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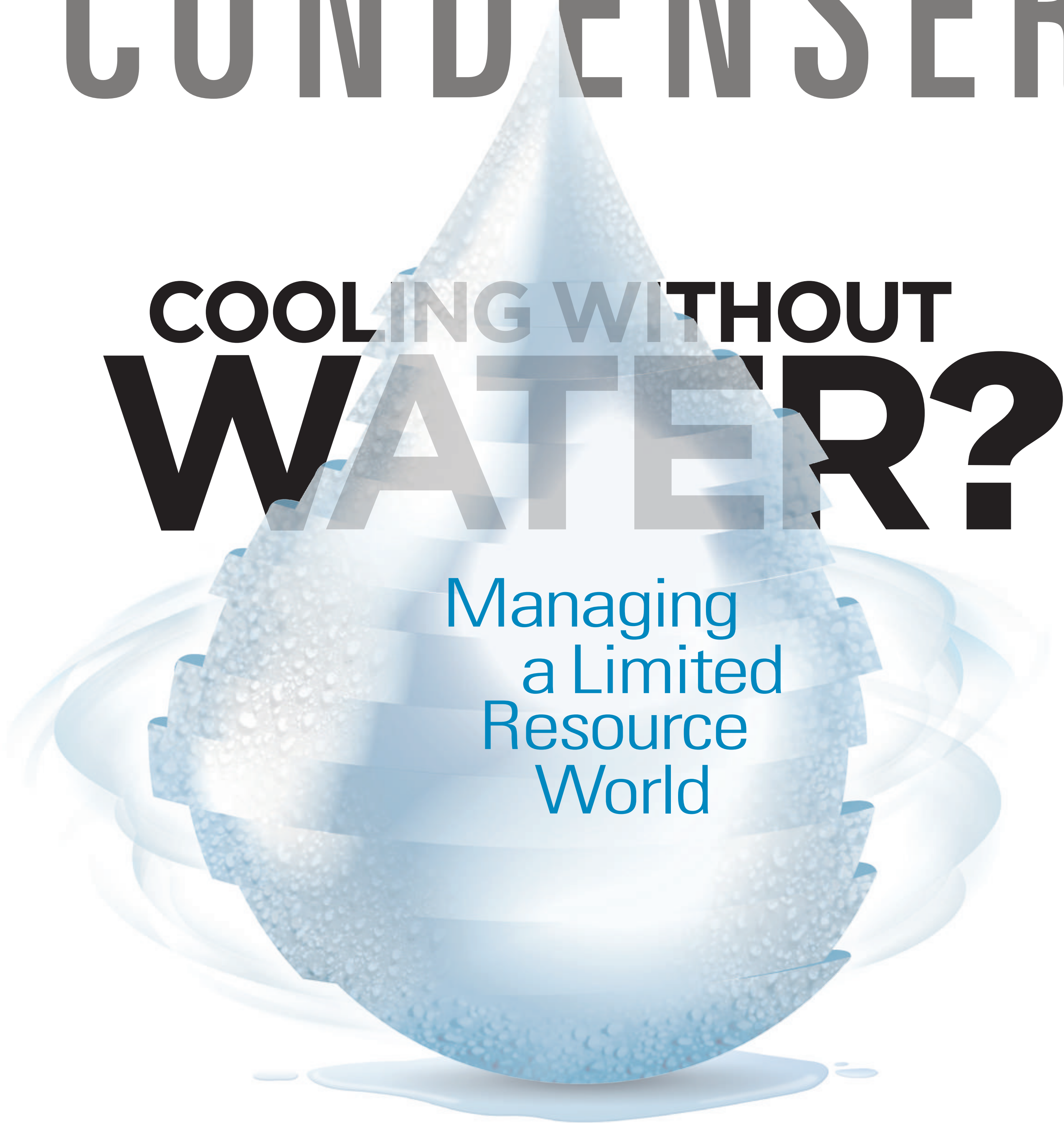
CONDENSER



COOLING WITHOUT WATER?

Managing a Limited Resource World


EXPERTISE

SEPTEMBER 2015

contents

8 COVER STORY

Cooling Without Water?

Although water problems continue to be seen as a mostly regional issue for many in the industrial refrigeration industry, there's no mistaking that water scarcity will loom larger in the years to come. And as the cost of water – both to use it and dispose of it – begins to rise, several factors determining the availability and environmental feasibility of water as a resource for industrial refrigeration are already narrowing possibilities and informing design and operational decisions.

4 Chairman's Message
6 President's Message
12 Government Relations
16 ARF News
20 Lesson Learned
22 TECHNOMERCIAL: Lowering Charge with Advanced DX Ammonia
24 Safety
25 Committee Update
26 IIAR Remembers Fred Gary Walker
28 Two Years Later: Texas Explosion is Catalyst for Change
29 Technical Paper

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chairman's MESSAGE

THOMAS LEIGHTY

We're nearing the second half of the year, and for IIAR staff, committee, and volunteer members, that means building on the substantial work completed so far in 2015 on a variety of different initiatives. You'll read in this issue of the Condenser about two important research projects, a new scholarship initiative and work to reach our funding goal for the Ammonia Refrigeration Foundation.

IIAR's ARF-funded 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.

In addition to awarding a new scholarship recipient for 2015, ARF has also launched a new process to select its research projects, which now starts with a simple, one-page form. The process makes it easier for IIAR members to submit their ideas to the research committee. The form, which is available online, is used to explain the proposed project, state its potential benefits and merit, and can be submitted by any IIAR member.

These types of initiatives are projects that really are state of the art in terms of addressing the practical information and design that underlie everything we do as an industry. 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.

We're pleased to announce that IIAR has recently formed a new committee. The Compliance Guidelines Committee is one of the organization's newest committees. Its purpose is to review, revise and publish IIAR guidance documents that currently do not have a formal home within any of the other committees. Those documents include the Ammonia Data Book, the Process Safety Management & Risk Management Program and the Ammonia Refrigeration Management Program.

We're pleased to announce that IIAR's newest committee, the Compliance Guidelines Committee, will review, revise and publish IIAR guidance documents that currently do not have a formal home within any of the other committees.

This committee will begin work to review those publications, and will also be working with the Standards Committee to develop a Recognized and Generally Accepted Good Engineering Practices standard.

Meanwhile, standards 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.

While each of our IIAR committees are 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. Your involvement and input within this industry as IIAR members moves us all forward.

Of course, behind the ongoing work of our membership, our staff at headquarters is always working to deliver new products and resources, and our biggest resource, the IIAR Annual Conference is no exception.

The 2015 event was one of our best conferences yet. The packed technical paper sessions, workshops and technomercials were the usual highlights of our annual meeting, as well as the exhibit hall, which was crowded this year with a record-breaking number of exhibitors and sponsors, representing manufacturers, service providers and educational organizations.

It's time to start thinking about how to use that renewed enthusiasm in the coming year to strengthen IIAR's member presence and plan for our next event. The 2016 IIAR Industrial Refrigeration Conference & Exhibition will be held in Orlando, Florida on March 20-23, 2016.

As always, your staff, board and volunteer members are working hard to make sure the upcoming conference is an even bigger success.

We're focused on many different initiatives this year, and as a volunteer member, you too can get involved in our industry's work. Some of that work represents big steps the industry is taking to advance standards and safety, as in the case of the rewrite of the IIAR-2 standard. And some initiatives represent smaller, but just as important goals, like the creation of new task forces and committees. It is the ongoing support and participation of IIAR members that make these conversations possible. Thank you for continuing to enrich our industry with your collaboration, input, and knowledge.

president's MESSAGE

BY DAVE RULE

In this issue, we're presenting news on many exciting activities in our industry and our organization. IIAR is working harder than ever to deliver on its promise to membership: to promote the ongoing growth and health of industrial refrigeration. And this is a theme that touches on so many important goals, including an emphasis on environmental sustainability, future growth through scholarship and research programs and an ever-widening commitment to the foundation work done by our volunteer members through IIAR committees.

In my column this month, I'd like to address a subject that underlies much of the work that IIAR does on behalf of membership, and that is our relationship with the regulatory community.

Regulatory issues are front and center in everything we do now. Our industry is continuing to see increased enforcement activity from OSHA and the EPA, and I'm pleased to report that IIAR has come to the table on many important activities.

We've worked very closely with OSHA over the last year, involving decision makers at that agency in the public review process for IIAR-2, one of our most important efforts, and a standard that has the potential to have a real and lasting impact for years to come.

That effort – to work closely with OSHA throughout our standards development process – has paid off in a big way. In June, OSHA released its 2015 guidance to inspectors related to Recognized and Generally Accepted Good Engineering Practices, or RAGAGEP. In that guidance, OSHA referenced IIAR-2 for the first time as the RAGAGEP standard for the industry.

As you know, RAGAGEP plays an important role in how inspectors evaluate a facility's compliance with PSM.

Under the PSM regulation, employers must document that all equipment in PSM-covered processes complies with RAGAGEP.

RAGAGEP, along with inspection and test frequency, must follow manufacturer's recommendations and good engineering practice, and inspections and tests performed on process equipment are subject to the PSM regulation's mechanical integrity requirements.

Importantly, the recent OSHA guidance recognizes that PSM does not strictly define RAGAGEP.

Under the new guidance, facilities have the ability to select their own RAGAGEP.

The guidance points to the importance of consensus standards and cites IIAR as a primary source of RAGAGEP.

According to the new guidance, if a facility is properly following consensus standard, then they are likely in compliance. That means that engineering documents and technical papers, like IIAR-2, can also form the basis of RAGAGEP.

The formal reference to the IIAR-2 standard in this important guidance from OSHA is a major step for IIAR and the industrial refrigeration industry as a whole because it represents the first time that the relationship between IIAR standards and best regulatory practices has been acknowledged in writing.

As a result of that guidance, we, as an industry, may now indicate that IIAR-2 should be used as a basis for RAGAGEP in ammonia plant inspections – rather than other standards and guidelines belonging to different, unrelated industries, such as the petroleum and refining industry.

This is a very significant step, given that standards from the American Petroleum Institute have often been referenced in regulation of our own industry, where fundamental differences in RAGAGEP have necessitated costly and drawn-out appeals.

OSHA's RAGAGEP guidance is just the first in what I hope will be a series of beneficial outcomes as we work ever closer with regulatory agencies.

Next up is an effort to work together as an industry with the Environmental Protection Agency at a local level. Together with RETA, GCCA and other organizations, IIAR is leading an effort to open communication with regional EPA inspection offices.

We're holding meetings with the heads of those regions, most recently EPA region 1, to discuss and identify common issues they are facing in the field, for example, facility owners not being aware of their regulatory requirements or responsibilities during an inspection. And we're also collecting data on the number of non-compliant facilities they are finding in a region.

To back up these efforts, IIAR has created a new regulatory member portal, to make standards and other information available to all regulatory agencies, particularly OSHA and EPA.

Alongside that effort, IIAR continues to work with the New Jersey Department of Labor to identify opportunities to initiate change in regulations to make markets like New Jersey more economical for the safe use of ammonia and other natural refrigerants.

All of these activities point to the importance of taking direct involvement in the work of IIAR and our industry. Anyone who operates an ammonia or natural refrigerant facility should find some way to participate in the work of IIAR. Investing in this association can make a real impact when it comes to creating a strong, safe industrial refrigeration industry for the future.


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COOLING WITHOUT WATER?

Managing a Limited Resource World

Agriculture and food processing operations across the American West are scrambling to find new water sources amid a record drought. And although their water problems continue to be seen as a mostly regional issue for many in the industrial refrigeration industry, there's no mistaking that water scarcity will loom larger in the years to come.

As the cost of water – both to use it and dispose of it – begins to rise, several factors determining the availability and environmental feasibility of water as a resource for industrial refrigeration are already narrowing possibilities and informing design and operational decisions.

"Everyone is looking for ways to save water because it is getting much harder and more expensive to use it as we always have," said Jay Kliewer, P.E., president of California-based contractor, California Controlled Atmosphere. "It's not only the aquifers here in California that are being depleted, shortages are beginning to happen in the Midwest and other places, and this [as an issue for refrigeration] has the potential to snowball. It could very well be what we are all facing in the next decade."

While many in the industry look to California as a model for problems to come, comparisons are already being drawn between the industry's past focus on energy efficiency and a future focus on water usage as the most important factor governing day-to-day operations.

"Water shortages are beginning to affect agriculture, and that's obviously a serious problem for the refrigeration industry," said Gary Dunn, president of Applied Process Cooling Corp. "The optimization of water usage in our industry is something that has as much focus now as energy conservation has had in the past."

CCA's Kliewer agreed, saying, "We're seeing the pendulum starting to swing in the direction of water over energy when it comes to the major issues our industry is facing."

And as with energy conservation, the cost and a drive towards environmental sustainability will be behind an increased focus on water usage as an issue.

A facility "may have abundant water, but the sewer and treatment bill is what can get you," said Steve Heidenreich, regional sales manager for Johnson Controls, Frick, Food and Beverage Division. He said that many customers are seeking ways to mitigate water usage simply because the twin costs of water supply and water treatment after its use are growing.

