WILL U.S. VALVE SHIPMENTS GROW IN 2017?

VALVE MAGAZINE

SPRING 2017 | VOL. 29, NO. 2

Materials Play Critical Role in Today's Power Plants

THE DANGERS OF WATER HAMMER

WHAT WENT WRONG?

BASICS OF LUBRICANTS

MEASURING PROOF TEST EFFECTIVENESS

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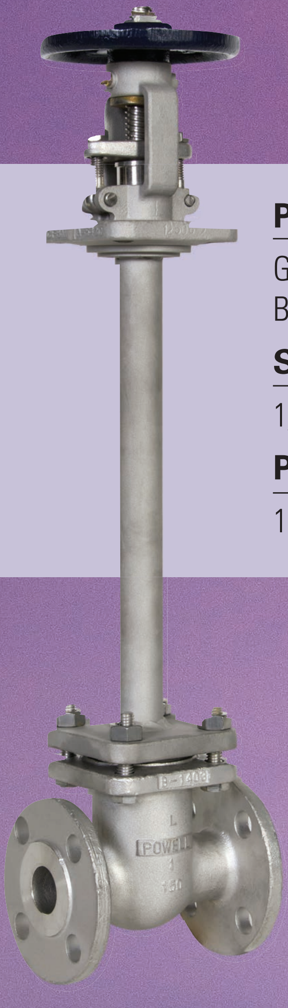

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VALVE MAGAZINE

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VALVE MANUFACTURERS ASSOCIATION OF AMERICA
The voice of the flow control industry

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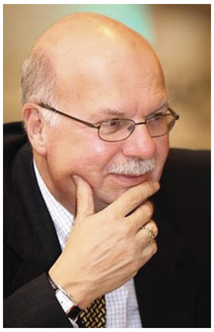
The 2017 Industry Outlook—Little or No Growth



The year 2017 will not be a banner year for the industrial valve industry, according to our Market Forecast of Industrial Valve Shipments in the United States for 2017. However, unlike 2016, when we saw no growth at all, we have forecast a growth of slightly under 2%.

The only end-user industries indicating growth are water and wastewater, petroleum refining, and iron and steel with slight gains in co-generation and gas distribution. Other markets are either flat or down, our figures show. This reality was reflected in what was said by industry leaders at our Valve Industry Leadership Forum in Philadelphia last month as well as discussions among attendees. Some of the phrases I heard to describe both 2017 and 2016 were “challenging,” “tough” and “small turnaround.” At the same time, I also heard many people refer to current attitudes as “cautiously optimistic,” and several people pointed out that these market conditions were not limited to the U.S. and Canada—it’s a worldwide phenomenon.

The presentation by our economic consulting firm ITR Economics pretty much echoed what our industry leaders shared with me, namely slight growth in 2017 for the leading indicators related to our industry. ITR also went on to say the firm’s forecasters are still predicting a mild depression at the end of 2018. At the Leadership Forum, we also featured a panel of experts representing the water and wastewater, power, and oil and gas industries, who painted a similar picture.

As always, VMA will continue to monitor the economic picture so that you can get the most up-to-date information on market conditions. We hope you’re already planning to attend or send someone to Boston in August for our Market Outlook Workshop. At that event, we delve deeper into the economic issues as we learn what 11 end-user industry experts see coming for 2018.

Stayed tuned to VALVE Magazine for our summer issue where I’ll share with you the outlook for our European counterparts based on what I learn from the area’s Annual Congress in Brussels. In fall’s issue, you’ll also hear what 2018 may have in store for us. We hope all of this information will help you with the decisions you make every day that ensure your companies’ and our industry’s continued success. VM

Bill Sandler
President, Valve Manufacturers Association of America

NEW CONTRACTS & PARTNERSHIPS

GE, Transocean Announce Service Agreement

GE Oil & Gas secured a new contractual service agreement with Transocean valued at about $180 million. Under the agreement, GE will provide condition-based monitoring and maintenance services for pressure control equipment on seven of Transocean's rigs over the next 10 to 12 years.

Powell Valve Approves Flotech as Authorized Facility

The Wm. Powell Company recently approved Flotech as an authorized modification and repair facility for Powell Valves. Flotech has been manufacturing and repairing valves for over 40 years.

Curtiss-Wright, Clarke Sign Licensing Agreement

Clarke Industrial Engineering entered a licensing agreement with Curtiss-Wright Corporation, whereby Clarke's patented and proprietary Shutter Valve technology will be exclusively available to Curtiss-Wright for the worldwide naval defense market, the U.S. maritime homeland security market and the commercial nuclear power market.

LESLIE SOPHIA LINDELL PHOTOGRAPHY

Stone Edge Farm's microgrid system relies on different energy sources.

Emerson Selected to Manage Microgrid Power Project

Stone Edge Farm selected Emerson Automation Solutions to operate its new microgrid, a self-sufficient energy production and distribution facility relying on diverse sources of electricity including solar

MARKET FOCUS: Limited Growth for 2017

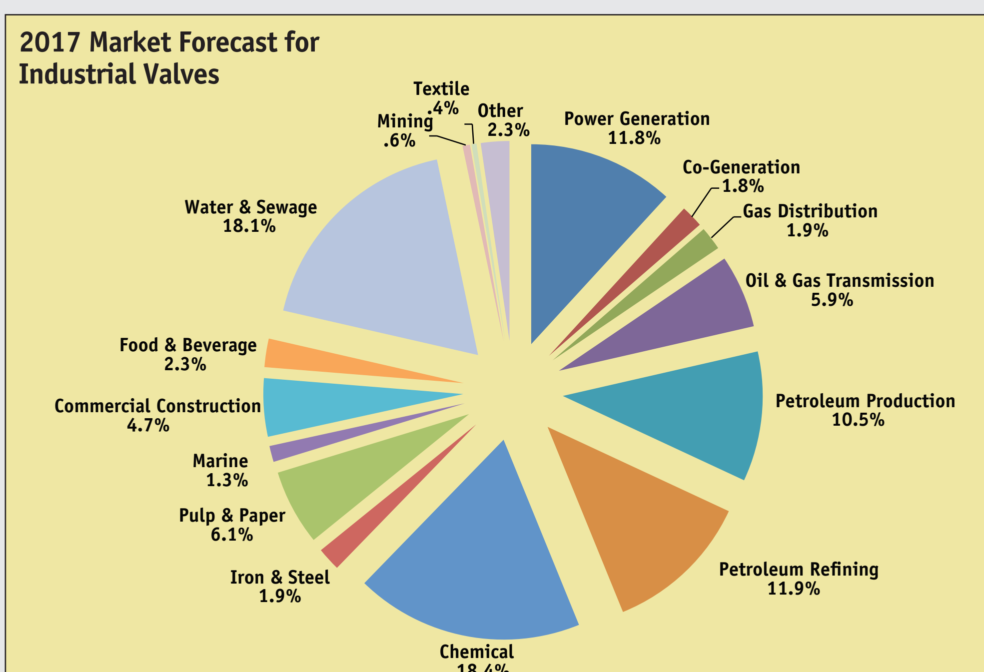
U.S. valve shipments will gain some ground this year: about 2% for 2017, according to VMA's annual forecast of valve shipments. That's an improvement over last year's forecast, which was almost flat.

The growth means valve shipments for the year will be $4.559 billion, a rise of about $94 million over 2016's numbers.

The gains can largely be attributed to an increase in business for water/wastewater, petroleum refining, and iron and steel. Also, co-generation and gas distribution are expected to have slight gains. The industries losing the most ground for the year will be power, oil and gas transmission, chemical, and construction, though none of the losses will be significant.

As it has been for years, the chemical industry remains the end-user category that is the largest with 18.4% of the total. Close behind now is water/wastewater at 18.1%. Petroleum refining, power generation and petroleum production constitute the next three largest markets.

As far as valve types, automated valves continue to grow in use and are the most-often used type of valve, climbing by about $281 million in shipments during the last 10 years.



power, wind power, hydrogen power and advanced storage battery technology. Home to a farm, spa and vineyard in Sonoma, CA, Stone Edge Farm hopes to achieve energy independence. A microgrid can act as an "island" operation, connecting and disconnecting from the larger distribution grid to satisfy power needs.

ATI Announces Singapore Partnership

Automation Technology, LLC (ATI) formed a partnership with Hekaph Koda Pte Ltd as its representative and valve automation solutions provider in Singapore.

Hekaph Koda has a portfolio that includes valves, actuators, flow meters and high-quality, high-performance hand tools. The company also provides valve automation, engineering support and maintenance, repair and operations services in the Asia-Pacific region including Malaysia and Thailand.

Eastern Controls to Distribute ITT/PBM Valves

Eastern Controls, Inc. (ECI) is now an ITT and PBM factory-authorized distributor for New York and northern New Jersey. ECI distributes a variety of sanitary process valves and instrumentation that serve the life sciences industry.

Cameron Signs Two Transocean Agreements

Cameron, a Schlumberger Company, signed two, 10-year pressure control equipment management service contracts on behalf of Transocean valued at greater than $350 million.

Schlumberger worker on site

The first calls for Schlumberger to manage Transocean's Cameron risers in the Gulf of Mexico. For the second, Schlumberger will provide a comprehensive suite of solutions to maintain and service blowout preventer systems and other pressure control equipment for nine of Transocean's ultra-deepwater and harsh environment drilling rigs.

Total Valve Systems Signs Distributorship Deal

Total Valve Systems announced a new distributorship with Continental Disc (CDC) and Groth Corporation. The two companies will provide customer service, and relief and vacuum products to customers worldwide. Total Valve Systems will be responsible for sale and distribution to Oklahoma, Kansas, Texas and Arkansas.

Bernard Controls Supplies Actuators for Nuclear Submarines

A new generation of nuclear-powered attack submarines ordered from the French Navy includes six submarines that will be built starting in 2019 and finalizing in 2028. Bernard Controls took part in the project by delivering sets of fully customized multi-turn actuators, which will be used to operate the cooling system of the nuclear reactor.

Rotork Provides Actuation for Oil Sands Development

Under a recent contract, Rotork supplied electric and pneumatic actuation to the Suncor Fort Hills oil sands mine project in the Athabasca region of Alberta in Canada. Suncor is Canada's leading integrated energy company. The project is scheduled to produce first oil as early as the fourth quarter of 2017.

The Suncor Fort Hills oil sands project

CALENDAR 2017

MAY

1-4
Offshore Technology Conference
Houston
www.otcnet.org

JUNE

11-14
ACE 17 Annual Conference & Exposition
Philadelphia
www.awwa.org

20-21
Valve World Americas Expo & Conference 2017
Houston
www.valveworldexpoamericas.com

AUGUST

3-4
VMA Market Outlook Workshop*
Boston
www.vma.org/MarketOutlook2017

SEPTEMBER

13-15
VMA/VRC Annual Meeting*
Fernandina Beach, FL
www.vma.org/AnnualMeeting

OCTOBER

SEP 30-OCT 4
WEF-TEC
Chicago
www.weftec.org

3-5
Valve Basics Seminar & Exhibits
Pasadena, TX
www.vma.org/ValveBasics

DECEMBER

5-7
Power-Gen International
Las Vegas
www.power-gen.com

* Open to VMA/VRC members only. Visit www.VMA.org to learn if your company qualifies for membership.

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welcomes articles, proposals, manuscripts, photographs and ideas from our readers. For a copy of the magazine's Author's Guidelines, contact Genilee Parente, managing editor, at gparente@vma.org.

The new branch of MRC Global in Rayong, Thailand

NEW FACILITIES/ DEVELOPMENTS

MRC Global Opens New Branch in Thailand

MRC Global opened a new location in Rayong, Thailand. The team hosted an open house for customers and suppliers on Jan. 12, 2017. The event was followed by a traditional blessing of the new building.

Wolseley Changes Name

Wolseley plc is changing its name to Ferguson plc, subject to shareholder approval. Ferguson is the most significant brand in the Wolseley Group of companies and accounts for 84% of the Wolseley Group's profitability.

Emerson Expanding ASCO Operations

Emerson will expand its ASCO operations in South Carolina's Aiken County. ASCO's fluid and pneumatic technologies are part of Emerson Automation Solutions.

Emerson's ASCO business unit will be consolidating its regional cylinder, motion control and accessory product lines to the Aiken facility.

STANDARDS & CERTIFICATIONS

ATI Completes Factory Acceptance Test for IPL Water Project

Automation Technology, LLC (ATI) has successfully completed the Factory Acceptance Test on the first of its five hydraulically-operated linear actuators for the Integrated Pipeline Project, co-partnered by the Tarrant Regional Water District and City of Dallas Water Utilities. The actuator, believed to be the largest in the world for this service, has a 30-inch bore with a 110-inch stroke and operates a Blackhall-manufactured parallel-faced metal-seated gate valve on a 108-inch raw water line.

It will be used to regulate the water flow on the first phase of the 20-year planned project that will consist of 150 miles of pipeline, three pump stations and three booster stations.

Weir Receives SIL Certification

Weir Valves & Controls USA Inc. received Safety Integrity Level (SIL) Certification on the Atwood & Morrill Free Flow Reverse Current Valve. The certification, which was performed by Exida, verifies that the product meets an SIL of 3 in accordance with IEC 61508 standards.

The actuator for the Tarrant Regional Water District is one of the largest of its kind.

MERGERS, SALES & ACQUISITIONS

Hunt Valve Company Acquires Precision

May River Capital and Hunt Valve Company have purchased Precision Technology, a severe-duty, solutions-based designer, manufacturer and supplier of linear motion actuators for automation, machinery, material handling and positioning applications. Precision will be rebranded Hunt Valve Company–Actuator Division.

REXA and CCC to Modernize Turbine Controls

REXA and Compressor Controls Corporation (CCC) have formed a joint initiative to modernize steam turbine controls for enhanced performance based upon each company's core competency.

More than 10,000 turbomachinery trains worldwide are powered by CCC. By upgrading mechanical and hydraulic governors to the latest technology, plant operators can achieve greater speed control and eliminate unnecessary trips.

