



Sustainability Built Into Big Rock Ranch

By Jeff Blaevoet, P.E., Member ASHRAE

George Lucas' Big Rock Ranch is set in the rural, rolling hills of Marin County, north of San Francisco. One of the project's requirements was that rooftop equipment could not be used for the Frank Lloyd Wright prairie-style building. Other project parameters included underground parking, no natural gas, a limited supply of well water, no sanitary sewer and the desire for a quiet, invisible and energy-efficient system. A dam was built to create a lake next to the buildings. A leach field was established in the ample surrounding grounds for sanitary waste disposal, and a hill was created to hide the project from the road.

Early discussions with Bill Browning, of the Rocky Mountain Institute and U.S. Green Building Council, targeted a Leadership in Energy and Environmental Design® (LEED) Silver Rating of green measures for the project.

Project Overview

The project, located in Nicasio, Calif.,

includes a main office building with a gross floor area of 123,000 ft² (11 430 m²) over two floors, a 19,000 ft² (1765 m²) single-story commons building, a 10,000 ft² (930 m²) single-story daycare/fitness center, a 31,000 ft² (2880 m²) archive building, and a gatehouse. The commons building houses a full-service kitchen and dining facility and a 3,500 ft² (325 m²)

screening room. A single-level underground parking structure located under the main office building provides discrete accommodation of cars.

The site has summer conditions (0.1%) of 96°F (36°C) DB and 71°F (22°C) WB and winter conditions (median of extremes) of 30°F (-1°C) DB. At the owner's request, even more stringent values of 105°F (41°C) DB, summer and 18°F (-8°C) DB winter, were used. The climate has 2,440 heating degree-days.

The facility's remote location means that natural gas is not available at the site. Gas-fired equipment must rely on propane trucked to the facility.

Architecturally, the buildings were designed with shallow floor plates, resulting in a predominantly perimeter space. The buildings mainly have enclosed offices with relatively few open-plan floor areas. The envelope is comprised of

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George Lucas' Big Rock Ranch, north of San Francisco, includes many sustainable features.

stucco-covered metal frame walls with R-19 batt insulation and metal frame roof also with R-19 insulation.

The glazing is a high-efficiency double-pane glass with a low-E coating and has a U-value of 0.40 and an overall solar heat gain coefficient (SHGC) of 0.29. The campus-wide building exterior has an overall glazing ratio of 28%. Operable windows initially were included in the design, but ended up value engineered out of the project.

Geothermal Heat Exchanger Design

The adjacent property, Skywalker Ranch, has a similar set of utility circumstances which, at the time, resulted in a system of underground propane boilers and a built-up underground air-cooled condenser to reject heat from the chilled water plant. The only water available is from underground wells. The local authorities impose strict limits for the amount of water that can be drawn, which precludes the use of evaporative cooling.

The geothermal heat exchanger enabled a cooling system to be used with an efficiency comparable to one using cooling towers, but without the need to use scarce water resources and hazardous chemicals (including their discharge to the sanitary [septic] system). The closed system also results in reduced fouling, has no space requirements, and no noise emissions. Using the ground as a heat source and sink was considered to be a viable option for the circumstances at Big Rock Ranch.

The site landscaping created a new 2-acre (0.8 ha) lake by expanding an existing pond. This lake was considered as a possible geothermal source. However, this idea was abandoned because of the potential to raise the lake temperature, which

could cause problematic algae growth and have an adverse effect on the aquatic life.

The leach field was considered as a possible complementary companion, as wet conditions improve heat transfer, but the idea was eventually rejected because of difficulty in scheduling with the leach field construction. Regrading for the hill also presented an opportunity to share costs for a horizontal loop, but again the logistics of scheduling precluded this approach.

A vertical bore arrangement proved to be the most feasible field configuration with a cost of approximately \$1 million. A thermal conductivity test was conducted to establish the actual heat transfer characteristics of the ground. Drilling of the vertical field consisted of 288 bores each 400 ft (122 m) deep and 5 in. (127 mm) diameter, drilled 20 ft (6 m) on center. Inside each bore are two 1 in. (25 mm) diameter HDPE pipes with fusion welded u-tubes at the bottom, back-filled with bentonite grout with a thermal conductivity of 1.2 Btu/h (0.35 W).

Water is circulated in a closed loop through the vertical bores and the ground acts as a heat source or heat sink for the heat pumps and chillers. Heat recovery from the chillers to the heat pumps, and vice versa, is possible. An economizer sequence optimizes the position of a bypass valve to the field. The operation sequence bypasses the geofield if the temperature of the water approaching the field is greater than 64°F (18°C) and less than the temperature of the water leaving the field, or if the water temperature is less than 64°F (18°C) and greater than the water temperature leaving the field.

Pure water is used as the heat transfer medium since loop temperatures well above freezing are maintained. The lowest ground loop water temperatures were calculated to be 40°F (4°C). This

would ensure that, in the unlikely event of an underground loop bursting, no soil contamination would occur. The absence of glycol in the loop also simplifies system maintenance, reduces operating costs, increases heat transfer and reduces pumping energy compared to a system with highly viscous glycol. The life expectancy of the geo-exchange loop is 50 to 100 years.

