

# OUTLOOK

PRODUCERS AND FABRICATORS OF REACTIVE AND REFRACTORY METALS AND CHEMICALS

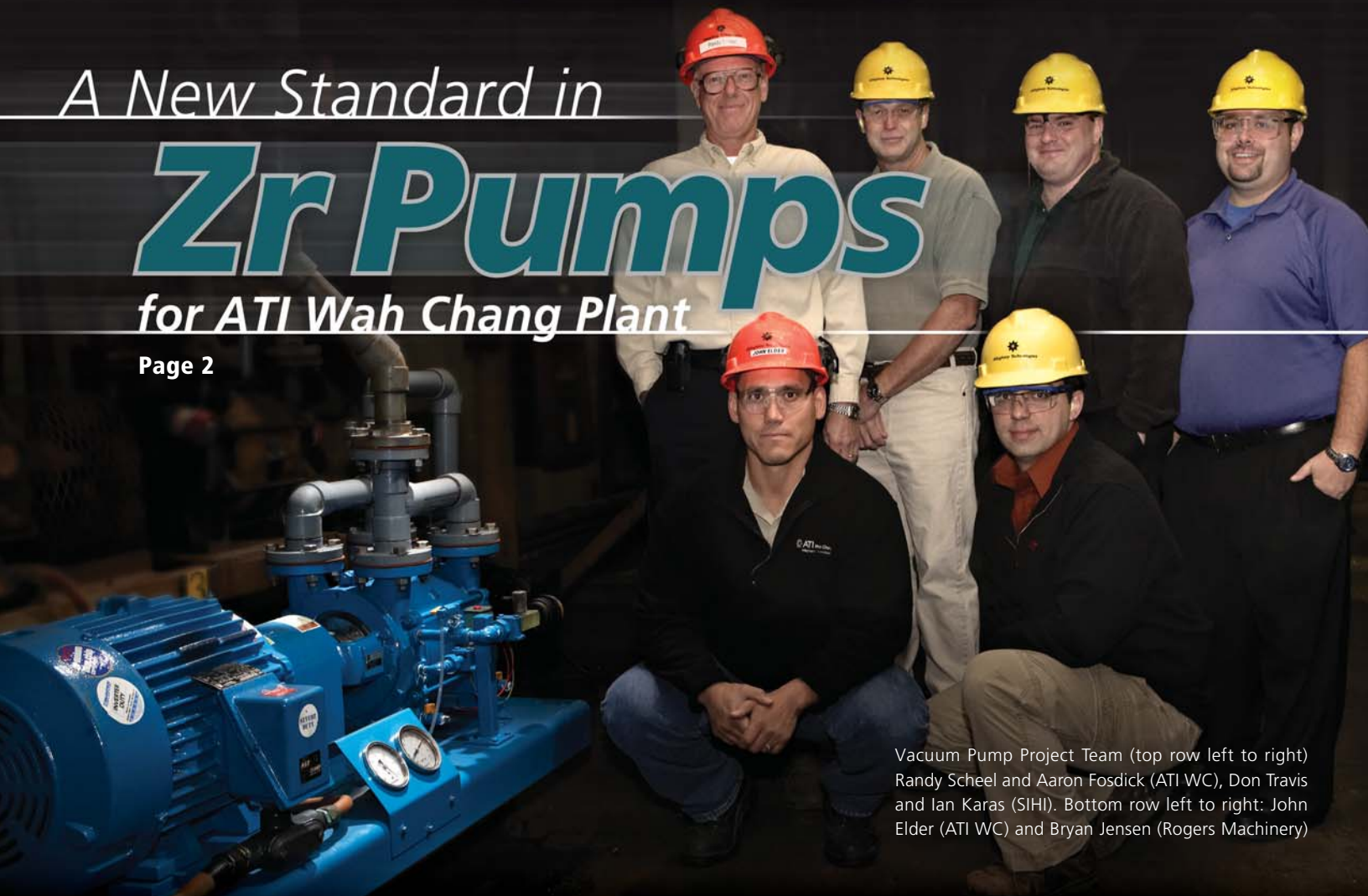
ALLEGHENY  TECHNOLOGIES

*A New Standard in*

## Zr Pumps

*for ATI Wah Chang Plant*

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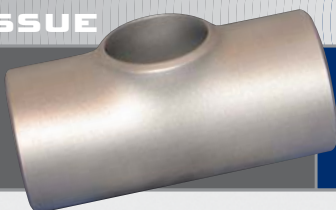


