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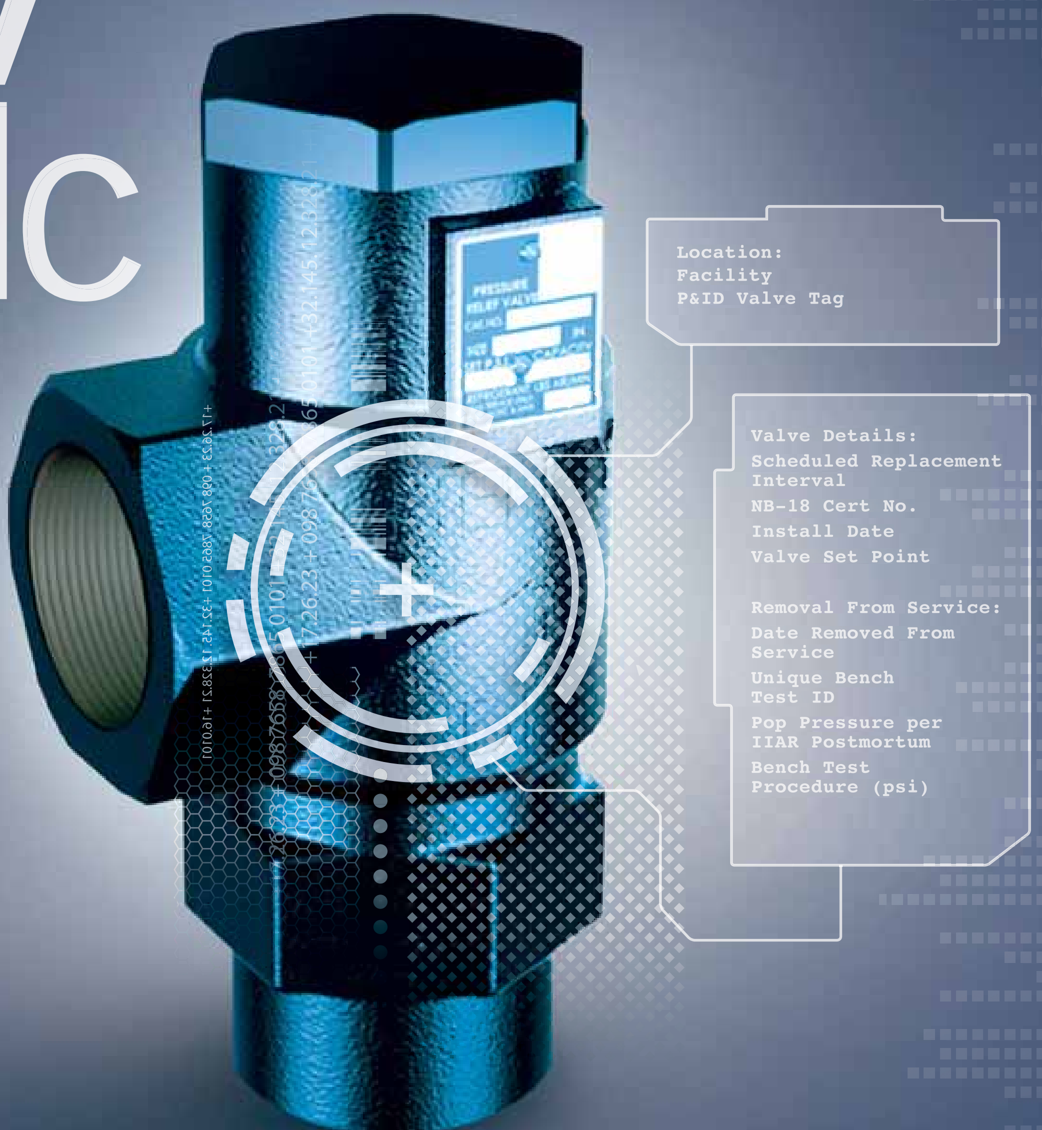
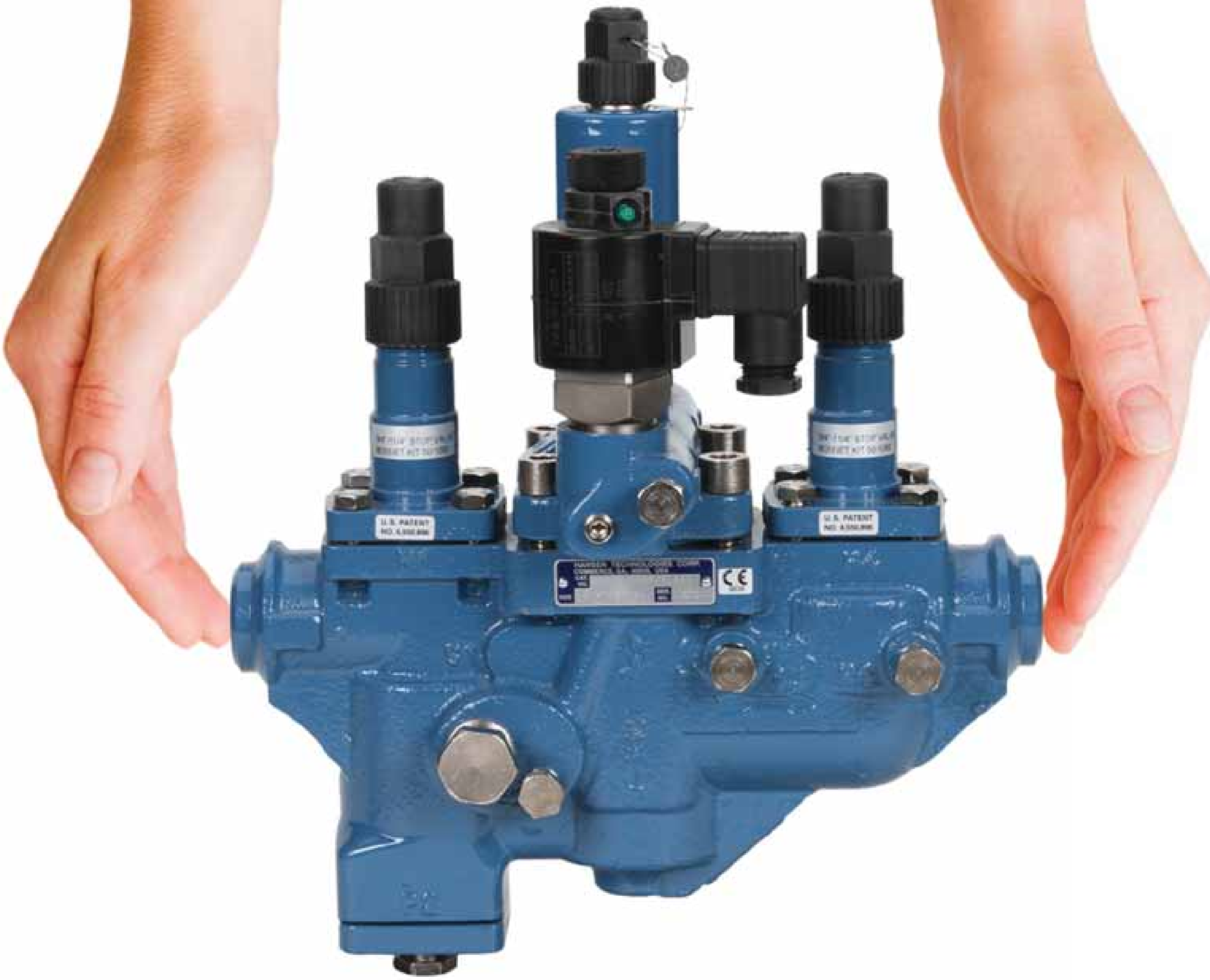
THE OFFICIAL MAGAZINE OF THE AMMONIA REFRIGERATION INDUSTRY ■ SEPTEMBER 2014

CONDENSER

SRV Calc

USING WEIBULL ANALYSIS TO PREDICT VALVE REPLACEMENT





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contents

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The five-year replacement interval for relief valves is spelled out in IIAR Bulletin 110, but at its core, that five-year estimate for optimal replacement of valves is just that, an estimate. Until recently, no real mechanism for quantifying those replacement intervals — and the potential benefits of extending or shortening them— has existed.

A new analysis tool, called SRVcalc, may prove to be a powerful way to do just that, with long reaching implications for how the industry implements generally accepted practices that have been on the books for years.

chairman's MESSAGE

MARCOS BRAZ

The end of summer is here, and that means it's time to refocus our attention on important projects and get ready for the whirlwind of activity coming our way this fall.

For IIAR staff, committee, and volunteer members, that means building on the substantial work completed this summer on a variety of different initiatives.

You'll read in this issue of the Condenser about two important research projects that have recently been completed.

Both projects are great examples of the real-life value of IIAR's committee work in our industry. The IIAR Research Committee, like all IIAR committees is dedicated to solving real world problems, producing practical tools and advancing our understanding of our technology and operations in a way that makes what we do safer and more efficient.

These types of initiatives are projects that really are state of the art in terms of actual machinery and materials we use to put our systems together.

And in the same way that the Research Committee is dedicated to solving practical in-use problems, all of IIAR's committees are working to find meaningful, actionable solutions to issues that impact the day-to-day operations of our industry.

Currently, a wide variety of committee members, volunteers, and consultants are involved in the update and release of IIAR's Suite of Standards, and that wide variety of perspectives is helping ensure we create the best resource possible.

But it's not just our Research and Standards Committees that are working hard on special projects.

The Safety Committee is working with the *Ammonia Safety Training Institute* (*ASTI*) to create a new ammonia safety video; the Education Committee is working on a variety of training materials and scholarship programs; the Marketing Committee is spreading the word about IIAR and the value it provides the industry. Meanwhile, the International Committee just finished our Santiago-Chile seminar and is very active in promoting ammonia refrigeration systems operation and safety with local government entities and associations. Finally, the Government Relations Committee (our newest committee) is creating new partnerships with government officials and spreading the word about the challenges and opportunities we face as an industry.

While each committee is focused on different initiatives, collectively they are making the world of ammonia and natural refrigerants safer by ensuring all of us have access to the best resources available.

As IIAR members, your involvement and input within this industry is the sole force that moves us all forward. Whether it's testing new technology or new practices, increasing communication with regulatory agencies or developing cutting edge resources like safety training and standards, we can't do any of it without you.

Our committees are the spine of our organization. They are the work vehicles that move our ideas and initiatives from abstract goals into reality. At the same time, our Board officers and voting members bring so much vitality and substance to our organization.

If you are an IIAR member and have not yet had a chance to get involved in the work of your industry, I urge you to take a look at how your expertise might help an IIAR committee further its work goals.

Of course, behind the ongoing work of our membership, our staff at headquarters is always working to deliver new products and resources. Make sure to visit and interact with them as you have the opportunity to do so through committee meetings and our annual convention.

This year, I'm pleased to announce that we're focused on improving and updating our handbooks, a process that will include a transition to electronic format to improve access to IIAR materials.

If you don't already have a complete library of IIAR Publications in your office, now is a good time to make that a priority. They are an extensive resource of documented knowledge in our industry that we've produced over the years.

As an industry, our passion and dedication for what we do easily translates into the kind of "can do" attitude that affects real change in our world.

Your ongoing support makes all of our projects and opportunities possible. Thank you for continuing to enrich our industry with your collaboration, input, and knowledge. I'm looking forward to keeping you updated on the progress of these projects and initiatives, and the many others we have slated for the rest of the year. ■

president's MESSAGE

BY DAVE RULE

Throughout this edition of the Condenser, you'll see a common theme: Progress. I couldn't be more excited about where IIAR – and the industry as a whole – are heading.

Over the past few months, IIAR, and the ammonia refrigeration industry, have experienced several signs of promise and growth.

From new research projects that promise to deliver practical tools that have the potential to improve day-to-day operations; to new partnerships and events in Latin America that broaden our reach; to growing awareness within regulatory agencies of IIAR's resources and expertise, we're forging ahead to meet new opportunities and realize new goals.

One of the most exciting new goals I'll point to is our continued emphasis on developing a stronger relationship with regulatory agencies.

We're making stronger headway than ever before on this initiative, opening new avenues of communication with the Department of Homeland Security, Occupational Safety and Health Administration, and Environmental Protection Agency.

Recently, IIAR participated in formulating responses to two Requests for Information from OSHA and EPA, respectively. And we're preparing to answer a similar request from DHS, recently issued as a Notice of Proposed Rulemaking.

These notices are attempts by our regulatory agencies to collect information from a variety of chemical sector industries. Their intent is to help all three update regulations and provide new guidance as a result of Executive Order 13650, which was a presidential directive to improve chemical facility safety and security.

President Obama issued the EO following the tragic accident last year in West, Texas. At its core, the EO is intended to enhance the safety and security of chemical facilities and reduce risks associated with hazardous chemicals to facility workers and operators, communities, and responders.

Since the signing of the EO, a group of federal agencies led by DHS, OSHA and EPA has been working to implement the order and identify additional actions to improve chemical safety and security.

Some of the potential policy changes could have a significant impact on the cold chain, particularly companies with over 10,000 pounds of ammonia subject to Process Safety Management and the Risk Management Program.

That's why our involvement as an industry has never been more important. We've already had follow up discussions with OSHA on the comments we provided via our response to the agency's RFI, and we're looking forward to similar conversations with EPA and DHS.

But it's not just in the regulatory process where we're seeing increased involvement. IIAR is also working closely with all three agencies to find ways to develop educational and training materials that will promote the best practices of our industry and inform regulators on a broader level.

Of course, securing our homeland against terrorist threats has never been a more important initiative, and it's one that our industry takes very seriously.

That's why we've also started to build stronger lines of communication with the Department of Homeland Security.

Beginning last February, with his visit to Nashville to attend and speak at our annual conference, David Wulf, DHS Deputy Director of the Infrastructure Security Compliance Division within the Office of Infrastructure Protection, made it clear that he is committed to listening to our input on regulatory development and learning about our industry.

I'm happy to announce that our increased level of participation between IIAR and DHS will continue into next year. DHS has already been scheduled to deliver a major workshop at our next conference in San Diego, and you can read more about David's approach to our industry in a special interview with him that appears in this issue of the Condenser.