"I think water is going to be something that companies look at environmentally, but also from a cost savings

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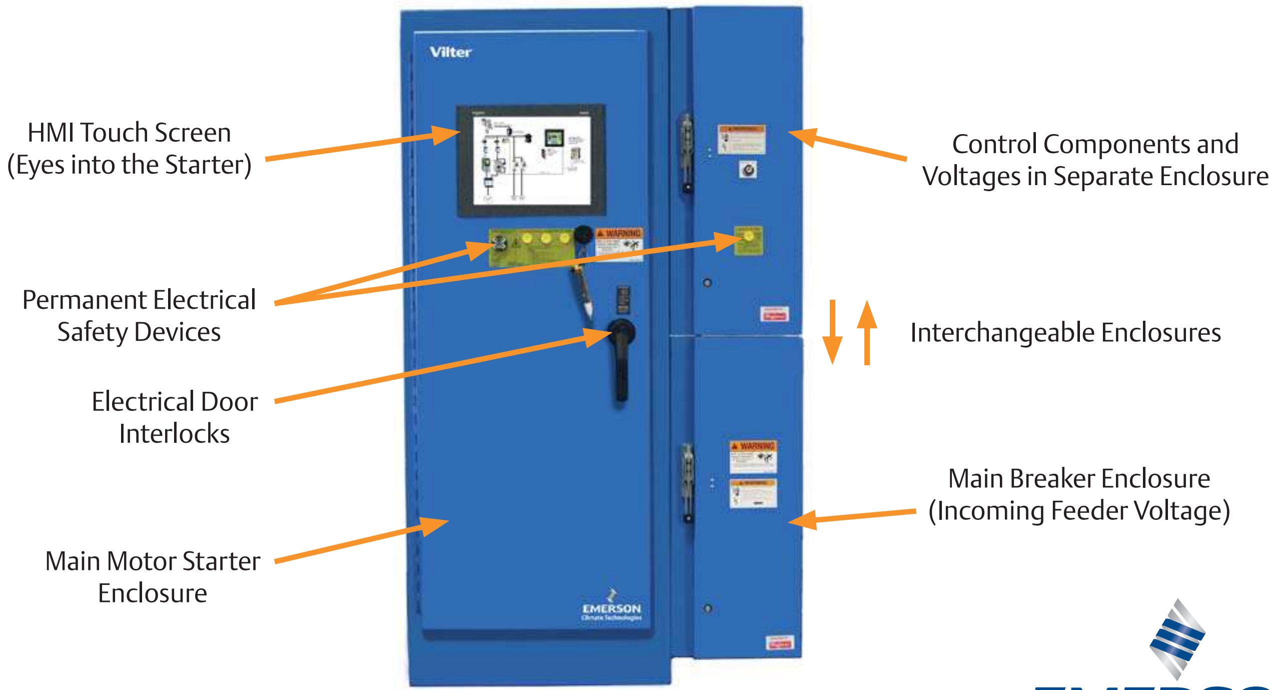

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standpoint. The cost of water is really jumping in California – in some cases it's ten times or more what it was years ago. For the foreseeable future, water is going to be a predominant issue. People are really starting to look at what they can do to save water now."

One company already focused on reducing bottom line utility costs by controlling water usage is WalMart. And for the nation's largest retailer, those costs can be massive.

Jeff Cato, Senior Manager of Material Handling Equipment at WalMart said the company's average site utilizing evaporative condensing will consume between 600 to 800 thousand gallons of water per month in the summertime across roughly 40 sites. Cato has been tasked by the company to find new ways to dramatically decrease water consumption across its fleet of evaporative condensers.

"This is a bottom line issue for us," he said. "The benefit of reducing water usage is that at the same time, we're reducing sewage wastewater, which typically runs between two and three times per gallon the cost of raw water. If we're operating at the industry standard of four cycles of concentration, eliminating just four gallons of water will eliminate one gallon of sewage."

"Being the largest retailer in the U.S., when there is a call to action like tightening water supply, the first to feel it [and look for ways to address it] is typically WalMart," said Cato. "With a lot of issues nationwide, and especially in California, tightening water supply has caused us to take the long look at what we're doing and how we're doing it" when it comes to water.

While companies like WalMart are actively looking for ways to dramatically reduce their water usage across the board, many others are just starting to look at the issue.

"The end user and design engineer are concerned, or at least they are evaluating the water issue, but that focus hasn't yet reached the level where water is driving change in the industry," said Joe Mandato, Senior Vice President, Evapco Inc. He added that one exception is where a lack of water availability in certain areas forces a facility owner to make an immediate change.

"Much of the industry has not grasped the concept yet that water availability will be a serious concern in the future," said Mandato. "We've seen some customers being progressive and attacking the problem now. But as an industry, we need to be looking out ten years, selecting equipment and making operational decisions based on what water supply is going to look like."

So what will it take to push the industry to that level of change? According to Mandato, three scenarios will begin to move water to the forefront of the industry's issues as they gain momentum.

First, for reasons driven both by environmental sustainability and cost, more and more companies may follow WalMart's lead in instituting corporate philosophies to utilize existing water reduction technology immediately, where that technology results in reduced water consumption.

Second, a growing number of project sites – where existing facilities are located or planned – may face water scarcity or shortages in the future. And those shortages will require designers, owners and builders to consider the use of new technology to bring consumption into line with site-specific water projections.

And finally, the use of water may be regulated more by local and state government and various municipalities, as local codes and regulations are developed to force any water using industry to measure and monitor its water.

"All three of these scenarios are likely to directly impact our industry at some point in the future," said Mandato. "We're definitely seeing the first and second scenarios happening now."

And as with energy, California may be the first place to look to see how new regulations will shape water usage in the years to come. "In California, further regulation of water use is becoming more of a focal point," said CCA's Kliewer. "Regulations are on the horizon surrounding water. We think there will be a focus on recycling. Facilities will need to show that they are recycling water where and when they can. Whatever form new regulations take, they will include some recycling component, whether directly related to refrigeration or other processes that reduce wastewater."

For many in the industry, where new technology investments like air cooled condensing, adiabatic condenser cooling or hybrid condensing units may be prohibitive, the answer to the question of how to prepare for impending water shortages and regulations may be to take a simple, practical approach: measure water usage and look for ways to reduce it within the scope of normal operations.

"We're getting as many or more calls from customers for help with reclaiming water and finding new ways to conserve it – as we have in the past for energy savings," said Dunn. "One way to minimize water use is to try to find water that has already been used in a plant but is not too difficult to clean. We're talking to several facilities about where to find opportunities for reclaiming the water in their plants that isn't too difficult to clean up and prepare for use as condenser water makeup."

Of course, measuring water usage in the first place is one obvious step that many facilities may not have been paying attention to until recently.

"Facilities do a certain amount of monitoring now," said Kliewer. "But we [as an industry] need to know exactly how much water we're using to begin with. Most facilities don't know exactly how much water they're using. With load variations, it's always a guess, so the first step is to look at where we're starting from and then make changes and monitor how well those changes are doing."

For Doug Scott, president of VA-Com Technologies, measuring water usage is the logical first step for an industry faced with impending water usage problems.

"In the past, water usage has not been a big enough element to quantify, but it's worth quantifying now," he said. "Just like electricity in the days before our focus on energy efficiency – water is not always measured separately. As an industry, we have got to learn how to do this if we're going to prepare for shortages in the years to come."

"It's an important cost to get accurate if people are going to be making more and more financial decisions around water," he added. "We've been doing that analysis for energy for the last fifteen to twenty years. For water, we're just starting to look at quantifying [its use]."

Executive Order 13650 — Improving Chemical Facility Safety and Security

iiar government RELATIONS

BY LOWELL RANDEL, IIAR GOVERNMENT RELATIONS DIRECTOR

On August 1, 2013, President Obama signed Executive Order 13650 entitled: Improving Chemical Facility Safety and Security. The action was driven in response to an explosion at a fertilizer facility in West, Texas. The focus of the EO is to reduce risks associated with hazardous chemical incidents to owners and operators, workers, and communities by enhancing the safety and security of chemical facilities. In the two years since the signing of the order, agencies including the Department of Homeland Security (DHS), Occupational Safety and Health Administration (OSHA) and the Environmental Protection Agency (EPA) have been working to address the goals established in the order. The Obama Administration released a status update fact sheet in June 2015 outlining the progress of the agencies.

One of the main areas of agency activity with the potential to have a major impact on the cold chain is modernizing policies and procedures. OSHA, EPA and DHS are all considering significant policy changes to major regulatory programs including Process Safety Management (PSM), the Risk Management Program (RMP) and the Chemical Facilities Anti-Terrorism Standards (CFATS) program. Each of these agencies has taken steps towards regulatory change and the issue of chemical facility safety and security will continue to be a high priority for the remainder of the Obama Administration.

OSHA PROCESS SAFETY MANAGEMENT

In November 2013, OSHA released a Request for Information (RFI) detailing potential changes to the PSM program. IIAR worked with the Global Cold Chain Alliance (GCCA) and others to develop a coalition of partners to jointly submit comments to OSHA. The comments express concern over the additional and unnecessary burdens that would be placed on industry should the regulatory proposals be enacted. The coalition of groups signing on to the comments to DHS and EPA includes: American Frozen Food Institute, American Meat Institute, GCCA, International Association of Refrigerated Warehouses, International Institute of Ammonia Refrigeration, Refrigerating Engineers and Technicians Association and the U.S. Poultry and Egg Association.

The next step in the regulatory process is formation of a Small Business Regulatory Flexibility Review Act (SBREFA) panel. These panels are designed to solicit input from small businesses impacted by the regulation. The PSM panel was announced in June 2015 and will convene during the summer of 2015. The OSHA regulatory process tends to take longer than many other agencies, so the formal proposed rule to amend the PSM regulation is not anticipated for some time.

In addition to working on changes to the PSM regulation, OSHA is also exploring non-regulatory issues related to the PSM program. An example of this is OSHA's June 2015 guidance to inspectors related to Recognized and Generally Accepted Good Engineering Practices (RAGAGEP). RAGAGEP plays an important role in how inspectors evaluate a facility's compliance with PSM.

Under the PSM regulation, employers must document that all equipment in PSM-covered processes complies with RAGAGEP. Inspections and tests performed on process equipment are subject to the PSM regulation's mechanical integrity requirements in accordance with RAGAGEP and Inspection and test frequency must follow manufacturer's recommendations and good engineering practice.

The OSHA guidance importantly recognizes that PSM does not strictly define RAGAGEP. Employers have the ability to select their own RAGAGEP. The guidance does point to the importance of consensus standards and cites IIAR as a primary source of RAGAGEP. It goes further to state that if a facility is properly following consensus standard, then they are likely in compliance. Engineering documents and technical papers can also form the basis of RAGAGEP. Employers may also develop their own RAGAGEP, but only if it meets or exceeds other applicable standards.

The document gives guidance to inspectors on the interpretation of "shall" and "should" contained in consensus standards. The guidance is clear that "shall," "must" or similar language means that the practice is a mandatory minimum requirement. "Shall not," "prohibited" or similar language means that the practice is unacceptable. "Should" or similar language in the RAGAGEP reflects an acceptable and preferred approach.

If an employer adopts "should" practice, it is presumed appropriate. If an employer does not adopt a "should" practice, inspectors are directed that more investigation is required. Inspectors will evaluate whether the employer has determined and documented that the alternate approach is at least as protective, or that the published RAGAGEP is not applicable to the employer's operations. In the absence of such documentation from the employer, the inspector

continued on page 10

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should examine documents, such as relevant process hazard analyses and management of change procedures, to determine if the employer's approach is as protective. These clarifications are important, as some members have reported inspectors citing facilities because they have not followed "should" language.

The guidance also provides a list of "enforcement considerations" for inspectors. It is important for facilities to also understand these considerations, as inspectors will be following these when they evaluate a facility's compliance. A list of the enforcement considerations is provided below:

- Multiple RAGAGEPs may apply to a facility.
- Employers don't need to comply with inapplicable RAGAGEP.
- Using inapplicable RAGAGEP can be dangerous – citations may be warranted.
- Where there is not RAGAGEP to provide full coverage, the employer is expected to develop standards to address it.
- More stringent internal standards are acceptable, but must be consistently followed or the facility will risk citation.
- Selectively applying pieces of consensus standards could be problematic.
- Inspection and testing of equipment must follow RAGAGEP.
- Employers must document compliance with RAGAGEP.
- Equipment under Mechanical Integrity that is outside acceptable limits must be corrected before use.
  - Interim measures may be acceptable, but warrant inspector scrutiny.
- Employers must ensure that older covered equipment is designed, maintained, inspected, tested, and operating in a safe manner.
- When evaluating citations for equipment:
  - Establish age and installation date
  - Modifications
  - RAGAGEP selected
- When organizations update RAGAGEP (IIAR standards, as an example):
  - When the update is explicitly retroactive, facilities must comply.
  - When stated proactively – Facilities are not mandated to comply, but must demonstrate how new hazards are addressed.
    - – Can use PHA, MOC, corporate monitoring, review of published standards
- Inspectors are directed to notify OSHA headquarters if they encounter RAGAGEP that is not adequately protective.
- When writing citations for inspections and testing:
  - Reference RAGAGEP selected by employer.
  - If no RAGAGEP selected, reference applicable example(s).
- When citing for inspections and testing frequency:
  - Cite frequencies listed in manufacturer's recommendations and GEPs.
  - Or more frequently, if indicated by prior operating experience.
- RAGAGEP citations should only reference applicable RAGAGEP.
- Cites cases where API is used in ammonia refrigeration facilities.

EPA RISK MANAGEMENT PROGRAM

EPA issued a Risk Management Program (RMP) Request for Information (RFI) on July 31, 2014 seeking comment on potential revisions to EPA's RMP regulations and related programs to modernize its regulations, guidance, and policies. The proposed rule seeks to reduce the likelihood of accidental releases of toxic and flammable substances at chemical facilities, and improve emergency response when those releases occur. IIAR, along with coalition partners, provided detailed comments on the RMP RFI expressing concern with many of the proposed revisions. Similar to OSHA, EPA is also seeking small businesses, governments, and not-for-profit organizations to participate as Small Entity Representatives (SERs) for a Small Business Advocacy Review (SBAR) Panel. This panel will focus on the Agency's development of a rule that proposes to modify the current RMP.

EPA has indicated its desire to issue a proposed rule to amend RMP by the end of calendar year 2015. The rulemaking is a high priority for the Obama Administration, so EPA will be pushing to have a final rule completed before the end of President Obama's second term.

DHS CHEMICAL FACILITIES ANTI-TERRORISM STANDARDS PROGRAM

As a part of the implementation of the Executive Order, DHS published an Advanced Notice of Proposed Rulemaking (ANPRM) in August 2014 to modify the Chemical Facility Anti-Terrorism Standards (CFATS) program regulations. IIAR and coalition partners also provided comments on the CFATS rulemaking. The coalition's comments centered on the applicability of CFATS to ammonia refrigeration facilities. To date, the number of facilities deemed high risk and given a CFATS tier with ammonia being the only chemical of interest is extremely small. The coalition is urging DHS to remove the Top Screen requirement for facilities only subject to CFATS due to anhydrous ammonia.

DHS is in the process of reviewing the comments received from the ANPRM. DHS has indicated that a formal proposed rule could be published during 2016. A final rule would not likely come until late 2017 or sometime in 2018.

As the Obama Administration and key agencies including OSHA, EPA and DHS continue implementation of Executive Order 13650, IIAR and its partners will continue to actively engage in the process to promote and protect the interests of the cold chain industry. Members are encouraged to stay informed so they can be aware of the potential changes that could impact their business.


