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Small-Scale Geothermal Power Plant Field Verification Projects

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C. Kutscher

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National Renewable Energy Laboratory

1617 Cole Boulevard
Golden, Colorado 80401-3393

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Small-Scale Geothermal Power Plant Field Verification Projects

Charles Kutscher

National Renewable Energy Laboratory
1617 Cole Boulevard
Golden, CO 80401

Key Words

Geothermal, power plant, binary cycle, Kalina cycle

Abstract

In the spring of 2000, the National Renewable Energy Laboratory (NREL) issued a Request for Proposals for the construction of small-scale (300 kilowatt [kW] to 1 megawatt [MW]) geothermal power plants in the western United States. Five projects were selected for funding. Of these five, subcontracts have been completed for three, and preliminary design work is being conducted. The three projects currently under contract represent a variety of concepts and locations: a 1-MW evaporatively enhanced, air-cooled binary-cycle plant in Nevada; a 1-MW water-cooled Kalina-cycle plant in New Mexico; and a 750-kW low-temperature flash plant in Utah. All three also incorporate direct heating: onion dehydration, heating for a fish hatchery, and greenhouse heating, respectively. These projects are expected to begin operation between April 2002 and September 2003. In each case, detailed data on performance and costs will be taken over a three-year period.

Introduction

Geothermal power plants generate more than 2000 MW of electricity in the United States, most of which is provided by plants over 5 MW in size. There are approximately 50 geothermal power plants in the world with electrical outputs at or below 5 MW. However, in the United States there are only six plants smaller than 5 MW and only a single plant smaller than 1 MW. Small-scale geothermal power plants have the potential for widespread application, but achieving cost effectiveness in small plant sizes presents a number of challenges.

To investigate cost-effective small-scale plants, NREL held a solicitation to design and build plants between 300 kW and 1 MW in size. The specific objectives of this program are: (1) to determine and validate the performance and operational characteristics of small-scale geothermal electric power plants in different regions, and (2) to determine their ability to provide distributed power to facilitate their increased use in the western United States. This project focused on the western United States because we believe that the most immediate and significant potential for small-scale geothermal power plant development lies there.

Five projects were selected for funding: Empire Energy in Empire, Nevada; Exergy-AmeriCulture near Cotton City, New Mexico; Milgro-Newcastle in Newcastle, Utah; ORMAT/LDG near Cotton City, New Mexico; and Vulcan Power near Las Cruces, New Mexico. All five projects include the design, installation, and operation (for a 3-year period) of a small-scale geothermal power plant. The first three projects also include direct use of geothermal heat, and one (Milgro-Newcastle) involves drilling a new geothermal production well.

The projects will be conducted in three phases as follows. Phase I includes identification of permitting requirements, preliminary design, resource characterization, performance monitoring and evaluation plan, market development, and Phase I presentation. Phase II includes financing, detailed plant design, a construction management plan, permitting, and Phase II presentation. Phase III includes power plant construction, instrumentation, startup/checkout, operation and performance monitoring and evaluation, and information dissemination. Progress will be evaluated at the end of each phase to determine whether work should proceed to the next phase. Because it requires drilling of a new production well, the Milgro-Newcastle project will have an additional Phase IA, between Phases I and II, to cover the drilling.

Project Descriptions

The following three projects are currently under contract.

Empire Energy

Located in Empire, Nevada, about 90 miles north of Reno, this project involves the design, installation and operation of a 1,200-kW (gross) air-cooled, binary geothermal power plant downstream from a geothermally-heated dehydration plant that produces 26 million pounds of dried onion and garlic annually. The plant, which will be located within a few hundred feet of the dehydration plant, will use 1,200 gallons per minute (gpm) of 245º F geothermal fluid from an existing 1,800-ft production well in the San Emidio geothermal system and will deliver 1,000 kW of power (net) for sale to Empire Foods, LLC. There is already an existing 4-MWe ORMAT plant at Empire. The new plant will use the same isopentane working fluid. The estimated total project cost is $2,585,000, 80% of which is being provided by NREL. The contract for Phases I and II was awarded on January 23, 2001.

