GEOTHERMAL NOISE CONTROL

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In these times of growing need for new energy sources, geothermally produced energy has shown great promise. Geothermal energy is a green, relatively nonpolluting energy source that can provide power on a scale large enough to make a significant contribution to the nation's needs. One of the challenges of geothermal energy development is noise emission. This occurs after a geothermal well encounters steam and before a plant is constructed. It also arises from the necessity of shutting down a power plant for periodic maintenance. While the power plant is down, the steam (and noise) is vented to the atmosphere.

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Geothermal wells

Geothermal steam is accessed by drilling a well in areas of natural volcanic activity where the Earth's magma is close enough to the surface to encounter ground water. These areas are scattered around the world in such places as Hawaii, Iceland, Italy, New Zealand, and the Geysers area of Sonoma County, California. In Sonoma, wells are drilled to a depth of up to two miles. Wells in northern California yield so-called dry steam, a relatively clean gas, which, after the removal of entrained rocks and debris, can be used to power steam turbines directly. Once enough wells have been drilled, the steam is collected and piped to a power-generating plant.

A geothermal well has been compared to inserting a straw into a closed teapot. The water deep within the Earth's crust is heated by hot rock and the resulting super hot steam is forced out of the pipe (straw). When the pipe is open at the top the steam vents directly to the atmosphere. At the narrowest opening in the pipe, usually near the wellhead, the flow reaches a velocity of Mach one. Once the steam passes this point, if the pipe expands, its velocity can even increase for a short distance. If vented directly to the atmosphere it can produce sound pressure levels as high as 130 dBA at fifty feet. Noise from well venting has an impact on the neighborhood even in a sparcely inhabited region but it can be attenuated in a straightforward manner.

In the 1970s, while working on Environmental Impact Reports in the Geysers area of California, we studied noise generating activities associated with geothermal development. Some noise is caused by equipment used for well drilling. Most comes from the high pressure steam emanating from an active well. During several trips to the Geysers area, I met with many of the field engineers. These men were a rugged group, having gained their experience on oil drilling rigs. Their reaction to a young engineer with very little oil field experience was polite tolerance. They would explain the drilling process and what they had tried, and I would explain how the noise was generated.

Their approach to a suggestion was to build whatever it was, based on a verbal description or a crude sketch, to see if it would work. They usually found their own solutions to drilling problems.

Wells are drilled through a number of valves, as shown in Fig. 1. The middle valve has a flow diverter, which routes the steam out horizontally away from the well. The upper valve is fitted with a rotating coupling, which allows the drill string to turn while sealing off the flow. Drilling continues after the initial steam flow is encountered until there is sufficient pressure and flow to sustain a producing well. The drilling engineers explained to me the steps that had been tried to quiet the wells. A muffler has to be able to tolerate rocks and debris. The mean-time-between-failures of several conventional mufflers that had been tried were quite short. During drilling, the steam is directed into a

Fig. 1. Steam well at the Geysers geothermal field near Calistoga. (Courtesy http://www.flickr.com/photos/kqedquest/1544212039/).

Fig. 2. Drilling a steam well at the Geysers (Courtesy Calpine Corporation).

wheel about the size of a car's steering wheel, and are used to cap the well or divert the flow when steam is encountered. Due to the rocks and debris in the steam flow there is wear on the valves and they have to be periodically replaced. The practice is to use two or more valves, mounted on top of one another. After the drilling is finished the top valve can close off the well when necessary, while the bottom valve is used only when the top valve needs to be replaced. However, periodically, the bottom valve must also be changed.

The technique for bottom valve removal was to have a worker approach the valve, while the well was venting, and remove two bolts in the valve flange, one on either side of the pipe. He would then thread a large diameter steel cable up through the bolt holes and secure a cable clamp near the end of the cable. Tension was then taken up on the two cables using a D8 Caterpillar tractor. The volunteer would then gingerly remove the remaining flange bolts and retire to a safe distance while tension was being maintained on the valve via the tractor. The tractor would then drive toward the well to release the tension on the cables and allow the valve to dance around until it fell to the ground. To install the new valve the process was repeated in reverse, using a bucket loader to hold the new valve.

