Brine is the key word in the day-to-day working life of these two specialists. According to Mr Furmanski, the brine that CalEnergy uses to generate power is one of the most aggressive in the world and is therefore extremely demanding on the materials of construction. “We are responsible for the implementation and development of new projects in the geothermal field. These projects are aimed at improving power station performance and building new power stations. Our biggest challenge throughout these projects is finding the right material.” Mr Furmanski explained that geothermal power generation plants are fed with highly corrosive hot brine with chloride levels varying between 106,000 and 167,000 ppm at pH levels between 4.5 and 5.7. The geothermal brine also contains H2S and CO2 at a concentration of 10-50 ppm and 800 to 4,800 ppm respectively. “The combination of high chlorides with H2S and CO2 in two-phase liquid/vapour flow pattern makes this brine extremely corrosive.”

CalEnergy is an American-based independent power producer. Its geothermal operations in California produce 340 megawatts of electricity – enough power to meet the energy needs of 340,000 homes.

Stainless Steel World spoke with senior project engineer George Furmanski and senior procurement specialist Robert Eberle about their activities and the use of corrosion-resistant alloys in their operations.

In different applications throughout the plant, Inconel 625, in high-temperature and duplex 2205, in low-temperature have performed well. Super duplex 2507 plays an important role as a substitute for Inconel 625 in high-temperature applications.
In the third part of the production process, brine is delivered to the first vessel of the plant, a high-pressure separator. This vessel is fabricated from Inconel 625 explosion-clad carbon steel plates. Mr Furmanski: “After the brine leaves the first vessel, the temperature drops to 320º F (160º C). The piping from there on is, again, Inconel 625 or 2205 duplex. In further downstream stages, the brine temperature is reduced even further to 225º F (107º C) and at this final stage the geothermal brine is pumped back into the reservoir through cement-lined piping, which works well in the low-temperature single phase flow.”

**Lean Duplex**
The engineers’ search for the most cost-effective material selection within the brine processing facilities is not limited to duplex 2507 and 2205. According to Mr Furmanski, they are also starting to use lean duplex materials such as AL 2003. “This material was developed by several companies, but we feel that the lean duplex coming from Allegheny is the best solution to our needs. We recently completed a job using lean duplex tubing in a condenser. It was the first time anyone has ever used this material for this application, and we are very anxious to see how it performs over the long term. The original material selected was 316 stainless, but it failed after four years in service. Over 20 per cent of the tubes cracked and started to leak.”

With failures we reach a topic that is sometimes overlooked: welding. Mr Furmanski indicated that in the United States there are not many companies that can provide proper welding specialists or welding equipment. “The majority of the stress corrosion cracking failures

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Traditionally, the wellhead assembly is made of Inconel 625 and this material is also used for the piping directly off the wellhead to the pressure controlling station.

**About geothermal power**
Geothermal power is a renewable source of energy and uses the natural heat of the earth to generate electricity. Rainwater seeps below the earth’s surface and comes into contact with magma (molten rock), becoming very hot. To reach this fluid, wells are typically drilled to a bottom-hole depth of 5,000 to 10,000 feet and the fluids brought to the surface are partially converted or “flashed” into steam. The steam drives the turbines that generate electricity. Any remaining fluid is reinjected back into reservoir.
DUPLEX

that we have seen occurred in the weld or the heat-affected zone. We therefore now tend to favor companies that use fully automatic welding machines. Our biggest technical challenge right now is to find people who can weld 2507 duplex.

STEAM

Piping equipment including valves and pumps are required to meet the same high standards to deal with the brine, high temperatures and pressures. Mr Eberle: “Our valves are also exposed to the same torturous brine. We therefore use an in-house developed technique to overlay the valves and valve gates with highly abrasive resistant-materials like Stellite and Ultimet. This technique is commonly applied to our API gate valves. There are applications that require specially made valves for steam applications. These valves are manufactured by Vanessa Valve and are constructed using a combination of alloys.”

The pumps that are used for geothermal power generation are typically API-style pumps and made from high nickel alloy and reactive metal, says Mr Eberle. “The majority of our pumps are used to handle brine at high temperature without solids. We also have a number of pumps in low-temperature service that handle brine with solids. They are typically rubber-lined.”

ACIDIFIED BRINE

The last territory to be conquered is medium-temperature acidified brine at pH below 3, for which the company is currently testing super duplex and high-nickel alloys. As a procurement specialist, this presents Mr Eberle with a number of challenges. “The metals that we deal with are non-standard materials for construction of pipes, valves, pumps, fittings and the like. In many ways we have to work closely with the manufacturer and bring in the expertise that will produce a material or product to suit our needs. This approach has stimulated the use of duplex. It is a step up from stainless steel but keeps us out of the more expensive nickel alloys.”

About Robert Eberle

Robert Eberle began his career in power generation in the mid 1980’s working for Boe-Con Construction, a division of Boeing Co. He was involved in capital purchasing of construction equipment until joining Magma Power.

