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Condenser

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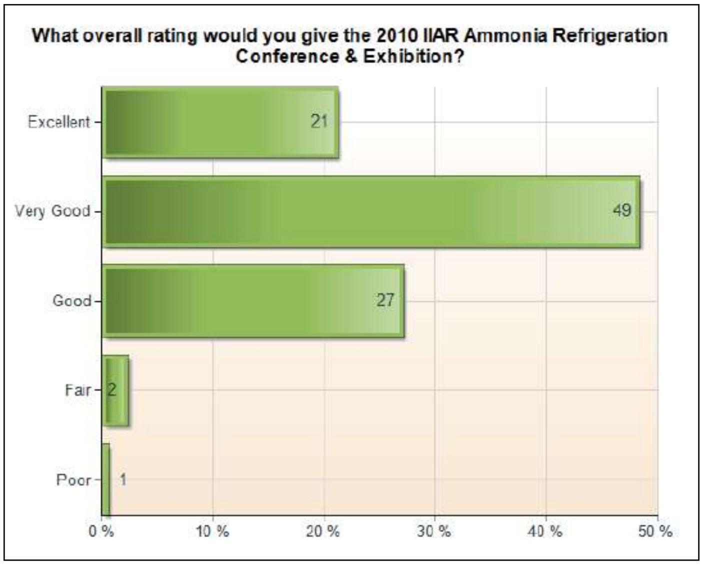
Chairman's Message

By Peter Jordan

In October 2010, the IIAR Board of Directors meets to conduct its annual strategic planning session. The two-fold purpose of the session is to: 1. Define goals for the IIAR in the upcoming year, and 2. Set in motion plans to achieve these goals.

A key goal identified during the strategic planning session is to implement additional programs designed to make safe practices part of the refrigeration culture. The 2010 IIAR Industrial Refrigeration Conference & Exhibition was our first opportunity to demonstrate to our membership that we are serious about achieving this goal. We had a very successful conference with over 1,000 attendees. And, according to the post-conference survey results, more than 97% of the attendees gave the conference an overall rating of good or better.



We emphasized safe practices during the technical papers, workshops and panels presented at the conference. Several workshops focused on issues directly related to the IIAR's recently completed Ammonia Incident Survey. For example, workshops focused on issues related to evaporative condenser maintenance and precautions which can be taken to prevent ammonia releases from flanges and joints. Two topics which were addressed at the conference, a Sight Glass Task Force Report and an ARF Relief Valve Research Project, are summarized in this issue of the *Condenser*.

Another important topic that received plenty of attention during the 2010 conference is the OSHA National Emphasis Program (NEP). The purpose of OSHA NEP is to reduce or eliminate workplace hazards associated with the catastrophic release of highly hazardous chemicals using a new approach for inspecting Process Safety Management (PSM)-covered facilities. On Page 10 of the *Condenser* you'll find a report from IIAR Government Affairs Director Lowell Randel summarizing the results of the one-year NEP pilot program. The pilot program is well over halfway to completion. According to his report,

- As of March 16, 2010, OSHA had opened 46 inspections under the NEP. When programmed and unprogrammed inspections are combined, ammonia facilities represent 44 percent of all inspections.
- The average inspection takes roughly 100 hours for the OSHA teams to complete. By comparison, this total is about 10 percent of the time required by OSHA to conduct inspections under the NEP for Petroleum Refineries.
- Thirteen of the inspections under the Chemical Facilities NEP have closed, resulting in an average of six citations per inspection. On average, 3.5 of the citations issued were related to PSM, resulting in approximately $5,300 in penalties per inspection. Facilities should be aware that non-PSM related infractions of OSHA regulations will also be cited during NEP inspections (currently averaging 2.5 out of every 6 citations).
- For PSM related citations, the PSM element cited most frequently is Mechanical Integrity, with 13 citations. The Process Safety Information and Process Hazard Analysis elements are the second most cited elements, with nine citations apiece.

