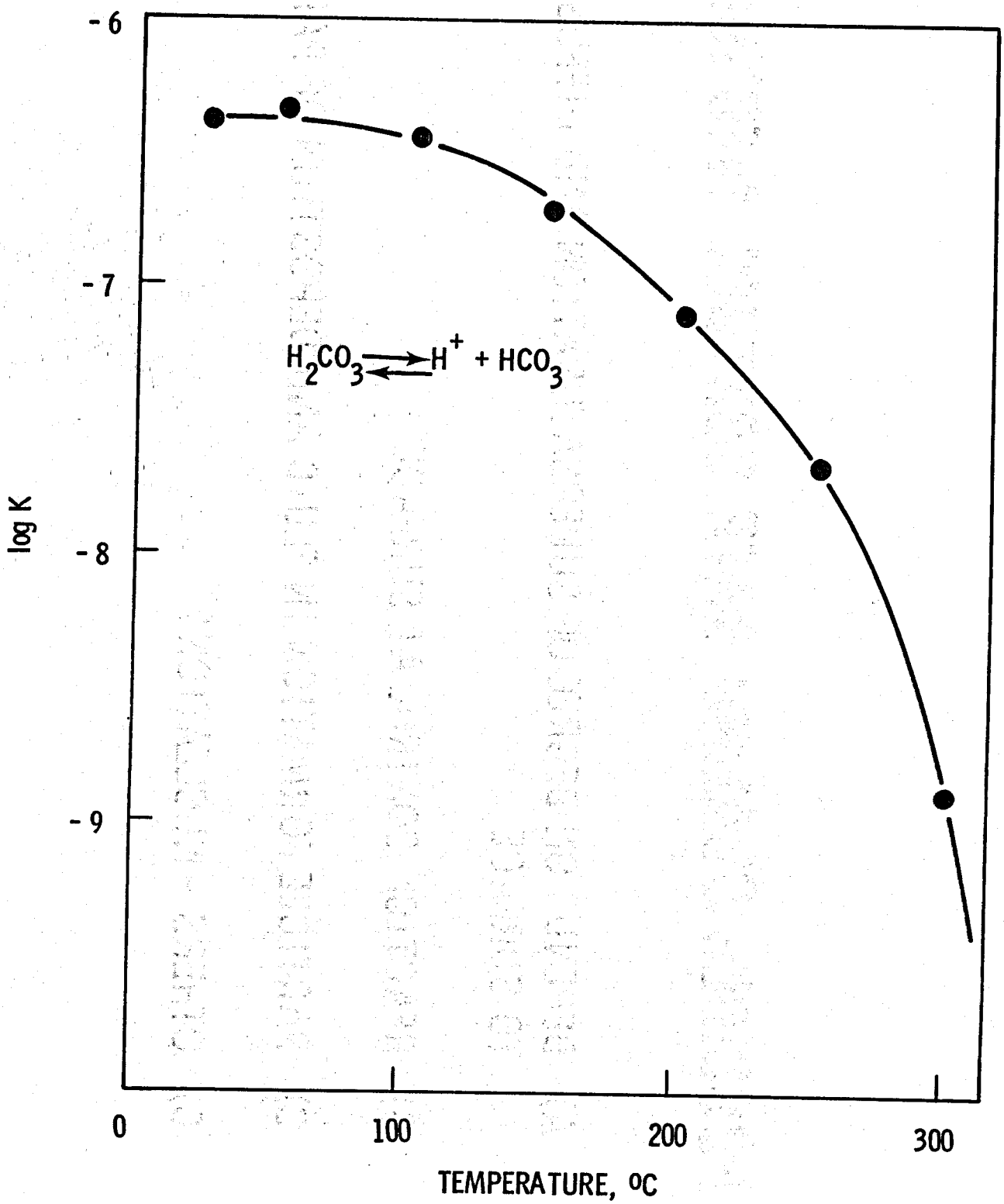
  $H_2S \rightleftharpoons H^+ + HS^-$

  3/2 K-FELDSPAR + $H^+ \rightleftharpoons$ 1/2 K-MICA + $3SiO_2 + K^+$

  7 ALBITE + $6H^+ + 3H_2O \rightleftharpoons$ 3 Na-MONT. + $10\ SiO_2 + Na^+$

- AS SALINITY INCREASES pH DECREASES

THE DISSOCIATION CONSTANT OF CARBONIC ACID



POSSIBLE SCALING RATE CONTROL MECHANISMS

A) DEPENDS ON DEGREE OF SUPERSATURATION AND DIFFUSION TO SURFACE

B) REACTION CONTROL AT SURFACE

C) PARTICLE FORMATION IN FLUID AND DEPOSTION OF PARTICLES

D) OTHERS - NUCLEATION?