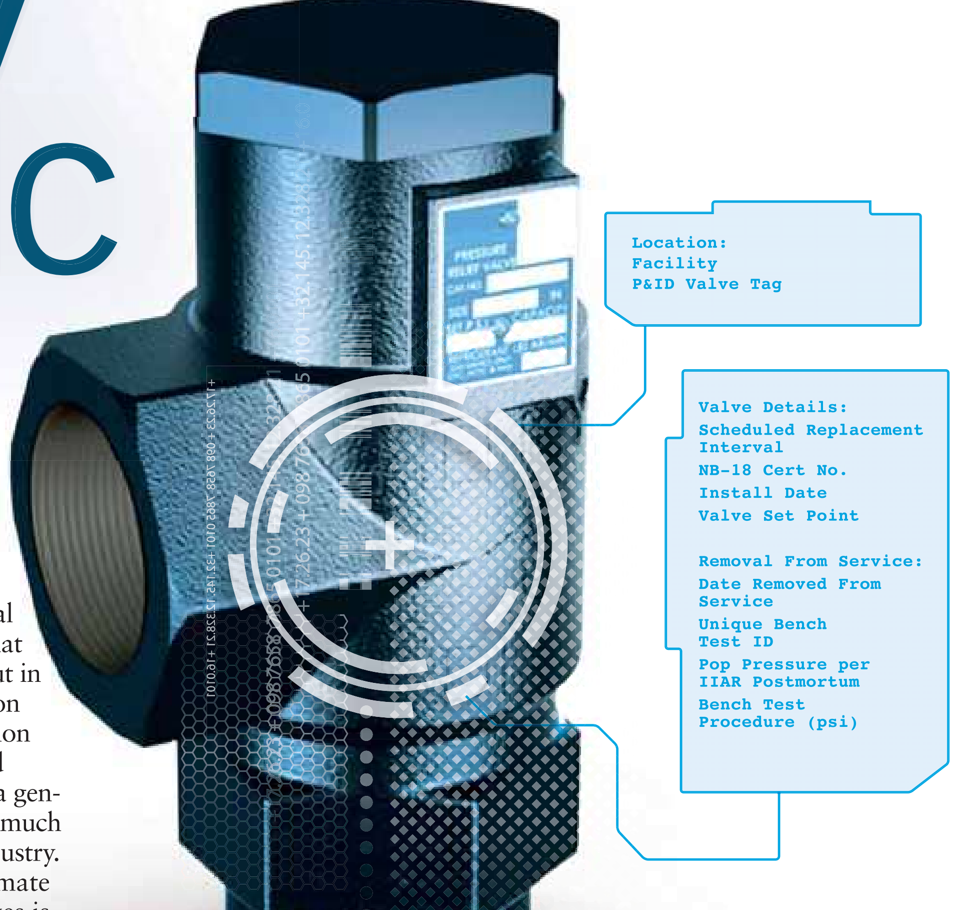
The bottom line when it comes to these activities is simple: your voice matters. As an IIAR member, you are closest to the operations and procedures these regulatory agencies are taking a renewed look at.

I'm confident that IIAR members are better equipped than any other group to help agencies address compliance issues. And the larger that group becomes, the clearer our voice is heard. If you work closely with colleagues who are not IIAR members, now is the time to become an advocate for your organization.

The more individuals we can reach, the more knowledge we can share and spread throughout the world. I'm looking forward to seeing IIAR grow in the coming months, and to seeing our industry continue to expand in positive ways thanks to the hard work of all of you. ■

SRV Calc

USING WEIBULL ANALYSIS TO PREDICT VALVE REPLACEMENT



BY ANDREA FISCHER

The five-year replacement interval for relief valves isn't a practice that gets much scrutiny. It's spelled out in IIAR Bulletin 110, and a provision establishing the need for a common interval appears in the Boiler and Pressure Vessel Code, making it a generally accepted "no-brainer" for much of the industrial refrigeration industry.

At its core, that five-year estimate for optimal replacement of valves is just that, an estimate. And it's an estimate that raises questions about how relief valve replacement intervals can impact optimal safety, efficiency and economics in any facility.

Until recently, no real mechanism for quantifying those replacement intervals - and the potential benefits of extending or shortening them - has existed.

But a new analysis tool, called SRVcalc, may prove to be a powerful way to do just that, with long reaching implications for how the industry implements generally accepted practices that have been on the books for years.

SRVcalc is a tool intended to statistically analyze post-mortem relief valve test data to refine the replacement interval of relief valves for a given installation. SRVcalc is the byproduct of a research project funded by ARF and overseen by the IIAR Research Committee. The principal investigator for this project was Dr. Frederick T. Elder of Frederick T. Elder and Associates, Madison, WI.

"Like all IIAR research projects, SRVcalc is intended to fill in the gaps in our knowledge base," said Bruce Nelson, IIAR Research Committee Chair and President of Colmac Coil Manufacturing Inc.

"Up to this point, we've really just depended on what is, essentially, a very general rule-of-thumb that specifies a five-year replacement interval regardless of facility, type of vessels, location or environment. SRVcalc gives contractors and end-users a way to acquire some good science to determine that frequency based on real test data from real valves in specific locations."

The ability to finally quantify replacement intervals could pay off for end users and any facility looking to focus on safety and efficiency, said IIAR President, Dave Rule. "The potential advantage for this tool is that the five-year interval may be too soon [for some facilities], the possibility of extension is different for everyone. This is good because it's a way to determine which direction an individual company might need to head. It might help you see opportunities to use a different grade of valve, or it may tell you you're right where you need to be."

"The status quo is always safety and the protection of vessels, it's just a matter of how you go about managing that system," said Rule. "It's a benefit to understand the capabilities of the equipment offered in the industry at this point."

Nevertheless, IIAR's Nelson stressed that SRVcalc is in no way an attempt to do away with the accepted five-year replacement interval, but rather it provides a foundation for those looking to apply the second requirement for determining replacement as laid out in IIAR Bulletin 110.

According to Bulletin 110, Guidelines for Start-up, Inspection and Maintenance of Ammonia Mechanical Refrigerating Systems, "pressure relief valves should be replaced or recertified in accordance with one of three options: 1) Every five years from the date of installation; 2) If an alternative to the prescriptive replacement interval, i.e. five years, can be developed based on documented in-service relief valve life for specific applications using industry accepted good practices of relief valve evaluation; or 3) [According to] the manufacturer's recommendations on replacement frequency."

"That second provision will be an attractive option for end-users, now that

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a way to conduct the kind of evaluation it specifies exists," said Nasser Karimzadeh, Department Manager for Mechanical and Refrigeration Engineering for Design Group Facility Solutions.

"Of course, the number one issue is safety, but the second issue here is cost," said Karimzadeh. "From an end-user's perspective, [replacing valves on a less-than optimal interval] presents a rather substantial cost. If that interval is too frequent, you're wasting money and taking away from other repair and maintenance functions. It's best to have the proper cycle for replacement."

That optimization of safety and efficiency are often the driving forces behind any effort to quantify a commonly used practice, and SRVcalc should be seen by IIAR's members as an attempt to further those goals, said Eric Smith, IIAR Vice President and Technical Director.

"This technique allows us to quantify replacement intervals for the first time in the ammonia refrigeration industry," he said. "Having the ability to finally drill down and get these specific measurements is valuable."

Smith added that the real value in using SRVcalc, beyond the primary emphasis on improving safety, exists in three different arenas: finding potential cost savings, assessing environmental conditions, and maintaining flexibility in meeting regulatory requirements.

First, finding cost savings in facilities or companies that replace large numbers of relief valves is an obvious benefit. "When it comes to replacement, there's expense for time, labor and documentation, and if you can extend intervals safely, then why wouldn't you want to do that?" he said.

Second, the tool gives users the ability to assess valve life in unique environments, such as those in an area close to the ocean, for example, where salt in the air can impact an operating environment.

Third, the tool allows users the ability to retain flexible decision making, while still meeting regulatory requirements. "This is a way to substantiate why a facility may be following the prescriptive five-year relief valve replacement interval," said Smith. "It allows facilities to pick their method and gives them flexibility in how they meet code and regulatory requirements."

In order to generate data on relief valves, SRVcalc relies on a two step process. First, valves at the end of a specified use-period must be tested as they come out of service. ARF funded the first phase of this research that entailed developing appropriate facilities and protocols for the post-mortem testing of relief valves. The IIAR Research Committee provided oversight of this project and Dr. Todd Jekel along with Professor Douglas Reindl both of the University of Wisconsin Madison's Industrial Refrigeration Consortium were the project's principal investigators.

"As valves come out of service, they are put on a bench test rig to see how they function," said Reindl. "Then, that data gets logged and input into statistical analysis software."

The statistical analysis, the second part of the tool, allows a user to arrange data based on equipment type and generates optimal intervals for replacement.

Because data sets can often be small as batches of valves come out of service slowly an appropriate statistical analysis methodology was needed to predict the service life-expectancy of relief.. For that, Dr. Elder – who is an adjunct professor at the University of Wisconsin, Madison, and president of Frederick T. Elder and Associates – turned to a kind of statistical modeling called the "Weibull Analysis."

"We needed to build a tool that could take into account and measure with accuracy the frailties of different environments and subsystems," said Elder. "SRVcalc deals with small data sets and can take into account low failure rates. It deals with a lot of issues we have when we're measuring the lifecycle of a valve, and generates accurate data over time." (Read more about the technology behind this process in the technical paper section that appears at the end of this issue of the Condenser).

As SRVcalc was developed, "what really became apparent is that you can't generalize with this type of data," said IIAR's Nelson. "This tool is intended for use by the specific end user in their specific facility. It makes measurements that depend on a range of unique variables, including climate, installation, etc. Relief valves exist in a variety of places, you can have them in a nice dry, clean engine room, or on a rooftop exposed to the elements. The analysis tool is intended to give a picture of relief valve life in local facilities."

While SRVcalc may prove to be a valuable tool for some in the coming years, the impact it has on how the industry views relief valve replacement intervals may be longer term, said IIAR's Smith. He added that if long term use of the tool is widespread enough, the industry may eventually have enough data to take another look at its five-year requirement, but that possibility is far off.

For now, SRVcalc simply exists as another engineering tool developed by the industry to help meet the unique needs of its members, said Nelson. "It's giving the industry a tool to determine in a defendable way, a method for potentially saving money by finding the optimal interval for safety relief valve replacements on a facility by facility basis." The IIAR Board of Directors is currently reviewing how it will distribute the tool, said Nelson, adding that SRVcalc will be made available to IIAR members sometime in the next twelve months. ■

IIAR Research Committee Completes Quantitative Risk Analysis Project

The International Institute of Ammonia Refrigeration recently completed a research study using quantitative risk analysis, or QRA, to evaluate the effectiveness of five methods for mitigating an ammonia release during an overpressure event.

Under the direction of the IIAR's board of directors, the intent of the study, called "Using Quantitative Risk Analysis to Evaluate Various Methods for Mitigating an Ammonia Release During an Overpressure Event," was to use QRA to calculate the relative risk of each method and to assign a cost to that risk.

"Prior to our research, this had never been done before," said Bruce Nelson, president of Colmac Coil Manufacturing, Inc. "The project provided a clear indication of the risk from each method, with the QRA serving as a template for members to use to evaluate the relative risk at their facility."

The situations studied included: direct ammonia charge into the atmosphere; ammonia absorption into a water tank; the discharge of ammonia through a scrubber system; burning discharged ammonia using a flare system; and the effects of an emergency pressure control system.

The study determined the impact of an ammonia release to a surrounding population and the associated damage to health cost. This health cost, in conjunction with the expected failure rate of a particular mitigation system, provided the cost impact of that specific system.

For the purposes of the study, a conservative assumption was made concerning the pressure relief of the vessel, so that the flow of ammonia through the pressure relief valve would continue at the rated condition for one hour, Nelson said.

The analysis involved use of the dispersion model SLAB (2012) that predicted downwind concentrations in the ammonia vapor plume. A typical industrial refrigeration facility using ammonia where the refrigeration load was 362 tons and the ammonia charge was 11,590 lbm was used as a model. The impact of an ammonia plume was assessed by determining the medical costs associated with exposure to the population.

The mitigation systems analyzed all reduced the consequences of an ammonia release to the surrounding population, but each method can now be more fully analyzed for risk and costs by individual facilities using the QRA, said Nelson.

"This is not one-size fits all," he added. "The study did not point to one method as being appropriate to use in all circumstances."

The study confirmed that each method carries different levels of risk, and the choice of method for a facility depends on a variety of factors, including their location. "For example, if a processing plant is in the middle of nowhere far away from a population center, the risk of ammonia by dispersion is tolerable," Nelson said.

A discharge to atmosphere, the simplest system, proved to be the most reliable because there are fewer components with the potential to fail. Conversely, a water diffusion tank has eight components that could fail and cause a release, while a scrubber system has 15 components and a flare system, the most complex of all, has 18.

"These mitigation methods are all still valid, and the project reinforced that," Nelson said. "But the most valuable result of this project was that it provided us with a scientific method to calculate relative risk in a way that gives guidance to end users regarding each mitigation method they might consider." ■

Presidential Working Group Recommends Policy Changes Impacting Chemical Facilities

iiar government RELATIONS

BY LOWELL RANDEL, IIAR GOVERNMENT RELATIONS DIRECTOR

In response to the tragic accident last year in West, Texas, President Obama issued Executive Order (EO) 13650, Improving Chemical Facility Safety and Security. The EO is intended to enhance the safety and security of chemical facilities and reduce risks associated with hazardous chemicals to facility workers and operators, communities, and responders.

The Executive Order directed federal departments and agencies to:

- Improve operational coordination with, and support to, state and local partners
- Enhance Federal agency coordination and information sharing
- Modernize policies, regulations, and standards
- Work with stakeholders to identify best practices

Since the signing of the EO, a working group of federal agencies led by the Department of Homeland Security (DHS), Occupational Safety and Health Administration (OSHA) and Environmental Protection Agency (EPA) have been working to implement the order and identify additional actions to improve chemical safety and security. Some of the potential policy changes could have a significant impact on the cold chain, particularly companies with over 10,000 pounds of ammonia subject to Process Safety Management (PSM) and the Risk Management Program (RMP).

For example, OSHA released a Request for Information seeking public comment on proposed changes to the PSM standard. IIAR partnered with the American Frozen Food Institute (AFFI), American Meat Institute (AMI), Global Cold Chain Alliance (GCCA) and the Refrigerating Engineers and Technicians Association (RETA) in communicating concerns about the proposals.

The EO also tasked the working group with providing a report to President Obama by the end of May 2014 highlighting the actions taken to date and future recommended actions. The report entitled Actions to Improve Chemical Facility Safety and Security – A Shared Commitment was released on June 6, 2014. The report highlights activities undertaken to improve chemical facility safety and security and provides a consolidated plan of actions to further minimize chemical facility safety and security risks.

