

## Innovator Devises Nickel-Titanium Alloy Products that Shape the Way We Live

By **Kirk Richardson, Editor**

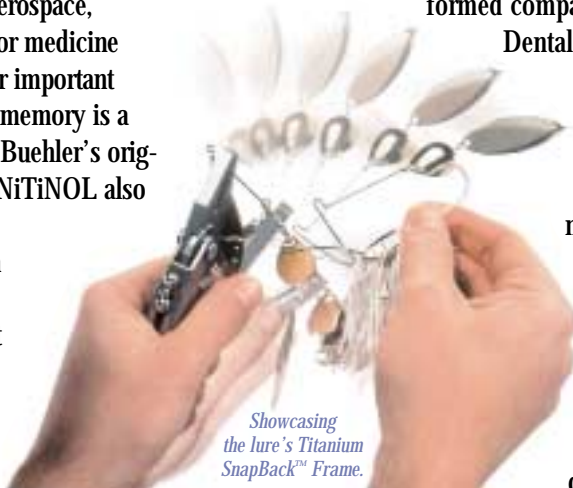
As U.S. Naval Ordnance Laboratory metallurgist William J. Buehler was developing the super-elastic alloy NiTiNOL (Nickel Titanium Naval Ordnance Laboratory) in 1959, he likely didn't envision the full range of applications for his amazing new material. At the time, Buehler was focused on developing metallic materials for the U.S. Navy Polaris reentry vehicle's nose cone. In 1962, a colleague of Buehler's, Dr. Fredrick Wang, opened the door to even more possibilities when he discovered how the shape memory property of NiTiNOL works.

Years later, this latter discovery has led to nickel-titanium couplings and other critical parts for aerospace, NiTiNOL stents for medicine and a host of other important uses where shape memory is a key attribute. But Buehler's original super-elastic NiTiNOL also made its mark.

Enter Dr. Ben Johnson, a Tulsa, Oklahoma dentist and not inconsequentially, a former bass fishing enthusiast. In

the 1980's Johnson was looking for ways to make root canals less painful for his patients...as well as for himself. NiTiNOL proved to be the answer. As it turned out, the alloy's flexibility and torsional strength make it an ideal file material for cleaning and shaping during root canal procedures. NiTiNOL tends to bend to the shape of the root, whereas other rigid materials occasionally break off during the process, causing all kinds of new problems.

Armed with this knowledge, the dentist-turned-inventor created a NiTiNOL version of the endodontic file and was soon manufacturing and marketing the product from his newly formed company, Tulsa Dental Products.



Showing the lure's Titanium SnapBack™ Frame.

On his doctor's advice, Johnson eventually made time for life outside of work. "My doctor said, 'Son you're working yourself to death.' He says

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## AstroCosmos' Zr-Clad Solution

By **Greg Becherer**

When a major producer of water treatment chemicals was told more than five years ago that the reactor vessel they needed was "impossible to build," they refused to listen. The producer's unwillingness to settle for less than a long-term solution paid off. Today, after five years of steady production, the Zircadyne® Zirconium vessel is operating trouble-free.

The project took shape when the chemicals producer contacted AstroCosmos Metallurgical and other fabricators seeking a solution to

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## Davis Named President



Lynn D. Davis

*(Story on Page 2)*

# Innovation

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to me 'You're going to die wealthy, but you are going to die,'" quips Johnson. That's the point that the dentist decided to return to a sport he loved as a boy in Texas...bass fishing. There was only one hitch...the thing about innovators like Johnson is that they rarely sit still long enough to "catch" their breath let alone bass.

While fishing with a friend one day, his mind began spinning like a reel. Johnson came up with a brilliant idea. Observing his fishing partner re-tune a bent spinnerbait,



Bill Dance "The Babe Ruth of Bass Fishing" ties on a Terminator Titanium Spinnerbait. Dance is the hallmark promoter for Outdoor Innovations.

he wondered whether anglers would be willing to pay extra for equipment that would snap back to its original shape and withstand the rigors of an afternoon underwater and in the brush.

