

Wine Caves Beneath the Northern California Vineyards

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Wine caves are an integral component of the northern California wine industry, with an estimated 130 to 150 caves currently in use for wine aging, barrel storage, tasting rooms and marketing events. The design and construction of wine caves represents a unique application of underground construction techniques.

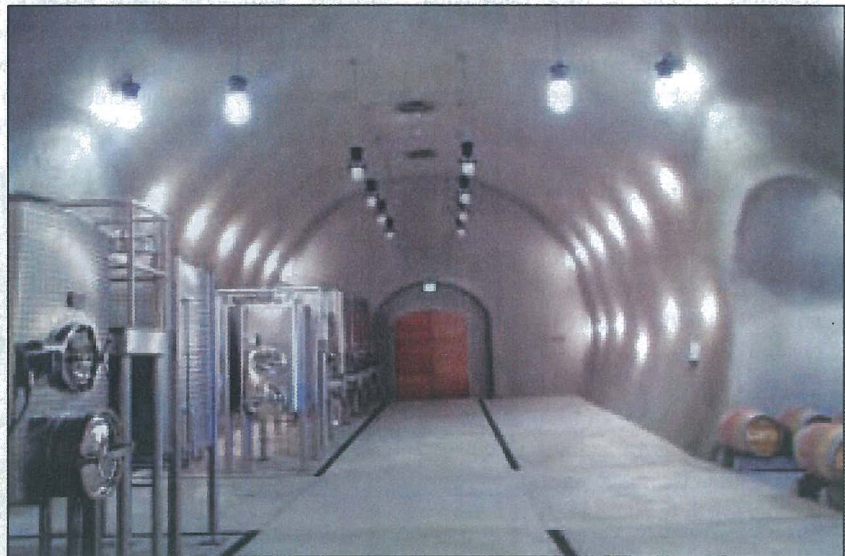
The storage of wine underground offers the benefits of energy efficiency and optimum use of limited land area. Wine caves naturally provide both high humidity and cool temperatures, key to the storage and aging of wines.

High humidity serves to minimize evaporation. Wine makers consider that humidity of over 75 percent for reds and over 85 percent for whites as ideal for wine aging and barrel storage. Humidity in wine caves ranges naturally from 70 to 90 percent.

In northern California, wine barrel evaporation in a surface warehouse is on the order of 4 gallons (15.1 liters) per each 60 gallon (227 liter) barrel per year. In a wine cave, barrel evaporation is reduced to about 1 gallon (3.8 liters) per barrel per year.

Since red wines are usually barreled and aged for two years, this represents a 10 percent gross volume loss difference. For white wines, which are barreled and aged for about one year, a 5 percent loss difference is realized. This is a significant savings for the wine makers.

The wine industry has long considered that a constant temperature between 55°F and 60°F (13.0°C and 15.5°C) is optimum for the storage and aging of



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wine. The mean annual temperatures in northern California result in a uniform underground temperature of about 58°F (14.5°C), optimum for wine caves. With a surface warehouse comes the energy-consuming requirement to cool, heat and humidify. While the most basic wine cave can cost in excess of \$100 per sq ft to construct, lower energy costs result in a net savings over the mid- and long-term.

In the Napa-Sonoma wine-growing region, as in many areas of California, land values are at a premium. Non-agricultural development is often restricted. A storage warehouse reduces the land available to grow grapes, impacts open space and natural habitats, and precludes other land uses. Land-use regulation in California places strict limitations

on the types and locations of land development. Many land use restrictions and permitting requirements do not apply to underground space.

Marketing is an important component of the modern wine industry, and many caves serve varied marketing and public relations functions. Recently constructed caves contain commercial and private kitchens, wine-tasting and dining rooms, sales rooms, wine libraries, concert and exhibit halls, staff offices, elevators, restrooms and other amenities. Some have high-end interiors, including ceramic and stone flooring, masonry-lined walls and ceilings, sculpture and artwork, mood lighting, fountains, waterfalls and chandeliers. At Stag's Leap Wine Cellars, a Foucault pendulum swings continuously across a bed of

black sand in the central exhibit hall.

The history of wine cave construction in the United States dates back to the 1870s in the Napa Valley region. Jacob Schram, a German immigrant and barber, founded Schramsberg Vineyards near Calistoga in 1862. Eight years later, Schram found a new job for the Chinese laborers who had recently finished digging and blasting tunnels and grades over the Sierra Nevada Mountains for the Union Pacific Transcontinental Railroad. He hired them to dig a network of caves through the soft Sonoma Volcanics Formation rock underlying his vineyard.