The status report includes an analysis of existing regulatory programs to inform immediate actions as well as a consolidated Federal Action Plan of priority actions. The Federal Action Plan is organized by five thematic areas:

- Strengthen Community Planning and Preparedness
- Enhance Federal Operational Coordination
- Improve Data Management
- Modernize Policies and Regulation
- Incorporate Stakeholder Feedback and Develop Best Practices

Of the five thematic areas, the one with the greatest potential to impact companies in the cold chain is "Modernize Policies and Regulation." The report details a series of action items under this theme to change regulations including PSM and RMP. Below is a list of the actions of most interest and concern:

MODERNIZING OSHA'S PSM STANDARD TO IMPROVE SAFETY AND ENFORCEMENT

Building on the PSM Request for Information, OSHA plans to move forward with developing a proposed rule to modernize the PSM standard. Key actions recommended in the action plan include:

- Clarifying the PSM standard to incorporate lessons learned from enforcement, incident investigation, and advancements in industry practices, root cause analysis, process safety metrics, enhanced employee involvement, third-party audits, and emergency response practices.
- Adding substances or classes of substances to the PSM Appendix A List of Highly Hazardous Chemicals and providing more expedient methods for future updates.
- Expanding coverage and requirements for reactive chemical hazards, which have resulted in many incidents.
- Continuing harmonization with EPA's RMP regulation.
- Requiring analysis of safer technology and alternatives.
- Requiring coordination between chemical facilities and emergency responders to ensure that emergency responders know how to use chemical information to safely respond to accidental releases, possibly including exercises and drills.

EPA'S RISK MANAGEMENT PROGRAM (RMP)

Because of the close connection between PSM and RMP, the action plan proposes modernizing EPA's RMP regulations in a similar fashion to PSM. The action plan indicated that EPA would be publishing a Request for Information related to RMP.

On July 24, 2014, the Request for Information (RFI) entitled: Accidental Release Prevention Requirements: Risk Management Programs under the Clean Air Act, Section 112(r)(7) was released. Through the RFI, EPA is requesting public comment on potential changes to the Risk Management Program and is likely the first step towards rulemaking.

The RFI is divided into two main sections. The first section parallels

continued on page 14


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IIAR Builds Coalition to Comment on Proposed PSM Changes

many of the issues raised in the RFI for Process Safety Management. The second section addresses policies not included in the RFI for PSM.

ITEMS IN OSHA'S RFI RELEVANT TO EPA'S RMP REGULATION:

- Removing Certain Substances from the List or Raising their Threshold Quantity
- Lowering the Threshold Quantity for Substances Currently on the List
- Additional Risk Management Program Elements
- Define and Require Evaluation of Updates to Applicable Recognized and Generally Accepted Good Engineering Practices
- Extend Mechanical Integrity Requirements to Cover Any Safety-Critical Equipment
- Require Owners and Operators to Manage Organizational Changes
- Require Third-Party Compliance Audits
- Effects of OSHA PSM Coverage on RMP Applicability

ADDITIONAL ITEMS FOR WHICH EPA REQUESTS INFORMATION:

- Safer Technology and Alternatives Analysis – (Note: This is a potential pathway towards requiring the assessment and mandatory implementation of "inherently safer technologies".)
- Emergency Drills to Test a Source's Emergency Response Program or Plan
- Adding new requirements for automated detection and monitoring systems, or adding performance measures for facilities already using these systems.
- Additional Stationary Source Location Requirements
- Compliance with Emergency Response Program Requirements in Coordination with Local Responders
- Incident Investigation and Accident History Requirements
- Worst Case Release Scenario Quantity Requirements for Processes Involving Numerous Small Vessels Stored Together
- Public Disclosure of Information to Promote Regulatory Compliance and Improve Community Understanding of Chemical Risks
- Threshold Quantities and Off-site Consequence Analysis Endpoints for Regulated Substances Based on Acute Exposure Guideline Level Toxicity Values
- Program 3 NAICS Codes Based on RMP Accident History Data
- The "Safety Case" Regulatory Model - The "safety case" regulatory model66 is a framework for regulating high-risk industries where owners or operators of industrial facilities are required to demonstrate to the regulator that they have reduced risks to a level that is "as low as reasonably practicable", or ALARP.
- Streamlining RMP Requirements

IIAR is following a similar approach to the RMP RFI as it did for the PSM RFI. A task force has been formed to analyze EPA's proposed changes to RMP and develop a response. IIAR is also reaching out to likeminded partners to form a coalition around shared concerns related to the RMP RFI.

BUILDING A STRONGER CFATS PROGRAM

The action plan also includes items designed to strengthen the Chemical Facilities Anti-Terrorism Standards (CFATS) program. DHS plans to solicit public comment on an ANPRM on potential updates to the list of chemicals of interest (COI) and other aspects of the CFATS regulation. Specific activities include:

- Improve the methodology used to identify and assign risk tiers to high-risk chemical facilities.
- Coordinate chemical facility security activities and explore ways to increase harmonization among chemical facility security regulatory programs.
- Identify facilities that should have submitted a CFATS Top-Screen but failed to do so.
- Work with Congress to seek long-term CFATS authorization to ensure that an authority lapse does not occur and to provide regulated chemical facilities with the certainty they need as they consider making substantial capital investments in CFATS-related security measures.
- Work with Congress to pursue action to streamline the CFATS enforcement process to allow DHS, in extreme circumstances, to immediately issue orders to assess civil penalties or to close down a facility for violations, without having to first issue an order calling for correction of the violation.

DEVELOPING GUIDANCE AND OUTREACH PROGRAMS TO HELP INDUSTRY UNDERSTAND PROCESS SAFETY AND SECURITY REQUIREMENTS AND BEST PRACTICES

In addition to proposing regulatory changes, the action plan suggests the development of resources to help industry understand regulatory requirements and best practices. This would include guidance on EPA and OSHA process safety terminology, how to conduct root-cause analyses and assistance for small businesses. OSHA would consolidate best practices for process safety and metrics from OSHA Voluntary Protection Program (VPP) facilities. The order also proposes the development of a comprehensive regulatory fact sheet covering EPA, OSHA, and DHS programs, for State regulators, facilities, stakeholders, and other non-Working Group Federal agencies as well as a checklist of Federal Regulations that stakeholders can use to determine regulations applicable to their facilities.

Implementation of the Executive Order remains to be a high priority for the Obama Administration and the working group's report to the President highlights numerous regulatory changes that will be considered. Many of the changes to programs such as PSM and RMP have the potential to impact companies in the cold chain. IIAR will continue to monitor implementation and actively engage with agencies throughout the process. ■

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Avoiding That "Oh No" Moment

KEM RUSSELL

Having well thought out and properly used operating procedures is important, but having good plans and people in place in case something goes wrong can make a world of difference. Think back to your own past. Have you ever been doing something and all of a sudden you get this cold queasy feeling in the pit of your stomach and breakout in a cold sweat? Well here is one of those "oh no" moments and a great lesson learned.

This particular company put a lot of time and effort into developing good standard operating procedures, or SOP's, and in training and documenting training of all of their refrigeration operators. One of their SOP's addressed oil draining. In order to do the oil draining procedure, the person had to not only understand the procedure, but be trained under supervision then finally authorized to do the procedure.

In this particular procedure, the direction was that "two refrigeration operators" would be involved in any oil draining procedure. It also directed that the appropriate personal protective equipment would be worn. The PPE in this case includes a full face ammonia cartridge mask, chemical resistant gloves, and coveralls.

On the day in question, two refrigeration men were tasked with checking and draining any oil from several surge drums that served a refrigerated room. One man did the draining, while the other stood by ready to assist if needed. At the third surge drum, the refrigeration operator started unscrewing the steel plug from the oil drain hand valve. As he unscrewed the plug he started to hear something. That's when he got that cold queasy feeling. Two things happened almost instantly. First, the man thought, "Did I check that the hand valve was closed?" And second, the plug blew out spraying oil and a lot of ammonia out of the valve.

There may be locations where there is only one escape route. If so, develop a plan on what to do if an emergency happens so you can safely and quickly exit that location.

The surge drum had approximately 30 psig of pressure, and unfortunately the hand valve was far from closed. The pressure sent oil and ammonia splashing onto the operator, even covering his full face cartridge mask. Wearing that full face ammonia cartridge mask may have saved his life.

Even in the turmoil of the situation, the refrigeration operator who had just gotten hit with oil and ammonia made the effort to stop or slow the leak by trying to close the oil drain hand valve.

He got the valve about a turn from fully closed before he started to get a strong smell of ammonia through the mask ammonia cartridge, at which point he realized he had to get out of there!

The second person was standing where he had to pass by the release point to exit. He said that he could just see the shining of one of the overhead lights through the haze of the ammonia cloud, but that is how he knew where to go. Both men quickly exited the area and notified their supervisor.

For this incident and from the follow-up incident investigation, several lessons were learned for this company and all of their refrigeration personnel. First, always, always verify that the hand valve is fully closed before removing a plug.

This is not only for oil drain locations, but anywhere in an ammonia system where a valve can open directly to atmosphere. In this incident the oil draining person's attention was on something else and he skipped a very important part of the procedure.

He had checked the hand valve position on the previous surge drum, but not on the one that really counted.

The second lesson learned is always wear your PPE. This incident strongly reinforced the wearing of PPE for both men. Wearing PPE very likely saved the life of one, and possibly both of these men.

The third lesson here is to verify that there is an alternate escape route. In this case there was an alternate escape route, and both men thought they had checked it, but it was later found to be inoperative. There may be locations where there is only one escape route. If so, develop a plan on what to do if an emergency happens so you can safely and quickly exit that location.

Fortunately, both of these men had on sufficient PPE and were able to escape.

The fourth lesson was to identify any valve that is out of its normal position. If that procedure had been followed, this incident may never have happened.

The sixth lesson was, if possible, try to remove as much ammonia from the equipment, vessel, pipe, etc. before attempting to drain oil.

Finally, have contact phone and cell numbers readily available. Being able to quickly make a call had a big impact on what happened next in this incident.

After the call was made to the supervisor, the supervisor used the control system to electrically de-energize the zone, which closed the liquid feed solenoid and greatly limited the release.

The next call went to the Manager of the Refrigeration Department who quickly activated the company's ammonia response team, then began notifying the NRC, State, LEPC, and the Fire Department. While this was going on the man who had been hit with the ammonia was washed down with water. Due to the clothes they had on and the other PPE, neither of the men suffered any injuries.

The company's well trained ammonia response team quickly assembled and, following the Incident Command System, began to deal with the release. The Fire Department served only in a "standby" role since they did not have hazmat capability, but they had trained many times with the company and each was familiar with the others capabilities.

Zones were quickly established (Cold, Warm, Hot). Any employees in the affected area were evacuated, the area was blocked off to prevent others from entering, area ammonia monitoring began, and isolation valves to that section of the building were closed as an added precaution. When all was ready, and all response team members set (entry, backup, decon, medical, safety, etc.) the entry team prepared to go into the release location. Before the entry team went into the area, ventilation had been set in place so when the entry team reached the leak location, the area was clear of ammonia, and one turn of the oil drain valve ended the event.

Many important lessons about the oil draining procedure were learned here, but the response to this incident is one of the most valuable lessons learned. The event reinforced the prior emergency training efforts.

In the response to this emergency the employees knew what they were to do, and did it right. The Refrigeration Department Manager said he couldn't have been more pleased with the response of the ammonia team. The refrigeration operator's "oh no!" moment is a lesson that will not be forgotten by him. Hopefully others can learn from this experience and avoid a similar one. ■

SAFETY

Performing Mechanical Integrity Inspections of Air Coolers

BY JOE FAZZARI, P.E.

Owners should perform periodic mechanical integrity inspections on air coolers to ensure the continued reliability of the unit and to minimize the risk of an accidental ammonia release. This article lists some of the more common issues to look for when performing mechanical integrity inspections of a typical air cooler.

1. EXCESSIVE ICE OR MATERIAL BUILDUP

Inspect all air coolers for material buildup on the fins and drain pans. Dust and, or, packaging material fibers are common sources for this build up. Inspect the air coolers operating in areas below freezing for excessive ice buildup on the fins and drain pans. Excessive ice and material buildup could interfere with air flow and reduce the coil capacity. Excessive ice buildup between the bottom of the coil tubes and the drain pan could cause mechanical damage to the coil tubes and drain pan. Remember that hot gas defrosted air coolers commonly have an array of heating tubes attached to the drain pan. Any damage to these tubes or to the tubes in the coil core could result in an ammonia leak. Follow the manufacturer's guidelines for defrosting air coolers, which might include adjusting the number of defrosts and their duration. Adjustment of the defrost regulator pressure setting may also be needed to ensure complete defrosting. If adjustments to the defrost scheme do not prevent excessive ice buildup, contact the air cooler manufacturer, a contractor, or a consultant for further analysis.

2. CORROSION OF TUBES, FINS OR CONNECTIONS

Inspect the surface of the tubes, fins, and piping connections for signs of pitting or uneven discoloration. Also inspect any insulated pipes where the vapor barrier might be compromised. Excessive pitting could result in an ammonia leak if the pit continues through the wall thickness of the tube or pipe. Corrosion of the fin surfaces results in reduced refrigeration capacity, so it is important to also check these surfaces. Visually inspect all areas of the coil with a flashlight. For hard to reach areas, use a flexible, lighted bore scope. If possible, measure the depth of large pits with a micrometer depth gauge. Generally, any pit deep enough to measure is cause for concern and remedial action to stop the corrosion and repair the materials should be taken. Consider taking digital pictures of any corrosion in early stages for future comparison. Corrosion of tubes and fins can be prevented by only using cleaning chemicals that are suitable for the materials of construction. Many cleaning chemical suppliers and, or, your air cooler manufacturer will have recommendations regarding this. In some corrosive environments, a water rinse system can be utilized to keep contaminants from building up on tube and fin surfaces.

3. EXCEEDING MAXIMUM ALLOWABLE WORKING PRESSURE (MAWP)

Inspect the ends of the evaporator header pipes for signs of bulging. The largest diameter end cap is typically the first location that any signs of over-pressurization will be evident. Tubes or pipes that look misshapen are also signs of over-pressurization. Trapped liquid in an air cooler could expand and cause the internal pressure to exceed the MAWP. This could result in ruptured components and ammonia leaks. Hydraulic shocking, or vapor propelled liquid, is another internal force that could exceed the air cooler's MAWP and cause ammonia leaks.

Fig. 1

Ice accumulation in drain pan of hot gas defrosted air cooler

Fig. 2

Corroded air cooler tubes

Fig. 3

Bulged end cap on air cooler header

Prevention measures include using good piping practices per the IIAR Piping Handbook, keeping hot gas lines clear of liquid, and always allowing the defrost pressure to equalize before opening the suction stop valve.

4. FAN VIBRATION AND INTEGRITY

The fan assemblies on air coolers should be inspected annually, or per the manufacturer's recommendation for your specific air coolers. With the fans running, look and listen for any vibrating components. Typically, vibration in larger sheet metal panels will be the most noticeable. Keeping a safe distance from the fan, and with all guards in place, watch the fan in operation, looking for any vibration as it rotates. Listen for any sudden changes in noise levels or tones. For variable frequency controlled fans, check for vibration over the entire range of speeds. For multi-fan units, shutdown individual fans to localize the source of vibration. With the fan motors off and safely locked out, check the torque on the bolts securing the fan assembly to the motor shaft. Also check the torque on the bolts holding the fan motor to its mount.