Vacuum Pump Project Team (top row left to right) Randy Scheel and Aaron Fosdick (ATI WC), Don Travis and Ian Karas (SIHI). Bottom row left to right: John Elder (ATI WC) and Bryan Jensen (Rogers Machinery)

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## Zirconium Pump Sets New Standard for ATI Wah Chang Sponge Plant

BY: KIRK RICHARDSON — ATI Wah Chang

“Tribal knowledge” is a good thing until too many members of the “tribe” retire. Potential loss of institutional knowledge was recently on John Elder’s mind as the ATI Wah Chang Engineer planned for replacement of key processing equipment as part of the company’s chemical plant expansion project.

Elder’s challenge involved a relatively small but important vacuum pump in the zirconium production process. Ironically, what keeps this equipment from withering away in the severe service environment are its zirconium components. Plant Engineering and Chemical Operations decided that it would be wise to develop a standard, repeatable method of manufacturing the pumps.

Wah Chang machinists originally built the equipment about 30 years ago. “We have had those in service for all that time,” he says, adding that they are pulled and repaired as needed. “This specific application has a lot of corrosion out there, so it’s not like we could bring in the regular cast iron liquid ring.”

According to Division Director Randy Scheel, acid and temperature spikes in the sponge-making process can corrode many alloys. “Corrosion can cause the pumps to not achieve required vacuum levels,” he explains. Resulting leaks in a system could allow air where it’s not wanted and lead to significant problems, according to Scheel.

Though it helps keep the pumps from leaking over extended periods, zirconium is not a magic bullet. Even one of the most corrosion resistant alloys in the metals family wears down over time and needs to be factored into plant maintenance plans. “They get rebuilt often to replace pump seals and bearings, but not the zirconium components.” reports Elder.

Rebuilt from old blueprints, according to Elder. “We’ve got some guys in the shop that are really talented and can take those prints and build a pump out of it,” he says. “They can work miracles with that kind of print, but those guys have been around for awhile, and when you lose one or two of them to

retirement, you lose that. For us to rely on tribal knowledge with the next generation coming aboard, it’s really scary.”

A facility expansion project offered the perfect opportunity to look for a long-term, standard solution. Elder pulled together a team that included longtime ATI Wah Chang equipment supplier Rogers Machinery and SIHI Pumps Limited. According to Bryan Jensen, Rogers’ Eugene Branch Manager, the company has supplied ATI with air compressors, rotary screws, dryer equipment, filtration equipment for air compressor systems, and a number of other manufacturing-critical components. “We turned around the skid in a couple of weeks from the time we got the pump in, got a motor for him and everything fabricated up to the specs required and got the final product to you down at your facility,” reports Jensen.

It took a team effort and an existing pump design to make the project a success. “We took a standard design from SIHI, and we didn’t have to go through the heartache of trying to design in-house from old prints and relay that to so many people,” says Jensen. “They have their off-the-shelf design; the only difference is that we were implementing in zirconium.”

That was a big, but not insurmountable difference. Ian Karas, an Applications Engineer with SIHI, mentions that the company had worked with titanium before, but never zirconium. “This is a new metal that we have never machined in-house,” reports Karas. “We took our standard design, but made special drawings in terms of the machining tolerances to ensure a precise as fit as possible. A lot of the tolerances got smaller. From a machining standpoint, it was done to a very tight standard and very tight tolerance, so that we did meet the requirements.”