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ARF Launches New Research Project Selection Process

The Ammonia Refrigeration Foundation has launched a new process to select its research projects, which now starts with a simple, one-page form. The process makes it easier for IIAR members to submit their ideas to the research committee. The form, which is available online, is used to explain the proposed project, state its potential benefits and merit, and can be submitted by any IIAR member.

In addition to this form, there have been improvements made, including a formal research plan to track all phases of the ideas and projects and a format to create a research project work statement.

Wayne Wehber, chair of the ARF research committee, said he hopes the simplified one-page form that starts the selection process will encourage more members to submit ideas.

The research committee, which is made up of 13 voting members, will review the one-page form. If the committee supports the idea, either the initiator of the idea, another volunteer or even a team of volunteers will develop the idea further by completing the research project work statement.

"This would be the document that would be reviewed and approved to move forward in addition to being utilized to define the scope to allow a vendor to bid on a project," Wehber said. "If you [as the idea submitter] don't want to go through the next step—the work statement – someone on the research committee can do that."

The research committee has been developing the revised research process for the past year-and-a-half, and has defined the process to select a project, obtain bids, and follow the project with sub-committee reviews. "The research committee now has a structured format to take ideas and make them into projects that have some substance," Wehber said.

Ideas should address areas that, if analyzed, tested or studied, would benefit the organization in some manner.

"The stereotype that the research committee focuses only on types of research that may be earth shattering for the future is incorrect. We look for practical solutions and answers in many categories," Wehber said.

The research committee typically focuses on topics that can directly benefit IIAR members in their daily lives in the industrial refrigeration environment, including safety, sustainability and energy efficiency, as well as system design and operational practices.

"Many times the projects that are chosen have originated from other committee members to provide clarity or input to solve an issue or to derive a conclusion that provides direction to that committee," Wehber said.

He added that ARF-funded research often falls into two broad categories. The first includes instances where data is collected on an issue, then is organized to provide an appropriate guideline for industry use. The second includes instances of IIAR conducting research to better understand the mechanics or characteristics of a situation that affects the industry.

Currently, two research projects are underway. Future projects now being considered include installation guidelines for insulation, modeling of an ammonia leak to determine ammonia gas monitor locations and operating system challenges in cold temperatures.

There is no limit to how many projects the industry can take on, and Wehber said he would like to see ARF research get to a level where three to four projects are in process at all times.

Funding for the research committee comes from the Ammonia Research Foundation, which exists thanks to the generous donations provided by IIAR members. "I encourage everyone to submit ideas, work through any of the committees as appropriate, or possibly become a member of the Research Committee to help us in this process," Wehber said.

ARF-Funded Research Projects Near Completion

COMMITTEE CONSIDERING ADDITIONAL TOPICS

IIAR's research committee is continuing to move forward on two research projects funded by the Ammonia Refrigeration Foundation. Both projects will be presented as papers at future IIAR conferences.

The first project, titled *The Investigation of Entrance Effects on Two-Phase Flow in Vertical Suction Risers*, covers the influence, appropriate use and benefits of a P-trap versus a 90-degree elbow inlet on a two-phase vertical suction riser. The second project, titled *Optimum Pipe Sizing*, revisits the economic sizing methodology the industry uses to determine optimum pipe sizing.

With the first project, focused on two-phase flow, researchers are hoping to more fully understand how different configurations affect fluid flow behavior and how liquid is collected before being swept up the pipe. "The study examines the effect of the entrance to two-phase suction risers on flow patterns and on pressure drop," said Bruce Nelson, a member of the research committee, and the project's monitoring subcommittee chairman.

Researchers are currently examining the differences in pressure drop produced by using a simple 90-degree elbow to a vertical two-phase suction riser versus the pressure drop produced by a P-trap installed at a vertical two-phase suction riser. No such comparison exits today, Nelson said.

"The arrangement and the design of piping in an ammonia refrigeration system are very important to the proper operation of evaporators," Nelson said, adding that evaporator performance is very sensitive to pressure drop in two-phase suction risers.

The research project – which is being conducted by the Danish Technical Institute – is utilizing equipment and information from research into refrigerant flow that DTI is conducting for ASHRAE. "That study is examining the two-phase flow in the riser itself," Nelson said. "What we're doing is putting a P-trap at the exit to the evaporator, and that forms a liquid seal and also serves to aspirate liquid so that liquid droplets can be carried up the vertical suction riser, carried away by the piping and carried to the liquid recirculator package."

The information will help designers configure vertical suction riser systems in a way that minimizes pressure drop, Nelson said. The research should be complete by March. "The study results will provide designers and engineers with guidance on the appropriate use and benefits of utilizing a P-trap versus a 90-degree elbow," Nelson said.

Meanwhile, the Optimum Pipe Sizing research project will provide an up-to-date, electronic means of determining pipe sizing for industrial refrigeration systems using a software program. The study will also revisit the economic sizing methodology the industry uses to determine optimum pipe sizing.

The goal is to produce a computer-based tool that takes into consideration construction costs, system energy costs and life expectancy, and will allow end users to determine optimum pipe sizing based on input data. That input data would include the initial cost of a piping system, energy cost, life expectancy and refrigeration system operating efficiency, said Wayne Wehber, chair of the IIAR research committee.

Under the project, researchers will also 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. Researchers will use current piping system cost data, including current figures for 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.

Ultimately, the computer tool will help facilities make the decision on how much to spend on piping initially, and will help to determine the return on investment.

In addition to creating a computer-based tool, the research will be used to update and expand the recommended pipe sizing in the IIAR Piping Handbook. "Inside our piping handbook there is a table or guideline on the recommended pipe sizes to use based on a combination of costs—and that was put together last in the 1960s. One can imagine that there is a lot more to it now," Wehber said.

IIAR is also in the process of reviewing and drafting additional work statements on potential research projects, and has set the goal for several of them to become ARF-funded projects in the upcoming year.

One such project, if approved, would monitor a dispersion event to

ARF Meets Growing Industry Need for Research

In 2006, the IIAR leadership realized that in order to meet the growing need within the industry for targeted research with industry-wide benefit, it needed to put a mechanism in place for funding a growing list of important research projects. This led to the formation of the Ammonia Refrigeration Foundation (ARF), a non-profit 501(c)(3) organization, whose mission is to fund research and education projects for the benefit of all IIAR members. ARF works closely with the IIAR Research Committee to make this mission a reality in the area of research.

help determine the location and level of ammonia to help researchers determine the best locations for ammonia level monitoring detectors.

ARF Trust Fund Tops $2.2 Million

The Ammonia Refrigeration Foundation reported that it has raised $2.2 million to fund research and education in the industrial refrigeration industry. The number represents nearly two-thirds of ARF's $3.5 million funding goal, which it expects to reach in the next three years.

"The [$2.2 million] that we reached this year is the highest that the ARF endowment has ever been," said Tim Facius, ARF Executive Director. "It's particularly exciting now because there are many activities and developments currently taking place within ARF."

ARF funding drives IIAR research activities and scholarship programs. Among several goals for 2015, ARF announced a new scholarship program administered by a subcommittee of the IIAR Education Committee. The new program will deliver larger scholarship awards geared towards creating higher levels of engagement from scholarship awardees within the industry.

"The scholarship program has been completely revamped and is now being administered by an education subcommittee," said Facius. "The key is that we are providing larger awards, and we're working harder to get much better engagement of our awardees in our industry."

Among a few new goals of the scholarship program are an increased emphasis on getting awardees to attend the IIAR conference and setting up programs so that more mentorship is available.

"We are working to make sure our scholarship awardees are motivated to seek fulltime involvement in this industry when they graduate," said Facius.

In addition to the scholarship program, IIAR's ARF-funded research program is delivering two important research projects that are currently underway, and recently announced a new method of vetting future potential projects.

Meanwhile, ARF's growth is expected to continue as the foundation nears its $3.5 million funding target in the next three years. Recently, ARF contracted with Graham-Pelton Fundraising Consultants for help in structuring ARF to meet that goal.

"We're not complacent at our current $2.2 million endowment level," said Facius. "Our goal is to reach $3.5 million because that is the level we need to sustain growth in our research and education areas."

Facius added that ARF expects Graham-Pelton to help the foundation structure itself for growth and provide the infrastructure to better communicate ARF successes and better reach potential contributors.

"This is such an exciting time for ARF, and for our organization," said Facius. "This effort significantly benefits our industry. So many great things are going on, and those efforts are laying a strong foundation for the years to come."

ARF Names Scholarship Recipients

he Ammonia Refrigeration Foundation, which supports research and education programs benefiting the industrial refrigeration industry, has honored Munier Francis, a senior at California's Polytechnic Institute at San Luis Obispo, with its annual scholarship award.

Francis is pursuing his degree in mechanical engineering. "My real passions within mechanical engineering are thermodynamics and heat transfer, so naturally I'm very intrigued with refrigeration," Francis said. "It means a lot that I won since I truly feel passionate about this field of mechanical engineering."

The goal of the ARF scholarship program is to encourage young engineers to pursue careers in industrial refrigeration and help develop new interests for natural refrigerants. Bob Port, chairman of the IIAR scholarship committee, said college students often have little exposure to industrial, ammonia refrigeration in college. "There is not really a vehicle in colleges where students get exposed to the industry at all. This whole program is a way to allow young men and women to become more aware of the industry while they are in college," Port said.

Francis received a $3,000 base scholarship for the year and will receive another $3,000 if he attends the IIAR convention, which he is looking forward to. "I'm very excited about the meeting because I will get a very close look into the organization and the industry. I also look forward to meeting others in the organization and learning about what opportunities exist for someone in my position," he said. "Industrial refrigeration is such a critical part of our economy and civilization as a whole. I'm excited to see what's in store and what potential roles I can fill."

Going forward, ARF will present three scholarships annually to students who are entering their junior year, Port said. "In broad terms, they are a base scholarship of $2,000 a year for two years. If an individual goes to the IIAR annual meeting—we will include the invitation as the part of the scholarship in the junior year—then we will kick in another $2,500 a semester, or $5,000 for the year, into their senior year scholarship," he explained, adding that ARF's goal is for six students to be receiving the scholarship at one time.

ARF's goal is to announce three scholarship recipients in March 2016, and is targeting Feb. 1, 2016, as the application deadline. "We want to get in a cycle where on the last day of the annual meeting, we would announce three additional scholarship students," Port said.

To promote the scholarship, ARF sends the announcement to the general membership and to a list of contacts at a number of universities. "Start looking for an online application around the first of October on the ARF website," Port said, adding that applicants need to have a B average in an engineering discipline applicable to the refrigeration industry to apply.

ARF will also be presenting a second scholarship opportunity this year to allow disadvantaged students to attend the IIAR annual meeting. The opportunity is meant to give them a greater understanding of the industry. Applications for the conference scholarships, which are funded with a grant from Praxair, will be available in October, and will be due mid-December.

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Curb Your (People's) Enthusiasm

BY KEM RUSSELL

Having enthusiasm for your work and a desire to accomplish something is good. I have worked with many people in the industrial refrigeration field that are enthusiastic, fun to be around, and even in challenging or stressful situations they have worked through issues in a positive manner.

But I also have seen some instances where enthusiasm quickly overwhelmed the knowledge and training level of facility personnel, which put them and others in an unsafe situation.

In every work environment, a manager's responsibility is to safeguard that enthusiasm. And while that often means encouragement, it also means cultivating a high level of situational awareness so that the talent of your people can thrive in a safe environment. For this edition of Lessons Learned, I'm going to focus on the dangerous side of enthusiasm.

Several years ago I was involved in the startup of a distribution center that was mostly low temperature storage, using ammonia as the refrigerant. This facility was in a Spanish speaking country in South America, and since I speak only a few words of Spanish, I relied on others who were bi-lingual. As the startup went along, I communicated to the installing contractor and the operators, through an interpreter, about various aspects of the gas powered liquid recirculation refrigeration system and the refrigeration computer control system.

A few days into system start-up, as we arrived at the facility, I could immediately tell from the frenzied activity of the team and that "deer in the head lights" look that something was definitely wrong. We were asked to immediately come to the machine room. When we got to the door of the machine room, we heard that distinctive, loud, sound of pressure being released, similar to a relief valve discharging. At the same instant we saw a white cloud rapidly develop just below a low pressure receiver and float down the walk space between the compressors. The release seemed to last only a few seconds, but it certainly could have been longer – as time perception often gets distorted during an emergency (another lesson learned). Two operators had started to disconnect the relief discharge line from the relief valves on a liquid transfer vessel (LTU).

The lesson I learned here was "DO NOT" skip the step of teaching and verifying that all those involved in a project have and know how to use the appropriate personal protective equipment, and have reviewed procedures to follow if a release happens.

Having no idea what was happening or how soon this might happen again, we first directed others to ventilate the room. At this point I realized – that in my own enthusiasm to get this system operational – I had neglected to communicate a few very important pieces of information to the operators and others working in and near the ammonia system.

I, or someone else, should have instructed everyone to continually ask themselves: What is this chemical?; What are we doing with it?; and, What can it do to you?

The answer to that last question would have addressed not only the situational awareness that was missing, but how to properly protect yourself, and important steps to consider when a release occurs.

The lesson I learned here was "DO NOT" skip the step of teaching and verifying that all those involved in a project have and know how to use the appropriate personal protective equipment, and have reviewed procedures to follow if a release happens.

As I mentally kicked myself for not being able to speak Spanish and better prepare the operators, I saw two refrigeration operators – with good intentions, but an over-abundance of enthusiasm – that were in the machine room near the release point trying to do something.

One of these men was standing right next to a LTU located directly below the low pressure receiver, and the relief valve that appeared to be releasing was on that LTU. The other person stood within arm's reach of the first person. The only PPE the man next to the LTU had on was a face shield. The other man didn't even have that. If the release happened again, the man nearest the LTU could have been seriously injured, or killed.

I stood in a safe location, but was extremely scared of what could happen to those two men if they stayed where they were. Through an interrupter I said those men need to "Get out of there!" It seemed like it took a long time before they finally, and reluctantly, did leave the machine room. Just after they left, a release happened again. These men again wanted to get back in there and stop the leak. We told everyone that "No one" is going back into that machine room until we get some idea of what is happening, make sure there was proper PPE worn, and it is safe to enter.

