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# Condenser

Published by the International Institute of Ammonia Refrigeration
as a service to its members and the Industrial Refrigeration Industry

## Time for Low Charge Ammonia Refrigeration Systems

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# IIAR Seeks Associate Technical Director

**The IIAR is seeking an individual with experience in the ammonia refrigeration industry for the position of Associate Technical Director.** Candidates should have a good working knowledge of industrial refrigeration applications represented by the membership of IIAR. The candidate should be well informed on various code and regulatory compliance requirements associated with ammonia refrigeration and should have a good command of written and verbal language skills. All applicants should be customer service oriented, and be able to fastidiously document, sort and record proceedings of meetings, conferences, and project outcomes.

**Responsibilities of the Associate Technical Director will include providing assistance in:** answering technical questions submitted to the IIAR; developing technical papers, seminars and workshops for the IIAR Annual Conference; managing development and technical editing of all new and updated IIAR technical publications such as standards and guidelines; and managing American National Standards Institute (ANSI) procedures and documentation for the development of Accredited Standards. The Associate Technical Director will also be expected to attend IIAR and ASHRAE committee meetings and contribute to the development and writing of newsletter, magazine and website articles and postings.

The selected individual will join the IIAR staff in the Washington, DC suburb of Alexandria, Virginia. The job requirements include an engineering or chemistry degree with industrial refrigeration experience. This is a career opportunity with potential for advancement. Compensation will be commensurate with educational degrees and experience. Benefits include medical, dental, vision and 401k plan. Candidates interested in applying for this job should email a cover letter and resume to eric.smith@iiar.org. iiar

# Chairman's Message

The second half of the year is always a busy time for the International Institute of Ammonia Refrigeration, and this year is no exception. As we wrap up our 2012 activities on behalf of the industry, the IIAR leadership is excited to report on several initiatives in many different areas. Global outreach, IIAR conference preparations, a new $CO_2$ workshop and ARF fundraising efforts are just a few of the things we're focused on as we prepare for 2013.

This year, IIAR continued to build its working relationship with the industry's European counterparts by participating in the Chillventa International Trade Fair for Refrigeration, Air Conditioning, Ventilation and Heat Pumps in Nuremberg, Germany. The conference is the largest of its kind in Europe.

A strong delegation of IIAR members attended, including IIAR Treasurer Tom Leighty, International Committee Chair Paul Bishop, Government Relations Chair Mark Stencel, Natural Refrigerants Task Force Chairman David Blackhurst, Marketing Committee Chairman Tim Facius, President Bruce Badger and myself.

The biennial event included presentations this year by the IIAR international committee as well as meetings with IIAR alliance partners, Eurammon and the Association of Ammonia Refrigeration from India. As a result of those meetings and presentations, IIAR is in a strong position to continue promoting the expansion of natural refrigerants on a global level.

Meanwhile, the IIAR staff and leadership are hard at work, preparing for the 2013 IIAR Conference & Exhibition in Colorado Springs, Colorado. The volume of sponsorship opportunities and exhibit booth space commitments that have been made is well ahead of prior years.

In addition, recent reports from the IIAR conference hotel, the Broadmoor, indicate that hotel room reservations are moving rapidly, another sign that this will be a well attended conference. IIAR has negotiated a very low room rate at this fabulous hotel. The Broadmoor is also the home of one of the nation's most beautiful golf courses, which will play host to the ARF Golf Tournament Saturday, March 16, preceding the conference.

From a technical standpoint, IIAR's 2013 conference program is shaping up to be one of our best.

The eight technical papers, eight workshops and two panel sessions will focus on a wide range of topics. From an examination of the prospects of ammonia based ocean thermal energy conversion systems, to a variety of in-depth case studies, IIAR's technical program promises to deliver new perspectives and useful information.

Additionally, IIAR will address the need for forming consensus and guidance around ammonia detection and alarms with a special panel session. The session will focus on a discussion of all the possible considerations that should be taken into account as we examine this topic.

IIAR is proud to announce another conference related event, a special workshop focused exclusively on $CO_2$, on Sunday March 17. New in 2013, the workshop expands the training resources of the industry, continuing a valuable training initiative which started with the IIAR ammonia safety training event offered at the 2012 conference.

The workshop has been designed by IIAR's $CO_2$ Committee to provide practical training on this technology, which has only recently emerged as both a primary refrigerant and a low temperature partner for ammonia in cascade systems.

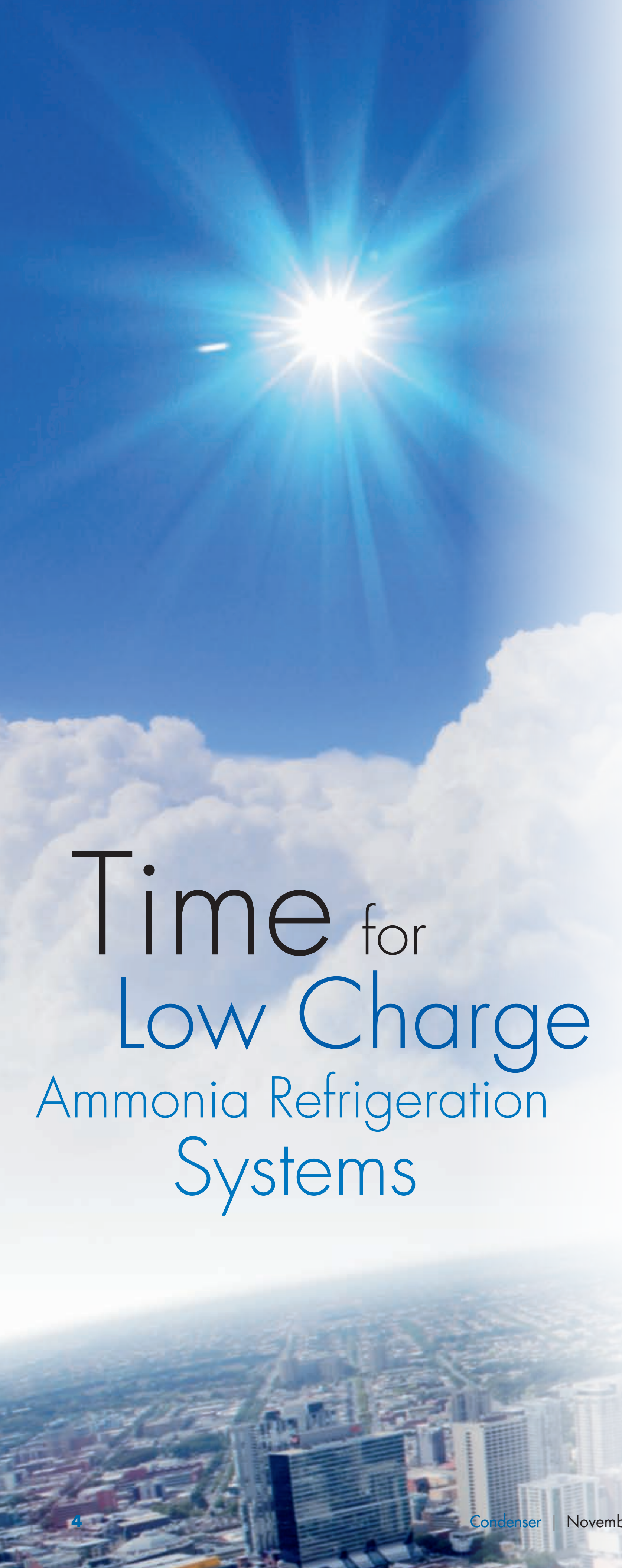
The need for $CO_2$ has become more important as synthetic refrigerants, particularly those used for industrial applications, are being phased out. In the future, the use of both $CO_2$ and ammonia will only continue to increase.

With the $CO_2$ workshop, IIAR will introduce a new, updated $CO_2$ handbook. The workshop is offered in conjunction with the 2013 annual conference. The event is a great deal because this specialized training is essentially free. The price for the four-hour training session is less than the member price of the $CO_2$ handbook, provided as part of the workshop.

I urge you to make plans to arrive at the conference early in order to participate in both the ARF golf tournament and the $CO_2$ workshop.

In addition to the $CO_2$ workshop, IIAR has begun many exciting new initiatives this year. One of those, a special new ARF fundraising initiative, was introduced in the last issue of the Condenser. The new program will focus on individual donations to ARF, to be used for funding specific projects. Turn to the ARF section of this issue of the Condenser to read more about how to get involved.

This has been a great year for IIAR, but even the best years often bring with them their share of setbacks. IIAR extends its heartfelt sympathy to those whose livelihoods and homes were devastated by Hurricane Sandy. As the affected communities begin the rebuilding process, our industry will do everything it can to volunteer its time and attention to the recovery. Additionally, we're saddened this month to recognize the loss of a dear friend and colleague, Anders Lindborg. Please join us in remembering him by reading the special article dedicated to his life in this issue of the Condenser. iiar



# Time for Low Charge Ammonia Refrigeration Systems

As industrial refrigerants go, ammonia has emerged as a clear winner thanks to the unmatched combination of efficiency, cost effectiveness and environmental friendliness. But despite more than a century of proven service in industrial refrigeration and a stellar safety record, ammonia has never been well accepted as a refrigerant for applications in urban areas, mostly because of its mild flammability, pungent odor and toxicity.

However, one factor makes ammonia surprisingly well suited for applications in urban areas, according to Pega Hrnjak, Professor and Co-Director of the Air Conditioning and Refrigeration Center at the University of Illinois, Urbana Champaign.

Ammonia is one of those rare refrigerants that is lighter than air, in the vapor state. That characteristic gives ammonia a safety advantage because the refrigerant vapor cannot increase in concentration as it is being freely exhausted. The vapor dissipates in the atmosphere if it exhausted vertically upward with sufficient velocity.

In addition, ammonia has the lowest demand for charge in microchannel heat exchangers compared to any currently used refrigerant. This means less refrigerant in the system and less refrigerant that could be accidentally released.

In the paper, "Low Charge Chillers Based on Microchannel HXs: Opportunity for Expanding Use of Ammonia," which was first presented at the International Institute of Refrigeration's 2009 annual conference in Ohrid, Macedonia, Hrnjak discusses options for expanding the use of ammonia in densely populated areas by utilizing low charge chillers for air conditioning, refrigeration or the high side of a cascade system.

The complete paper, presented on the following pages of the Condenser, focuses on charge reduction in heat exchangers, especially microchannel condensers, along with the use of hermetic compressors.

## LOW CHARGE CHILLERS BASED ON MICROCHANNEL HXs: OPPORTUNITY FOR EXPANDING THE USE OF AMMONIA

Pega Hrnjak
Professor and Co-Director, Air Conditioning and Refrigeration Center
University of Illinois, Urbana Champaign
President, Creative Thermal Solutions

### ABSTRACT

This article discusses the options for expanding the use of ammonia in densely populated areas by utilizing low charge chillers for air conditioning, refrigeration or the high side of the cascade system. The focus is on charge reduction in heat

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*Time for Low Charge Ammonia Refrigerating Systems continued from page 4*

exchangers, especially microchannel condensers, along with use of newly developed hermetic compressors.

## 1. BASIC STATEMENTS

Nobody objects to the fact that ammonia is a very efficient refrigerant, inexpensive and natural. Over a century of proven service in industrial refrigeration has offset the mild flammability, bad or alarming odor and mild toxicity of this refrigerant. Nevertheless, ammonia was never well accepted as a refrigerant for applications in urban areas mostly because of the smell that could cause panic in people unfamiliar with it. On the other hand, ammonia is also one of rare refrigerants that have a vapor lighter than air. That characteristic positions ammonia as a safety advantage because refrigerant vapor cannot increase its concentration in open areas, thus avoiding creation of LFL (lower flammability level) concentration values when unobstructed upward paths are provided. In addition, ammonia has the lowest demand for charge in microchannel HXs compared to any currently used refrigerant. This leads to an excellent opportunity for ammonia to be used as a refrigerant in urban areas: *very low charged, hermetic chiller placed on the roof with unobstructed vapor release.*

Such small (compared to typical industrial size), low charged ammonia systems, chillers in particular, used for refrigeration (commercial – supermarkets, or similar), air conditioning with a coolant as a part of secondary loop or cascade system provide excellent potential for market penetration of ammonia. In that way the excellent thermodynamic and thermophysical properties of the fluid can be fully utilized and systems are more likely to abide by local codes due to the extremely low charge.

These systems are possible and even realistic due to recent advances in microchannel air cooled condensers, miscible oils (even immiscible combinations would work), low charge DX evaporators, and specifically hermetic compressors. Hermetic compressors are extremely important because they make ammonia look like any conventional refrigerant used for chillers today.

Use of microchannel heat exchangers made of aluminum pave the road for another significant potential improvement: material selection. Ammonia always suffered from poor compatibility with copper. That was perceived as a drawback when compared to systems that were able to use that lighter weight material, easier to work with and less corrosive, all compared to steel. The full utilization of aluminum presents another, yet unrealized, potential for greater competitiveness with ammonia. With increasing cost of copper, even in systems with conventional refrigerants, aluminum is opening new applications. That opportunity should be used for ammonia.

This development should not be a surprise, given some earlier work including: microchannel condensers for ammonia and small systems (Litch and Hrnjak [9], [16], Hrnjak [18], [19]) while a new semi-hermetic compressor for use with ammonia was announced at the Purdue conference in 2008.