As we all know, ammonia has a sharp, irritating, pungent odor that acts as a warning agent to let us know that it is present, giving it a self-alarming nature. Ammonia can also be considered a self-limiting chemical, because that same odor that alerts us to its presence also limits us to safe levels of ammonia. Given these characteristics it is fair to ask whether this increased emphasis on safety is necessary. At first glance, the OSHA NEP inspections would appear to be an unnecessary burden on an industry that is already highly regulated.

In our efforts to promote ammonia as a "Green Refrigerant," however, we must never lose sight of the precautions that should be taken to safely design, operate and maintain an industrial refrigeration system. There are inherent risks associated with all refrigerants including ammonia. This issue of the *Condenser* contains a description of two such incidents which had tragic consequences. Though neither of these incidents occurred at a facility operating an industrial refrigeration system they do demonstrate the importance of following proper safety procedures. That is why we must sometimes temper our potential criticism of increased regulatory

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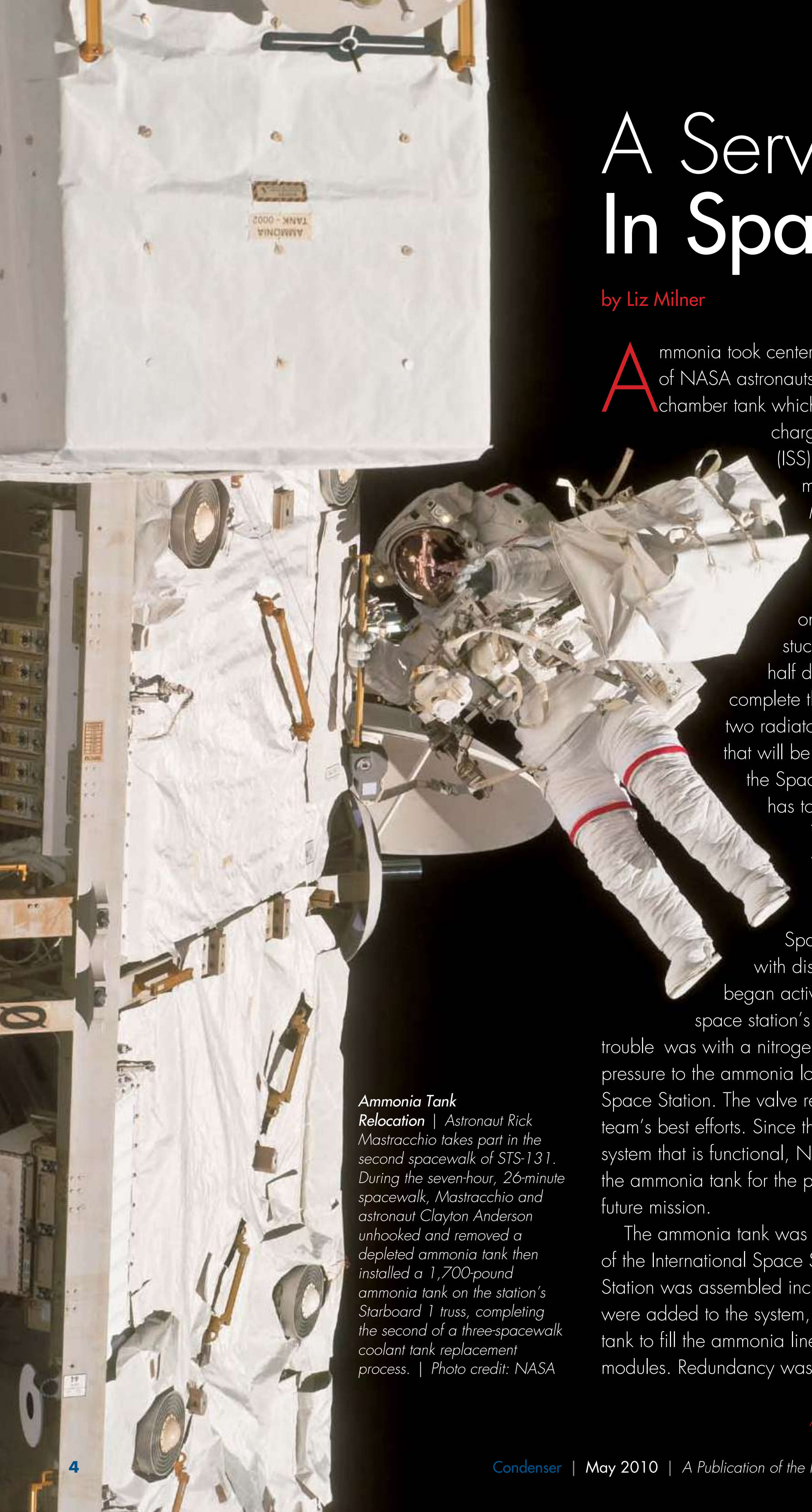