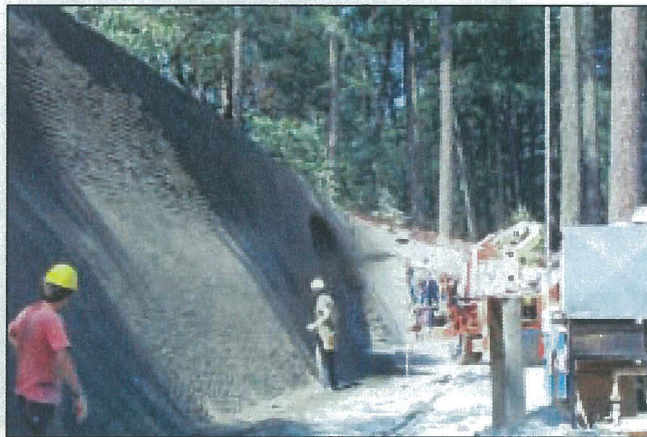
Another Chinese workforce took time away from their regular vineyard work to excavate a labyrinth of wine-aging caves beneath the Beringer Vineyards near St. Helena. These caves exceeded 1,200 ft (365 m) in length, with interior dimensions of 17 ft (5 m) in width and 7 ft (2 m) in height. In those days, the Chinese workers used pick-axes and shovels — and on the rare occasion, chisel steel, double jacks and black powder — to break the soft rock. They worked by candlelight, and removed the excavated material by hand, in wicker baskets. At least 12 wine storage caves were constructed by these methods.

From the late 1800s to the early 1970s, the development of wine caves went through a long period of “dark ages.” No new caves were built and many existing caves were abandoned or fell into disrepair. A “renaissance” of cave building began in 1972, when Alf Burtleson Construction started the rehabilitation of the old Beringer wine caves. This was soon followed by the design and construction of new caves.

In 1981, the Far Niente Winery completed the first of these “new age” wine caves in the Napa Valley. The cave was only 60 ft (18 m) long and was used exclusively to age the wine and to store empty barrels. In 1991, 1995 and 2001, the caves were expanded with ambition.

New rooms and storage areas were added, featuring different crown heights and intriguing shapes. An octagonal room was constructed for a wine library and a round-domed room was added in the complex’s center. Far Niente Winery caves now encompass about 40,000 sq ft (3,700 sq m).

In 1991, Condor Earth Technologies Inc. joined with Alf Burtleson on the design and construction of the elaborate Jarvis Wine Cave project. Over 45,000 sq ft (4,200 sq m) of underground winery and cave space was constructed, with cave spans exceeding 85 ft (25.5 m) in width. At Jarvis, the entire winery is contained within the tunneled areas, including crushing, fermentation, barrel storage, bottling, lab,



At the portals, soil nail and shotcrete walls are typically used for permanent support and are constructed from the top down in lifts.

office, marketing and hospitality areas. These caves are open for public tours, by appointment only.

It can be difficult to find optimal locations for the siting of wine caves in northern California. Much of the ground in the Napa-Sonoma areas is weathered, decomposed, faulted and jointed rock with variable amounts of soil overburden. The challenge for the design and construction of most wine caves is to create a fairly wide span in weak rock with low cover. The size of a typical wine barrel storage cave is 13 to 18 ft (4 to 5.5 m) wide and 10 to 13 ft (3 to 4 m) high. Constructed caves, however, range up to 85 ft (30 m) in width and 50 ft (15 m) in height; difficult to achieve in poor quality rock.

In areas of complex geology, good portal sites are hard to find. A typical wine cave is constructed with two or more portal sites, for safety and operational reasons. At least one portal leads directly outside, but in many cases at least one portal makes a direct connection to a winery building.

Most portals into the wine caves have rock/soil overburden heights less than 0.2 times their entrance heights and widths. The height of the portal face normally ranges from 12 to 20 ft (3.5 to 6 m). The portal areas are seldom stripped of the loose soil material and the portals are cut from the native ground surface using excavators. The side slopes of the portal are often laid back to 0.5H:1V or steeper; and the portal face is excavated to vertical or near vertical.

The construction of cave interiors can be complicated by the elaborate curves and labyrinth-style floor plans selected by some owners for their wine caves. As the ground surface slopes upward, providing more cover and usually sounder rock, caves can accommodate multiple drifts. Where possible, the cave is designed and constructed to provide intersections at least 1.2 times their width of cover at intersections. Room and pillar layouts, reminiscent to underground mine design, provide an economical construction arrangement. Tunnel legs are usually 30 to 100 ft (9 to 30 m) in length and pillars are typically a minimum of 20 ft (6 m) wide.

On most occasions, the New Austrian Tunneling Method (single or multiple face), also known now as Sequential Excavation Method (SEM), with minor innovative technology advances, is used to excavate and support wine caves.

The caves are typically excavated in an inverted horseshoe shape with a crown radius and with straight or curved legs. The tunnels are usually excavated using a tunnel roadheader or a milling