## 2. POTENTIAL FOR CHARGE REDUCTION

Compared to other refrigerants, ammonia has excellent potential for charge reduction. Simple comparisons (researchers typically present  p as a function of the mass flux) indicate high pressure drops in ammonia flows compared to other refrigerants. This is a consequence of light vapor which increases velocity and thus increases pressure drop for the same mass flux. Nevertheless, the high latent heat of ammonia can result in almost ten-fold lowering of the mass flow rates needed for a given capacity. An often forgotten fact is that the major resistance to the heat transfer in the air cooled condenser is on the air side, thus limiting the need for a refrigerant side surface.

It will be shown that overall effects are very positive for ammonia compared to other fluids, demonstrating that ammonia can work very well in microchannel heat exchangers. In addition, very low vapor density contributes to increasing void fraction in heat exchangers compared to other refrigerants.

Both Table 1 and Figure 1 present a comparison between several fluids when used in a condenser with microchannel tubes. The charge represents the mass in tubes only assuming homogenous flow void fraction, based on 2kW capacity, 2m of tube length, evaporation and condensing temperatures 0oC and 40oC, and a variable cross section (channel size–number of ports) to provide pressure drop which reduces COP for 1 percent for each refrigerant. The way air and refrigerant sides were treated is presented in Figure 2. More details can be found in Traeger and Hrnjak [15].

| Refrigerant | Dp [kPa] | m dot [g/s] | A [$mm^2$] | m [g] |
|---|---|---|---|---|
| R12 | 9.58 | 17.84 | 123.5 | 43.3 |
| R22 | 15.17 | 13.78 | 65.7 | 25.7 |
| R134a | 11.07 | 14.08 | 92.3 | 29.6 |
| R290 | 12.82 | 7.49 | 58.3 | 10.1 |
| R600a | 5.66 | 7.37 | 140.1 | 13.8 |
| R717 | 17.49 | 2.09 | 22.6 | 2.1 |
| R410A | 23.8 | 14.32 | 42.3 | 21.6 |

Table 1: Potential for charge reduction of several refrigerants

Regardless of the simplifications, these results clearly show great opportunities for ammonia charge reduction in microchannel heat exchangers compared to some other refrigerants. The closest low charge potential refrigerants in this example are HCs but their high solubility in oils may be an issue to resolve.

The relatively smaller air to refrigerant side area ratio in these condensers compared to some conventional air-cooled designs is compensated by a significantly increased air side heat transfer coefficient.

Generally, the simplest way to reduce charge in heat exchangers is to reduce internal volume by reducing the internal diameter, but that, in principle, increases pressure drop. Really there are more sound options to reduce the charge:

- Reduce internal volume but not increase pressure drop;
- Manipulate mass flux to increase void fraction;
- Experiment with heat exchanger type.

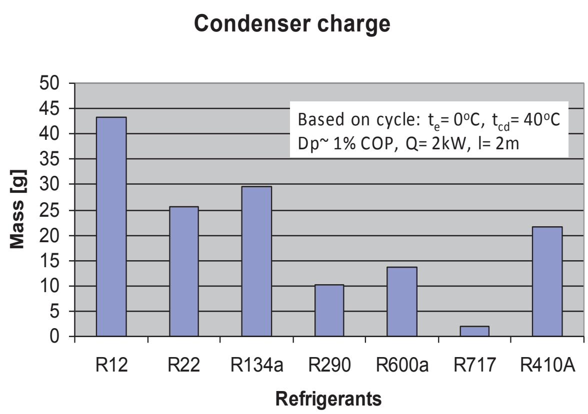


Figure 1: Refrigerant charges in tubes of a 2 m long microchannel condenser that generate pressure drop which causes 1 percent reduction of COP at $T_e$=0°C and $T_{cd}$=40°C

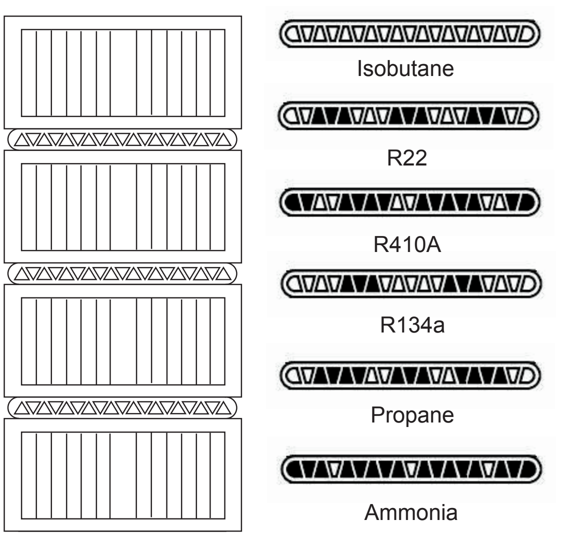


Figure 2: Air and refrigerant side in the same example

Reduction of the internal volume without an increase in pressure drop and internal heat transfer resistance could be done by the reduction of the internal diameter or change in the shape (i.e. flattening the tubes, which in the extreme, lead to plate heat exchangers). These options significantly change the internal surface to volume ratio. Control of the pressure drop is done by increasing the number of parallel passages, thus maintaining or even reducing mass flux. This approach is very effective but unfortunately opens another set of issues: distribution of the two phase mixture. There are various ways of mitigating distribution issues, but these are considered to be beyond of the scope of this paper.

Manipulation of the void fraction requires detailed understanding of the issues. Even though void fraction has been studied extensively (see Zivi [14], Butterworth [5], Newell [10], etc.), to our best knowledge there is no data for ammonia in microchannels except for publications by Litch and Hrnjak [9] and Adams, Hrnjak and Newell [1]. Typically, for the given fluid and local quality, some reduction of the charge (increase of void fraction) could be achieved by increasing the mass or heat flux, affecting flow regimes, as discussed in [22].

Adams, Hrnjak and Newell [1] shed some light on void fraction for ammonia in microchannels. The major findings are shown in the following two figures (3 and 4) which present void fraction data as a function of quality for three mass fluxes, along with correlation predictions from the homogenous and Nino et al. [11] models.

Increase in mass flux typically results in increased pressure drop unless the design goes to multiple parallel channels and reduced length. Parallel flow offers ample opportunities, but the limit is a single pass design.

Heat flux, and consequently mass flux, is affected by the other side of a heat transfer surface. Typically, heat exchangers with air operate at lower heat fluxes. Even lower air side heat transfer is compensated by fin enhancement, while water on the other side increases the heat flux which typically results in lower charge. It was demonstrated in various instances that a water cooled chiller application is by far easier and more successful in charge reduction compared to use of an air cooled condenser.

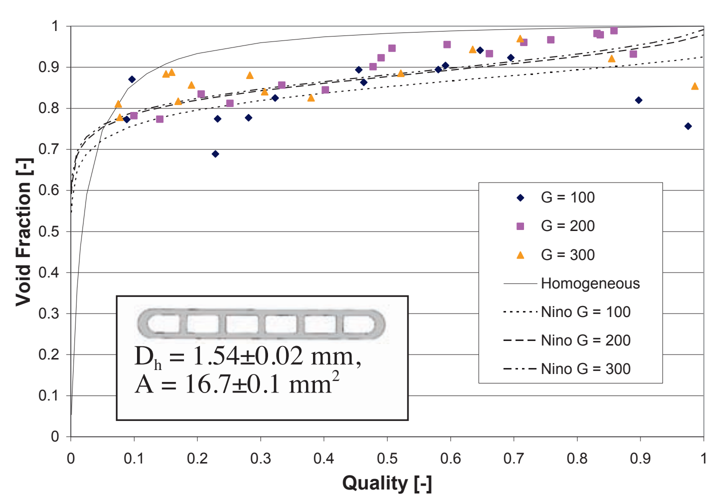


Figure 3: Void fraction of ammonia in a 6-port microchannel.

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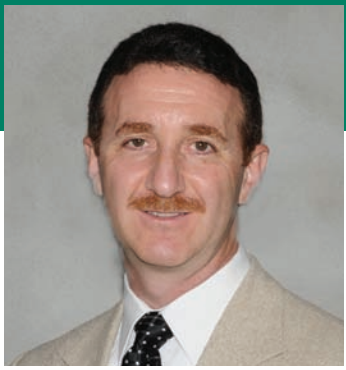
# IIAR Code Advocacy Update



By Jeffrey M. Shapiro, P.E., FSFPE

## Refrigeration Industry Standards: Lead, Follow or Get Out of the Way

Since its inception, IIAR has always been an organization with a keen interest in codes and standards. In fact, a primary driver for creating IIAR was the need for a broad-based advocacy effort by the ammonia refrigeration industry to change the National Electrical Code (NEC). At the time, the NEC designated ammonia machinery rooms as hazardous electrical locations, generally requiring electrical equipment therein to be suitable for use in flammable atmospheres. IIAR was eventually successful in addressing that unnecessary obstacle to ammonia refrigeration, and the organization went on to become the leading developer of design and operational guidance documents and standards for the ammonia refrigeration industry.

For years, IIAR bulletins, IIAR-2 *"Equipment, Design, and Installation of Closed-Circuit Ammonia Mechanical Refrigerating Systems,"* ASHRAE 15 "Safety Standard for Refrigeration Systems" and model fire and mechanical codes have co-existed and served reasonably well as a basis of design and regulation for ammonia refrigeration systems, but the status quo became partly unsustainable as the regulatory climate evolved to become more rigorous. Particularly in the past decade, guidance documents have become increasingly referenced as standards of care that must be followed to satisfy a general duty for safe design, installation and operation of refrigeration systems.

With the "handwriting on the wall" with respect to where things were headed, IIAR made the decision to lead the industry in a proactive fashion. Given the amount of technical expertise that resides within the IIAR membership, it made no sense for IIAR to step aside and allow other organizations, or even the Federal Government to develop standards for ammonia refrigeration.

One of the most noticeable changes will come from IIAR's decision to move away from publication of IIAR bulletins and, instead, incorporate bulletin contents into new and existing IIAR standards. This decision was met with questions from some folks who regarded bulletins as non-mandatory guidance and disliked the idea of making bulletin contents mandatory. However, IIAR bulletins are now being referenced as minimum standards of care. Continuing to label these documents as bulletins and suggesting that they are optional doesn't change the fact that regulators consider the documents to be enforceable as good engineering practice.

IIAR has moved forward with the development of a full suite of industry standards, which include:

- IIAR-1 *Definitions and Terminology Used in IIAR Standards*
- IIAR-2 *Equipment, Design, and Installation of Closed-Circuit Ammonia Mechanical Refrigerating Systems*
- IIAR-3 *Ammonia Refrigeration Valves*
- IIAR-4 *Installation of Closed-Circuit Ammonia Mechanical Refrigerating Systems*
- IIAR-5 *Start up and Commissioning of Ammonia Refrigeration Systems*
- IIAR-6 *Maintenance and Inspection of Closed-Circuit Ammonia Mechanical Refrigerating Systems*
- IIAR-7 *Developing Operating Procedures for Closed-Circuit Ammonia Mechanical Refrigerating Systems*
- IIAR-8 *Decommissioning of Closed- Circuit Ammonia Mechanical Refrigerating Systems*

It's clear from reviewing this list that the approach is comprehensive, prescribing a basis of regulation that starts with the initial planning and design of an ammonia system and ending with the decommissioning of systems that are being removed from service. Some of these standards take on new territories, while others are being expanded to better address topics that IIAR documents previously covered. For example, IIAR-2 was recently enhanced by Addendum A to more comprehensively address ammonia machinery room design, and the IIAR code and standards committees are currently investigating expanded coverage of refrigerant leak detection systems and refrigeration equipment permitted to be installed outside of machinery rooms.

Beyond simply developing and publishing these standards, IIAR also decided to address the issue of enforceability. There is no doubt that the industry will be held accountable for compliance with IIAR standards, so it simply makes sense

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that the standards be offered for adoption by model codes. Gaining such recognition accomplishes a couple of objectives. First, having IIAR standards adopted by model codes firmly establishes IIAR's prominence as a standards developing organization and attests to the quality and credibility of our documents. Second, having our standards adopted by model codes helps to avoid codes prescribing conflicting regulations since adopted reference standards are generally treated as part of the code. Code developers ordinarily avoid deliberate conflicts between a code and a reference standard unless there is a compelling reason for not following the reference standard.

IIAR has already initiated the process of getting our new standards referenced by model codes; however, because there are multiple codes in different cycles that must be addressed, the process will take several years to complete.

Looking at the list of standards above, it's evident that IIAR-2, 3, 4 and 5 relate to construction and start-up. These topics are encompassed within the scopes of model mechanical codes. IIAR-6 and 7 are operations related and are encompassed within the scopes of model fire codes. Likewise, IIAR-8, which deals with decommissioning, is also encompassed in the scopes of model fire codes.

IIAR-2 is already referenced by the International and Uniform mechanical codes, and we will be working to update the referenced edition to the latest version before the 2015 International and Uniform codes are published. IIAR-2 will also be added as a reference to the 2015 NFPA Fire Code because there is some overlap between these documents.

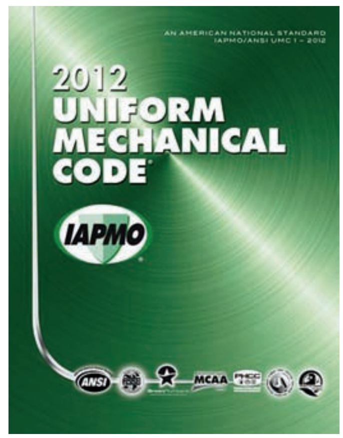
IIAR-3, IIAR-4 and IIAR-5 will be submitted for recognition in the 2015 Uniform Mechanical Code, but the documents were not far enough along to make the submittal deadline for the 2015 International Mechanical Code (IMC). That recognition will have to wait until the 2018 edition of the IMC is published.

