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SAMPLING IN GEOTHERMAL OPERATIONS-PHILOSOPHY AND REALITY

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1.0 INTRODUCTION

The sampling and analysis (chemical or other) of geothermal fluids, i.e., liquids, gases and suspended particles, is being done today by different investigators using methods of their own choice. It is a wide-spread opinion among chemists and engineers involved in geothermal operations that sampling and analysis is filled with "pitfalls for the unwary". In the majority of the cases, the analytical numbers reported are not truly representative of the geothermal systems. Sampling problems are compounded by two-phase flows (or even flows with more than two phases present), gas flashing (and/or losses), and chemical reaction and precipitation processes occuring during sampling.

The problem of sampling and analyzing geothermal fluids is further compounded by the fact that many wells produce fluids which can change their composition at various times as a function of changing reservoir and operational conditions.[1]

It seems clear that unless positive action is taken, the literature of geothermal energy will soon be filled with published chemical analyses of dubious quality at best.

Recent comprehensive studies on the chemical characterization of geothermal brines[2] revealed that the reported data on a large number of brines can not be compared due to the contradictions between data reported by different authors and the lack of details describing when, where and how the samples were taken in any given instance. Battelle PNL[3] is presently undertaking a new and comprehensive study of sampling and analytical methods used in geothermal operations. This study does not involve sampling for suspended or deposited solids.

What is needed is an assessment of the state-of-the-art, a selection of candidate methods and a verification of various sampling procedures.

This paper describes the reasoning behind Battelle's efforts. The final goal of this study is to evaluate the possibility of standardizing the sampling methods in geothermal operations.

Solutions to sampling problems in any geothermal field play a major role in solving field problems. A large variety of field operations are based on data retrieved from the analysis of specific samples. Therefore, the importance of sampling procedures can not be over-emphasized. One can say - without exaggeration - that the entire investment of a geothermal field, its numerous stages of development and operation will depend on the proper collection and analyses of samples.

The need for a manual listing the possible candidate methods for sampling and containing a critical evaluation of the various methods together with suggestions for future developments seems to be unquestionable. This need is also indicated by various attempts of industry and government supported organizations to gather and collect the ideas on sampling procedures used or suggested by all parties interested or involved in geothermal operations.[4]

One must also be aware of the fact that a number of geothermal fluid characteristics can not be determined through the examination of samples collected in the system. These fluid characteristics must be measured in situ.[2]

2.0 REASONS AND OBJECTIVES FOR SAMPLING

Unfortunately, there are many reasons and motivations for collecting and analyzing samples in geothermal operations at various locations and times in the field. Table I lists some typical examples of objectives and reasons for sampling. Table I is not an exhaustive treatment of the subject; there can be many more, sometimes very specific reasons to collect samples.

Arbritrarily, we divided the type of samples into three major groups:

1) Samples of Reservoir Fluids

2) Samples of Wellbore Fluids

3) Samples in Surface Equipment

Battelle PNL's present contract calls for a study and evaluation of the numerous methods used in todays geothermal fields. Only the third sample category (surface operations) is presently considered. However, the reasons and objectives for collecting samples and many of the basic sampling problems are similar in all three catagories.

The large number of reasons or objectives for collecting samples and the numerous technical problems encountered during any sampling process create a complicated situation: None of the present sampling methods fullfills the need of all objectives: There is no ideal sampling procedure. In addition, only a very few methods take all the sampling problems into proper account.

The present and future sampling methods could be divided into two major groups:

1) Standardized Methods

2) Special Methods

Both groups must consider the objectives of the sampling and the special properties and problems of geothermal fluids at the location and time of sampling.

3.0 STANDARDIZED METHODS

No standardized sampling or analytical methods exist in the geothermal industry despite the apparently strong need for standardizing various sampling methods. Battelle PNL's recent studies and field experiments indicate that some of the more frequently used methods and some of the newly developed or conceived methods could be raised to the rank of a standardized method. One of the suggestions to be considered could be the standardizing of components used in various sampling methods instead of standardizing entire methods. The components could be combined into various equipment (component) arrangements to fullfill the need for the large number of sample types to be collected. The components as well as the arrangements could be standardized.

It is felt that some of the more frequently used components could fall into these catagories: 1) Hardware used to connect sampling devices to field equipment, 2) Stationary and traversing sample probes, 3) Connectors to combine components, 4) Cooling coils, 5) Physical separators, 6) Chemical separators, 7) Components measuring the critical parameters of fluids in sampling devices 8) Components controlling the critical parameters of fluids during sampling, 9) Sample containers used as component, 10) Storing and shipping containers, 11) Sample treatment, preservations, shipping and storing.

Each of these components must handle and control certain parameters of the sampled fluid during the sampling process. In addition, each component will offer problems of its own and can have a serious effect on the composition of the final sample.