SIHI also simplified the pump in the process. “Typically when we get into these types of special metallurgy and special designs, we steer away from that two-stage design due to the complexities of the liquid ring vacuum pump design,” according to Karas. “We recommend a single-stage design, which



SIHI manufactured this corrosion resistant zirconium vacuum pump to withstand acid and temperature spikes in ATI Wah Chang’s challenging sponge-making process.

## United Titanium, Inc. Turns Exotic Alloys into Critical Parts

Since 1962, United Titanium, Inc. has been known for its capabilities in precision machining and upsetting of titanium, zirconium, nickel alloys and tantalum for critical applications in the aerospace, power generation, chemical processing and medical industries.

"We regularly make parts from alloys that most job shops aren't familiar with," says Charlie Gray, vice president and general manager at United Titanium "We specialize in exotic alloys for critical parts in corrosive and/or strength environments, and we leave the commodity alloys to others. We fill orders ranging from several thousand to just a handful of parts." Gray should know, having worked at United Titanium for 44 years.

"We've been partnering with ATI Wah Chang for 40 years," he adds, "beginning with 702 and 705 zirconium, and later tantalum. We use zirconium for fasteners, fittings, and precision pump components. The tantalum is used for parts that go into missiles."

Zirconium is ductile and has useful mechanical properties similar to those of titanium and austenitic stainless steel. Zirconium also has excellent resistance to many corrosive media, including superheated water, and is transparent to thermal energy



*United Titanium Inc. has a modern facility measuring 132,000 square feet. It houses fastener manufacturing as well as the service center.*

### About United Titanium, Inc.

United Titanium Inc. is owned by Mike Reardon, who purchased it in 1974. The company has 130 employees, a number that has been stable since about 2005. Products include precision-machined components, fasteners, fittings, and mill products. Their service center also provides services such as shearing, welding, saw cutting, machining, and waterjet cutting. The company was selected by the Wooster Chamber of Commerce as Business of the Year in 2007.

neutrons. These properties prompted the U.S. Navy to use zirconium in water-cooled nuclear reactors as cladding for uranium fuel.

Today, a high proportion of zirconium is used in water-cooled nuclear reactors; the next largest use is in chemical-processing equipment. Additional applications include flashbulbs, incendiary ordnance, and gettingerating contaminating gases in sealed devices such as vacuum tubes.

"ATI Wah Chang has been a good partner," says Gray. "We developed a proprietary heat treating process for zirconium parts, to relieve stress and develop an oxide coating to help with erosion resistance. At first we had some difficulties, and consulted ATI Wah Chang engineers. It turned out the reason was that we needed a different solvent to more effectively clean the parts prior to heat treating. ATI Wah Chang engineers helped us find a solvent that did the job. We have not had heat treating problems since then."

The most difficult zirconium parts United Titanium makes are wear rings and extremely close-tolerance pump housings. Precision is challenging with tolerances as close as +/- 0.0002 inch, even though zirconium machines well.

Tantalum provides a combination of properties not found in many refractory

*[ continued on page 4 ]*

is a different model than what a lot of people may have been used to here."

A successful dry run followed by months of trouble-free operation, and Elder is sold on the solution. "SIHI Pumps (Limited) had their own patent and a very nice product that we could buy from them with a warranty

and get our vacuum pumps that we need in an accelerated schedule," he says. "With our machine shop bogged down, it didn't really have the time to make this equipment, nor did we really want them to."

Scheel adds that the breakthrough could benefit others. "While the zirconium pump

is a solution for ATI Wah Chang's plant, the SIHI design could be a solution in other processing environments that require corrosion resistance," he explains. "It may just be a matter of letting people know that there is another option available." For more information, visit [www.sihi-pumps.com](http://www.sihi-pumps.com). ✨

# United Titanium, Inc. Turns Exotic Alloys into Critical Parts

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metals. It has a high melting point (2296°C, or 5425°F), tolerance for interstitial elements, and reasonable modulus of elasticity. Tantalum also possesses excellent room-temperature ductility, with >20% tensile elongation, and is readily weldable.

