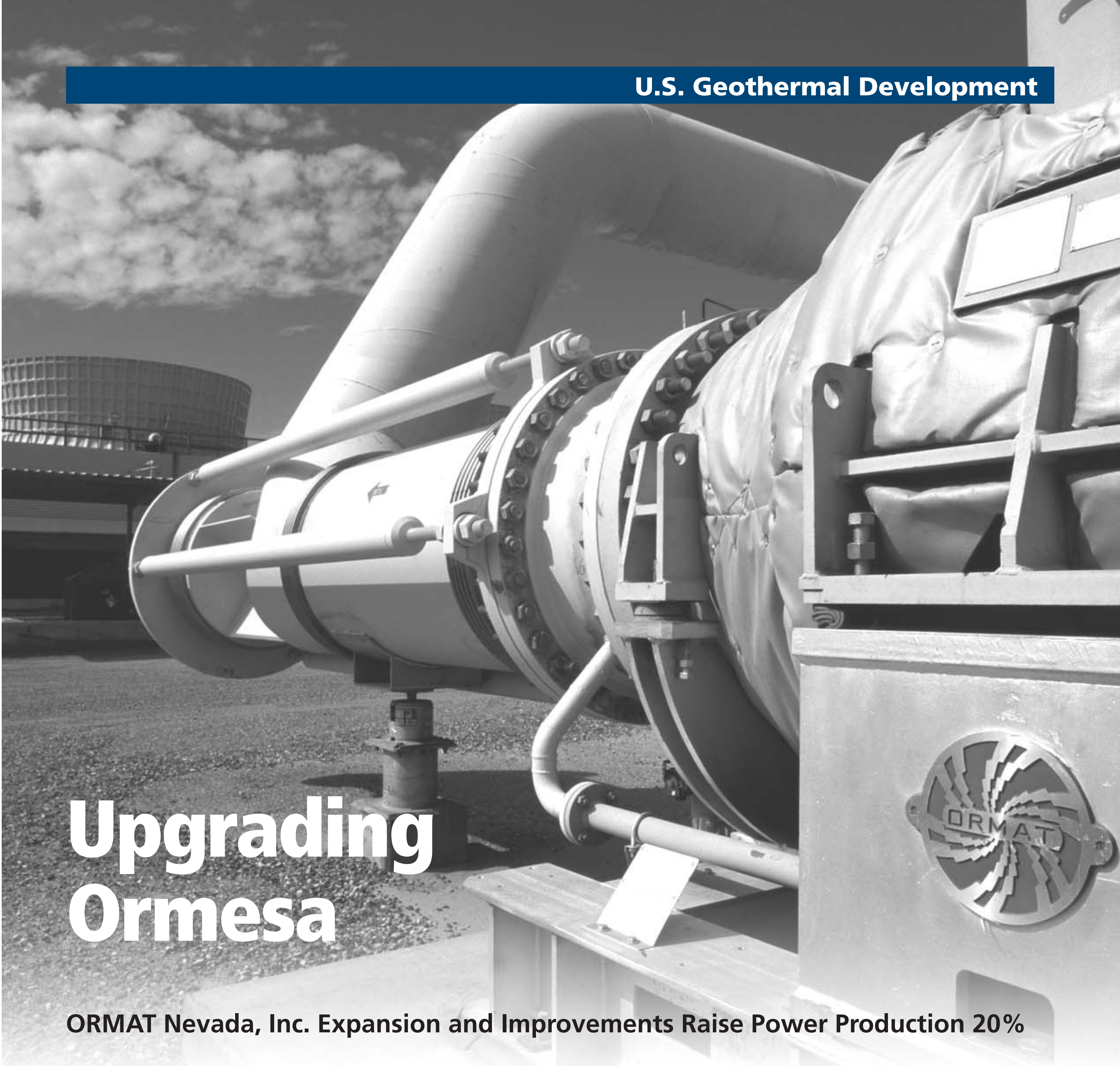


Upgrading Ormesa

ORMAT Nevada, Inc. Expansion and Improvements Raise Power Production 20%

By Don Campbell, Daniel N. Schochet and Zvi Krieger

The East Mesa geothermal power facility lies a few miles east of El Centro in southern California's Imperial Valley. Its moderate-temperature (300° to 375° F) resource is associated with the tectonic environment of the Salton Trough. After initial exploration efforts in the 1960s and 1970s, ORMAT (Sparks, NV) developed the field with the 24-megawatt (MW) Ormesa I project completed in 1986. By 1998, the facility was expanded by an additional 42-MW with ORMAT's Ormesa projects. In the years since then, the Geo East Mesa (GEM) and Ormesa operations were reliable power producers, but aging equipment and wells—and third party ownership and operation—led to inefficiencies in both geothermal fluid and power production.

