An Interview with John Farison on the Challenges of Producing Power at the Geysers

John Farison is director of process engineering for Calpine Corporation at the Geysers geothermal field in northern California. His career has focused on solving problems related to impurities in geothermal fluids, including scaling, corrosion, and emissions abatement. He has a bachelor of science degree in chemical engineering from Ohio State University. The following interview took place on February 7, 2008.

Q: The resource that you're tapping at the Geysers is permeable rock—permeated with steam. How large is this resource?

A: The Geysers is the largest dry steam reservoir in the world. The Geysers' steam reservoir covers about 40 square miles at the surface, as defined by where steam has been found at depth in over 700 wellbores that have been drilled into it. The top of the steam reservoir is about 4,000 feet below the surface, and wells average about 8,000 feet deep, with the deepest wells being over 12,000 feet deep. The reservoir rock is estimated to be about 8,000 feet thick over that 40-square-mile area. So the volume of the steam reservoir is estimated to be about 50 cubic miles.

John Farison *(John Farison)*

Q: How is the Geysers different from other geothermal resources?

A: There are many geothermal reservoirs in the world, but there are relatively few—four or five—that are called “dry steam” reservoirs. When you drill a well into these, they produce, just as the name says, dry steam. Whereas all of the other geothermal resources have hot brine/hot water, and some of them will, when the pressure is released on the fluid at depth, flow under their own pressure. The hot water flashes or boils to form steam, and you have to separate out the residual water before you can use the steam. Here at the Geysers, the steam comes out of the ground without any excess water, and we’re able to use it directly. We pipe the steam overland to a centrally located power plant, where it drives a turbine and spins a generator.

Q: Are you currently tapping most of it?

A: Yes. There are some areas that may be underdeveloped, and we’re currently working to move into those areas. But I’d say the majority of the field has been developed.

You might consider the Geysers the biggest heat exchanger in the world. With geothermal energy, the resource is the heat energy contained in the rock, and steam and hot water—the fluids that we produce out of a geothermal reservoir—are, you might say, the “working fluid” used to extract and transport that heat. There is a certain amount of fluid that is in the rock when you first tap into it, and then as you produce it, that amount of fluid is reduced, but you still have additional usable heat in the rock. So if we can put more water down to continue to tap that heat, we can increase the output of the reservoir over time. We’ve been producing electricity at the Geysers for 47 years now, and it’s going to produce for another 40 years or so. It is really a huge heat exchanger, with steam wells tapping into it to produce the steam, and water injection wells distributed across the field to put water back in.

Q: Roughly, what volume of rock is needed to support one power plant?

A: It varies. Every geothermal resource is different in terms of how much fluid is produced per acre.

Q: Even within the Geysers?

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A: Yes, even within the Geysers. There is a different flow rate from each of the wells, and they change over time. That's something that we monitor, and if we can figure out that there is some problem with the wellbore, we can go back in and repair it. That is something that we are doing right now. We're repairing some wells, and adding some additional injection wells to distribute where we put the water to get the best return of steam to mine that heat out of the rock.

Q: And when the steam emerges from the wellhead, what is the chemical makeup of the steam? Does it have to be cleaned up before it's put through the turbine?

A: Geothermal steam picks up some impurities. It has rock dust. There are also some trace gases. There's carbon dioxide, hydrogen sulfide, a bit of hydrogen and methane. Those are the main gases. Inside the power plant, we have to have vacuum systems to remove those gases from the condenser to make the power cycle work.

Q: They are not removed before the power is generated?

A: No, they are removed after the steam has expanded through the turbine. The steam expands through a "condensing turbine," which converts the heat energy of the steam into mechanical energy to spin the electrical generator. As the power is taken out of the steam, the steam condenses, and it exhausts into a condenser that is operated at vacuum. And the gases that are in the steam are not condensed when hit with cold water or when you put it into a condenser with cold tubes, and those gases would build up if you didn't have a vacuum system such as a steam ejector or a vacuum pump to continuously draw those gases out of the condenser.

Q: Oh? At that point the trace gases are removed and disposed of, and some of the water that has been condensed is injected back into the formation? Is that how it works?

A: The steam that has been condensed is at about 120°F. We send that water to a cooling tower, where a lot of the water is evaporated to cool the remainder. The remaining water is cooled back down to 75°F or 80°F and is sprayed back into the condenser or pumped through the shell and tube condenser to condense the incoming steam. So it's a cycle. Virtually all steam power plants operate the same way; whether it's fired with nuclear power or fossil fueled to boil the water, the power cycle works the same way. The main difference here is that our boiler is Mother Earth.