FCX Performance Buys Renew Valve

FCX Performance of Columbus, OH acquired Renew Valve and its Cleveland-based Valve & Gauge division. This is FCX's fourth acquisition in recent months, following RL Stone, SW Controls and PCI. This expands FCX's footprint to 41 offices nationally, staffed by more than 800 employees.

Mueller Water Products to Acquire Singer Valve

Mueller Water Products, Inc. has signed a definitive agreement to acquire Singer Valve, a manufacturer of automatic control valves. Once the transaction has closed, Singer Valve will become part of Mueller Water Products' Mueller Co. operating segment. Singer Valve designs and manufactures automatic control valves, offering engineered products for pressure management within water works.

Forum Energy Technologies Gets Assets of Cooper Valves

Forum Energy Technologies, Inc. acquired the assets of Cooper Valves and a 100% ownership interest in Innovative Valve Components.

Based in Stafford, TX, Cooper Valves manufactures metal-seated ball valves engineered to meet Class VI shutoff standards for use in severe service applications, as well as a full line of cast and forged gate, globe and check valves.

Innovative Valve Components, in partnership with Cooper Valves, commercialized critical service valves and components for the power generation industry.

Mueller Water Products Announces Sale

Mueller Water Products, Inc. sold its Anvil International division to One Equity Partners, a private equity firm. Mueller Water Products estimated net cash proceeds from the transaction, after taxes and transaction-related expenses, will be about $250 million.

Rotork Combines Three Businesses

Flow-Quip, Inc. and Rotork ValveKits Inc. have merged with Roto Hammer Industries, Inc. All three were based in Oklahoma and were businesses of Rotork. Following the merger, Roto Hammer, based in Tulsa, OK, has been renamed Rotork Tulsa, Inc. The combined company will have a new location in Tulsa.

CIRCOR Announces Historical Segment Information

CIRCOR International announced the availability of certain historical segment information that reflects its previously announced organizational realignment. The new "Energy" segment, including the recent acquisition of Critical Flow Solutions, will primarily serve the oil & gas market. The second segment, "Advanced Flow Solutions," includes the historical Aerospace and Defense businesses plus the businesses that serve the power and process and industrial end markets. VM

PEOPLE IN THE NEWS

EGC ENTERPRISES… named **John Popovich** vice president of fluid sealing and thermal systems sales. In addition to his primary role, he will assume responsibility for customer service and will be developing a sales force for both businesses for current and future markets.


Popovich

FARRIS ENGINEERING… appointed **Andrew Masullo** general manager. The appointment follows the retirement of longtime Farris general manager **Frank DiTomasso** in December of 2016. Masullo formerly served as general manager, relief valves and instrumentation for Tyco Valves and Controls.

FLOWSERVE… named **R. Scott Rowe** president and CEO, effective April 1, 2017. He succeeds **Mark Blinn**, who is retiring. Rowe will also join the Flowserve board of directors. Vice president, investor relations, and treasurer **John E. (Jay) Roueche III** will assume the role of interim chief financial officer (CFO).


Roueche

A.W. CHESTERTON… The new president of the Fluid Sealing Association is **Phil Mahoney**, manager of research and development for stationary sealing devices at Chesterton. He currently serves as chair of the membership committee, as well as a member of the government affairs working group, the marketing committee and the technical coordinating committee.

THE WEIR GROUP… appointed **David Paradis** president of the Weir Flow Control Division. Paradis succeeds **John Heasley,** who was appointed Weir Group CFO in October 2016. Paradis is currently president of Weir Oil & Gas Pressure Pumping business.

WOLSELEY PLC... announced that CEO **Frank Roach** will retire on July 31, 2017. Current COO **Kevin Murphy** will assume the role of CEO effective Aug. 1, 2017. Murphy joined Ferguson in 1999 through the acquisition of his family's business, Midwest Pipe and Supply.


Murphy

CAMERON… has appointed **Olivier Le Peuch** president following the departure of **R. Scott Rowe** to Flowserve. Le Peuch previously served as president, completions in Schlumberger's Production Group.

Reporting to Le Peuch will be **Brent Baumann**, president, valves and measurements, who is replacing **Douglas Meikle**.

CONVAL… named **Michael Glavin** its new vice president of engineering. Glavin brings over 25 years of engineering experience in the fluid handling industry, recently serving as director of engineering at Engineered Controls International.


Glavin

DEZURIK… president & CEO **Bryan Burns** was named one of the '5 Under 40' recipients by the *St. Cloud Times*. The awards recognize leaders under the age of 40 who show influence on the local economy and involvement in the community. Burns assumed leadership of DeZURIK in September 2013.

VELAN... completed its CEO succession plan with the appointment of **Yves Leduc** as CEO. Leduc also was elected to the board of directors of the company. Leduc, hired in January 2015 as president, has become the first non-Velan family member to lead the company.


Yves Leduc (left) and Tom Velan

MUELLER WATER PRODUCTS… appointed **J. Scott Hall** as president and CEO. Hall, who will also become a Mueller Water Products board member, succeeds current president and CEO, **Gregory E. Hyland**, who will transition to executive chairman.

ADMIRAL VALVE, LLC (DBA CPV MANUFACTURING)… announced **Michael Beisser** is the new vice president of operations. Beisser has more than 15 years of experience in operations management. Before joining the CPV Manufacturing family, he served as the operations manager for Robern Inc. as well as many other operations positions.

The Trump Administration and the 115th Congress

Reducing the regulatory burden on business is one of the goals of Republicans, who now have control of both houses of Congress and the White House, said **Eric McClafferty**, Kelley Drye and Warren.

McClafferty gave a special report on early actions of President **Donald Trump's** Administration to the VMA board at the recent Leadership Forum.

Among other issues of concern to the valve industry are international trade policies and the administration's "buy American, hire American" approach.

EARLY EXECUTIVE ACTIONS

McClafferty said that, while not all of the president's early actions directly affect the valve and attendant industries, several executive orders should be noted.

For example, White House Chief of Staff **Reince Priebus** issued a "regulatory freeze" memo on Jan. 20. Shortly after that action, the president signed an executive order requiring agencies to identify two outdated regulations that should be repealed for every new regulation put into place. This could have an effect on power generation, oil and gas exploration and development, and petrochemical production. The goal is to reduce the regulatory burden, but it is unclear how federal agencies will implement these instructions.

As far as oil and gas and environmental issues, the president has issued orders advancing the Keystone XL and Dakota Access pipelines, and expediting environmental reviews for priority infrastructure projects. Following confirmation of Environmental Protection Agency Administrator **Scott Pruitt**, the president also issued an executive order calling for reconsideration of the Waters of the U.S. rule, which addresses water controlled by the government and has been a source of controversy for industries that border or affect those waters. The administration has also issued orders related to the "border wall" and "sanctuary cities" as well as a memorandum on rebuilding the U.S. Armed Forces.

While all these efforts will have some implications for the valve industry, a new buy-American requirement may be one of the most noteworthy, according to McClafferty's report. For example, Trump has instructed the Commerce Department to develop a plan to ensure all new and retrofitted pipelines in the U.S. use domestically produced iron and steel, which could prove to be a challenge because it may mean pipeline valves would have to meet this buy-American requirement.

For certain projects, the administration wants to limit casting from anywhere except in the U.S.

The memorandum addressing these issues defined "produced in the United States" to mean that all manufacturing processes, which for iron or steel products would be from the initial melting stage through the application of coatings, must occur in the U.S. Steel or iron material or products manufactured abroad from semi-finished steel or iron from the U.S. would not fall under that definition. Also, steel or iron material or products manufactured in the U.S. from semi-finished steel or iron of foreign origin would not be considered applicable.

As McClafferty explained: "Fewer companies are making rough castings for valve bodies in the U.S. now, so this requirement is going to be a challenge for some valve companies supplying the pipeline industry."

For certain projects, the administration also wants to eliminate casting from anywhere except in the U.S.

"That's a shocker for a lot of folks, not just valve industries, but pipes and fixtures," McClafferty noted.

TRADE ISSUES

In regards to trade, President Trump issued a memorandum formally withdrawing from the Trans-Pacific Partnership trade agreement and signaling the administration's intent to focus on bilateral trade agreements, as opposed to broader global and regional trade pacts.

A move to renegotiate the North American Free Trade Agreement (NAFTA) is also expected. While the Trump Administration has taken no official action yet, the president and his team have repeatedly stated their desire to renegotiate the 23-year old agreement with Canada and Mexico. Priorities recently outlined by U.S. Commerce Secretary **Wilbur Ross** include tightening Rules of Origin, aligning living standards and smoothing currency exchanges.

The buy-American issue is likely to affect all of this and will be a discussion topic in the bilateral and regional trade agreements. Each agreement is going to have a rule about what products qualify, just as such rules already exist in NAFTA, the U.S. Israel Free Trade Agreement and other regional agreements.

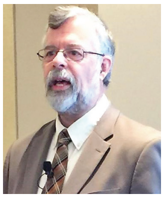
McClafferty suggested that the administration officials who want to reinvigorate American manufacturing and manufacturing jobs see these discussions as mechanisms to achieve that goal. They also see that goal as part of the border adjustment tariff proposal, which McClafferty says has many unresolved issues.

Those include: "How precisely will it be implemented, who's going to be responsible for tariff payments, what exactly will be subject and not subject to the tariff? The devil is in the details and determining how that proposal will affect the industry, currency valuations and ultimately the economy will be complicated." VM

A longer version of this article is available on VALVEmagazine.com.

Mixed Economic News from VMA's Leadership Forum Speakers

Alan Beaulieu of ITR Economics shared some welcome good news with attendees at VMA's 2017 Leadership Forum, which was March 23-24 in Philadelphia.


Alan Beaulieu of ITR Economics

"You're going to like 2017 and 2018," Beaulieu said. "Consumers are in great shape, retail sales are at a record high level, housing starts are positive, interest rates remain favorable, employment and wages are rising, and banks are lending."

However, there is more than smooth sailing ahead, he cautioned. One concern for many in the valve industry is the price of oil, which is still hovering around $50. Yet Beaulieu also noted that the U.S. has 300 years' worth of oil reserves, whereas Europe has only about 30 years, which is a positive situation for this nation because it gives the U.S. the decided advantage of energy independence.

The economy is expected to improve in 2017 and 2018, but there will be a mild consumer-led recession in 2019. However, that reality is not likely to impact the valve industry much, and Beaulieu projects that metal valve production will increase over the next two years.

He also recommended that any capital investments be made now because capex rates are very low. "There has never been a better time to invest in improvements," Beaulieu advised.

Beaulieu also noted a few other areas of concern. He gave as an example China's debt situation, which is even worse than the U.S. and pointed out that country's banking system is filled with fraud. "It all leads to a ticking bomb," he concluded.

Another concern is getting laborers to fill manufacturing jobs. "And if you do find employees, you will be paying them more or you will be losing them," he warned.

Finally, Beaulieu noted that ITR's prediction for a major depression starting in 2030 still stands. However, until that happens, "Expect more upside than down over the next 12 years."

FUGITIVE EMISSIONS

Greg Johnson of United Valve said he does not expect the Trump Administration cuts in funding for the Environmental Protection Agency to affect fugitive emissions (FE) requirements because changes have already been made and limits are already being enforced. Traditionally, oil refineries and petrochemical plants were the main points of interest for inspections; now, however, consent decrees have been issued to other sources because of piping system FE leakage in industries such as a meat packing plant for ammonia, a steel mill plant for benzene and an automobile manufacturer and paint manufacturer for solvent emissions. The common denominator is leakage of volatile organic compounds or hazardous air pollutants. The worst offenders are linear valves, which constitute 60% of the valve population in refineries and petrochemical plants.

Once a consent decree has been issued, the offending user must admit to guilt and agree to fix the leaking valves. The user must guarantee the valves will not leak at more than 100 ppm for five years while valve packing manufacturers must guarantee through a signed legal document that the packing will not leak. All of this means a huge undertaking to check the torque on every single one of the linear valves in a plant.

The difficult valves to test and certify are upstream wellhead valves because of extremely high pressures, Johnson said.

Several questions have arisen about the future of FE testing, including whether argon could become a viable test gas and whether the EPA will adopt the 100-ppm acceptable leakage rate nationwide. Johnson does believe there will be more replacement of large outside diameter gate valves with quarter-turn products. He also believes there could be more of a push for bellows seal valves because they work very well, though anything above two inches is very expensive.

END-USER PERSPECTIVES

A panel of end users from the power, water, and oil and gas sectors convened during the meeting to share their outlook for the coming year.

Lyle White, vice president and global director of business development, power generation services at Black and Veatch, pointed out the new energy paradigm is forcing big changes in the power industry. "If we don't get proactive with energy, we will be at the back of the pack. Smaller is better, and we must adapt to innovations such as distributed power, and small plants and renewable resources closer to end users," he said.

White believes that control technology is key to advanced power generation and distribution programs, and that monitoring of the performance of power assets will be more regular and done remotely. Opportunities for suppliers to the industry will come from existing power asset enhancement rather than new builds.

Thomas Decker of Thomas E. Decker Consulting said that, regarding the water and wastewater market, U.S. water infrastructure is pretty far down the list of priorities compared to other countries. Canada is in better shape than the U.S. and in the midst of a multi-billion-dollar program to improve its infrastructure.

Decker addressed attendee concerns on the repeal of the Waters of the U.S. rule but said he wasn't overly concerned about that issue and had other regulatory concerns.

"What could hurt is that among the new proposals is eliminating tax-free interest on municipal bonds.

Naturally, the interest rates would rise and that could cost $6 billion over the next few years," he said.

Decker also noted that the proposed one trillion-dollar infrastructure plan is mostly for roads, bridges, airports, ports and oil pipelines. Water will not be a priority.

John Spears of Spears and Associates advised that U.S. oil production peaked in the second quarter of 2015 and declined through the fourth quarter of 2016 but has since begun to rise in response to increased drilling activity. U.S. oil production is forecast to increase 35% from 2016-2020 to 3.2 million barrels per day, and this increase is expected to drive growth in liquid line pipeline construction.