Proposals to adopt IIAR-6, IIAR-7 and IIAR-8 have already been submitted to the NFPA Fire Code, and if successful, these references will appear in the 2015 edition of that code. Similar proposals will be submitted to gain recognition in the 2015 International Fire Code.

Of course, since some of IIAR's standards are still in the development phase, it goes without saying that these standards will only be referenced by codes if they are completed in time to meet various processing deadlines. If the timing doesn't work out, the references will be delayed until the next code editions.

In the big picture, having a clearly established basis of regulation for ammonia refrigeration systems will significantly benefit the industry and regulators. Everyone will be provided with a clear understanding of what's expected, and it won't come as a surprise for non-compliant facilities to be cited for failure to meet those expectations. On the other hand, an expected consequence of IIAR's proactive approach will be less freelancing by inspectors seeking to create rules that are neither predictable nor technically substantiable. That, in turn, will hopefully reduce the level of tension that is often associated with facility inspections.







Finally, it's important to point out that, simply because codes and standards may provide prescriptive regulations to cover a particular topic, there is no intent to tie the hands of designers or others with respect to creative approaches that accomplish design, installation or operational objectives in a different way than what might be specified it the text of a regulation. Model codes always provide a pathway for alternative methods of compliance to be considered and approved by regulators as long as the intent of a regulation has been satisfied.

It is clear that IIAR's decision to be a leader in developing and promulgating standards for the ammonia refrigeration industry was initially, and remains today, a prudent action that will benefit IIAR's members and the industry as a whole for many years to come. iiar

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# IIAR Government Relations

by Lowell Randell, IIAR Government Relations Director

## IIAR Legislative Round-up – Status of Bills Impacting Industrial Refrigeration

Election years, especially presidential election years, are tough times to make progress on legislative proposals and 2012 is no exception. Congress currently has before it a number of legislative proposals that could impact the industrial refrigeration industry. Some legislative proposals would potentially add regulatory requirements to the industry, while others seek to clarify regulations or lessen the burden on industry. Given the complexities of an election year, it appears that many of these issues will be pushed off until next year.

Below is a summary of some of the legislation being considered by Congress that could impact the industrial refrigeration industry:

### Toxic Substances Control Act

Passed by Congress in 1976, the Toxic Substances Control Act (TSCA) provides EPA with the authority to require reporting, record-keeping and testing requirements, and restrictions relating to chemical substances and/or mixtures. TSCA also addresses the production, importation, use, and disposal of specific chemicals. There is a growing bipartisan recognition, along with recognition from industry that the TSCA needs to be modernized, particularly to incorporate new science into the regulations. However, there is a lack of consensus on how to accomplish such modernization.

On July 25th, the Senate Committee on Environment and Public Works approved S. 847, entitled the Safe Chemicals Act. While efforts were made by the committee to draft a bipartisan bill, the current version of the Safe Chemicals Act was opposed by all of the Republicans on the Committee, and by most industry groups. Critics are concerned that the current version gives too much additional power to EPA and would weaken policies designed to protect trade secrets and stifle new product development.

There have been no recent movements in the House of Representatives to advance TSCA reform. Given the controversy surrounding the Safe Chemicals Act in the Senate it is unlikely that TSCA reform will be completed this year. Look for Congress to revisit this issue in 2013.

### Chemical Facilities Anti-Terrorism Standards (CFATS) Reauthorization

The Chemical Facilities Antiterrorism Standards (CFATS) program's legislative authority has been subject to a series of short term extensions as Congress considers proposals to provide longer term reauthorization. The latest extension came as a part of the six month continuing resolution passed by Congress to fund the government through late March 2013. In the meantime, Congress has drafted multiple bills that would provide longer term authority for the program. Efforts by the last Congress were hung up by differences over Inherently Safer Technology (IST) provisions. This year, it appears that IST is effectively "off the table". However, while committees in both the House and Senate have passed respective versions that would reauthorize the program for several years, none of the versions have made it to the floor for full consideration by the House or Senate.

In the midst of reauthorization considerations, the CFATS program has been embattled by controversy. Earlier this year, the House Energy and Commerce Subcommittee on Environment and the Economy held a hearing to evaluate internal operation and implementation of the CFATS program by the Department of Homeland Security (DHS). The subcommittee expressed its concerns about reports of the inefficiency at which DHS has been implementing CFATS. DHS acknowledged that there are challenges with the CFATS program and that staff have come forward with an action plan to address these challenges.

More recently, Senator Grassley (R-IA) and others in Congress have raised a number of concerns such as allegations that CFATS assigned employees to non-existent field offices, allowing employees to work from home while claiming on paper to be located in phantom CFATS field offices. Sen. Grassley stated that one byproduct of this was that employees often lived in low locality-pay areas while claiming duty stations in high locality-pay areas and receiving higher pay, as a result. Allegations also included routine procurement by CFATS of tactical and field equipment for which the program had no use. In addition, a high level official in the Department of Homeland Security allegedly refused to report information about the abuses to the Inspector General.

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Expect Congress to continue closely watching DHS implementation of CFATS as long term reauthorization of the program is considered again in 2013.

## General Duty Clarification Act

On August 2, 2012, Congressman Mike Pompeo of Kansas introduced the General Duty Clarification Act, aimed at requiring the Environmental Protection Agency (EPA) to promulgate regulations related to the General Duty Clause of the Clean Air Act. On September 11, 2012, Senator Pat Roberts, also of Kansas, introduced the same legislation in the Senate. The bills responds to concerns by industry that the EPA continues to cite facilities under the Clean Air Act's General Duty Clause, but has never fully defined the provision, not issued by any regulation, for how the clause should be enforced.

According to Rep. Pompeo, the General Duty Clarification Act would:

- Require EPA to complete a rulemaking process before finding any facility in violation of the General Duty Clause.
- Require definitions of "extremely hazardous substance," "appropriate hazard assessment techniques," and "design and maintain a safe facility" in any General Duty Clause regulation.
- Require EPA to issue guidelines to ensure that EPA enforcement procedures are uniform across its Regions.
- Clarify that EPA's mission is environmental protection, not homeland security, by prohibiting EPA from regulating chemical facility security under the General Duty Clause, reinforcing exclusive jurisdiction under the Department of Homeland Security.

The added clarity required by the General Duty Clarification Act could help industry better understand the approach being taken by EPA and facilitate more effective compliance efforts.

## Regulatory Reform Legislation

In July, the House of Representatives approved a package of regulatory reform policies in the form of H.R. 4078, the Red Tape Reduction and Small Business Job Creation Act. The bill passed the House on July 26th by a vote of 245 – 172, with a few Democrats crossing the aisle to support the legislation. The package includes a number of regulatory reforms that could impact the industry. Below is a summary of some key provisions of interest to the industrial refrigeration industry:

- **Title I (Regulatory Freeze for Jobs Act of 2012)—H.R. 4078:** The bill would prohibit an agency from finalizing any significant regulatory action (i.e., rule or guidance) for two years or until the unemployment rate falls to 6.0 percent or less, whichever occurs first. The bill would allow an agency to finalize a significant regulatory action during the time period described above if the President determines that it is necessary for purposes of an imminent threat to health or safety, the enforcement of criminal laws, national security, or pursuant to an international trade agreement.
- **Title II (Midnight Rule Relief Act of 2012)—H.R. 4607:** The bill would prohibit a Federal agency from proposing or finalizing any midnight rule during the moratorium period (i.e., after Election Day through Inauguration Day of the following year if a President is not serving consecutive terms) if the rule is likely to result in any of the following:

  (A) An annual effect on the economy of $100,000,000 or more;

  (B) A major increase in costs or prices for consumers, individual industries, Federal, State, or local government agencies, or geographic regions; or

  (C) Significant adverse effects on competition, employment, investment, productivity, innovation, or on the ability of United States-based enterprises to compete with foreign-based enterprises in domestic and export markets.
- **Title III (Sunshine for Regulatory Decrees and Settlements Act of 2012)—H.R. 3862:** H.R. 3862 would increase transparency and judicial scrutiny of sue-and-settle decrees and settlements, improve fairness to the public and those affected by regulations, and assure that sue-and-settle rulemakings observe proper rulemaking procedure. Specifically, the bill would impose new requirements upon consent decrees or settlement agreements in any action to compel a federal agency to take regulatory action that is alleged to be unlawfully withheld or unreasonably delayed that affects the rights of private parties other than the plaintiff or the rights of state or local governments.

While the legislation has passed the House, it is unlikely to become law this year. President Obama has issued a veto threat and the Democrat controlled Senate is unlikely to bring the bill to the floor for a vote. The results of the November election will determine whether the prospects for these reforms become more or less likely in 2013.

As the results of the November election are sorted out, the prospects of the above legislative proposals will become clearer. IIAR will continue to actively monitor these and other legislative issues and engage with Congress, the Administration and industry partners to promote and protect the interests of IIAR members. iiar.

# Remembering Anders Lindborg

By Andrea Fischer

The ammonia refrigeration industry lost a dedicated advocate, colleague and friend last month with the passing of Anders Lindborg. Anders was a longtime member of several international industry organizations and an Honorary Life Member of the IIAR.

"We are very sad that one of our founding members Anders Lindborg is gone," said Monica Witt, President of Eurammon. "We are not only losing a refrigeration engineer who has spent his whole professional life working for the advancement of natural refrigerants, but also a good friend. We will miss him and keep the memory of all he has done for our industry alive."

Aptly nicknamed "Mr. Ammonia," Anders was dedicated to safety, especially when it came to confronting perceptions surrounding the safe use of ammonia for refrigeration systems.

At a time when the general public and others not directly involved with the safe handling of ammonia were wary of its use in large operations, Anders was one of the first professionals to promote the idea that ammonia refrigeration is, in fact, a very safe technology.

Anders was dedicated to safety within the industry, said Bob Hampson, former President of Maritime Terminal, Inc. "His approach and his knowledge will not be easily replicated."

"He was an incredibly knowledgeable guy, and he used that knowledge to communicate the idea that the risk associated with operating an ammonia refrigeration facility is relatively very small," said Jeff Welch, Past IIAR Chairman. "His message was that if you step back from the immediate reaction to an incident, the numbers are actually very favorable in support of our industry. He was one of the few guys who initially recognized and communicated that idea."

Beyond communication, Anders was passionately devoted to education, believing that increasing familiarity with ammonia would lead to a greater understanding of the safety of the industry.

"He was very enthusiastic about training others in the safe handling and use of ammonia in a practical, hands-on way," said Witt. "He gave them a chance to smell and handle ammonia, and he always displayed a graph showing that people are more likely to be hit by lightning than to have an accident with ammonia."

Serving as a resource for his colleagues, and learning from them as well was a pursuit that was also very important to Anders, said Jim Calm, Engineering Consultant and ASHRAE Fellow.

"Anders and I turned to each other a number of times for help over the years," said Calm. "Whether in personal contacts, collaborative work in international committees, or casual encounters in conferences, I remember his smile when Anders answered a question or request. His in-depth insights not only to the reasons, but also the background for regulatory requirements and common approaches reflected his significant experience in refrigeration practices."

Anders was a well-educated engineer with a deep knowledge of his specialty and a dedication to protocol, said Göran Löndahl, noted author and United Nations FAO consultant. "The technical solutions he proposed or considered had to be as close to perfection as humanly possible, and also meet both technical and financial specifications." Anders was nothing if not consistent when it came to other things he was passionate about, including his favorite sport, said Löndahl. "His view on golf coincided with his view on refrigeration: The rules must be followed!"

Next to refrigeration technology, ammonia and golf, Anders was devoted to music, participating in many choral groups, including the Concert Hall Choir in Helsingborg. Anders Lindborg graduated from KTH Royal Institute of Technology in Stockholm. In 1962 he joined STAL Refrigeration AB in Norrköping where he became manager of the project design and installation department. In 1968 he was recruited by Frigoscandia AB in Helsingborg to lead their refrigeration activities. When Frigoscandia AB was acquired by AGA AB his role was expanded to cover refrigeration units for air gas production in Europe and South America.

Anders was involved in both national and international organizations to promote the use of ammonia. His work in the Swedish and International Institutes of Refrigeration resulted in honorary memberships in both. He was a lifetime member of ASHRAE and The International Institute of Ammonia Refrigeration. He was also a Board member of the Ammonia Safety Training Institute.

In 1995 he received a prestigious award in refrigeration technology, A.J.A. Ottesen's memorial medal. Until recently, he was also actively working with the Swedish refrigeration code and modernizing security standards.

In 1995 he started Ammonia Partnership AB, focusing on refrigeration consulting and education.

Apart from project planning and design he also worked on risk analysis for Carlsberg and other companies.

"The international refrigeration industry, and his colleagues from all over the world have lost a knowledgeable specialist, skilled tradesman and dear friend," said Löndahl. "Anders will be missed." iiar

# Understanding the Causes of Surface

Author: Jim Young, ITW Insulation Systems

Preventing surface condensation on insulated piping is of vital importance when it comes to the prevention of safety hazards and opportunities for equipment damage in an ammonia refrigeration facility.