Because of its high melting point, tantalum is used for heating elements, heat shields, and other components of vacuum furnaces. It has also been selected for specialized aerospace and nuclear applications, as well as for prosthetic devices in contact with body fluids, and as an alloy component in superalloys.

Sizable quantities of tantalum are used

in chemical process equipment such as heat exchangers, condensers, thermowells, and lined vessels. This equipment handles nitric, hydrochloric, bromic, and sulfuric acids, or combinations of these acids with many other chemicals. Spinnerettes for extruding man-made fibers constitute another important application of tantalum.

Special tantalum screws were one of the biggest challenges for United Titanium. "They were tough to make because we were trying to forge a head on a very small shaft (0.071-inch diameter) of tantalum," explains sales manager Doug Meigs. "But the head required more material than can normally be controlled in upset forging. The piece must be hit perfectly dead center with specially designed tools to make it right. It took weeks and weeks to produce the required number of perfect parts."

Such perfection is standard for United Titanium products. "We are proud of our quality," says Meigs. "Our manufacturing engineers and quality control departments do whatever it takes to ensure we ship quality parts. We are just as proud of our reputation for on-time delivery."

They manufacture parts as small as 00-96 screws and dental implant components. "Each one is inspected," says Meigs, "all under a microscope!"

"We are able to machine such parts because we constantly upgrade our equipment," he

adds. "We even have a number of CNC machines that we have developed in-house to service specific customers, especially for medical and dental implants."

Medical screws and implants of many sizes are a major part of United Titanium's business. Titanium Grade 23 (Ti-6Al-4V) ELI is used most frequently for medical components by United Titanium because of its high strength and biocompatibility. Titanium is completely inert and immune to corrosion by all body fluids and tissue, and is thus completely biocompatible. In addition, when bone-forming cells attach themselves to the titanium implant, a structural and functional bridge forms between the body's bone and the new implant.

Carlos Weekley formed United Titanium back in 1962 in the early years of the titanium industry. He saw the need for titanium fasteners, and started the company in an old feed mill in Shreve, Ohio, to focus on that market. His first customer was Chemcut Corporation, which needed pump shafts, coils, and fasteners for chemical process equipment. They are still a customer today.

Another early customer was NASA, for which United Titanium supplied fasteners for the Pioneer space program. NASA still relies on the company for a variety of satellite and spacecraft parts.

Located since 1985 in Wooster, Ohio, United Titanium occupies 132,000 square feet and includes a fastener facility and a newly formed service center.

"We are the largest stocking distributor of zirconium fittings in the world," says Stephen McLain, International Sales Manager, Service Center. "In our distribution center, we stock titanium Grades 2 and 7 and zirconium in a whole raft of forms, including sheet, bar, plate, pipe, and fittings, in a wide range of sizes."

For fasteners they stock a wide range of titanium, zirconium, Inconel 686, and other nickel-cobalt alloys, including some super duplex stainless steel. "The more demanding the application and the more exotic the alloy, the better we are at differentiating ourselves from everyone else," says Gray.

For more details about United Titanium products and services, please visit [www.unitedtitanium.com](http://www.unitedtitanium.com). ✨



United Titanium, Inc. makes a range of precision fasteners of a wide variety of alloys.



Zirconium fittings are among the many product lines United Titanium, Inc. manufactures and supplies.

## Fabricating with Reactive and Refractory Metals

BY: BRETT KRUEGER — ATI Wah Chang

For as long as reactive and refractory metals have been accessible, the question of how to manufacture parts or structures has perplexed fabricators, particularly those who are accustomed to more common metals, such as steel, stainless, nickel, aluminum or copper. Understandably there may be some apprehension, but consider that all these materials are metals and that they can be processed by virtually all modern metal working technologies (albeit with some special considerations). With a basic understanding of material characteristics, fabricators can quickly develop processing techniques that allow them to produce parts.