Q: I was under the impression that some of the condensed water recovered at the Geysers was injected back into the steam reservoir.

A: Yes, about 25 percent of the steam that is produced is recovered and injected as condensate back into the steam reservoir. The remaining 75 percent of the water that comes out of the ground is evaporated in the cooling towers. We now replace most of that lost volume of working fluid by injecting reclaimed water pumped to the Geysers from Lake County and Santa Rosa.

Q: With respect to the individual plants, these plants have been installed one after another over the years. Have the designs of the plants at the Geysers changed over the years?

A: There have been some design changes. The initial plants had "direct contact condensers" meaning that they had spray nozzles. Water was sprayed into this open chamber, hitting the steam as it exited the turbine. The steam would then condense, collapse, and form a vacuum. Over time we've moved to a new design that has a "shell and tube condenser," where the steam comes in contact with banks of tubes that have cold water going through them, and the steam condenses to water. In both cases the water is pumped out of the condenser to a cooling tower.

The change of design was due to the need for hydrogen sulfide abatement. There is a small amount of hydrogen sulfide in the steam, and that creates a potential odor nuisance problem, and there is an ambient air quality standard for hydrogen sulfide emissions that must be met to avoid annoying our neighbors. The initial plants had no abatement systems, and to be allowed to develop the Geysers field, they had to add

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abatement systems to the existing plants by retrofitting them with abatement systems. The new plants had to be designed to have abatement from Day 1. It turns out that the shell and tube condenser allows you to extract the gases in a more concentrated form and pipe them to an abatement system more readily than if all the cooling water mixes with the steam, which makes it more difficult to abate the H_2S.

Q: Are the new plants also more efficient thermally?

A: Yes, there have also been some improvements in low-pressure steam turbine design over the years, so the newer plants have more efficient turbines. We've also retrofitted some of the oldest plants with state-of-the-art steam turbines to extract the maximum amount of energy out of the steam.

Q: The plants are not all of the same size. What accounts for the differences in size as time went on and more plants were built?

A: The very first two plants were 12.5 MW and 14 MW capacity, and the utility that built the plants wasn't too sure about geothermal energy so they hedged their bets by making them smaller. As the steam-field developers demonstrated ongoing success in drilling high flow-rate steam wells, the utility was willing to invest in larger power plants designed to operate for 30 years. There are a few localized areas at the Geysers that have thermal features, evidence of surface leakage of steam from the reservoir below—hot springs, fumaroles—and that's where the first wells were drilled, adjacent to those thermal areas. But they started stepping out in quarter-mile increments to see if the reservoir down below was bigger than that. They kept stepping out and stepping out on this trial-and-error basis and kept hitting steam until they had—over several decades—defined an area that turned out to be about 40 square miles. Wow! But the majority of the field here has no surface manifestations of hot springs, fumaroles, etc., that would give any indication that there is this hot reservoir below that is full of steam.

Q: I've noticed that the power output of the Geysers has fluctuated over the years. First, of course, rising quite rapidly but then tailing off. What accounts for that?

A: There was a boom time for renewable energy back in the '70s in response to the OPEC "oil crisis" and we had many companies all competing to rapidly develop the Geysers. As a result too many "straws" were being put into the same steam resource, and the output from the Geysers peaked in about 1989. Over time, they've found that they had overdeveloped the field for how much fluid is in place and for how long those flow rates can be sustained. So there was some drop off in steam production and output. Some of the plants needed to be retired. That hints at one of the challenges of geothermal energy: There is a reservoir engineering aspect of being able to determine how big the geothermal resource is, how much fluid is in place, and how long it can last. Over these last three decades there have been advances in geothermal reservoir engineering that have given engineers a better way of determining how much is there and how long it will last. But those engineering skills were in their infancy back in the '70s, when all of this development happened. They didn't really have a good way of determining how big the steam reservoir was at depth, and so that is what led to the overdevelopment. There used to be a rough rule of thumb of about 40 acres per well, but that might be too dense or it might not be dense enough. It depends on how deep the resource is and so on.

Q: Over the years have you managed to bring the cost per kilowatt-hour down? Have there been changes in terms of the economic efficiencies at which the plants are operated?

A: Early on, there were companies that operated the steam field, and there were other companies that operated the power plants, and those two might have had incentives to work at cross-purposes with one another. In 1999, during deregulation of the electricity industry in California, Pacific Gas and Electric sold its geothermal power plants to Calpine, and

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Unocal sold its steam fields to Calpine. So we now have the steam fields and the power plants under one management, and we are now able to optimize the resource and match it to the power plant and improve our efficiency. That also allows us to reduce our management and manpower costs. We've reduced the costs by consolidating under one management and reducing the manpower needed to run this whole facility.