In addition to reducing heat gain from the ambient environment, one of the main purposes of insulation on pipe and mechanical equipment operating at below ambient temperatures is to prevent condensation on the outer surface of the insulation system.

Preventing this kind of surface condensation is simple in concept. The system must only be designed to keep the surface temperature of the insulation system above the dewpoint temperature of the surrounding air.

However, that simple relationship becomes more complicated in practice because each of these two temperatures is dependent on the interrelationship of a myriad of factors.

In order to assure optimum control of insulation system surface condensation – commonly called condensation control – all of these factors must be fully and properly considered.

Some of the most common factors impacting the surface temperature of the insulation system are: fluid temperature; insulation thickness; thermal conductivity; pipe size; jacket material; and wind speed. Meanwhile, common factors influencing the dewpoint of air are ambient temperature and ambient relative humidity.

Of these factors, selection of the proper relative humidity to use for system design is the most important and also the most complicated to handle.

The influence of each of the design and climatic factors impacting condensation control will be discussed in detail as part of a special series presented here and in subsequent issues of the Condenser.

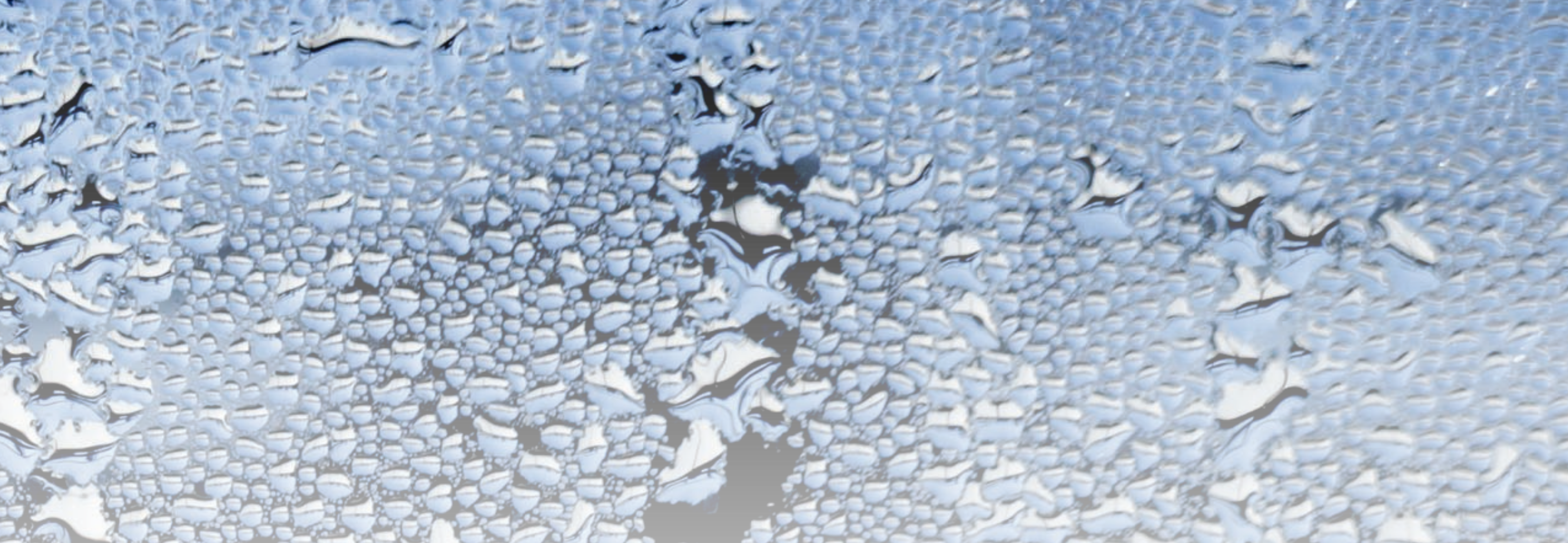
In this installment, we'll take a close look at the background and theory of surface condensation before moving on, in the February issue of the Condenser, we'll discuss the influence of climatic conditions and system components on condensation.

**Background**

Pipe, tanks, ducts, vessels, and other mechanical equipment operating at below ambient temperatures are insulated for various reasons with a key one being to prevent condensation of water vapor from the ambient atmosphere on the exterior surface of the insulation system. Condensation can lead to numerous problems including:

- Safety hazards as the water drips onto the floor below
- Damage to inventory as the water drips onto the merchandise below
- Poor aesthetics when dripping water stains ceiling tiles
- Damage to the insulation system materials
- Reduced insulating ability of the insulation (increased k-Factor)
- Shortened insulation system lifespan
- Corrosion of jacketing or pipe
- Growth of mold on the insulation system surface or on other building materials where condensed water drips

Because of these potential problems, prevention of condensation on the surface of cold mechanical insulation systems is of critical importance. This series of articles will discuss the causes of surface condensation, the factors



# Condensation on Insulated Piping

influencing it, and how to best identify design conditions and select system components to prevent surface condensation on mechanical insulation systems.

Various tables or charts will be presented throughout this discussion to show the insulation thickness necessary to prevent condensation under various conditions. These thicknesses were not generated by experimentation but, rather, are based on common modeling or thickness calculations using the ASTM C680 standard thickness calculation method. This is the normal method in which insulation thicknesses are designed in the mechanical insulation industry.

All of the thickness charts or tables presented assume that the material properties and ambient conditions are accurate. These thickness charts or tables presented also assume that the insulation system is working perfectly and is impervious to water and water vapor penetration.

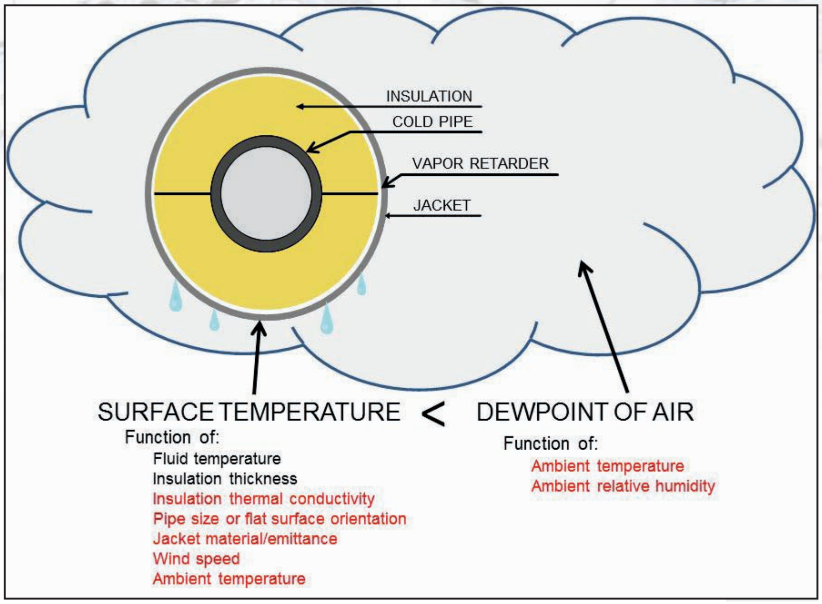



Figure 1 – Cause of surface condensation and the factors influencing it.

While the water resistance of various system components is important, especially in a cold pipe application, that is a subject for another time. There will be no discussion here related to which insulation or vapor retarding materials have better or worse resistance to water. This discussion will be limited solely to insulating to achieve condensation control. Other design criteria including meeting energy code requirements, achieving heat gain limits, maintaining temperature control, and freeze protection will not be addressed.

## Theory

The cause of surface condensation is quite simple in concept. Water vapor in the air will condense on a surface that is below the dewpoint temperature of the surrounding air. This is a complicated topic when applied to mechanical insulation systems because there are so many factors which influence either the dewpoint or the surface temperature of the insulation system. Figure 1 illustrates this concept and lists the various factors influencing each component of the equation. The factors shown in red are discussed in detail later in this series.

The system designer must understand this theory, select the appropriate climatic design conditions, the proper insulation system components, and then determine the required insulation thickness to achieve their desired performance.

Now that the background and theory of surface condensation has been examined, the influence of climatic conditions, together with the influence of system components on surface condensation will be explored in the next installment of this series. Check this space in the February issue of the Condenser to read more. iiar.

*Time for Low Charge Ammonia Refrigerating Systems continued from page 7*

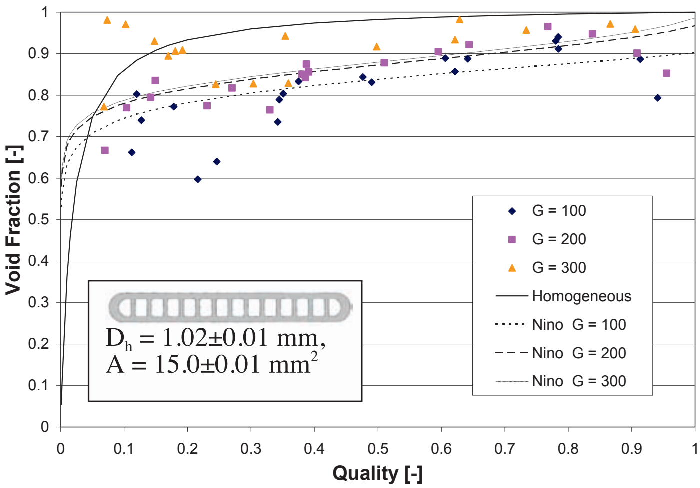



Figure 4: Void fraction of ammonia in a 14-port microchannel.

## 3. APPROACHES AND ACHIEVEMENTS IN LOW CHARGE HEAT EXCHANGERS AND SYSTEMS

Reducing internal volume typically increases the surface to volume ratio and thus, does not significantly affect heat transfer resistance (keeping in mind that refrigerant side heat transfer is hardly ever a bottle neck). Thus, shrinking the hydraulic diameter in the way pressure drop effects are minimized is a rational approach. A parallel flow channel arrangement reduces the pressure drop, but is limited to a single pass design. At that point, the trade-off between pressure drop and efficiency becomes the objective.

Increasing void fraction by manipulating the heat and mass flux helps to some extent. Conditions in which liquid retention is minimized typically occur when liquid and vapor velocities are similar; that is mostly in the intermittent and misty flow regimes. Higher mass fluxes result in slightly higher void fractions. Flow patterns in microchannels are also affected by surface tension extending the range over which intermittent flow is seen, resulting in void fractions similar to homogeneous flow in most of the channel length.

Condensers with intermediate liquid removal offer improved heat transfer characteristics and less liquid retention, but are more complex.

At this point of heat exchanger development, the lowest charges have been achieved by using a microchannel approach and will be presented later in more detail. Nevertheless, microchannel technology is not the only way to reduce charge. Very good results have been achieved by using plate evaporators or condensers with water, or other fluids, on the other side (brazed, gasketed, cassette, welded shell and plate, etc…). The automotive industry has developed plate evaporators for air cooling, but the application is still limited to mobile air conditioning (aero, automobiles, off-road vehicles etc…). Spray evaporators are also known for their low charge. It should not be forgotten that in microchannel heat exchangers, significant liquid quantity is retained in the headers.

Typical values for refrigerant inventory in larger heat exchangers as given by Pearson [13] are shown in Table 2.

| Heat exchanger type | Specific charge [g/kW] |
|---|---|
| Shell and tube | 1000 |
| Plate | 500 |
| Gravity fed plate | 250 |

Table 2: Refrigerant inventory for larger heat exchangers

Ayub in [1] to [3] reports about low charges in spray evaporators and recent improvements. These results are shown in Table 3.

| Ref. | Capacity [kW] | NH3 charge [kg] | Specific charge [g/kW] |
|---|---|---|---|
| 1 | 1408 | 159 | 113 |
| 2 | 2816 | 204 | 72 |
| 3 | 4189 | 227 | 54 |

Table 3: Specific charge values for some ammonia spray evaporators

Pearson [13] reports that "optimal charge" chiller had 100g/kW charge. The optimal value had an unspecified additional charge for leakage and operation.

Litch and Hrnjak [9] presented data for some small ammonia systems with published charges in Table 4.

| Chiller System | Capacity, Evaporator [kW] | System specific charge [g/kW] |
|---|---|---|
| *Air cooled:* | | |
| Hrnjak & Litch (MC condenser) | 13 | 18 |
| Cecchinato & others | 120 | 84 |
| Refcomp VKA16-14 | 16 | 125 |
| York YSLC F4F00UW | 220 | 129 |
| N.R. Koeling LK 25 | 25 | 159 |
| *Water cooled:* | | |
| Palm, KTH – Sherpa project | 9 | 11 |
| ILKA MAFA 100.2-11K45 | 108 | 23 |
| ABB (York) BXA | 108 | 157 – 43 |
| Gram (York) LC | 38 – 228 | 228 – 37 |
| Sabroe (York) PAC | 57 – 1074 | 172 – 36 |

Table 3: Specific refrigerant charges for some commercially available ammonia chillers

*Time for Low Charge Ammonia Refrigerating Systems continued on page 20*

*Time for Low Charge Ammonia Refrigerating Systems continued from page 18*

In the summary of a decade of charge reduction at KTH, B. Palm [20], presented a small ammonia system (a laboratory setup simulating a domestic water to water heat pump) as a part of the Sherhpa project. Their largest challenge was to get the oil back to the compressor in the direct expansion system, so they used miscible oil and a heat exchanger with narrow channels. The same special aluminum heat exchangers were used as condenser and evaporator. Plate heat exchangers were also tested and performed well as condensers but not as evaporators due to problems with oil return. The system with an open compressor had 9kW capacity with 100g of charge (an amazing 11 g/kW).