As the release happened again, and with people no longer in danger, we watched and thought it didn't look like it was coming from the relief valve on the LTU. Investigating further, we noticed that most of the main relief header running down the middle of the machine room was covered in frost, and one particular line going up through the roof was also frosted.

Why was this vertical relief line frosted? We went up on the roof to see where this line came from and there we found the source of the continuing release. The release source was a roof mounted purger that had its relief connected into the main relief header system. The purger was not functioning properly and was periodically filling up with liquid, building up pressure, then blowing its relief. Each discharge was a small amount of liquid ammonia, which vaporized as it traveled down the relief piping system and blew out the loosened relief discharge piping connection at the LTU.

In this incident, the two operators, in their enthusiasm, had focused on what they thought was the cause of the release. They had rushed in to stop the leak without proper PPE, not understanding what was happening, or even looking for other clues that could have lead them to the real cause. Their enthusiasm nearly cost them their lives.

The lesson that these men and all of us should learn is: if you don't have the proper training, proper PPE, and do not understand what is or what can happen "DO NOT GO." Wait until there are trained and knowledgeable people with the proper equipment to safely address the incident. The second lesson is to have training, adequate and knowledgeable leaders on site, and sufficient PPE available and ready to use prior to introducing ammonia into a system, or a portion of a system.

Generally, people are interested in doing their work well and helping, but many times they let their enthusiasm to get something done interfere with taking that essential step of stopping and thinking, "Is what I am about to do safe?; Do I and others have the proper training, PPE, and equipment to handle this situation?" Take time to consider what is happening, or could happen. And if you're in doubt, ask some other knowledgeable or experienced person to take a look.

Yes, we all have times when there are deadlines we need to meet, but don't be in such a rush that your enthusiasm to do good work gets in the way of doing your work safely, and most importantly, training others to ask if they are doing their work safely.

Lowering Charge with Advanced DX Ammonia

This technomercial was authored by Colmac Coil Manufacturing Inc. to highlight the company's offerings and provide an overview of Advanced Direct Expansion technology, with case studies.

Colmac Coil is one of the world's leading manufacturers in the new and replacement coil markets with a mission to provide heat transfer and refrigeration markets worldwide with innovative products that are configured, manufactured and shipped with some of the shortest lead times in the industry

Figure 1 Preferred Freezer Services, Richland, WA

New technology that utilizes low charge direct expansion at low temperatures can improve safety and reduce the first cost of installation, while significantly reducing the ammonia charge required on site. That, in turn, can reduce the regulatory burdens associated with large ammonia inventories.

"We've developed a special evaporator technology that allows us to get the same cooling effect from the evaporator with less ammonia," said Bruce Nelson, president of Colmac Coil. "Our Advanced Direct Expansion (ADX) technology requires 30 to 50 times less ammonia in the evaporator compared to pumped ammonia. This removes a lot of ammonia from the occupied space."

Reducing the amount of ammonia required in the refrigeration system is directly related to safety. Ammonia is the perfect refrigerant. It is highly efficient, low cost and environmentally friendly. Reducing the amount of ammonia on the site reduces risks associated with exposing people and products to ammonia in the event of a release.

The new ADX technology also provides faster defrosting, effective operation at multiple temperature levels, good response to changes in load, fast restart after power failure, and simplified maintenance and operation through elimination of recirculation pumps.

"Most of the reduction in the ammonia charge takes place in the evaporators. We have to have ammonia in the system, but using the Advanced Direct Expansion system can minimize the amount. The evaporators are installed in the cold space to absorb the heat and cool the air and are the part of the system closest to the products and people, so reducing the ammonia charge in the evaporators has a big benefit in terms of reducing risk." Nelson said.

Figure 2 Setting ADX Evaporators

To make direct expansion with ammonia work at low temperatures, three fundamental problems had to be addressed.

"The first had to do with finding a way to overcome the separation of the liquid and vapor phases inside the evaporator tubes. At low temperatures all of the ammonia liquid runs along the bottom of the tubes, leaving the top of the tubes dry, and that results in a very large reduction in cooling capacity. Colmac solved this problem by adding a proprietary enhancement on the internal tubing surfaces which acts to distribute the liquid ammonia and wet all of the tubing surfaces evenly."

"The second problem is the large negative effect on evaporator performance of even small amounts of water in the ammonia. The ADX design automatically and continuously removes water from the system and keeps evaporators operating at peak performance."

Case Studies

TA number of facilities with ADX have been successfully installed and are operating in the United States and in Australia:

Joliet Cold Storage, Joliet, IL
Joliet Cold Storage is a 402,000 square foot Public Refrigerated Warehouse designed and installed by AMS Mechanical of Chicago. The total refrigeration load of 1,007 TR requires only 8,500 lbs of ammonia charge. According to Rick Watters of AMS Mechanical, "The system is easy to work on and restarts quickly after a power failure."

Preferred Freezer Services, Richland, WA
This project is a 40 million cubic foot, fully automated high rise refrigerated warehouse serving multiple frozen potato product processing facilities in central Washington. The facility is the largest refrigerated warehouse in North America and the largest automated freezer in the world. The project has a total refrigeration load of 1,140 TR. It is also the first project in North America with a low-oxygen fire suppression system in the freezer area. The refrigeration system was installed by Unitemp Refrigeration of Atlanta.

United States Cold Storage, Laredo, TX
In Laredo, Texas, United States Cold Storage built a 75,000 square foot expansion to an existing public refrigerated warehouse facility. The total refrigeration load of 207 TR was delivered with ADX and 1,500 lbs of ammonia. The ADX system allowed this expansion without an additional recirculator package. The design build contractor was Stellar Group of Jacksonville, FL.

The new ADX technology has also been able to compete successfully with conventional HFC systems:

Bidvest Bibra Lake, Perth, Australia
For this project, a new 46,300 square foot food service distribution center was constructed using ADX technology and highly efficient two-stage compression with reciprocating compressors and VFD controls. The total refrigeration load is 141 TR with an ammonia charge of 1,067 lbs. Just the reduction in power consumption compared to an air-cooled HFC system resulted in a simple payback of three years. The facility is also fitted with a 300 kW PV solar array on the rooftop, which generates more power than the facility consumes. The design build installing contractor was Scantec of Brisbane, Australia.

"The third challenge had to do with distributing the ammonia equally to all of the parallel circuits in the evaporator. Conventional refrigerant distributors that operate on a pressure drop-turbulence principle just don't work well with ammonia. Our Tank Distributor is designed to work with very low pressure drop over a very wide range of cooling capacities. It is insensitive to subcooling, and allows the same evaporator to work over a very wide range of temperatures and load conditions - for example in convertible rooms," said Nelson.

Low-charge ADX ammonia technology brings with it a number of cost savings. It is less expensive to install than a traditional pumped ammonia system because of smaller line and vessel sizes, and elimination of the recirculator package, making return on investment extremely attractive with ADX.

Additionally, lowering the amount of ammonia stored on-site can reduce the number of regulatory inspections facilities face.

Meanwhile, several government agencies are taking a closer look at the regulation of refrigeration plants. Because of the National Emphasis Program, systems with an ammonia charge of 10,000 lbs or more may put that facility on a short list for visits and inspections by EPA, OSHA, and the Department of Homeland Security. Reducing the system ammonia charge is beneficial, no matter the size of an operation, but being able to design a large facility with less than 10,000 lbs is a significant reduction in regulatory burden. With a technology like low-charge ADX, that capability is coming into the mainstream.

The Colmac ADX system is covered by a number of USA and foreign patents.
For more information about Colmac Coil ADX technology, please contact Jeremy Olberding, VP Sales, at jeremy.olberding@colmaccoil.com, or call (800)845-8331.

Implementing Real-Time Profitable Safety

Profitability is always an important issue, and plant managers are frequently faced with addressing safety challenges while striving to achieve higher levels of production and efficiency. But instead of looking at safety and production separately, as many facilities often do, the two can be combined into one dynamic process called real-time profitable safety.

"Even though everyone has good intentions, production usually wins out as a focus [with safety as a supporting priority] unless you've created a culture where production and safety are one in the same," said Gary Smith, president and co-founder of the Ammonia Safety and Training Institute.

But improving safety has a direct correlation to the bottom line, and the idea of real-time profitable safety can create a 3 to 5 percent improvement in earnings, said Smith. "When the team has a safe operating environment, it allows them to produce more. The idea that safety and profitability go hand-in-hand presents a genuine opportunity for each function to supplement the other, boosting both," Smith said.

Real-time profitable safety is driven by dynamic production forces within a plant, such as higher levels of power consumption, use of raw materials and increased production team activity, according to Peter G. Martin, a PhD and industrial engineer.

Martin, who serves vice president of Schneider Electric, headquartered in Boston, said the safety of people, equipment, facilities and the environment is becoming increasingly important in industrial operations, in part, because executives are increasingly aware that safety is directly linked to profitability.

As part of the day-to-day operations in the industrial refrigeration industry, the safety manager should be an active member of the production team, which helps to make safety and production a combined concern of the entire management team. "Make sure they are actually a member of the production team so when they have the need to make a decision related to safety, they have the authority to do so," Smith said.

Martin has recommended that the traditional vertical hierarchy of safety spending approval be replaced by horizontal leadership empowerment and funding authority to maintain a safe and productive work environment. "The production manager and safety manager can work together," Smith said.

Profits increase when workers are supported by effective managers who set a priority on maintaining a clean and safe work environment. Smith pointed to one incident he witnessed when he served as fire chief – where he was involved in a serious fire that started as an arc in a panel and grew into a full structure fire because of poor housekeeping and large amounts of goods stored within the mechanical room.

"Sometimes those habits of not keeping things clean and organized, or ready for an emergency, can cause a small problem to lead to something big," Smith said. "When you're keeping things squared away and organized and things are operating smoothly, you'll see when something out of the ordinary starts to happen. It could be a minor leak or a gasket or a seal on an ammonia pump or it could be something more significant. In either case the operator knows that the problem needs to be fixed before the small problem suddenly grows to cause need for emergency response."

Management should also closely monitor storage load capacity, scrutinize room temperatures and address mitigation. "There are things you engineer or design into the system to reduce the potential for a problem to become a significant issue," Smith said.

Having barricades or safety guards are one way to mitigate a potential problem, as are early warning devices that can alert employees to an issue before a problem arises. "The operations team must also be trained to engage the plant emergency plan without delay, so when something does go wrong, you know what to do and can stop the problem when it is small," Smith said.

Martin said executives are typically willing to invest in approaches that measurably improve profitability, but, traditionally, the payback for safety measures is not always obvious. By embracing a new way of thinking about measuring and improving safety and embracing real-time profitable safety principles, the organization will improve safety, resulting in better working attitudes around safety and higher levels of commitment to all plant management goals.

Real-time profitable safety is driven by dynamic production forces within a plant, such as higher levels of power consumption, use of raw materials and increased production team activity.

– Peter G. Martin, a PhD and industrial engineer.

IIAR Creates Compliance Guidelines Committee: Issues Call for Volunteer Members

IIAR Committees serve as a valuable forum for the open discussion of the critical issues facing the industry. IIAR's Compliance Guidelines Committee, is one of the organization's newest committees. Its purpose is to review, revise and publish IIAR guidance documents that currently do not have a formal home within any of the other committees. Those documents include the Ammonia Data Book, the Process Safety Management & Risk Management Program and the Ammonia Refrigeration Management Program.

"In the past these documents were written externally, and we want to bring it in house and rely on the expertise of our members, rather than going outside to somebody else if possible," said Eric Johnston, chair of the new committee. Johnston is also principle engineer-PSM for ConAgra Foods, a member of IIAR's board of directors and a voting member on the Standards Committee.

Johnston said it has been a number of years since the documents were last updated. The Ammonia Data Book was last updated May 2008. The Process Safety Management & Risk Management Program Guidelines Volume I & II was updated in 2012, and the ARM Program was last updated in 2005 with references within the document being updated in 2007.

The committee will begin work to review those publications, and will also be working with the Standards Committee to develop a Recognized and Generally Accepted Good Engineering Practices standard. "This document is currently in the process of being developed, and I anticipate a lot of time and effort in the immediate future on this document," Johnston said.

Michael Chapman, manager of process safety and risk management programs at Tyson Foods and an IIAR board member, is the co-chair for the committee. Johnston encouraged IIAR members to get involved.

"We're looking for additional members that want to be actively involved in reviewing these documents and making modifications," Johnston said. "From my standpoint, the best people to get involved are those that deal with the regulatory agencies and compliance. These documents are specifically giving guidance to end users on how to comply with regulations."

IIAR Remembers Fred Gary Walker

Fred Walker was known for his unfailing work ethic, integrity and commitment to the refrigeration industry, in which he was involved for more than 40 years.

"A saying Fred used was, 'The only thing better than coming in early is staying late,' and he lived it. I don't remember going to the office and he wasn't there and he never left before I did," said Mike Elliott, regional PSM manager, Central, for Americold Logistics, who worked alongside Walker for more than 25 years.

Walker, 68, passed away on August 10 after a brave battle with cancer. He was born on Nov. 21, 1946, in Modesto, California. After finishing school, Walker served in the U.S. Military before entering the refrigeration industry. He was employed as an engineer by Americold Logistics for 41 years, retiring as vice president of engineering in July. "He started as a plant engineer and he made his way up through the ranks with hard work," Elliott said.

What's more, Walker was a true advocate of safety and technology. "We were at the forefront of installing process safety management early on," Elliott said. "He was always at the forefront of the refrigeration industry. The reality is that he was always willing to advance new technology."

Wayne Hay, director, regional facility services, U.S., for Agro Merchants, and a former colleague of Walker's, said, "I think the one thing I have noticed while Fred was sick and after he passed is that I could not attempt to count how many times I have said and heard from others, 'If it wasn't for Fred….'"

Walker served two terms on IIAR's board of directors, including one term as chairman—something that was a lifelong goal for him. "He told me one time on a long car trip in the middle of the night that one of his life's goals was to be chairman of the IIAR, and he was able to achieve one of his life dreams," Elliott said, adding that Walker was always willing to share his knowledge with others.

"He was a taskmaster. He expected the best of all of us. It made us all better people."

– Wayne Hay, director, regional facility services, U.S., Argo Merchants

Hay said, "Fred wrote many bulletins published by the IIAR and helped create many training videos. Fred also was very involved with the Lanier Technical College of Ammonia Refrigeration Training."