This project will use evaporative cooling enhancement of the air-cooled condensers to improve summer performance. Also, the direct use will occur upstream, rather than downstream of the plant because of the dehydration process temperature requirements. A diagram of the cycle used in this plant is given in Figure 1.

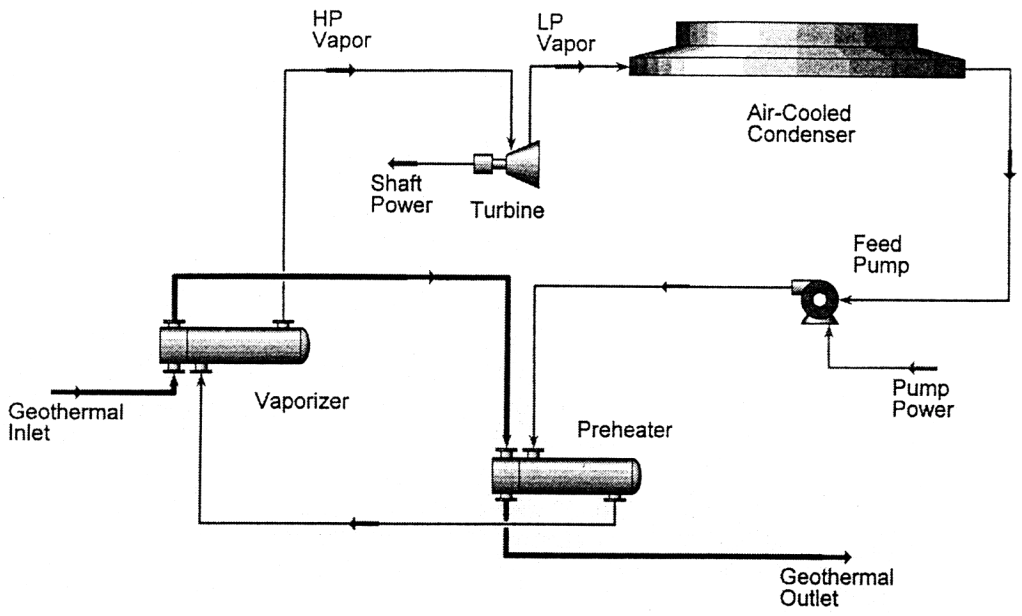

Figure 1. Empire Energy binary-cycle system schematic.

Exergy/AmeriCulture

Located near Cotton City, New Mexico, south of Lordsburg, this project involves the design, installation and operation of a 1,420-kW gross (approximately 1,000-kW net) water-cooled Kalina-cycle geothermal power plant that uses ammonia-water as the working fluid. Electricity will be provided to the AmeriCulture fish hatchery. The project will use an existing 400-ft production well to provide approximately 1,000 gpm of 240º – 245ºF brine from the Lightning Dock geothermal resource to the power plant. The plant's exit brine will be used to heat the tanks of a tilapia fish hatchery on the site. The estimated total project cost is $3,370,000, 50% of which is provided by NREL. A diagram of the cycle used in this plant is given in Figure 2. The contract for Phases I and II was awarded on December 18, 2000.