It didn't take long for him to develop a NiTiNOL prototype, which he soon showed off to legendary bass angler and tackle shop owner Don Butler. Butler immediately saw a breakthrough product. Up to that time, most spinnerbaits couldn't withstand being bent back into shape more than four or five times. Johnson's new NiTiNOL product could be re-tuned 400 times without breaking. In addition, since it's made of nickel-titanium, the spinnerbait proved to be very corrosion resistant and, according to some, had a more natural movement in the water (due to the alloy's

apparent low modulus of elasticity).

Johnson the entrepreneur was back at it again, establishing a new company, Outdoor Innovations, then acquiring an existing Texas company, Horizon Lures, to design and manufacture the new nickel-titanium spinnerbaits.

In 1997, when the product was ready to launch, the company advertised it on a television infomercial. The results? According to Public Relations and Marketing Manager Alan McGukin, Outdoor Innovations sold one million Terminator baits its first year in business (1997), despite the fact that the new product cost nearly three times as much as ordinary spinnerbaits.

The success story continues today. In June 2000, *Fishing Tackle Retailer*, an industry magazine ranked the Terminator Titanium Spinnerbaits among its top ten springtime bass products.

So where does an innovator like Johnson go from here? Since he launched Terminator, Johnson's company has started manufacturing and marketing titanium products for aeronautics as well as golf and tennis. "There are lots of things out there that nickel-titanium can make better," he says, but adds that he's not looking at anything in particular right now. These days

Johnson is content spending most of his work time on the dental lecture circuit... and, occasionally, the innovator heeds his doctor's warning and finds a little time to fish for bass.

*Many thanks to Bass Club Digest and Outdoor Innovation's Alan McGukin, who supplied the background instrumental in "tackling" this story. For information on Outdoor Innovations' products, contact the company at 918-488-8585. If you're an innovator and would like more information on Wah Chang's nickel-titanium (NiTiNOL) and other groundbreaking metals, contact us at 541-967-6977. ■*

## Lynn D. Davis Appointed President of Wah Chang

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Pittsburgh, PA, September 21, 2000 - Allegheny Technologies Incorporated (NYSE: ATI) today announced that Lynn D. Davis, age 51, has been appointed to the position of president of Wah Chang, an Allegheny Technologies company. He reports to Jack W. Shilling, president of Allegheny Technologies' high performance metals segment.

"Wah Chang is an exciting business with significant growth potential in ultra-high performance metals," said Jack Shilling. "In his new capacity as president, Lynn is uniquely qualified to lead Wah Chang. He has been instrumental in developing new markets and has demonstrated strong operating and technical leadership in meeting the strict customer requirements that define these highly specialized markets."

Most recently, Mr. Davis was executive vice president and general manager of Wah Chang. He joined the company in 1977 and has steadily progressed with positions of increasing responsibility in engineering, operations and technical at Wah Chang.

Lynn Davis holds bachelor and master degrees in metallurgical engineering from the University of Idaho. ■

### NiTiNOL SE 508 Data

#### Physical Properties

Melting Point	2390°F	1310°C
Density	0.234 lb/in <sup>3</sup>	6.5 g/cm <sup>3</sup>
Electrical Resistivity	32 μohm-in	82 μohm-cm
Modulus of Elasticity	11x10 <sup>6</sup> psi	75x10 <sup>6</sup> MPa
Coefficient of Thermal Expansion	6.1x10 <sup>-6</sup> /°F	11x10 <sup>-6</sup> /°C

#### Mechanical Properties

Ultimate Tensile Strength (UTS)(min)	167x10 <sup>3</sup> psi	1150 MPa
Total Elongation (min)	10%	10%

#### Superelastic Properties

Loading Plateau Stress @ 3% strain (min)	65x10 <sup>3</sup> psi	450 MPa
Superelastic Strain (max)	8%	8%
Permanent Set (after 6% strain)(max)	0.2%	0.2%
Transformation Temperature	41 to 64°F	5 to 18°C

# Wah Chang Strengthens Sales and Marketing Teams

## Mr. Doug Brenizer

was promoted to Director of TCS Operations of Allegheny Technologies' Total Corrosion Solutions (TCS) team. The TCS team was formed in 1998 and is composed of marketing, sales, and technical personnel from Allegheny Ludlum, Allvac, and Wah Chang. The group provides a range of metals, from stainless steels to nickel alloys to titanium and zirconium. Most recently, Mr. Brenizer was Manager of Wah Chang's Chemical Processing Industry Sales Group. He has 28 years' experience in metals sales and marketing. Contact Mr. Brenizer by phone at 541-967-6906, by fax at 541-924-6892, or by e-mail at [doug.brenizer@wahchang.com](mailto:doug.brenizer@wahchang.com).