Thomas Decker, John Spears and Lyle White

Spears also said he expects North American drilling activity to jump 56% in 2017 to about 1,000 active rigs and 27,500 new wells. This is because breakeven prices have been reduced to below $50 a barrel in many basins due to reduced pricing and increased efficiency. However, some of the cost savings extracted from the oil services sector over the last two years will be reversed in 2017 as activity and the demand for people and equipment increases. VM

An expanded version of this article is available on VALVEmagazine.com.

WELCOME NEW MEMBER

Union Tech Co., LLC recently joined the membership ranks of VMA. Union Tech is a manufacturer of severe-service metal-seated and rising-stem ball valves, offering a product line that covers both critical isolation applications and high-performance frequent cycling with positive shutoff application. It has been in business since 1982.

EVENTS

Valve World Americas Coming in June

Thousands of people will gather at the George R. Brown Convention Center, Houston, June 20 and 21 for Valve World Americas Expo & Conference. The attendees come from all over the world to learn about valves and related equipment and to see the products on the exhibit floor.

The conference program includes sessions from experts on topics that affect the valve industry including the future of shale gas, outlook for the energy industry, latest technology, challenges in special industries such as cryogenics and much more. They also come for the workshops on areas such as valve design, maintenance and repair, valve testing, asset management, casting and materials, and other specialty topics.

The attendees include end users, valve makers and distributors, consultants and a host of other flow control professionals.

The expo features more than 250 companies—many of them members of VMA—that come to showcase their newest products and latest services. Experienced technical and sales staff are on hand to answer attendee questions and provide information on what's available.

Visitors are invited to stop by booth #750, where VMA and VALVE Magazine staff will be available to discuss new educational products, requirements for joining and much more.

For information on this year's show, go to www.valveworldexpoamericas.com.

ACE17 Theme is "United the World of Water"

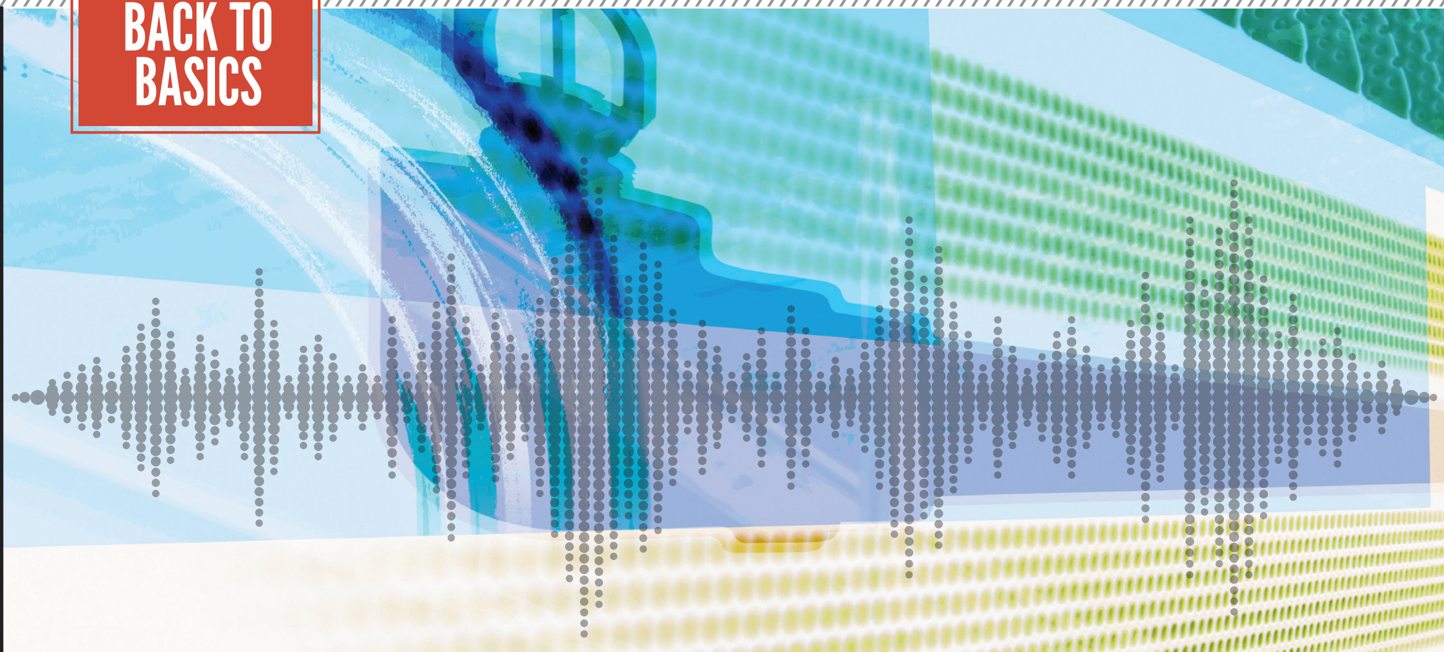
ACE17, the annual meeting for the American Water Works Association, will be June 11-14 at the Philadelphia Convention Center, Philadelphia.

The conference brings together officials, water plant operators, manufacturers, researchers and other people from around the world whose job is to ensure safe water and clean water systems, and provides them a wealth of educational opportunities as well as a giant hall of exhibits.

Hundreds of sessions and roundtables are designed around 11 different tracks in areas such as policy, utility operations, infrastructure, water quality, different forms of treatment, technology and much more. Among the special sessions is a free seminar sponsored by AWWA, as well as the U.S. Department of Commerce, the Office of Energy and Environmental Industries, on what to expect from the Trump Administration.

Exhibitors come from nine different countries and feature products that range from valves and related equipment to chemicals and treatment systems, technology in use today, supplies for testing, data collection devices and services such as design and engineering, government consulting and others. Eight tours of nearby facilities are also in the works.

For information, go to www.awwa.org. VM



Water Hammer

BY ARIE BREGMAN

Water hammer is a shock wave transmitted through fluid contained in a piping system. The most basic explanation is that water hammer occurs when a fluid in motion is suddenly forced to stop moving. The momentum of the fluid abruptly stopping creates a pressure wave that travels through the media within the pipe system, subjecting everything in that closed system to significant forces.

Normally the pressure wave is dampened or dissipated in a very short amount of time, but the pressure spikes can do enormous damage during that brief period.

Water hammer is evidenced by a thumping or banging sound that, in extreme cases, can indicate that extensive and costly damage is occurring to expansion joints, pressure sensors, flow meters and pipe walls.

Water hammer also can occur in a multiphase fluid, which is a liquid media that also has entrained solids. An example would be sand slurry or liquid pulp (which is basically water transporting the pulp fibers). The key factor is that water is the main transport medium in the piping system, and water can transmit shock waves very effectively.

FLASHING VS. WATER HAMMER

Flashing is a different kind of pressure spike event. Flashing occurs in steam systems where steam condensate (liquid water) has accumulated within the piping system. This liquid water can suddenly convert from a liquid to a steam with a subsequent volumetric expansion factor of 400-600 times. Flashing needs to be dealt with in totally different ways. While it's equally important to control, for purposes of this article, we confine our discussions to liquid mediums and water hammer noises only.

CAUSES OF WATER HAMMER

Water hammer can result from improper valve selection, improper valve location and sometimes poor maintenance practices. Certain valves, such as swing check valves, tilting disc checks and double door check valves also can contribute to water hammer problems. These check valves are prone to slamming because they rely on reversing flow and backpressure to push the disc back onto the seat so that the valve closes. If the reverse flow is forceful, as in the case of a vertical line with normal flow upwards, the disc is likely to slam with a great deal of force.

Executive Summary

SUBJECT: The consequences of water hammer can be severe or light. However, when a loud banging noise occurs, it can indicate problems that may mean extensive damage and cost.

KEY ISSUES:

- What is water hammer?
- What does it do?
- How can it be alleviated?

TAKE-AWAY: Choosing the right valve, knowing how to design the system, replacing equipment with what's designed to eliminate or minimize problems can help.

The resulting shock can damage the alignment of the disc so that it no longer makes full, 360-degree contact with the seat. This leads to leaks that, in the best case, undermine the efficiency of the system. In the worst case, this could do serious damage to other piping system components.

Localized, abrupt pressure drops are an annoyance at the least and a serious problem at the most. Certain steps can prevent or mitigate water hammer. The first is to study causes, consequences and solutions.

HYDRAULIC SHOCK

The most common cause of water hammer is either a valve closing too quickly or a pump shutting down suddenly. Hydraulic shock is, in fact, the momentary rise in fluid pressure in a piping system when the fluid is suddenly stopped. As Sir Isaac Newton observed, an object in motion tends to stay in motion unless acted upon by another force. The momentum of the fluid traveling in its forward direction will work to keep the fluid moving in that direction. When a valve suddenly closes or a pump suddenly stops, the fluid in the piping system downstream of the valve or pump will be elastically stretched until the momentum of the fluid is arrested.

The fluid then wants to snap back to its normal, unstressed condition, much like an extended spring that has been released. This causes the liquid to travel back through the pipe. The back-flowing fluid then encounters the closed valve, potentially with significant destructive force. The reflection of this fluid pressure wave is the loud bang (and there could be more than one pressure pulse) (Figure 1).

Sudden valve closure is most often associated with quarter-turn types of valves and more specifically, automated quarter-turn valves. A simple solution is to close those automated quarter-turn valves more slowly. This works in many cases but not all of them. For example, emergency shutdown valves need to close quickly, so other solutions may be necessary for these types of applications. More on valve closure time calculations is included later in this article.

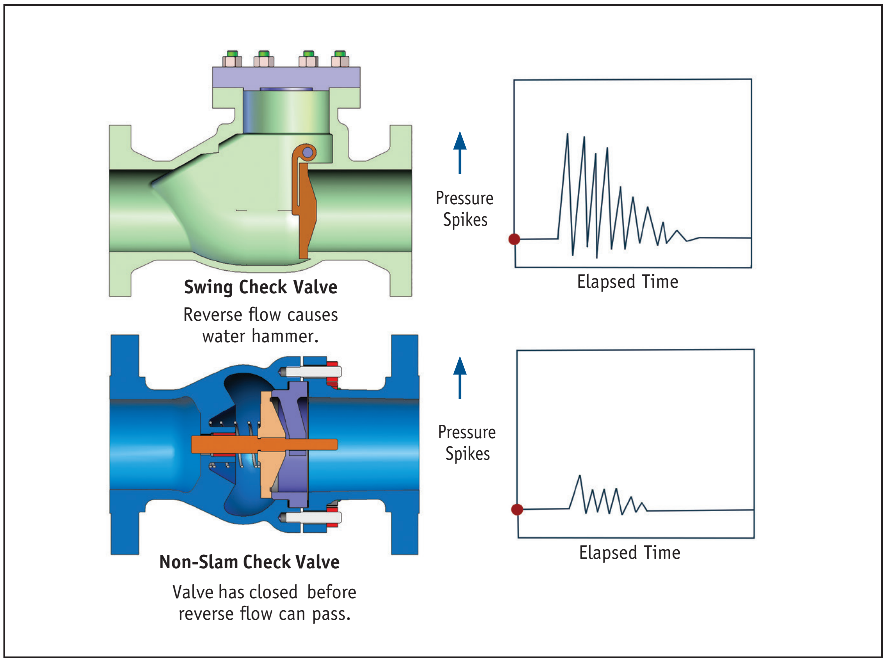


Figure 1. Effects of reverse flow

The other most common cause of water hammer is sudden pump shutdown. Multiple pumps feeding into a common header, as in cooling tower applications or mine dewatering, either need to be shut down slowly, or they need to have in-line silent check valves installed immediately after the pump. Silent check valves can be extremely effective in reducing and sometimes eliminating water hammer.

PREDICTING WATER HAMMER PRESSURE SPIKES

It is possible to calculate the magnitude of water hammer pressure spikes based on detailed knowledge of the piping system and the media transported. The actual force of water hammer depends on the flow rate of fluid when it is stopped and the length of time over which that flow is stopped. For example, consider 100 gallons of water flowing in a 2-inch pipe at a velocity of 10 feet per second. When the flow is quickly brought to a halt by a fast-closing valve, the effect is equivalent to that of an 835-pound hammer slamming into a barrier. If the flow is stopped in less than a half second (which might be the closing speed of the valve), then a pressure spike over 100 psi greater than the system operating pressure can be generated.

The equation for calculating the potential magnitude of the spike is as follows:

$$\Delta H = a/g * \Delta V$$

ΔH is the change in head pressure
ΔV is the change in fluid flow velocity
a = acoustic velocity in the media
g = gravitational constant

An example is:

a = 4864 feet per second
g = 32.2 feet per second^2
ΔV = 5 feet per second

ΔH would be 756 feet (328 psi)

This value is assuming instantaneous valve closure exists.

VALVE CLOSURE TIME CALCULATIONS

Water hammer is obviously a serious issue in industrial settings, such as at a wastewater plant or municipal water system. In contrast to the example above, the average bathroom faucet is usually based on a half-inch nominal line size and has a water pressure that ranges between 60-80 psi and delivers about 8-10 gallons per minute. A 6-inch line in a water treatment plant would deliver 900 gallons per minute with a velocity of 10 feet per second. A 24-inch water main could be delivering over 12,000 gallons of water per minute, enough to fill the average backyard swimming pool in less than two minutes.

The basic formula for valve closure time is: $T = 2L/a$

T = minimum time in seconds
L = length of straight pipe between the closing valve and the next elbow, tee or other change

For water at 70°F (21°C) where you have 100 feet of straight pipe:
T= 41 milliseconds minimum closure time

CONSEQUENCES OF WATER HAMMER

The consequences of water hammer can range from mild to severe. A common sign is a loud banging or hammering sound emanating from the pipes, especially after a water pressure source is shut off quickly. This is the sound of the pressure shock wave hitting a closed valve, joint or other blockage at high force. This sometimes-deafening noise can be a source of great distress and concern, especially if people are working close by.