Fig. 4

Typical air cooler axial fan assembly

Check with your air cooler manufacturer for proper bolt torque values. If left unchecked, loose fasteners in either the fan hub or the motor mount could result in a catastrophic failure such as mechanical damage to the air cooler tubes which could result in an ammonia leak.

5. REFRIGERANT DISTRIBUTION TUBE CONDITION

Some air coolers are equipped with refrigerant distributor devices that meter equal amounts of liquid and vapor refrigerant to each coil circuit. The distributors are commonly connected to each coil circuit by means of long, small diameter feed tubes, usually about ¼" in diameter. It is important to periodically check these feed tubes for signs of rubbing. This will typically show up as a flattened area on one or more distributor tubes. If not repaired, the rubbing could eventually wear through the tube wall, causing an ammonia leak. Visually inspect each tube paying close attention to those that are touching or close to touching. Contact the air cooler manufacturer or a refrigeration contractor to reorient the tubes, install wear sleeves, or replace the tubing.

Fig. 5

Typical distributor tube assembly

6. INTEGRITY OF HOUSING, UNIT SUPPORTS, AND PIPING SUPPORTS

The condition of the air cooler's housing and supports should be inspected annually. Visually inspect the unit housing and the hangers for cracks, missing or loose fasteners, and any signs of corrosion. Deteriorated supports could result in the unit falling from the mounting location, which could result in an ammonia leak. Also inspect piping supports near the air coolers. Typically, air coolers are not designed to support piping, control valves, or hand valves. Improperly supported piping could overstress the coil connections, resulting in a leak. Any unit and piping supports that show any signs of damage should be repaired or replaced immediately.

Fig. 6

Ceiling suspended air cooler

7. PROTECTION AGAINST TRAFFIC HAZARDS

Air coolers that are operating in areas of high fork truck traffic should have their protective barriers inspected annually. Visually check each barrier for evidence of damage due to fork trucks. Damaged barriers should be repaired or replaced. Traffic impacting an air cooler could cause mechanical damage and ammonia leaks. Prevention measures include

This article lists some of the more common issues to look for when performing mechanical integrity inspections of a typical air cooler.

Fig. 7

Floor mounted barriers

continued on page 21

adding additional protection, training lift operators to not hit the protective barriers or units, and adding warning and caution signs.

8. ELECTRICAL INTEGRITY

Electrical components mounted to air coolers should be inspected annually. Look for loose connectors or signs of overheating, such as black marks, melting of wire insulation, or cracks in wire insulation. Visually

Fig. 8

Infrared photo showing overheating wire

Operating air coolers below the minimum design temperature could result in material failures and rupture due to embrittlement at low temperatures.

inspect the electrical connectors and use an infrared camera to look for overheating components. Any electrical issues, if left uncorrected, could result in a fire. Contact a company electrician or an electrical contractor to either repair or replace defective equipment.

9. MISSING FAN GUARDS

The presence of and condition of fan guards should be inspected annually. In the absence of proper guarding, people could be injured or product could come into contact with moving fan blades. Visually inspect each air cooler to make sure that each fan is guarded and what condition each guard is in. Contact the equipment manufacturer to obtain replacement fan guards.

Fig. 9

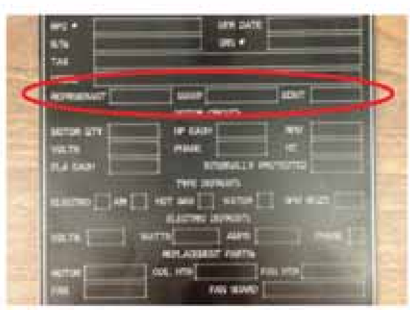
Air cooler with missing fan guards

10. DETERMINE SUITABILITY FOR OPERATING CONDITIONS

Air coolers should be inspected annually to determine that the unit is still being operated within the intended conditions. One way to verify this is to check the unit serial plate for the minimum and maximum design operating temperatures and pressures. Operating air coolers below the minimum design temperature could result in material failures and rupture due to embrittlement at low temperatures.

Fig. 10

Typical serial plate for an air cooler



This is especially true for air coolers constructed from some carbon steels and hot dip galvanized. Air coolers with aluminum or stainless steel tubes typically can operate safely at very low temperatures. Air coolers operating above design temperature could lead to over-pressurization and rupture, which could be possible during higher temperature cleaning processes. Contact the equipment manufacturer to verify design values and only operate equipment within recommended design parameters, or replace equipment operating outside of design.

Owners can be assured of continued reliability and the minimum risk of an accidental ammonia leak by performing these mechanical integrity inspections on air coolers in their facilities.

Owners can be assured of continued reliability and the minimum risk of an accidental ammonia leak by performing these mechanical integrity inspections on air coolers in their facilities. More information can be found in the following reference materials:

- Manufacturer's IOM's
- IIAR Bulletin No. 109
- Standard IIAR-2
- ASME B31.5
- ASHRAE Standard 15
- ASHRAE Refrigeration Handbook

IIAR'S NINTH INDUSTRIAL REFRIGERATION SEMINAR HIGHLIGHTS GROWTH IN LATIN AMERICA

The International Institute of Ammonia Refrigeration held its ninth Industrial Refrigeration Seminar in Latin America in Chile last month, an event that marked the organization's increasing involvement in education and safety advocacy in the region.

IIAR leaders said the seminar attracted a record number of attendees from ten different Latin American countries, reflecting a growing level of participation of IIAR members throughout Latin America.

The seminar was produced by IIAR with the support of the Chilean Chamber of Refrigeration.

Seminar participants said they attended the August 21-22 meeting in Santiago, Chile, to take advantage of the education and networking opportunities in a region that is seeing an increased focus on industrial refrigeration.

In South America, IIAR and the Chilean Chamber of Refrigeration and Air Conditioning provide technical resources that serve to inform a growing industry, especially through events like the recent seminar, said Cristian Cuadros, Deputy Manager of Industrial Processes for *Compañía de Cervecerías Unidas*, or United Breweries Company.

"In general, our group is always seeking continuous improvement and looking for the best existing practices in the market and specifically from this seminar," he said. "We seek the best techniques to perform our job well, and our main objective is to take care of people, safety and then preserve quality. We have to make sure our equipment meets the standards required for [safety and] the quality we need in our products."

Cuadros added that industrial refrigeration seminars in Latin America are instrumental in helping his company meet that need.

The events "help us a lot because there are many instances where we learn and gain a better understanding of this knowledge and then we can share it within our organization," he said. "That is my main goal . . . to take the best practices from other parts of the world, and replicate and carry them out. Our operations are based on continuous improvement, so we are always searching for the best. If a standard says to move in a particular direction, then that is the direction we go; and if a standard doesn't exist, we look for the best guidance like what is presented here [at the seminar]."

The Chilean Chamber of Refrigeration and Air Conditioning operates an extensive education and advocacy program in the region, producing the Expo Frio Calor Chile trade show, the second largest event of its kind in the region after Brazil's FEBRAVA show.

The organization is collaborating on the development of the country's first ammonia-specific regulation, formed a certification program and is working with other parties in Chile to produce a best practices manual for Chile´s ammonia refrigeration industry, said Alejandro Requesens, President of the Chilean Chamber of Refrigeration and Air Conditioning, in his inaugural address to seminar participants.

The regulation, which the Chamber is currently working with Chile's Health Ministry and local IIAR members to develop, will be the first regulation in the country to address ammonia refrigeration specifically.

Collaboration between govern-

ment and private industry to develop the regulation was an initiative that arose from the concern generated by a series of ammonia incidents in the O'Higgins region of Chile, an important agribusiness center, said Carolina de la Fuente, a representative of the Department of Occupational Health of Chile's Health Ministry.

During a presentation at the IIAR seminar, De la Fuente said the intent of Chile's regulation is to boost incident prevention, describing it as a tool that will allow companies to control the risks associated with ammonia refrigeration systems.

De la Fuente estimated that work on the regulation is now 70 percent complete and said she expects it to conclude at the end of this year, allowing the regulation to enter into force in 2015 with an implementation program taking effect prior to enforcement.

While the development of the regulation is one, very visible milestone, it is part of a larger focus in Chile on ammonia and other natural refrigerants, said Peter Yufer, a member of the Chilean Chamber of Refrigeration and Air Conditioning's board of directors.

He added that the cooperation of the public and private sectors on the development of the best practices manual for ammonia refrigeration paved the way for further cooperation in the development of the regulation and certification program.

According to Yufer, who coordinated the working groups involved in developing the manual, the project has already had an impact in Chile, establishing a good working relationship between the Chilean government and private sector representatives of the ammonia refrigeration industry. IIAR members Patrick Fossey of AMRISA and Giorgio Magnani of Intercal played key roles in the project, and were also integrally involved in the organization of the recent IIAR seminar, said Yufer.

Developing that best practices manual – and pursuing other training and regulatory activities – will have a big impact on the growth of the industrial refrigeration industry in Chile, he said.

With the manual, "We are mainly concerned with finishing the work we began two and a half years ago which only aims to raise the safety standards for the people in Chile. We hope this can serve as an example [to other countries in Latin America] whether as a motivation to do something similar, or copy what we're doing. This is definitely a source of pride for us."

Yufer added that the Chamber is open to collaborating with other countries that are pursuing the same safety and efficiency objectives.

"In everything we have developed, we have received support and assistance from outside; for example, IIAR has provided us with unconditional support. We know that in matters of safety and development, no one has the absolute truth. We all contribute a grain of sand, and as we were helped, we should help too. This is a moral obligation."

Beyond updates on regulatory and industry activities in the region, IIAR's seminar was also heavily focused on delivering technical information in a format that mirrored IIAR's annual conference and exhibition.

This year's seminar was the first to offer the same technical program in two separate rooms, allowing for more interaction between speakers and attendees, said IIAR International Programs Director, Chris Combs.

The technical presentations delivered at the seminar included two CO_2 related topics, addressing the growing interest of CO_2 refrigeration technologies in the region. The program also included a special plenary presentation on CO_2 in Industrial Refrigeration Systems by Eurammon Chair Monika Witt. A presentation on CO_2 brine for low temperature chambers followed.

Other technical presentations covered defrost procedures as outlined in Chile's best practices manual, pipe sizing and evaporator certification.

Speakers from the three valve manufactures also participated in the seminar to deliver a revised version of their 100-minute valve maintenance workshop, first presented at the IIAR Industrial Refrigeration Seminar in Costa Rica in 2013.

"We're excited to be a part of the industry in Chile, and make the expertise of our members and our organization available wherever possible," said Combs. "Industrial refrigeration is growing in this region, and the benefits of collaboration have never been more visible." ■

IIAR SPECIAL ANNOUNCEMENT

IIAR Issues Call for Technical Papers, Announces New Production Schedule

The International Institute for Ammonia Refrigeration issued a "call for papers," in preparation for its 2016 IIAR Industrial Refrigeration Conference & Exhibition and beyond.

IIAR implemented a new timetable for the development of technical papers, which will now begin about 18 months prior to each annual conference. The change is meant to provide authors more time to develop and produce technical papers, as well as provide ample time for peer reviews, editorial, and presentation efforts.

Technical papers for the 2015 conference have been selected, but selection and development for conference years 2016 and forward is now taking place.

IIAR is currently requesting proposals for technical papers, including Spanish-language technical papers. Abstracts that address any topic related to ammonia refrigeration are invited. However, papers that address specific topics will receive preferential consideration.

Specific topics of interest to IIAR include:

- DX and/or Low Charge Ammonia Case Studies
- Oil Management in CO2 Systems
- Hot Gas Defrost Costs
- Parameters Affecting Total Cost of Defrosting
- Economic Analysis of Desiccant Dehumidifiers in the Anteroom
- Energy Consumption of Various Arrangements of Evaporator Control Valve Groups
- Pipe and Vessel Inspection Criteria
- Establishing Communication with Fire Service
- Requirements of Emergency Action vs. Emergency Response
- Developing Confidence in Team Training for Emergency Events
- Verifying Adequacy of Training.
- Management: What to Look for During a Plant Walk-Through
- Codes and Regulations from a Global Perspective (NH3 and other refrigerants).
- Best Practices Managing OSHA and NEP Inspections
- US Government Regulatory Strategy and Relationships
- Regulatory Considerations for Small Charge Systems
- Future Refrigerant Choices
- Alternate Ventilation Design
- Ammonia Equipment Outside the Machinery Room
- Machinery Room Design
- System Contaminant Removal (purging, non-condensables, and water)
- Refrigerated Air Make-up Units (standards, safety and risk analysis)
- Comparison of Relief Valves, Rupture Discs, and a combination thereof
- Changes in IIAR-2
- Mitigation Methods for Ammonia Releases
- Trans critical CO2 clarifying ASHRAE 15 9.2.6 language
- Review of Compliance Inspectors Check List Items

Technical papers should explore technical or regulatory topics that are substantiated by original research and development with documented references. Case studies should describe actual situations where actions, testing, or data accumulation are used to prove or demonstrate the outcome of applied methods, and could be reasonably applied to other similar situations. Promotion of products or companies or any other form of commercialism is prohibited.

The IIAR recognizes that new technologies are often offered by only one or a few companies. In these cases, it might be obvious that a method or technology is unique to a company. However, authors must strive to describe the method or technology based on a neutral analysis.

The technical papers are a central part of the Institute's annual meetings, representing a vital exchange of information within the field and serving as a forum for technical experts, engineers and operations managers as they address important issues within the industry.

Please submit abstracts along with author name and contact information online via the IIAR website annual conference page, or via email, to Eric Smith, IIAR Vice President and Technical Director, email: eric.smith@iiar.org.

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2015 IIAR Conference to Feature Navy SEAL Keynote

MARK STENCEL, IIAR CONFERENCE CHAIR

As we move into the fall season, thoughts of IIAR's annual conference in March seem almost premature but the IIAR staff is already putting the final touches on preparations for our 2015 conference in San Diego, and there are many exciting new features to announce.

To begin, the facility hosting the event, the Hilton San Diego Bayfront, benefits from the combination of very professional staffing and an outstanding location. Positioned right on the San Diego bay, it is just an easy walk from the Hilton to Petco Park, home of the San Diego Padres and to the Gaslamp Quarter, San Diego's historic entertainment and dining district.

The Gaslamp Quarter is a sixteen block area that is home to more than 100 restaurants and is the location for more than 70 shops and boutiques. Rich in history, there are more than 90 Victorian era buildings in the Quarter and it is reported that Wyatt Earp once ran four different saloons and gambling halls there. Today, the area bustles with activity day and night.

At the Hilton, our meeting rooms are large and contemporary as this modern facility opened in 2008. Public areas in and around the hotel are attractive and spacious, providing ample opportunity for all of those important side meetings within our meeting.

