

Larderello to Las Vegas: 1818, 1944, 2013

by Susan Fox Hodgson
cosmos@dcn.org

Larderello and Las Vegas—*la dulce vida* for geothermal travelers. Listen, no matter where you live, you can't get to the GRC Annual Meeting in Las Vegas without an itinerary. So why not begin your trip in Larderello, Italy, on the curvy backroads of geothermal memory? Here you'll meet the geothermal big three: brine mineral extraction, drilling, and power plants—with a pinch of enhanced recovery thrown in for good measure. They're all mixed together with dollops of innovation, as an amazing number of modern-day practices come straight from Larderello. "First at this," "first at that"—you hear it all the time.

Unfortunately in the early summer of 1944, near the end of World War II, change took a downward turn at Larderello when the geothermal field was completely destroyed. At the Annual Meeting in Las Vegas, keynote speaker Paolo Romagnoli, Enel Geothermal Centre of Excellence Manager, will describe all that's happened since the war—the amazing rebirth of this famous geothermal area.



But let's go back in time to 1818 when a small geothermal company named for the four owners—Chemin-Prat-La Motte-Larderel—was incorporated in Livorno, Italy, where the partners lived as French exiles in the wake of Napoleon's Italian conquest.^{1,6} One partner, Francesco de Larderel (1789-1858), a chemist by training, became executive manager for technical activities—and he was brilliant at the job.



A *lagone coperto* ("covered pool"), shown above, is made out of bricks. It collects steam and boron-bearing waters from geothermal pools in the Southern Tuscan Hills. Note the pipes for extracting the steam (a) and boron-bearing geothermal waters (b). The waters, piped into nearby tanks heated by the steam, will evaporate—leaving the borax. COURTESY OF ENEL.

Eyeing the highly mineralized hills of Southern Tuscany in Central Italy and the pools of hot geothermal waters rich in borax, the men leased what were called the *lagoni* at Monteceboli, just north of today's Larderello. (*Lagoni* are natural or artificial pools of warm or hot waters.)

Italiens landschap met parasoldennen (Italian landscape with parasols), by Hendrik Voogd, 1807. REPRINTED COURTESY OF THE RIJKSMUSEUM, AMSTERDAM.

Soon the partners were digging artificial pools for more hot waters.

All the hot waters were poured into iron boilers heated over wood-burning fires. The heat evaporated the waters, leaving the borax, and from this around 50 tons a year of boric acid was produced for about 10 years. However the increasing demand for firewood depleted the forests and cut into profits. By now it was 1827 and Francesco de Larderel, a recently naturalized citizen of the Grand Duchy of Tuscany (which ruled the area), bought out his three partners. He, and later on his sons and other family members, began fine-tuning the borax-extraction operations.

First de Larderel built one of the famous brick domes above every natural pool, calling it a *lagone coperto* (“covered pool”). A riveted metal pipe was inserted in the top of each dome to release the steam. To collect some of the steam in a controlled manner, a pipe was inserted into the dome wall about a third of the way up; to extract the hot waters, another pipe was inserted at the base of each dome. The hot waters flowed into the nearby iron boilers and the steam was fed beneath them for heat. Thus with great efficiency, the steam heated and evaporated the geothermal waters, leaving the borax and making wood and fires obsolete.^{1,3}



A drawing of the world’s first geothermal drilling rigs placed over geothermal wells at Larderello. The three-legged rigs came first and were commonly used to drill water wells with percussion bits. The print illustrates (A), a *verga artesiiana* (“artesian bar”) on a three-legged rig; and (B), a square-based drilling rig and a winch—chosen by Francesco de Larderel to replace the artesian bar, thus increasing the percussive efficiency. Through the years, de Larderel and his company made many improvements to drilling rigs and tools—and we still use his innovations.