At Ormesa I, two new 10-megawatt Integrated Two-Level binary turbine units now use 7 dedicated production wells for supply of geothermal fluid. The units incorporate two geothermal energy conversion levels into a single module to reduce piping and installation complexity.

Table 1. Ormesa Resource Utilization as of November 2002 and March 2004

Plant Name	Average GeoFluid Temperature 2002 / 2004	Total Geo-Fluid Flow Rate (GPM) 2002 / 2004	Average Cooling Rate (°F/year) (2004)
Ormesa I	296°F / 294°F	12,700 / 8,500	0.70
Ormesa I-Level III	- / 217°F	- / 3,200	-
Ormesa II	305°F / 309°F	9,466 / 7,500	1.48
Ormesa IH	296°F / 308°F	2,164 / 4,500	2.17
Ormesa IE	280°F / 276°F	1,175 / 5,000	0.65
GEM 2/3	331°F / 325°F	16,395 / 15,200	0.47

On April 15, 2002, ORMAT announced it had taken complete control of the GEM and Ormesa operations and began a number of rehabilitation measures that have successfully eliminated many of those problems. The company paid $41 million for the geothermal complex, which consists of six individual power plants sharing the East Mesa geothermal resource. Four of six project sites utilize ORMAT-manufactured generation equipment supplied in the late 1980s. The remaining two power plants utilize flash technology. Geothermal electricity from Ormesa is sold through long-term power purchase agreements with Southern California Edison. Projected sales are 31.5 MW and 18 MW through 2017 and 2018, respectively.

Background

Two petroleum exploration wells were drilled at East Mesa in the 1960s, followed in 1972-74 by five deep geothermal wells drilled by U.S. Bureau of Reclamation (USBR). Well locations were suggested by shallow temperature gradient holes. The USBR wells confirmed the existence of the East Mesa thermal anomaly, with 5,000 to 8,000-foot bottomhole temperatures ranging from 300° to 375° F. In 1975–1976, Republic Geothermal drilled three wells in the northern part of the field, confirming the extension of commercial temperatures, and in 1977 drilled seven additional confirmation wells.

In late 1984, ORMAT purchased development rights to the East Mesa geothermal resource area, along with the assignment of the Republic Geothermal's SO4 power purchase agreements and access to a U.S. Department of Energy geothermal reservoir loan guaranty. ORMAT then developed the East Mesa Project with a $50 million loan for the 24-MW Ormesa I power plant, which was paid in full only one year after the loan was funded.

With its December 1986 grid synchronization and subsequent continued successful operation, the Ormesa I project established the technical feasibility of larger scale commercial modular binary power plants tapping moderate-temperature, liquid-dominated geothermal resources. From 1986 on, the East Mesa projects were expanded by the 20-MW Ormesa II project (1998); the 10-MW Ormesa IE project (1988), and the 12-MW Ormesa IH project (1989).

In April 2002, after 16 years of third party ownership and operation, ORMAT acquired a 100-percent interest in the four Ormesa binary power plants, the two adjacent GEM dual-flash geothermal power plants, and the entire well field that supplies the turbines. With no power purchase agreement, the GEM facilities supply plant usage power to the four Ormesa power plants and associated wellfield pumps.

With its purchase, ORMAT eliminated multi-entity field ownership, which constrained effective management. By operating the well field to optimize power production, and replacing 20 of the original 1-MW ORMAT Energy Converter (OEC) units at Ormesa 1 with two new, high-efficiency 10-MW OEC Integrated Two-Level Units, power production from the Ormesa complex has increased from an average 42 MW to over 50 MW, without drilling any new wells. This is a shining example of the benefits conveyed by a single, value-added upgraded plant and field operations management program.