Walker was also eager to teach, and was an incredible resource to many as a mentor. "At the end of the day he was one of the smartest men I ever knew," Elliott said. "He was a taskmaster. He expected the best of all of us. It made us all better people."

Walker's wife of 47 years, Maxine, warned Hay about her husband's work ethic before he went to work for Walker. Hay and his wife visited the Walkers in Atlanta and the four went out to dinner. "At the dinner Maxine said, 'Wayne, do not take this job. You will end up working 24 hours a day.' I took the job and yes she was very close. If I got to the office at 5 a.m., Fred was there. If I stayed to 9 p.m., Fred was there," Hay said, adding that he worked with Walker for more than 13 years at Americold.

Walker's colleagues said he had an impressive memory. "Fred never forgot anything. If he told you to do something in a warehouse and he went back 10 years later, the first thing he would do is check to make sure what he told you 10 years ago was done," Hay said.

Walker is survived by Maxine along with his daughter, Tina Koehler, and her husband, Christopher; his son, Rodney David Walker, and his wife Candace; six grandchildren; and his mother, Olive Walker.

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Two Years Later: Texas Explosion is Catalyst for Change

For the ammonia and chemical industry, the ammonium nitrate explosion in West, Texas, in 2013 has served as a catalyst for change, causing several government agencies to examine their policies and update safety regulations. Now, regulatory agencies are drafting requirements for a number of chemical industries that will require them to follow the Process Safety Management guidelines—requirements that the industrial refrigeration industry has had to follow for years.

"If we hadn't had the accident in West, Texas, there wouldn't have been an executive order issued by the Obama Administration then there wouldn't be a working group looking at modernizing policies and procedures," said Lowell Randel, vice president of government and legal affairs for IIAR. Randel pointed out that the tragic accident led to increased scrutiny on sectors of the chemical industry that were previously not subject to safety programs that the ammonia refrigeration industry has followed for decades.

The explosion, which was caused by ammonium nitrate, occurred in a part of the farm industry that is not currently subject to some of OSHA and EPA's regulations. However, the media scrutiny that followed the event made it clear the public is largely uneducated about the safety record of the industrial refrigeration industry, which has one of the best safety records of all American chemical industries. In fact, in the West, Texas, explosion, the tanks that were holding anhydrous ammonia on the site remained intact before and after the explosion.

The refrigeration industry is heavily regulated and must meet very stringent and formalized safety standards. Agencies are considering the application of these standards for other chemical users, like farm installations that use ammonia compounds in hopes of preventing future disasters that result in scrutiny of all chemical industries. "With respect to ammonium nitrate, it has not been subject to these programs in the past," Randel said.

While some of the regulatory proposals surrounding safety directly relate to the West, Texas, incident, some don't. "This is an opportunity for agencies to explore potential policy changes they've maybe been thinking about for some time but haven't had the opportunity on which to act," he said.

The new regulations address a number of areas, including restrictions to retail exemptions and expansion of the PSM reach that deals with chemical concentrations. Randel said the changes will also put more emphasis on engagement with first responders and the coordination between federal agencies as well as data sharing among federal agencies.

IIAR has been communicating with the Occupational Safety and Health Administration and the Environmental Protection Agency on many of the proposed changes, because they will have significant impact on IIAR's membership, Randel said. He added that he believes the EPA will most likely move forward with their proposals first. "This is a high priority for the Obama administration and they will want to see movement in these changes before the end of the administration," he said.

COMPARING EVAPORATIVE AND AIR COOLED CONDENSING FOR AMMONIA SYSTEMS

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Editor's Note

For ammonia refrigeration systems, evaporative cooled condensers are the most common technology in use today. But increased water costs as well as reduced water availability in many areas are making water conservation an important component of sustainability efforts for many companies. In this technical paper, the author compares evaporative cooled condensing and air cooled condensing for an ammonia system in a refrigerated warehouse in six U.S. cities. The comparison uses detailed hourly simulation of the refrigeration plant and local electric and water rates. The primary effort of the analysis work focuses on energy usage and electric costs, since this is the greatest "unknown" in considering air cooled ammonia systems. The most intriguing value of air cooled ammonia systems may be as an alternative to other refrigerants, changing the default assumption that air cooled condensing requires halocarbon refrigerants. However, the scope of this technical paper is limited to ammonia, to provide a focused comparative analysis of energy use and costs between evaporative and air cooled condensing methods.

The author of this technical paper will present a follow-up paper on this subject at the 2016 IIAR Conference in Orlando, Fla., where he will provide additional case study analysis with new information on alternate refrigerants. The author will include broader climate region data and comparative equipment cost as part of the analysis.

ABSTRACT

Ammonia is the ideal industrial refrigerant, with high efficiency and broad utilization in industry, as well as attractive environmental properties. Use of air cooled ammonia systems is uncommon, though, with almost all ammonia systems employing evaporative condensers, based on past practice and assumptions concerning efficiency and system performance. The efficient use of air cooled condensing could allow the benefits of ammonia to be realized more widely. This paper studies efficiency and utility cost of a refrigerated warehouse using an ammonia refrigeration system in six U.S. cities, comparing evaporative and air cooled condensing.

INTRODUCTION

Ammonia refrigeration systems use evaporative cooled condensers almost exclusively. Due to the large size of most ammonia systems, historical context, and industry perceptions regarding performance and efficiency, air cooled condensing is seldom considered for ammonia.

Increased water costs as well as reduced water availability in many areas are making water conservation an important component of sustainability efforts for many companies. This paper compares evaporative (evap) cooled condensing and air cooled condensing for an ammonia system in a refrigerated warehouse in six U.S. cities. The comparison uses detailed hourly simulation of the refrigeration plant and local electric and water rates. The primary effort of the analysis work focuses on energy usage and electric costs, since this is the greatest "unknown" in considering air cooled ammonia systems.

The most intriguing value of air cooled ammonia systems may be as an alternative to other refrigerants, changing the default assumption that air cooled condensing requires halocarbon refrigerants, historically HCFC-22 which is currently being phased out, and more recently HFC refrigerants which are under pressure to be phased down. However, the scope of this study is limited to ammonia, to provide a focused comparative analysis of energy use and costs between evaporative and air cooled condensing methods.

BACKGROUND

Ammonia is the dominant refrigerant for industrial refrigeration systems due to its low cost and availability of ammonia, its attractive thermodynamic and its physical properties, resulting in high system efficiency. Evaporative condensing has been the standard for ammonia systems, with almost no use of air cooled condensers.

The higher design pressures required for air cooled systems, affecting compressors, piping, valves and vessels, has limited equipment availability and has been a significant cost consideration. During compression ammonia produces high actual discharge temperatures, which are exacerbated by the higher discharge pressures with air cooled systems. While not a concern on screw compressors which use oil or liquid cooling during compression, this characteristic becomes more apparent and more difficult to address with reciprocating compressors. This, in addition to higher operating pressures, helps explain why air cooled condensing has had little historical use in ammonia systems.

STUDY DESIGN

For this study, a medium sized refrigerated warehouse was employed, as shown in Figure 1, with freezer, cooler and dock spaces. The ammonia refrigeration system uses two suction levels, each with two equal-size screw compressors. The design assumptions and equipment selections are shown in Appendix I.

Six cities were used for the study, primarily to obtain a range of weather conditions. Since there is no particular correlation between weather conditions and electric rates across the country, the comparison of annual energy consumption provides the most relevance in understanding the effect of climate on the two means of condensing.

In addition, the local electric and water rates for the subject cities were used to provide examples of actual operating costs. Table 1 shows the six cities along with the ASHRAE1 design dry bulb temperature (DBT) and wet bulb temperature (WBT)conditions.

Local utility costs for electric and water usage were used to provide realistic economic examples but are only examples since electric and water rates could vary greatly within a given climate selection.

Condenser Selection

The evap cooled condenser selections for each location were made using the compressor total heat of rejection (THR), based on compressor capacity, and using the approach (i.e. temperature difference or TD) between saturated condensing temperature (SCT) and entering wet bulb temperature, as shown in Table

Figure 1 Refrigerated Warehouse Space Layout

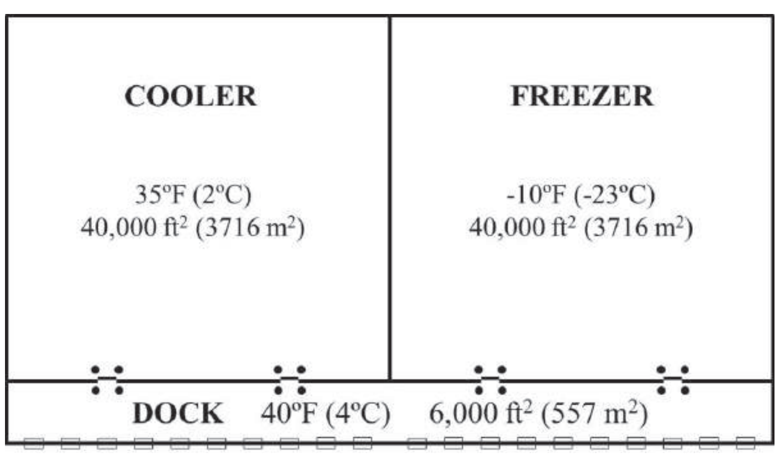

Table 1 Study Cities and Design Weather Conditions

City	ASHRAE 1% DBT °F (°C)	ASHRAE 1% WBT °F (°C)
Dallas, Texas	98 (37)	74 (23)
Chicago, Illinois	88 (31)	73 (23)
Denver, Colorado	90 (32)	59 (15)
Miami, Florida	90 (32)	77 (25)
Salinas, California	78 (26)	62 (17)
Portland, Oregon	86 (30)	66 (19)

Table 2 Evap Condenser Design Approach

Design WBT	TD
<= 76°F (24°C)	20°F (11.1°K)
Between 76°F and 78°F (24°C to 26°C)	19°F (10.6°K)
>= 78°F (26°C)	18°F (10.0°K)

Table 3 Design Load Calculations for Dallas, Texas Location

		Freezer		Cooler		Dock	
Transmission		295,722	27%	157,239	16%	59,592	9%
Infiltration		153,135	14%	4,952	1%	398,644	59%
Internal	People	38,667	3%	38,667	4%	11,600	2%
	Equipment	304,348	27%	304,348	31%	91,304	14%
	Fans	138,829	12%	124,474	13%	84,823	13%
	Lights	95,564	9%	95,564	10%	28,669	4%
	Product	41,667	4%	226,042	23%	0	0%
	Defrost	43,219	4%	38,750	4%	0	0%
Total Peak Load		1,111,150	100%	990,035	100%	674,633	100%
Load with Safety Factor		1,277,822	115%	1,138,540	115%	775,828	115%
SF per Ton		376		160		65	
Load for Coil Selection		1,393,988	125%	1,242,044	125%	846,358	125%

2. These condenser approach values are equivalent to the minimum requirements in the California Title 24 Standards for new refrigerated warehouses. The closer approach (lower TD) at higher design wet bulb temperatures (WBT) does not mean a condenser is necessarily larger as a result of the closer approach; rather the lower TD reflects the physics of moist air and the fact that condensers have greater capacity at the same approach as the WBT increases. This effect can be observed in the heat rejection capacity factor tables provided by all manufacturers of evaporative condensers for selection at specific application WBT and SCT conditions2. Thus the approach would be lower even for a same-size condenser and the same THR and a higher WBT. Industry practice often specifies condensing temperature rather than approach temperature, which can result in condensers being oversized or undersized, at least from an energy efficiency standpoint. Specifying the approach is more consistent in terms of overall system energy efficiency and the goals of this study.

The air cooled condenser selections were based on a 15°F (8.3°K) approach between SCT and entering dry bulb temperature (DBT). The air cooled design approach is the same for all ambient conditions.

The assumed approach temperatures directly determine the size of the condenser, and thus affect the results of the study. These sizes are considered to be a reasonable balance of energy efficiency and cost effective sizing that could be applied across numerous climates. Note this condenser sizing is not intended to be a comprehensive design recommendation; in actual system design for a particular facility, climate and utility costs, the optimum condenser may be smaller or larger.

Load Calculations

Cooling design loads were calculated for each location, including envelope, infiltration and internal loads. The design loads, in BTUh were used to select compressors and condensers. A summary of the loads for one location, Dallas, Texas, is shown in Table 3.

Note that the hourly cooling loads calculated for hourly system modeling and energy analysis are based on weather files and operating assumptions, and are not based directly on design loads.

Compressor Selections

To minimize unintended part load effects, the compressors for each location were size-adjusted from a single representative base compressor model each for the low and high temperature suction levels. In other words, the compressor size was made to exactly match the desired capacity, to avoid unintended part load effects that would be caused by limiting selections to actual compressor models. Part load operation assumed slide valve control and used representative actual compressor part load performance curves.

Condenser Specific Efficiency

Both evap and air cooled condensers are available with a very wide range of fan power for a given capacity. In a given cabinet size, for example, evap condensers are available with fan motors ranging from 10 hp (7.5 kW) to 40 hp (30 kW). Historically, air cooled condensers had an even larger range, going from 2 hp (1.5 kW) to 10 hp (7.5 kW) for the same size fan on certain belt drive condensers. Today, air cooled condensers tend to utilize direct drive motors and have smaller motors, but still with a substantial range in power for a give capacity. Specific efficiency is the term used to define condenser fan power vs. capacity. Specific efficiency is the heat rejection capacity at an assumed specific efficiency rating point divided by the input power for the condenser fans and, for evap condensers, the spray pump. Specific efficiency rating conditions are unrelated to the application conditions. The rating conditions for evap cooled condensers and air cooled condensers are necessarily different, since one is based on WBT and one is based on DBT. For the same reason, numerical comparison of specific efficiencies can only be made between like condensers, not between air and evap cooled condensers. Table 4 shows the rating assumptions and assumed specific efficiencies used in this study.

The condenser specific efficiency rating conditions are taken from the values used by California utility incentive programs, where this parameter first came into use, as well as more recently in the California Title 24 Standards[3,4]. Note that nothing is particularly special about the rating points; other rating point assumptions could evolve in the future, which would result in different specific efficiency numbers for each condenser as well as for minimum standards. The 275 BTUh/W value assumed for this study is lower (e.g. higher fan horsepower) than the values required by the 2013 California Title 24 Standard of 350 BTUh/W. The California value was determined to be cost effective for California climates, utility rates and programmatic assumptions, and only for new refrigerated warehouses. The value of 275 BTUh/W is the efficiency estimated by the author that would generally be cost effective on a national basis for a refrigerated warehouse.