In 1832, to augment his supply of hot waters, de Larderel drilled the world’s first geothermal wells at Larderello. He ordered hand-operated drills set up near each fumarole and natural hot pool—with fantastic results. “Although the wells had small diameters (about 10 centimeters) and were 6 to 8 meters deep, most produced more fluids at higher temperatures, pressures, and boron concentrations than any of the pools at the surface.”¹

“Around 1841, de Larderel began working with percussion bits and the three-legged drilling rigs used for water wells. Soon he switched to four-legged drilling rigs, a winch to enhance percussion efficiency, several types of drilling bits (some with a flat cross section, others helicoidally shaped), and bucket-like tools, called bailers, for removing cuttings from the well bores.

“To make the well bores rounder, de Larderel manually rotated the drill stem, allowing drillers to line the first 6 to 8 meters of the hole with an anchor pipe (surface casing) of riveted metal plate. By 1842, he could drill wells 25 to 30 meters deep.”¹

Further innovations from 1856-1870 included elevated working floors (2 meters high), walking beams to operate the drill stem and increase the percussive efficiency of the bit, protective shields for winch operators, and wellheads with a side outlet called a *gomito* (“elbow”), the first blowout-prevention device for geothermal wells. Now the wells were reaching depths of 150 to 200 meters.¹

The practice of “casing as you drill” began at this time—as did stimulating geothermal wells to increase production. To stimulate wells, the de Larderel company invented a tool called a *serpent* that extracted cold water flowing into well bores from the shallow aquifers. Removing the cold water helped waters from the deeper, hotter aquifers rise to the surface.¹

“Around 1875, the company invented and used steam-driven pumps both to stimulate wells and move borate solutions to processing plants; used insulated and riveted pipes—instead of wooden or brick channels—to gather steam and boric solutions, greatly reducing heat dissipation; and used multi-tubular boilers as heat exchangers for all production processes using pure steam or non-geothermal hot water.”¹

The first of the nine chemical production plants

Larderello



The Larderello chemical production plant in 1850, from a print of the time. COURTESY OF ENEL.

built by de Larderel in the Southern Tuscan Hills was named *Larderello* in his honor in 1846.³ The Larderello chemical plant was far enough away from the surrounding villages that workshops were erected nearby to build and maintain equipment, tools, and materials. Thus the village of Larderello came to be. The shops not only supported the drilling activity but they also provided services for the chemical production plants and for every other need of the chemical industry and the community.¹

All of these improvements—plus many more—greatly expanded boric acid production in the Tuscan Hills. In fact, production went from 1,000 tons in 1850 to 2,000 tons in 1860—creating by 1870 a near monopoly of the United States and the Western European markets. Until this time, the markets had been dominated by English and Dutch trading companies buying borax compounds from Persia and the Middle East.

And here is where borax becomes the first documented connection between Larderello and The Geysers Geothermal Field in Northern California—then a resort. In 1856 John Veatch, a California doctor, found borax in the hot springs at today's Sulphur Bank Mine, very near The Geysers and related to the vast geothermal system in the area. Veatch explored further, and at nearby

Borax Lake he helped establish the California Borax Company, the first commercial borax mining operation in the U. S. The company mined borax from 1860 to 1868. From 1882 on, others founded borax mines in Death Valley, in Southern California.⁷ All of the activity caused world borax prices to plummet in the 1880s, taking business away from Larderello and the Tuscan Hills, which adjusted to the loss with stellar innovations.

The changes happened at Larderello where, on July 15, 1904, a pivotal event in geothermal history occurred, the start of modern geothermal-electrical generation. On this day five light bulbs were lit with electricity generated from geothermal steam—a process invented by Prince Piero Ginori Conti (1865-1939)—the son-in-law of Florestano de Larderel. (Florestano was the son of Federigo, who was the son of the founder, Francesco de Larderel.) In 1906, Ginori Conti became head of the very company his inventions helped revive.^{1,4}



Photo of Prince Piero Ginori Conti at Larderello in 1904. He is standing by his invention, the first mechanical device to generate electricity from geothermal steam. COURTESY OF ENEL.