Resource Characteristics

East Mesa is located within the Salton Trough geologic province, an area characterized by tectonic extension and very high heat flow. Both are a result of its location astride the onshore extension of the East Pacific Rise, a zone of upwelling in the mantle and subsequent rifting of the overlying crust of the earth. As shown in Figure 1, there are several producing geothermal areas located within the Salton Trough.

Like other geothermal reservoirs in the Salton Trough geologic province, the East Mesa geothermal reservoir is contained within an alternating sequence of sandstones and shales deposited in a deltaic environment (the ancient delta of the Colorado River). Geothermal production in the field is generally obtained from sandstones, though some fracture permeability may occur within indurated shale units. Above the reservoir lies a thick section of fine-grained rocks that forms a low-permeability cap on the geothermal system. The East Mesa reservoir has relatively low salinity and is therefore considered to be relatively benign from a chemical perspective. However, some scaling has occurred in the hotter GEM production wells, primarily because of mixing of fluids from different zones.

There has been a significant amount of drilling in the East Mesa Geothermal Field. This activity has effectively defined the thermal anomaly and the permeability structure of the reservoir. Active production and injection wells at East Mesa typically range in depth from 5,000 to 8,000 feet. Analysis of subsurface temperature data reveals a broad, N-S trending temperature anomaly that covers an area of more than 12 square miles. Maximum pre-exploitation temperatures of about 375°F have been observed at a depth of about 6,000 feet.

Using reasonable assumptions regarding how much heat can be recovered at the surface and how efficiently it can be converted to electricity, GeothermEx, Inc. (2004) estimated recoverable energy reserves of the East Mesa Geothermal Field. The results indicate a 90-percent probability that recoverable (gross) geothermal energy reserves exceed 118 MW. The most-likely value is 148 MW, with a mean value of 167 MW (standard deviation of 38 MW).

Resource Mitigation Plan

The East Mesa geothermal resource is relatively large and has a consistent and predictable structure, which has resulted in a favorable drilling success rate. The resource is contained in a porous sedimentary formation, with highly productive zones at depths of 2,000 to 6,000 feet. Well spacing to minimize interference is a key issue, and well maintenance on a regular basis is required. However, the production and injection wells are located reasonably close together and are often completed at similar depths, resulting in cooling of the production wells as injected fluids have migrated back to production zones. The flow-weighted average temperature decline at Ormesa, is approximately 1° F per year (Table 1).

The stratified nature of the East Mesa geothermal reservoir and the operational flexibility in the field (which allows fluid to be moved from one area to another) enables cooling mitigation with one or more of the following three techniques:

- Well workover operations (selective isolation of cooler inflow zones);
- Conversion of production to injection wells; and/or
- Directing the geothermal fluid to the facility that can use it with the highest possible conversion efficiency.

All production wells at East Mesa are pumped, with pump replacements required every 24 months on average. Pump setting depth averages about 1,400 feet, and ranges from 800 to about 1,750 feet. Liner tops which limit how deep the pumps can be set are typically at a depth of about 2,000 feet, leaving room to lower most production pumps if an unanticipated reservoir drawdown were to occur. At East Mesa, however, cooling is a more important issue than drawdown. Injection wells show a gradual decline in injectivity because of one or more of the three following causes:

Scale, which forms on casing walls, in liner slots, and on the wall of the formation behind liners;

With control of the East Mesa geothermal resource completely in its hands, ORMAT instituted a comprehensive geothermal well rehabilitation program.

Fines (particles of clay and silt), which come from production wells and accumulate in the injection wells at the sand face; and

Fill, which accumulates in the bottom of injection wells as a result of sloughing into the well bore of formation sand.

Scale in injection wells is observed primarily in the GEM area. Calcium carbonate and silica are inhibited in the flash plant separator, but there is a small residual of mostly magnesium silicate. Mitigation techniques include mechanical cleanout with a drill rig or coiled tubing unit; backflowing the well by nitrogen lift using a coiled tubing unit; acidization with a combination of hydrofluoric and hydrochloric acid; and re-perforation of plugged intervals. In general, these techniques provide enough options to allow the injectivity of most injectors to be maintained.