Repeated occurrences of water hammer aren’t just an annoyance, however. Water hammer also seriously damages pipelines, pipe joints, gaskets and all the other components of the system (flow meters, pressure gauges, etc.). The pressure spikes can easily exceed 5 to 10 times the working pressure of the system upon impact, thereby placing a great deal of stress on the system. Water hammer causes leaks at the joints in the system. It also causes pipe wall cracks and deformation of piping support systems. Repairing or replacing damaged pipeline components and equipment can involve steep costs. If the spill results in an environmental issue, the costs can be staggering.

In most situations, water hammer is considered a safety hazard. The extreme pressure of water hammer can blow out gaskets and cause pipes to rupture suddenly. People in the vicinity of such an event can be seriously injured.

SOLUTIONS TO WATER HAMMER

There are many ways to mitigate the effects of water hammer, depending on its cause. One of the simplest methods of minimizing water hammer caused by hydraulic shock is to train and educate operators. Operators who learn the importance of opening and closing manual or actuated valves properly can take precautions to minimize the effects. This is particularly true for quarter-turn valves such as ball valves, butterfly valves and plug valves.

PIPING DESIGN CONSIDERATIONS

Water hammer arrestors provide a point of relief for pressure spikes caused by water hammer. These piping system components reduce the characteristic noise and resultant stress on the pipeline system by acting like a shock absorber. When sized and installed properly, water hammer arrestors can be an effective solution.

On the other hand, pumps that output into a long run of vertical pipe should be avoided. The vertical leg should either be minimized, or silent check valves installed as close to the pump as possible should be used.

Another area to look at in minimizing water hammer is installing check valves in vertical pipe lines. Swing checks, tilting discs and double-door valves can be made to operate in a vertical line. However, they will not prevent reversing flow in this orientation. Only a silent check valve can work in this orientation.

Hydraulic shock resulting from the sudden closure of swing check, tilting disc and double-door check valves can be remedied by exchanging these valves with silent or non-slam check valves. Silent check valves close upon the decrease of the differential pressure across the closure member of the valve, rather than closing from reverse flow. Thus, they are far less likely to slam shut, which induces water hammer. When the differential pressure across the disc approaches the cracking pressure of the valve, the valve has fully closed. This allows the fluid flow to decelerate, which allows the momentum of the fluid to decrease before the valve is fully shut while still

CONTINUED ON P. 44

WHERE VALVES ARE USED

Mihama Nuclear Power Plant and Nyu Bridge seen from Mount Saiho in Fukui prefecture, Japan

WIKIPEDIA: ALPSDAKE

Supercritical Power Plants: Materials and Specifications

BY KATE KUNKEL

Charles Henley, a senior mechanical engineer at Black & Veatch, was one of the presenters at the 2017 VMA Technical Seminar held in early March in Nashville. His presentation on supercritical power plants was especially well received because he shed light on some of the critical issues. This report is based on what he said in his session.

THE HISTORICAL CONTEXT

Until WWII, power plants were relatively low heat, and not particularly efficient when compared to today. After WWII in the 1950s and 1960s, however, efficiencies improved when reheating cycles were instituted. Then, in 1957, the first supercritical power plant was built in the U.S: A 125-megawatt plant operating at 4,500 psi with temperatures at 1150°F/1050°F/1000°F (621°C/566°C/538°C)—a double reheating system. Today, more than 200 supercritical units have been built around the world with Japan and South Korea claiming the largest capacities.

Both subcritical and supercritical are Rankine cycle processes, which means they are comprised of a boiler, a turbine and a condenser. All the systems within the plants support those three pieces of equipment, including the power block and the balance of plant and air quality control systems. The main differences

Executive Summary

SUBJECT: What goes on inside the supercritical power plants of today's world is particularly important to the valve industry because of the challenges exceptionally high temperatures and pressures present when specifying materials.

KEY ISSUES:

- The different levels of plants
- The challenges for materials
- What types of materials are used

TAKE-AWAY: As stronger, lighter piping materials are developed, the demand on the valve industry will be to make appropriate valves in compatible materials.

Subcritical vs. Supercritical cycles		
Unit Type	**Main Steam/ Hot Reheat Conditions**	**Efficiency**
Subcritical—Water boiling to steam with pressures below 'critical point.'	• 2,400 psig (165bar) • 1050°F/1050°F (566°C/566°C)	38%
Supercritical—Water to steam without boiling. Pressure above 'critical point'	• 3,500 psig (241bar) • 1050°F/1080°F (566°C/582°C)	40%
Advanced Supercritical—Main steam and hot reheat temperatures above 1100°F (593°C).	• 4,710 psig (325bar) • 1130°F/1166°F/ 1166°F (610°C/ 630°C/ 630°C)	44%
Ultra Supercritical—Main steam temperatures above 1200°F (649°C).	• 5,000 psig (345bar) • 1300°F/704°F)	46%

Temperature + Pressure = High Efficiency; Higher Efficiency = Less Emissions

Figure 1. The different levels of efficiency

between subcritical and supercritical plants are the higher temperature and pressure levels.

There are four major levels of plants (Figure 1). While there are many levels of advanced plants, essentially, they can take on higher temperatures and pressures. At these higher levels, the plants are more efficient and have fewer emissions.

While subcritical plants generate power by boiling water into steam, supercritical systems turn water to steam without boiling. A supercritical steam generator operates at pressures above the critical pressure (where liquid water immediately becomes steam). The term, "supercritical" is given because the pressure is above the "critical point" of 3,200 psig.

MODERN PLANT MAKEUP

Supercritical power plants have four unique systems: boiler feedwater, main steam, hot reheat and startup.

Engineers in these plants select piping material first. Then, they decide what components will be needed and what families of materials can be used for valves and attendant components that will ensure compatibility with the piping system materials.

The extreme high temperatures and pressures in supercritical power units have a huge impact on the choices. The extreme high pressures necessitate thicker materials with a higher stress range, high cyclic fatigue resistance and increased creep resistance. The extreme temperatures also present the potential for fire-side corrosion and steam-side oxidation in the boiler, which is taken into consideration.

Erosion and Corrosion in Feedwater Systems

Erosion is the damage to materials caused by physical processes such as high-speed impinging flows or solid impacts on the surface. In plants, this can be from cavitation, flashing, solid particle erosion or droplet impingement.

Figure 2. ABOVE: FAC damage in 2004 to Mihama Unit 4, which caused five fatalities and several injuries. BELOW: FAC damage to tube interior. Looking inside of a header tube shows FAC damage that occurred at tube bends. Courtesy: Tetra Engineering Group

Corrosion is chemical or electrochemical attacks on materials, which can create a widespread attack on an operating system resulting in more general or flow-accelerated corrosion. This also can result in localized attacks such as galvanic corrosion, which occurs when two dissimilar metals are in contact or in crevice corrosion or cracking and pitting.

Flow accelerated corrosion (FAC) is a process that degrades carbon steel material. It first showed up in the nuclear industry, and it appears under relatively unique conditions, depending on the chemistry and PH of the water. FAC occurs when normally protective iron-oxides dissolve into the flowing stream. It also occurs around elbows and Ts, which cause turbulence in the flow, as well as in localized high-velocity areas. FAC is a global attack on piping that creates widespread thinning and can cause substantial wall loss over time. In other words, it's not like a local attack such as pitting or cracking; FAC-caused failures are often sudden and catastrophic.

In the past, failures due to FAC have caused major incidents with loss of life (Figure 2). FAC has not caused as many failures in recent years because a good inspection system is now in place.

FAC damage appears a few different ways: Under single-phase (i.e., water only) conditions, the damaged surface displays a "scalloped" or "orange-peel" surface. This type of surface is conclusive evidence FAC occurred, though depending on conditions, magnification may be required to see the scalloping (Figure 3).

Under two-phase conditions, the surface may show a pattern of dark and light areas known as "tiger striping," which is also conclusive evidence of FAC. Wet steam of some type will cause this (Figure 4).

Where It Hits

Piping is susceptible to FAC if 1) the material is carbon steel, 2) there is water or wet steam flowing in the pipes, 3) temperature conditions are within band 200°F to 500°F (93°C to 260°C) and 4) the water is deoxygenated (i.e., service water systems do not experience FAC)

Systems where FAC is of concern are:

- Generally, all the secondary side of a pressurized water reactor and the equivalent boiling water reactor (BWR) systems
- Some BWR auxiliary systems (e.g., residual heat removal may also be susceptible.)

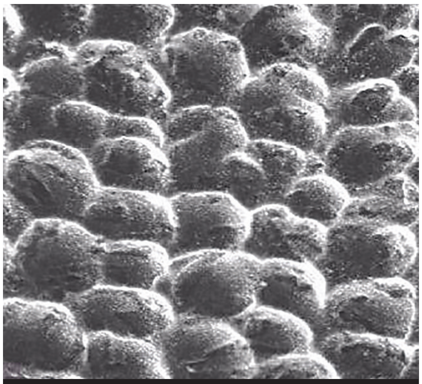


Figure 3. What FAC damage looks like.

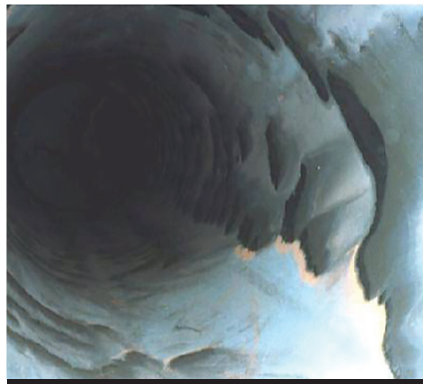


Figure 4. What tiger striping looks like.

- In fossil plants, condensate and boiler feed systems as well as some extraction steam lines.
- Some auxiliary systems such as building steam

An important point to note is that, while it is basically impossible to eliminate this kind of damage, it can be managed through materials selection. Often, a chrome-equivalent pipe will be specified (i.e., chrome plus a certain percentage of copper or another material.)

MATERIALS

In modern supercritical plants, steam pressures range from 3,200 to 3,500 psi with temperatures maintaining about 1050°F to 1080°F (566°C to 582°C). In advanced and ultra-supercritical applications, the temperature is pushed even higher to nearly 1200°F (649°C). At this temperature, material families are typically shifted from a ferritic- to a nickel-based alloy because generally, after 1200°, the next jump is to at least 1300°F to 1350°F (704°C to 732°C), which requires the nickel-based materials.

Now that the temperatures in these plants have generally exceeded the practical limits of CS, P11 and P22 materials, engineers are specifying P91 and P92 in steam systems. For feedwater systems, the trend is up from Grades B and C to chrome equivalent (CrEQ) and P36 materials, especially in China and Asia.

Currently, for applications up to 800°F (427°C), CrEq carbon steel or P36 is used for applications where flow-accelerated corrosion is a concern. Between 800°F and 1025°F (427°C to 552°C), P11 and P22 materials are used. Above those temperatures, P91 or P92 material is used. Recently, the American Society of Mechanical Engineers (ASME) lowered the allowable stresses on P91, so the decision about when to shift from P91 and P92 has become more about economics than technical choices.

Alternate materials are a good solution because sometimes CrEQ materials are difficult to find.

P36 has become popular in India and China. It was developed in Germany specifically to reduce the rate of FAC in feedwater systems. P36 has a 35% reduction in wall thickness compared to carbon steel. The major disadvantage of this material is that there is no P36 casting equivalent for valves and other inline equipment.

Because valves of another material cannot meet with the piping, it doesn't make sense to buy a superior piping material because there would need to be a transition between the piping and valves. P36 has welding challenges similar to those that affect creep strength enhanced ferritic steel (CSEF).

CSEF is a family of high-alloy materials that contain between 9-12% of small amounts of various other materials including molybdenum, vanadium, niobium and varying additions of tungsten, cobalt, boron, nitrogen and nickel.

P91 is one such ferritic alloy steel. It has been in use for 25 years and is also called 9Cr-1Mo steel (based on its composition). Chemistry doesn't define P91, however; it's only half the equation for getting the strength these materials need to have. That strength also comes from grain structure caused by the heat-treating process—it is a tempered martensitic material.

The advantage of CSEF steels generally is that they are over twice as strong as P22 with half the wall thickness. This is very important because it reduces cost and increases flexibility.

The disadvantage of CSEF steels is that the strength is obtained through chemistry and heat treatments, so it is very easy to destroy the steel during the welding process. In a shop, that destruction can be controlled; but in the field, that's very difficult. Welding requires strict controls to maintain martensitic grain structure, so preheat and post-weld treatment and interpass temperatures are tightly managed. P91 is listed as a P5B Weld Code by ASME, which means a post-weld heat treatment is mandatory. Weld heat-affected zones (HAZs) are the likely failure locations, and they can lead to type IV cracking. P91 is also susceptible to carbon migration and hydrogen embrittlement.

There are, however, other CSEF steels. In the last 15 years, materials used more often include P92, P911 and P122.

P92 was originally developed by the Japanese company Nippon Steel as NF616. P92 has about 30% reduction in wall thickness compared to P91 and includes tungsten in its composition. The addition of tungsten creates its own set of challenges regarding welding; but the main concern is the lack of a market for scraps (because of the tungsten).

P36 was developed by Vallourec & Mannesmann, which also developed a copper-nickel-molybdenum-alloyed carbon steel. These are standard materials in India and China for supercritical applications. P36 is approved under ASME Code Case 2353 and has been used in more than 30 plants since 1972.

The advantages of this material include having a 35% reduction in wall thickness over A106 Grade C as well as a high resistance to FAC. However, no casting equivalent currently exists so transition pieces or forged valves are needed.

Forged vs. Cast Steel Valves

The trend over the last few years is that forged valves are quoted as an alternative to cast steel valves, especially for high pressure applications. Forged valves have traditionally been used for small bore applications (2 inches and smaller and at the most, up to 8 inches). However, currently 18- to 24-inch sizes have been developed, but they're not closed-form forged valves—they are valves machined out of a forged billet. These valves are showing up more and more, presenting unique challenges.