## 4. EXPERIENCES WITH MICROCHANNEL HEAT EXCHANGERS

Recent advances in manufacturing technologies of microchannel tubes and heat exchangers resulted in expansion of some important mass production markets and consequently opened opportunity for further reduction of costs. That situation generates the possibilities for the application of microchannel heat exchangers in areas with traditionally lower production volumes, ammonia being one of them.

Litch and Hrnjak [9] presented data for an ammonia chiller with an air-cooled microchannel condenser. This resulted in the lowest specific charge air-cooled chiller for ammonia reported in literature so far.

Two aluminum condensers were evaluated: one with a single serpentine tube and the other with a parallel tube arrangement between headers having 24 tubes in the first pass and 14 in the second. Each tube has 19 triangular ports of equal dimension with a hydraulic diameter less than 1 mm. The fins are multi-louvered. The serpentine condenser has a single tube that passes 16 times through multi-louvered fins. There are five enhanced square ports in the tube. Additional details of these condensers may be found in Litch & Hrnjak [9].

Overall heat transfer performance and charge measurements were taken for each condenser and the system as a whole. The microchannel heat exchanger with parallel flow performed better in every respect. Overall, condenser performance was quantified in terms of U values for different air flow rates, superheating and subcooling conditions and is presented in Figure 5.

Refrigerant inventory measurements of the condenser were taken at different operating conditions. Refrigerant inventory measurements are compared to model results using different void fraction model predictions. All void fraction correlations perform similarly in helping to predict total charge. The use of Newell's correlation (Newell et al. [10]) for the serpentine condenser yields the smallest average error of 9.3 percent, with a maximum of 15.7 percent. With the Butterworth [5] and Zivi [14] correlations, the average and maximum errors are 10.1/22.8 percent and 12.3/24.9 percent, respectively. The slight over prediction results in a simulated subcooled region that is larger than the actual region, inflating predicted charge. Data by Adams, Hrnjak and Newell [1] fit well in the prediction. These results are presented in Figure 6.

Obviously, predictions for a serpentine condenser are much more accurate than for microchannel when using the same correlation and experimental data. That clearly indicated a significant inaccuracy in the charge prediction in headers (see Figure 7.). Another insight from Figure 7 (serpentine condenser) is that liquid subcooling is a large contributor to

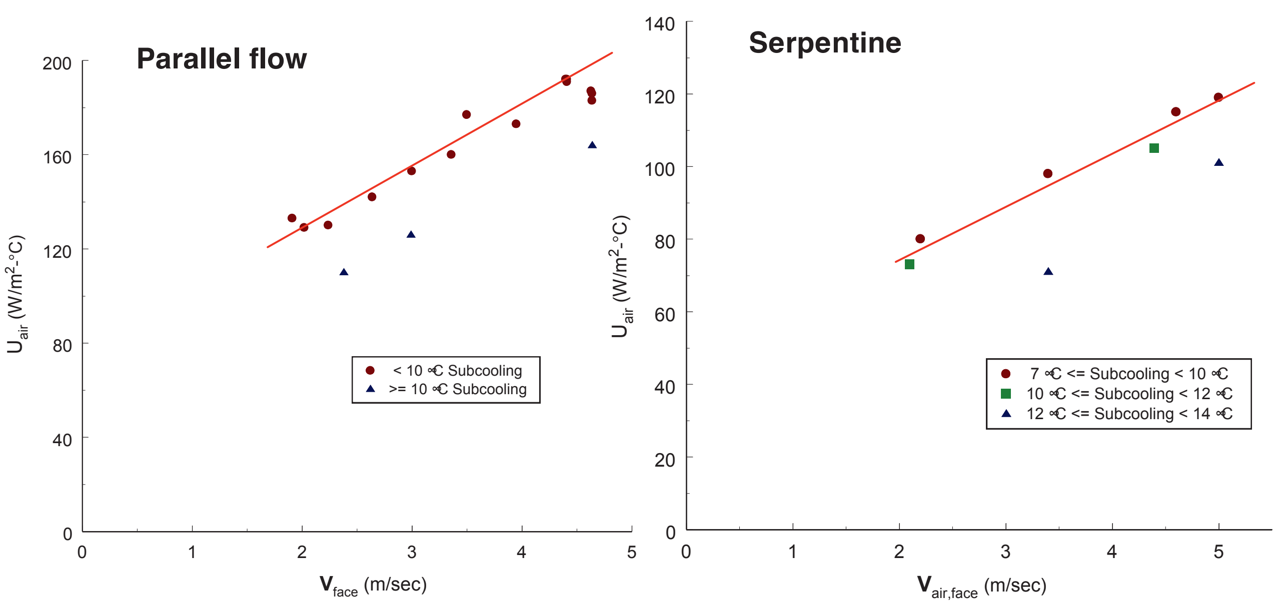



Figure 5. Overall heat transfer coefficients for two microchannel condensers for ammonia.

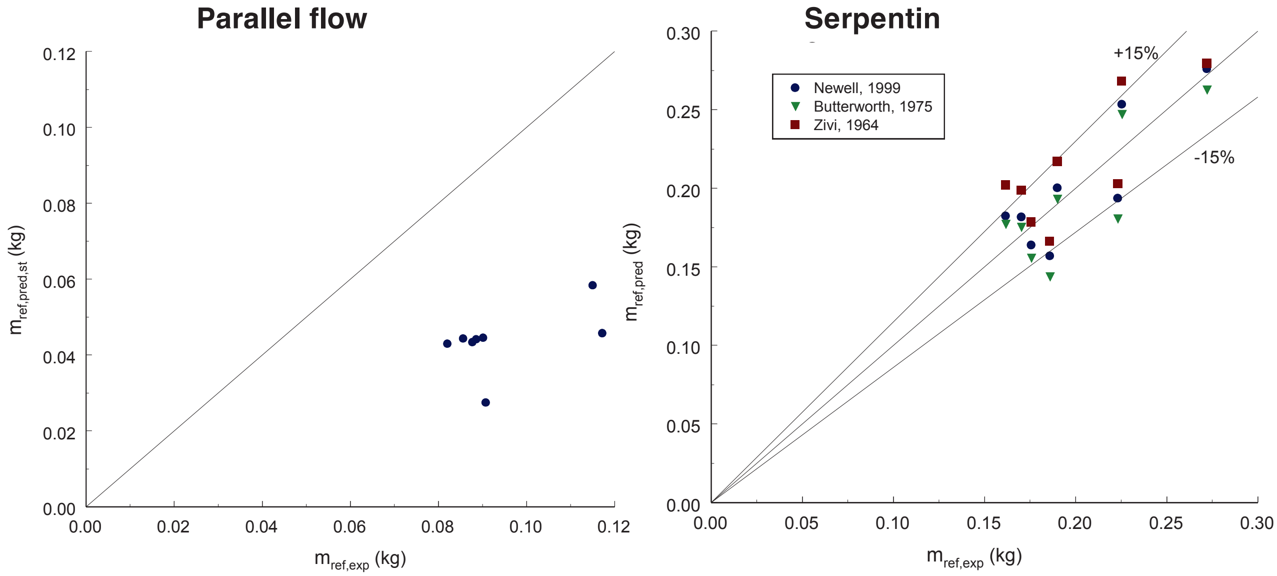



Figure 6. Predictions and measured values for the charge in two condensers.

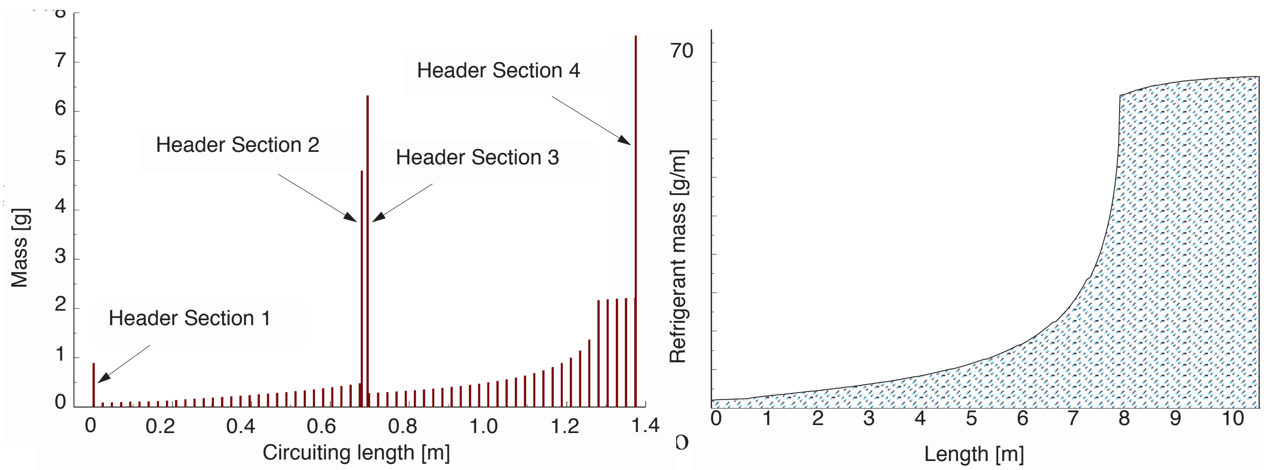



Figure 7. Charge distribution in two microchannel condensers.

total charge. The relative predicted charge contributions from the refrigerant phase zones for the data point with the highest liquid subcooling tested are 0.5 percent in superheated zone, 29.2 percent in the two-phase region, and 70.3 percent in subcooling region. From the data point with the lowest liquid subcooling, the contributions are 0.5 percent, 60.1 percent, and 39.4 percent in subcooling. Even though the subcooling region is only 26 percent of the total tube length, it comprises 70 percent of the total charge. Thus it is advantageous to reduce subcooling not only for increased heat transfer, but to reduce refrigerant charge.

From the experimental data taken, the microchannel parallel flow condenser appears to outperform the macrochannel serpentine condenser. The overall heat transfer coefficient for a given face velocity is 60-80 percent higher than for the serpentine condenser; and the charge is an average of 53 percent less. The microchannel condenser has a smaller volume for approximately the same face area. Also, it has less charge and better heat transfer than the serpentine and typical condensers.

## 5. NEW DEVELOPMENTS IN COMPRESSORS AND MICROCHANNEL HEAT EXCHANGERS AS CONDENSERS IN SMALL SYSTEMS

Probably the most important recent development is the new hermetic compressor that is used for both refrigeration and heat pumping. The wrap is specifically designed for use with ammonia. The nominal capacity in cooling (at –5°C/50°C) is 45 kW while in heat pumping is 47 kW. The motor is an IPM type with aluminum windings. There are two models: one for low and one for high temperature. The weight of the hermetic version is about 100 kg. This compressor is equipped with an oil pump. The ammonia charge of the unit is 6 kg (see Table 4 and Figures 8 and 9 below).

| New unit with hermetic scroll compressor | | |
|---|---|---|
| Shell | High pressure chamber | |
| | Design pressure | 2.7 MPa |
| Motor | IPM type Al windings | 15 kW |
| Operating Conditions | Design temperature | 120 °C |
| | Condensing temperature | 30 to 55 °C |
| | Evaporating temperature | –35 to +10 °C |
| | Rotational speed | 1800 3600 rpm |
| Lubrication | Oil pump | |
| | Oil cooling | Liquid injection |
| | Oil type | PAG |
| Weight | | 100 kg |
| Refrigerant charge | | 6 kg |
| Capacity at –5/50 °C | Cooling | 45 kW |
| | Heating | 47 kW |

Table 4. Characteristic of the first chiller unit with hermetic scroll compressor.

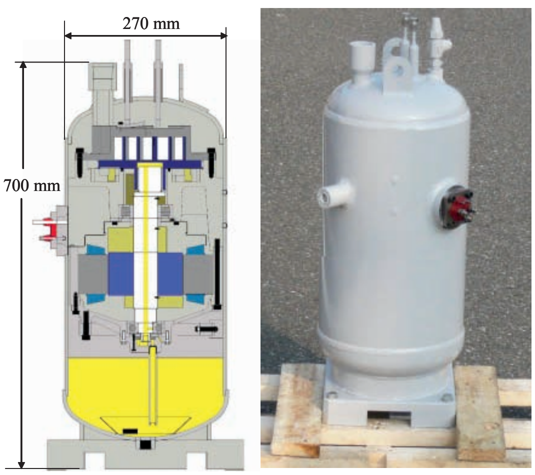



Figure 8. New compressor: cross section and photo.

Figure 9. New chillers with hermetic ammonia scroll and conventional condensers.

Development of microchannel condensers for ammonia has moved from the Air Conditioning and Refrigeration Center at the University of Illinois to Creative Thermal Solutions (CTS), a high tech company that specializes in research and development of novel refrigeration and air conditioning approaches.

Figure 10 presents a photo of a condensing unit with a microchannel heat exchanger used in an experimental facility for evaluation of ammonia evaporators, while Figure 11 shows a unit from Figure 9, CTS instrumented for implementation of MC condensers.

The MC condensers used improved performance with 87 percent face area of original round tube condenser, with only 19 percent of core volume and just 7 percent or original weight and 27 percent or original refrigerant volume – charge. These results were presented by M. Tomooka in a paper at a past IIAR meeting in Orlando, FL "**Application of Micro-channel heat exchangers to compact ammonia systems**."