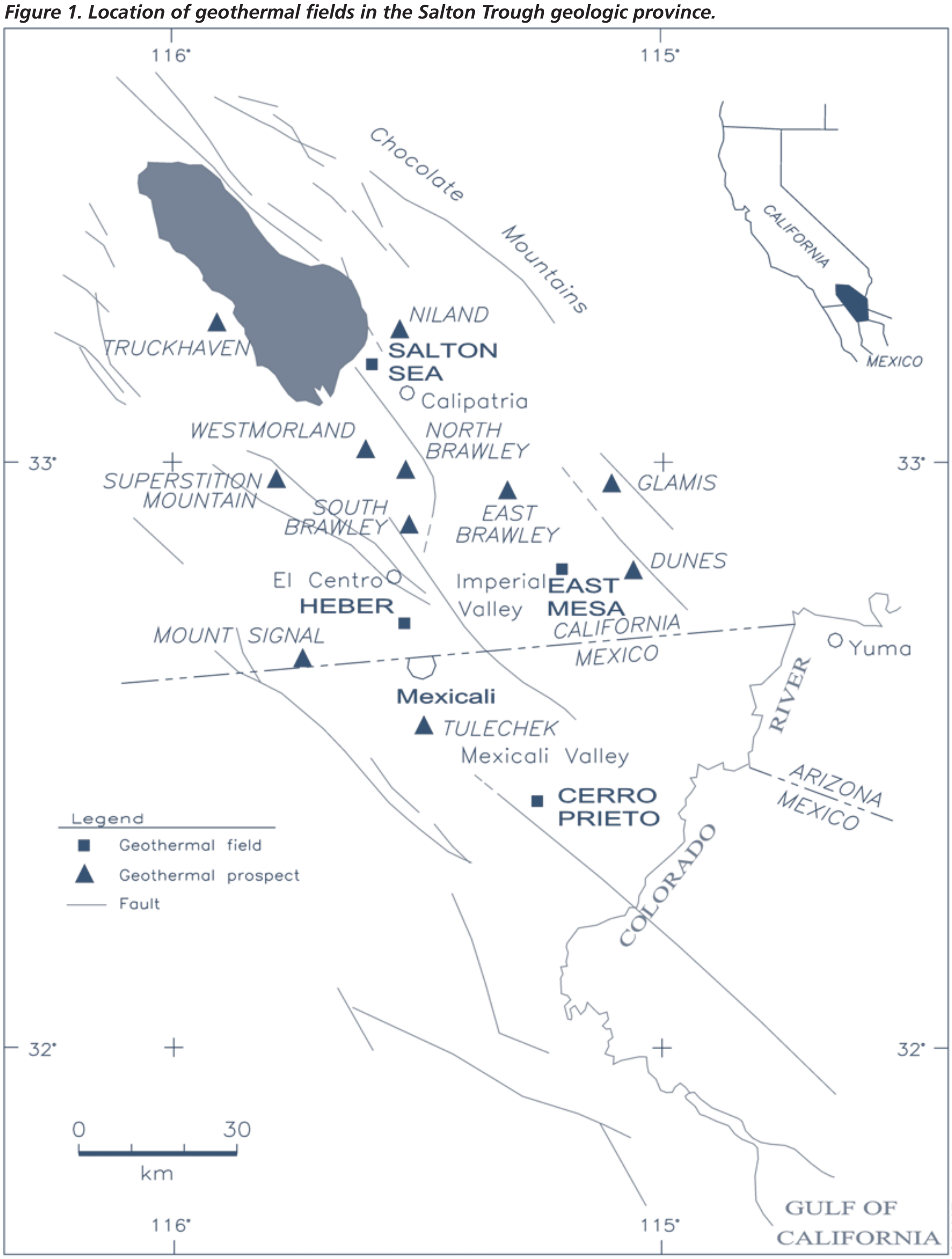
Ormesa Project Technology

In the basic organic Rankine sub-critical cycle, geothermal energy increases the organic motive fluid temperature to its boiling point without superheating. The motive fluid is then vaporized at constant temperature and pressure. The organic vapors drive the turbine, which is coupled to the shaft of the generator. The spent vapors are condensed in either a water or air cooled condenser, and pumped back into the vaporizer to continue the Rankine cycle. Geothermal fluid is maintained under pressure and 100-percent of produced geothermal fluids and gases are injected back to the reservoir. Use of the sub-critical cycle results in lower internal power consumption and lower internal pressures than encountered in the super critical cycle. As a result, the power plant design is simpler and operation is more reliable.