Let's establish what metals comprise these two groups. For the purpose of a general overview, reactive metals are those that melt below about 1750°C and include titanium and titanium alloys. Metals that melt above this temperature are considered refractory and include zirconium, vanadium, molybdenum, hafnium, niobium, tantalum, tungsten and their alloys.

In all cases, whether working with a reactive or refractory metal, two very important points need to be understood that differentiate these materials from more common metals:

- First, at temperatures above about 425°C, all reactive and refractory metals become susceptible to contamination from carbon, oxygen, nitrogen, and hydrogen. If sufficient amounts of these elements are absorbed into the metal, it can result in a loss of ductility, increased susceptibility to corrosion and can lead to premature failure of the component.
- Second, metal cleanliness and surface condition prior to processing is critical. Surface contaminants such as dirt, oils, iron flakes, grinding swarf and gouge marks that have imbedded particles need to be removed. Processing grimy or damaged metal can produce areas of high stress concentration and increased metal corrosion. Thoroughly cleaned metal is fundamental to producing high quality parts.



An example of the GTAW process (gas tungsten arc welding) during ATI Wah Chang's Annual Welding Seminar.

Generally, reactive and refractory metals are formable, can be cut and welded, and like other metals, they have a wide variety of bend radius limits. It is important to understand these constraints for each alloy before starting any forming operations. When forming a particularly complex shaped part or a piece that has a tight bend radius, the use of heat to warm the part will greatly enhance its movement. Just be aware of the 425°C temperature ceiling. If processing requires temperatures greater than 425°C, subsequent cleanup may be necessary to remove absorbed atmospheric surface contaminants. These metals can be formed dry in a press break or forge, for example, and can also be drawn into shapes with forming dies. The use of drawing or dry film lubricants will help reduce the tendency to damage the metal surface.

Differences in machining practices from more common metals include a greater tendency to gaul, smear and work harden (similar to stainless steel). Because of this, low cutting speeds and feeds provide the best performance. Chip management is also different. It's not uncommon to produce a chip that is stringy, continuous and difficult

to break. In some applications chip winding tools have proven to be highly successful. To help control chip production, machine with sharp tools that have high cutting rake angles, avoid chip pileup at the cutter point and use machining coolants. These metals are tough and will require high torque (at low RPM), ridged machine tools with solid fixture setups.

Welding requires the incorporation of argon and/or helium shielding gas into the process. Trailing and root backing shields are necessary to protect the molten pool and surrounding heated metal. Without a shielding gas component, the metal will become embrittled from atmospheric contamination. The most common processes are GTAW and GMAW, however plasma, laser, or electron beam welding have all proven successful.

It's always good practice to investigate and identify all special processing parameters of any unfamiliar metal before starting a project. ATI Wah Chang is a tremendous resource that can help provide guidance when working with reactive and refractory metals. For more information, contact Technical Services at 541-967-6977. ✨

## Titanium for Renewable Energy Applications

BY: ROBERT HOUSER — ATI Wah Chang

In addition to being a material of choice for engineers designing airplanes and medical implants, titanium has many other applications. One niche in which titanium alloys have not been used widely is in renewable energy production.

This article takes a look at the potential application of corrosion resistant titanium alloys in a challenging production environment that is becoming critical to meeting the world's energy needs.

### APPLICATION AREAS

Titanium alloys have been used for over 40 years in many corrosive applications such as chemical processing, refineries, metal finishing and pulp and paper. More recently, these alloys have been used in the power generation industry, such as geothermal wells and oil and gas applications requiring higher strengths and good corrosion resistance. The conditions encountered in these geothermal, oil and gas applications include high temperatures and pressures combined with high concentration of dissolved solids, which make the environment especially corrosive. In some applications, there will be significant levels of acid gases, such as H<sub>2</sub>S and CO<sub>2</sub>, which affects the more common downhole materials.