Some feel forged valves have better quality, and the wall thickness can be less. But both forged and cast valves can provide acceptable performance for most power applications. Forged valves are used more in streams where matching piping material to valve material is difficult. This is because code requirements such as ASME's quality factor can cause design challenges with regards to transitions between pipe and valve materials and wall thicknesses.

With new materials, cast grades often lag in development, and forged valves provide more direct use of advanced materials. Designers are forced to specify a lower strength material, and transitions are required for differences in strengths in addition to dissimilar metal welding.

This has caused a delay in use of P92 and P36 materials in the U.S. market.

FUTURE TRENDS

In the U.S., supercritical requirements are likely to remain the same, but new materials are continually developed. There are new ferritic steels and meta-stable austenitics coming into the market.

One is called SAVE12D (grade 93), a normalized and tempered steel that is 30% stronger in creep than P92 at 1200°F (649°C). This material has improved creep rupture ductility and is type IV-free for less-degradation welds. SAVE12D was approved in October of 2015 by ASME Section I Code Case 2839 and is a proposed designation of P93 for pipe, T93 for tube and F93 for forgings in American Society for Testing and Materials and ASME.

Another material on the horizon is HR6W (UNS N06674), which is a solution-annealed nickel alloy. This has stability of long-term creep rupture strength, superior creep rupture ductility and much better corrosion resistance than 18Cr-8Ni austenitic stainless steels. Also, it has microstructural phase stability at elevated temperatures, which contributes to superior stress relaxation and fatigue properties. Tests have shown better formability, wider available size range and better weldability than other nickel-based alloys.

What this means for the valve industry is that traditional mid- to high-alloy steels will be used for supercritical units operating below 1200°F (649°C). Higher fatigue cycle resistance will be required for fast-responding assets as renewables come to market, and nickel-based materials will be used for supercritical applications greater than 1200°F (649°C). This will most likely be limited in markets outside the U.S. and Europe.

Going forward, the valve industry's great challenge when it comes to all this will be to make valves that are compatible with the new materials. VM

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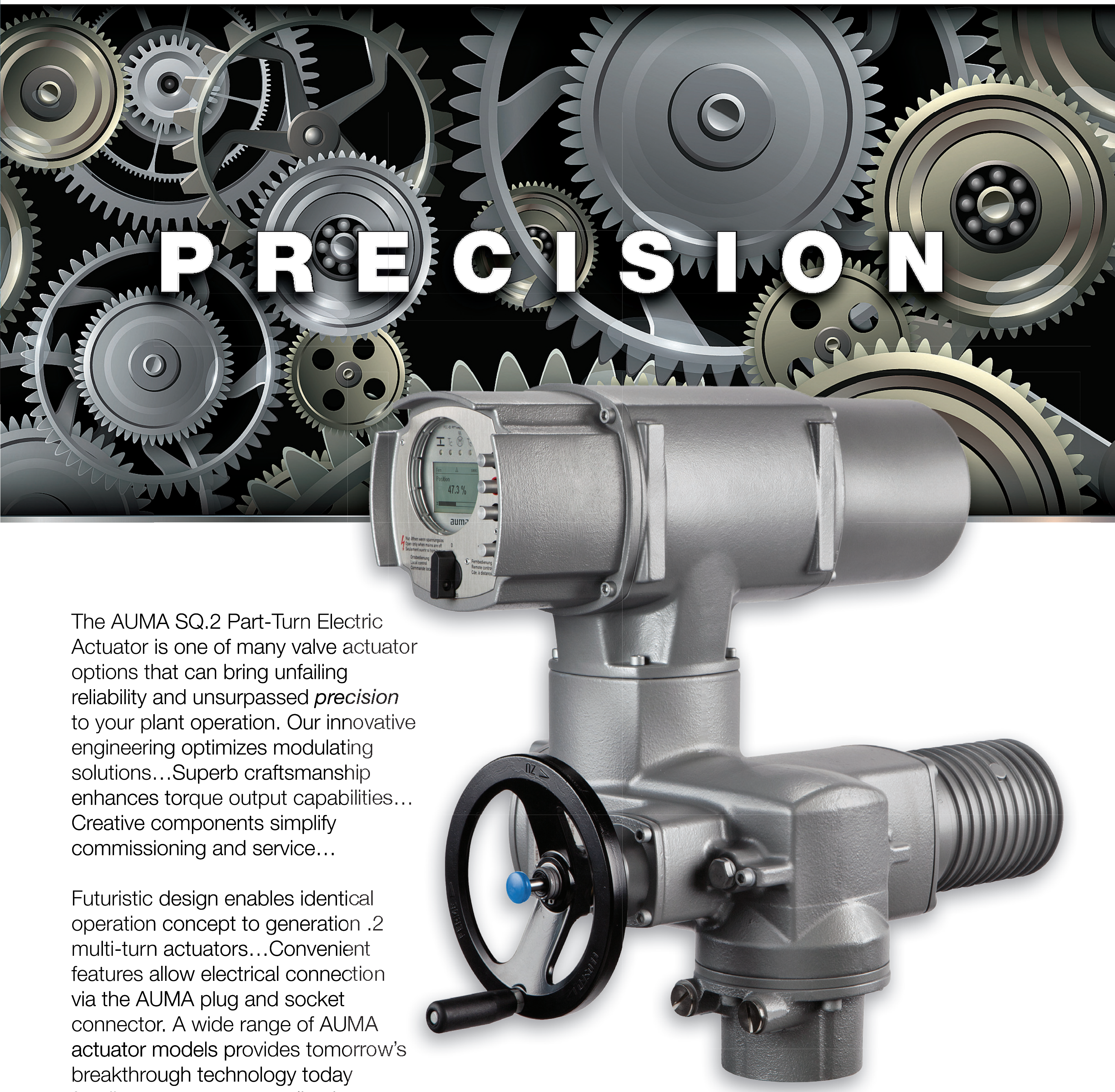
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Studying What Went Wrong

BY KATE KUNKEL

In October of 2016, the Chemical Safety Board (CSB) released its findings into the tragic 2013 explosion and fire at the Williams Olefin Plant in Geismar, LA that killed two workers and injured 167 (Figure 1).

The incident occurred during non-routine operational activities that introduced heat to the reboiler, which was offline and isolated from its pressure relief device. The heat increased the temperature of a liquid propane mixture confined within the reboiler, resulting in a dramatic pressure rise within the vessel. The reboiler shell ruptured catastrophically, causing a boiling liquid expanding vapor explosion and fire.

The CSB investigation revealed deficiencies in the plant's safety culture that resulted (among other things) in failure to manage appropriately or review effectively two significant changes. These changes introduced new hazards involving the reboiler that ruptured. The first was installation of block valves that could isolate the reboiler from its protective pressure relief device. The second was

Figure 1. Post-blast photograph of the heat exchanger that ruptured catastrophically, causing extensive explosion and fire damage to the plant.

WIKIPEDIA

Executive Summary

SUBJECT: While everyone who makes or uses valves and related equipment wishes they always worked perfectly, we all live with the reality that doesn't always happen.

KEY ISSUES:

- Cases where valves failed
- Why they failed
- What was learned

TAKE-AWAY: Some of the best lessons we can learn come from studying the source of problems in a disaster or near disaster.

the administrative controls Williams relied upon to control the position (open or closed) of those block valves.

The CSB analysis concluded that a risk-reduction strategy known as the "hierarchy of controls" should have been in place to effectively evaluate and select safeguards to control process hazards. Using this strategy could have resulted in Williams choosing to install a pressure relief valve on the reboiler that ultimately ruptured instead of relying on a locked open block valve to provide an open path to pressure relief, a less-reliable solution because of potential human errors.

While incidents like this one as well as the 2010 gas line explosion in San Bruno, CA and the 2010 Deepwater Horizon spill in the Gulf of Mexico were attributed in part to valve failures, most valve failures have much less dramatic results. All of them, however, can teach the industry valuable lessons. Here's a few examples.

CASE ONE: THE MOST EXPENSIVE DOES NOT ALWAYS WORK BEST

VALVE Magazine reader Rex Tucker was just a young engineer when he saw the folly of thinking the best of the best is always right.

Incredibly, nobody was hurt in this case, but it left an indelible impression on Tucker, who is now co-owner of Anew Industrial in Brady, TX and business development manager for Anthony Machine, San Antonio.

About 20 years ago, Tucker was working in an ethylene plant that expanded through installation of new cracking furnaces and associated compression equipment.

"We purchased very expensive metal-seated ball valves to isolate the individual furnaces from a common quench tower," he explains.

The selection of the valves, actuators and interlock checks was an important part of engineering decisions associated with the expansion. Because engineers had experienced problems with valves in similar service on the old furnaces, they paid particular attention to the details of the new equipment.

"Instrument engineers chose spare-no-expense actuators that allowed for testing at any time by placing the valve in a local or remote arrangement and driving the valve open or closed using actuator mounted knobs," Tucker explains.

Preventive maintenance procedures meant control room operators could initiate an electronic test and field technicians could see lights to show the signals were received at the actuator. The strategy was an engineer's dream, but it turned into an operator's nightmare.

"A ruptured tube in a cracking furnace initiated an emergency shutdown," Tucker explains. "Operators took the cracker and the rest of the plant through a chaotic and dangerous shutdown. But the new valve didn't close and quench tower gasses from other crackers back-flowed into the furnace, which had a ruptured tube."

Because of the valve failure, pressurized fuel and flames blew out of the registers of the wall burners. Flames burned vertically and destroyed a large section of the ancillary equipment and caused months of downtime.

"A couple of quick-thinking operators were able to close huge, new, very difficult to operate, rising stem gate valves. It was a heroic effort that was exactly what designers sought to avoid," he explained.

The valve stayed open because one of the poorly labeled knobs on the actuator was left in a mode that ignored the control room operators' demands of closure. A field-mounted emergency switch did not work for the same reason.

The complexity of the actuators meant instrument techs were the only people trained on how the knobs and switches worked. During one of the preventive maintenance checks, the valve was inadvertently left in a mode that ignored remote signals. The next day, the switch was put in the correct position, and the valve worked as designed.

Lesson learned: Any actuator bought for remote-initiated emergency shutdowns should have "a very big flashing light or audible alarm" to let the surrounding personnel know of an abnormal status.

"Over-complicating something that could have been so simple was something I haven't forgotten," Tucker said.

More often than something as dangerous as this, however, is the reality that valve failures result in expensive repairs. The next two cases were provided by Universe Machine in Edmonton, Alberta. They demonstrate how incorrect specifications or incorrect use of valves or actuators can trigger failures or leaks.

CASE TWO: PAYING ATTENTION TO VALVE RATINGS

A rotating stem globe valve was installed by its purchaser, who then removed the factory handwheel and installed a manual gear operator that had been removed from a used valve on site. After a very short period, the valve could no longer hold backline pressure, causing it to leak from upstream to downstream when the valve was in the closed position.

The purchaser of the valve contacted the valve supplier and asked that the valve be repaired or replaced under warranty.

The supplier had the valve sent

Figure 2. The cause of the valve failure was easy to spot: a broken stem.

into Universe Machine's facility for inspection to determine the cause of the failure.

"Once we disassembled the valve it was obvious that a broken stem had caused the valve to fail," the company said (Figure 2).

When the valve stem was in the open position (back-seated position), the end-user-installed gear operator applied so much force in the open position that it exceeded the yield strength the 410 stainless-steel stem could take.

"This caused the stem to break at the transition point between the packing area and back seat area of the stem," the company reported.

The end-user-installed gear operator also had a torque/thrust rating that exceeded that for which the valve was rated. The valve was scrapped because of the broken stem and the damage that it caused to the globe and body seat. The end-user then purchased a new replacement valve with a properly sized gear operator.

Lesson learned: When a gear operator or an actuator is needed, it is important to size it according to the valve on which it will be used.

☐ Figure 3. The product flowing through the valve was hitting against the seat face inserts when the valve was in a partially open position, which then caused a seat leak path when the valve was fully closed.

CASE THREE: FOLLOWING SUPPLIER INSTRUCTIONS

A three-piece trunnion ball valve started to leak downstream after just a few weeks, so the purchaser asked that the valve be repaired or replaced under warranty.

Universe Machine performed a hydrotest at its facility in accordance with American Petroleum Institute 6D (API-6D); the valve failed a seat leakage test on both sides of the valve. The repair team disassembled the valve to inspect for the cause and found that the upstream and downstream seats both had damage that correlated to the valve being used for throttling or the valve being not fully closed when installed on site.

"If looking down the valve bore with the stem at the 12 o'clock position, the damages found on the seats were 180 degrees from each other at the 3 o'clock on one and the 9 o'clock on the second," the company reported. This correlated to the valve being used in a partially open position. Figure 3 shows the damage found on one of the seats—the other seat had the same damage in the polymer seat inserts.

Universe Machine machined and installed new seat inserts and assembled the valve, ensuring that the stops on the valve gear operator were set correctly and that the inside bore of the ball was in proper alignment with the inside bore of the valve and seats.

The valve was hydrotested according to API-6D and passed with zero leakage. The valve supplier had instructed the end user not to use a ball valve in a partly open position to control flow so the supplier billed the end user for the repair. This was because it was not a warranty issue, but misuse by the end user.

Lesson learned: Don't use a ball valve in a partly open position to control flow and make sure to use valves only in processes the supplier warranties cover.

CASE FOUR: LOOKING FOR THE REAL REASON BEHIND FAILURE

As the Universe Machine cases show, because failing equipment has to be repaired, valve shops are often the place where the lessons emerge. John D. Arthurs, vice president of sales at Allied Valve, had another case to share. Arthurs had a power plant customer that had a smaller flanged pressure relief valve installed in a high-pressure application. The valve was found to be leaking in service, which is why it needed repair.

"We discussed a few of the most

common valve failure reasons to try to determine the failure problem up front," Arthur explained.

The customer removed the valve and brought it into the shop so the valve had not received an initial inspection by the repair shop.