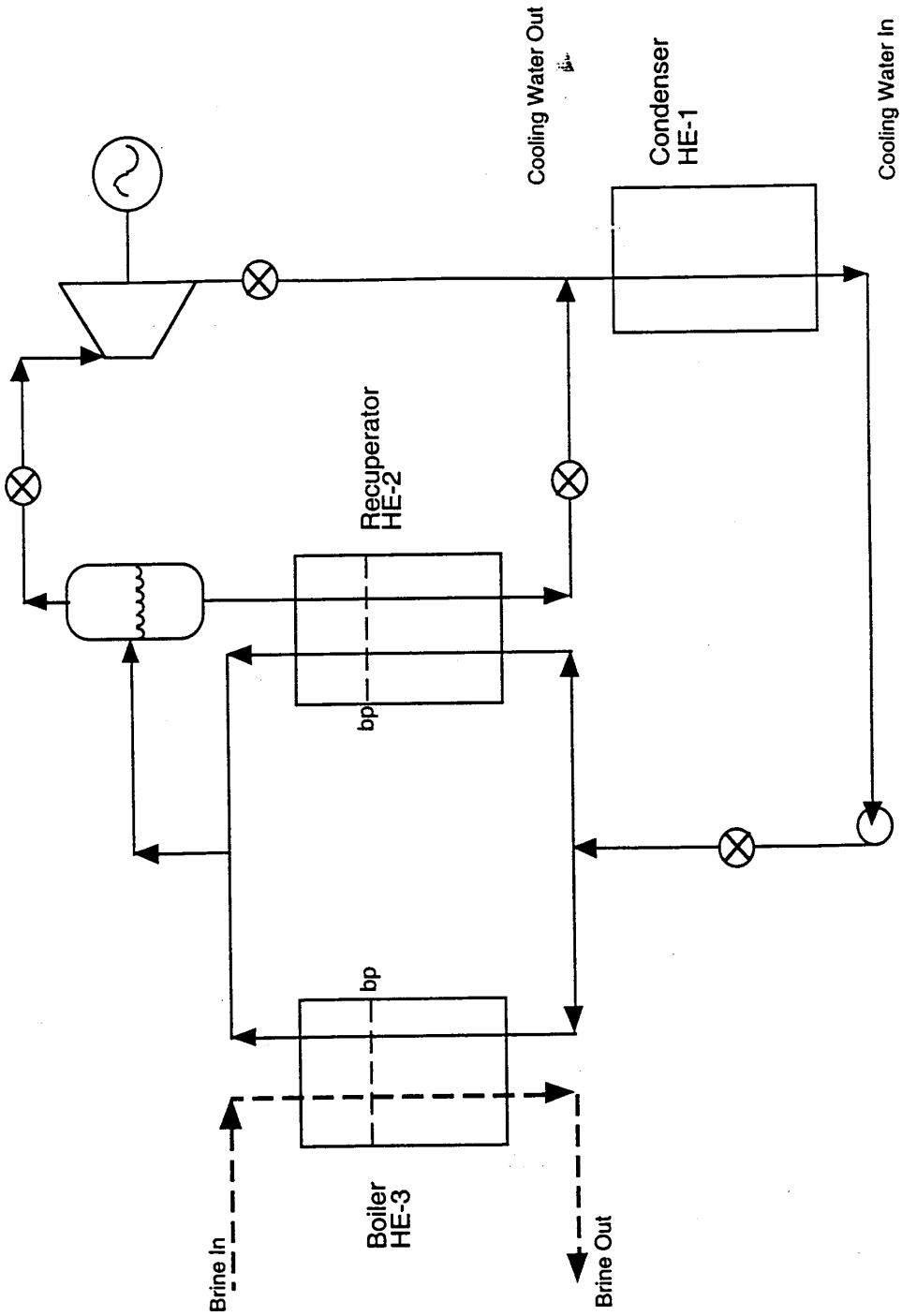

Figure 2. Exergy/AmeriCulture Kalina cycle schematic.

Milgro-Newcastle

Located about 150 miles northeast of Las Vegas, Nevada, in Newcastle, Utah, this project involves the design, installation and operation of a low-pressure flash plant that utilizes an estimated 260ºF resource from the Escalante Valley to deliver 750 kW net to the Milgro nursery. The flash plant will then provide water at 190ºF for greenhouse production at the Milgro nursery. The estimated total project cost is $2,550,000

(including approximately $400,000 for well development) of which the NREL share is 44%. A diagram of the cycle used in this plant is given in Figure 3. The contract for Phases I, IA, and II was awarded on March 27, 2001.

