

# OUTLOOK

PRODUCERS AND FABRICATORS OF REACTIVE AND REFRACTORY METALS AND CHEMICALS

**ALLEGHENY TECHNOLOGIES**



**Allegheny Technologies**

Specialty Materials That Make Our World

*Zirconium Stopper is*

## **Music**

*to Flautist's Ears*

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*Musician David Symmington is discovering new sounds using zirconium, titanium, and other metals.*

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*NACExpo 2004  
New Orleans, LA*

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# Zirconium Stopper is Music to Flautist's Ears

BY: KIRK RICHARDSON — *Wah Chang*

**David Symington is an innovator, though you won't get him to admit it. Truth is, the amateur flute player has become a bit of a musical metallurgist.** These days, the ex trader likes to experiment with titanium, zirconium, and other materials for stoppers and other flute components, eliciting new sounds out of an ages-old instrument.

In fact, the flute is the oldest known wind instrument, dating back to the 900 B.C (an early Chinese version called a ch'ie). The instrument has come a long way since its first note.

According to Symington, "The modern concert flute is basically a tube made out of wood or one of a variety of metals and about 67 cm long. It is commonly divided into three parts: the head, the body, and the foot and is kept in its case, split down into these three components, which are re-assembled when it is used." The instrument has a little sister, the piccolo, which plays an octave above the flute.

Inside the head of most flutes, there is a cylindrical cork faced with a metal disc, which provides an airtight seal. It's jammed precisely in place between the hole in the head (across which the player blows) and the open end of the head. Without the cork or a cork substitute, the instrument will not sound. The open end of the head is stopped with the crown.

The substitution of the cork by a cylindrical metal stopper held in position by a rubber O-ring was first proposed and implemented by Ernest J. Eggs and his son Leslie in the 1960s, according to Symington. "They claimed that



(left to right) Zirconium Stopper (heat treated); Zirconium; Silver Crown.

the cork dampened the sound, and its substitution by a metal stopper would improve matters," he says, "and they were, in my opinion, right."

Symington knows his subject well. "I started playing the recorder when I was about 12 and turned to the transverse flute when about 14," he points out. "I do not remember what attracted me to the instrument in the first place." Whatever it was, he hasn't lost interest.

The flute maker Robert Bigio makes a stopper similar in principle to that of the Eggs', but made of a plastic. Symington gave it a try. "I was using a Bigio Delrin (a type of plastic) stopper and found it improved the tone of the instrument as compared with the result using the cork supplied by the maker of my instrument," he says. "My flute is an open-hole type, that is the perforated key plates are stopped by the fingers. This can be awkward, so I stopped two of the perforations with plugs. This improved the tone. On the underside of the plugs facing inside the tube there were metal studs to which I attributed this improvement. I then conjectured that

substituting the plastic stopper in the head with a metal one might have a good effect."

His perceptivity led to a series of experiments with different metals. Since 2002, Symington has tested a symphony's-worth of stopper materials, including aluminum ("light airy tone"), tin ("uninteresting"), brass ("unremarkable"), copper ("bright and resonant"), lead ("unusual"), gold ("expensive"), and tungsten ("powerful and responsive, but with an arid, empty tone") among many others. The oddest material the innovator has used is Indium, which he says provides a "very good sound", but is so soft that "even putting the rubber O-ring on damaged it."

Among the long list of metals with which Symington has experimented, a few stand out musically speaking. These include sister metals titanium, zirconium and hafnium. He compares their sounds with cork as "markedly more direct, louder and more interesting — like a wine with fruity flavours — and more flexible." Symington says that "there is a family resemblance" between hafnium, zirconium, and titanium, but that "titanium gives a light sound" while "zirconium is fuller and hafnium fuller still. They all are bright and bell-like."

To-date, the only zirconium stopper maker Symington knows of is Bigio. "He has made some few commercial sales of zirconium stoppers for flutes to professional players, and the feedback from the purchasers has been enthusiastic," he says. "A couple of sales of zirconium stoppers to piccolo players have been made, and these have been well received by their owners." There may also be other applications for these metals in other components and even different instruments. "We are investigating the possibility of making

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Piccolo made from African Blackwood and disassembled silver flute.