At Ormesa, a proprietary cascade design was employed to maximize conversion efficiency of the binary power plants. The Ormesa I power plant as originally constructed employed 26 OEC units (16 Level I units, 8 Level II units and 2 Level III units). Geothermal fluid pumped from all 12 wells at East Mesa entered all 16 Level I vaporizers at 296 °F and exited at 240 °F. The brine then flowed directly into all 8 Level II vaporizers. Exiting at 190 °F, the brine flow entered the 2 Level III vaporizers, where fluid temperature was further reduced to 165 °F.

Before being injected back to the geothermal reservoir, the brine enters all 26 preheaters in parallel to warm the organic motive fluid. This cascading principle is implemented in current ORMAT binary power plant design by means of an Integrated Two-Level Unit that incorporates

Figure 1. Location of geothermal fields in the Salton Trough geologic province.



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two geothermal energy conversion levels into a single module to reduce piping and installation complexity. The Ormesa power plants were designed as follows:

Ormesa I: The Ormesa I project utilized 26 modular OECs, in three cascading levels, with a capacity of 24 MW (net). Though projected resource temperature was well suited for binary technology, actual fluid temperatures were different than predicted and accommodated by power plant design. In December 1986, the project was completed and synchronized to the Imperial Irrigation District (IID) grid for transmission of power to Southern California Edison.

Ormesa II: With successful development of the Ormesa I well field, it was determined that a project expansion was feasible to utilize an unused portion of the East Mesa geothermal resource. Because of financing considerations, the Ormesa II project was owned and operated by a different entity. The Ormesa II project was developed in 1987, with synchronization to the IID grid in December. The 20-MW power plant utilizes 20 modular OECs in two cascading levels.

Ormesa IE: Following successful development of Ormesa II, the 10-MW Ormesa IE expansion plant was constructed utilizing 12 OEC modules in two cascading levels, producing 8 MW net power. As utilization of the East Mesa geothermal resource became more complex, the location of injection wells was carefully managed by the coordinated field management team.

Ormesa I H: The 13.2-MW Ormesa IH was developed and placed in service in 1989. The Ormesa IH power plant utilizes 12 OEC modular units in a two-level cascading configuration.

Ormesa Upgrade Program

Upon taking ownership of the East Mesa projects in 2002, Ormat embarked on a series of changes designed to simplify field operations and increase generation. These measures included:

- At Ormesa I, two new 10-MW Integrated Two-Level units use 7 dedicated production wells, and no longer rely upon part of the flow from two GEM wells, one Ormesa IE well, and one Ormesa II well. In addition, 3,200 gpm of 217° F waste fluid from the GEM plant supply the Level 3 OECs.

- At Ormesa IE, two Ormesa I wells and one Ormesa IE well continue to be used, but the remaining part of the flow is replaced by a single additional Ormesa I well.

- At Ormesa IH, one well was shut in because of low temperature. Another IH well is dedicated to the plant, as is fluid from three GEM producers, but 270 gpm of fluid at a weighted average of 317° F is diverted to Ormesa II.

- The Ormesa II project is now supplied by its own five production wells (a sixth was converted to injection), plus the 270 gpm of 317° fluid diverted from Ormesa IH.

Photos: TJC / GRC

ORMAT's work at the East Mesa Geothermal Field includes overhaul of GEM flash power plant turbine-generators.

- The number of production wells supplying the GEM plant was increased by five, resulting in a significantly higher mass flow and overall generation.

There are 41 injection wells at East Mesa, with the injection requirements of the Ormesa I and IE projects met using 10 injection wells in the Ormesa I area and four in the Ormesa IE area. The Ormesa IH and II power plants dispose of their waste fluid in four IH wells and six II wells, which also accommodate 3,200 gpm of waste fluid from Ormesa I and 1,800 gpm of waste fluid from the GEM plants.

The injection requirement for the GEM plants is disposed of in 19 injection wells within the GEM area. The net result is a simplification of operations in the field by reducing fluid transfer across the field. Minor increases in production rate (less than 3%) and injection rate (less than 2%) are easily accommodated by the existing wells.

Figure 2. Histogram of recoverable geothermal energy reserves, East Mesa Geothermal Field.