Doug Brenizer

## Mr. Kirk Richardson

has assumed the role of Marketing Communications Manager for the Total Corrosion Solutions Team. Mr. Richardson will continue to handle trade shows and events for TCS as well as advertising, promotions, and special projects for the group. In addition, he is back as editor of Outlook. Mr. Richardson's "vacation" from this newsletter lasted all of two issues. Contact him by phone at 541-967-6955, by fax at 541-924-6892, or by e-mail at [kirk.richardson@wahchang.com](mailto:kirk.richardson@wahchang.com).



Kirk Richardson

## Ms. Rhonda Marshall

recently moved to Wah Chang's CPI Sales Group. Marshall worked in the Quality and Zr Reduction



Rhonda Marshall

Departments while earning her degree in Mechanical Engineering. After completing college, she became a Process Engineer, spending nearly 14 years in the Extrusion Department. Marshall has experience selling a variety of metals to companies in the nuclear and chemical processing industries. She can be reached by phone at 541-917-6780, by fax at 541-967-6979, or by e-mail at [rhonda.marshall@wahchang.com](mailto:rhonda.marshall@wahchang.com).

## Mr. Rob Henson

was promoted to Process Industry Sales and Business Development Director at Wah Chang. Mr. Henson has 23 years' experience working with zirconium, titanium, niobium, and other metals. Mr. Henson's background includes 12 years in the company's Corrosion Laboratory. In his current position, Mr. Henson will handle Sales and Business Development for Wah Chang's corrosion resistant chemical processing products as well as the company's nickel-titanium line. He can be reached by phone at 541-967-6920, by fax at 541-967-6979, or by e-mail at [rob.henson@wahchang.com](mailto:rob.henson@wahchang.com).



Rob Henson

## Mr. Jim Cloonan

was promoted to Zirconium and Silicon Tetrachloride Sales Manager at Wah Chang. Mr. Cloonan has been with Wah Chang for 16 years, the last four in chemical sales. Prior to that, he helped develop some of the company's own chemical processes, working in production as well as R&D positions. Mr. Cloonan's strong technical and production skills will continue to benefit Wah Chang



Jim Cloonan

and its chemical customers. He can be reached by phone at 541-967-6903, by fax at 541-967-6994, or by e-mail at [jim.cloonan@wahchang.com](mailto:jim.cloonan@wahchang.com).

## Mr. Mike Angell

recently joined Wah Chang's Processing Industry Sales Group. Most recently, Mr. Angell managed the company's Service Center, which stocks and ships selected Zr and Ti products for customers with immediate requirements. Prior to joining Wah Chang in 1997, he worked for Ti Industries then Phoenix, fabricating Ta, Ti, and Zr equipment for chemical processing and other applications. Mr. Angell's extensive "hands-on" experience should prove valuable in his new role. He can be reached by phone at 541-924-6881, by fax at 541-967-6979, or by e-mail at [mike.angell@wahchang.com](mailto:mike.angell@wahchang.com).



Mike Angell

## Mr. Robert Marsh

has taken on added responsibilities in Business and Project Development for Wah Chang. Mr. Marsh has over 25 years' experience with metals production and sales. He began his career at Wah Chang working in zirconium production and, over many years, has built extensive knowledge of the company's niobium and titanium product lines. In his new role, Mr. Marsh will handle business and project development as well as sales to customers in the Processing, Consumer Products, and Aerospace Industries. Contact Mr. Marsh by phone at 541-967-6919, by fax at 541-967-6979, or by e-mail at [robert.marsh@wahchang.com](mailto:robert.marsh@wahchang.com). ■



Robert Marsh



# Heat Treatment

By Rick Sutherlin

Technical Services Manager

In this issue's Q&A column, Mr. Rick Sutherlin, Wah Chang's Technical Services Manager, answers questions he is often asked about heat treatment of zirconium. Mr. Sutherlin, a Metallurgical Engineer, has conducted technical seminars since 1985 and is currently teaching a course on corrosion resistant materials in locations around the world. He is a member of ASTM, serving on several committees, and is a recognized expert in welding heat treating, and working with reactive metals.

