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The Spectrum of Clean Energy Innovation

Fundamental Science
Market-Relevant Research
Systems Integration
Testing and Validation
Commercialization
Deployment

# Advanced Condenser Boosts Geothermal Power Plant Output

When power production at The Geysers geothermal power complex began to falter, the National Renewable Energy Laboratory (NREL) stepped in, developing advanced condensing technology that dramatically boosted production efficiency—and making a major contribution to the effective use of geothermal power.

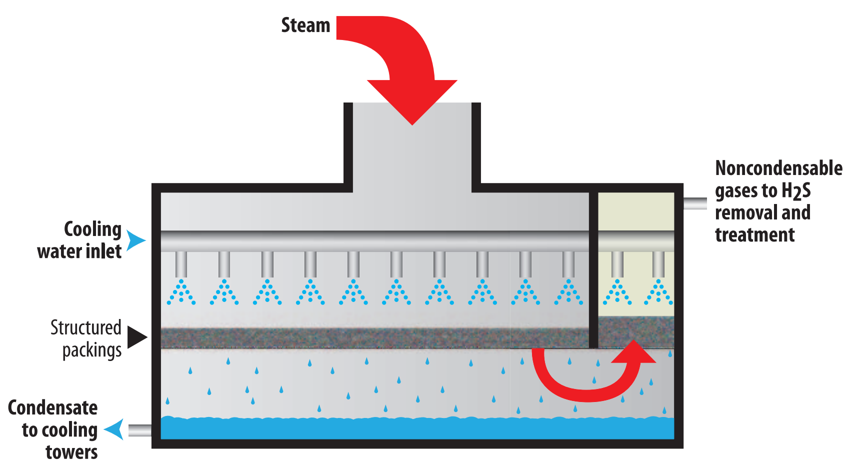
Geothermal resources—the steam and water that lie below the earth's surface—have the potential to supply vast amounts of clean energy. But continuing to produce geothermal power efficiently and inexpensively can require innovative adjustments to the technology used to process it.

Located in the Mayacamas Mountains of northern California, The Geysers is the world's largest geothermal complex. Encompassing 45 square miles along the Sonoma and Lake County border, the complex harnesses natural steam reservoirs to create clean renewable energy that accounts for one-fifth of the green power produced in California.

In the late 1990s, the pressure of geothermal steam at The Geysers was falling, reducing the output of its power plants. NREL teamed with Pacific Gas and Electric (PG&E) under a cooperative research and development agreement to create a solution for boosting production efficiency at the complex.

## Introducing a sophisticated structured packing framework

To generate geothermal energy, power plants at The Geysers capture vapor and water from beneath the earth's surface, directing it through steam turbines. These turbines drive generators, which produce electricity. Condensation of spent generator steam is a critical part of




*In NREL's Advanced Direct-Contact Condenser (ADCC), spent steam flows downward through a cocurrent section and mixes with cool water released from above the structured packing layer. Most of the spent steam condenses on the innovative structured packing framework and drips down into a hot well to be pumped to cooling towers. Any steam that has not condensed is drawn upward through the countercurrent section, and noncondensible gases are pumped out for treatment. The ADCC achieves lower condenser pressures than conventional direct-contact condensers, boosting power plant output.*

*Through deep technical expertise and an unmatched breadth of capabilities, NREL leads an integrated approach across the spectrum of renewable energy innovation. From scientific discovery to accelerating market deployment, NREL works in partnership with private industry to drive the transformation of our nation's energy systems.*

*This case study illustrates NREL's contributions in Market-Relevant Research through Deployment.*

NATIONAL RENEWABLE ENERGY LABORATORY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this power cycle, and in the 1990s, about half of The Geysers' power plants relied on direct-contact condenser systems to process the steam.