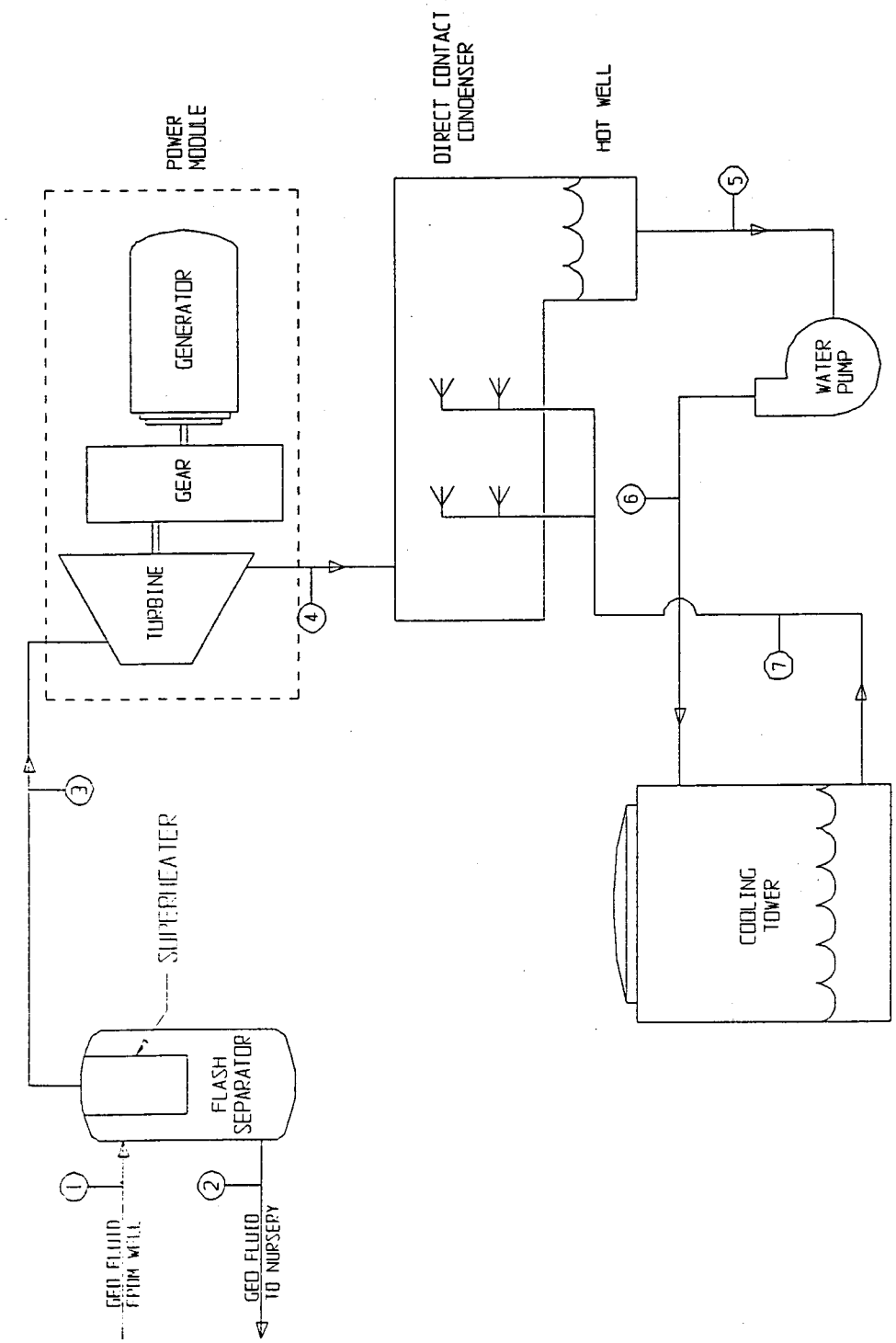

Figure 3. Milgro-Newcastle low-pressure flash system schematic.

The following two projects were selected for funding, but no contract has been awarded yet for reasons explained below.