cyclonic separator sometimes called a *blooie muffler*, as shown in Fig. 2. This is a large, ten-foot diameter, vertical cylinder with the inlet off axis to induce cyclonic motion. Rocks are flung to the outside and collected in pockets where they can later be removed. Water is often introduced to cool the steam and reduce its volume, which lowers the flow noise. The steam exits the silencer vertically through a smaller, three-foot diameter pipe. Under strong flow conditions (170,000 lbs/hour) blooie silencers still generate loud noise levels (108 dBA at 50 feet without water injection and 103 dBA with water injection) and require large quantities of water, typically 150 gallons/minute. Thus a blooie muffler is more effective as a rock separator than as a noise silencer.

The realities of well drilling and handling the steam introduce a number of interesting engineering problems for which clever solutions have been developed by the drilling crew. A good example of the in-field ingenuity was the solution to the valve replacement problem. Like oil wells, geothermal steam wells are drilled using long sections of pipe screwed together into a drill string. The drilled hole is cased with a steel pipe about twelve inches in diameter surrounded with concrete that has been fitted with one or more large gate valves at the top. The valves are operated by hand with a

Rock mufflers

In free jets, noise is produced by the high velocity fluid mixing with the quiescent atmosphere. This is similar to aircraft exhaust noise, where the sound power follows the eighth power of the velocity. The cause of the noise is the turbulence created by the mixing, which occurs five to eight pipe diameters downstream of the pipe opening. Thus the key element in controlling the noise is to reduce the flow velocity.

Clearly, conventional mufflers would not work because the exit pipe diameter is almost the same as the inlet pipe diameter, so the flow would not slow down. The exit area had to be much larger than the entrance area. A silencer would also have to tolerate high velocity rocks and debris. I suggested blowing the steam into the bottom of a large bed of rocks in a pit dug into the ground or placed in a large steel or concrete enclosure. The open top of the pit would be the exit area, which could be made quite large. The pipe below the rocks extends across the enclosure to allow debris to impact against a steel plate at its end, which could be removed for cleaning. A perforated pipe could be used to distribute the steam evenly over the bottom of the pit. This was the first rock muffler.

I subsequently learned that a trial muffler was built on

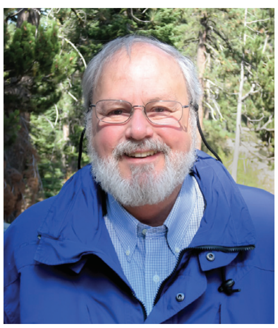
Fig. 3. Rock mufflers in El Salvador (Courtesy LaGeo).

the back of a flat bed truck. In the first prototype, the well pipe was introduced horizontally into the base of a large steel box. The truck was backed up to a well and the steam pipe was welded to the entrance pipe of the box. The pipe at that point had a diameter of about 30 inches. Unfortunately no one had determined the depth of rock required to slow the flow down and keep the rocks in the box. The first trial turned out to be more of a rock launcher than a rock muffler since quite a few rocks were blown out of the top of the box. Later, additional depth was added until the weight of the rocks counterbalanced the pressure of the flow.

Eventually rock mufflers were installed at each plant so the entire stream could be vented during shut down. I measured 72 dBA while standing next to one during a full plant vent test, almost a 60 dB reduction from raw well venting. This has become the industry standard methodology for controlling geothermal power plant noise throughout the world (Fig. 3). Later, Dick Stern and I worked under a Department of Energy program to quantify geothermal noise during drilling and production.[1] **AT**

References

1 M. Long and R. Stern, "Evaluation of Noise Associated with Geothermal Development Activities," Department of Energy, Department of Environment, under Contract DEAC-01 79-EV06200 (1982).



Marshall Long received a BSE degree from Princeton University in 1965, attended the University of Grenoble in France and the University of Madrid in Spain in 1966. He received M.S. and Ph.D. degrees in engineering from UCLA in 1971. While still a graduate student, he founded his own acoustical consulting firm, now in its 38th year. Marshall Long Acoustics specializes in architectural acoustics, audiovisual design, noise and vibration control, and other technical areas related to acoustics. He enjoys sailing, judo, soccer, reading, and writing, and is living with his family in Sherman Oaks, California. He is a Fellow of the Acoustical Society of America.