It is also important to note that the cost-effective specific efficiency assumptions are based on a design with all condenser fans running in unison and using variable speed fan control, as will be discussed below. An alternative design approach could utilize physically larger condensers with smaller fan motors, in order to obviate the need for variable speed drives, albeit at higher capital cost. With this alternate design approach, the condensers would have a much higher specific efficiency.

Table 4 Specific Efficiency Assumptions

		Evap	Air
Specific Efficiency Rating Basis	SCT °F (°C)	100 (38)	105 (41)
	WBT °F (°C)	70 (21)	
	DBT °F (°C)		95 (35)
Specific Efficiency (BTUh/W)		275	90

Air cooled condenser specific efficiency is based on motor sizes that are currently available from manufacturers, either as standard or with nominal adaptation to standard products. A specific efficiency of 90 BTUh/W was used for the study. Products choices are limited, naturally, since there is not a significant U.S. market for air cooled ammonia condensers. The currently available equipment has a large range of specific efficiencies, with some models substantially higher than 90 BTUh/W.

No adjustments were made to the specific efficiency assumption for altitude. In the case of the Denver location, certainly, the air cooled condenser size would need adjustment for altitude. Air cooled condenser manufacturers publish capacity adjustments for altitude, but no information on motor power at altitude. The typical air cooled capacity adjustment for 5,000 ft (1,500 m) altitude is approximately 12%; which is roughly similar to the air density change from sea level. Since fan power and density are nominally proportional (i.e. based on Affinity Laws) it was assumed that the same specific efficiency basis was reasonable at higher altitude.

As noted previously air cooled specific efficiencies and evap cooled specific efficiencies cannot be directly compared. Air cooled condensers require far greater air volume than evap condensers and thus generally have higher fan power. Table 5 shows the input power for evap cooled and air cooled condensers for the six study locations.

Table 5 Condenser Power by Location

		Dallas	Chicago	Denver	Miami
Evap Cooled	Fan, kW	26.6	26.4	30.3	27.5
	Pump, kW	4.2	4.2	4.2	4.2
	Total	30.8	30.6	34.5	31.7
Air Cooled	Fan, kW	46.0	43.1	40.7	45.2

Hourly Modeling

Building and system modeling was performed using the DOE2.2R simulation program[5]. This program includes hourly calculation of loads, refrigeration system performance and utility costs. The heat load calculations include transmission with consideration of hourly weather and solar effects; infiltration which utilizes ASHRAE formulas for inter-zonal (doorway) mass exchange, and considers wind velocity; and internal loads which may be automatically calculated (e.g. evaporator fan speed and thus power and heat) or scheduled as part of input instructions (e.g. product and defrost loads). The refrigeration system portion of


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the program is mass-flow based and calculated at a component level. Refrigerant mass flow is determined from the cooling loads, with compressor operation developed to meet the required mass flow, and based on balance with the available condenser capacity and ambient conditions. Compressor performance is determined from regressions based on saturated suction temperature (SST) and saturated discharge temperature (SDT), with a separate relationship for part load (e.g. slide valve) efficiency. Control strategies for evaporator fans, supervisory compressor sequencing and part load control, and condenser setpoint and fan control are all explicitly modeled (within the limits of an hourly simulation model) in a manner consistent with actual control operation. TMY3 weather files were used for hourly ambient temperatures, solar values and wind velocity.

Adjustments to catalog ratings, primarily equipment de-rating, are essential to effective modeling and in particular to refrigeration modeling and this study for several reasons, including:

- Equipment catalog ratings are based on steady state operation, for new equipment and generally at design (peak) conditions, whereas most hours of operation are not at steady state and the system is operating at off-design conditions (which may not be within the catalog ratings) and at part load.
- Condenser performance values in catalogs have historically not referenced a rating standard and the ratings are not certified. This has changed recently with some evap condenser manufacturers now or soon using CTI standards6 and/or ASHRAE standards7 for testing of evaporative condensers and moving towards future certification of their evap condenser ratings. Manufacturers of air cooled refrigeration condensers in the U.S. have not referenced rating standards in their catalog ratings. The AHRI standard for air cooled condensers, ASNI/ AHRI Standard 4607, uses test rating conditions which are more suitable for air conditioning applications than refrigeration, e.g. 30°F (17°K) approach. Beyond considerations of actual vs. catalog performance at full capacity, factors for performance at part load are less certain and in most cases are not published and given the many variables, would be very difficult to test.
- Transient operation, e.g. fan cycling and cyclical pressure variations may have a large effect on condenser operation.
- Field effects including multiple adjacent condensers, building configuration and effect of prevailing wind, result in recirculation of air from the condenser outlet and reduced condenser capacity. Piping pressure drop and flow imbalance would be part of this factor.
- Scale, corrosion and bio-fouling in evaporative condensers often comprise a large factor, reducing condenser capacity and sometimes condenser longevity.

To address all of these factors, de-rating of the catalog capacity values is necessary to simulate real-world condenser performance at average hourly conditions. Individual factors, largely based on the author's judgment and opinion, were estimated and summarized in Table 6.

These de-rating factors undoubtedly seem high at first glance; indicating the realized average capacity is approximately a third less than the catalog ratings. Based on the author's experience in evaluating expected vs. actual hourly performance at a limited number of facilities this is not an unreasonable conclusion, particularly noting the purpose of these factors is to develop an accurate hourly simulation through the course of the year, inclusive of off-design and part load effects, and not just at peak design conditions. Specific de-rating components may be more or less manageable though system design and ongoing system maintenance; for example, a relatively small amount of scale on evaporative condensers can have a very large effect on capacity. Each de-rating component could be subject to a more detailed consideration and study. In terms of this paper, the important issue is whether the various de-rating components for evaporative condensers and air cooled condensers are likely to cause a difference in performance of one vs. the other. There is little difference in the net de-rating factors shown above, thus no large comparative effect on modeling assumptions.

Water usage was estimated using the actual hourly heat of rejection from the simulation model and assuming the industry guideline for evaporation of 2 GPM per 1,000 MBTUh. It's useful to see how this simply equates to the evaporation of water: 2 Gallons per Minute X 8.34 Pounds per Gallon X 60 Minutes/ Hour X 1,000 BTUs per pound of water equals 1,000,800 BTUh, or 1,000 MBTUh. In addition, bleed rate and drift were estimated and were

Table 6 Condenser De-rating Factors for Hourly Analysis

	Evap	Air	
Catalog Capacity	100%	100%	Notes
Applied vs. Catalog Adjustment	0%	10%	Authors opinion there is less certainty with air-cooled
Scale, Fouling and Dirt	20%	10%	Evap fouling is higher on average due to ubiquitous scale
Non-steady State Factors	5%	5%	Small factor, considering large system with variable speed
Field Installaton Effects	5%	10%	More likely air-cooled is more compromised by recirculation
Part Load Effects	5%	5%	Equal assumption
Net De-rate vs. Catalog	**69%**	**66%**	

approximately equal to the hourly evaporation rate. Water treatment cost was included at $750 per month.

Head Pressure Control

Control of head pressure or condensing temperature, which are essentially interchangeable terms in this context, is the essential consideration in comparing evap cooled and air cooled condensers. Without a balanced and consistent assumption the results would be skewed. Head pressure control elements include how condenser fans are controlled (cycling or speed modulation), the control strategies used to control fans, and how low head pressure is allowed to drop, as cooler weather permits.

Floating Head Pressure

Aside from the relatively few hours (if any) in a year that the compressors and condensers run near their maximum capacity, there is a constant opportunity to employ controls to optimize the total power used by the compressors and condenser fans. For lack of a better description, this is called floating head pressure. Floating head pressure is somewhat vague and can have multiple meanings but here it is used for the overall effort to control to the lowest total energy use of compressors and condensers throughout the year. There are three elements:

- How low can the head pressure (or condensing temperature) go, weather permitting?
- How are the condenser fans controlled?
- How is the condenser fan control setpoint determined?

Minimum Condensing Temperature

The lowest possible steady state condensing temperature is a function of compressor oil separator sizing and other compressor limitations, and system design pertaining to liquid supply to evaporators. Generally all modern systems can operate to 70°F (21°C) SCT or lower, i.e. 114 psig (7.9 Bar) for ammonia. Some existing systems have a need for higher pressure during defrost periods, however newer systems typically need no more than 95 psig (6.6 Bar) for defrosting and are equipped with regulators to limit defrost pressure, thereby allowing head pressure reduction to near 95 psig (6.6 Bar) pressure with no effect on defrost.

The value of a minimum condensing temperature lower than 70°F (21°C) may be small a warm climate but could yield large incremental savings in a colder climate. This also becomes an important difference between evap and air cooled systems in many climates. As noted previously evap condensers "lose" capacity as the wet bulb temperature drops, in terms of the approach the condenser can achieve for a given heat rejection, whereas an air cooled condenser maintains the same approach temperature at lower dry bulb temperatures. Coupled with this fact, the difference between DBT and WBT varies through the day and the year in a manner that favors evap cooled condensers in the hottest weather periods but favors air cooled condensers during the moderate and cool temperatures that typically comprise most of the year.

Figure 2 shows the daily temperatures for a hot day and an average day for Dallas, Texas.

Note the much larger difference between DBT and WBT on a hot day than on an average day; here a 33°F (18°K) difference on a hot day and a 10°F (6°K) difference on a cool day.

The relationship between dry bulb and wet bulb temperatures can also be seen by comparing the maximum, average and minimum dry bulb and wet bulb temperatures and the difference, which indicates the nominal advantage of evap cooled condensing. Table 7 shows weather statistics for Dallas, Texas, taken from the TMY3 weather file. Note that the maximum WBT does not coincide with the maximum DBT, which is typical for most if not all climates. The WBT that coincides with the peak DBT results in a 27°F (15°K) difference, compared with the average difference between DBT and WBT being approximately 8°F (4°K).

Figure 5 shows the dry bulb temperature for each hour of the year, arranged from hottest to coldest, with the coincident wet bulb temperatures, showing the greatest difference between DBT and WBT during peak temperatures and a declining difference in moderate and cold weather.

Added to these "facts of weather," it is also useful to consider the characteristic increase in approach at lower

Figure 2 Hot and Average DBT and WBT Daily Variation for Dallas Texas

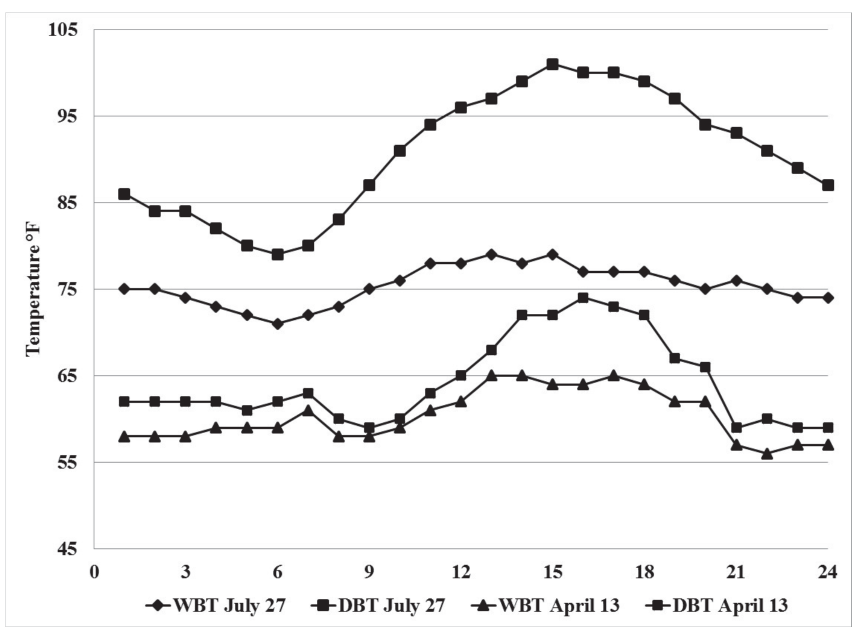


Table 7 Dallas Texas Weather Statistics

	DBT	WBT	Difference
Maximum	104°F (40°C)	83°F (28°C)	
Coincident	104°F (40°C)	77°F (25°C)	27°F (15°C)
Average	66°F (19°C)	58°F (14°C)	8°F (4°C)
Minimum	11°F (-12°C)	9°F (-13°C)	

Figure 5 Dallas Texas DBT and Coincident WBT

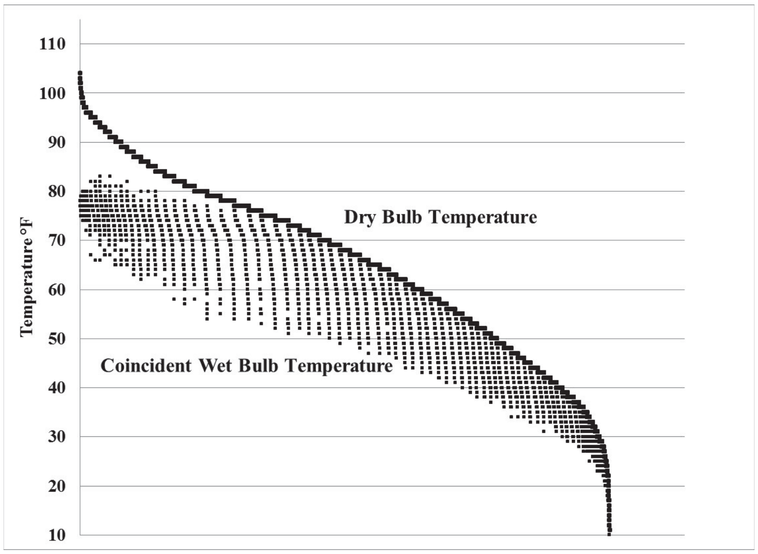
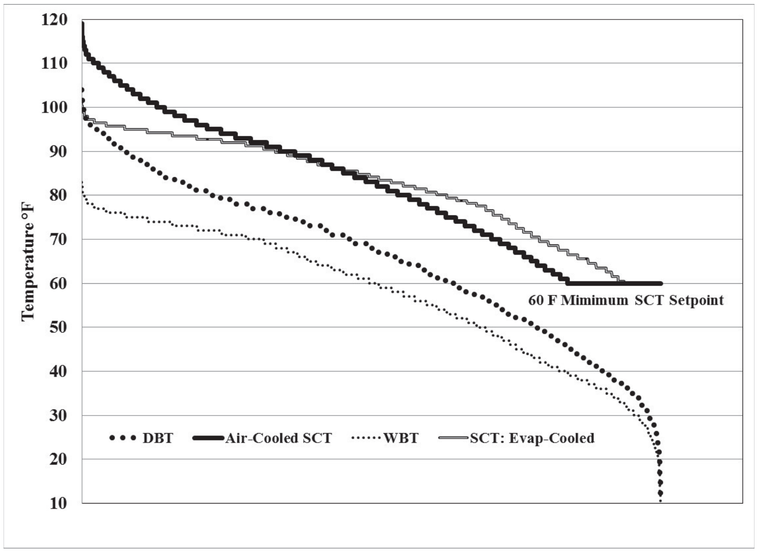


Figure 6 Dallas Texas Full Load Condensing Temperature Comparison



WBTs observed with evap cooled condensers vs. the fixed approach with air cooled condensers. If condensing temperature is reduced along with ambient temperature, the difference between DBT and WBT gets smaller, and at the same time the difference between air cooled and evap cooled condenser approach gets larger. Thus, air cooled condensing should have greater advantage the lower head pressure is allowed to float.