Q: In a conventional fossil fuel plant, there would be people concerned with providing the fuel, moving the fuel, managing the boiler, and all of that—

A: Yes, for a natural gas–fired power plant—you have the gas fields, the gas wells, and gas pipelines, which are very far away, and you don't see those. They arrive underground at the power plant. There might be a natural gas–fired power plant on 11 acres, let's say, and a fairly small crew that operates that power plant. Here, we have all the wells, pipelines, and all the facilities all in one place. So you see everything related to the geothermal production all in the same area. For a natural gas–fired plant all those facilities that provide the fuel are hidden and far away. The overall footprint of a geothermal facility is actually smaller.

Q: Sure. The supporting infrastructure (for a natural gas– fired power plant) is distributed over the whole globe sometimes. With respect to a geothermal power plant, how many engineers would it take to operate a plant?

A: It varies with the geothermal resource and over time as the facility goes through its life cycle. We need engineers for all phases of the operation during the life of the facility. All of the equipment must be designed, constructed, operated, and maintained through the life of the equipment. Engineers play different roles during all of those phases. You have reservoir engineers, drilling engineers, and geologists focused on resource characterization, modeling, and forecasting. On the operations and facilities side, you have chemical, mechanical, and civil engineers, and maybe some electrical engineers dealing with all those kinds of issues. And then to operate and maintain the facilities we need trained operators, mechanics, and technicians to run the facility and keep it operating efficiently throughout its life.

Q: With respect to the future of the Geysers, when power production started dropping off because it was overdeveloped, the operators at the time—and I don't know if that was Calpine—started to inject treated wastewater from nearby municipalities. Has this stabilized the output of the Geysers?

A: Yes, injection of additional water has helped to stabilize the output of the Geysers. We started injecting water from Lake County in 1997, at about 8 million gallons per day. Then, at the end of 2003, we started injecting an additional 11 million gallons per day from the Santa Rosa area. So a combined 19 million gallons per day (about 13,000 gallons per minute) is distributed across the Geysers field. We've successfully stabilized the output at about 6 million megawatt hours of electrical generation per year for the last six years. This is enough electricity to supply the annual needs of over 1 million people.

Q: How long do you expect to operate the Geysers at this rate? Can you maintain this permanently?

A: For the long-term there will be some ongoing decline. We look at capital investment projects, adding wells, modifying equipment in plants, and trying to maximize how much we get out of the steam to continue to keep the output at the current level. We're doing a pretty good job of it currently, and we have teams of engineers and geologists working to figure out which projects would help us maintain the current output.

Q: I'm not clear about what the challenges are. Is it that water is not being distributed through the system? Is the formation itself cooling off? What are the challenges you face as you work to maintain production?

A: The key challenge is managing the steam resource. Water can short-circuit and go from an injection well right over to a steam well. That's called "breakthrough," and that can stop steam production in adjacent

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wells. You have to be careful to avoid that. We can inject too much in an area and that can, as you mentioned, "cool" an area. So we monitor the output in adjacent steam wells to see if the steam production is going up or stabilizing or is actually dropping off. By careful management over where we put water and how much—through watching the output of the nearby wells—we can optimize where we put it and the results. In some cases we were putting too much in one area and we realized that we were hurting the steam production and the plant output dropped off. Then we back off on injection into that area, and let steam production recover for awhile. We have about 350 steam wells and about 60 injection wells, and we have a computer system that monitors flow rates, temperatures, pressures, and the plant performance, and all the equipment in the power plant, and we are able to track the performance of these different plants and wells and try to optimize it.

Q: That's fascinating. Calpine manages all the plants as a single network?

A: Yes, we operate 17 power plants at the Geysers and they are interconnected with crossover pipeline so if one shuts down we are able to transfer the steam to an adjacent power plant. That adds to our reliability and how much we are able to produce, but it also helps us minimize steam emissions. It prevents us from wasting the steam, and also prevents us from emitting some of those gases that have to be abated.

Q: What would be the single largest challenge in maintaining output from the Geysers?

A: The biggest challenge is managing that water. The biggest single cost is drilling a well. Each steam well at today's prices is over $4 million. We have about 350 steam wells and 60 injectors. So we need to make sure that we protect those wells, monitor how they are doing, and do repairs on some of them. We could not afford to drill all of those wells at today's prices.

Q: This has been fascinating. I very much appreciate your time and insights on this.