A Service Call In Space

by Liz Milner

Ammonia took center stage recently in televised images of NASA astronauts attaching a 1700 lb, double-chamber tank which contained a 600 lb ammonia charge to the International Space Station (ISS). During the seven-hour-and-26-minute spacewalk, astronauts Rick Mastracchio and Clayton Anderson removed a depleted ammonia tank from the International Space Station and replaced it with a new one. Despite problems with some stuck bolts that caused an hour-and-a-half delay, the astronauts were able to complete the tank change-out and also install two radiator grapple fixture stowage beams that will be used in the event that a radiator in the Space Station's climate control system has to be replaced.

Two days later, a follow-up space walk to connect the new tank's fluid lines so that it would become a fully functioning part of the Space station's cooling system met with disappointment. As flight controllers began activating the tank to join it with the space station's cooling system, a valve stuck. The trouble was with a nitrogen tank, which is needed to provide pressure to the ammonia loops that cool the exterior of the Space Station. The valve remained frozen in place despite the team's best efforts. Since the Space Station has a redundant system that is functional, NASA engineers decided to leave the ammonia tank for the present and to fix the problem in a future mission.

The ammonia tank was replaced in one of the final stages of the International Space Station's construction. The Space Station was assembled incrementally. As the new modules were added to the system, ammonia was diverted from the tank to fill the ammonia lines associated with these new modules. Redundancy was also built into the system, so there

Ammonia Tank Relocation | *Astronaut Rick Mastracchio takes part in the second spacewalk of STS-131. During the seven-hour, 26-minute spacewalk, Mastracchio and astronaut Clayton Anderson unhooked and removed a depleted ammonia tank then installed a 1,700-pound ammonia tank on the station's Starboard 1 truss, completing the second of a three-spacewalk coolant tank replacement process.* | *Photo credit: NASA*

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are two Ammonia Tank Assemblies (ATAs) at either end of the Space Station. Each ATA consists of a dual chambered tank, so there is a total of four chambers with a charge of 300 lbs each. In addition, there are four Photovoltaic Thermal Control Systems that have a fixed ammonia charge of 52 lbs each. The Photovoltaic Thermal Control Systems rely on the ATA for ammonia refills.

The International Space Station could not exist without its cooling system. Cooling is not just for keeping the astronauts comfortable, but also for insuring that computers and other delicate electronic systems are protected from being alternately frozen and overheated. "Without thermal controls," a NASA publication says, "the temperature of the orbiting Space Station's sun-facing side would soar to 250°F (121°C), while thermometers on the dark side would plunge to −250°F (−157°C)." Given this volatile environment, it is no wonder that ammonia, with its high thermal capacity and wide range of operating temperatures, was selected as the refrigerant for key components of the Space Station's thermal control system. But ammonia's advantages don't stop there. Ammonia is also readily available and inexpensive. Even in outer space where ammonia's environmentally friendly characteristics do not matter; its advantages still exceed those of synthetic refrigerants such as Freon. Because ammonia refrigeration is a relatively mature industry, there is a knowledge base on how to handle it safely—even in deep space!