When the conference opens, the keynote speaker will be Rear Admiral Ray Smith (Ret.), former Commander of the Navy SEAL Force. As the Naval Special Warfare Training Center, where Navy SEAL training is conducted, is located minutes from the Hilton we are fortunate to have been able to arrange for this inspiring and accomplished speaker. Admiral Smith served as a Navy SEAL for almost 39 years and served as Commander for the 2300 man SEAL force for a four-year tenure, leading them through over 200 missions in Operation Desert Storm without incurring a single casualty. His talk to us, focusing on leadership and applying the lessons learned from the elite SEAL teams to the industrial refrigeration business is certain to be a conference highlight.

Additionally, Admiral Smith will be leading a privileged few attendees through a SEAL officer training drill combining both physical and mental challenges in a common exercise.

In San Diego, we will also be leveraging our location to produce a unique and memorable evening event. In lieu of the more formal banquet, we're planning to have a fun night out at the ballpark. One week prior to opening day, IIAR will be taking over Petco Park with a multi-level party. Certainly there will be plenty of food and beverages for our members, but there will also be great opportunities at this venue for some truly special and memorable IIAR moments, details of which we will be unveiling shortly.

And most importantly, we've arranged for a most productive schedule of high caliber papers and workshops. The engineering and operational insights that the IIAR conference is renowned for are certain to be on display through the excellent array of papers that our members have voluntarily produced.

Given the international nature of our membership and the proximity of this venue to our Latin American colleagues, we are arranging for all of our English language presentations to have an available simultaneous translation to Spanish and for all of our non-English language presentations to feature a simultaneous translation to English. This effort to expand the shared body of knowledge amongst our international community reflects IIAR's desire to share our knowledge of best practices to the enhancement of safe and efficient operation of refrigeration systems everywhere.

Finally, we are structuring the framework for a four-hour engineering training session for CO2 refrigeration systems. This in-depth program will benefit from the commitments to participation already made from industry leaders to share their unique knowledge on a variety of CO2 system designs. Slated for the Sunday afternoon of the conference, we anticipate strong attendance and real value to be derived from participation.

We are fortunate to have our industrial refrigeration community understand the value of our annual conference, to have them participate so willingly and to have them contribute so meaningfully. The IIAR team is already hard at work to ensure that we provide a forum that lives up to these commitments. ■

ENERGY EFFICIENCY

Small Leaks Lead to Big Costs

When it comes to energy efficiency, the dollars are in the details. And those details can be easily overlooked, especially when multiple small system leaks start to add up in a large facility.

System leaks of any kind can represent small efficiency gaps that can place a big drain on efficiency. An individual leak might not seem overly costly, but taken as a whole they can add up quickly.

Two words should be on the lips of every facility owner when it comes to saving money in operating costs: efficiency and implementation.

Keith Nienhaus, project manager at Hixon Architecture, Engineering, Interiors, recommended a variety of energy-savings costs during a recent webinar hosted by Food Engineering Magazine entitled “Saving Energy Without a Capitol Investment.”

Even a microscopic 1/32-inch pinhole leak can cost $150 per year, which doesn’t sound like much unless you consider there could be dozens of such leaks in a facility.

One of his suggestions was to search for those money-draining leaks, which can appear throughout the facility on a number of systems. “It can be due to [many] factors,” he said. “Pinhole leaks, excessive bleed off, faulty solenoids [not closing completely] or even poorly seated flange connections.”

And those kinds of small leaks are a certain way to bleed money. Even a microscopic 1/32-inch pinhole leak can cost $150 per year, which doesn’t sound like much unless you consider there could be dozens of such leaks in a facility. Steam leaks, most commonly found with steam traps, waste approximately $1,500 per year for each leaking steam trap. A water leak will drain up to two gallons per minute, which translates into 130,000 gallons in 60 days.

“If leaks go unchecked, they can really grow on you,” Neinhaus said. “If the leak is even bigger, say a solenoid valve that’s not closing, that cost can really climb.”

Compressed air leaks should also be regularly monitored, Neinhaus added. He pointed out that the average facility has up to five percent of its compressed air usage coming from leaks in the system. The issue is especially costly on weekends when production is low, yet leaks cause air compressors to work overtime in order to maintain system pressure.

Neinhaus said it’s important to pay special attention to water leaks. Water leaks are particularly costly, because in addition to paying for the cost of incoming water, a facility is also being hit with the expense for wastewater, he said. Compounding the problem, water that leaks onto a hot water system will waste all the energy used to heat the water.

The implementation of a maintenance and repair program for system leaks is critical for all utility systems. Neinhaus suggests regularly monitoring all piping valves and equipment. Because large facilities include so many systems, that task can seem overwhelming. But Neinhaus said, “It’s important to stay on top of it. It should be done on a routine basis, because you probably are not going to get through everything in one day.”

He points out that one facility traced down every foot of pipe and inspected every piece of equipment. The result of their due diligence was to reduce leaks to five percent of system capacity. “Now the trick is to make sure to remain at that level,” Neinhaus said. “It should be an ongoing effort. Once you fix all the leaks, if you start ignoring everything, [they] will probably resurface.”

Another important step toward reducing costs is through the maintenance and repair of insulation. All hot and cold piping, valves, equipment and ancillary components should be properly insulated and regularly monitored for damage. Damaged insulation allows moisture into the system, which will spread.

Each 100-foot section of pipe not insulated means $1,500 per year in heat loss. “Just because a pipe is still able to run the system doesn’t mean you should ignore damage to the insulation,” Neinhaus said.

Neinhaus recommends insulating new piping when installed and also insulating long runs of existing piping if needed. “That requires additional capitol but the payback is relatively short,” he said.

For more generalized leaks, there are a number of obvious ways to save money and become more efficient. One of the easiest is by checking that doors fit tightly and are appropriately sealed. That includes overhead doors, sliding doors and all entryways to coolers and freezers.

Dock doors are the first line of defense for keeping ambient air from infiltrating the facility, he said. Poor seals will cause extra load on the refrigeration system. It’s also important to caulk and seal any gaps in the building envelope, especially at pipe and conduit penetrations.

Finally, a clean system is a happy system. Dirty equipment lowers efficiency, mainly via buildup that reduces the amount of air flow through the condenser. “A regular schedule of system maintenance and cleaning will improve your bottom line,” Neinhaus said. ■

DHS Looks to Increased Collaboration with Ammonia Refrigeration Industry

Changes could be coming to the Chemical Facility Anti-Terrorism Standards, or CFATS, program run by the Department of Homeland Security, which could mean the agency will issue revised regulations and seek increased collaboration within the ammonia refrigeration industry.

In response to President Obama's executive order requesting improved safety and security at chemical facilities, the DHS issued in August an advance notice of proposed rulemaking for CFATS, which was created seven years ago.

> **"I encourage IIAR and its membership to take a look at the advance notice and think about how CFATS regulations can be enhanced."**

For the ammonia refrigeration industry, this could result in changes in regulatory approach and risk-based standards, along with new guidelines for perimeter security, cyber security, training, and even the thresholds and concentration of "chemicals of interest" that trigger regulation.

"It's the right time to build the next generation of CFATS regulation," said David Wulf, DHS Director of the Infrastructure Security Compliance Division (ISCD) within the Office of Infrastructure Protection. "I encourage IIAR and its membership to take a look at the advance notice and think about how CFATS regulations can be enhanced. Can the approach for [site security plan] approval be streamlined? Do we list the right chemicals? Should threshold quantities be adjusted? There will be plenty of opportunity for dialogue for our stake-holders."

For its latest notice of proposed rulemaking, the DHS will hold a series of "listening sessions" and webinars across the country, after which a formal notice of rule-making will be issued, followed by another period for feedback.

One initiative DHS is currently working to implement is designed to simplify the process of approval for a site security plan for companies with multiple facilities. The new approach was outlined at the recent Chemical Sector Security Summit and then discussed with the Chemical Sector Coordinating Council, an organization comprised of representatives from across the chemical industry, including IIAR that was formed to foster dialogue between the agency and the chemical industry.

Under the plan for streamlining site security for companies with multiple facilities, a corporate point of contact from DHS's compliance branch would be assigned to work on a one-on-one basis with an individual company. Looking at security-related policies that may apply across multiple facilities will streamline the review, inspection and site security plan approval process. The resulting plan would extend to all facilities that a company might manage.

"IIAR members with multiple facilities regulated under CFATS might want to consider participating in this. Inspections will go more quickly because policies that are applicable across the company will have essentially been pre-reviewed," Wulf said. "Having a point of contact and developing a plan that makes sense given the company's footprint, leads to more efficiency and allows facilities to reach approval more quickly."

Wulf said the DHS will also continue to focus on an outreach program to provide education on the requirements outlined in CFATS by talking directly to facilities, speaking to industry associations at the national and state level and working closely with state regulatory agencies.

He added that the CFATS program benefits the industry because of its "non-prescriptive nature."

"Industry members and facilities are able to tailor their security measures to their specific facility and business needs," he said.

Since its creation, the CFATS program has been authorized on a yearly basis, but there are signs that could soon change. The House of Representatives recently passed the CFATS Authorization and Accountability Act, which would provide long-term authorization for the program. In August, the Senate Homeland Security and Governmental Affairs Committee passed out-of-committee a bill that would extend authorization for four years. If the bill passes through both houses of Congress, it will reach the president's desk before the current session of Congress ends this fall.

"Our focus [with CFATS] is to get to the next generation of regulation, to get the word out about the program to ensure that all chemical facilities that should be reporting information to DHS are in fact doing that, and for the chemical industry to continue providing us feedback on ways we can enhance the program" Wulf said. ■

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IIAR Takes on Optimum Pipe Sizing Research Project

A new research project, recently implemented by the International Institute of Ammonia Refrigeration, will revisit the economic sizing methodology the industry uses to determine optimum pipe sizing.

The project, expected to be completed in the next year, will provide a computer tool that will allow end users to determine optimum pipe sizing based on input data that includes the initial cost of a piping system, energy cost, life expectancy and refrigeration system operating efficiency.

The concept of economic pipe sizing was introduced to the ammonia refrigeration industry in 1984 by Bill Richards, one of the founding members of IIAR. Richards initially established the capital cost of piping by looking at diameter and length, and provided corrective factors for piping systems with varied costs relative to a baseline value, while also making adjustments for energy costs and hours of usage.

"This project is intended as an update of Richards' methods," said Bruce Nelson, IIAR Research Committee Chair and President of Colmac Coil Manufacturing, Inc. "It is a balancing of the initial cost for a facility with the operating costs."

For example, a facility could use a small pipe that is cheap to install but has a high pressure drop, so operating costs are higher, or they might go to a large pipe with low pressure drops that is more expensive to install but has lower operating costs.

"This computer tool will help facilities make the decision on how much to spend initially and what the return will be on that investment," said Nelson.

"The funding from ARF and the commitment of our industry is making these types of research projects possible. We have a very active research committee with some of the best and the brightest in the refrigeration industry. Thanks to them, we are able to identify and conduct this research, generating valuable information for our members and our industry."

In the years following Richards' initial analysis, the cost of electricity for industrial customers has remained flat, but expenses for pipe, labor, fittings and insulation systems has risen dramatically.

And the sizing criterion for portions of piping systems – such as two-phase vertical risers – is not based on economics. Instead, it is dictated by the need to ensure superficial velocity during operation to maintain a consistent level of liquid, said Nelson.

In addition, piping in today's industrial ammonia refrigeration systems are generally in service beyond the 15 years that Richards assumed, and his analysis did not include other key elements of capital costs such as exterior pipe preparation, valves, insulation systems and pipe support infrastructure. It also did not differentiate labor and material costs and quality assurance.

IIAR's Nelson said the project is intended to deliver recommended pipe sizing tables in the IIAR Piping Handbook that are updated and expanded to account for these new variables.

Under the project, researchers will evaluate and document economic sizing bases for a number of industrial refrigeration piping subsystems, including vapor-only piping, suction piping, overfeed return piping and liquid-only piping, he added.

Initially, Richards assumed piping capital cost in proportion to pipe size. The new project will use current piping system cost data to test this assumption, including materials and labor. The capital cost analysis will also consider specialty piping materials that are commonly used for low temperature piping systems. Stainless steel piping, currently popular among end-users and contractors, will also be studied.

"The funding from ARF and the commitment of our industry is making these types of research projects possible," Nelson said. "We have a very active research committee with some of the best and the brightest in the refrigeration industry. Thanks to them, we are able to identify and conduct this research, generating valuable information for our members and our industry." ■

Chile´s Ammonia Sector: Leading the Way on Regulation and Certification in Latin America

CHRIS COMBS, IIAR INTERNATIONAL PROGRAMS DIRECTOR

In November 2012, this column discussed developments in Chile´s Ammonia Refrigeration sector including the public-private initiative to create a Best Practices Manual for the local Ammonia Refrigeration Industry and the potential for cooperation between IIAR and the Chilean Chamber of Refrigeration and Air Conditioning. Since then, a number of important developments have occurred. First, IIAR and the Chilean Chamber have formed an alliance leading to cooperation in areas including the organization of IIAR's recent Industrial Refrigeration Seminar in Chile (see article "IIAR's Ninth Industrial Refrigeration Seminar Highlights Growth in Latin America" for more details).

Second, the Chilean working group that began developing the Best Practices Manual is now preparing the chapters for a public review. In addition, two other important initiatives are now underway in Chile. These include the development of a new regulation and a certification program, both specific to ammonia refrigeration.

The principal objective of the regulation, as with the Best Practices Manual, is to reduce the number of accidents in Chile's ammonia refrigeration industry.

Now that the core chapters of the manual are complete, finalizing the appendices and carrying out a public review are the remaining steps before the expected publication of the document in early 2015. According to Peter Yufer, the Chilean Chamber of Refrigeration and Air Conditioning board member who coordinated the working groups involved in developing the Best Practices Manual, the development of the manual has already had an important impact in Chile by establishing a good working relationship between the Chilean government and private sector representatives of the ammonia refrigeration industry. The cooperation of the public and private sectors on the development of the manual has paved the way for further cooperation in the development of the regulation and certification program mentioned above. Furthermore, given the inquiries received from other Latin American countries about how this project developed, the initiative may have an impact outside of Chile.

The regulation initiative emerged in 2013 from the working group developing the Best Practices Manual. Work on the regulation officially began in March of this year with a new working group convened by the Chilean Government's Health Ministry in March of this year. Representatives from the Health Ministry's Department of Occupational Health lead the working group. The private sector is represented by the Chilean Chamber of Refrigeration and Air-conditioning. Three other food and export industry associations were invited to participate but they excused themselves because of the lack of personnel qualified in ammonia refrigeration technology.

The principal objective of the regulation, as with the Good Practices Manual, is to reduce the number of accidents in Chile's ammonia refrigeration industry. Such incidents had become a big concern in Chile prior to the development of the manual. Current regulations cover hygiene and worker safety but fail to address matters specific to ammonia refrigeration. The approach to achieving this goal centers on requiring a minimum level of training for all those involved in the sector.