# Explosion Welding: From Principle to Practice

BY: KIRK RICHARDSON — *Wah Chang*

There's probably a book worth writing some day titled "Strange but True Metals Tales". If and when it's published, explosion welding is certainly worthy of its own chapter. And, in the footnotes, one would find several references to Allegheny Technologies products, such as titanium, zirconium, and other alloys, since many have played key roles in the history of this marriage of metals.

It was during World War I that soldiers first took notice of this phenomenon. They observed that shrapnel from disintegrated metal shell casings traveling at high velocities sometimes bonded with steel stanchions and other metallic surfaces that they struck. Though it was decades before industrious engineers finally put the phenomenon to practical use, explosion welding was born.

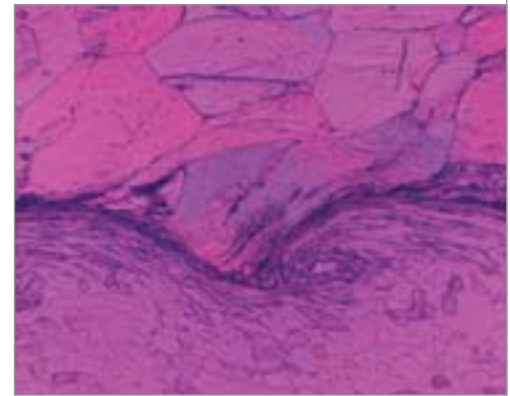
The technology didn't take hold until years later. In Bernard Crossland's book *Explosive Welding of Metals and its Application*, he reports that L.R. Carl appears to have been the first to note welding under high velocity impact in 1944. In these experiments, Carl used a detonator separated by two half-hard brass shims from a booster charge of high detonation velocity explosive. "Recovery of the brass discs after detonation of the charge showed that they had been welded together,

and a micrograph of the section shows small poorly formed interfacial waves now frequently associated with explosive welds. Carl concluded that the weld was not a fusion weld but that it had been formed by a solid-state mechanism."<sup>1</sup>

Still, the technology was in its infancy. Crossland credits V. Philipchuk with first recognizing its commercial value. In 1957, Philipchuk noted explosion welding while explosively forming an aluminum U-channel in a steel die.

About the same time, Arnold Holtzman and his colleagues at DuPont were working to develop applications. "The pathway to our inventing the cladding process started with an explosive forming experiment in which the steel being formed bonded to the die in several spots," he remembers. "Metallographic study showed a true metallurgical weld at these spots, but they were of very small size."

This was soon followed by hardening experiments on austenitic manganese steel in which thin steel shims were driven into the steel as a way of increasing the shock wave pressures.<sup>2</sup> Metallurgical bonding between the steel shim and the austenitic steel was found in larger areas. "It was clear that a metallurgical welding process was occurring, and George



Typical explosion weld showing wavy interface.

Cowan, our fluid flow expert, began to develop theories for its mechanism," Holtzman says. "This led to the theory of jetting that was proven by framing camera work in which pictures are taken every micro-second."

Holtzman and his colleagues never lost sight of commercializing explosive welding. "At the outset, we decided to pursue the process so as to desensitize the variables such that operations could be conducted routinely under non-research conditions by manufacturing units," he says. "This work was extraordinarily successful and by adjusting the speed of the explosive and the spatial conditions, we were able to work out proper parameters for a wide variety of metal combinations."