Boeing is the prime contractor for the ISS's ammonia cooling system and ammonia was selected as the refrigerant for the Space Station's external cooling system because, in the words of Boeing Active Thermal Control System (ATCS) Analysis & Integration engineer, Thang Mai, it is simply "the best…it's more efficient and has great viscosity which means liquid ammonia can travel through piping with minimum pumping power. This translates into lower energy use."

Mr. Mai continued that ammonia also has enormous thermal capacity. It can collect, store and transport heat without using a high pumping power. It also has a low freezing point of −108°F at standard atmospheric pressure. "No other fluid can go that low and still be pumpable." Ammonia, moreover, is lighter than water by 30% which means that an ammonia system has less launch weight — another huge plus in an application where every bit of weight in the payload has to be justified.

PSM For Extraterrestrials

So how does working with ammonia in outer space differ from working with it on Earth? Are there any special safety or operating considerations that come into play? Could an ammonia leak create ammonia hailstones that could damage the space station or injure an astronaut?

According to the experts, this scenario is unlikely. Peter Carpenter, Boeing Hardware Engineer for the Ammonia Tank Assembly (ATA), Orbital Replaceable Unit (ORU) and Interface Heat Exchanger (IFHX), volunteered that "when we have vented our lines while changing out an ammonia tank, it looked like snowflakes or white dust blowing around." Tara Michel, EATCS SPRT Co-Chair, International Space Station Program, The Boeing Company, added that, "We make sure that we vent the ammonia when the astronauts aren't out there. When the ammonia is vented, it tends to stay around the space station, so the External Environment Team does an analysis to ensure that none of the ammonia particles is large enough to damage the space station. What the ammonia looks like when it's vented depends on how much ammonia there is and the velocity at which it's being vented." Thang Mai said that the leak size and system pressure determine how the ammonia will look. He described a leak he'd seen that took place in a thermal vacuum chamber—"the ammonia coated the walls of the chamber with very soft ammonia snowflakes."

Ms. Michel said that working with ammonia in outer space "is not a whole lot different from working with it on earth… we take a lot of precautions to ensure that the astronauts aren't exposed. When they go on their spacewalks and they have to handle any equipment that has ammonia in it, they have to make sure that they have enough time to "bake out," that is, to be in the sun long enough for all of the ammonia vapor to be dissipated from their suits because they can't bring it into the cabin. Before they go out, we often vent equipment that has ammonia in it so that they can't get contaminated. We also take a lot of precautions with our heat exchanger that

The International Space Station's Ammonia Respirator

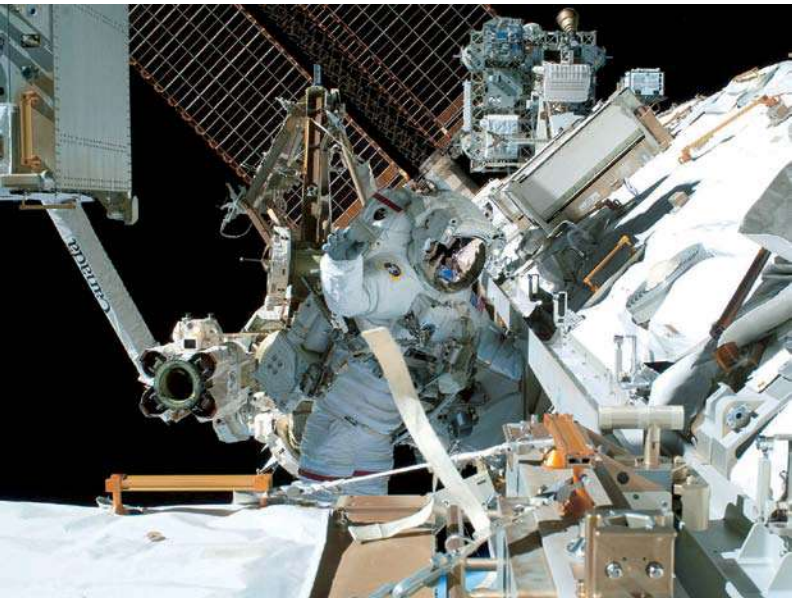
To insure that crew members can leave a contaminated area safely, NASA has developed a special ammonia respirator kit just for the International Space Station. These respirators scrub the ammonia to an internal concentration of no greater than 20 ppm and provide for up to eight hours of protection in an ammonia environment where the ammonia concentration is linearly decreasing from 1200 ppm to 30 ppm. The respirator kits contain six pairs of carbon-treated zinc chloride ammonia-scrubbing cartridges. The cartridges were fabricated to be easy for users to change out. The cartridge change out is critical because NASA scientists calculate that on the ISS, the time required for an ammonia concentration to be decreased to a safe level is about 17 hours. The cartridges were also tested for vulnerability to vibration since launch vehicles typically experience a wide range of vibrations.