Figure 6 shows DBT, coincident WBT (using a regression to smooth the hourly values) and the respective condensing temperatures, assuming system operation at full load for the purpose of this figure.

The minimum condensing temperature used in this study for all six locations was 60°F (15.6°C).

Fan Control

For both evap and air cooled condensers the study assumes all fans are controlled in unison with variable speed, rather than fan cycling. The use of all surface, all of the time, is generally the most efficient means of condenser capacity utilization. The affinity laws define physical principles of flow, pressure drop and power and specifically the "third power" relationship between airflow and fan power. This relationship is shown as the curve in Figure 7 and is applied to compare a condenser with fan cycling to the same condenser with variable speed fan control, with both condensers at 50% capacity. Condenser capacity is nominally proportional to airflow and fan speed whereas power varies with the cube of fan speed, thus increasing the part load condenser efficiency at 50% capacity from 90 to 360 BTUh/W.

The nonlinear relationship of fan power to airflow, and thus to condensing temperature and compressor power is important, and inherently points to an important aspect of control optimization as described below.

Setpoint Determination

The final aspect of condenser control and optimizing system energy is setpoint determination. The essential objective is balancing the compressor and condenser power to obtain the lowest total power. From only the per-

Figure 7 Condenser Capacity vs. Power for Fan Cycling and Variable Speed

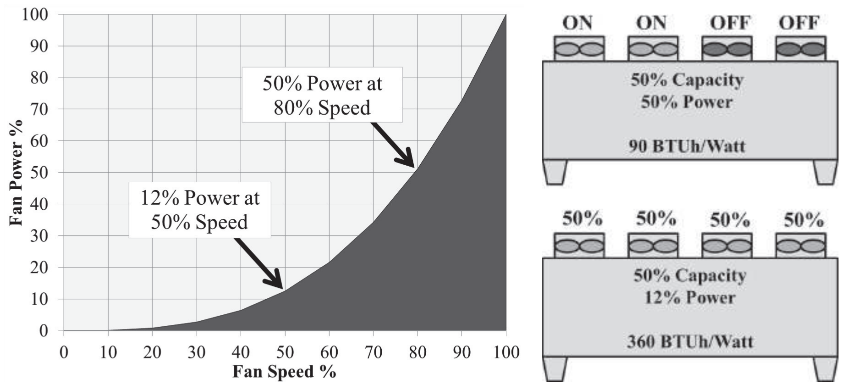
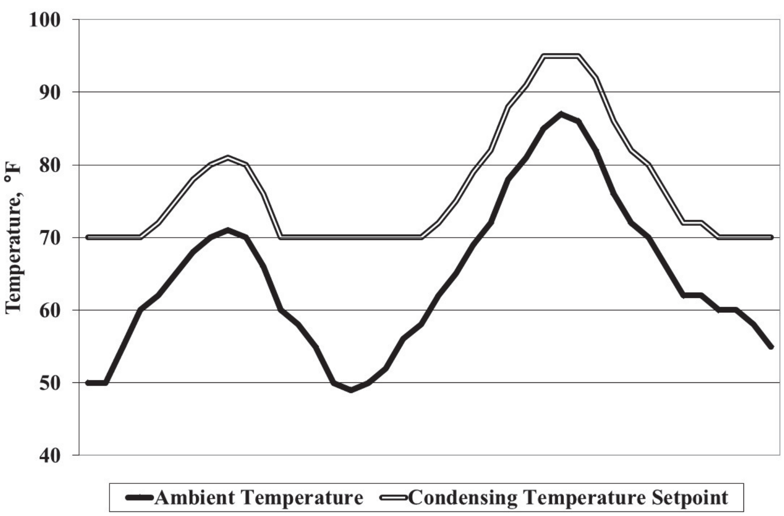


Figure 8 Ambient Following Condensing Temperature Setpoint



spective of reducing compressor power, the condenser would simply run at 100% capacity to balance at the lowest head pressure possible at the ambient temperature. Or course, the condenser uses energy as well, which creates the tradeoff between compressor power and condenser power. As shown previously, fan power vs. condenser capacity is non-linear, following a third power relationship. In addition, like all heat exchangers, increased condensing capacity has diminishing return in terms of the heat exchanger approach. For example, if doubling condenser capacity (and power) reduces the approach (TD) by 20°F to 10°F (11.1°K to 5.6°K), a reduction of 10°F (5.6°C) in condensing temperature, an additional doubling would only reduce the approach and condensing temperature by 5°F (2.8°C), producing only half the benefit at the compressor. Both of these non-linear relationships complicate the goal of balancing condenser fan control vs. compressor power. Simply put, the goal is to use as much condenser capacity as possible, without increasing condenser power more than the gain achieved in compressor power.

The most common control strategy used to control floating head pressure for optimum power use is ambient-following logic, where the condenser control setpoint is determined by adding an "offset" value to the current ambient temperature to determine the target saturated condensing temperature setpoint. This offset is typically called the control TD. For evap cooled condensers, WBT is used and for air cooled condensers DBT is used. A simplified example of ambient following control is shown in Figure 8. The condensing temperature setpoint follows ambient temperature, bounded by a minimum setpoint limit defined by the system design minimum pressure capability (e.g. of 70°F (21.1°C) in this example figure) and typically a maximum setpoint limit as well (e.g. of 95°F (35.0°C)) at which it is desirable for the fans to run at 100% to limit maximum system pressures, regardless of energy optimization.

When using an energy simulation, as was employed for this study, the optimum control TD value is determined by iterating the simulation control TD value to obtain the lowest total combined power. To allow for real-world control variations, the control TD is then raised slightly. In actual plant operations, typically lacking detailed guidance from energy analysis, the control TD setpoint is commonly optimized using a condenser fan speed "sweet spot" of 60-80% target, when not at minimum SCT.

An average speed of 60-80% is normally close to the ideal operating point; utilizing a large fraction of the condenser capacity and still providing a sizable reduction in condenser fan power.

Other control and optimization methods are feasible, but ambient following is the most common method and for the purpose of this study, creates a relatively balanced and consistent comparison between evap cooled and air cooled condensing.

WATER COSTS

Water, sewer and water treatment costs are generally the impetus for considering air cooled condensing, in

Table 8 Water and Sewer Costs

	Dallas	Chicago	Denver	Miami	Salinas	Portland
Supply Water Cost, $/CCF	$ 2.50	$ 2.40	$ 2.50	$ 1.80	$ 2.00	$ 3.40
Sewer Cost, $/CCF	$ 2.60	$ 2.30	$ 2.70	$ 5.00	$ 1.60	$ 8.70
Sewer Fraction of Water Usage	40%	100%	40%	40%	40%	40%
Effective Cost, $CCF Water Usage	$ 3.54	$ 4.70	$ 3.58	$ 3.80	$ 2.64	$ 6.88

Table 9 Comparison of Energy Usage

	Evaporative Cooled				Air Cooled			Air Cooled Increase (Decrease)	
	Compr (kWh)	Cond Fan (kWh)	Cond Pump (kWh)	Total (kWh)	Compr (kWh)	Cond Fan (kWh)	Total (kWh)		
Chicago	1,143,648	24,555	36,525	1,887,091	1,196,414	26,383	1,905,159	18,068	1.0%
Denver	1,024,504	22,755	36,525	1,766,146	1,202,049	23,668	1,908,079	141,933	8.0%
Portland	1,104,550	28,565	36,525	1,852,002	1,162,040	29,761	1,874,164	22,162	1.2%
Dallas	1,349,923	37,149	36,524	2,106,087	1,491,260	39,973	2,213,723	107,636	5.1%
Miami	1,563,839	37,807	36,520	2,320,530	1,707,717	41,321	2,431,402	110,872	4.8%
Salinas	1,119,998	31,183	36,524	1,870,068	1,155,856	36,675	1,874,894	4,826	0.3%
							Average:	67,583	3.4%

Table 10 Comparison of Electric and Water Costs

	Evaporative Cooled					Air Cooled		
	Energy Cost ($)	Demand Cost($)	Total Energy Cost ($)	Water Costs	Total Energy and Water	Energy Cost ($)	Demand Cost($)	Total Energy Cost ($)
Chicago	$ 128,322	$ 53,584	$ 181,906	$ 30,972	$ 212,878	$ 129,551	$ 57,201	$ 186,752
Denver	$ 103,292	$ 26,652	$ 129,944	$ 25,316	$ 155,260	$ 113,298	$ 32,757	$ 146,055
Portland	$ 112,064	$ 25,284	$ 137,348	$ 41,303	$ 178,651	$ 113,509	$ 27,896	$ 141,405
Dallas	$ 169,249	$ 61,380	$ 230,629	$ 27,453	$ 258,082	$ 177,899	$ 68,285	$ 246,184
Miami	$ 128,074	$ 81,167	$ 209,241	$ 30,467	$ 239,708	$ 134,344	$ 87,270	$ 221,614
Salinas	$ 158,029	$ 95,382	$ 253,411	$ 21,627	$ 275,038	$ 158,991	$ 106,016	$ 265,007

	Air Cooled Increase (Decrease)			
	Electric Only ($)	Electric Only (%)	with Water ($)	with Water (%)
Chicago	$ 4,846	2.7%	$ (26,126)	-12.3%
Denver	$ 16,111	12.4%	$ (9,205)	-5.9%
Portland	$ 4,057	3.0%	$ (37,246)	-20.8%
Dallas	$ 15,555	6.7%	$ (11,898)	-4.6%
Miami	$ 12,373	5.9%	$ (18,094)	-7.5%
Salinas	$ 11,596	4.6%	$ (10,031)	-3.6%
Average:	$ 10,756	5.9%	$ (18,767)	-9.1%

addition to concern regarding future water availability. For each city in this study the water and sewer rates were investigated, with the results shown in the Table 8.

For cities that adjust the sewer rate based on measured flow or sub-metering credits to account for water that is evaporated, the sewer cost was factored to 40% of the supply water cost, and the two added to obtain the effective cost of both supply water and sewer costs is expressed in $/CCF (hundred cubic feet) of supply water consumption.

RESULTS

Simulation results for the six cities are shown in Table 9 and Table 10.

Energy Usage

Table 9 shows the energy usage for compressors and condensers, as well as the total simulation energy for the facility which includes the balance of the loads in the simulation, specifically evaporator coil fans and lighting in refrigerated spaces.

In all locations, air cooled condensing uses more total energy (kWh) than evaporative cooled condensing, ranging from almost no difference to an 8% increase in Denver, which is a very dry climate obviously attractive for evaporative cooling. The evaporative condensing advantage in Miami, which has a very high humidity and thus relatively little difference between DBT and WBT is interesting and points out to the closer approach achieved by evaporative condensers at higher wet bulb temperatures.

Operating Costs

Table 10 shows the electric utility cost and water costs for each location. Water costs are based on Table 8 plus water treatment costs which were estimated at $750 per month for all locations. The electric costs are separated between energy cost (kWh usage) and demand charges.

The effect of high demand charges for air cooled condensing is apparent and is due to the air cooled condenser response to DBT and the fact high DBT temperatures coincide with utility summer on peak demand charges.

Electric costs increased in all cities, from 3% to 12%, with the highest being Denver. The average cost increase is approximately 6% and on the order of $1,000 per month, so in the context of other system design variables and associated operating cost differences, this is not a large penalty. With water costs savings, the annual cost decreases for all locations. The net savings with both electric and water costs considered ranges from 4% to 20%, with dollar savings from approximately $9,000 to $37,000. The highest savings, for Portland, is largely due to the water costs in Portland; nearly double the average of the other locations, with most of this cost difference due to high sewer rates.

Note that the simulation did not include any form of cooling load shifting control for either evap cooled or air cooled systems. Load shifting on high efficiency systems should be undertaken cautiously to avoid increasing total energy usage, but to the extent load shifting is cost effective in all other respects, it would yield greater benefits on air cooled systems than on evap cooled systems, due to the higher day-to- night range in dry bulb temperatures than wet bulb temperatures, particularly in peak periods.

The assumptions described in this paper, naturally, impact the results. The assumptions were intended to accurately assess both condensing options with the control methods (related to condensers) that would be employed in a modern facility. The sensitivity of various assumptions was not investigated. Most assumptions likely have a small comparative difference, whereas others (e.g. minimum condensing temperature setpoint) would be expected to have a large comparative difference.

Also, the condenser de-rating assumptions were definitely substantial and either through error in these assumptions, or actions taken to minimize the factors in a particular design or application, the comparative outcome in energy usage could be materially different. There is also a learning curve that could be expected in applying large air cooled ammonia condensers (e.g. field effects), although the ammonia plants on most refrigerated warehouses are moderately sized and not significantly beyond the scale experienced with other air cooled refrigeration and chiller applications.

Water consumption used in the study may be somewhat overstated for a facility with excellent water conditions and/or very well managed water treatment. However, in the author's opinion, the water consumption assumptions are likely to understate the average refrigerated warehouse system, since water usage to condensers is often not metered and rarely managed vs. expected usage for the actual heat rejection. Of course, this is an opportunity for improvement that can be addressed aside from the comparison of air cooled and evaporative condensing.