ORMAT/LDG

Located near Cotton City, New Mexico and in the same geothermal resource area as the Exergy-AmeriCulture plant, this project involves the design, construction and operation of a 1,300 kW (gross) self-contained, factory-integrated organic Rankine binary-cycle geothermal power plant. The plant will use air-cooled condensers and deliver approximately 900 kW net to the grid. The project will use an existing well from the Lightning Dock geothermal resource that can deliver fluid at 300º – 315ºF from a 1,300-ft-deep production zone at 770 gpm. The estimated total project cost is $2,870,000 of which the NREL share is 44%. At the time of this writing (May 2001), this project is on hold pending the resolution of litigation between the owner of the surface rights and the U.S. government concerning rights to the geothermal fluid.

Vulcan Power Co.

Located near Las Cruces, New Mexico, this project involves the design, construction and operation of either a 750-kW (net) or 1,000-kW (net) ORMAT binary-cycle geothermal power plant. The project will use an existing geothermal well from the Radium Springs Known Geothermal Resource Area that will deliver 223ºF fluid to the plant at a flow rate of either 1,000 or 2,000 gpm, depending on the final plant size. The estimated total project cost is between $1,630,000 and $2,200,000, of which $500,000 will be paid by NREL. At the time of this writing, no contract has been awarded, and this project is on hold until well rights are secured.

The projects are summarized in Table 1.

Table 1. Summary of Small-Scale Geothermal Field Verification Projects

Project Name	Location	Net Power (kW)	Maximum Resource Temperature (F)	Total Project Cost (est.)	Description
Empire Energy	Empire, NV	1,000	245	$2,585,000	Evaporatively-enhanced, air-cooled binary cycle using isopentane. Uses effluent geothermal fluid from direct heating of dehydration plant.
Exergy-AmeriCulture	Cotton City, NM	1,000	245	$3,370,000	Water-cooled Kalina cycle (KCS-34) using ammonia-water. Geothermal fluid exiting plant used to heat fish tanks.
Milgro-Newcastle	Newcastle, UT	750	260	$2,550,000	Low-pressure flash plant. Plant effluent fluid used to heat greenhouse.
ORMAT Intl.	Cotton City, NM	900	315	--------	Factory-assembled binary cycle using isopentane.
Vulcan Power	Radium Springs, NM	750 or 1,000	223	--------	Factory-assembled binary cycle using isopentane

Project Economics

For the three projects now under contract, projected cost information is provided in Table 2. In addition to the cost of electricity (COE) with and without NREL cost share, costs are given in $/kW for plant, field, and well costs. The total cost is the sum of these plus other miscellaneous costs. Projected annual operation and maintenance (O&M) costs are also given. Note that a new production well is only required for the Milgro-Newcastle plant; hence it has a significant well cost.

Table 2. Projected costs of the projects.

Project Name	Plant Cost ($/kW)	Field Cost ($/kW)	Well Cost ($/kW)	Total Project Cost ($/kW)	Annual O&M Cost ($/kW)	COE with Cost Share (¢/kWh)	COE without Cost Share (¢/kWh)
Empire Energy	2,089	256	0	2,585	80	5.2	8.8
Exergy-AmeriCulture	2,600	185	30	3,370	70	4.4	6.4
Milgro-Newcastle	2,495	165	333	3,400	30	4.1	6.2

The COE range without cost share is roughly 6-9 cents per kWh. This compares favorably with the cost range of about 7-9 cents per kWh predicted for the most favorable (top eight) locations covered in the NREL study by Gawlik and Kutscher (2000).

Data Collection and Evaluation

Each project will be monitored for a three-year period following plant startup. The data collection will (1) characterize the operating characteristics, O&M requirements, and economics of the plant; (2) determine the resource supply characteristics (temperature and flow rate) as a function of time; (3) determine the plant's applicability and effectiveness in providing distributed power generation; and (4) extrapolate the expected technical and economic performance over its life cycle (e.g., 20 years), using actual data on performance and O&M costs. To determine subsystem performance, temperature, pressure, and, where applicable, quality measurements will be made at key points around the power cycle. Performance reports will be provided to NREL, monthly during the first year of operation and quarterly thereafter. At the end of the three-year data collection period, each subcontractor will prepare a final report describing all performance and cost results for the three years as well as research and development needs for improving the cost effectiveness of small-scale geothermal power plants. A typical piping and instrumentation diagram (P&ID) showing currently planned instrumentation for the Empire plant is shown in Figure 4.