Direct-contact condensers mix cooling water with spent steam in an open chamber, typically relying on a series of perforated plates to provide surface area for condensation. The water and condensate mixture is pumped out to cooling towers to be recycled as circulating water, and noncondensible gases—including potential pollutants such as hydrogen sulfide—are removed. In Power Plant Unit 11 at The Geysers, standard direct-contact condenser technology had proven to be inefficient, consuming too much steam during the removal of noncondensible gases and creating high back pressures that decreased turbine performance.

Drawing upon previous condenser research related to ocean thermal energy conversion, NREL developed advanced direct-contact condenser (ADCC) technology to condense spent steam more effectively. ADCC systems replace traditional perforated plates with a sophisticated geometric framework resembling a three-dimensional maze. This framework—or structured packing—increases the surface area for interaction between cooling liquid and steam. Additionally, ADCC technology employs cocurrent and countercurrent flow to allow for maximum contact between the substances and to channel noncondensible gases more efficiently for removal.

## Delivering dramatic performance improvements

After implementing ADCC technology, power production efficiency in Unit 11 improved by 5%—a phenomenal gain for an industry in which performance improvements are typically measured in mere fractions of a percentage. Potential generating capacity increased by nearly 17%, and the cost of hydrogen sulfide emission abatement was reduced by half.

In the course of developing its solution, NREL created a computer model that evaluates the thermal performance of possible packing structures for a particular condenser and power plant. In addition to helping geothermal plants determine optimal packing structures, the program models chemical interactions between cooling water and spent steam—an important development for units with high quantities of noncondensible gases.

Based on the overwhelming success of NREL's solution at The Geysers, Ecolaire (formerly Alstom Energy Systems) licensed ADCC technology for use in its own geothermal power plants. Now a division within SPX Heat Transfer Inc., Ecolaire has deployed ADCC at numerous international locations, including sites in Mexico, Indonesia, and Turkey.

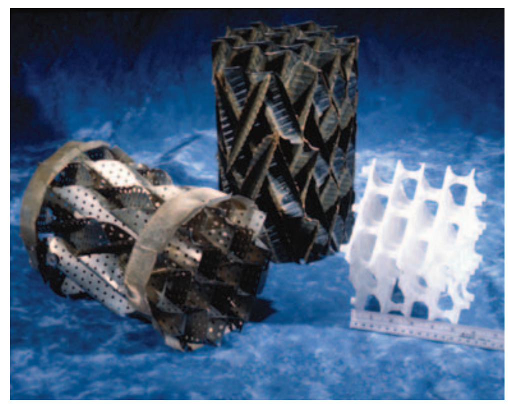
## Promising greater efficiency and reduced costs

ADCC technology holds great promise for geothermal power plants seeking greater efficiency and lower operational costs. Many plants constructed after 1980 deployed surface condenser systems—in which vapor runs around sealed coolant pipes—to prevent the release of hydrogen sulfide into the atmosphere. ADCC systems control hydrogen sulfide emissions as effectively as surface condensers and expend much less energy doing so, driving down overall costs for condenser systems by half. And for new geothermal power plants, ADCC systems cost two-thirds less than traditional direct-contact condenser installations.

When combined with intermediate-plate heat exchangers, ADCC technology also offers a lower-cost alternative to the surface condenser systems used in fossil fuel power plants. NREL designed an ADCC system with modular heat exchangers that can be cleaned individually, without requiring power plant shutdowns. Sequential cleaning eliminates condenser downtime that costs the utility industry more than a billion dollars each year, according to Electric Power Research Institute estimates.

## Key Advantages of the NREL-Designed Advanced Direct-Contact Condensers (relative to conventional direct-contact condensers):

- Achieves a lower condenser pressure to boost power plant efficiency
- Operates at a higher thermal efficiency
- Experiences minimal performance degradation by noncondensible gases
- Less susceptible to fouling and corrosion
- Requires less cooling water
- Results in lower hydrogen sulfide abatement costs
- Uses less energy for gas ejectors and vacuum pumps
- Requires less volume, with a reduced need for auxiliary support structures and piping.



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*To create a better packing for geothermal condensers, NREL researchers modeled and tested a variety of structures.* Credit: NREL


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