To pinpoint the trouble, the shop performed a complete teardown of the equipment, conducted a full inspection, performed lapping of the internal seats assembly and gave it a final test, tagging and sealing the valve and returning it to the customer for immediate installation. However, the customer started up their system and after a few days, the valve was leaking again.

"At this time we scheduled an on-site visit and performed a quick walk-down of the valve," Arthurs explains. The repair company noticed right away the outlet piping was hard piped and not supported properly.

"We asked the plant to disconnect the union in the piping to see if that would affect the valve. It immediately allowed the valve to close," he explained.

In this case, piping strain was the reason for the valve failure. Consequently, the valve had to be removed again because the piping strain caused the internal seats to be scored up. A full repair was performed again, which included teardown, full inspection, lapping of internal seats assembly and final test, then tagging and sealing of the valve.

Lesson learned: Never underestimate the value of an on-site visit to help solve a problem.

CASE FIVE: PAYING ATTENTION TO REASSEMBLY

During a regular, proactive inspection that occurred while a maintenance outage was in place at the Oyster Creek Nuclear Generation Station in New Jersey, technicians found an inoperable electromagnetic reactor pressure relief valve.[1] The relief valve had been installed to depressurize a reactor during a pipe break. It was one of five such valves, which can be used to release reactor pressure during the unlikely event of an emergency. Operation of such valves is necessary to allow coolant to be injected into the reactor core if an emergency shutdown occurs.

Technical specifications required that all of those valves be operable when the plant is running, but the valve malfunctioned from Sept. 5, 2014 until Sept. 19, 2016 (a period between outages for refueling and maintenance). The cause was determined to be improper re-installation of lock washers attached to a cut-out lever for the valve, which created a level of friction between the lever and the solenoid that impaired the valve.

Nuclear Regulatory Commission inspectors found the energy company Exelon failed to follow reassembly instructions for the relief valves that required plant personnel reinstall previously removed lock washers on the cut-out switch lever, which occurred for one of the relief valves. This caused excessive friction between the solenoid frame and the cut-out switch level, which led to the valve not performing its safety function.

To correct the problem, Exelon installed new cut-out switch lever plates with increased clearance, replaced the washers and verified the valves were correctly assembled after the most recent refueling outage.

NRC inspectors called attention to this whole issue during a problem identification and resolution inspection at the end of 2016. A preliminary report gave the situation a "white" classification for the current cycle, which was one step below a fully satisfactory safety categorization.

The generating station is currently under normal oversight levels. If the classification status remains as-is in the finalized report, the plant would be subject to increased scrutiny by federal regulators.

Lesson learned: Follow reassembly instructions after any maintenance activities.

CONCLUSION

Cases such as these are the exception, not the rule. But what they can teach us can help avoid similar mistakes or pitfalls in the future. VM

[1] Case five comes from several news accounts. A good summary can be found at: http://patch.com/new-jersey/lacey/nuclear-regulatory-commission-could-boost-oversight-oyster-creek-after-finding

A valve/actuator that makes up a plant's safety system

Are your Safety Instrumented Systems Proof Tests Effective?

BY LOREN STEWART

Many people assume that a proof test of a safety function is 100% effective. Depending on the test used, this may very well be wrong.

A weak proof test design can impact the effectiveness of a safety function significantly, which can be shown through the average Probability of Failure on Demand (PFDavg) calculations.

This article explains proof test coverage for valves, actuators and solenoids and why this test is an important safety parameter. It also shows that the real objective is to detect failures that are not detected by any automatic diagnostics, and points out that safety instrumented systems (SIS) products will have much higher safety even with a lower proof test coverage if automatic diagnostics are used. In other words, it explains why a lower proof test coverage is not a bad thing.

WHAT IS A PROOF TEST?

Proof testing, which is an important part of safety design, is receiving an increasing amount of attention today. Most engineers who design and verify safety instrumented functions (SIF) understand how hard it is to design a manual proof test with high effectiveness. However, confusion exists on what must be included in the test and what coverage should be claimed.

A proof test is a test designed to uncover failures within the SIF that would otherwise be undetected and that prevent the protection function (dangerous failures). In general, the more frequently a proof test is run and the more extensive the test is, the greater the safety integrity.

Proof test coverage is expressed as a percentage of failures classified as undetected dangerous failures. Coverage is expressed as a range of 0–100%. Typical values range from 40-90%.

Executive Summary

SUBJECT: Proof test designs are critical to the safety function of our products. The average Probability of Failure on Demand, and many other functional safety calculations rely on a realistic proof test coverage.

KEY ISSUES:

- How proof tests can impact functional safety calculations
- Real life examples of safety systems with different proof test levels
- How to find the effectiveness of a proof test design

TAKE-AWAY: The real purpose for proof test coverage is to detect what automatic diagnostics cannot find.

PROOF TEST DESIGN

The final step in conceptual design of equipment is to perform the safety integrity level (SIL) verification calculations to see if that equipment, its architecture and the test philosophy will achieve desired risk reductions. When designing a proof test, both the functional requirements, such as what the SIF needs to do, and the performance requirements, such as the leakage and timing parameters and any exceptions to the safety manual, are considered.

For example, look at an SIF that is a close-to-trip application (the valve is in the normally open position and if there is a need to stop the process flow, the valve closes) with a final element that must close in accordance with International Electrotechnical Commission (IEC) 60534-4 Class III leakage within 180 seconds. In this example, the SIF is clearly identified with a given time requirement. However, as time increases, the probability of having a failure occur increases as well. This reality is shown in PFD calculations (Figure 1). When an ideal or perfect proof test is done, we know no failure has occurred or we have identified the failure and repaired it. However, when a condition (a demand) occurs infrequently and is an independent event, the average probability of failure is a valid way to represent failure to respond to the demand.

Simplified equations have been used to model SIFs. These equations can be useful for quickly approximating the reliability of an SIF. However, several pitfalls in using simplified equations exist. For example, the equations given often do not account for imperfect proof testing and mission time (lifetime of the system). Equation 1 above is the simplified equation often given for a one out of one (1oo1) function. This equation results in the PFDavg for a single SIF as a function of the dangerous failure rate in terms of Failures in Time (FITS), expressed in the rate of a device, which is the number of failures that can be expected in one billion (10^9) device-hours of operation.

In Equation 1, no term reflects an imperfect proof test. As a result, many users neglect to model the effect of testing during the SIL verification process. This invariably leads to optimistic results.

$$PFD_{AVG-1oo1} = \frac{\lambda^{DU} * TI}{2} + \lambda^{DD} * MTTR$$

Where: $PFD_{AVG-1oo1}$: is the average probability of failure on demand
λ^{DU}: is the dangerous undetected failure rate (FITS)
λ^{DD}: is the dangerous detected failure rate (FITS)
TI: is the proof test interval
MTTR: is the mean time to restore

Equation 1

$$PFD_{AVG-1oo1} = \frac{C_{PT} * \lambda^{DU} * TI}{2} + \lambda^{DD} * MTTR + \frac{(1 - C_{PT}) * \lambda^{DU} * MT}{2}$$

Where: C_{PT}: Effectiveness of proof test, 0–100%
MT: Mission time: life time of the system

Equation 2

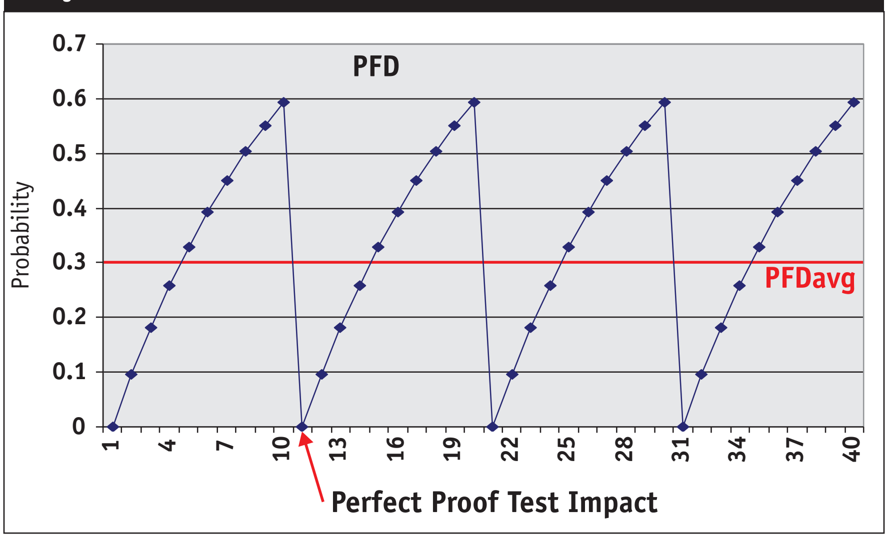
For a valve, a proof test that only confirms that the valve can fully stroke typically has effectiveness of about 70% (proof test coverage may be much lower even if tight shutoff performance is required). If this valve is modeled as having perfect proof testing, the PFD for the valve will be underestimated. Equation 2 is the simplified equation for a 1oo1 function and accounting for proof test coverage.

Yet, these questons arise: Why is a proof test not perfect? Is everything tested? If a functional test is run and we see the system respond, then does that mean everything we need to work does work? If not, what's the problem?

As an example look at a proof test where a pressure sensor is isolated and pumped up such that the sensor pressure exceeds the trip point. The remote actuated valve is observed to verify it moves, but there are many dangerous failures that might not be detected with the proof test mentioned. Those include:

1. The valve seat may not seal properly.
2. If response time is not measured, component failure may be causing the speed of response to exceed process safety time.
3. Process connections to the sensor may fail.
4. Power supply droop/wire resistance may be limiting maximum current disabling diagnostic alarms.

Figure 1



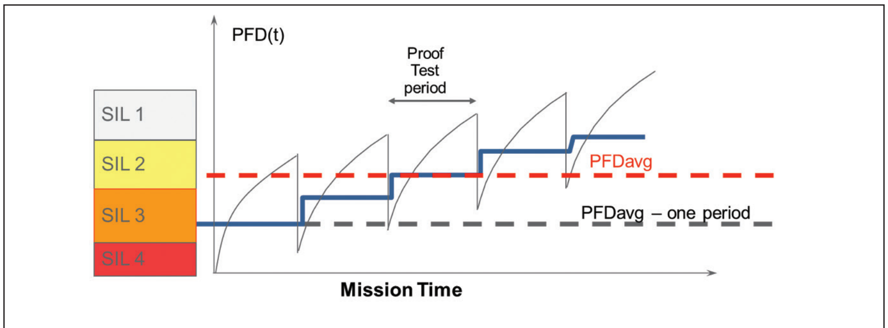


Figure 2

Because of imperfect testing, the PFD never returns to its original value. This may not make a meaningful difference after possibly the first proof test, but what about after the second or the third proof test? As the starting point of each proof test climbs, the risk reduction achieved can be significantly lower than what's necessary. It can even affect the achieved SIL rating of the SIF. Figure 2 shows this as a function of SIL ratings, where at some point in the third proof test period, the SIF will no longer achieve an SIL 3.

PFDAVG EXAMPLE

To demonstrate the significance of this, consider a high-level protection SIF. The proposed design has a single SIL 3-certified level transmitter, an SIL 3-certified safety logic solver and a single remote-actuated valve consisting of a certified solenoid valve, a certified scotch yoke actuator and a certified ball valve.

First analyze the SIF with the following variables selected to represent results from simplified equations:

- Mission time = 25 years
- Proof test interval = 1 year for the sensor and final element and 5 years for the logic solver
- **Proof test coverage = 100%**
- Proof test done with process offline
- MTTR = 48 hours

Then, compare it to the case in which a set of realistic proof test coverage numbers and other variables are considered:

- Mission time = 25 years
- Proof test interval = 1 year for the sensor and final element, 5 years for the logic solver
- **Proof test coverage = 90% for the sensor and 70% for the final element**
- Proof test duration = 2 hours with process online
- MTTR = 48 hours

Maintenance capability = "Medium" for the sensor and final element, "Good" for the logic solver with all other variables remaining the same.

Table 1. Summary of Calculation Errors

Proof test coverage	100%	90% and 70%
Failure rate λ^{DU}	1250 FITS	1250 FITS
Mission time	25 years	25 years
PFD_{AVG}	6.82E-03	5.76E-02
Risk reduction factor	147	17
Achieved SIL rating	SIL 2	SIL 1

The comparison of the results show that assuming 100% proof test coverage results in overestimating the risk reduction by a factor of 8.5 times. This is a significant error that will impact the reliability of the SIF. To ensure that accurate results are achieved, equations that account for proof test coverage must be used. Because of the complexity of these equations, it often is beneficial to use more advanced techniques such as Markov models (or software) that directly account for factors such as proof test coverage, repair times and other variations.

HOW TO KNOW PROOF TEST EFFECTIVENESS

One accurate method of predicting proof test effectiveness is to review all the components in a product by failure mode and record or test whether a specific manual proof test would detect that particular component's failure. This can be done through a product Failure Mode, Effect and Diagnostic Analysis (FMEDA) on a cross-sectional drawing of the product and assigning the appropriate functional failure modes, resulting in a product failure rate expressed in FITS (10^{-9}).

The following simple process helps to determine the effectiveness of each of those proof tests:

1. Establish a reasonable baseline failure rate for a device.
2. Perform an FMEDA with appropriate functional failure modes.
3. Assign coverage as a function of failure mode and test.
4. Evaluate effectiveness through the diagnostics and proof tests.

It should be understood that a manual proof test is done to detect failures that are not detected by automatic diagnostics. Tests designed to detect the same failures as the automatic diagnostics consume time, increase costs and accomplish little.

Proof test coverage is a measure of how many undetected dangerous failures are detected by the proof test. Imagine a product with 100 FITS of dangerous failures. Automatic diagnostics are poor and will detect only 10 FITS. That means λ^{DD} is 10 FITS and λ^{DU} is 90 FITS. Imagine that a manual proof test can be done during operation that can detect 72 of the 90 FITS. The proof test coverage is 72/90 or 80%. In other words, 18 FITS of dangerous failures are never detected.