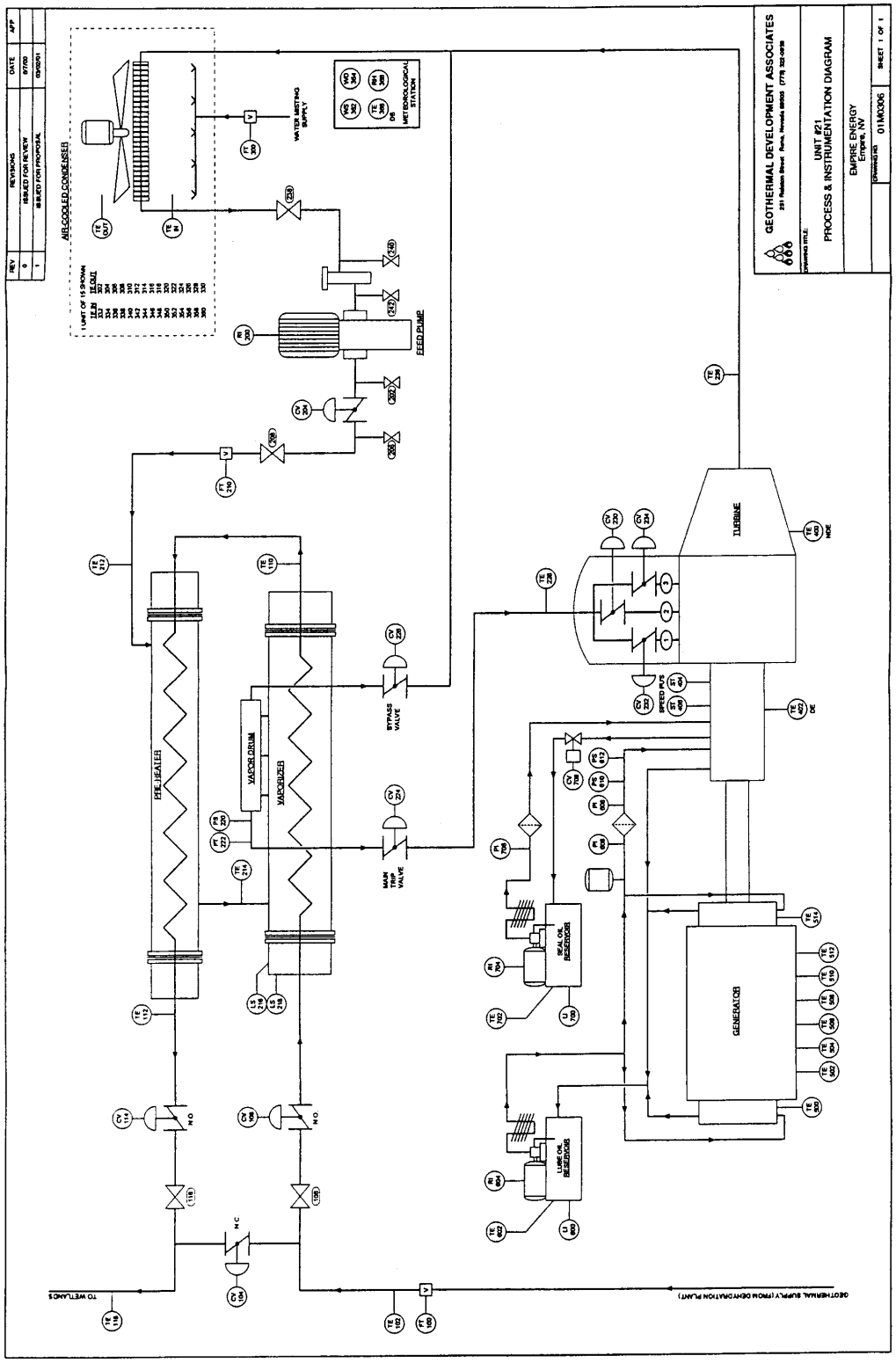

Figure 4. Piping and instrumentation diagram for Empire Energy plant.