To light the bulbs, Ginori Conti used a piston engine coupled with a 10 kilowatt dynamo; the electro-mechanical device was driven by pure steam produced in a small heat exchanger fed with wet steam from a well near Larderello. Thus the first use of geothermal steam for power generation was carried out with a transformation cycle, today called a “binary” or an “indirect cycle.” Ginori Conti chose the indirect cycle with the aim of re-launching his chemical company. He wanted to lay the technological basis for a simultaneous use

of the heat in fluids for power generation and the minerals in fluids for chemical production.¹

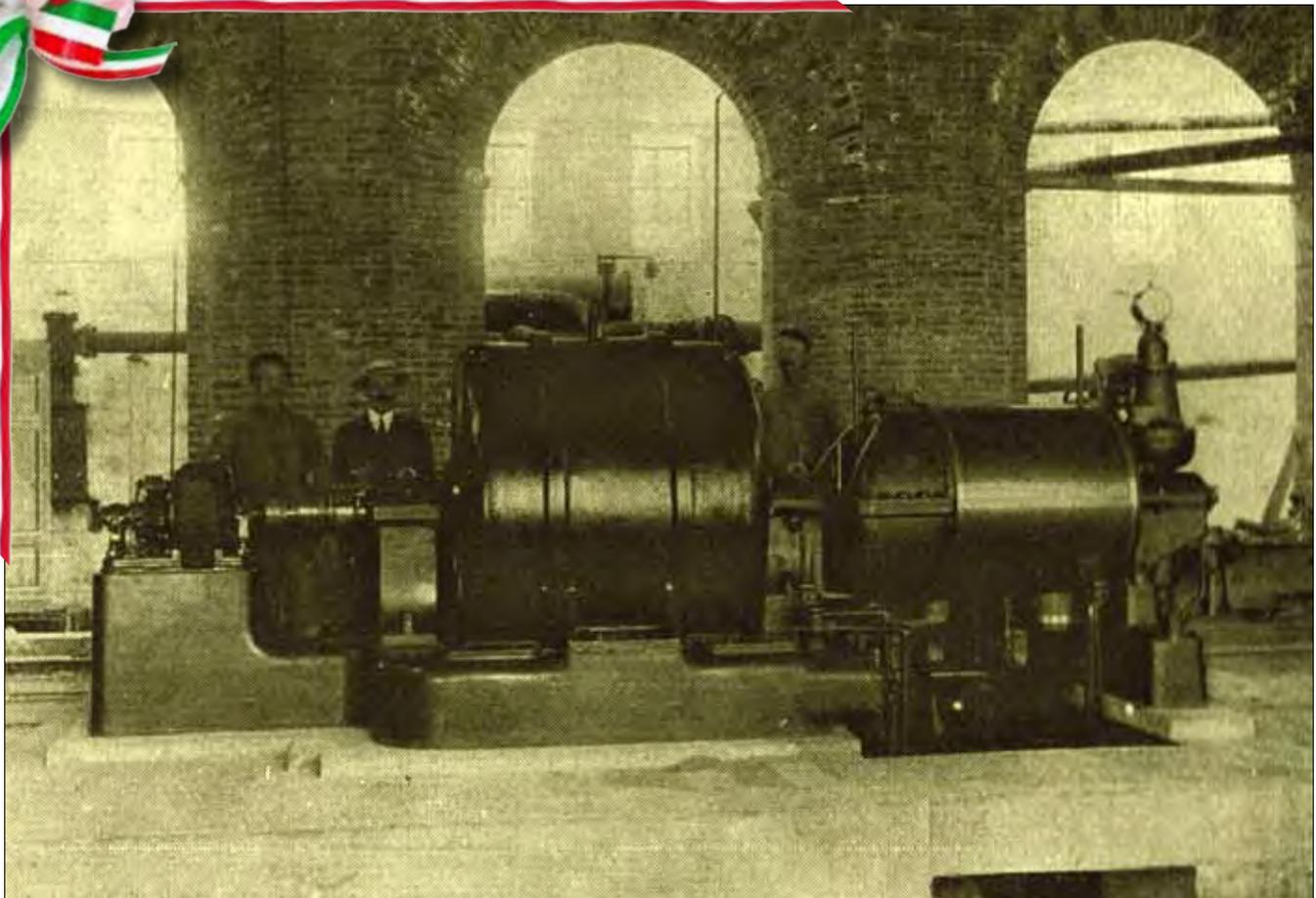
The encouraging results of his experiment quickly led to the first prototype of a geothermal power plant, which went into operation in 1905. The plant included a Cail reciprocating engine connected to a 20 kilowatt dynamo. The first small power station, along with another installed in 1908 composed of a Neville reciprocating engine coupled to a second 20 kilowatt dynamo, enabled electrification of Larderello's most important industrial plants and the main residential buildings.¹