Another very good example is presented by Cecchinato and others [23] who described the main features of the newly designed prototype, including:

- refrigerating capacity of 120 kW;
- open inverter-driven screw compressor with nominal volumetric flow rate equal to 118 m3/h;
- evaporation and condensation temperatures of 2°C and 50°C respectively;
- temperature of the secondary refrigerant (water) at the evaporator outlet was set at 7°C and at the evaporator inlet at 12°C;
- plate heat exchanger evaporator with 52 plates having high chevron angle with overall dimensions equal to 618x191 mm.

The chiller uses low internal volume heat exchangers and the direct expansion evaporator providing the charge of 10.0 kg of ammonia. Experimental results showed COP of 5.0 to 2.7 at ambient temperatures from 10 to 40°C. The authors estimated potential for a charge reduction of 20 percent if a microchannel condenser were used.

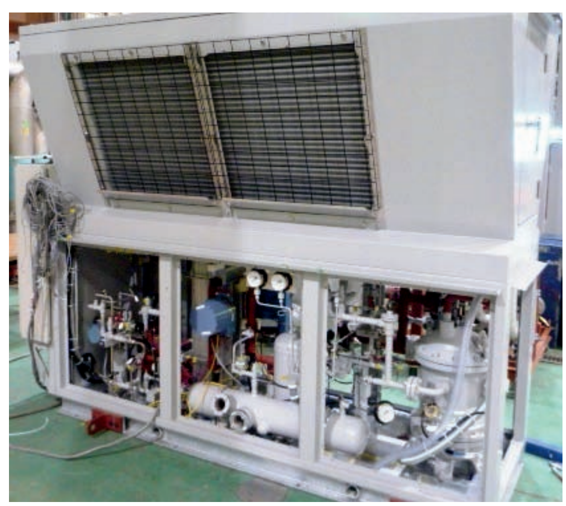


Figure 10. Condensing unit with MC condenser as used at CTS during $NH_3$ evaporator studies.


Figure 11. Mycom $NH_3$ chiller with prototype hermetic compressor, CTS instrumented.

## 6. CONCLUSIONS

This paper presented a case for a small, low charge, air cooled ammonia chiller using microchannel condensers and hermetic compressor with miscible oil. Microchannel air cooled condensers along with DX plate or similar evaporators provided the basis for low charge.

In addition, the external volume of the chiller could be reduced because the external volume of a microchannel design is small. Besides being compact, microchannel heat exchangers are also made from lightweight aluminum. Thanks to the technology developed in the automobile industry, these exchangers are relatively inexpensive.

Expanding the use of aluminum beyond the MC condenser, it is possible to reduce the weight and the cost even further, making the chillers cost competitive in conventional systems.

The hermetic compressor with miscible oil provides a low leak and a low maintenance environment and in every respect displays a similarity with conventional chillers.

Since ammonia is one of the few refrigerants that have vapor lighter than air, the location of the chiller should be on the roof.

Assuming unobstructed release, even in the worst case scenario of a catastrophic leak, refrigerant vapor cannot increase its concentration beyond LFL (lower flammability level) or toxic concentrations values. That represents a great improvement in safety and puts ammonia below the radar of regulations.

All these features provide an excellent opportunity for the use of ammonia as a refrigerant in urban areas: ***very low charged, hermetic chiller placed on the roof with unobstructed vapor release***.

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by Chris Combs, International Programs Director

## Chile's Ammonia Refrigeration Industry at a Turning Point

In January 2012, an ammonia leak from the refrigeration system at a fruit packing plant in Codegua in central Chile resulted in the death of one worker and the ammonia exposure of 122 workers. The exposed workers were taken to a local hospital, but before the incident was over, nearly 50 people were evacuated from nearby homes.

This was one of several recent incidents involving ammonia leaks from refrigeration systems in Chile, especially within installations that support the country's large fruit and vegetable export sector. An ammonia leak in May at a fruit packing facility in San Bernardo, in the vicinity of the capital Santiago, affected 135 workers, including 11 with more serious injuries

The incidents have focused attention on the issue of safety in ammonia refrigeration facilities in Chile, leading to a major effort by government and industry to create guidelines for Chile's ammonia refrigeration industry. These developments coincided with the planning and execution of IIAR's first Industrial Refrigeration Seminar in Chile, leading to closer ties and cooperation between IIAR and the Chilean Chamber of Refrigeration and Air Conditioning.

Reports on the incident in the press brought unwanted attention to ammonia refrigeration end users, including discussion of inadequate controls, possible negligence and a lack of concern for worker safety on the part of companies in the sector using ammonia refrigeration systems. These concerns were echoed in the public reaction, which included strong criticism of the lack of safe working conditions in fruit export facilities.

The government's response included a push to regulate the ammonia refrigeration industry. In the aftermath of the incident in Codegua, Agriculture Minister Luis Mayol pointed out that there was no official position regarding ammonia safety despite Chile's status as the largest fruit exporter in the Southern Hemisphere. The Labor Minister Evelyn Matthei expressed the need for certification programs for any workers handling ammonia refrigeration systems. The Labor, Agriculture, Health and Work ministries began working together to determine what was needed in terms of regulations for ammonia refrigeration users.

Chilean industry took a proactive approach to this situation, joining together to produce the content for the Chilean guidelines for ammonia refrigeration.

In February 2012, the Chilean Chamber of Refrigeration and Air Conditioning began developing a Good Practices Manual for Ammonia Refrigeration Systems. The Manual is intended to set out minimum criteria for the safe operation of new and existing installations. Another aim for the guidelines is that they be both easy for managers and operators to understand and simple in terms of implementation. The first version of the Good Practices Manual is expected to be completed by April 2013 and will include chapters covering:

- Definitions;
- Management Tools for Ammonia Refrigeration Systems;
- Training Plant Personnel;
- Safe Operation and Maintenance;
- Refrigeration System Design; and
- Emergency Plans.

A total of of 55 professionals from different sectors related to ammonia refrigeration are volunteering on the different working groups developing the manual. The sectors involved include end users (both local and multinational), government, firefighters, engineers, insurers, manufacturers and others. IIAR members involved in the effort include Alberto Mayer and Peter Yufer, the Director of the Chamber's Ammonia Division, as well as individuals from Alfa Laval, Danfoss, Güntner, Intercal, Johnson Controls, Mayekawa and Nestle.

At the beginning of August, Peter Yufer met with IIAR staff during the IIAR Industrial Refrigeration Seminar in Santiago. Topics discussed at the meeting included the development of the ammonia refrigeration guidelines for Chile and possible areas of cooperation between IIAR and the Chilean Chamber of Refrigeration. The President of the Chamber, Heinrich Stauffer, participated in the closing ceremony of the Seminar on August 3.

The issue of ammonia safety was an important theme of the technical program at the Seminar in Chile. Carlos Bravo of Johnson Controls Chile prepared a presentation for the event in Santiago on "Safety in Ammonia Refrigeration Systems: Machinery Room and Refrigerated Chambers." Several other topics presented also had safety themes including:

- Recommendations on the Use of Safety Relief Valves and Criteria for Preventing Liquid Slugging in Evaporators;
- Gas Sensors: Fundamentals and Applications for the Detection of Leaks in Refrigeration Systems;
- Indirect Refrigeration Applications with Glycol: Safe for the Personnel and Product.

Since the IIAR event in Santiago, the Chamber sent an official request to IIAR for documentation to support the efforts of the working groups elaborating the Good Practices Manual. IIAR responded by donating a set of safety training modules and an Ammonia Refrigeration Management (ARM) Program book and encouraged the IIAR members participating to take advantage of their access to the IIAR standards and other materials available online through the IIAR website as sources for the new Chilean guidelines. This exchange represents just the first step towards developing longer range cooperation between IIAR and the Chilean Chamber of Refrigeration and Air Conditioning. iiar


*Speakers, Exhibitors and Organizers at the IIAR Industrial Refrigeration Seminar in Lima, Peru, August 6 and 7, 2012.*

IIAR would like to recognize the efforts of the member companies in each country that partnered with IIAR to make these events happen. For all three events, local members assumed responsibility for all the financial aspects of the seminars within the country including contracts with and payments to the hotel and other local vendors, registration of attendees and exhibiting companies, not to mention providing logistical support locally for the exhibitors and IIAR staff that flew in from overseas. In Argentina, we thank Carlos Frontaloni and his staff at ASEMFI for handling the local meeting finances and logistics and Francisco Szewc of FrioRaf for the additional support he provided. In Peru, we are grateful for the role played by Jorge Huanqui, Victor Figueroa and their staff at ASAP for managing the local event functions. Finally, in Chile we express our gratitude to a larger group of members that formed a volunteer committee to handle all the local planning and execution of the IIAR Industrial Refrigeration Seminar in Santiago including Giorgio Magnani of Intercal, Alberto Mayer and Patrick Fossey of A. Mayer Refrigeración Industrial, Pablo Ibaceta of Danfoss, Carlos Bravo of Johnson Controls, Daniel Faundez of Mayekawa and Juan Arias of Guentner. We congratulate our members in Chile for coming together as a group to handle the local management of the event and hope that their model of cooperation is followed in other countries hosting IIAR Industrial Refrigeration Seminars in the future. iiar

IIAR Committees serve as a forum for the open discussion and advancement of important issues we face in our industry. In the last issue of the Condenser, we introduced a new column, designed to update our readers on current IIAR committee projects and plans for the future. We're focusing on one committee at a time, delving into the purpose of the committee and spotlighting the important issues that the committee is currently tackling.

Any IIAR member is invited to participate in the work of the organization's committees, either by serving as an active member or by bringing an important issue to the attention of the appropriate committee. Read on for our second committee spotlight – IIAR's Marketing Committee.

## IIAR Marketing Committee Communicates Organization's Goals

The mission of the International Institute of Ammonia Refrigeration is to provide advocacy, education, standards, and information for the benefit of the ammonia refrigeration industry worldwide. The goal of the IIAR marketing committee is to work hand-in-hand with IIAR marketing staff to communicate our organization's programs and actions in support of that mission to members and non-members alike.

Beyond just communication, IIAR's marketing committee also works to increase membership and involvement within the organization, said Tim Facius, IIAR marketing committee chairman.

"This committee is important because IIAR's marketing committee really is the mouthpiece of our organization," he said. "We're responsible for carrying the message of IIAR's role in the global refrigeration industry as the experts in safe and efficient use of ammonia and other natural refrigerants. That responsibility plays a key role in the overall productivity of IIAR, the participation of our members and our ability as a group to attract new members."

One of the ways the marketing committee accomplishes its communications and membership goals is to reach out to professionals who may not be members of IIAR, but who nevertheless, depend on the organization for technical resources.

For example, "we have a large group of people who depend on publications like the Process Safety Management and Risk Management Program Guidelines, but may not necessarily be IIAR members. Our job is to reach out to that group of people and others like them to make them aware of all the additional resources and benefits that IIAR has to offer its members. Likewise, we have a when non-members call in for technical information or support." Facius said, "IIAR staff is constantly fielding questions from non-members about industrial refrigeration, and this is another great opportunity to promote IIAR membership.

"Another big marketing opportunity is to really carry the message that the vision of our organization is broader than ammonia refrigeration systems only. We're expanding our reach to include natural refrigerants in general." The special session focusing on $CO_2$ at the upcoming IIAR Industrial Refrigeration Conference is evidence of that goal, said Facius. And the marketing committee's work to update of IIAR's ammonia refrigeration video has been a very effective tool for communicating and advocating the safe use of ammonia refrigeration, he added.

Meanwhile, the committee is also focused on promoting IIAR's efforts to expand its reach globally. "We're growing our relationships with organizations and operators in other regions of world," said Facius. "To that end, the marketing committee works hand in hand with the international committee to extend our message globally."

Maintaining an IIAR presence at other technical organization events and forums is also an important goal of the committee. "For the first time this year we had a booth at several of the ASTI safety training days. The fact that IIAR participates as a sponsor of ASTI is wonderful because we think that whole area of education is extremely important," said Facius. "We want to make sure everyone involved in the industry is using safe and efficient practices and recognizes IIAR as a resource for this information."

Beyond the general activities of the marketing committee, the group is currently working to update IIAR's web presence with a complete redesign of the IIAR website. "We're going to make the website more navigable and streamlined so that we can better communicate what we offer," said Facius, adding that the group is also looking at ways social media can be used to better communicate IIAR's message.

Leading the marketing committee has been a rewarding experience, said Facius. "This is such a vibrant organization. It is energizing to work with so many volunteer members who want to get involved."

Volunteerism has always been a core value of IIAR, and the desire to provide educational opportunities and expand technical expertise has always been a central goal, said Facius.

"When you believe in the goals of an organization like this one, it really makes it a pleasure to communicate those values to the industry at large," said Facius. "There's plenty of work that needs to be done, so we welcome and encourage other IIAR members to consider joining the marketing committee, we appreciate as much help as we can get."

# Ammonia Refrigeration Foundation UPDATE

## ARF Needs Your Help!

One of the most important activities in the industrial refrigeration industry is the advancement of technology through research and education. The Ammonia Refrigeration Foundation is dedicated to this goal, enabling IIAR to advocate for code and government policy changes which benefit the industry in design, construction and the operation of increasingly safer and more efficient systems.

Since its founding, ARF has awarded a number of scholarships and completed several significant research projects designed to answer critical questions related to making the refrigeration system safer and more efficient.