EXPERIMENTAL SCALING PROGRAM OBJECTIVES

- TEST VALIDITY OF ANALYTICAL EXPRESSIONS
- TEST BRINE PRECIPITATION VS EQUILIB-GEOTHERM PREDICTIONS
- DEVELOP RATE CONSTANTS FOR SCALING
- ESTABLISH HOW 2 AND 3 SIMULTANEOUS DEPOSITION PROCESSES ADD TOGETHER
- ESTABLISH HOW TOTAL SALINITY EFFECTS RATES

EPRI-SCALING TEST FACILITY
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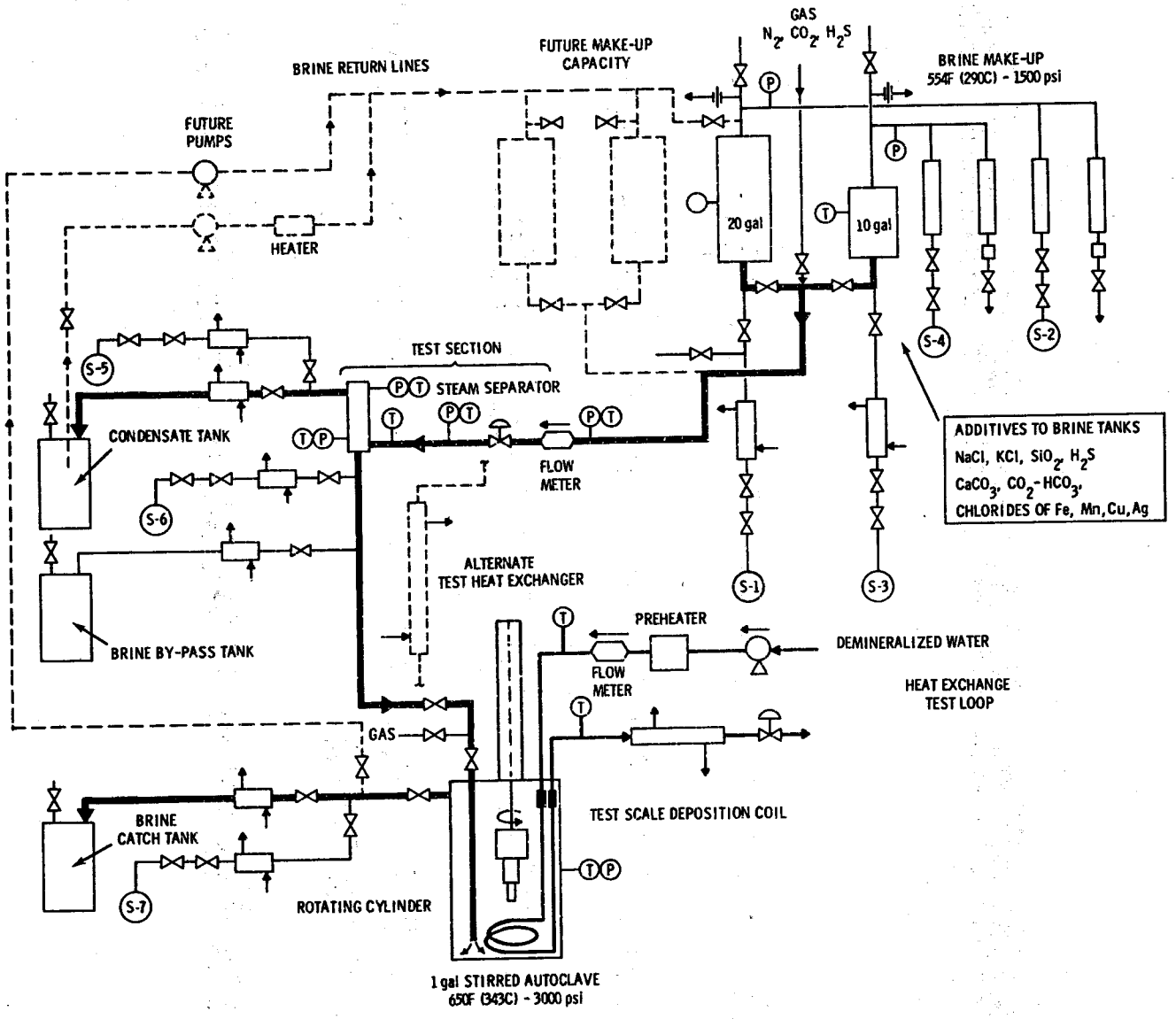
GEOTHERMAL BRINE CHEMISTRY PROGRAM



WHAT DATA IS NEEDED ?

- REVIEW HELGESON DATA BASE FOR ACCURACY - CORRECT AS REQUIRED
- OBTAIN HIGH TEMPERATURE THERMODYNAMIC DATA FOR DATA BASE
  ESPECIALLY EQUILIBRIUM CONSTANTS
- ESTABLISH SCALING RATE CONTROL MECHANISMS
- DEVELOP VALID ANALYTICAL SCALING EQUATIONS

$$\frac{dX}{dT} = f(T, \Delta C, \text{FLOW EFFECTS, SURFACE EFFECTS})$$

- ESTABLISH HOW MULTICOMPONENT SCALES RELATE TO BRINE CHEMISTRY
- DEVELOP CORROSION RATE EQUATIONS
- VERIFY ANALYTICAL EQUATIONS TO DESCRIBE FLOW THROUGH COMPONENTS e.g. TURBINES, VALVES, HEAT EXCHANGERS
- EXTEND BRINE THERMODYNAMIC (STEAM TABLE) DATA TO MULTICOMPONENT BRINES AND SUPERHEATED AND COMPRESSED LIQUID REGIONS
- SCALING BEHAVIOR IN PUMPS, TURBINES, STEAM SEPARATORS AND GAS EJECTORS