The geo-exchange system greatly reduced the facility's need for propane as a heating source. The propane used at Big Rock Ranch mainly is for kitchen cooking equipment and for boosting the temperature of domestic and cooking hot water. This significantly reduces the delivery frequency of propane to the facility, which is in itself an energy using and polluting activity. It also reduces the owner's vulnerability to gas price hikes. Electricity can be generated from many different sources—including sustainable sources—making reliance on it less risky.

Central Plant Design

The central plant contains two 240-ton (844 kW) helical screw chillers and three 96 ton/1,050 MBH (338 kW/308 kW) circuit-reversing screw-compressor heat pumps. The heat pumps provide 110°F (43°C) heating hot water to the facility, eliminating dependence on propane-fired boilers. The chilled water primary pumps are provided with variable frequency drives (VFDs), and a primary-only, variable-flow pumping scheme circulates chilled water through the evaporators to the air handlers.

Maintaining minimum flow through chillers always is a concern in primary-only, variable-flow systems. "Active flow controls" with modulating bypass were used to avoid this problem and ensure that the chilled water flow rate is not reduced below the manufacturer's specified limits.

For improved redundancy, each large chiller is capable of handling 60% of the facility's load and the smaller circuit reversing machines can be used in cooling duty during maintenance of one of the large chillers.

The pumps also are sized for 60% of total capacity and, with the VFDs, can be overdriven to provide 80% capacity. The central plant chilled water and heating hot water serve the office, commons and day-care buildings, which are in close proximity. The archive and gatehouse structures are too remote from the central plant and have stand-alone systems.

Six air-handling units (AHUs) serve the main office building located centrally on the interior of each wing, with another two computer room cooling units serving the garage-level computer room. Outside air and relief air are brought in and exhausted through the eaves of the pitched roof. Air distribution in the office building is via a raised access floor, with custom-designed windowsill-mounted hot water VAV convectors. The chilled water temperatures are optimized for underfloor air at 54/64°F (12/18°C) (vs. the standard 44/54°F [7/12°C]), yet the overhead systems for the commons and day-care buildings use the same warm chilled water by careful design.

Heating hot water at a supply temperature of 110°F (43°C), with a 10°F (6°C) ΔT , is used for heating coils, finned tube convectors, and plate and frame heat exchangers for domestic hot water generation.

Energy Modeling

During the design phase, a detailed computer model of the facility was created using DOE-2 energy simulation software. The model showed that the building design was 37.7% below California's Title 24 Energy Standards, which are more stringent than ANSI/ASHRAE/IESNA Standard 90.1, *Energy Standard for Buildings Except Low-Rise Residential Buildings*. This is the largest reduction in Pacific Gas and Electric Company's Savings-by-Design program. Based on the building design, the facility qualified for more than \$100,000 in utility incentives for the owner.

The geothermal system provides heat rejection and generation without the need for a cooling tower or boiler. The geofield provides condenser water for the chillers and heat pumps thereby allowing the use of water-cooled equipment with significantly higher efficiencies than air-cooled chillers, without evaporating any water or discharging chemically treated wastewater to the sewer system. The 240-ton (844 kW) chillers have an efficiency of 0.45 kW/ton (0.13 kW/kW). The 96-ton (338 kW) circuit reversing screw chillers have an efficiency of 0.56 kW/ton (0.16 kW/kW) in the cooling mode and an efficiency of 1.05 kW/ton (0.3 kW/kW) (3.4 COP) in heating mode. The seasonal heating efficiency has an average COP of 4.48, which was high enough to make the project eligible for geothermal tax credits. Calculations determined that the long-term local ground temperature would not increase by more than 9°F (5°C) over 20 years.

Variable speed drives were installed on all pumps and fans. The use of the underfloor supply air-distribution system with displacement ventilation results in very low fan static pressures. The reduced static pressures allowed significant reductions in fan brake horsepower. The six units serving the underfloor system have a power-to-airflow ratio of 0.55 W/cfm (1.2 W per L/s), which is 57% less than the Title 24 allowed ratio of 1.25 W/cfm (2.6 W per L/s) for VAV systems.

This system also significantly reduced combustion gases and other products of combustion such as SO_x and NO_x produced by propane combustion. The DOE-2 energy model showed that the building design resulted in a savings of 576,200 kWh/year over a standard building designed to comply with the Title 24 Building Energy Standards. Approximately 1.33 lb (0.6 kg) of CO₂ is produced for each kilowatt of electricity generated. The 576,200 kWh reduction in energy use corresponds to the elimination of more than 766,350 lb/year (347 600 kg/year) of the greenhouse gas CO₂.

Based on actual utility cost data for the first year of operation, the energy cost savings compared to a minimally complying building (with air-cooled chillers and propane heating) were \$214,000, giving a simple payback of 4.2 years for the geothermal heat exchanger.

Conclusions

This is one of the first significant geo-exchange systems on the West Coast, and the first in the United States to use a ground loop heat exchanger with central chillers and chiller heat pumps to generate chilled water and heating hot water. ●