### Geothermal

Downhole conditions for geothermal applications can range from moderate to most severe. The Salton Sea wells in Southern California represent probably the most severe downhole environment encountered anywhere in the world. Companies tapping into this natural resource may use steel for drilling exploration holes, but they rely on titanium, such as Ti Grade 29 (Ti 6-4 ELI w/ Ru), to replace the steel that can fall apart after 18 months of service.

Most corrosion in geothermal environments and other similar applications described previously is caused by seven key corrosive species<sup>[1]</sup>:

- Oxygen
- Hydrogen Ion
- Carbon Dioxide
- Hydrogen Sulfide
- Ammonia
- Chloride Ion
- Sulfate Ion

Depending on the location, certain metals will be suitable for the environment. As the industry progresses to deeper and more corrosive

conditions, steel will likely be replaced with materials like titanium. Titanium's corrosion resistance and strength make it ideal for production wells and heat exchanger tubing.

Typical convective hydrothermal energy reaches temperatures in the 260-330°C range. New advances in the industry could lead to magma-based energy where temperatures exceed 500°C. Alaska and Hawaii are likely locations for this to start<sup>[2]</sup>. These are ideal conditions for titanium alloys with the addition of a Platinum Metal Group (PMG).

Tubular products are not the only titanium forms used in the geothermal industry. High strength, corrosion resistant metals are required for parts such as springs, snap-rings and other important components.

### Nuclear

When it comes to materials used in nuclear power production, zirconium gets most of the credit. However, there are areas in the process where titanium is used, such as the steam turbine condenser (typically Ti Grade 2). In some nuclear applications, Ti Grade 2 does not provide sufficient corrosion resistance. One such case is drip shields used in spent fuel repositories.



The Nesjavellir Geothermal Power Plant in Iceland

Ti Grade 7, which is suitable for this demanding environment, is Ti Grade 2 with the simple addition of PMG (palladium). The expected lifetime of this alloy is over 10,000 years because stress corrosion cracking, localized corrosion and microbiological influenced corrosion are not expected to occur<sup>[3]</sup>.

### Wave/Tidal

Although this form of power production is not very widespread, it is another ideal application for titanium. Titanium has been widely studied for its corrosion resistance in seawater. There are even boat hulls made of titanium. It won't be long before you hear about power buoys off the Pacific coastline being installed with corrosion resistant metals.

### TITANIUM CHARACTERISTICS

ASTM has registered 38 grades of titanium; however, only a few are commonly used in industry. Their strength to weight ratio makes titanium alloys ideal for aerospace applications as well as offshore heat exchangers. Their thermal conductivity is 30% greater than 300 series stainless steel. Titanium grades range

Table 1.

### Comparison of Corrosion Resistant Alloys

Alloy	Ultimate, ksi	Yield (0.2%) ksi	Elongation %
Ti Gr2	50	40	20
Ti Gr5	130	120	10
Ti Gr7	50	40	20
Ti Gr9	90	70	15
Ti Gr12	70	50	18
316 SS	85	30	40
Nickel Alloy 625	115	60	30

from commercially pure (Ti Grades 1-4) to alloys with multiple alloying elements such as Ti Grade 32 (Ti-5Al-1Sn-1Zr-1V-0.8Mo-0.1Si).

Titanium alloys are also attractive because their density is 60% of that of steel. The weight savings with higher strength materials means increased load carrying capacity as well as decreased wall thickness and section size. With proper heat treatment, sufficient yield strengths have been obtained for risers and swivel components for offshore systems. Additional savings are achieved because

titanium does not require corrosion inhibitors for production environments containing H<sub>2</sub>S and high levels of CO<sub>2</sub>.

### Mechanical Properties

The strength of titanium will depend on its alloying elements. Table 1 summarizes several titanium alloys and other metals for comparison.

With increased strength comes reduced formability; however manufacturers continue to search for an alloy with high strength,

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## Titanium for Renewable Energy Applications

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formability and weldability. One such alloy is Ti Grade 38, which is slightly less strong (115 ksi) than Ti Grade 5, but readily formable when cold and weldable<sup>[4]</sup>.

