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GEOTHERMAL COMPLETION TECHNOLOGY LIFE-CYCLE COST MODEL (GEOCOM)

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ABSTRACT

GEOCOM is a model developed to evaluate the cost effectiveness of alternative technologies used in the completion, production, and maintenance of geothermal wells. The model calculates the ratio of life-cycle cost to life-cycle production or injection and thus is appropriate for evaluating the cost effectiveness of a geothermal well even when the most economically profitable well completion strategies do not result in lowest capital costs.

The project to develop the GEOCOM model included the establishment of a data base for studying geothermal completions and preliminary case/sensitivity studies. The code has the data base built into its structure as default parameters. These parameters include geothermal resource characteristics; costs of geothermal wells, workovers, and equipment; and other data.

The GEOCOM model has been written in ANSI (American National Standard Institute) FORTRAN 1966 version. Documentation of the model will be available in a Sandia National Laboratories report (Anderson et. al.).

INTRODUCTION

In the development of technologies for completing geothermal wells it is necessary to evaluate the impacts of proposed new completion technologies. The Geothermal Completion Technology Life Cycle Cost Model (GEOCOM) was designed to aid this evaluation. It uses estimates of costs for completion operations and estimates of well performance to derive a measure of effectiveness for completion procedures. It facilitates comparisons of various completion activities and sensitivity analysis of individual technologies.

USE OF THE MODEL

The model includes the basic data required to analyze completions as default parameters. These include data on performance and characteristics of the major resources in the U.S., information on the cost of performing workovers, data on the scheduling of workovers, and general information on the economics and use of geothermal wells. The user of the model can generate a new case or study by modifying the appropriate parameters to change the values from default. This is done by use of a simple input processor designed to ease implementation of the model. Cases can be stacked one behind the other for convenience of parameter or sensitivity studies. The code itself was written using program design language and is explained with frequent comments making it easy for a person not already familiar with the code to understand its operation and make any modifications that might be desired. The code is divided into functional modules which reflect the various steps that must be done in calculating life-cycle costs of completion technologies. These modules include elements that initialize and allow for input of the parameters, determine the workover schedule, compute total production or injection of the well, compute the cost of the well, and output the results.

The GEOCOM model is an analytical tool designed to assist the engineer in evaluating the cost effectiveness of a geothermal well. Specifically, it will aid in integrating engineering economics, operations, resource characteristics, etc. into a single measure of the value of a well. It automatically accounts for such things as time-value-of-money, reservoir depletion, etc., but it is not intended to replace the engineer's understanding of geothermal completions. It is possible, for example, to ask the model to determine the cost effectiveness of configuraitons the engineer would automatically reject, such as a submersible pump in a dry stream reservoir.

For a single initial analysis, use of the model would likely require more effort than doing the work without a computer; however, many workovers have already been analyzed and are included in the model. Thus, for new technologies or uses, the model provides a quick method of comparison to baseline conditions and a structure for consistent analysis. Futhermore, "new" technologies or uses are often variations of existing methods already included in the model. The strength of the model lies in its ability to perform repeated calculations of cost effectiveness for multiple values of the parameters. It can thus be used for sensitivity studies or optimization.

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SCOPE OF THE MODEL

The model includes sufficient detail to allow comparisons between various completion and usage alternatives for both production and injection wells. It combines capital cost of the well and other equipment; continuing cost for workovers, the cost of routine O&M, electricity, and chemicals; and analysis of productivity. To adequately analyze productivity, the model uses different data to characterize different geothermal resources and associates the appropriate well drilling cost with each resource. Since the scheduling of workovers can greatly impact productivity, the model allows freedom in scheduling workovers. The user can select which workovers he wants and when they are to be performed. The user can also select how the well is to be produced (artesian flow, submersible pump, line shaft pump, etc.). In order for the model to be appropriately sensitive to completion technologies, it could not use costs based on gross historical averages, such as annual workover costs equal to a percentage of capital cost. Instead, the model calculates cost for each workover performed and determines production as a function of time.

Geothermal Reservoirs

The differences in well performance and completion technology between the Geysers, with dry steam at 365°F, and East Mesa, with hot water at 340°F, are so great that it would be unreasonable to use average parameter values in GEOCOM. Thus, each important reservoir was considered separately and described by representative values for the basic reservoir-related parameters. The reservoirs included in the model are Brawley, Heber, The Geysers, Baca Ranch, Roosevelt Hot Springs, and East Mesa.