has ammonia and water in it. If ammonia leaks into the water system, the astronauts have to don their portable breathing apparatus and leave the contaminated area."

Contamination of the internal system through the heat exchangers may occur in several ways including water freezing in the heat exchanger's core, an internal structural failure or over-pressurization of the heat exchanger. Safeguards have been built into the system to guard against these vulnerabilities. To prevent freezing of the heat exchanger core, the system features three levels of redundancy in the ammonia temperature control. System components are carefully selected, manufactured and tested to ensure durability. To prevent over-pressurization of the interface heat exchangers, relief valves and bleed lines are incorporated into the system design. If these safeguards fail and contamination occurs, the crew members must leave the contaminated area.

The International Space Station's Active Thermal Control System

From the first, the ISS was designed and built with thermal balance in mind. The electronic devices aboard the Space Station generate excess heat which must be removed and either distributed to cooler parts of the station or ejected into outer space. When the heat aboard the Space Station exceeds the capabilities of the Passive Thermal Control System (i.e., the ship's insulating layers) to maintain temperatures, the Active Thermal Control System (ATCS) comes into play. The Active Thermal Control System is comprised of 3 cooling sub-systems:



Space Maintenance | *Astronaut Rick Mastracchio, STS-131 mission specialist, participates in the mission's first spacewalk as construction and maintenance continue on the International Space Station. During the six-hour, 27-minute spacewalk, Mastracchio and astronaut Clayton Anderson helped move a new 1,700-pound ammonia tank from space shuttle Discovery's cargo bay to a temporary parking place on the station, retrieved an experiment from the Japanese Kibo Laboratory exposed facility and replaced a Rate Gyro Assembly on one of the truss segments.* | *April 9, 2010*

- The External Active Thermal Control System (EATCS) which uses anhydrous ammonia as a coolant
- The Photovoltaic Thermal Control System (PVTCS) which also uses anhydrous ammonia coolant
- The Internal Active Thermal Control System (IATCS) which uses water as a coolant

The ATCS cools the astronauts' living quarters and working areas, electronic equipment and laboratories by means of a pumped liquid ammonia heat transfer system. Mechanically pumped fluids in closed-loop circuits perform three functions: heat collection, heat transportation, and heat rejection. It is a dual system: the internal, inhabited areas are cooled through a closed loop system that utilizes water as a refrigerant, while the external areas utilize a closed loop ammonia system. A compact, plate-fin, liquid-to-liquid heat exchanger is used to interface the internal thermal loops that use water as a refrigerant and the external thermal loops that use ammonia refrigerant. Waste heat is removed in two ways: through cold plates and heat exchangers, both of which are cooled by circulating ammonia loops on the outside of the station.