Capital Cost and Payback

The additional cost for air cooled condensing includes:

- Air cooled condenser cost premium over evaporative condensers
- Cost of increased design pressures for vessels and piping
- Increased compressor motor cost for higher peak operating pressures
- Additional condenser piping
- Structural support for condensers (potentially lighter weight but larger area)

Detailed equipment selection and installation pricing was not undertaken as part of this paper, since costs vary greatly based on design conditions and site-specific factors. Based on high level estimates by the author, the added capital cost for air cooled condensing on the subject facility is estimated between $200,000 and $300,000, which would equate to a payback of 10 to 30 years. Payback in this range would typically not encourage use of air cooled systems solely on the basis of energy savings, but would help support an air cooled choice if other factors such as water conditions and availability present challenges. In some areas, evaporative condenser life is shortened by difficult water conditions. For these facilities, a life cycle analysis would reflect the value of air cooled condensers which (if properly designed) would have a longer life.

High side design pressure requirement may be a significant cost determinant. In certain areas with low design dry bulb temperatures, the design pressure requirements may be within the current standard practice for evap cooled systems, thus causing no additional high side costs other than the condenser and structural cost difference.

CONCLUSIONS

The use of air cooled condensers for ammonia systems is potentially attractive. Energy cost is greater in all areas evaluated, but when water costs are considered, the net operating cost is lower in all six U.S. locations considered in this paper, which utilized hourly simulation of air cooled and evaporative cooled condensing in a representative refrigerated warehouse.

Energy usage for air cooled condensers over evap cooled condensers ranged from almost no increase to an 8% increase in Denver, Colorado. Electric cost increase ranged from approximately 3% to 12%. With water cost included, cost reduction ranged from 4% to 21%, with the savings from greatest to least in the following order: Portland, Oregon; Chicago, Illinois; Miami, Florida; Dallas, Texas; Salinas, California; and Denver, Colorado.

Higher electric operating costs with air cooled condensing reflect the higher electric rates concurrent with high dry bulb temperatures, when the comparative advantage of evaporative condensing is greatest. No refrigeration load shifting was included in the analysis, and may comprise a potential advantage for air cooled condensing due to the higher daily range of dry bulb temperature compared with wet bulb temperature.

Water usage was calculated based on heat rejection from the hourly simulation and typical water bleed rates. Actual water usage may be lower or could be substantially higher if not carefully controlled. The study results are dependent on control assumptions, in particular the use of variable speed control of all fans in unison and ambient-following control.

Given the wide range of water costs, utility rates (and rate shapes in peak periods), site specific analysis may often be necessary to accurately identify operating costs of evap cooled and air cooled condenser options. For both air cooled and evap cooled condensers, the catalog capacity ratings were de-rated by more than 30% to develop the average capacities for the hourly simulation. This is a significant assumption for which there is limited field testing. Future work is required for both evap cooled and air cooled condensers to evaluate installed average performance in order to achieve more accurate annualized analysis, as well as establish performance expectations.

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6 Cooling Technology Institute (CTI) 106-ATC (04)–Acceptance Test Code for Mechanical Draft Evaporative Vapor Condensers.

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8 ASNI/AHRI Standard 460-2005 – Performance Rating of Remote Mechanical-Draft Air cooled Refrigerant Condensers.

APPENDIX I – SIMULATION ASSUMPTIONS

Weather	
Design WBT, DBT	Chicago: 73°F design WBT 88°F design DBT Dallas: 74°F design WBT 98°F design DBT Denver: 59°F design WBT 90°F design DBT Miami: 77°F design WBT 90°F design DBT Portland: 66°F design WBT 86°F design DBT Dallas: 62°F design WBT 78°F design DBT The design DBT and WBT are based on the ASHRAE 90.1-2007 weather data.
Compressor Information	
Refrigerant	R-717
Suction Group Design SST	LT System: -23°F HT System: 22°F
Design SCT	Chicago: Evaporative condenser system: 93°F design SCT Air cooled condenser system: 103°F design SCT Dallas: Evaporative condenser system: 94°F design SCT Air cooled condenser system: 113°F design SCT Denver: Evaporative condenser system: 79°F design SCT Air cooled condenser system: 105°F design SCT Miami: Evaporative condenser system: 96°F design SCT Air cooled condenser system: 105°F design SCT Portland: Evaporative condenser system: 86°F design SCT Air cooled condenser system: 101°F design SCT Dallas: Evaporative condenser system: 82°F design SCT Air cooled condenser system: 93°F design SCT

Compressor description	LT System Serves freezer area. (2) Ammonia screw compressors with slide-valve unloading HT System Serves cooler and dock areas. (2) Ammonia screw compressors with slide-valve unloading
Compressor capacity, power, nominal motor HP, and motor efficiency at design conditions	LT Frick RXF-101: 72.2 TR, 208.8 BHP at -23°F SST and 100°F SCT, 250 Nominal HP, 94.5% efficient motor HT Frick RXF-50: 105.8 TR, 137.3 BHP at 22°F SST and 100°F SCT, 150 Nominal HP, 93.6% efficient motor The actual compressor capacities were scaled for each city so that the compressors meet the design cooling load.
Suction Group SST Control Strategy	LT System: -23°F fixed SST setpoint, 1°F throttling range HT System: 22°F fixed SST setpoint, 1°F throttling range
Lead compressor unloading strategy	Slide valve unloading
Oil cooling type	Thermosyphon
Useful superheat for compressor ratings	0°F
Liquid subcooling for compressor ratings	0°F
Evaporator Coil Information	
Air Unit Fan Operation	All zones Fans run 100% of the time, except for defrost. Variable speed control, 65% minimum speed, 2 hours/day forced at 100% speed
Defrost Assumptions	Cooler: (2) 30-minute off-cycle defrosts/day Dock: (2) 30-minute off-cycle defrosts/day Freezer: (2) 30-minute hot-gas defrosts/day
Air Unit Quantity	Cooler: 6 Dock: 6 Freezer: 6
Air Unit Capacity (per unit)	Cooler: 161.0 MBH at 10°F TD Dock: 124.2 MBH at 10°F TD Freezer: 173.1 MBH at 10°F TD
Design Saturated Evaporator Temperature:	Cooler: 25°F Dock: 30°F Freezer: -20°F
Air Flow Rate (per unit)	Cooler: 32,200 CFM Dock: 24,800 CFM Freezer: 34,600 CFM
Fan Power	Cooler: 4.74 kW Dock: 3.65 kW Freezer: 5.09 kW Based on specific efficiency of 34.0 BTUh/kW at 10°F TD between SET and space temperature

Condenser Information	
Condenser type	Evaporative / Air cooled
Design Temperature Difference	Chicago: Evaporative condenser: 20°F TD Air cooled condenser: 15°F TD Dallas: Evaporative condenser: 20°F TD Air cooled condenser: 15°F TD Denver: Evaporative condenser: 20°F TD Air cooled condenser: 15°F TD Miami: Evaporative condenser: 19°F TD Air cooled condenser: 15°F TD Portland: Evaporative condenser: 20°F TD Air cooled condenser: 15°F TD Dallas: Evaporative condenser: 20°F TD Air cooled condenser: 15°F TD Fixed TD of 15°F was used for air cooled condensers. TD for evaporative condensers was determined as follows: Design WBT <= 76°F, TD = 20°F 76°F < Design WBT < 78°F, TD = 19°F Design WBT >= 78°F, TD = 18°F.
Capacity at Design Conditions	Chicago: Evaporative condenser: 5,565 MBH at 93°F SCT and 73°F WBT Air cooled condenser: 5,822 MBH at 15°F TD Dallas: Evaporative condenser: 5,686 MBH at 94°F SCT and 74°F WBT Air cooled condenser: 6,216 MBH at 15°F TD Denver: Evaporative condenser: 4,907 MBH at 79°F SCT and 59°F WBT Air cooled condenser: 5,493 MBH at 15°F TD Miami: Evaporative condenser: 5,857 MBH at 96°F SCT and 77°F WBT Air cooled condenser: 6,102 MBH at 15°F TD Portland: Evaporative condenser: 5,219 MBH at 86°F SCT and 66°F WBT Air cooled condenser: 5,574 MBH at 15°F TD Salinas: Evaporative condenser: 5,027 MBH at 82°F SCT and 62°F WBT Air cooled condenser: 5,262 MBH at 15°F TD The above mentioned capacities were de-rated by 31% for evaporative condensers and by 34% for air cooled condensers in order to account for: fouling, non-steady state factors, field installation effects and part-load effects.

Pump power and efficiency (for Evaporative condenser)	5 HP, assumed 89.5% efficient, 4.17 kW – for all cities Pump runs continuously.
Fan power	Chicago: Evaporative condenser: 26.4 kW (Based on specific efficiency of 275 BTUh/Watt at 100°F SCT, 70°F WBT) Air cooled condenser: 43.1 kW (Based on specific efficiency of 90 BTUh/Watt at 10°F TD) Dallas: Evaporative condenser: 26.6 kW (Based on specific efficiency of 275 BTUh/Watt at 100°F SCT, 70°F WBT) Air cooled condenser: 46.0 kW (Based on specific efficiency of 90 BTUh/Watt at 10°F TD) Denver: Evaporative condenser: 30.3 kW (Based on specific efficiency of 275 BTUh/Watt at 100°F SCT, 70°F WBT) Air cooled condenser: 40.7 kW (Based on specific efficiency of 90 BTUh/Watt at 10°F TD) Miami: Evaporative condenser: 27.5 kW (Based on specific efficiency of 275 BTUh/Watt at 100°F SCT, 70°F WBT) Air cooled condenser: 45.2 kW (Based on specific efficiency of 90 BTUh/Watt at 10°F TD) Portland: Evaporative condenser: 27.3 kW (Based on specific efficiency of 275 BTUh/Watt at 100°F SCT, 70°F WBT) Air cooled condenser: 41.3 kW (Based on specific efficiency of 90 BTUh/Watt at 10°F TD) Salinas: Evaporative condenser: 30.5 kW (Based on specific efficiency of 275 BTUh/Watt at 100°F SCT, 70°F WBT) Air cooled condenser: 39.0 kW (Based on specific efficiency of 90 BTUh/Watt at 10°F TD)

Condenser fan control	60°F minimum SCT setpoint Ambient temperature following SCT control (wetbulb-reset for evaporative condenser, dry bulb-reset for air cooled condenser) Variable-speed fan control 1°F throttling range Chicago: Wetbulb-reset control TD: 19°F Drybulb-reset control TD: 14°F Dallas: Wetbulb-reset control TD: 18°F Drybulb-reset control TD: 14°F Denver: Wetbulb-reset control TD: 19°F Drybulb-reset control TD: 15°F Miami: Wetbulb-reset control TD: 17°F Drybulb-reset control TD: 15°F Portland: Wetbulb-reset control TD: 19°F Drybulb-reset control TD: 14°F Salinas: Wetbulb-reset control TD: 19°F Drybulb-reset control TD: 14°F Wetbulb-ratio for evaporative condensers: 0.0
Load Information	
Facility Size	Freezer Area: 40,000 SF Cooler Area: 40,000 SF Dock Area: 12,000 SF Total Area: 92,000 SF
Ceiling Heights	All areas: 30 ft.
Temperature Setpoints	Freezer: -10°F Cooler: 35°F Dock: 40°F
Load Profiles	Internal loads are product load, lights, infiltration, people, forklifts/pallet lifts, equipment
Infiltration, leakage open, closed, etc.	Cooler: (2) 10' x 10' doors from cooler to dock Freezer: (2) 10' x 10' doors from freezer to dock Dock: (20) 10' x 10' dock doors. Assumed 200 CFM design infiltration per dock door, subject to infiltration schedule Inter-zonal doors assumed open 15 times per hour, 12 seconds per opening. Doors are not assumed to have strip or air curtains. Subject to hourly production schedule

Product Loads	Freezer: 41.7 MBH (Assumed 400,000 lb/day product load, from -5°F to -10°F, with specific heat of 0.50) Cooler: 226.0 MBH (Assumed 400,000 lb/day product load, from 45°F to 40°F, with specific heat of 0.65, plus 750 tons of respiring product. Heat of respiration: 5,500 BTUh/ton of product per 24 hours) Dock: 0 BTUh Subject to hourly schedule
People Loads	20 people, distributed evenly by S.F. Assumed people heat gain is 580 BTUh sensible, 870 BTUh latent, 1,450 BTUh total. Subject to hourly schedule
Forklifts	15 forklifts, 5 pallet lifts, distributed evenly by S.F. Assumed 20 MBTUh/forklift, 10 MBTUh/pallet-lift Subject to hourly schedule
Facility Envelope Insulation	
Climate	Dallas, Chicago, Portland, Miami, Denver, Salinas
Azimuth	0°
Building Size	Freezer: 40,000 S.F. (200' x 200') Cooler: 40,000 S.F. (200' x 200') Dock: 12,000 S.F. (400' x 30') Total area: 92,000 S.F. Ceiling heights: 30'
Roof Construction	Freezer Construction: Built-up roof, R-36 insulation Inside Film Resistance: 0.90 Hr-SF-°F/Btu Absorptance: 0.45 (Thermal emittance of 0.55 manual) Cooler Construction: Built-up roof, R-28 insulation Inside Film Resistance: 0.90 Hr-SF-°F/Btu Absorptance: 0.45 (Thermal emittance of 0.55 manual) Dock Construction: Built-up roof, R-28 insulation Inside Film Resistance: 0.90 Hr-SF-°F/Btu Absorptance: 0.45 (Thermal emittance of 0.55 manual)
Wall Construction	Freezer R-36 insulation Cooler R-28 insulation Dock R-28 insulation Inter-Zonal Wall R-26 insulation

Floor Construction	<u>Freezer</u> 8″ Concrete slab, R-36 insulation <u>Cooler</u> 8″ Concrete slab (no insulation, assumed concrete U-factor: 0.20) <u>Dock</u> 8″ Concrete slab (no insulation, assumed concrete U-factor: 0.20)
Hours of Operation	9 AM to 1 AM, 7 Days/Week (lights, infiltration, people, forklift/pallet lifts)
Lighting	
Lighting Power Density	All areas: 0.7 Watts/S.F. 8

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