Robert joined the geothermal industry in 1991 as a procurement specialist involved in major multi-million dollar projects for the plants. His background in the welding and metallurgy fields fits well with the research and development projects he has been involved with. He was selected by engineering to participate in projects involving high nickel alloys such as Inconel 625, and Hastelloy C-276, super duplex 2205, 2507 and Al 2003 alloys as well as titanium production well casing. Robert’s vast knowledge surrounding these materials has involved him in projects such as loose alloy linings of pressure vessels and many duplex stainless piping projects. Robert’s responsibilities have not only required knowledge of materials, but the welding and joining of many dissimilar metal combinations such as carbon to nickel alloys, nickel to stainless and super duplex to carbon or stainless. Most recently, Robert has been involved with engineering in the investigation and possible purchase of thousands of feet of 2507 piping and fittings to be formed, welded, X-rayed and heat-treated for a major pipeline modification.

Update.

Since work on this article was completed, we have learnt that CalEnergy has ordered 30” super duplex 2507 pipe for hot-brine service from H. BUTTING GmbH & Co. KG. The order was supported by PM International Suppliers LLC and BUTTING Canada Ltd.
About CalEnergy

CalEnergy’s domestic geothermal operations are a part of CE Generation, LLC, a limited liability company owned by MidAmerican Energy Holdings Company and TransAlta (CE Gen) Investments USA Inc. MidAmerican Energy Holdings Company specializes in the production of energy from diversified fuel sources including geothermal, natural gas, hydroelectric, wind and coal. TransAlta is a power generation and wholesale marketing company that operates a highly contracted portfolio of similarly diversified assets in Canada, the United States, Mexico and Australia. CalEnergy’s geothermal operations in California produce 340 megawatts of electricity – enough power to meet the energy needs of 340,000 homes.

Titanium

To deal with these conditions and the hostile down-hole environment, the down-hole well casing is made of titanium grade 29. Mr Eberle: “The titanium casing in the wells is set at 2,000 to 4,500 feet. Total depth is 5,500 to 7,500 feet (producers). The temperature in the production zone normally ranges from 550 to 600° F. They need to withstand a 600 psi wellhead pressure and, at the moment, titanium is the only answer. In view of the depth and size of the wells, this makes us one of the biggest domestic consumers of titanium in this industry.” Mr Eberle said that considering the high titanium prices, CalEnergy has looked at and tested alternative materials for well casing and found only one alloy that comes close: alloy 2550, which is made by Sumitomo in Japan. Nevertheless, titanium is still the preferred option and the engineers expect this material to be used for the well casings in the foreseeable future.

Inconel vs 2507

In the second part of the production process, after brine has been brought to the surface, there is a shift to be seen in the material selection. “Traditionally, the wellhead assembly is made of Inconel 625,” explains Mr Furmanski, “and this material is also used for the piping directly off the wellhead to the pressure controlling station. At this station, the brine pressure and temperature is slightly reduced. These pipelines are made of either cement-lined carbon steel, thick-wall carbon steel or Inconel 625. These are 20”, 24” or 30” in diameter. There are over 33,000 feet of production pipelines. Production pipelines that are made of cement-lined carbon steel and thick-wall carbon steel do not last long, so the CalEnergy engineering team took up the challenge to find a more economic Inconel 625 substitute.” Duplex 2205 and super duplex 2507 are both viable substitutes for Inconel 625, depending on the application. Mr Furmanski: “In different applications throughout the plant, Inconel 625, in high-temperature and duplex 2205, in low-temperature have performed well. Super duplex 2507 plays an important role as a substitute for Inconel 625 in high-temperature applications. In early 2005, we initiated a demonstration project where we use 2507 instead of Inconel 625. We installed a 340-foot trial production pipeline and recently a comprehensive examination was completed on pipeline segments after 13 months in service. The micrographic examination found no indications of stress corrosion cracking or pitting, no change in mechanical properties and the general corrosion (calculated) rate was between 2 and 4 mils per year. All experts commissioned by CalEnergy concluded that super duplex 2507 performance was excellent and the selection of super duplex was appropriate for the hot-brine service.”

About George Furmanski

George Furmanski received a master’s degree in metallurgy at the Academy of Mining and Metallurgy in Kraków, Poland, in 1970. After a brief spell at Skawina Aluminium Smelter as a plant engineer, he joined Chemadex as a design engineer working on projects related to environmental engineering and pyrometallurgical plants. In 1981, Mr Furmanski went to Australia to work on uranium projects for Wright Engineers in Sydney. In 1983, he joined BHP Engineering Australia, where he was involved in numerous hydrometallurgical projects that in 1997 brought him the Rio Tinto Award of Excellence in Chemical Engineering for outstanding achievement. This award was given for his participation in the design of the Electrolytic Manganese Dioxide plant, where lean duplex 2304 and duplex 2205 were used for the first time in hot sulphuric acid leaching. His experience with “exotic alloys” was used during his work at SNC-Lavalin Canada as a chief process engineer for a magnesium metal plant. His long-term involvement in chloride hydrometallurgy was finally tested at CalEnergy, where he has been working since 2001 on demonstration projects related to selection of materials for construction for high-chloride, high-temperature geothermal brine application.