What about a similar product with good automatic diagnostics that can detect 90 of the 100 FITS? In this case, the λ^{DD} is 90 FITS and the λ^{DU} is 10 FITS. Imagine the same proof test has been used, but the automatic diagnostics have already detected 70 of the 72 FITS. The proof test now detects two of the 10 FITS and proof test coverage is at 20%. That does not sound impressive, but the bottom line is that in the first case, the automatic diagnostics, combined with the proof test, detect all but 18 FITS. In the second case, automatic diagnostics combined with a proof test detect all but eight FITS. Looking at it this way shows a much better situation.

This illustrates why we should never use proof test coverage as a measure of quality for a product and why the opposite may well be true.

As automatic diagnostics get better, manual proof test coverage goes down, total detected DU failures (those detected by automatic and manual testing) increase and the PFDavg drops.

HOW MUCH DIFFERENCE CAN A PROOF TEST MAKE?

Proof testing is an important part of the management of safety instrumented functions. When testing the final element, we check to see how it functions and whether it is meeting its safety criteria. For example, if we have a floating ball valve, we can design at least five different proof tests for the valve:

TEST ID	DESCRIPTION OF TEST
PT1	Partial valve stroke test
PT2	Full valve stroke test
PT3	Full valve stroke test at operating conditions
PT4	Full valve stroke test and leak test
PT5	Full valve stroke test at operating conditions and leak test

Test 1 or PT1 is a partial stroke test where the valve is moved only 5–10% of its total stroke. We could also perform a full valve stroke test where the valve is opened 100% of its total stroke (PT2). Full valve stroke tests are usually done when the process is down, so another variation would be a full valve stroke test at operating conditions (PT3). A fourth test, PT4, would do a full valve stroke test with an added leak test. As with full tests, the system would be down during PT4 so we could do that same test except at operating conditions (PT5). Those are the five proof tests that could be carried out on that valve assembly.

Table 2. PT1-5 Dangerous undetected failure rate

Devices	Dangerous Total Failure Rate	PT1	PT2	PT3	PT4	PT5
Solenoid	432	43	4	4	4	4
Poppet Valve	60	6	1	1	1	1
Actuator	500	287	181	149	37	5
Valve	549	315	198	163	41	5
Assembly Accessories	50	28	16	13	4	1
Total	**1591**	**679**	**400**	**330**	**86**	**16**
%		57%	74%	79%	94%	99%

Which proof test would you use? If, for example, you have a full stroke test of a remote valve assembly as a manual proof test, but it is not tested at operating conditions, which would apply? This would be PT2, so it does not provide 100% coverage. This test is more effective in detecting failures in solenoid valves and actuators where the primary function of mechanical movement can be observed. The test does not do well in detecting damage to valve seats because such damage is not typically observed. However, if we are going to try to stroke test the valve, time it, and do a leak test, the proof test would fall under PT4.

SIF PROOF TEST EXAMPLE

Using a real-life example looking at the entire SIF, we could have a solenoid, a poppet valve, an actuator, a ball valve and accessories such as mounting and coupling. We achieved the failure rates of both safe and dangerous failures by performing an FMEDA. From the FMEDA, we can evaluate the dangerous failure rates with respect to the five proof test categories, PT1-PT5 (Table 2).

Table 2 shows each device listed with the associated total dangerous failure rate in FITS ($10e^{-09}$) and evaluates each device at every proof test level in the FMEDA process. As you raise a level in proof test effectiveness, more and more dangerous failures are detected. This means that undetected failures are turning into detected failures, leaving the undetected failure rate to descend. Looking at the entire SIF, the differences between proof tests begins to stack up, which could have a significant impact. For example, comparing Proof Test 1 through Proof Test 5, 663 FITS dangerous undetected failures quite possibly are unaccounted for!

SOME TERMINOLOGY

Because many VALVE readers are not safety experts, here are a few of the terms in this story that are commonly used in the industry and what they mean:

- **Safety function**—the purpose of the valve/actuator/solenoid/SIF is to take the system to a safe state when needed
- **Automatic diagnostics**—a system test done automatically after a period of time
- **Manual diagnostic**—a system test done as a manual test after a period of time

SUMMARY

To summarize: A realistic PFDavg calculation depends on several variables, including realistic proof test coverage. This coverage can be measured by a detailed examination of a product, which shows that proof test coverage can impact PFDavg by an entire SIL level. VM

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Why Air Valves are Needed in Water Applications

BY AMERICAN WATER WORKS ASSOCIATION

Air valves are hydromechanical devices designed to automatically release air and wastewater gases or admit air during the filling, draining or operation of liquid piping systems for water and wastewater services. The safe and efficient operation of a liquid piping system is dependent on the continual removal of air and wastewater gases from the liquid piping system. The following includes an explanation of the effects of air and wastewater gases and their sources in liquid piping systems.

OCCURRENCE AND EFFECT OF AIR AND WASTEWATER GASES

Water contains approximately 2% dissolved air or gas by volume at standard conditions (14.7 psia [101 kPa absolute] and 60°F [16°C])[1] but can contain more, depending on the liquid pressure and temperature within the liquid piping system.

Wastewater systems can also contain more undissolved air and wastewater gases due to the decomposition of materials in the wastewater. Dissolved air and wastewater gases can come out of solution in pumps and in different locations along the liquid piping system where turbulence, hydraulic jumps and other pressure variation phenomena occur. Once out of solution, air and wastewater gases will not readily dissolve and will collect in pockets at high points along the liquid piping system.

Air and wastewater gases come out of solution in a liquid piping system due to low pressure zones created by partially open valves, cascading flow in a partially filled pipe, variations in flow velocity caused by changing pipe diameters or slopes, and changes in pipe elevation. Entrained air that reaches water service connections may be detrimental to the customer's water systems.

An air and wastewater gas pocket may reduce the flow of liquid in a liquid piping system by reducing the cross-sectional flow area of the pipe, and if the volume of the air and wastewater gas pocket is sufficient, complete binding of the liquid piping system is possible, stopping the flow of liquid.[2]

The velocity of the flow of liquid past an enlarging pocket of air and wastewater gases may only be sufficient to carry part of the pocket of air and wastewater gases downstream unless the liquid velocity is greater than the critical velocity for transporting air and wastewater gases in that particular pipe diameter.[3] The velocity needed to scour a pocket of air and wastewater gases in larger piping systems (e.g., 24 inches [610 millimeters]) may be as high as 7.1 feet per second [2.2 meters per second] at a 5% slope as shown in Table 1.[4] Although the flow velocity of the liquid may prevent the liquid piping system from complete air and wastewater gas binding, the pockets of air and wastewater gases will increase head loss in the liquid piping system.[5] As shown in Figure 1, a pocket of air and wastewater gas can reduce the flow in the pipe to "d" and create head loss equal to "HL" due to the restricted cross section. Additional head loss in a liquid piping system decreases the flow of liquid and increases power consumption required to pump the liquid.

Pockets of air and wastewater gases in a liquid piping system are difficult to detect and will reduce the liquid piping system's overall efficiency. Pockets of air and wastewater gases may also contribute to water hammer problems, pipe breaks, system noise and pipe corrosion—especially hydrogen sulfide corrosion—and can cause erratic operation of control valves, meters and equipment. Studies have shown that small pockets of air and

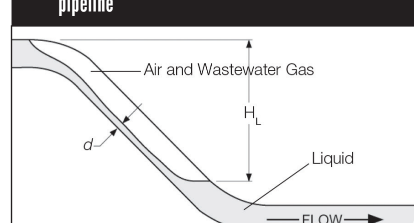
Editor's Note: This article is Chapter 1 of the M51 Air Valves: Air Release, Air/Vacuum, and Combination, Second Edition by the American Water Works Association. The manual also covers specific types of air valves (see Chapter 2: Types of Air Valves), where they should be located, design of the valve orifice, the effects of water hammer and installation, operation, maintenance and safety of air valves. For information, go to www.awwa.org.

Table 1. Velocities required to scour air and wastewater gases from pipelines

Scouring Velocities by Pipe Size and Slope					
Pipe Size	Velocity, ft/sec (*m/sec*)				
	Negative Slope				
in. (*mm*)	0° (0%)	2.9° (5%)	14° (25%)	45° (50%)	90° (vertical)
4 (*100*)	2.7 (*0.8*)	2.9 (*0.9*)	3.1 (*0.9*)	3.4 (*1.0*)	3.5 (*1.1*)
8 (*200*)	3.8 (*1.2*)	4.1 (*1.2*)	4.4 (*1.3*)	4.8 (*1.5*)	5.0 (*1.5*)
12 (*300*)	4.7 (*1.4*)	5.0 (*1.5*)	5.4 (*1.6*)	5.9 (*1.8*)	6.1 (*1.9*)
24 (*600*)	6.6 (*2.0*)	7.1 (*2.2*)	7.6 (*2.3*)	8.3 (*2.5*)	8.6 (*2.6*)
36 (*900*)	8.1 (*2.5*)	8.7 (*2.7*)	9.3 (*2.8*)	10.2 (*3.1*)	10.6 (*3.2*)

Source: Jones et al. 2008.

Figure 1. Air and wastewater gas pocket in a pipeline



wastewater gases in certain locations along the system can cause transients and surge and/or intensify transients and surges, including downsurges.[6] However, temporary pockets of air and wastewater gases may be needed in special circumstances to prevent vacuum conditions in a liquid piping system after pump outages or line breaks. Vacuum conditions should be avoided as they may result in collapse and/or deformation of thin-walled pipe. Finally, on system applications, in locations where liquid column separations and returns may occur, a vacuum breaker with air-release valve or an air valve with restricted outflow (slow-closing device or throttling device) should be considered.

Figure 2. An air valve installed on the outlet of a pump and upstream of the check valve

SOURCES OF AIR AND WASTEWATER GASES

In addition to air and wastewater gases coming out of solution, air may enter liquid piping systems at leaky joints where the pressure within the liquid piping system falls below atmospheric pressure. These conditions exist in the vortex at the pump suction, at pump glands where negative pressure occurs and at all locations where the pipe elevation is above the hydraulic grade line.

Air may enter liquid piping systems through air/vacuum and combination air valves following complete pump shutdown, through the orifices of air-release valves installed in locations where the pressure is less than atmospheric and through pump suction pipes or inlet structures that are not properly designed to prevent vortexing. Finally, most vertical turbine and well pumps start with air and wastewater gases in the pump column as shown in Figure 2, which may pass by the check valve and flow into the liquid piping system with every pump start.

Air and wastewater gases entrainment is much greater in wastewater force main systems than in other pumped liquid transmission systems owing to their unique design and operational characteristics. Lift stations with wet wells or other sewage collection basins are a major source of entrained air and wastewater gases induced by plunging jets of sewage and by vortices of air and wastewater gases sucked into the pump. Because of the cyclic operation of force main systems, sections of the force mains empty out at the end of each pumping cycle, drawing air and wastewater gases into pipes. At the entrance to sewage lift stations, air and wastewater gases are entrained from plunging jets of sewage.

GAS POCKET BEHAVIOR

Four major factors influence entrained air and wastewater gas behavior in liquid piping systems: buoyancy, velocity, drag and equilibrium in surface tension between the liquid, air and wastewater gases, and the pipe wall. These factors, together with air and wastewater gas pocket size and concentration, influence the tendency of bubbles to aggregate and increase in size and determine the direction of their movement either with or opposite to the direction of liquid flow.

These factors also affect the entrained air and wastewater gases pockets' influence on liquid flow capacity, head loss and energy consumption. In rising pipe sections and when there is no flow in the pipeline, buoyancy will force air and wastewater gas pockets of all sizes and shapes to travel to peaks or high points along the liquid pipeline. At down-sloping and level pipe sections, when buoyancy exceeds drag, the pockets will travel upward in the opposite direction to the flow. When drag exceeds buoyancy, the pockets will travel in the direction of liquid flow.

Large air and wastewater gas pockets traveling in opposite direction to the liquid flow often break up in flow due to buoyancy, resulting in smaller air and wastewater gas pockets, including bubbles, changing direction and being dragged in the direction of the liquid flow with the larger air and wastewater gas pockets or continuing to travel upstream against the flow. Pockets of air and wastewater gases traveling with the liquid stream also break up into smaller air and wastewater gas pockets and bubbles that disperse in the liquid stream, traveling in different velocities.

In all these cases, the air and wastewater gas pocket's movement disturbs the flow where drag and turbulence increase head losses, resulting in decreased flow capacity and increased energy consumption.[7] VM

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Lubricants: Always Important—Sometimes Essential

BY GREG JOHNSON

Most valve professionals take more notice of the oil or fluid flowing through the valve than the oil that lubricates the valve's mechanical parts. That should not be the case. Virtually every valve with moving metallic parts needs lubrication, and some valves such as lubricated plug valves simply cannot function without it.

Lubricants serve four main purposes in valves: 1) to grease metallic mechanical joints such as those found in stem to bushing and gear interfaces; 2) as a hydraulically activated surface coating to enable lubricated plug operation as well as allow some gate and ball valves to operate smoothly; 3) as an injectable, emergency sealant between disc or ball and valve seats; 4) as a coating to prevent corrosion or oxidation. Sometimes the corrosion prevention function is combined with a cavity filler function as well.

On most linear valves, the primary lubrication location is the stem bushing. This interface between a threaded stem and a similarly threaded bushing requires lubrication to keep it operating freely. Most manufacturers use a general-purpose grease for the job. In larger valves, there is usually a grease fitting to enable post-installation relubrication.

☐ This linear valve manual gearbox is packed with NLGA #2 EP grease to keep the parts meshing smoothly and to keep the moisture out.

THE RIGHT SLICK

When people think about oil, they picture the stuff that goes into car engines or the little tube that says "Three in One." But lubricants come in many types, chemistries and viscosities. From alcohol-thin oil to the thickest, stickiest grease, they all serve important purposes in operating valves.

