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GEOTHERMAL STEAM SEPARATOR EVALUATION

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Introduction The current technology for handling geothermal fluids has been developed to meet the specific needs of operating geothermal installations at locations such as Lardarello, Italy; the Geysers, California; Wairakei, New Zealand; Cerro Prieto, Mexico; and various locations in Iceland and Japan. The geothermal fluids at each location--vapor or liquid dominated--present unique problems in terms of mineral content, moisture content, operating temperature and pressure, and other properties.

These fluids contain many types of dissolved minerals in a wide range of concentrations. There is a need to develop criteria for the optimum selection of steam separation equipment that will meet the requirements imposed by the fluid characteristics in these fields.

The carryover of brine droplets with separated steam can hinder system performance and increase capital and maintenance costs.

Bechtel undertook a study of geothermal fluid process technology to help establish criteria for the selection and/or design of steam separators. The specific objective of this study is to establish the performance requirements for steam separators in a geothermal environment and analyze the applicability of current technology for separator apparatus. The result of this analysis is used to select four candidate separators, three of which will be the subject of a detailed analysis and field testing during the project.

Geothermal Steam Contamination Problems The project deals with geothermal steam extracted from hydrothermal resources. Hydrothermal resources can be subdivided into either liquid or vapor dominated resources depending upon the amount of steam present. In either case, the steam is used to generate electrical power either directly in a steam turbine or indirectly in a binary process.

This steam can be contaminated from the following sources:

- Moisture carryover
- Carryover of dissolved solids from the liquid phase (steam purity)
- Vaporization of partially volatile solid materials
- Entrainment of suspended solids, such as sand and mud

This study considers the first three contaminants. The removal of suspended solids is solved by other equipment than that used for moisture and phase separation. The problems of non-condensible gases such as carbon dioxide and hydrogen sulfide were not included within the scope of this project.

In a typical geothermal power production facility, fluid from a geothermal well enters a steam separator. This is the primary separator whose function is to separate steam from a steam-water mixture. The brine then enters a flasher. This is a secondary steam generator which creates a two phase mixture from the brine and separates out the steam.

In both cases, the steam generated contains the contaminants of interest--moisture, dissolved solids, and volatile solids. This steam is characterized by its quality and purity.

Quality is defined as the fraction by mass of vapor in a mixture of liquid and vapor. It is expressed as a percentage so that 100% quality is a saturated vapor (0% moisture) and 0% is a saturated liquid (100% moisture). A saturated vapor is also known as dry steam.

Purity is the insoluble matter (residue) found upon evaporation of a sample of the condensed steam. It is expressed as parts per million, ppm, by weight.

Excessive moisture and dissolved ions can lead to problems with mechanical components (particularly the steam turbine but also downstream components such as the condenser) and affect the plant performance. These problems arise from the following effects:

1) Corrosion results from chemicals carried over with the steam.
2) Erosion of turbine surfaces results from water droplets.
3) Depositon can cause either turbine problems by deposits of solids which reduce the pas-

sage area with resultant loss in efficiency and capacity. It can also lead to problems with other equipment. For example, there can be a significant loss in the heat transfer rate in the condenser.

4. Moisture in the steam leads to a loss of turbine efficiency. It is estimated there is about a three-quarter percent loss in turbine efficiency for every percent moisture in the steam to the turbine.

One of the most troublesome chemical elements for a steam turbine is silica. This can be carried over either as a dissolved solid or in a volatile form. Conventional steam turbines set limits of silica in the steam of 0.01 to 0.02 ppm and at this level, no silica deposition occurs. Thus, many years of operation can be expected without turbine maintenance. Two years or less appears to be common as an operational time for a geothermal steam turbine. However, a case is reported for which the geothermal steam turbine has operated over 15 years without silica depositon. In addition to maintainance problems, there can be a loss of turbine output which can represent a very significant cost. For an assumed case, based upon Cerro Prieto experience, the cost is in excess of $2 million per year per 37.5 MW power plant.

Steam Separators A review was made of the types of steam separators most commonly used or under consideration for geothermal power plants. This was accomplished by a literature review and the submittal of a questionnaire to users, designers, and developers. The most commonly used separators are the bottom outlet cyclone (also known as BOC or Webre type), the impingement type, wire mesh, centrifugal/impingement, and scrubbers. Moisture and salinity removal efficiencies of 99.95 percent are reported for the BOC type. A summary of their performance is shown in Table 1. Of the separators listed, the highest removal efficiencies are for the wire mesh, impingement, and centrifugal/impingement types.

Test Program As part of this project, a field test unit is being built to determine the performance and efficiency of the selected separator types under geothermal operating conditions. The design conditions for a 50MW geothermal power plant have been used to establish the desired operating conditions. Testing is expected to begin near the end of 1981.

Two 50 MW plant design cases were examined to establish design conditions under which steam separators must work. The first case is representative of a high salinity, high temperature brine as found near the Niland area of Southern California. The second case is representative of moderate temperature, low-to-intermediate salinity geothermal fluids, as found in the areas near Heber and Ease Mesa in Southern California.

The test unit will be able to test for these brines the following devices:

- Bottom outlet cyclone
- Impingement type separator (in conjunction with the BOC)
- Mesh type separator (in conjunction with the BOC)

The BOC produces an adequate steam purity by itself for many locations. However, when combined with either the impingement or the mesh type separator, improved purity can be expected.

Conclusions The following conclusions are made:

1) Moisture and salinity in the steam can cause significant problems, especially for the turbine. This results in a substantial increase in cost due to downtime and reduced plant output.
2) One of the most troublesome chemical elements is silica as it causes depositions on the turbine blades. Other elements affect turbine material selection due to their corrosive properties.
3) Adequate steam purification can decrease the

Table 1 **STEAM SEPARATOR COMPARISON CHART**

TYPE \ CHARACTERISTIC	APPLICATION	PRESSURE DROP
B.O.C.	PP	HIGH
WIRE MESH	MR	LOW
IMPINGEMENT	MR	LOW
CENTRIFUGAL/ IMPINGEMENT	MR	MED
SCRUBBERS	MR, PI	MED

Application: PP--Primary Phase
MR--Moisture Removal
PI--Purity Improvement

Pressure Drop: Low--<5 in H_2O
Med--5 in H_2O to 5 psi
High-->5 psi

silica level to the turbine so that no deposits will occur. Silica levels of 0.02 ppm in the steam are required. Steam purification methods by other than mechanical means may be required to reach this level.

4) The amount of steam purification required depends upon the plant operating conditions (pressure and pH) and salinity content of the geothermal brine.

5) Although the bottom outlet cyclone separator appears to do an adequate job of moisture removal and purity improvement, further improvements in performance can be obtained by the use of other moisture removal devices. This may significantly increase the plant efficiency and performance, and decrease the cost of operation.