All of the materials shown in Table 1 are readily available in cast, forged blocks, bars, sheet, plate, and tubes. One exception is Ti Grade 5, a material so inherently strong that it cracks when fabricated into tubes. Any heavy forming requires working this material at elevated temperatures.

### Corrosion Resistance

Titanium exhibits excellent corrosion resistance in oxidizing chloride environments, which led to some of its first applications in the chemical process industry over 30 years ago. The corrosion resistance of titanium relies on the formation of a thin oxide film, which occurs spontaneously in air or water. Once the oxide film is compromised, damage may occur.

Reducing acids are often the cause of general corrosion on titanium. The corrosion

### Titanium exhibits excellent corrosion resistance in oxidizing chloride environments...

resistance of titanium in reducing acids (hydrochloric, sulfuric, phosphoric, etc.) will depend on concentration and temperature.

When Ti Grade 2 will not work because of concentration or temperature concerns, other titanium alloy grades, like Ti Grade 12, may be viable alternatives<sup>[5]</sup>. There are other limitations that can cause problems with titanium, such as crevice corrosion. Although Ti Grade 5 and Ti Grade 2 can suffer crevice corrosion in high temperature hypersaline brines, no crevice attack occurred on Ti Grade 2 when low to medium (< 15,500 ppm) chloride brines were tested<sup>[6]</sup>. Titanium alloys containing aluminum, tin, manganese, cobalt and or oxygen greater than 0.317 percent are susceptible to stress corrosion cracking caused by chloride ions concentrating in pre-existing cracks<sup>[7]</sup>.

Another alternative to increase titanium's

corrosion resistance is to add small amounts of a PGM, typically palladium or ruthenium. The PGM addition has no effect on mechanical properties, but enhances the corrosion resistance of the material in chlorides and extends the range of performance in mildly reducing environments. A common use of these grades is for gasket faces and crevices where Ti Grade 2 might be subject to crevice corrosion or pitting under NaCl deposits<sup>[8]</sup>.

For more information about alloys for renewable energy applications, contact ATI Wah Chang at 541-967-6977. ✨

### REFERENCES

1. Ellis, P., Smith, C., Keeney, R., Kirk, D., Conover, M., and Radian Corporation: "Corrosion Reference for Geothermal Downhole Materials Selection", Contract No. DE-AC03-81SF11503, (1983), 7, 101.
2. Sanyal, S.: "Future of Geothermal Energy", Proceedings, CanGEA Conference, Vancouver, B.C., Canada (2009).
3. Hua, F., Mon, K., Pasupathi, P., Gordon, G., and Shoesmith, D.: "Corrosion of Ti Grade 7 and Other Ti Alloys in Nuclear Waste Repository Environments – A Review", Proceedings, Corrosion 2004, NACE International, Paper No. 04689.
4. Kerr, J., Stoiber, R., and Hebda, J.: "New Applications for 425", Proceedings, Corrosion Solutions Conference, Sunriver, OR (2005).
5. Schutz, R., and Grauman, J.: "Selection of Titanium Alloys for Concentrated Seawater, NaCl and MgCl<sub>2</sub> Brines", Proceedings, San Francisco, CA (1986).
6. Thomas, R.: "Titanium in the Geothermal Industry", GHC Bulletin (December, 2003), 22-26.
7. Ellis, P.: "Geothermal Materials Survey: Arkansas Power and Light Development and Demonstration Project. 100KW Power System Using Direct Contact Heat Exchangers, El Dorado, Arkansas", Radian Corporation, July 1980, Contract No. AC02-79ET27026, (1980), 5, 16, 20.
8. Blauvelt, P., Rowan, D., Motiva Enterprises LLC, Willey, B., McMaster, J., and Titanium Fabrication Corporation: "Titanium – Proven Performance in Hydrocarbon Processing", Proceedings, Corrosion 2000, NACE International, Paper No. 00684.

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## OUTLOOK

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