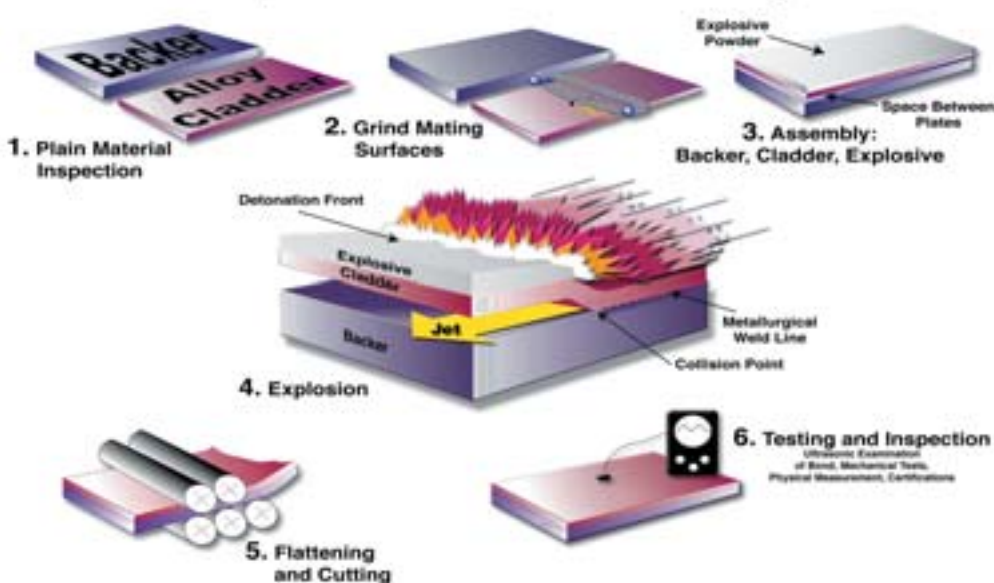
The effort proved well worthwhile. Commercial operations began in 1963, then in 1965, DuPont used the explosion welding process to produce the clad metals needed by the US Mint for new coinage. During the next three years, the team made over 70 million pounds of dime, quarter, and half dollar blanks. John Banker, a former DuPont employee and currently Vice President at DMC Clad Metal, jokes, "DuPont made lots of money making money."

Holtzman recalls that it wasn't all easy-going. "The US Government made the change from silver to clad coins in 1965," he says. "We at DuPont produced 30,000 tons of Cu-Ni/Cu/Cu-Ni clad metal strip for the Philadelphia and Denver Mints in the first three years (1965-1967). Our billets were 6 inches thick and were rolled, starting hot, to the required gage.

The first two small runs led to low yield due to a billet temperature a bit too high for the clad even though it would have been fine

The controlled detonation of an explosive layer on the cladder plate results in a high pressure collision of the metals. The collision conditions create a metallurgical weld between the cladding and base metal plates.

## Explosion Clad Plate Manufacturing



ARTWORK COURTESY OF DMC CLAD METAL

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# Explosion Welding: From Principle to Practice

[ continued from page 3 ]

for the outer layer. Had we made coins from these, George Washington would have appeared to have a case of measles. We reduced the temperature and the process went smoothly thereafter."

Eventually, DuPont dropped out of the coin business and concentrated on developing other markets for the technology. "In time, the

to steel for large tube sheets and pressure vessels for chemical processing plants. "These were followed quickly by titanium to steel and other metal/steel combinations that would normally form intermetallic compounds and prevent bonding by standard methods," according to Holtzman. "These combinations included vanadium, tantalum, zirconium,

Holtzman concludes saying that "as a company, DuPont profited from the commercial cladding operations, the licensing, and importantly, the ability to acquire chemical vessel constructions for its own operations that it could not have had previously."

As one might imagine, the road to success in the history of explosion welding wasn't

## **Allegheny Technologies products, such as titanium, zirconium, and other alloys, have played key roles in the history of explosion welding.**

copper companies from whom we bought the metals and who rolled our billets learned to make the clads (by roll-bonding of strip) and made it impossible for us to compete further in the Government procurement," Holtzman says. "We took great pride in the fact we never supplied the mints with anything other than high quality product."

Coinage was one of a number of early applications for explosion welding. According to Banker, DuPont had invested "significantly" in explosion welding research and development during the 1960s, and the investment paid off. "When I joined the (DuPont) Detaclad team in 1969, there were over 20 metallurgists and technicians developing everything from shipbuilding products to multi-layer razor blades," he says.