These parameters and problems for a component system are described by using the cooling coils as an example (See Table II).

4.0 SPECIAL SAMPLING METHODS

All methods presently being used must be considered "special sampling methods" because of a total lack of standardized methods. Many methods being used have major "flaws" and are in need of changes. In addition, there are a number of objectives for which no sampling methods have been described in the open literature.

We believe that a large number of special methods will be used even after the development of standardized methods. The reasons are:

1) The objectives are too manifold to allow standardization of all methods (components or arrangements).
2) Quite often, the sampling methods may require too costly instrumentation and/or the collected data may be an "overkill" for a specific objective. Therefore, a number of different methods should be developed for similar purposes or objectives to allow more cost-effective collecting and analyzing of samples. There is already a considerable complaint in the industry because of the exorbitant cost of some sampling and analytical methods.

5.0 MAJOR PROBLEMS ENCOUNTERED DURING SAMPLING

There are two major problems encountered during sampling in geothermal operations: (1) The fluids to be sampled may behave in an absolutely unexpected or unknown way and, therefore, the wrong approach to the sampling may be chosen, (2) the entire sampling method or certain components of the sampling equipment does not take into account the very special properties of the fluids within the sampling equipment itself.

Basically, both problems have the same effect: The geothermal fluids will change their chemical and physical behavior if any of the thermodynamic or kinetic conditions are changed. Sampling per se, will change both sets of conditions in most cases. Therefore, the sampling itself will exhibit properties quite different from those of the sampled fluid. For example, the fluid to be sampled may be steam, whereas, the actually retrieved sample may be a liquid and a gas.

The basic differences between actual sample and sampled fluid caused by the process of sampling itself quite often need an elaborate and sophisticated interpretation of the final analytical data. The lack of reporting the sampling methods and conditions in papers listing analytical data are one of the two major reasons for the questionable reliability of the information.

The other reason lies with the flow of the fluids in geothermal installations. Drawing a sample from a truely single phase fluid into a sample port is fairly easy if detrimental phase changes

are avoided. However, many fluids in these installation represent two or more phase systems which can also be multicomponent systems. Quite often, it is required to sample these multiphase systems. In this case, it may become extremely difficult to draw a "representative" sample. Quite often, the flow regimes at the sample port are not even known. We may encounter mist flow, bubble flow, slug flow, annular flow, etc. Without knowing the flow regime it becomes impossible to collect a "representative" sample. The only conceivable methods for two-phase sampling seem to be: 1) Proper instrumentation is installed in the lines to allow the precise measuring or calculation of the flow profile or 2) Various samples are drawn from the cross-sectional area of the fluid line and analyzed separately. This latter information can than be used to calculate either the flow profile itself or to calculate the composition of the "recombined" fluid.

Battelle PNL's effort is pointed in the direction of clarifing all these problems comparing presently used or suggested sampling methods for single-phase and two-phase geothermal fluids in the East Mesa area. The main objectives are 1) To point out the problems encountered during the comparison of the sampling methods and 2) To suggest the development of more appropriate sampling methods to properly characterize the liquids and gases that flow in a geothermal operation.

REFERENCES

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Table I. TYPICAL EXAMPLES OF REASONS AND OBJECTIVES FOR TAKING SAMPLES IN GEOTHERMAL OPERATIONS.

OBJECTIVE-PROFESSION	REASON
Formation Fluids	
- Geologist	Geology of Area and/or Reservoir
- Geochemist	Geothermometry
- Reservoir Engineer	Reservoir Evaluation and Characteristics
- Drilling Engineer	Mud Design and Drilling Method Wellbore Completion
- Production Engineer	Wellbore Equipment Design
Wellbore Fluids	
- Production Engineer	Surface Equipment Design Well/Surface Equipment Monitoring Reservoir and/or Wellbore Stimulation
Surface Equipment Fluids	
- Production Engineer	Reservoir and/or wellbore Stimulation
- Power Plant Engineer	Power Plant Design
- Environmental Engineer	Emission Control
- Field Engineer	Reinjection
- Reservoir Engineer	Reinjection

Table II. COOLING COILS AS A COMPONENT IN SAMPLING DEVICES.

A. PARAMETERS:
   1. Geometry
      (A) Tubing (Diameters, Length)
      (B) Coil (Diameters, Shape)
      (C) Orientation of Coil
   2. Material
   3. Temperature
   4. Flow Rate of Fluids

B. PROBLEMS:
   1. Slug Flow of Fluids (e.g., Gas-Liquid)
   2. Slip of Fluids in Horizontal Parts
   3. Condensation Profiles
   4. Time Delay Between Line Fluid and Sample
   5. Averaging of Composition
   6. Deposition of Scale
   7. Corrosion and Corrosion Products