## QUESTION:

**When is heat treatment required for zirconium equipment?**

## ANSWER:

There are three types of heat treatment that are performed on zirconium: stress relief, oxide thickening and a full (high temperature) anneal. Normally, for most applications, heat treatment is not required for Zirconium Grade 702 unless high thermal or mechanical stresses are introduced during fabrication. Heat treatment, however, may be required depending on the specific environment or application that the zirconium is to be placed in. In all cases, heat treatment is required for all welded Zirconium Grade 705 equipment.

## QUESTION:

**When is an air thickening heat treatment used?**

## ANSWER:

Oxide thickening is the process of taking the thin, transparent zirconium oxide film and thickening it to increase the abrasion and erosion resistance. The zirconium oxide film has a hardness approaching that of sapphire, which resists galling and seizing. This heat treatment is recommended on all applications where erosion/abrasion or galling concerns exist, such as pumps, valves, trays or fasteners. This oxide thickening treatment is performed under the same conditions as the stress relief heat treatment but for a longer time. Oxide thickening is accomplished at temperatures of 500–600°C for 4–6 hours at temperature. The resulting oxide has a thickness of approximately 0.0002 in.

## QUESTION:

**What factors should be considered when heat treating zirconium equipment?**

## ANSWER:

Many factors should be considered when a heat treatment is required, such as “should the heat treatment be performed in a furnace or can localized heat treatment be used”. Of course, this will depend on size of equipment, method of construction and design considerations, to name a few. When heat treating zirconium equipment, the unique thermal properties of zirconium, such as the low thermal expansion coefficient and thermal conductivity, should be considered. Cleanliness of the vessel, temperature control, proper support and



In-shop heat treatment of Zr702 tube welds and tubesheet for a heat exchanger. Photo courtesy of Phoenix, a division of Kodiak Industries Inc.

furnace atmosphere must also be considered to help ensure that the heat treatment is performed correctly.

#### QUESTION:

**Is heat treatment performed to improve the corrosion resistance of zirconium?**

#### ANSWER:

**Yes, some applications require that heat treatment be performed in order to improve zirconium's corrosion resistance.**

Both Zirconium Grade R60702 and R60705 require that a heat treatment of the weld and heat affected zone be performed when exposed to the higher concentrations of sulfuric acid (i.e. >55% at boiling). Full anneal is performed at temperatures above 600°C. Also, in media where zirconium has a susceptibility to stress corrosion cracking (>70% nitric acid), it requires a stress relieve anneal. For Zirconium Grade 705, a post weld heat treatment **MUST** be performed to reduce the susceptibility for delayed hydride cracking no matter what environment or application the welded zirconium is to be placed in.

Note: A full presentation covering zirconium heat treatment will be presented at the Total Corrosion Solutions Conference in September 2001.

For in-depth information addressing heat treatment and other technical topics (welding, fabricating, corrosion, project management, etc.), register for one of Wah Chang's Corrosion Solutions seminars. Phone 541-926-4211 ext: 6280 or visit our web site at

[www.corrosionsolutions.com](http://www.corrosionsolutions.com). ■

## AstroCosmos' Zr-Clad Solution

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corrosion problems that it faced with a glass-lined reactor vessel. The producer faced escalating maintenance costs to keep the glass-lined unit operational in a severe processing environment.

Reactive metals seemed like a logical path to follow, with one of these corrosion-resistant materials sought as a potential vessel liner. After extensive testing, the producer zeroed in on Zirconium 702 as its material of choice.

The project posed several fabrication challenges, including the fact that the process would require four different heating zones, with a fast cycle rate of pressure/temperature, and high stress conditions. In the end, AstroCosmos came up with the answer the customer wanted to hear.