Early clad products included stainless steel

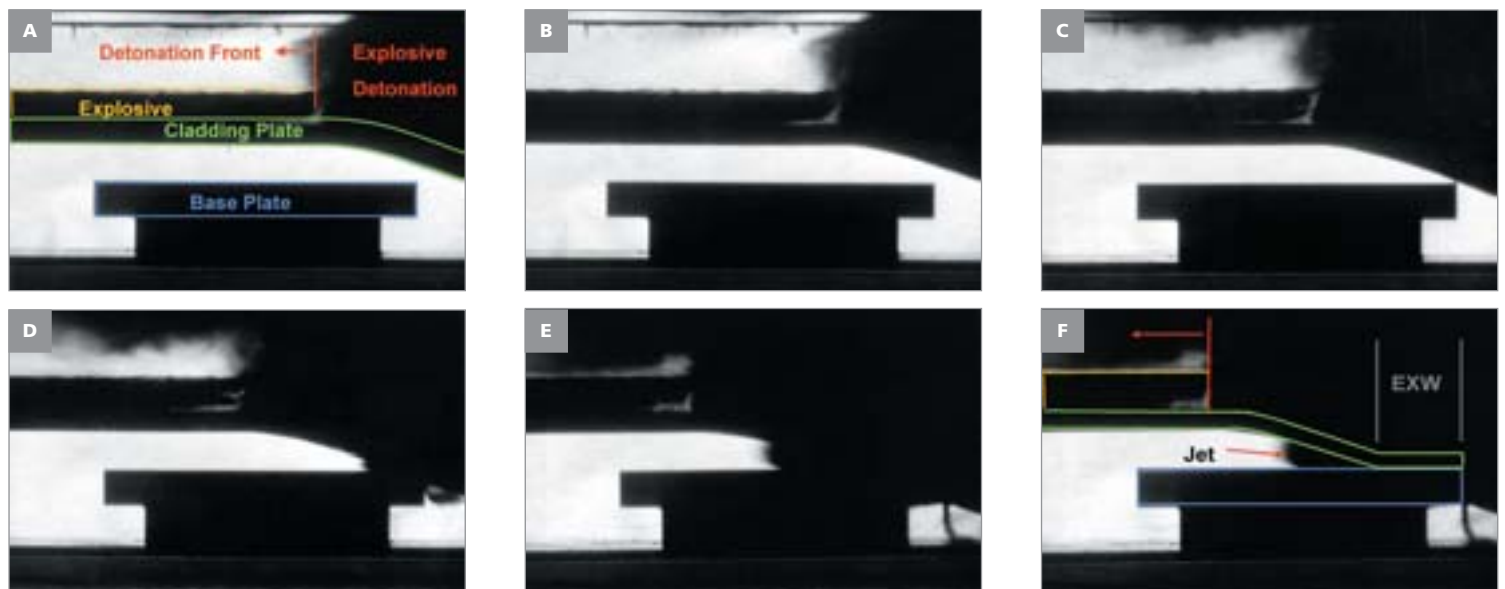
Hastelloy<sup>®</sup> alloys and aluminum." He also points out that aluminum/steel "clads" were used importantly as transition joints by the Electrical and Marine Industries as the metallurgical bonds proved advantageous over mechanical bonding processes.

"An especially rewarding moment came for me when I gave a presentation to a conference in Norway in 1964 in which I showed slides of huge explosively welded stainless steel/ steel clads being used for commercial tube sheets," Holtzman recalls. "This came at a time when other research organizations in the field were showing pictures of pieces explosively welded that were only several inches in size. The lead we had over others was a source of great satisfaction to all of us at the Eastern Laboratory of DuPont who had participated in our state-of-the-art effort."

without its twists. Banker tells the tale of one colorful episode with Explosive Fabricators Inc., which entered into the cladding business in 1975. "When I first came to EFL (from DuPont), we were doing our explosive work in a remote location in eastern Wyoming," he says. Upon arriving home one night, Banker's wife advised him that the local evening news reported an earthquake near Cheyenne about 9 pm. Banker says that "the press never found us out," but a prominent neighboring rancher did. "The following morning we had a call from his lawyer recommending 'that you should STOP blasting there immediately.'"

Then there was the group of "city slickers" from New York visiting a nearby ranch that felt an explosion and mistook it for a stampede of cattle. The visitors were apparently shocked when cattle never looked up from grazing.

Framing camera sequence, (A) Overlay, (B) Start "0.0", (C) + 0.000,005 second, (D) + 0.000,010 seconds, (E) + 0.000,020 seconds, (F) Overlay showing jet.



Banker has plenty of other amusing tales that include rattlesnakes, cattle with a taste for explosives, burning fields, and others that he says will never see "print". "Most of the better ones related to the days when we were doing our explosives work in the prairies of eastern Colorado," he explains. "We have since moved this work to an underground site in Mt. Braddock, Pennsylvania and can no longer enjoy these things."

