MODELLING FROM A USER'S POINT-OF-VIEW

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Introduction

In the context of this paper the 'user' includes all those involved in the management of a geothermal resource. The objective of reservoir modelling and simulation, in my view, should be to supply these 'users' with appropriate and reliable data so that they can make sound decisions, whether these be in financial or engineering fields. The scale of models would thus extend from a single well, which may require a workover to remove mineral deposition costing, say, $30,000, to a full geothermal field development, costing more than $100 million.

Geothermal development work can involve high risks. With the aid of modelling it should be possible to quantify risks, and, if these are considered excessive, to identify what data should be obtained to reduce them. Schemes relying on a single well are particularly hazardous. In 1974 an alfalfa drying plant was built at Broadlands next to well BR7. This well had previously been flow tested for three years, showing very reliable discharge characteristics. But when opened to supply the drying plant, the well did not perform satisfactorily and a 350 m pipeline was built to supply steam from another nearby productive well. All geothermal developments involve drilling and this, also, is a risky business. In New Zealand, over the last six years, the time to drill a 1200-1400 m investigation well shows variations of ±40% about the average (using the same rig and equipment). The time for workovers is even more variable, due to unforeseen downhole conditions affecting progress - an overrun of 100% would not be unexpected.

What information does the user want? Basic data will be the power-life and likely discharge characteristics of a field given certain operating conditions. For example, if we have a liquid dominated field, the design engineers will require information about changing enthalpy, gas and total flow for the system as a whole and for each individual well. There is no point in fitting a well with equipment to handle 100 t/h of separated steam if, after three years' production, it will only produce 50 t/h. Those providing finance for a scheme will require an assurance of its viability. How many years can the field sustain the projected withdrawal rate? For a well repair operation, those providing funds will want to know the chances of success and how much steam the well might produce if the operation succeeds. These factors must be balanced against the estimated cost of the operation, which itself relies on the problem having been properly identified in the first place. In a field which has been operating for some years, the question arises: What do we do now? Do we increase production, or do nothing, or maybe manage the field by operating only selected wells. Whatever the choice, predictions of future field and well performance are required to allow the field operator to evaluate the economics of alternative schemes.

Input Data

Reliable and accurate input data are an essential part of any useful model. Problems with input data arise in three areas. Firstly, the accuracy of the raw data, and secondly, the interpretation of this data. Raw data should always be treated with considerable scepticism. Data collection-processing systems have several possible sources of error; instrument calibration, measurement procedure and data processing to name a few. Where records have been collected over a long time period, accuracy will change as different equipment, techniques and personnel become involved.

Only in exceptional circumstances are fluid conditions inside a geothermal well and in the formation outside the well in equilibrium throughout the depth of hole exposed to formation. In most wells, there are internal circulation and interzonal flow effects. The raw data must first be interpreted to tell us what is happening inside the well, then we can extend this interpretation to obtain information about the reservoir outside the well. At this stage, we must ask ourselves: Can we make any other sensible interpretation? Is the interpretation influenced by basic assumptions and does it make sense?

The third and, possibly, the most important problem area with model input is the possibility that highly significant data may be missing - either undiscovered or ignored. For example, the importance of cool inflows originating above the geothermal reservoir at Wairakei was not recognised until very recently. Measured downflows in two wells total 100 l/s, compared with total withdrawal rate of 1500 l/s. At least three other wells have comparable downflows and an unknown amount may enter the reservoir from above via natural faults and fissures.

Wairakei

During the history of investigation and production at Wairakei an enormous quantity of data has been collected and hundreds of papers written, not a few on modelling and reservoir simulation. From the field user's point-of-view, much of this work has been interesting, but of no practical value. On the total-field scale only one simulation, by Wainwright[1], has been successful in itself as a management tool. This was written in 1969 when the field had been operating for ten years and further expenditure was being considered to increase system efficiency.

The simulation used the previous six years' production data to predict steam and water flows for the following 10-15 years. Several methods were tried and the most satisfactory was found to be one in which the performance of the reservoir was projected, then the outputs of the wells calculated for these future conditions. This method can only predict well outputs if there is no major change in fluid withdrawal rate, however it does face the problem that without a prediction of future steam flow rates in some detail, no engineering progress can be made. This simulation was complicated by the fact that the high pressure wells were to be slowly derated (to increase output) in order that power station turbines would remain fully loaded. The simulation has been remarkably accurate. In 1978 the high pressure steam flow was 8% below predicted values, and intermediate pressure steam flow was marginally in excess of the prediction. The predicted steam flows were then used in a further report to assure the engineering and financial viability of this proposed 'optimisation' scheme.[2] Construction of the scheme was completed in 1974 and power station output was increased 11% to 162 MW(e) with no change in mass withdrawal rate from the reservoir.

Ten years after Wainwright's prediction, power station output continues to fall and again the question is: What do we do now? Many options are open. Reinjection of waste water is being considered, we could drill extra production wells or as a longer term tool we could manipulate the overall field discharge enthalpy - by shutting high enthalpy or 'dry' steam producers.

All three of the above options are presently being considered. In detailed examination of the Wairakei field, Hitchcock[3] came to the conclusion that continuing rundown in output of the power station was mainly due to excess heat withdrawal from the reservoir via the high enthalpy and 'dry' steam wells. If output was to be maintained, these wells should be shut and their contribution made up from new wells producing from the liquid levels of the reservoir. Reinjection testing at Wairakei is currently in progress. Grant[4] has shown that provided there is no rapid return of cool injected fluid to the production wells, reinjection into the liquid reservoir should have a rapid and beneficial effect on wells producing from this level.

Broadlands

Since the first successful well was drilled at Broadlands more than $20 million worth of usable energy (at 1c/kWh) has been used while testing the field. Most of this energy was extracted during a three year field discharge at an average rate of 60 MW(e) equivalent. This has allowed much detailed work to be done on modelling of the behaviour of the western half of the field[5]. These, and other simulations have established optimum withdrawal rates versus lifetime for this part of the field, for a no reinjection condition, but our design engineers and financiers require much more detail. Can they be assured that reinjection is viable? What are the injection well flow characteristics now, and how will they change with time? How will production well characteristics change (in detail) over the first 3-4 years of field operation?

Conclusion

These questions cannot be answered directly by modelling. However, well presented conceptual models can be used, together with the best available information to make reliable engineering decisions. Extra assurance can be built into a scheme by having a flexible design, so that, in the event of unforeseen changes, a fallback position is available without changing the overall scheme viability. The effectiveness of this approach will depend on the skill and experience, and a mutual interchange of the information among all those involved in management decisions (i.e. financiers, design engineers, reservoir engineers, modellers etc.).

One of the prime reasons for the success of the Wairakei project was the direct, on-site involvement of a small group of very competent and resourceful engineers,who followed the project through from initial investigations, to planning, construction and later operation. All understood the problems peculiar to geothermal engineering and, as a result of this, their teamwork and down-to-earth approach, there have been few major problems with the project.

For new developments today, modelling can make a useful contribution, but much detailed engineering information must still be supplied by experience and intuition. To be effective the modeller should be part of a management team which must maintain a close and continuing liaison with those involved in investigation and design. From the user's point-of-view, the ultimate tests for any model are: Does it make sense? Does it 'feel' right? and What can I do with it?

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