As Mr. David Frey, Vice President of Projects and Market Development, recalls: "We built the vessel using explosion-clad technology, which is a high-strength bonding technique. We attached a zirconium liner to a 1.25-inch carbon steel substrate. By using a steel substrate, we gained both unit strength and cost savings. For example, we were able to fabricate the half-pipe coils from carbon steel substrates."

Mr. Frey added that AstroCosmos' extensive use of finite element analysis to determine the high-stress points during the heating and cooling modes was a key factor in the design and fabrication process. "However," as Mr. Frey points out, "the basic reason we were able to do this at all was because we had so

much experience in bonding and welding noble metals involving so many kinds of equipment, applications, and process chemicals."

"There's always something new and challenging in any customer requirement that presents unique or highly



*AstroCosmos fabricated this zirconium-clad reactor vessel, which has operated successfully for five years.*

demanding processes," he says. "But underlying it all is the fact that, so often, we've 'been there, done that'. And, in some cases, the impossible, turns out to be possible.

For more information on AstroCosmos Metallurgical's fabrication services, contact Mr. Gregory C. Becherer, Senior Vice President for Sales and Marketing, at 330-264-8639 ext: 252. For more information on Wah Chang's Zircadyne® Zirconium and other corrosion resistant metals, contact Rob Henson, Manager CPI Business Development, at 541-967-6920. ■

# Corrosion Lab Chronicles: HBr Acid

By Jack Tosdale

Senior Corrosion Engineer

*In this issue's Corrosion Lab Chronicles, Wah Chang Corrosion Lab Chief Jack Tosdale, discusses the lack of data he found when searching for information on materials resistant to Hydrobromic (HBr) Acid. Tosdale first describes the media and some of its attributes, then addresses the lack of data covering HBr, and wraps up this column with findings from his tests.*

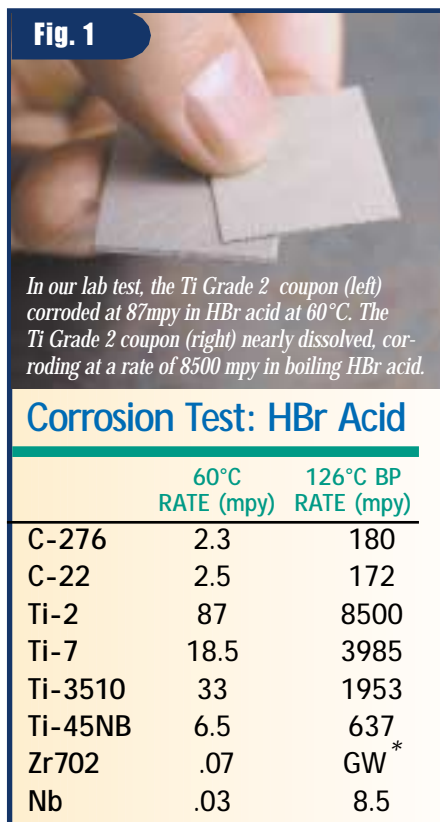
Hydrobromic acid, because it's one of the strongest mineral acids, presents a difficult material selection process for the plant designers. It is a stronger reducing agent than hydrochloric acid and can react with metals to produce flammable and even explosive mixtures of hydrogen gas. Bromine gas can be formed when HBr acid is exposed to strong oxidizers such as chlorates, chlorites and permanganates. The acid corrodes most metals, concrete, and other materials of construction. Acceptable materials for containing equipment include mostly organics, glass and a few metals.

It's wise to find a material that does an excellent job of containing this acid, one with strong corrosion resistance, not only from an operations/maintenance perspective but also from a safety perspective. Hydrobromic acid poses a serious health hazard and can cause severe burns to all body tissue.

The major uses of HBr are in the synthesis of alkyl and inorganic bromides, in medicines, as a catalyst in alkylation processes including those in the petroleum industry, as an ore solvent, and in analytical chemistry. It is commercially prepared by a catalyzed direct combination of its elements and can also be prepared by dissolving HBr gas in water, or by distilling a mixture of NaBr and sulfuric acid. There is a strong growth anticipated in flame-retardants,

pesticides, pharmaceutical intermediates and biocides.