Much has changed since the heyday of early development work, but a great deal of the progress made is the direct result of the technological seeds that Holtzman and his colleagues at DuPont sowed in their pioneering days. Banker notes "the technology today is essentially unchanged from Holtzman's days, but significant progress has been made in safety, industrialization, and cost reduction."

Over the years, knowledge built at DuPont spread as the company licensed its explosion welding technology to several companies worldwide. Banker said that the field of explosion welding manufacturers expanded to more than 10 in the 1980s. "It was dog eat dog," he says. "The dominant products were titanium and aluminum clads, products which benefited from the unique EXW cold welding technology." Banker adds that, in 1984, EFI made clad plates for the first zirconium-clad acetic acid reactor (using Zr 702 produced by Wah Chang). Since then, acetic acid reactors have been one of the major applications for explosion clad products.

By the 1990s, some small companies closed shop and others consolidated. In 1993, EFI changed its name to Dynamic Materials Corporation (DMC), then went on to purchase the DuPont cladding business in 1996. This combination made DMC the largest explosion welder in a world of expanding opportunities.

In 2000, SNPE (Societe National Poudre Explosifs) bought controlling interest in DMC, and eventually consolidated the American and European (Nobelclad) and (Nitro Metall) companies under DMC management. These



DMC Nobelclad produced the titanium-steel clad plates for this autoclave (4.3 m diameter x 29 m long). According to DMC's John Banker, the exceptionally uniform strength and ductility of Wah Chang's Grade 17 Titanium has helped to make the project one of "the most successful large titanium clad jobs ever".

business moves proved to be especially successful. According to Banker, DMC currently owns approximately 60% of the world market share for explosion clad products.

"As the industry leader, the DMC cladding companies are working continuously to entrench the culture of "Reliability in Quality and Delivery" that has been the cornerstone of the EFI/DMC business," Banker says. "DMC is investing significantly in R&D and marketing to further assure the long term future viability of the explosion cladding technology."

If history of the technology continues its course, there is strong reason to believe that DMC will carry on the pioneering tradition of Mssrs. Carl, Philipchuk, Holtzman, Cowan, and many others who have contributed to the development of explosion welding.

For more information about DMC's Detaclad® and related products, visit [www.dynamicmaterials.com](http://www.dynamicmaterials.com) or phone 303-604-3902. For more information about Allegheny Technologies suite of metal products, visit [www.alleghenytechnologies.com](http://www.alleghenytechnologies.com). \*

## References

1. Bernard Crossland (1982), *Explosive Welding of Metals and its Applications*, Oxford University Press, pages 7-8.
2. A. H. Holtzman and G. R. Cowan (1961), "The Strengthening of Austenitic Manganese Steel by Plane Shock Waves", *Response of Metals to High Velocity Deformation*, Interscience Publishers, page 447.

\* *Hastelloy®* is a registered trademark of Haynes International.

## Zirconium Stopper

[ continued from page 2 ]

a 'head' out of zirconium, but do not yet know how practical the idea is," says the inventive musician. "One zirconium crown has been made, and the result is good." He mentions saxophone mouthpieces as another candidate for metals "and perhaps the mouthpieces of brass instruments might be a fruitful field for experiment."

Not one to miss a note, Symington insists on making it clear that his remarks regarding the quality of sound apply to his experience as a player rather than as a listener. "Other experienced players find marked differences between different types of stoppers," he says.

"To listeners, the effects are more subtle and difficult to discern. This emphasis on the judgment of the players rather than the auditors may sound odd to the non-musician, but is of great importance to the player."

To that end, Symington will continue experimenting with metals because his music is most important to him. Restless in his pursuit of new sounds, he is currently considering \*niobium, another metal produced by Wah Chang.

For the moment though, he's found a metal that really resonates with him. "I have played in one operatic concert using a zirconium stopper," he pipes up. "I use one habitually for private chamber music and duet sessions." Sounds like zirconium is music to this innovator's ears.