The parameters used to define the characteristics for each of these resources are well depth, length of completion interval, well head temperature, well life, initial well flow rate, total dissolved solids fraction, steam fraction, and reservoir performance decline rate. The decline rate is important in determining how long the well will flow at a usable rate. It includes such elements as drawdown, interference, formation plugging, etc.; all effects outside of the well. In contrast, the well lifetime is a physical or mechanical parameter determining how long until a failure, such as casing collapse, destroys the well.

Technologies

Many of the completion technologies that have potential to reduce life-cycle costs are new ones for which there are no historical data on cost or performance. These new technologies are often composed of, or substituted for, existing technologies, operations, or equipment. Jet descaling is an example of a potential technology to improve the cost effectiveness of geothermal wells. It would supplant mechanical descaling (done with bit and reamer), but would utilize many of the same support equipment items, such as a rig. The difference between mechanical descaling and jet descaling would depend on such things as the rate of scale removal, effectiveness of scale removal, and any extra costs for additional or different equipment.

The GEOCOM model does not have sufficient data base to analyze all potential completion technologies. For many new ideas, cost and performance data do not exist. GEOCOM can, however, help evaluate such ideas. First, it is used to analyze the present completion method to which the new method will be compared. Second, the parameter changes which determine the cost difference between the new and old technologies are identified. Last, GEOCOM is used to estimate the impacts of the parameter changes that define the new completion method.

The basic technologies that have been included in the GEOCOM model are:

(1) Logging
(2) Perforating
(3) Mechanical Descaling
(4) Hydrojet Descaling
(5) Chemical Scale Inhibition
(6) Injection Pumps
(7) Submersible Pumps
(8) Line Shaft Pumps
(9) Remedial Cementing
(10) Underreaming and Gravel Pack
(11) Slotted Liner Replacement
(12) Well Repair with a Liner

MODEL STRUCTURE AND PARAMETERS

The parameters used in the calculation of an individual GEOCOM model case can be grouped according to function into the following categories: capital cost, continuing cost, productivity, schedule, and financial. A list of these parameters is given in table 1. For many parameters a default value is given. For others the value depends on which geothermal reservoir is picked or upon which workover type or method of utilitization is chosen, and this is indicated. In addition to the parameters directly used in calculation, the GEOCOM model also uses parameters of three types: case selection, general, and special. The case selection parameters determine the geothermal resource and method of using the well (injection or production well). The general parameters include parameters such as the rejection temperature (important in converting from pounds of production to Btus). Special parameters are used in the costing of the individual workovers. The model automatically calculates the base case cost for each workover type but allows the user to change the basis for cost calculations. For example, by use of the special parameter the user can change the number of shots per foot in cemeted perforated completions.

Use of the model is not limited to those workovers already programmed into it. Engineering calculations for the cost, frequency, duration, and effectiveness of a new workover can be input directly into the model.

TABLE 1. MODEL PARAMETERS

PARAMETER	VALUE	TYPE OF PARAMETER
INITIAL WELL FLOW	1	PRODUCTIVITY
RESERVOIR DECLINE RATE	1	PRODUCTIVITY
DISCOUNT FACTOR	0.00878/MO	FINANCIAL
INFLATION FACTOR	0.00695/MO	FINANCIAL
WELL LIFE	1	SCHEDULE
STUDY PERIOD	360.MO	SCHEDULE
WELL FLOW LOSS	0.125/MO	PRODUCTIVITY
INITIAL DELAY	0.0 MO	SCHEDULE
CAPITAL COSTS		CAPITAL COSTS
- WELL	1	
- OTHER	2	
WORKOVER		
- COSTS	2	CONTINUING COSTS
- FREQUENCY	2	SCHEDULE
- DURATION	2	SCHEDULE
- EFFECTIVENESS	2	PRODUCTIVITY
ROUTINE O&M		CONTINUING COSTS
- WELL	1	
- OTHER	2	
PER POUND PRODUCTION COSTS	2	CONTINUING COSTS
REPAIR		
- COST	$121,000.	CONTINUING COSTS
- TIME	999. MO	SCHEDULE
- DURATION	0.33 MO	SCHEDULE
- EFFECTIVENESS	40%	PRODUCTIVITY
ABANDONMENT COST	$18,000.	CONTINUING COST

1 RESOURCE DEPENDENT VALUE

2 CONFIGURATION AND USAGE DEPENDENT VALUE

Continuing Cost Parameters

There are five basic continuing cost parameters: workover costs, routine O&M costs, costs per pound production, repair costs, and abandonment costs.