The contents of the developing regulation are largely based on the Best Practices Manual. Besides the training requirements outlined above, the first section covers terminology used in the regulation and the general requirements for companies that have an ammonia refrigeration system including:

- Risk identification and evaluation
- Preventative maintenance program
- Safe work procedures
- Training program
- Standard plant maintenance procedures
- Emergency plan

The remaining sections of the regulation cover: II. General Design (plant, machine room, drawings and symbols), III. Installation, IV. Operation, V. Maintenance and VI. Inspections and Fines. Peter Yufer estimates that work on the regulation is now 70 percent complete and expects it to conclude at the end of this year, allowing the regulation to enter into force in 2015.

As for the development of the certification program, the Chilean Chamber of Refrigeration and Air Conditioning established the FRIOCALOR Center for Evaluation and Certification of Labor Competencies in April 2013 to evaluate and certify job skills and knowledge of workers in the HVAC&R sector. Currently the center evaluates and certifies for four labor competency profiles for installers and maintainers of commercial refrigeration systems, industrial refrigeration systems, commercial air conditioning systems and industrial air conditioning systems. For 2015, they plan to add two additional profiles:

1. Installer and maintainer of domestic heating systems
2. Operator of ammonia refrigeration systems

Each profile is a set of knowledge, skills and aptitudes that workers should have and utilize to carry out their work successfully. The FRIOCALOR Center grants official certificates and credentials to those who pass knowledge based and practical examinations within the profiles they pursue. The certification demonstrates that the individual has demonstrated the experience and knowledge required by the industry to do high quality work. Furthermore, it carries the recognition of the Chamber of Refrigeration, *ChileValora*, and the Ministry of Labor and Social Security.

ChileValora (the National Labor Competencies Certification System Commission) is the governmental entity that provides accreditation to the certifying bodies in Chile like the Chamber's FRIOCALOR Center and to their profiles including the ammonia refrigeration systems operator profile that the center aims to offer starting in 2015.

According to Claudia Cousiño of the Chilean Chamber of Refrigeration, the FRIOCALOR Center must meet a number of requirements set by *ChileValora* to offer a new profile. First, the Center must have an evaluator qualified in both the subject area and *ChileValora*'s evaluation methods. Second, each center must have the administrative and technical infrastructure for the profile. In this case, the Chamber provides the administrative support; the technical infrastructure for certifying ammonia industrial refrigeration operators will be obtained through an arrangement with a company from the sector that has adequate facilities for this purpose. The third requirement is that the center pay a fee to the certification commission. Lastly, the center must develop the new profile and the corresponding evaluation instruments. ■

Testing High Pressure Cutouts

The issue of how to test high pressure cutouts in a refrigeration system can be a contentious one. And although there is no simple solution, there are many guidelines that offer direction.

The Mechanical Code requires that every system have a cutout, but ASHRAE 15, considered the industry standard, forbids a shutoff valve between the source of the pressure and a shutoff switch. Meanwhile, IIAR-5 standards provide a clear definition for how to test a shutoff switch.

“IIAR-5 says that you close the discharge valve and you let it trip,” said Joe Pillis of Johnson Controls. The IIAR-5 standard reads as follows: A high pressure cutout should be tested and calibrated as required, plus discharge pressure must be increased slowly until the trained start-up technician can confirm that the cutout operates at the required setting. If the high pressure exceeds the cutout set point at which it is intended to operate, the compressor shall be manually stopped. It is unacceptable to adjust the high pressure cutout set point for testing purposes.”

“The margin between the high pressure cutout and the safety relief valve setting is important,” Pillis said. “The IIAR has taken a bold step in saying this is the way to do this.”

Whether the IIAR-5 standard is good or bad depends on your point of view, added Pillis. “The good thing is that you know it works,” he said. “The bad thing is that you must do it very carefully. There is an issue of how much margin you have between your high pressure cutout setting and the point where your relief valves may start to leak. If you’re playing around with the discharge stop valve and the pressure is rising, you need to have another pressure measurement checking that your transducer is reading accurately and that your switch is set accurately.”

“So you’re watching the gauge and the readout, bringing up the pressure, and if it doesn’t trip you don’t have long to get that stop valve back open before you have an ammonia release,” he said. “It’s a bit delicate because you may not have a lot of margin between your high pressure cutout level and your safety relief valve setting.”

There are alternative methods for testing a switch, but each has a downside, according to Pillis.

One alternative is to remove the transducer, depressurize the package and use a nitrogen bottle with a pressure measurement device. A bench calibration can then be performed by slowly increasing the pressure with nitrogen and watching the safety trip electronically on the panel.

“This gets around ASHRAE 15, but not IIAR-5,” Pillis says.

The downside is the complexity of the method. The refrigerant must be removed from the package, isolated and pumped out. The transducer must also be removed, yet left wired to the panel. After applying nitrogen pressure and watching it trip, the transducer must be hooked back up, and the package evacuated and recharged with refrigerant.

“There are a lot of moving parts,” Pillis says. “You’ve got to have enough flexibility in your wire so you’re able to keep the transducer wired while using the nitrogen bottle.”

A second alternative is to install an additional high pressure cutout with a shutoff valve below it. The second cutout can be locked and tagged out. It can then be tested with a nitrogen bottle to make sure it trips and then locked open.

“The problem is it doesn’t meet ASHRAE safety requirements,” Pillis says. “Plus, although you might be comfortable that it will trip by testing the parallel cutout, you haven’t tested the actual one.”

The questions surrounding the methods of testing high pressure cutouts can become hot topics, because if the procedure is not done correctly, it can result in an ammonia release. “It has happened that a high pressure cutout was not set correctly and there has been a reportable release. Nobody wants that,” Pillis said. “So that’s where the concern comes in. How do we make sure the cutout is set correctly and in compliance with codes?”

Pillis suggested an acceptable alternative that would require modification of the ASHRAE 15 standard.

“A safer way would be to allow the shutoff valve to be between the pressure source and the high pressure cutout,” he said. “But it would have to be locked out and tagged out with administrative controls that guarantee that it’s operating correctly when the compressor is in operation.” ■

“If you’re playing around with the discharge stop valve and the pressure is rising, you need to have another pressure measurement checking that your transducer is reading accurately and that your switch is set accurately.”

Thermosyphon Oil Coolers

BY ERIC SMITH, P.E., LEED AP, IIAR VICE PRESIDENT AND TECHNICAL DIRECTOR

Thermosyphon oil coolers for compressors have been designed in several ways. It has been a common design for the oil to be circulated through the "shell side" of a shell and tube heat exchanger, while ammonia is circulated through the tube side. These oil coolers are typically ASME pressure vessels and bear an ASME stamp. When shut off valves for the oil cooler are fitted, thus enabling isolation from the compressor package oil separator, they must also be fitted with pressure relief valves.

It might be presumed that a hydrostatic relief valve would serve as adequate protection. However, the shell might be full of oil, or it might be full of ammonia vapor or it could be a combination of both. In some cases it could even contain some liquid ammonia. But because it is an ASME vessel, the ASME Boiler and Pressure Vessel Code, IIAR 2 and ASHRAE 15 all require a vapor relief valve in the event of a fire. So the issue of concern is how to handle both the compliance for vapor relief and the more likely scenario of hydrostatic relief of fluid. The following outlines a few ways to address this situation.

When this design was prevalent, one compressor manufacturer would generally use a "dual stamped" relief valve, rated for vapor and liquid relief. This manufacturer coordinated with a relief valve manufacturer to have a typical relief valve tested and rated for both liquid and vapor service. An internet search reveals that there are other relief valve manufacturers, who seem to serve the petroleum industry, that provide vapor relief valves with "liquid trim" and vice versa which could also be used.

If the oil side of the shell and tube cooler is stamped for 400 psi it can be relieved to the oil separator vessel if the vessel is rated for 300 psi. A 75psi relief valve would be installed between the two vessels. The oil separator relief valve must include the capacity of the relief valve from the cooler.

If the design pressure of the oil cooler is the same as the oil separator you can relieve the cooler to the oil separator with a bellows or balanced piston type relief valve. These types of valves are not appreciably affected by backpressure. However, this is generally expensive.

Another method to address this situation is to remove the stop valves on one of the oil lines back to the separator to provide an un-valved relief path. This can be done if the design pressure of the oil cooler is the same as the oil separator. Again, the oil separator relief valve must be sized to handle the volume of both vessels. However, this generally means someone would have to depressurize the oil separator to replace an oil filter or service the oil cooler, an obvious inconvenience.

If none of the above is acceptable, the oil side of the vessel can be piped with an atmospheric (vapor) relief valve at the design pressure of the oil side of the cooler, generally through a dedicated relief line, because it is unacceptable to introduce anything but ammonia vapor into a common relief header for vapor relief valves. However, the risk of opening and blowing oil to the roof is not desirable. One means of avoiding this is to combine an atmospheric relief valve with a small relief regulator in parallel, set roughly 40 psi below the atmospheric relief valve and piped back to the oil separator. If the pressure goes up in the oil side of the cooler the relief regulator would open and relieve the pressure. This will relieve an oil pressure hydraulic spike and avoid opening of the atmospheric relief valve. And the atmospheric relief valve provides the code compliance.

The more common current design of thermosyphon oil coolers is to use a "plate and shell" heat exchanger. In this arrangement, oil is circulated through the plate, and ammonia is circulated through the shell. The shell is an ASME stamped vessel and will require typical relief protection, which can be back to the oil separator or to the atmosphere, in the same manner as described above. The plate side is not an ASME vessel, and if fitted with shut off valves, these can be protected with a common hydrostatic relief valve. Alternatively, if there is a procedure in place such that trained technicians isolate the plate only during maintenance, the hydrostatic relief valve can be omitted. This arrangement would also work for shell and tube heat exchangers with ammonia in the shell and oil in the tubes. ■

The more common current design of thermosyphon oil coolers is to use a "plate and shell" heat exchanger.

IIAR Remembers...

IIAR Remembers Donal Ballou

Donal Ballou was enthusiastic about everything he did in life, whether as a founding member and chairman of the IIAR, or with the company he created, Refrigeration Systems Corp.

"When he became involved in something he was very passionate about it. That was part of his personality," said Bob Appleton, who worked alongside Ballou at Refrigeration Systems Corp. for 30 years. "He was energetic and he was very active in all aspects of our industry."

Ballou, 87, died on July 9 at his New London, N.H. home, where he spent his retirement with his wife of 65 years, Betty. The family also lived in New Jersey, Connecticut, Texas and Ohio before settling in Waynesboro, Pa. They returned to New Hampshire in 1990.

"His business acumen was a real strength," said Tom Leighty, CEO of Refrigeration Systems Corp. "He certainly had the engineering and sales background, and that helped him guide the company very successfully for many years."

Leighty worked for Ballou in the early 1970s and was brought back to the company to take over upon his mentor's retirement in 1992.

"Don made a significant contribution to the industry," he said. "He was certainly very involved in IIAR and he was instrumental in moving this organization forward."

Ballou was a devoted family man. He obtained his pilot's license in mid-life, not solely to aid in the company's business development, but so he could fly the company plane home to Waynesboro, Pa. on weekends. He also adored the challenge and the thrill. Ever active, he was an avid golfer and workout fanatic, forever living up to his motto of "just keep on doing what you've always done."

After retiring to his New Hampshire cottage, he purchased a scull, a kind of seat rowing *boat,* and would be on the lake every morning, faithfully recording his time to the second. "He'd be out there rain or shine," Leighty said. "He was always very fit."

Leighty recalled regular lunch-time racquetball matchups with Donal, who was as passionate about those meetings as he was about business.

"We'd play three games and for the longest time he would beat me," he said. "Finally, one day I got him all three games. After that I refused to play him anymore. It drove him crazy. He was so competitive and he wanted the chance for a rematch. That competitiveness was a big part of his personality and what made him successful."

Born in Lawrence, Mass., Ballou spent his childhood in Croydon, N.H. After graduating from the University of New Hampshire and serving in the US Navy, he joined the York Division of Borg-Warner and Frick Corp. as a mechanical engineer. He founded Refrigeration Systems Corp. in Columbus, Ohio in 1974, eventually expanding the business into several states.

IIAR Remembers Cliff Preston

Preston Refrigeration is mourning the loss of the company's chairman, Cliff Preston, 79, who began working at Preston in 1955 at the age of 16.

A long-time IIAR member, Preston was an innovative thinker who was often ahead of the curve when it came to energy savings.

A long-time IIAR member, Preston was an innovative thinker who was often ahead of the curve when it came to energy savings.

"Cliff would design around energy costs. He was very into that," said Preston CEO Dave Smreker, who began working for Preston in 1974. "He would put forth economical jobs with energy conscious savings and operations. I think people copied that. We were on the edge all the time of doing something new."

Smreker, who worked as Preston's personal project manager, points out that the company went to larger evaporators at a time when others were using two-horsepower fan motors and evaporators.

"I always felt he was ahead of the curve," Smreker said. "He would design systems for 90, 95 degrees condensing back in the 1980s when the typical system design temperature was 96.3 degrees. He would sit down with customers and talk to them about brake horsepower per ton" and how it related to potential energy savings.

Preston president Brian Schnepf said Cliff Preston will be missed, but that his legacy will continue.

"Preston Refrigeration is mourning the loss of a great man, but this company will carry on in memory of him," he said. ■

Editor's Note

The SRVcalc project is a two-phase research initiative to develop a method and tool for determining whether relief valve replacement intervals can be extended or shortened depending on the conditions in which they are installed.

The first phase of the project included the development of a physical testing apparatus and test methodology to generate data on real-life relief valves that can feed into an appropriate statistical analysis.

The second phase of the project developed the appropriate statistical modeling using a technique known as "Weibull Analysis," to predict the life performance of tested relief valves. Part of the second phase of the project was to develop and make available a software program, called SRVcalc, which can be used as a tool to complete Weibull Analysis for a set of data.

As discussed in the cover story of this issue of the Condenser, "Using Weibull Analysis to Predict Valve Replacement Intervals," IIAR is preparing to release software to make the analysis tool available for wider use.

Reprinted in the following pages of this issue of the Condenser, is an account of the findings of the University of Wisconsin Madison's Industrial Refrigeration Consortium concerning the first phase of the SRVcalc project, which were delivered at IIAR's 2011 conference in San Diego.

The results of the project included a relief valve test rig design and corresponding test procedures suitable for data collection by post-mortem testing of relief valves.

DEVELOPMENT AND VALIDATION OF A BENCH TEST PROCEDURE FOR POST MORTEM TESTING OF RELIEF VALVES

By Jekel, T. B., Claas, M., and Reindl, D. T., Industrial Refrigeration Consortium, University of Wisconsin-Madison

In 2007, IIAR revised its recommended practice for replacing pressure relief valves on industrial ammonia refrigeration systems (Section 6.6.3 of Bulletin 110). In addition to the prescriptive five year relief valve replacement interval, the revisions to Bulletin 110 added an alternative replacement method based on an evaluation of in-service relief valve life using appropriate testing and data analysis methods.