David Symington can be reached on the telephone in the U.K. at 011 44 20 8788 1331. Robert Bigio's products can be found at [www.bigio.com](http://www.bigio.com). For more information on Allegheny Technologies' "Metals that Make our World," visit [www.alleghenytechnologies.com](http://www.alleghenytechnologies.com). \*

\* *Niobium is next to zirconium in Period 5 of the Periodic Table and has the atomic number 41 (zirconium 40). Symington conjectures that niobium, being close in atomic structure to zirconium, may share its musical qualities or be even better. "There is only one way to find out and that is to make a niobium stopper and try it," he writes.*

# How Does Surface Condition Affect the Corrosion of Zirconium in Acidic Chloride Solutions?

BY: STEVE SPARKOWICH — Wah Chang & TE-LIN YAU — Independent Consultant

**Question:**

How does surface condition affect the corrosion of zirconium in acidic chloride solutions?

**Answer:**

Zirconium is well known for its corrosion resistance in pure hydrochloric acid, as shown in Figure 1. The data clearly demonstrates the wide range of zirconium's corrosion resistance in HCl solutions; for example, at 10% acid concentration, the temperature limit for zirconium is above 250°C, and at 37%, the limit is about 130°C. Figure 1 also shows that, with the exception of tantalum, the temperature limits for the other metals and alloys in hydrochloric acid are much lower.

However, zirconium is also known for its vulnerability to localized corrosion in oxidizing chloride solutions because of its low

breakdown potential. Breakdown potential refers to the electrochemical potential at which pitting is initiated due to breakdown of the passive oxide film.

Oxidizing species, especially ferric ion, often exist in acidic solutions. This localized corrosion has been observed in chloride solutions with varying amounts of ferric ions at the Wah Chang Corrosion Laboratory, as shown in Table 1.

Corrosion is mostly a surface phenomenon, and surface condition often plays an important role in the initiation and propagation of localized corrosion. Zirconium is a soft metal, so it can be easily embedded with foreign particles. These particles may be embedded during fabrication due to the use of unclean steel tooling, such as is used for roll or press brake forming and roller expansion, as well as from material handling equipment. In most applications, embedded iron particles will not present a problem; however, in hydrochloric

acid and other acidic chloride applications, these particles may produce harmful effects. For example:

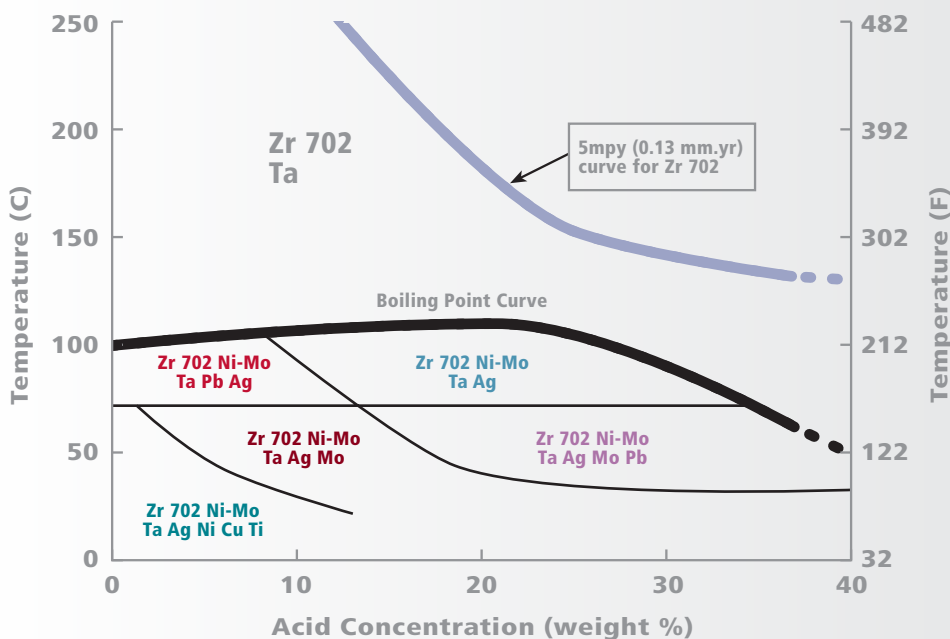
- A) Embedded iron particles may generate ferric ions.
- B) Embedded carbide particles provide cathodic sites to induce a breakdown in the oxide film on zirconium.
- C) A rough, contaminated surface reduces the likelihood of forming a highly protective oxide film on zirconium.