Workover costs are the costs to workover a well such as those for bringing in a workover rig to mechanically drill and ream out scale. Only the cost of the specific workovers selected by the user are included in the total cost of the well. Costs of the workovers are put into the cost stream at the times determined by the workover schedule. Routine O&M costs include labor to operate the well, materials and supplies, and maintenance. Routine O&M includes a flat yearly amount ($54,000/yr), plus a percentage of the well capital cost (3%), plus a percentage of other capital cost (varying depending upon the usage of the well).

Per pound production costs are the operating costs that depend on the amount of production. Examples are the electricity cost for downhole pumps and chemical costs for chemical inhibition.

The repair of a well is a one-time event such as the repair of a casing failure by cementing in a liner. This operation connot be repeated and changes the profile and productivity of the well.

Productivity and Schedule Parameters

There are five basic productivity parameters: initial well flow, reservoir decline rate, well flow loss, workover effectiveness, and repair effectiveness. Figure 1 shows the productivity and schedule parameters.

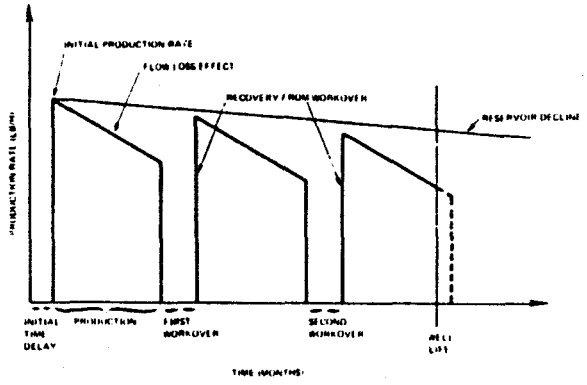

Figure 1. Workover and Production History Illustration

There are six schedule parameters: well life, study period, workover frequency, workover duration, repair time, repair duration, and initial delay. The GEOCOM model allows up to three types of workovers to be scheduled. The frequencies of the workovers are mutually independent. The model calculates the combined workover schedule and determines cost and productivity appropriately.

The initial delay parameter allows for inclusion of the effect of the delay between when the well is drilled and when the power plant is first on-line. The reservoir decline rate parameter is used to take into account the production or injection decline of the entire reservoir. The flow of individual wells may also decline because of damage to the well or scaling of the well. These effects are taken into account by the flow loss parameter. When a workover is performed the flow rate of the well can recover only well loss, not reservoir decline. In cases where the workover is not 100% effective, recovery is not complete.

If the study period, e.g., power plant lifetime, is more than the well life, the model combines the appropriate number of completed well lives plus a partial one. For the partial well, it prorates the initial capital cost according to the fraction of production during the partial well life divided by production of the whole well life. Continuing costs and benefit are taken as the values accumulated up to the end of the partial well life. All values for the wells needed after the initial ones are discounted and inflated to present value when the first well was drilled.

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SUMMARY

The results of the GEOCOM project are three fold: the establishment of a data base for studying geothermal completions, the development of the GEOCOM model, and preliminary case/sensitivity studies. The data base is included in the model in the form of default parameters. The GEOCOM code is documented in a Sandia report. The preliminary case/sensitivity studies have been reported elsewhere and are also in the Sandia documentation (Carson et. al.).

The model uses the ratio between life-cycle cost and life-cycle production or injection as a measure of effectiveness and provides sufficient flexibility to allow comparisons between the various completion and workover alternatives for wells in order to aid in management direction of a technology development program.

The GEOCOM model is an analytical tool designed to assist the evaluation of the cost effectiveness of a geothermal well. Specifically, it will aid in integrating engineering economics, operations, resource characteristics, etc. into a single measure of the value of a well. It will automatically account for such things as time-value-of-money, reservoir depletion, etc. The model provides a quick method of comparison to base-line conditions and a structure for consistent analysis. The strength of the model lies in its ability to perform calculations of cost effectiveness for multiple values of parameters. It can thus be used for sensitivity studies or optimization.

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