There appears to be a lot of scattered information in published data on the corrosion of various reactive metals in hydrobromic acid. For example, one materials handbook shows a corrosion rate for Zirconium (Zr) 702 of 5 mpy with shallow pits in 48% acid at boiling. Another lists a Zr corrosion rate of up to 50 mpy in a 40% acid concentration at ambient temperature. And yet another guide records a rate of <2 mpy in a 40% acid at ambient temperature for Zr and, at a 100% concentration,



\* Gained Weight

notes that Zr is not recommended. Another source indicates a pyrophoric film may develop.

For other metals, such as stainless steels, nickel alloys, titanium (Ti), niobium (Nb) and tantalum (Ta), the data is

either not complete or is inconsistent. With these gaps in mind, we developed a program to test various metals in 48% hydrobromic acid at its boiling point to help in the material selection process.

## Tosdale's Lab Notes/Conclusions

Corrosion coupons (1' x 2" x .1" thick) of several metals were immersed in a 48% hydrobromic acid solution in a reflux flask at both 60°C and 126°C (the boiling point) for up to two weeks. The different alloys were placed in separate flasks.

Coupons were removed and inspected after one day, one week and two weeks. In the boiling tests, the Ti alloy coupons corroded rapidly and were removed after just one day. All other coupons at both temperatures were held for the full two weeks. The corrosion rates are shown in Figure 1.

At the lower temperature, Zr 702, Nb and the two Hastelloys (C22 and C276) showed very low corrosion rates. The Ti-Nb alloy showed significantly better resistance to corrosion than the other Ti alloys.

In the high temperature test, only Nb and Zr 702 showed low rates. However, at both temperatures, the Zr 702 coupons did show some localized pitting-type corrosion. A longer-term test would be needed to verify the acceptability of the Zr 702 in this media.

As in hydrochloric acid (HCl), it is expected that oxidizing species will improve the corrosion resistance of both Ti and Nb, and will degrade the resistance of Zr 702. However, at this high acid concentration, it is doubtful that oxidizing species will make Ti useable. At lower concentrations of acid with oxidizers, Ti may be useful.

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E V E N T S

## Corrosion Solutions Seminar Update

*Dates and locations listed below*

This fall, winter, and spring, Wah Chang is offering its technically oriented Corrosion Solutions Seminars in North and Central America, Europe, Asia, and Australia. The course is designed to provide information on zirconium, titanium and other corrosion resistant materials to chemical, project, and other engineers; fabricators; maintenance personnel; and others facing corrosion challenges. Attendees at recent classes include representatives from chemical companies BP Chemicals, Samsung BP, Asahi Chemical, Polyplastics, Daicel Chemical,

Agrium, MES, Millennium, Orica, Catalytica Pharmaceuticals, Nitrochem, Dow Chemical, DuPont, as well as others.

“We offer a great deal of information in a single location, covering a range of material alternatives for corrosive environment applications,” says Rick Sutherlin, Technical Services Manager for Wah Chang and the principal instructor of the seminar series. “The idea is to share our expertise in the capabilities of corrosion resistant materials, including specialty steels, nickel alloys, niobium, titanium, and zirconium. People want to know the best applications for these metals, how to work with them safely, and how to fabricate them. Now we offer this information to them in a two-day course at a location convenient to them, and in some cases, even at their manufacturing facility.”

So far, attendee feedback has been positive, with 92% of the participants at one recent course rating the seminar good to excellent. “The commitment and knowledge shown by the Wah Chang staff is stellar,” according to Scott Hicks, President of Hicks Equipment. “Now, we at Hicks Equipment can take this commitment and knowledge to our customers.”

The seminar was developed and is presented by technical personnel and professionals in materials engineering, metallurgy, and other technical disciplines. After a background in the physics and causes of corrosion, the course turns to metallurgy, manufacturing processes, fabrication, welding techniques, and ongoing maintenance of corrosion resistant materials. The course also offers guidance in project manage-

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## Fall 2000 – Spring 2001 Schedule



Date	Location
October 19-20, 2000	Baton Rouge, Louisiana
November 2-3, 2000	San Francisco, California
February 1-2, 2001	Singapore
February 5-6, 2001	Perth, Australia
February 8-9, 2001	Melbourne, Australia
March 8-9, 2001	Houston, Texas
April 8-9, 2001	Delhi, India
TBD	Cancun, Quintana Roo, Mexico

## EVENTS

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ment, safety issues, materials specification, failure analysis, and other important issues.