Test results (as given in Table 2) demonstrate that there is an enormous difference between the mill finish and the HF-HNO<sub>3</sub> etched zirconium samples in boiling 10% ferric chloride solution. Properly cleaned zirconium performs well in oxidizing chloride solutions, environments which have been regarded as incompatible for zirconium.

The primary goals in surface cleaning are to remove surface contaminants and to smooth out surface features. Listed below are some suggestions that will help improve the surface cleanliness of zirconium vessels:

1. Always start with zirconium that has a pickled surface. Wah Chang typically provides a pickled surface finish on zirconium products, unless otherwise specified.
2. Minimize the risk of iron and other particles being embedded during fabrication by:
  - a. Utilizing a protective covering on forming equipment.
  - b. Using a hydro-swage for tube expansion.
  - c. Protecting material during handling and transport, e.g. forklift protectors.
3. After all fabrication and welding is completed, surface condition the areas which will contact acidic chloride media with a dilute HF-HNO<sub>3</sub> solution. We strongly recommend working with a chemical cleaning company experienced in working

**FIGURE 1. Suitability of Selected Metals and Alloys in Pure Hydrochloric Acid.**



## Affect the Corrosion

Table 1.

**Effect of Ferric Ion on the Corrosion of Zirconium in Hydrochloric Acid**

Corrosive Media	Temperature (C)	Corrosion Rate (mils/yr)	Corrosion Observations
10% HCl + 50 ppm Fe <sup>+3</sup>	30	<1	None
	60	<1	None
	100	<1	Pitting
10% HCl + 500 ppm Fe <sup>+3</sup>	30	<1	Pitting, SCC
	60	<1	Pitting, SCC
	100	<1	Pitting, SCC
20% HCl + 50 ppm Fe <sup>+3</sup>	30	<1	None
	60	<1	None
	100	<1	Pitting
20% HCl + 500 ppm Fe <sup>+3</sup>	30	<1	Pitting, SCC
	60	<1	Pitting, SCC
	100	<1	Pitting, SCC
32% HCl + 50 ppm Fe <sup>+3</sup>	30	<1	None
32% HCl + 500 ppm Fe <sup>+3</sup>	30	<1	SSC
	77	<5	SSC

NOTE: SCC = Stress Corrosion Cracking

Table 2.

**Corrosion Rate (mils/yr) of Zirconium in Boiling 10% Ferric Chloride Solution**

Etching Time (min)	0	1	2	3	4
Non-welded	21.0	0.4	0.1	0.0	0.0
Welded	<196	2.8	1.6	0.3	0.2

with reactive metals. Vessel geometries will vary, so each case needs to be evaluated separately to establish proper surface conditioning techniques.

Zirconium can be used very effectively in acidic chloride solutions as long as the surface condition issues mentioned above are addressed during fabrication. In addition, equipment installation and maintenance procedures must be controlled to avoid contaminating zirconium surfaces with iron. For any questions or concerns regarding this topic, please contact Wah Chang Customer Service at 888-967-6977 or email us at [custserv@wahchang.com](mailto:custserv@wahchang.com). \*

**References**

1. Yau, Holmes and Fahey: Performance of Zirconium in Bleaching Solutions, 1993 TAPPI Engineering Conference, Orlando, FL, September 20-23, 1993.
2. Fahey, Holmes and Yau: Evaluation of Localized Corrosion of Zirconium in Acidic Chloride Solutions, *Corrosion*, Vol. 53, No. 1, p. 54, 1997.

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## ATI Wah Chang Launches Web-based Customer Feedback System

BY: STARLENE LADD — Wah Chang

What is the Customer Feedback System? It is a Web-based system created to collect, categorize, and rank submitted feedback in order to eliminate or minimize recurrence of quality, service, documentation, and shipping related subjects.

Here is how it works. A Wah Chang representative receiving the feedback forwards the information to the appropriate departments for corrective actions or replies. After receiving required replies, the representative responds to the customer.

Customer Service follows the customer feedback from receipt to closure to make sure that it doesn't stall in the system. In addition, Customer Service also keeps management informed about feedbacks received. Feedback received from customers will help Wah Chang to identify and focus on areas that may need improvement.