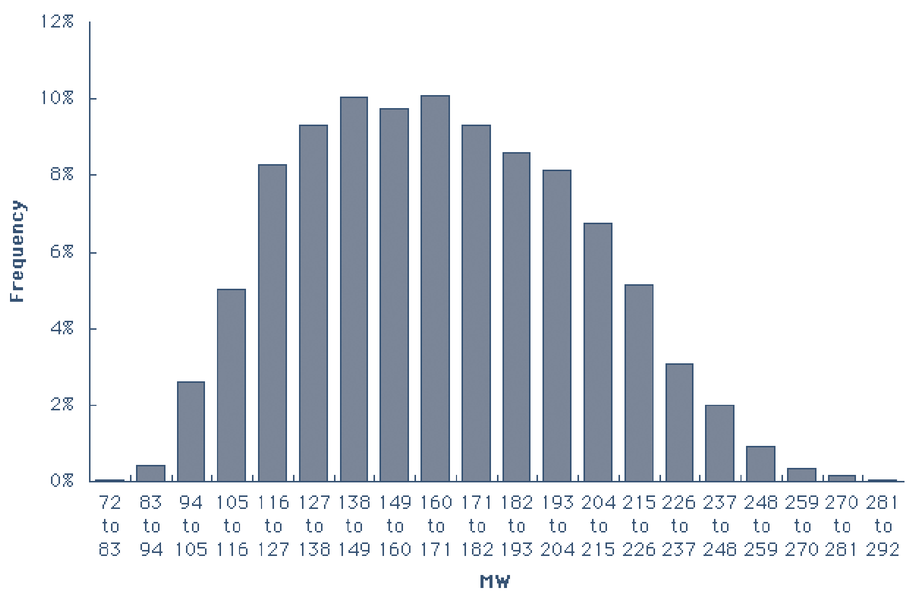
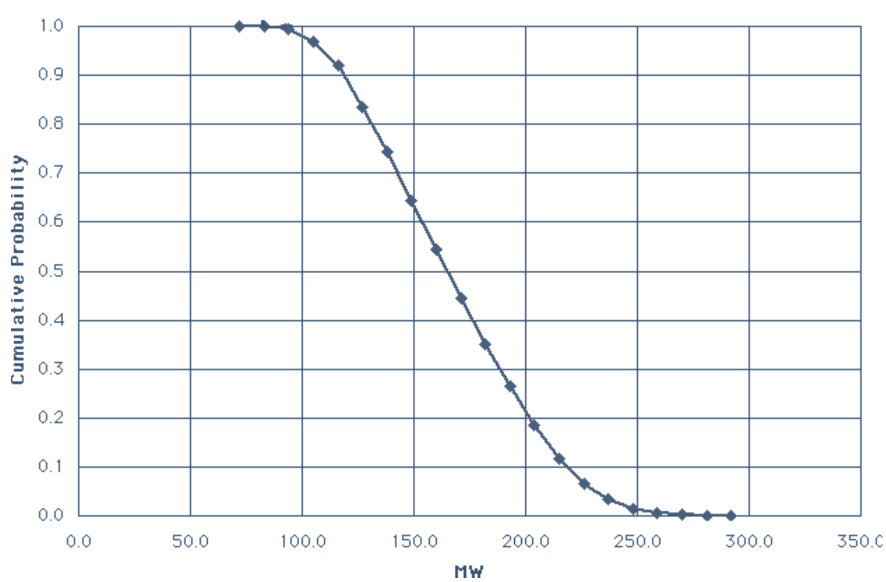


Figure 3. Probability of recoverable energy reserves, East Mesa Geothermal Field.



Acceptance Test

In October 2003, an acceptance test was undertaken to determine the success of the well field modifications described above and repairs/modifications to the above-ground facilities. The latter included:

- Repairing the cooling towers;
- Replacing the original 24 Level 1 and Level 2 OECs at Ormesa I with two new, larger Integrated Two-Level Units;
- Converting the Level 3 OECs at Ormesa I to accept the 217° F waste fluid from the GEM plants;
- Upgrading and modifying the injection pumps (includng an injection pump conversion in the GEM plants to make more steam available to one of the two GEM turbine-generators); and
- Overhauling one of the two GEM turbine-generators.

The test showed that power plant output met expectations. In fact, after correction for differences in assumed and actual ambient temperature, about 4 percent excess capacity was demonstrated during the one-week test. The upgraded Ormesa power plant projects have proved their ability to produce up to 57 MW—an increase of over 20 percent in output without any new production wells. ■

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