In the last issue of the Condenser, we introduced a new program that focuses on individual donations to ARF, to be used specifically for funding these projects.

The new annual fundraising program is designed to allow every corporate and individual stakeholder in our industry to make a 100 percent tax deductible donation to help underwrite the cost of ARF Research Projects.

The fund raising goal for the fiscal year ending June 30, 2013 is to raise $50,000. This will only happen with a broad response from IIAR Corporate and Individual Members, such as you.

Please take a few minutes to review, complete and return the form below. Your investment in the refrigeration industry today will help ensure that systems designed with ammonia and other natural refrigerants will continue to be the best technical solution, in terms of safety, efficiency and environmental stewardship, to advance the global cold chain for generations to come. iiar

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Your donation plays an important role in the future of ARF research. ARF has provided suggested giving amounts for each member type, but all contributions are welcome. If you choose to make a donation, please fill out this form and send your contribution to ARF headquarters.

**Attn: ARF**
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AMMONIA REFRIGERATION FOUNDATION

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# Further Improvements in Ammonia Low Pressure Receiver Systems

## Overcoming the Challenge of Internal heat transfer

By S. Forbes Pearson

The Low-Pressure receiver system was introduced in 1972 with the objective of making refrigerating systems using refrigerant R502 at least as reliable and as efficient as typical systems using ammonia. At that time it was considered that ammonia systems were more robust and more reliable than systems using halocarbon refrigerants.

The main source of unreliability of halocarbon refrigerating systems was the use of thermostatic expansion valves. An additional cause of unreliability was using one-quarter inch o.d. flared copper tubing for gauge and instrument lines.

A system was devised that used a float control on the high-pressure side of the system to drain the condenser and feed all refrigerant mass flow through the evaporator to a vessel containing a heat exchanger that evaporated any overfeed to dryness.

Small bore stainless steel pipe was introduced for gauge lines in place of copper tubing.

It was observed that, provided the expansion device was large enough, the evaporator would always be overfed with refrigerant in a stable manner.

A typical system, together with a Mollier diagram for the cycle is shown in fig 1. The only difference between systems using halocarbon refrigerants and systems using ammonia is in the method of oil return from the low-pressure receiver.

The new system proved to be very reliable when applied with R502 as the refrigerant.

The new system was also surprisingly efficient, despite its being used in single stage systems with evaporating temperatures as low as –30°C.

It was considered that high efficiencies resulted from the discharge pressure being allowed to float and the fact that discharge pressure was relatively low during most of the defrost cycle.

Heat transfer within the air coolers was at least as good as heat transfer in coolers using thermostatic expansion valves.

At that time it was not considered that the system would be applicable to installations using ammonia as the refrigerant because of the very high latent heat of ammonia which would result in low rates of overfeed to the evaporator (ref 1.)

Significant business built up for small to medium sized cold stores using R502 and single stage reciprocating compressors.

Unfortunately, when the Montreal Protocol was enacted, R502 was the first refrigerant to be withdrawn from the market because it contained R115 which has very high ozone depleting potential (ODP).

Many of the existing systems were transferred to R22 but discharge temperatures were higher and the systems became less reliable. It was also obvious that it was only a matter of time before all ozone depleting refrigerants would be withdrawn from the market.

The challenges of trying to use ammonia were re-examined. It was concluded that the challenge of low overfeed would be overcome if a new type of distributor could be designed and it was concluded that the challenge of high discharge temperature would be overcome if screw compressors with oil cooling were used instead of reciprocating compressors.

The new distributor used static head in a reservoir to distribute equal amounts of high pressure liquid ammonia to individual circuits through orifices. Flash gas was also distributed to individual circuits from a vapour space above the distributor tubes. The new distribution system seemed to work well.

Use of screw compressors opened the application of the low-pressure receiver system to much larger cold stores.

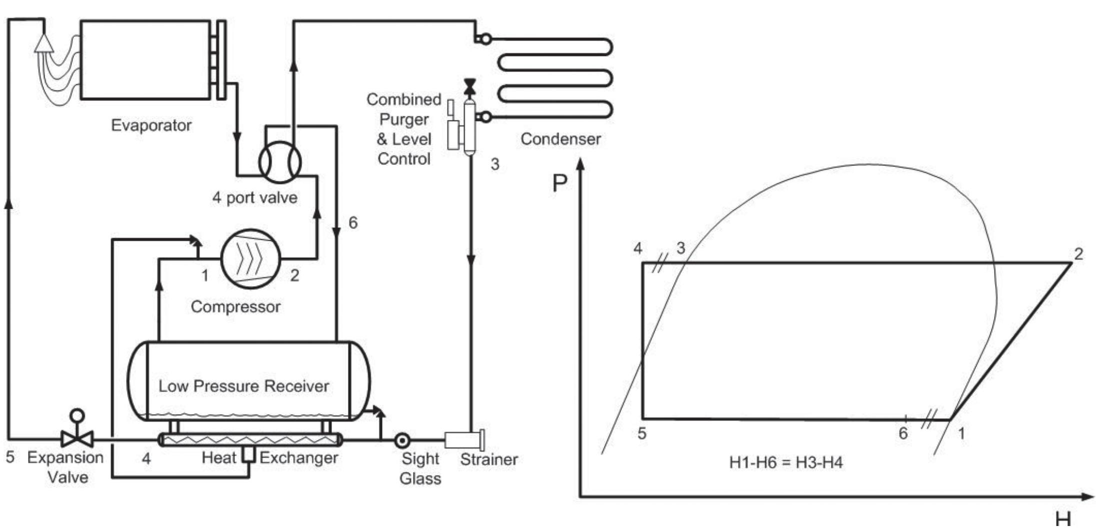


Figure 1

*Ammonia Low Pressure Receiver Systems continued on page 36*

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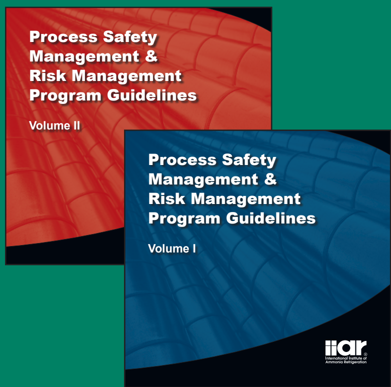


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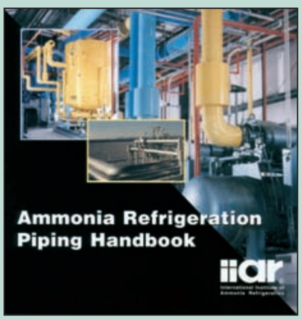


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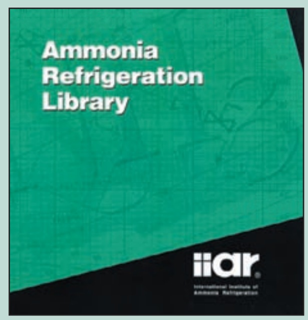


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*ANSI/IIAR Standard 3-2012 American National Standard for Ammonia Refrigeration Valves* | ANSI/IIAR Standard 3-2012 specifies criteria for materials, design parameters, marking and testing of valves and strainers used in closed circuit ammonia refrigeration systems. This standard is not intended to supplant existing safety codes. In cases where the authority with jurisdiction has special requirements that are more stringent than those in the standard, that authority shall prevail.

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*Ammonia Low Pressure Receiver Systems continued from page 34*

Air coolers for use with halocarbon refrigerants had been designed with copper tubes and aluminium fins. When the low-pressure receiver system changed over to using ammonia as refrigerant the coolers were changed to galvanised mild steel construction.

The galvanised coolers did not work as effectively on ammonia as the copper/aluminium coolers had worked on R502. Calculations and testing indicated that the circuits in the cooler should be longer than circuits for pumped circulation of ammonia and that the optimum arrangement was one in which refrigerant circuits were bottom fed and each pipe was vertically above the previous pipe.

This arrangement had the effect of retaining more refrigerant in the individual tubes than would have otherwise been the case. The reason for using long circuits was to increase mass flow per circuit and to minimise stratified flow in the tubes. Despite the rather poor performance of the cooler compared to performance of coolers using pumped circulation, the overall system performance still tended to be better than performance of pumped circulation systems because defrosting was much more efficient and pressure drop in the wet return line was lower (ref 2.).

Figure Two shows specific energy performance of a variety of low-temperature cold stores. It can be seen that the low-pressure receiver systems included are consistently more efficient than conventional systems. However, despite the high efficiency of the low-pressure receiver system, it was becoming difficult to sell it because of the large temperature differences at which the evaporators operated.

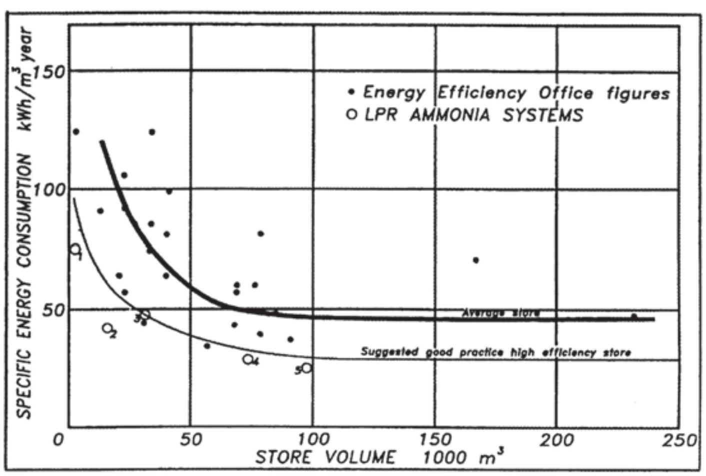


Figure 2

The situation took an immediate turn for the worse when stainless steel tube, aluminium finned evaporators were introduced.

In some cases where a cooler design with horizontal circuits was introduced, performance was so poor that the coolers had to be replaced with coolers using vertical circuits and, even then, performance was much poorer than simple theory would have indicated.

It was obvious that internal coefficients of heat transfer were very low due to stratification and poor wetting of the internal surface. When circuits were horizontal, the tubing appeared frosted for about eighteen inches from distributor outlet and then the frost disappeared when flow regime became stratified for the remainder of the circuit. The cooler was being overfed with refrigerant but only about 15% of the internal surface was effective.

In general, the external air-side resistance to heat flow dominates air cooler performance but in this case it was rather obvious that the dominant resistance to heat flow was at the inner surface of the tube.

## Diagnosing the Problem

Prof Jim Brown of University of Strathclyde concluded that the internal stratification was caused by the low conductivity of stainless steel and the thin wall of the stainless steel tubing. He produced a model showing how heat flowing radially in through the aluminium fin to the outer surface of the stainless steel tube had then to flow circumferentially round the thin wall of the tubing to the wetted portion of the tube. High conductivity tube material had allowed a sufficient flow of heat to vaporise the refrigerant thus producing enough vapour velocity to change the flow regime from stratified to annular or slug flow. This no longer applied when stainless steel tubing was used.

It is particularly difficult to avoid stratified flow in long tube ammonia evaporators because the ratio of liquid density to vapour density at –40°C is 1072. This is very high compared to the ratio for halocarbon refrigerants which would be about one tenth of the ratio for ammonia. It is obvious that behaviour of ammonia and halocarbons in long tube evaporators will be very different. Ammonia will inherently tend to stratify at duties where halocarbon vapours, that require higher mass flow rates and are more dense, would produce annular flow regimes.

The situation is made even more difficult for ammonia LPR systems with stainless steel tubing because of the low rates of overfeed and because of the low conductivity of stainless steel.

It was concluded that the challenge of poor performance would be overcome if the evaporator tubes were made of a material of high conductivity that was resistant to ammonia.

## Development of a Suitable Cooler

Finned air coolers with aluminium tubes had been made for many years but they had not found favour because they were considered to be less robust than steel or stainless steel coolers.

It was also considered that aluminium tubing was more liable to become corroded than stainless steel tubing.

One field in which aluminium tubing continued to be used for ammonia coolers was that in which direct expansion was employed.

It was highly desirable to use tube material of high conductivity in this application because direct expansion coolers tended to suffer from the effects of stratified flow to an even greater degree than was experienced in ammonia LPR systems.

Aluminium coolers worked well in direct expansion ammonia systems, especially at high evaporating temperatures, provided the systems did not contain more than about 5000ppm of water.

It was not realised for many years that presence of water in direct expansion ammonia systems would upset the superheat signal to the thermostatic expansion valve and cause it to close, thus starving the cooler.

Unfortunately, small amounts of water are relatively common in ammonia refrigerating systems and water tends to migrate into such systems because of its great affinity for ammonia.

Direct expansion ammonia systems remained unpopular with refrigerating engineers mainly because they couldn't get the thermostatic expansion valve to work reliably. This was, very unfairly, blamed on the valve or on the engineer trying to adjust it. Water was the culprit all the time!

The LPR system does not depend on measurement of superheat for control of the expansion valve and is therefore much less affected by the almost inevitable presence of moisture in the system.

It was concluded that ammonia LPR systems would operate much more efficiently if aluminium tubing were used in the coolers instead of mild or stainless steel.

Stainless steel is much stronger than aluminium and is therefore used in thinner walled tubing. The effect of the low conductivity of stainless steel is compounded by the fact that the wall of a stainless steel tube will be much thinner than the wall of an equivalent aluminium tube.