At the close of the seminar, participants receive access to the Corrosion Solutions' web site, which includes a database of technical articles, a conversion calculator, a Life Cycle Cost Calculator, online access to corrosion testing data, and more. Attendees also receive a voucher valued at \$400 for corrosion testing services.

To register for a course, contact Sheryl Renzoni at 541-926-4211 ext: 6280. For more details on content, contact Wah Chang's Rick Sutherland at 541-967-6924.

## ANPSG Meeting

November 6-9, 2000  
Destin, Florida

The 2000 ANPSG (Ammonium Nitrate Producers Study Group) Meeting is fast approaching. This year's study group will take place at the Hilton Sandestin Beach in Destin, Florida, November 6-9.

Mr. William Stampe of Royster-Clarke Nitrogen is organizing the technical sessions, which will address a wide range of production and maintenance-related issues. A sample of topics from past meetings includes Power and Control Failure Damage; New Source of Ammonium Nitrate and Ammonium Sulphate; Nitric Acid Plant Strength Tests; Explosive Properties of UAN; Risk Management Plan Communications; and Nitric Acid Plant Emissions. Plant personnel interested in presenting a paper (or leading a discussion) should contact Mr. Stampe at 1-815-747-3101 ext: 241 (or fax a title and short abstract to 1-815-747-3110).

In addition to the technical sessions, exhibition organizers Wah Chang along with a group of fabricators, engineering companies, and other vendors will host a variety of events in conjunction with the meeting. Following is a tentative schedule for the vendor hall portion of ANPSG 2000. (Note: the Ammonium Nitrate Producers have formal meetings scheduled for Tuesday, Wednesday, and Thursday.)

### Monday, November 6, 2000

- Reception  
(Exhibit Hall).....5:30-7:00 pm

### Tuesday, November 7, 2000

- Lunch  
(Exhibit Hall).....11:30-1:00 pm
- Reception.....5:30-9:00 pm

### Wednesday, November 8, 2000

- Reception (Exhibit Hall) ..5:00-6:00 pm
- Dinner/Entertainment .....6:00-9:00 pm

To make hotel reservations for the ANPSG 2000, contact the Hilton Sandestin Beach at 800-445-8667 and let them know you are part of the group.

If you have any questions regarding this event, please contact Kirk Richardson at 541-967-6955 or Sheryl Renzoni at 541-926-4211 ext: 6280. We look forward to seeing you at Destin this fall. ■

## CORROSION LAB CHRONICLES

(Continued from Page 6)

Of the metals that we tested, it appears the best choices for HBr service are Nb and possibly Zr 702. Based on literature values, Ta is a preferred metal and has near zero corrosion at temperatures to the boiling point at all concentrations. We plan to continue our testing efforts, and report the results in later issues of Outlook. For more information on our Corrosion Testing Services, please contact us at 541-917-6777 or visit our website at [corrosionsolutions.com](http://corrosionsolutions.com) ■

## OUTLOOK

LYNN DAVIS ..... President

PARRY WALBORN ..... Vice President, Commercial

GARY KNEISEL ..... Director of Sales

KIRK RICHARDSON ..... Editor

*Outlook* is published quarterly by Wah Chang (Albany, Oregon office). The newsletter contains information on reactive and refractory metals, including hafnium, niobium, titanium, vanadium, and zirconium, as well as chemicals. The properties listed herein are average values based on laboratory and field test data from a number of sources. They are indicative only of the results obtained in such tests and should not be considered as guaranteed maximums or minimums.

### INFORMATION & ORDER CONTACTS

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For information on agents/distributors of CPI products  
call: **(541) 967-6906**

For information on agents/distributors of nuclear-grade alloys  
call: **(541) 967-6914**

For information on agents/distributors of Ti, V, and Nb products  
call: **(541) 967-6977**

For information on Allvac products  
call: **(704) 289-4511**

For information on Allegheny Ludlum products  
call: **(412) 394-2800**