This paper describes the results of a research project that aimed to validate guidelines for the post-mortem testing of relief valves. The purpose of the data collected by post-mortem testing is intended to support the alternative path to determine the service life of relief valves following their removal from the system prior to their disposal (i.e. post-mortem). The testing procedure and data gathering methods described in this paper are intended for relief valves that have not discharged during their in-service life. A test rig suitable for post-mortem testing of relief valves was designed, constructed, and proof-tested. The function of the experimental rig was established by testing a range of alternative relief valves that included high and low set pressures; high and low capacities; as well as both new and used relief valves. The draft test procedure was modified using the information gathered during the rig proof-test. The results of this project include a relief valve test rig design and corresponding test procedures suitable for data collection by post-mortem testing of relief valves.

INTRODUCTION

Pressure relief valves are engineered safety devices designed to automatically function and relieve vapor caused by overpressure as a means of preventing the catastrophic failure of vessels and other equipment. Paragraph UG-125 of the ASME Boiler and Pressure Vessel Code (Section VIII Div. 1) prescribes basic requirements for pressure relief protection applied to vessels and other equipment built in accordance with the Code (ASME 2010).

A number of factors are essential for successful safety relief systems. First, appropriate relief valve selections are required for given equipment and relief scenarios. ASHRAE (2010) and IIAR (2008) provide prescriptive pressure relief valve selection requirements for vessels and positive displacement compressors. For other equipment, design engineers need to prepare appropriate analyses to properly size relief devices for envisioned scenarios per UG-133 (ASME 2010).

The most common basis used for sizing of pressure relief valves for refrigerant-containing vessels assumes a radiant heat load from an external fire condition (Fenton and Richards, 2002). Reindl and Jekel (2009) present principles of relief device capacity determination for other types of equipment. Applied relief devices not only require sufficient capacity (vapor mass flow rate) but also they must have a set pressure no higher than the maximum allowable working pressure (MAWP) for the vessel or equipment they are protecting per UG-134 (ASME 2010). Suitably engineered relief valve inlet and outlet piping is another necessary condition for proper relief device operability. Reindl and Jekel (2006) provide guidance on the principles and practices for properly engineering safety relief systems. Finally, the relief devices themselves must remain operational while installed throughout their life.

A number of factors can, potentially, influence the life of a pressure relief valve but corrosion on the outlet portion of the relief device tends to dominate (Gross, et al. 2006). Section 9.4.9 of ASHRAE Standard 15 (ASHRAE 2010) requires that suitable materials be used for the construction of relief valves to resist corrosion or other chemical action that may be caused by refrigerant exposure.

9.4.9 *The seats and discs of pressure-relief devices shall be constructed of suitable material to resist refrigerant corrosion or other chemical action caused by the refrigerant. Seats or discs of cast iron shall not be used. Seats and discs shall be limited in distortion, by pressure or other cause, to a set pressure change of not more than 5% in a span of five years.*

In addition, suitable materials for seats and disks must be used such that their set pressure will not change by more than 5% in a span of five years. Traditionally, relief valves were recommended for replacement at least every five years (IIAR Bulletin 110, 1993). In part, Section 6.6.3 of Bulletin 110 stated:

At least every five years pressure relief valves (or cartridges) shall be removed and replaced with new or with overhauled and recalibrated valves (or cartridges).

In 1992, OSHA issued its Process Safety Management (PSM) standard (1910.119) and paragraph (j) of that standard obligated end-users of covered processes, such as ammonia refrigeration systems with more than 10,000 lb of refrigerant inventory, to perform <u>inspections</u> and <u>tests</u> to ensure the ongoing mechanical integrity of their systems and equipment. Specific requirements for inspections and tests are not prescriptively identified in the PSM standard; rather, the details of required tests are based on industry-recommended practices with modifications based on site-specific experience.

In 1997, OSHA issued a series of citations to the Armour Swift-Eckrich plant in Kansas City, MO as a result of deficiencies found in the facilities' PSM program during an inspection. As part of a settlement following the OSHA inspection, Swift-Eckrich agreed to abate a number of items discovered during the inspection (OSHA 1997). A portion of the abatement action focused on various aspects of the pressure relief protection for its vessels and other equipment such as compressors. In these parts of the settlement, Swift-Eckrich agreed to address the ongoing function of pressure relief valves as a means of assuring their function as part of the facilities' mechanical integrity program. The following are specific references to the PSM standard and associated activities that Swift-Eckrich agreed to:

Item 28: 1910.119(j)(4)(i)

…

c. The company agrees to perform inspection and testing on pressure relief valves.

Item 29: 1910.119(j)(4)(ii)

…

d. The company agrees that the Mechanical Integrity Program will include procedures for the inspection and testing of pressure relief valves and vent systems that follow good engineering practices. Good engineering practices for the testing and inspection of pressure relief valves and vent systems include:

…

3. *A procedure that verifies replacement every five years is an adequate interval. To assure pressure relief valves are still operational when replaced, they must be visually inspected for corrosion or fouling when removed from service, pop tested in the "as received" condition by an authorized testing laboratory, and the testing and inspection or replacement interval reduced, if necessary.*

Under item 28 within the agreement, Swift-Eckrich agreed to perform inspections and tests on their pressure relief valves. Under item 29, Swift-Eckrich agreed to develop procedures for the inspections and testing of pressure relief valves that follow *good engineering practices*. The good engineering practices identified included conducing visual inspection of pressure relief valves for corrosion or fouling as well as *pop testing* when removed from service. At the time of the settlement agreement, no Recognized as Generally Accepted Good Engineering Practice (RAGAGEP) was available to guide the performance-based service life for pressure relief valves.

In 2001, IIAR revised section 6.6.3 in Bulletin 110 to state:

When a component reliability program is in place to verify relief valve functionality and longevity by history, testing, disassembly and inspection, and periodic statistical review of these activities, relief valves may be replaced at any interval justified by the findings of such a program. In the absence of such a program, each relief valve shall be replaced at the frequency recommended by the relief valve manufacturer. In the absence of both a component reliability program and manufacturers' recommendations, relief valves shall be replaced every five years if not indicated earlier at annual inspection.

The revision to IIAR Bulletin 110 gave end-users another option to the most common industry practice - the prescriptive replacement of pressure relief valves on a five year interval. Although the revised IIAR Bulletin 110 guidance established a performance-based interval for replacement, less clear were the specific means for methods of test as part of data collection on relief valves removed from service for replacement as well as the statistical analysis methods to guide altering the interval for replacement.

In 2006, IIAR formed a task force to look consider further modifications to section 6.6.3 of Bulletin 110. The task force considered relief valve inspection and test criteria and benchmarked with related industries. The task force also took action to further revise section 6.6.3 of Bulletin 110. In 2007, IIAR approved revisions to section 6.6.3 of Bulletin 110 prepared by the task force. An excerpt of Section 6.6.3 as-revised states:

Pressure relief devices shall be replaced or recertified in accordance with one of these three options:

1) Every five (5) years from the date of installation.

IIAR originally recommended (in 1978) that pressure relief valves be replaced every five years from the date of installation. This recommendation represents good engineering practice considering the design and performance of pressure relief devices; or

2) An alternative to the prescriptive replacement interval, i.e., five years, can be developed based on documented in-service relief valve life for specific applications using industry accepted good practices of relief valve evaluation; or

3) The manufacturer's recommendations on replacement frequency of pressure relief devices shall be followed.

Exception: Relief devices discharging into another part of the closed-loop refrigeration system are not subject to the relief valve replacement practices.

The task force continued to develop procedures for post-mortem testing of pressure relief valves. This effort was eventually transferred to the IIAR Research Committee which facilitated in the drafting of testing procedures. At the end of 2008, the IIAR Research Committee completed its development of procedures for *bench testing* relief valves. The test procedure document included a description of the test equipment and procedures that should be followed for the post-mortem testing of pressure relief valves; however, the test rig documented and the associated testing procedures had not actually been validated by practice. In 2009, the IIAR Ammonia Refrigeration Foundation (ARF) funded this project to validate and revise, as-needed, the test rig and corresponding procedures for post-mortem testing of pressure relief valves. This paper summarizes the results and findings of this project.

RELIEF VALVE TEST PROCEDURE

The original objective of the IIAR

Fig. 1 Pressure relief valve bench test rig (as-originally proposed):

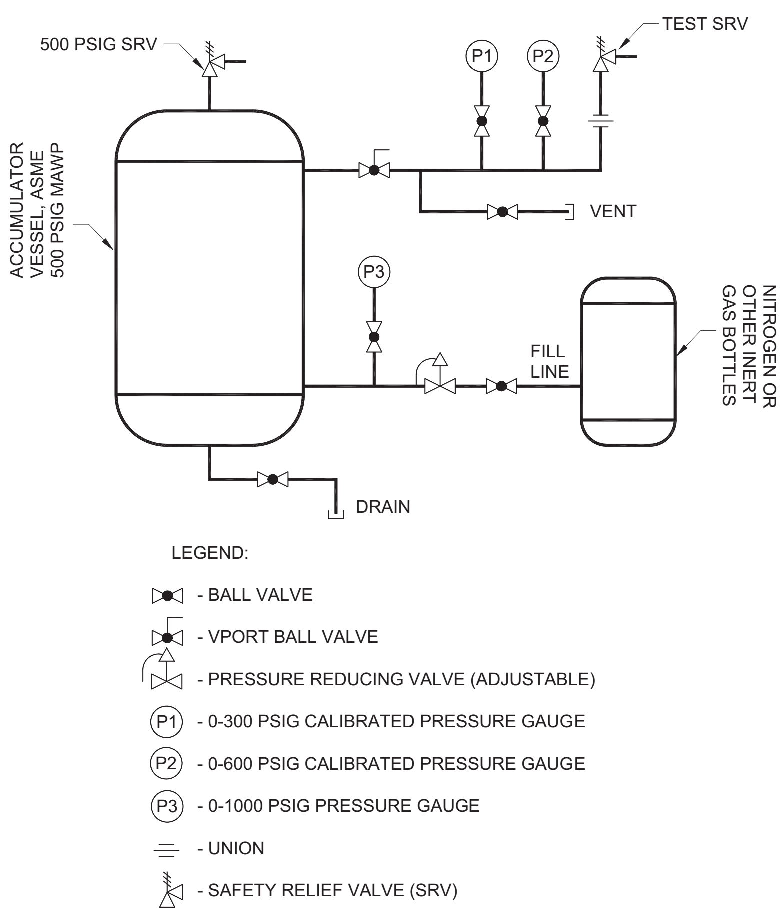


Fig. 2 Photos of the flanged relief valve inlet connections:

relief valve bench test procedure was to "to quantitatively determine the opening pressure and qualitatively verify operation (i.e. lift or flow) of a reclosing vapor relief valve after removal from service." The procedure was intended for bench testing reclosing safety relief valves designed to discharge to atmosphere and the procedure allowed the use of compressed air (or nitrogen) as the test medium. The procedure was not intended to test:

- Non-reclosing relief devices (i.e. rupture discs),
- Internal relief valves (i.e. valves with superimposed back-pressures greater than 1 atmosphere),
- Hydrostatic relief valves (i.e. liquid relief), or
- A test medium other than compressed air or nitrogen (e.g. steam, refrigerant, or incompressible liquids).

Figure 1 shows a schematic of the pressure relief valve test rig as *originally* proposed. Because a sufficient source of high pressure air needed to test relief valves with high set pressures (e.g. 300 psig) is not readily available in most facilities, the test rig relied on the use of high pressure gas cylinders to supply air or nitrogen for testing. From high pressure compressed gas cylinders, the pressure is regulated down as it flows to an accumulator. The purpose of the accumulator is to buffer the pressure and flow of gas to the inlet of the relief valve being tested. Service valves are located throughout the test rig to allow isolation of the compressed gas cylinders and relief valves for change out. Pressure gauges are used to provide the operator of the test rig accurate information in order to document the relief valve start-to-leak and pop pressure.

Note that it is important to consider and check the capacity of the safety relief valve protecting the accumulator vessel relative to the capacity of the pressure regulator feeding gas from the cylinder into the vessel to prevent the possible over pressurization in the event of the regulator failing open.

The present research project intended to answer a number of questions related to the originally developed test rig and procedure including:

- *Is a vessel or accumulator on the inlet of the test relief valve required? If so, is the recommended 12" x 48" adequate?*
- *What rate of pressure rise results in accurate opening pressure determination?*
- *Is the bubble method for start to leak reliable and repeatable?*
- *Is a pop test viable? If so, what safety precautions should be written into the procedure and integrated into the test stand?*
- *Should the procedure be altered based on the rated capacity or set pressure of the valve tested?*
- *Can the equipment for the test be readily acquired at a reasonable cost?*

The remainder of this paper describes the techniques used to validate the test method, observations and findings associated with testing a range of relief valves using the test rig, and conclusions.

TEST RIG DESIGN

The test rig design was modified from the one proposed in the original procedure drafted by the IIAR Research Committee in order to reduce the amount of piping, streamline the fabrication, and facilitate the changing of relief valves during sequences involving multiple valve tests. In addition to the cost benefits of streamlining the piping, there is an added benefit associated with the reduction of inlet pressure drop during the pop test of relief valves. The number of connections on the inlet piping for accommodating the vent and pressure gauges was also reduced from the original test rig concept design. The simplifications made to the inlet piping however requires that the pressure gauge be changed when testing valves with different pressure set points, but a higher value was placed on the simplification to the piping. Both ranges of pressure gauges could be incorporated easily if desired.

The accumulator vessel is rated in accordance with the ASME Boiler & Pressure Vessel code (ASME 2007) with a Maximum Allowable Working Pressure (MAWP) of 500 psig and a standard Minimum Design Metal Temperature (MDMT) of -20°F. All accumulator vessel connection sizes were oversized to allow flexibility. A ¾ inch connection on the bottom of the vessel serves as a vent/drain; a 1-½ inch connection on the top is for the test relief valve connection; two 1 inch connections on the top of the of the vessel are needed for air inlet from the pressure source supply and for a relief valve to protect the accumulator; and ¾ inch connection allows for the installation of a dedicated pressure gauge (0-600 psig range) for the accumulator vessel itself.

Different inlet connection sizes of the relief valves are accommodated by using a Class 600 flange (ASME/ANSI B16.5), fitting, and nipple for each size (½", ¾", 1, 1-¼") shown in Figure 2. This arrangement allows the installation of varying sizes of relief valves without the complexity of an elaborate manifold. With a proper experimental plan, this arrangement can decrease the time associated with changing relief valves.