Figure Three shows the cross-sections of stainless steel tubing and of aluminium tubing that were used in a comparative test of cooler efficiencies under controlled conditions. As will be shown later, the temperature difference across the aluminium cooler was only about half the temperature difference that was required to produce the same refrigerating effect using coolers with stainless steel tubes.

## Detailed Design of Aluminium Cooler

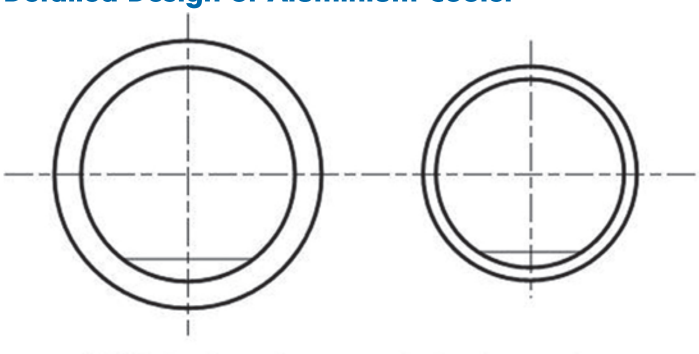


Figure 3

Special aluminium coolers for use in ammonia LPR systems were designed and manufactured by a well-known US company.

The coolers were bottom fed and used a gravity type distributor as previously described. The refrigerant rose vertically to the next horizontal tube in each circuit till it exited at the top of the cooler to a horizontal header.

It was expected that the horizontal air flow and the expected high coefficients of heat transfer would cause the circuits on the air-on side of the cooler to dry out, so arrangements were made for the cooler circuits to cross over from front to back at the mid-point of each circuit as can be seen in Figure Four.

The coolers were designed for reversed cycle defrosting but, in order to keep the circuits simple, it was decided to heat the drip tray electrically. This has the additional advantage that the tray heaters can be switched on before start of the very rapid defrosting sequence, thus preventing the defrost water from the fins landing on a very cold tray.

Figure 4

The aluminium tubes of the cooler were treated internally to produce a wicking effect as is done in tubes used for heat pipe systems. The nature of the internal treatment can be seen in Figure Five and in Figure Six which show part of a tube that has been flattened to expose the inner surface. This treatment is covered by US Patent No 7,958,737B2 of Bruce Nelson.

Figure 5

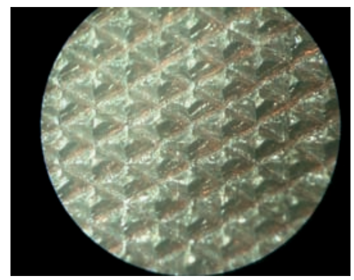

Figure 6

The special coolers were subjected to full scale testing in an existing cold store that used an ammonia LPR system with stainless steel coolers. (ref 3.)

Performance of the existing system demonstrated efficiencies and power consumptions that were comparable to, or better than, performance of conventional stores but it was felt that temperature differences across the coolers were too high and that some efficiency improvement might be demonstrated if aluminium coolers were substituted for stainless steel coolers.

## Test Results

The existing cold store was designed to operate at −25°C and was of about 3240 cubic metre capacity. The cold store was refrigerated by an ammonia LPR system having a single packaged unit with two Bitzer screw compressors serving two identical coolers in the cold room. It was therefore possible to operate the system at three different levels of cooler heat flux.

The lowest flux was produced by running two coolers served by one compressor. The medium flux was produced by running two coolers with two compressors as originally designed. The highest flux was produced by running one cooler with two compressors.

Tests under similar conditions were run with the original coolers and then, after the original coolers were replaced by aluminium coolers, the test was repeated under similar conditions.

Figure Six shows the overall heat transfer coefficient related to external surface for the stainless steel cooler and for the aluminium cooler related to circuit loading.

It can be seen that coefficients for the aluminium cooler are about twice as much as the coefficients for the stainless steel cooler.

It is interesting to note that coefficients for the stainless steel cooler appear to rise as the circuit loading increases. This is consistent with the opinion that high circuit loadings are necessary to minimise stratification.

Coefficients of heat transfer in the aluminium cooler appear to be less affected by circuit loading and, if anything, appear to fall slightly as circuit loading is increased. This is consistent with the opinion that high velocities and high circuit loadings are not necessary to improve wetting of the inner surface of the aluminium tube because liquid ammonia is distributed round the tube due to the wicking effect of the internal treatment.

The refrigerating system at the cold store is well instrumented and is monitored remotely so that performance can readily be checked over time.

Prior to changing the coolers, power consumption had been about 1000kW.h per day. After the change, power consumption stabilised at about 700kW.h per day. This is a greater improvement than had been anticipated. Cold store temperatures were easily maintained by either system but the system with aluminium coolers hardly required the second compressor to run.

The system is controlled and monitored by a special computer system that allows off-site readings to be observed at suitably equipped locations. Usually the monitoring is done by a company having a comprehensive maintenance contract from the operator but some operators with multiple sites prefer to do their own remote monitoring

Performance of the system has been monitored over a period of years. There has been no falling off of performance. This was very encouraging because there had been some concern that performance of the system might be impaired by oil logging of the internal treatment of the aluminium tubes. Figure Seven shows a print-out from the remote monitoring system.

## Implications of the New Cooler Design

The new cooler design operates reliably with maximum possible heat transfer and minimum pressure drop.

Previous designs of cooler were not applied to fully economised ammonia systems because the reduced amount of flash gas resulting from the sub-cooling of liquid in the economiser resulted in unacceptably poor heat transfer in the evaporator.

The new design has been applied to economised systems for spiral freezers with great success. As well as providing a system that is more efficient and more reliable than a pump circulated system, because of lower pressure drops in cooler and wet return line, the system can operate without need for valves or provision for oil recovery at the freezer. This minimises need for handling of ammonia in the food processing area.

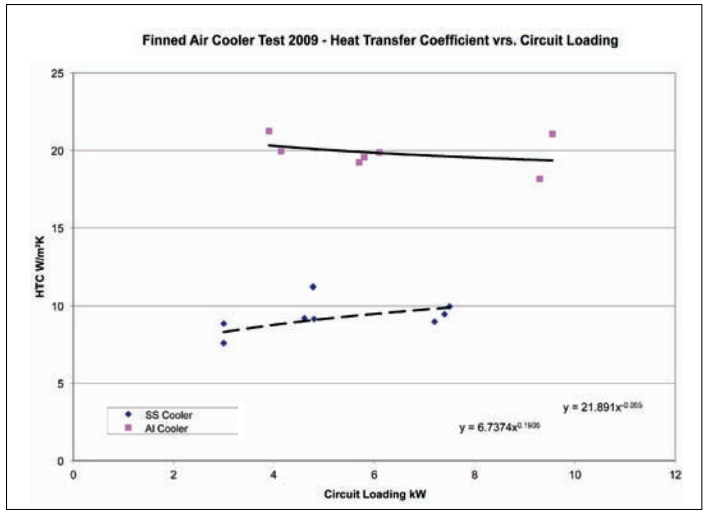


Figure 7

The low-pressure receiver system is similar in principle to the capillary tube system that is used in domestic refrigerators so there is no lower limit to the size of installation to which it can be applied except that set by availability of compressors.

The new cooler will allow low-charge, packaged, ammonia systems to be applied as replacements for obsolescent R22 systems.

Conditions in the United States are even more suitable for this application than in Europe because existing R22 installations in US are commonly sited on the roof of the cold store and the coolers are housed in pent-houses. In Europe, architects are not sufficiently aware of the great benefits of having the cooler in a pent-house, so coolers are usually sited at one end of the cold store or are supported on a gantry within the cold store. The cost of the gantry is not usually included within the budget of the cheapest possible insulated box that the architect is designing but the overall cost would have been less if the structure of the store had been designed to be strong enough to hold up pent-houses and associated individual refrigerating units.

Light weight individual packaged LPR systems would be well suited for installation by contractors capable of handling simple ammonia systems.

Successful development of an effective aluminium cooler means that replacement packaged ammonia systems will invariably be more efficient than the R22 systems that are to be replaced. This is very different from all other R22 replacements that would tend to be less efficient than the original refrigerant because their critical temperatures are lower.

In principle it is possible to design a pre-charged, packaged, ammonia LPR system.

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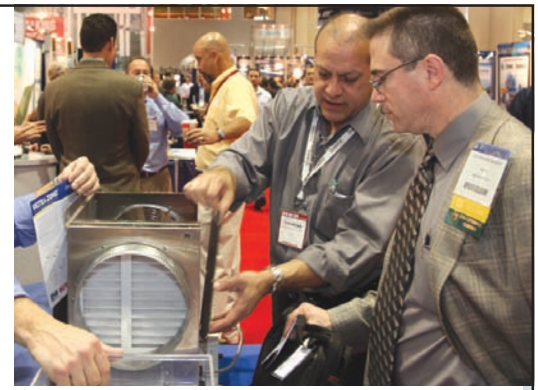
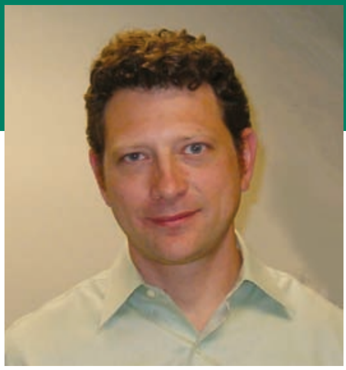


# From the Technical Director



by Eric Smith, P.E., LEED AP, IIAR Technical Director

## Emergency Response

Questions sometimes arise when considering whether or not a release (or a potential release) triggers an emergency response. Concentration readings of detectors alone often do not reflect the severity (or lack of severity) of the situation. After all, the concentration at the source of a leak will always be 100%, while only a short distance away the concentration can be very diminished. If a detector, set to alarm at 25 ppm or 50 ppm, is activated, it does not necessarily mean that emergency measures must be implemented. Nor does it mean that there is no emergency. The point is that a situation must be evaluated and appropriate action implemented.

OSHA mandates that an emergency action and response plan be in place as covered by CFR 1910.120, the Hazardous Waste Operations and Emergency Response (HAZWOPER) standard. The EPA also requires emergency plans. The details of a response plan are beyond the purview of this article. But it is important to note some aspects of the regulations. OSHA defines emergency response as "a response effort by employees from outside the immediate release area or by other designated responders…to an occurrence which results, or is likely to result, in an uncontrolled release of a hazardous substance." This definition excludes "responses to incidental releases of hazardous substances where the substance can be absorbed, neutralized, or otherwise controlled at the time of release by employees in the immediate release area, or by maintenance personnel" as well as "responses to releases of hazardous substances where there is no potential safety or health hazard…" (OSHA Instruction CPL 2-2.45A CH-1 of 9/13/94).

An OSHA letter of interpretation (6-24-03) states:

"Employers who expect their employees to become actively involved in an emergency response due to a release of a hazardous substance, i.e., ammonia at your client's facility, are covered by 1910.120(a) and 1910.120(q), and must train their employees accordingly. Again, from OSHA's HAZWOPER compliance directive, the Agency has stated that an emergency response can include, but is not limited to, the following situations:

1. The response comes from outside the immediate release area;
2. The release requires evacuation of employees in the area;
3. The release poses, or has the potential to pose, conditions that are immediately dangerous to life and health (IDLH);
4. The release poses a serious threat of fire or explosion (exceeds or has the potential to exceed the lower explosive limit or lower flammable limit);
5. The release can require immediate attention because of a potential imminent danger; and
6. The release may cause high levels of exposure to toxic substances.

All of the criteria listed above have potential to exist or in fact have existed at your client's ammonia refrigeration facility. Therefore, your client must comply with OSHA's HAZWOPER standard 1910.120."

These letters and clarifications may cause some consternation when considering when to initiate HAZWOPER plans and when to initiate an "incidental response." Fed OSHA's PEL of 50 ppm is for exposure over an 8 hour time weighted average (TWA) period (unless respirators are worn). The ACGIJ's 25 ppm is a short term exposure limit (STEL) and is set for 15 minutes. But brief exposure to these levels does not necessarily mean that employees are endangered. That stated, there are probably few incidents (when maintenance is NOT being performed) that a company could justifiably state that a HAZWOPER response is not required if they evacuate the area. But if procedures are in place, and employees are trained to them, a company could justifiably write into their plans that evacuation for maintenance or repair does not instigate an emergency response if the situation is orderly and under control. This is sometimes called a "pre-emergency" protocol.

In discussions among industry professionals, an often cited phrase is that "you know an emergency when you see one." During maintenance operations, 50 ppm can be easily reached, but provided that trained and appropriately equipped technicians are on hand, this would not be considered an emergency. During normal operations, a concentration level of 25-50 ppm is cause for concern and should initiate an investigation. The investigation might reveal that a response in the form of performing an immediate routine maintenance procedure is required. But this does not mean that employees are in immediate danger and require evacuation.

Alternatively, an investigation might reveal that an emergency is present even though the concentration is low. This is a matter of evaluation and ties back to the idea of detectors being limited in what they tell you, and that an initial assessment is critical. It is likely not arguable that if detectors indicate that 300ppm (IDLH) is present (and personnel are not equipped with respirators), a HAZWOPER response is appropriate. And there is no doubt that a concentration of 5000ppm (the requirement for level A suits) is an emergency. If there is ever any doubt, emergency response should be initiated.

Also remember that the function of a facility is to produce or store a product. So it is worth noting that the product in a room, even at 25 ppm, might require an immediate repair even though there is no life and safety issues present at those levels. iiar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