Project Schedules

The schedules for the three projects under contract are shown in Figure 5. Plant operation is set to begin in May 2002 for Empire Energy, in December 2001 for Exergy-AmeriCulture, and in September 2003 for Milgro-Newcastle. The contracts for each project will be for three years following startup to allow for data collection. The plants will then continue to operate under the ownership of the subcontractors.

Conclusions

NREL is providing cost sharing for 5 small-scale geothermal power plants in the western United States. Three projects are under contract and design work has begun. These projects represent a variety of system designs and locations. Data collected over a three-year period will allow us to compare the different concepts and provide information on the true costs and performance of small-scale systems. It will also identify ways in which these systems can be improved.

References

Gawlik, K. and C. Kutscher, March 13, 2000. *Investigation of the Opportunity for Small-Scale Geothermal Power Plants in the Western United States*, National Renewable Energy Laboratory.

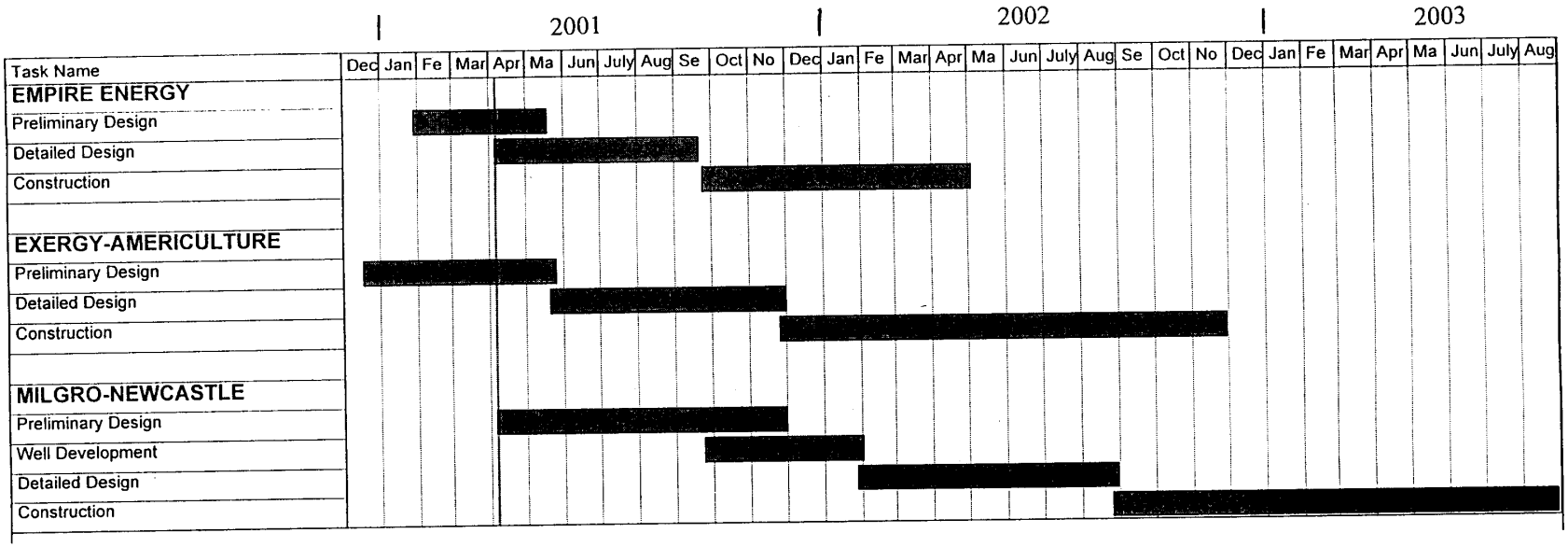

Figure 5. Project schedules.

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