Ball valves are used throughout the test rig for isolation for two reasons. First, the quarter turn ball valves provide quick actuation. Second, the valves are full area which minimizes gas pressure drop. All valves were

Table 1 Estimated test rig cost:

Component	Quantity	Unit Cost	Extended Cost
Vessel (500 psig MAWP)	1	$2,500	$2,500
Regulator	1	$400	$400
Test Gauges	2	$300	$600
Vessel Gauge			$20
¼" stainless steel tubing (4 ft)	1	$90	$90
1-1/2" Ball Valve	1	$250	$250
¾" Ball Valve	1	$15	$15
½" Ball Valve	1	$10	$10
400 psig pressure relief valve	1	$185	$185
Piping, flanges, bolts, and fabrication			$2,500
		Total	$6,570

Table 2 Pressure Relief valves tested during procedure validation:

	Relief Valve Set Pressure		
Capacity Range [lb/min air]	150 psig	250 psig	300 psig
5-20			✓
20-35	✓	✓	
50-70	✓	✓	
80-100		✓	
>100			✓

pressure rated in excess of the 500 psig MAWP on the vessel. For the rig, 3-piece, carbon steel ball valves with threaded connections and a maximum pressure rating of 1,480 psi WOG were used in all cases except for the bleed valve on the test section which was a two-piece, brass ball valve with threaded connections rated at 600 psi WOG.

The pressure gauge was located on the experimental test section. Its installation at that location does not affect the reading since the pressure of interest is the valve *starts-to-leak* and/or *pops pressure*, both of which are low flow conditions. As such, the pressure read off the gauge in this location is virtually identical to the relief device inlet pressure at the point of relief valve operation (i.e. either simmering or popping). The pressure gauge dedicated to the vessel is intended for monitoring the pressure in the accumulator vessel during periods where the test section itself may be isolated for relief valve change out.

Compressed air was chosen over nitrogen despite its lower price to avoid having to vent the outlet from the relief valve to an outdoor location for personnel safety. If nitrogen is used, or exhaust is required for other reasons, the vent piping should be adequately sized to insure that its presence does not affect the data. If nitrogen or another inert gas is used as the test medium indoors, an area monitor with low oxygen alarm set at 19.5% should be installed.

The final proposed design is shown below in Figure 3 and a close-up of the test section is shown in Figure 4. A 3-D schematic of the test rig is shown in Figure 5 and a photo of the completed test rig is shown in Figure 6.

The estimated cost of the rig is shown in Table 1. Note that fabrication with all screwed fittings and without the completely flanged test section and flanged inlet connection would lower the cost.

Fig. 3 Schematic of re-design of test rig (dimensions shown are in inches):

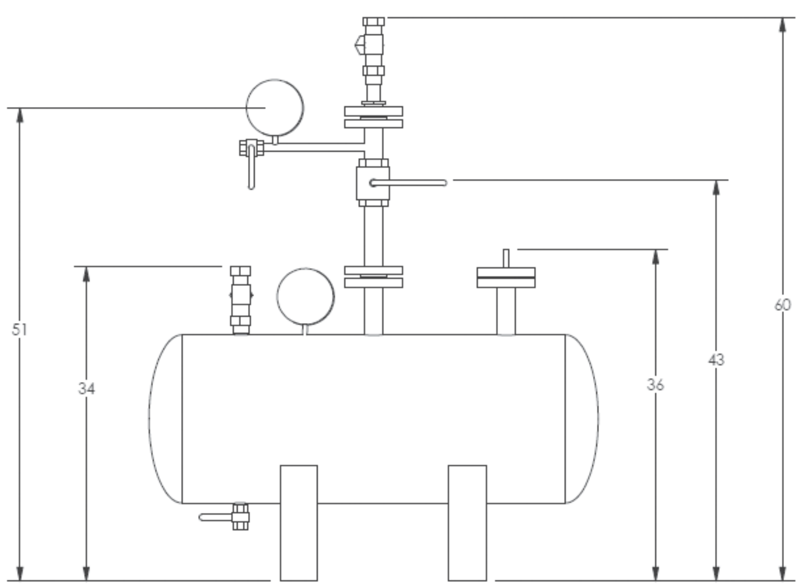
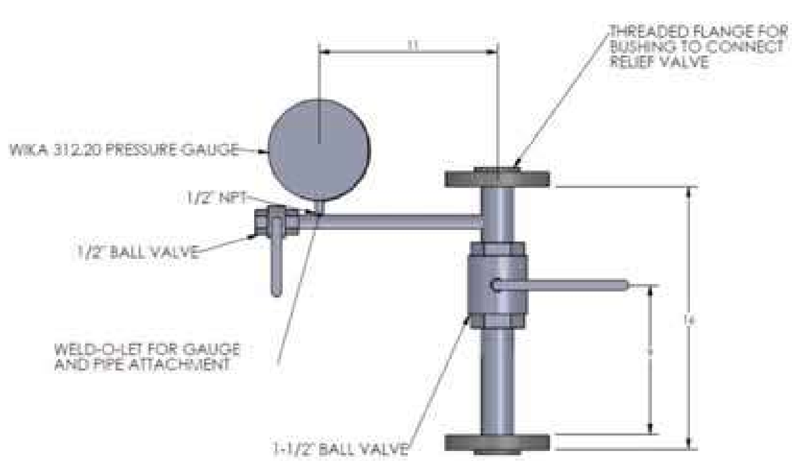


Fig. 4 Schematic of the test section portion of the rig (dimensions shown are in inches):



METHOD VALIDATION

With a rig designed and constructed, the project moved on to the test method validation phase. To validate the proposed test method, pressure relief valves with a range of capacities and set pressures were tested. Table 2 shows the combination of valve capacities and set pressures considered during the process of validating the test procedure. A check mark indicates that at least one pressure relief valve with that combination of capacity and set pressure was tested.

The relief valves tested included a mix of new and used (post-mortem) valves. We chose used relief valves from a variety of locations throughout the plants that provided them for the project. Used valves tested came from locations that included machinery room, condenser (outdoors), compressor, oil pot, and low temperature recirculator. The range of locations allowed us to test the "condition report" requirements of the procedure in order to see if the form included within the test procedure adequately captured the necessary information. Ultimately, we tested nine (9) used relief valves and five (5) new relief valves. Most of the used relief valves were in the middle range shown in Table 2 while the newly manufactured relief valves were chosen to reach the bounds for capacity and set pressure in Table 1.

Since the purpose of the tests was to validate the method, no archival *data* on the tested relief valves was generated. The outcome of this effort was focused on determining whether the test rig was adequate in size and function, and that the test procedure is capable of providing data that can support downstream statistical analysis of relief valve mechanical integrity (service life).

The pressure relief valves were put through the originally proposed procedure to see if the set pressure could reliably be determined with the start-to-leak test. Once the start-to-leak was done, the outlet tubing assembly (relief valve outlet connection size to ¼" connection reducer, ¼" hose barb and ¼" plastic tubing) was removed and the relief valve was *popped* with no outlet piping.

RELIEF VALVE TEST OBSERVATIONS

General observations

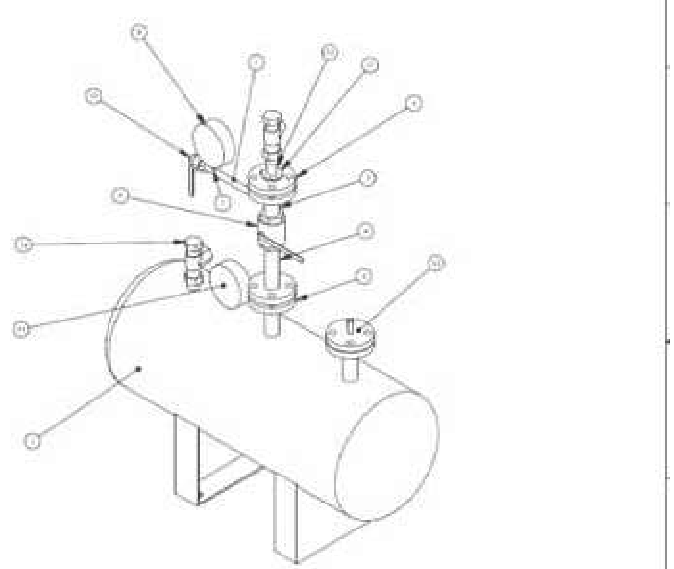
The experimental rig, as-constructed, performed well over the entire range of relief valve capacities and set pressures tested. Even with the compressed air supply regulator fully open, the relief valve inlet pressure rise was slow enough to provide the test rig operator an ample opportunity for reading the pressure gauge accurately. An obvious possible upgrade to the test rig would be to integrate a pressure transducer and computer data acquisition program, but that addition is not necessary to obtain good accuracy.

Start-to-leak tests

Start-to-leak tests initially looked like a viable and preferred option for determining the opening pressure of relief valves being tested. However, as we tested more relief valves, we found that not all pressure relief valves exhibit a *simmer* characteristic. In cases where a relief valve exhibited flow during a simmer condition, the pressure drop experienced through the outlet fitting on the pressure relief device for start to leak testing (¼ inch hose barb and tubing) was large enough to keep the relief valve from opening. During testing of valves with no simmer characteristic and the start-to-leak equipment installed, relief valve chatter occurred. Chatter is the rapid opening and reclosing of the relief valve which is undesirable for obtaining test data. We found that after a relief valve experienced chattering, its opening pressure during subsequent pop testing was susceptible to drift. In thinking about the start-to-leak test after this observation, the following question was

Fig. 6 Parts list and 3-d schematic of test rig:

1	Vessel	48" x 18" (1" Relief Connection, 2 1-1/2" Test Connections on top, 1 Drain connection on bottom) 500 psig MAWP	1
2	1.5" Flange	1.5" Nominal Pipe Flange	4
3	1.5" Flange	1.5" Threaded Flange	1
4	1.5" Nominal Pipe	Schedule 80 8" long	1
5	1.5" Nominal Pipe	Schedule 80 4" Long	1
6	1.5" Ball Valve	To isolate top assembly	1
7	1/2" Pipe	Schedule 80 18" in Length	1
8	Wika 312.20 Gauge	6" Dia. Gauge	1
9	3/4" Ball Valve	Drain and Test Bleed	1
10	1/2" Ball Valve	Bleed for top assembly	1
11	Reducer Bushing	For test relief size	1
12	Various Pipe Nipples	Connect test relief to bushing	1
13	1.5" Cap Flange	1/4" Pipe welding in middle	1
14	Tank Relief	400# Relief valve	1
15	1/2" Weld-o-let	Connect 1/2" pipe and gauge	2
19	600# Pressure Gauge	Reads tank pressure	1



NOTE: TANK PRESSURE GAUGE (19) CAN BE LOCATED WHERE CONVENIENT PROVIDED TANK STATIC PRESSURE IS READ AT ALL TIMES.

ENTIRE SYSTEM TESTED at 440 PSI

posed "what constitutes verification of the relief valve's function?" It was agreed that the opening of the relief valve (i.e. lift) was what verified function and that the start-to-leak test provided no additional useful information. Therefore, recommended eliminating the start-to-leak pressure test from the original procedure in favor of pop-testing only.

Pop tests

In response to the previous determination that opening the relief valve verifies its function, we performed *pop tests* of the relief valves tested. To perform pop tests, requirements for securing the test rig were emphasized and the use of proper personal protective equipment (PPE) for both eye and ear protection during testing. While no direct measurement of pressure relief valve lift is done, actuation of the relief valve is easily determined by the flow through the relief valve. The rig performed very well during these tests. The accumulator vessel provided a buffer for both better control of the pressure rise while approaching the popping pressure as well as adequate air volume to fully open the relief valves over the entire range of capacity.

An unintended side benefit of using the pop test is that the method allowed estimates of the relief valve's closing pressure, or blowdown pressure to be easily measured. When the relief valve recloses, the pressure on the gauge shows the closing pressure directly. This pressure is an estimate of the closing pressure unless the compressed air cylinder is isolated from the accumulator vessel, because there is still a small inlet flow into the accumulator vessel occurs otherwise. However, the makeup air flow is small compared to even the smallest relief valve tested. Some words of caution are required here. First, the blowdown pressure does not have an impact on the success or failure of the relief valve actuation (it just is additional information). Second, the observed blowdown pressure with no outlet piping will be much greater (i.e. lower closing pressure) than for a relief valve installed with vent piping. This is occurs because the pressure that builds up in the vent piping during flow provides an additional closing force on the relief valve resulting in closing at a higher inlet pressure. This operating characteristic was validated during the course of several experimental tests.

Multiple tests on single relief valve

Multiple tests on some relief valves were also performed. After the performing multiple tests on a given valve, the question was posed "is any additional information gathered?" The answer was always *no*. It was never the intent of data gathered by this testing procedure to provide justification for elimination of the recommendation to replace a relief valve after it lifts. Truly no experiment can adequately justify that change. The purpose of the pop test is to determine whether or not the relief valve would have actuated during an overpressure event prior to the relief valve's removal from the system. Multiple pop openings on valves removed from service do not provide additional insight on this determination. In fact, one might pose the scenario, where the pop pressure observed during a subsequent test varies significantly from the first pop. Changing pop pressure during multiple pop tests, it does not indicate relief valve failure. It is our view that multiple pop tests provides no additional value for post-mortem functional testing and, as such, was eliminated from the original test procedure.

CONCLUSIONS

The purpose of the project was to test and propose changes to the draft Bench Procedure for Post-Mortem Testing of Safety Relief Valves developed by the IIAR Research Committee. The main deliverable was to provide recommendations for changes to the procedure, test rig, and data collection sheets. This paper provides an overview of the project and the findings that were the background for the changes proposed.

The test rig was re-designed and performed flawlessly throughout the range of pressure relief valves considered. The procedure was altered to streamline the test by elimination of the start-to-leak test and multiple pop tests.

As a final note, the purpose of this bench test is to determine at what pressure the removed relief valve would have actuated. The next step is to use this data to determine whether or not the relief valve *passed* or *failed*. It is not the purpose of this test to recertify the tested relief valve for continued service. In other words, if a relief valve is tested using the equipment and methods described herein, they should not be placed back into service unless a qualified facility re-certified the relief valve.

Ultimately, the data generated from this test procedure can be used with a statistical analysis to justify changing the service life of the pressure relief valves in similar service to insure safe operation (i.e. the relief valve will actuate, that is, open, as expected during its service life).

ACKNOWLEDGEMENTS

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- Isotherm, Inc. for donating the vessel
- Rohde Brothers, Inc for donating piping, fittings, and welding services
- Hansen Technologies for donating pressure relief valves
- Refrigerating Specialties, a division of Parker for donating pressure relief valves
- Kraft Foods, Inc. for donating relief valves for post-mortem testing
- Schoep's Ice Cream for donating relief valves for post-mortem testing

Also thanks to the IIAR Research Committee for their oversight and guidance throughout this project.

- Table 1: Estimated test rig cost.
- Figure 1: Pressure relief valve bench test rig (as-originally proposed).
- Figure 2: Photos of the flanged relief valve inlet connections.
- Figure 3: Schematic of re-design of test rig (dimensions shown are in inches).
- Figure 4: Schematic of the test section portion of the rig (dimensions shown are in inches).
- Figure 5: Parts list and 3-d schematic of test rig.
- Figure 6: Photo of the completed test rig.

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Photo of the completed test rig.

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