In 1913, after absorbing all of the small local firms that had been producing boric acid with obsolete technology, Ginori Conti's company, now called the Società Boracifera di Larderello, began exploiting geothermal fluids over the whole of

Southern Tuscany, an area of several hundred square kilometers. That same year, just 100 years ago, Power Plant Larderello 1 began generating 250 kilowatts of electricity—the first commercial geothermal power plant in the world. The electrical energy it produced was fed into a network serving all of the chemical production plants, plus the main buildings of Larderello and the other villages in the region. The plant was designed and built by the Tosi Electromechanical Company to operate with wellhead fluid pressures of up to three atmospheres. The turbine was driven by pure steam obtained from a heat exchanger supplied by two wells.^{1,4}

Other technical changes followed, and many are not mentioned here. These included the switch from percussion to rotary drilling in 1920 and an increase in geothermal space-heating

*Happy Hundreth Birthday!
Buon Centesimo Compleanno!*



Congratulations! The year 2013 marks the world centennial for generating the first commercial, geothermal-electrical power. This 250 kW geothermal power plant was built in Larderello, Italy, in 1913. COURTESY OF ENEL.

Larderello

projects. By 1940, all establishments, plants, facilities, workshops, and residential buildings—and a number of greenhouses and agricultural installations created by the company, not only in Larderello itself but throughout the geothermal region—were warmed with the residual heat of low-pressure steam.¹

“But without a doubt, the most significant achievement of geothermal development at Larderello was the development of geothermal-electrical generation. Power Plant Larderello 1, dating from 1913, was followed in 1916 by two, 3.5 megawatt turbo-alternator units, also manufactured by Tosi. The units used an indirect cycle to generate power and were supplied with pure steam obtained from heat exchanges. The size of the two units, although very small by today’s standards, equaled most of world’s



This geothermal power plant at Larderello was destroyed in World War II, in the early summer of 1944.

“During World War II, New Zealand governmental scientists arranged for army engineers serving with the British 8th Army in the Italian Campaign to visit, inspect, and report on geothermal-power development at Larderello. The engineers were asked to gather as much information as possible about Larderello, with a view to using the technology at geothermal fields in New Zealand. Unfortunately when they arrived at the power plant in June 1944, they found much of it destroyed.”

“In 1948, New Zealand grew interested in developing Wairakei Geothermal Field on the North Island. The country again sent engineers to Larderello, where they found rebuilt power plants producing over 140 MWe of electricity and a 142 MWe power plant under construction.” PHOTO COURTESY OF IAN THAIN; TEXT BY JOHN LUND.⁵

installed hydroelectric and thermal power plants at the time.

“The first pilot turbine fed directly with natural steam produced by the wells (“direct cycle”) had a capacity of 23 kilowatts. It was installed at Serrazzano in 1923 and remained in operation with no significant problems for about two years. From 1925 on, it was used to train technical personnel at the Larderello company school. Following the pilot turbine, other direct-cycle turbines were installed at Castelnuovo (a 600 kilowatt unit in 1926 and an 800 kilowatt unit in 1927) and Larderello (a 3.5 megawatt unit in 1930). The total installed-electrical capacity in the hills of Southern Tuscany, as of December 1930, was 12,150 kilowatts—of which 7,250 were from an indirect cycle and 4,900 a direct cycle.

“The first larger geothermal power plant, named Larderello 2, was completed in 1939 and included six 10-megawatt units fed by pure steam in an indirect cycle. The choice of this cycle met the need to use most of the natural steam produced at Larderello to extract the valuable chemical by-products.