Oils, which are also the base ingredient for most grease compounds, come in many forms. They can be petroleum-, animal- or plant based, or they can be synthetic creations. To make a grease, the liquid base material is combined with a suitable thickener, called a "soap," to make the grease thick and sticky (or as a non-mechanically-inclined squeamish person might say—"thick and icky.")

The viscosity of a grease is measured on a linear scale developed by the National Lubricating Grease Institute (NLGI). The NLGI scale runs from 000 (less viscous) to 6 (thickest). For valve applications, the greases used are usually in the medium viscosity range of 1-2.

Grease descriptions also often contain the prefix AP, MP or EP. These acronyms have important meanings:

- AP stands for "all-purpose" grease. These thick lubricants provide good thermal and structural stability. They also offer a high degree of corrosion and rust resistance. AP greases are often used on cars and trucks and in some less-demanding valve applications.
- MP, or "multi-purpose" grease is an NLGI number 2 grease also popular in the automotive industry as well as in light industrial and agricultural applications.
- EP, or "extreme pressure" grease is the heartiest of the three types. Under high pressure or shock loading, normal grease can be compressed to the extent that the protective film breaks down and the protected parts can come into physical contact, causing friction and wear. EP grease contains additives such as graphite or molybdenum disulfide to protect the grease under heavy loadings. EP greases also contain solids that bond to the surface of the metal, adding a sub-layer that prevents metal-to-metal contact. Valve gear boxes, both manual and powered, require a hearty grease to keep the gears meshing smoothly and inhibit corrosion in the gearbox. EP NLGI #1 or #2 grease is a popular choice for these valve applications.

VALVE GREASE

Most valve lubricants are petroleum based. However, some applications, such as chlorine and oxygen service, require synthetic compounds. These synthetic compounds are often polytetrafluoroethylene (PTFE) based. Valves in oxygen service cannot tolerate petroleum-based lubricants of any kind because of the possibility of ignition. Other services such as chlor-alkali also require specific lubricants.

Valves used in high-temperature applications call for specially formulated high-temperature greases. These greases usually have a petroleum base that exists to spread additives such as graphite or lithium onto the metal parts. As the temperature rises and the petroleum products evaporate, the graphite or lithium coating remains, protecting the metallic surfaces from damage.

Injectable lubricants are popular in valves used in the midstream segment of the oil and gas industry. These applications, such as pipelines and gathering lines, are under the realm of the American Petroleum Institute (API) specification 6D, Pipeline Valves. Most 6D gate valves have grease fittings that allow a lubricant to be injected in the seat area to seal leaks or otherwise improve the valve's shutoff characteristics. API 6D ball valves are also equipped with lubrication ports or fittings.

Injectable lubricants are usually pumped into the valve through use of a grease fitting equipped with ball check valves. The grease is pumped into the seat area then squirts out and spreads between the seat and closure member, creating a thin, leak-sealing film. Since most of these lubricants are petroleum-based, their use is limited to valves in hydrocarbon service. However, a few injectable lubricants are specifically formulated for oxygen, chlorine and similar non-hydrocarbon applications.

Lubricated plug valves must have lubrication to operate. When not moving, the metallic plug sits tightly against the metal seat in the valve, with only a thin film of lubricant between the seats and the plug. However, when the valve must operate, a squirt of very-high-pressure lubricant causes the plug to move slightly off the seat and easily rotate 90 degrees.

Like injectable pipeline valve greases, injectable lubricated plug valve grease compounds come in many flavors to serve a variety of different applications. In API 599, the metal plug valve standard, paragraph 6.1.5 details the requirements for lubricated plug valve grease:

"Unless otherwise specified in the purchase order, lubricated plug valves shall be furnished with hydrocarbon resistant lubricating sealant that has a temperature range from -20°F (-23°C) to 225°F (107°C). This sealant shall have both the proper plasticity for tight sealing and the lubricity for ease of operation."

While all lubrication is important, for some applications, the use of lubrication in valves is strictly detailed and controlled. In API 598, the primary valve testing standard today, the use of lubricants in aiding sealability is limited. The wording in paragraph 6.4.1 states:

"If necessary to prevent galling (during the closure test procedure), the sealing surfaces may be coated with a film of oil that is not heavier than kerosene."

Valve lubrication is vital today for effective and efficient valve operation. Long gone are the days when a few drops of 30-weight motor oil in a squirt-can would keep valves functioning. Today's valve lubrication needs require specific compounds designed to meet the broad range of different valve applications. That means the squirt-can should remain on the shelf. VM

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Q: What are the pros and cons of using a thermal spray coating like HVOF? When does it make sense to use HVOF coatings?

BY BENJAMIN HAGARTY

The High Velocity Oxygen Fuel (HVOF) process is a thermal spray process developed in the 1980s that has since been commercialized for industrial use. The process involves projecting metal or ceramic particles onto a substrate at supersonic speed. To achieve this, a liquid (typically kerosene) or gas (propane, acetylene, hydrogen, etc.) fuel is mixed with oxygen and ignited in a combustion chamber. This produces a high-pressure jet of hot gas that flows through a nozzle. Powder is fed into the jet and propelled at the substrate at a velocity of more than 800 meters per second (almost 1,800 miles per hour). The particles, which have been softened but not melted, adhere to the grit-blasted surface of the target, ideally creating a hard and tough, high-strength coating with low porosity.

ADVANTAGES OF HVOF COATINGS

HVOF coatings provide several advantages including:

High hardness: The high velocity at which the particles are flung onto the substrate results in a dense coating, which contributes to higher levels of hardness. In addition, HVOF is an excellent option for applying carbide coatings. The short amount of time that the material is exposed to heat leads to reduced degradation of the hard carbide phases in a material.

Toughness: As compared to other thermal spray processes, the HVOF process provides coatings with high toughness. This is partly because of superior intersplat cohesion (the cohesive bonds that form between the softened particles after they are sprayed). The favorable combination of high hardness and relatively good toughness yields a coating with excellent wear resistance.

Thickness: Since the powder is often not completely melted, less residual stress in the coating occurs, which allows thicker coatings. The typical thickness of HVOF coatings is 0.005-0.010 inches (0.127-0.254 millimeters), but some coatings can be applied to a thickness up to 0.50 inch (12.7 millimeters). The thicker coating can be beneficial for wear resistance and protection of the underlying substrate from corrosion.

Corrosion resistance: HVOF coatings tend to have better corrosion resistance than most other thermal spray coatings. This depends heavily on the material applied, of course, but in general, the low porosity in HVOF coatings adds to corrosion resistance.

DISADVANTAGES

HVOF is a line-of-sight application with a spray range of about eight inches, which can restrict application on tight areas and internal surfaces of cylindrically shaped parts.

At a recommended maximum size of about 50 microns, the powder size needed for successful HVOF coating is smaller than other thermal spray applications. The distribution of particle size is also very important—it is not uncommon to see requirements for a distribution range of 20 microns (30-50 microns would be an example).

When done properly, HVOF coatings are highly effective. However, they are complex and the application requires highly trained personnel to supervise the process. Although the spraying is often performed by robots, personnel must be familiar with the process, make changes to parameters as needed for different powders and substrates, and ensure that the spraying is carried out safely.

WHEN HVOF MAKES SENSE

The HVOF process can be used to apply a wide range of metals including nickel alloys, cobalt alloys, carbides, aluminum bronze, molybdenum and some stainless steels. Also common for HVOF coatings is cermet (composite ceramic and metal) powders. In the valve industry, two of the more common cermets applied with the HVOF process are tungsten carbide particles in a cobalt matrix (WC-Co) and chromium carbide particles in a nickel-chromium matrix (CrC-NiCr). While the final coating properties depend in part on spraying parameters, these materials are favored for high wear and abrasion resistance, high bond strength and relatively good toughness.

HVOF coatings are an excellent option when an application requires high wear resistance and erosion resistance while maintaining moderate corrosion resistance. For example, in a slurry application, an HVOF coating can be a good choice on the valve ball, seat, plug or disc.

As the HVOF process has been developed over the past few decades, it has been used increasingly as an alternative to some traditional coating systems, such as plasma coating and hard chrome plating. The wear resistance offered by carbide HVOF coatings competes with that of hard chrome plating. In the best cases, the corrosion resistance, while dependent upon the environment and chosen alloy system, can match or exceed the performance of hard chrome. However, as mentioned, HVOF coating is line-of-sight, so hard chrome has an advantage when it comes to complex geometries and small inside diameters.

The cost of these two coating systems can be debated, but it depends on the geometry of the parts coated and the required thickness. HVOF is typically thought to be slightly more expensive, although when dealing with large parts with simple geometries, HVOF becomes more cost competitive and may be cheaper than hard chrome. Any polishing and grinding will contribute to cost as well. Again, cost is dependent upon the shape and complexity of the surface for both HVOF and hard chrome.

Also, while HVOF coatings are not a perfect replacement, increasing pressure to restrict hexavalent chromium for health and environmental reasons means HVOF coatings will probably grow in use in the coming years. VM

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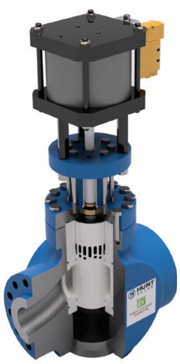
ASCO introduced the ASCO Numatics 617 Series SentronicLP proportional electronic regulator for accurate pneumatic pressure control in applications with limited power supplies.

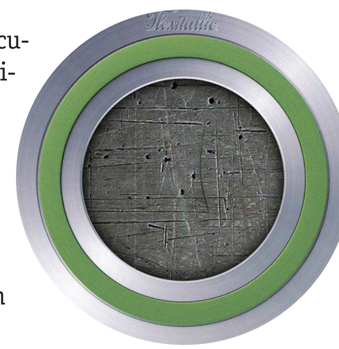
With hysteresis of less than 1 percent, excellent linearity and repeatability, and stable control under flowing conditions, the high-performance proportional valve is ideally suited for applications where precise pressure control is required. The space-saving design requires only one pressure supply, enabling economical, simple and quick installation.



Hunt Valve released a new descale valve that delivers two to three times longer service life. The new Mega-Flo "C" plunger-style descale valve incorporates advanced ceramic materials for reliable, continuous production with the least amount of downtime at rolling mills. It has an upgraded ceramic housing liner that can now be replaced in the field, saving the downtime of sending the liner out to the manufacturer to be repaired.

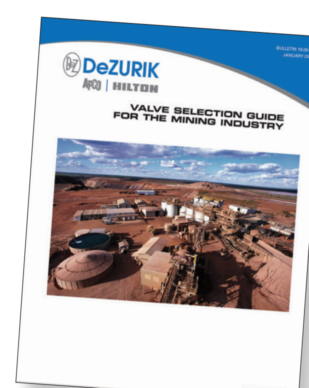
Emerson introduced the first WirelessHART Power Meter, making electrical demand and consumption measurement available via a secure and reliable network across numerous markets. Emerson incorporated WirelessHART technology into a revenue-grade wireless power meter to deliver a unique measurement solution that will greatly improve energy efficiency and sustainability.

Real-time monitoring of electricity consumption and instantaneous demand enables more granular energy management and effective equipment monitoring.



Flexitallic unveiled Corriculite for use in corrosion-sensitive applications, including offshore operations. A newly-developed gasket filler material, Corriculite tackles the problem of flange face corrosion on bolted joints in seawater and hydrocarbon applications.

The company created the filler material for a range of spiral wound gaskets, specifically designed for use in corrosion-sensitive environments in industries such as oil and gas, power and marine.



DeZURIK's newly revised Valve Selection Guide for the Mining Industry is designed to assist users in navigating the valve selection process. The guide features information on DeZURIK/APCO/Hilton's complete line of valves for mining applications including slurry, gate, plug, butterfly, check, air and rotary control valves.

The updated guide is highlighted by a detailed valve selection chart, which uses color-coded ratings to categorize each valve style's usage based on function, type of media and individual characteristics.

CIRCOR Energy offers the Series WB (Welded Body) trunnion mounted ball valve, 3D printed by 3D Print Texas. The fully welded API 6D ball valves provide a solution for buried service and above-grade applications. The robust welded body ball valves come standard with double-piston seats for added downstream safety, and offer industry-leading performance in reducing leak paths over bolted body valves for buried service pipelines.

Spirax Sarco released EP500, an ergonomically designed electropneumatic valve positioner. This positioner offers accuracy and reliability with an ease of installation, calibration and operation.

The positioner has a cast aluminum enclosure that is suitable for outdoor installations. It uses simple force-balance control technology and can be mounted onto pneumatic actuators with strokes between 10mm and 70mm. VM

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ensuring that the fluid flow does not reverse direction.

System designers must be familiar with the best practices and industry standards for minimizing water hammer, such as using slow-closing valves when appropriate, knowing optimal valve locations within a piping system and giving special piping design considerations for high-operating pressure systems.

When piping systems are properly engineered, the likelihood of water hammer occurring is greatly reduced or even eliminated. In systems that already are in place, the damaging effects of water hammer can be limited in a number of significant ways, such as installing water hammer arrestors, relocating check valves out of vertical lines, installing silent check valves as a primary line of defense and ensuring operating procedures for quarter-turn valves have a slow closing rate. Note that the closure time in automated systems should be at east 10 times what is calculated in the T=2L/a formula.

CONCLUSION

Water hammer has been studied for many years. Some of the founding research dates back to the late 19th century. Research continues today. Many major universities in the United States, U.K. and the Netherlands as well as well-respected valve companies have authored articles on the comparison of various styles of check valves and their installed dynamic characteristics.

This article only scratches the surface of the subject of fluid transients by exploring some of the causes and solutions of what we commonly call water hammer. Solutions to deal with water hammer problems can be quite costly, and, as always, an ounce of prevention is worth a pound of cure. Pumps feeding into vertical lines or common headers and rapid valve closures can all be designed out of a process at the beginning. Once the piping is in place and the plant processes are underway, the challenge is to find solutions given the specific constraints.

Most manufacturers of in-line silent check valves understand water hammer very well and have engineers on staff that can help. They can be the best source of knowledge when it comes to the right solution. VM

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