The Customer Feedback System allows customers to enter information and e-mail it to the Wah Chang representative of their choice. Customers also automatically receive a receipt after submitting feedback. They can then call Wah Chang Customer Service for updates, if necessary.

Wah Chang hopes that this new system will provide an effective tool for communicating with its customers in relation to feedback, whether it's a complaint, problem, suggestion, or a compliment, and give Wah Chang opportunities to increase customer satisfaction.

We encourage our customers to use this new Customer Feedback System located at: <http://portal.wahchang.com/feedback/feedback.cfm>. \*



# EVENTS

## WM'04

This winter, Allegheny Technologies Incorporated (ATI) will be on hand to display its corrosion resistant alloys and other specialty metals at 30th Annual WM'04 (Waste Management) Conference in Tucson, Arizona.

The University of Arizona is hosting the conference February 29 - March 4, 2004 at the Tucson (Arizona) Convention Center. Sponsors include the American Nuclear Society, New Mexico State University, the Waste-Management Education and Research Consortium (WEREC), the American Society of Mechanical Engineers (ASME), the Nuclear Energy Association — Organization for Economic Cooperation and Development, the U.S. Department of Energy and the International Atomic Energy Agency. Allegheny Technologies is also a Sustaining Sponsor.

The Conference is focused on the worldwide safe management of nuclear waste. This includes waste management, decommissioning, environmental restoration, energy security, utility waste management, public information, education, and regulatory requirements.

Show managers expect more than 2,000 scientists, engineers, government officials, academic leaders, and corporate managers attend the conference from national and international companies, agencies, and institutions. Approximately 68 Technical Sessions and 600 technical papers and several workshops are scheduled over the five-day event, according to organizers.

Allegheny Technologies' display (booths 359-361) will feature literature, samples, representatives who can answer your technical questions, and a few surprises. According to Dennis Emerson, of ATI Wah Chang, "We also will be co-sponsoring a function at the PIMA Air Museum (date and time TBD)." For more information about this function, contact [dennis.emerson@wahchang.com](mailto:dennis.emerson@wahchang.com).

## NACE

This spring, the National Association of Corrosion Engineers (NACE) is hosting its 59th Annual Conference & Exposition, Corrosion NACEExpo 2004. The event takes place at the Ernest N. Morial Convention Center in New Orleans, Louisiana, March 28 - April 1, 2004.

NACEExpo's exhibit hall opens Monday, March 29 (5:30 to 7:30 p.m.) and continues daily (10 a.m. to 5 p.m.) until closing Thursday, April 1 (10 a.m. to 2 p.m.). Allegheny Technologies' Total Corrosion Solutions (TCS) team will be on hand to display its wide array of corrosion resistant metals in Booth # 712.

Representatives from Allegheny Technologies Companies Allegheny Ludlum, Allvac, and Wah Chang will be present to answer technical questions and provide information on the companies' broad range of services and metals, ranging from stainless steels and High Tech Alloys® to nickel alloys, niobium, titanium, and zirconium. For more information about the conference, visit [www.nace.org](http://www.nace.org). ✪

# OUTLOOK

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# PEOPLE

**Ronald Williams has transferred from Allvac to Wah Chang.** Allvac is a leader in the development and supply of long products utilized in critical material applications. Mr. Williams was Product Manager, Titanium Ingot and Billet Products and Business Development Manager-Nuclear Markets at Allvac Headquarters in Monroe, North Carolina. In addition, he has had product management responsibility for jet engine shaft products. Mr. Williams holds a BS in Business Administration from Appalachian State University.



According to Andy Nichols, Director of Marketing at Wah Chang, "Ron brings more than 30 years of experience in stainless steels, specialty steels, and nickel and titanium alloys to Wah Chang. He has made significant contributions to materials development in the aerospace and nuclear industries and brings additional talent in market and product development."

Mr. Williams is initially focusing on Wah Chang and ATI products designed for civilian and government nuclear applications, but he will be working with many of Wah Chang and ATI's products across multiple markets. He can be contacted at [ron.williams@wahchang.com](mailto:ron.williams@wahchang.com) or by phone at 704-219-3328. ✪