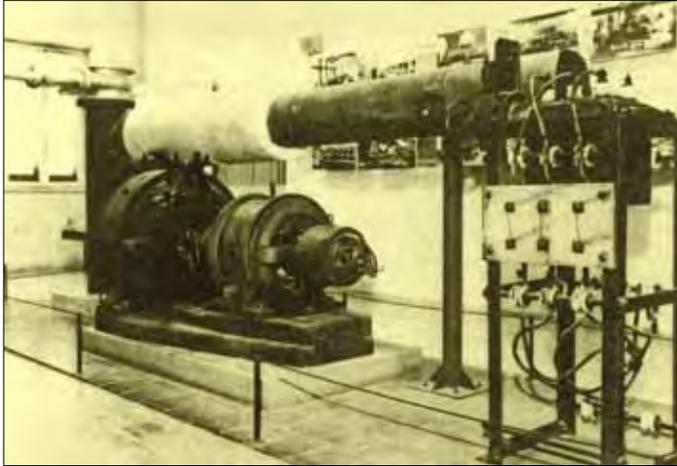
“Between 1940 and mid-1943, other units went into operation: four 10-megawatt units at Castelnuovo (similar to ones at Larderello), one 3.5 megawatt, direct-cycle unit at Sasso Pisano, and two units for a total of 8.5 megawatts at Serrazzano based on the direct cycle. By the end of 1943, the total installed capacity in the region was 132 megawatts.

“At the start of 1944, the Larderello region became directly and dramatically involved in the events of World War II. The Larderello power plants were strategically important, as they were fed from an indigenous energy source and were supplying electricity to the entire railway network of Central Italy. In the spring of 1944, not far

Today in Larderello Geothermal Field*

| Production Wells | Injection Wells | Power Plants | Megawatt Hours of Electrical Production |
|------------------|-----------------|------------------------------|---|
| 308 | 69 | 30 Units, 28 Power Plants | 4,765,000 |

*2012 DATA COURTESY OF PAOLO ROMAGNOLI.



The world's first exhausting-to-atmosphere geothermal turbine (23 kW), installed at Serrazzano in 1923 and used at Larderello for technical training since 1925. It survived the war unscathed. COURTESY OF ENEL.

from Larderello, the retreating armies in Italy organized the so-called 'Gothic Line,' a strategic line separating the two opposing forces.

"All of the geothermal power stations and chemical plants in the zone were heavily bombed and destroyed, and almost all of the geothermal-production wells were blown up by the charges placed at the bases of the master valves. A desolate scene of noise and ruin spread over the region, ending the first modern phase of geothermal development in Italy."¹

"Remarkably, the personnel at the power plants and the boric acid factory managed until June 28 to continue working 8-hour shifts, albeit at night. Once the plants were no longer in the line of fire [in the late summer], they were quickly rebuilt.' These comments on the destruction and rebirth at Larderello Geothermal Field are based on a diary kept by Mr. Geo Desi, an Italian eyewitness to the attacks at Castelnuovo and Larderello."²

But something tangible had remained after all. "Amid the destruction, found miraculously intact in the late summer of 1944, was the same 23 kilowatt, exhausting-to-atmosphere turbine that

had been used since 1925 for technical training."¹ Today it proudly sits in two Larderello museums.

One is an elegant, virtual, geothermal museum highlighting the early days in Larderello Geothermal Field. The wonderful website was created by Enel Green Power, the field operator. Enel Green Power itself is owned by Enel, standing for the Ente Nazionale Per L'Energia Elettrica, the largest power company in Italy. The virtual museum address is: Enel.com/geomuseo/.

If you are in Larderello itself, why not stop by the *Museo della Geotermia Enel*, relocated on the ground floor of the newly renovated Palazzo de Larderel? The enlarged museum features new exhibits with explanations in Italian and English. Find out more information at: www.museivaldicecina.it/it/museo_della_geotermia.php. The email address is: museogeotermia@dealcoop.com.

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Acknowledgments

The author wishes to thank Paolo Romagnoli, Ruggero Bertani, Raffaele Cataldi, Ronald DiPippo, Myriam Vinotto, Ian Thain, John Lund, and Toni Boyd for their help. ■