Basically, the internal cooling system uses water as a medium to cool the inhabited areas of the spacecraft. The heat is rejected to a liquid-to-liquid heat exchanger that interfaces between the water and ammonia. The water collects all the waste heat from the internal module and transfers it into the ammonia system. The heated ammonia is then pumped to a radiator where the heat is rejected into outer space. The external system consists of a pump, a tank which contains a 600 lb ammonia charge in two separate chambers, and the heat exchangers.

The External Active Thermal Control System is comprised of two independent loops that were designed so that a failure in one would not take down the entire external thermal control system. Both loops are physically segregated from one another to achieve redundancy and the fluid transport lines are buried within the truss structure to protect them from orbiting debris. If a loop fails to function, the EATCS continues to operate, but at a reduced capacity. Each loop collects heat from up to five Interface Heat Exchangers. The EATCS also provides ammonia resupply capability to the Photovoltaic Thermal Control Systems (PVTCS). All EATCS components are located outside the pressurized areas to prevent crew contact with ammonia.

There are five interface heat exchangers (IFHXs) for each EATCS loop. The IFHX units transfer heat from the IATCS water coolant loops to the external ammonia coolant loops. Each IFHX core is a counterflow design with 45 alternating layers. IATCS water flows through 23 of the layers, while EATCS ammonia flows through the 22 alternate layers in the opposite direction. These alternating layers of relatively warm water and relatively cold ammonia help to maximize the heat transfer

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IIAR Code Advocacy Update

By Jeffrey M. Shapiro, PE., FSFPE

Significant Changes to the 2009 Codes Affecting Ammonia Refrigeration

Every three years, new editions of the International and Uniform codes are published and made available for adoption by state and local jurisdictions. The most recent editions of these codes, dated 2009, incorporate more than a thousand changes when compared to the 2006 editions. Most of these changes are specifically identified in the code by vertical "bars" in the margins, which indicate new or revised text, or arrows in the margin, which indicate deleted text.

Because of the time and effort required by jurisdictions to review new code editions prior to adoption, most jurisdictions take a year or more to update their codes (many take far longer or entirely skip some code editions). So, now that a year has passed since the 2009 codes were published, we're beginning to see enactment of these codes.

Changes affecting the ammonia refrigeration industry in the new codes generally have a positive impact and will help us do a better job of ensuring safe installations of ammonia refrigeration equipment. To assist IIAR members in becoming more familiar with new and revised regulations, I've prepared a summary of the major revisions that you'll see as you go through the 2009 edition. Note that some of the information below has been duplicated where multiple codes had similar changes so that readers can quickly evaluate significant changes to each code in their entirety rather than having to cross-reference back and forth among the codes.

International Fire Code

Section 606.8 Refrigerant Detectors: This section was revised to require that refrigerant detectors, when activated, transmit an alerting signal to an "approved" location. The term "approved" refers to whatever the local authority will accept as a reasonable basis of system monitoring. In some cases, this might be a central station service monitoring other alarm signals for the same facility. In other cases, it may make the most sense to have the approved location be a pager carried by the on-duty refrigeration engineer responsible for the facility.

Section 606.9.1 Refrigeration System Emergency Shutoff: The requirement for an emergency shutoff switch for machinery rooms has been revised in three ways. First, the previous mandate requiring the switch be mounted in a "break glass" enclosure has been changed to allow any tamper-resistant cover that is satisfactory to local authorities.

Second, equipment required to be controlled by the emergency shutoff switch has been clarified. Previously, the code implied that all electrical equipment and devices in the machinery room had to be stopped by the switch, and some jurisdictions interpreted the provision as even requiring shutoff of convenience outlets. The code is now specific in only requiring shutoff of refrigerant compressors, refrigerant pumps and normally-closed automatic refrigerant valves. It is recognized that some owners and designers prefer a complete electrical shunt for machinery rooms in the event of a significant leak, as opposed to what the code now requires. This type of design remains an option for those who chose it, but it's no longer the code mandated minimum.

The third revision to Section 606.9.1 is a new requirement for the shutoff control to be integrated with refrigerant leak detectors located in the machinery room. The detection system, upon sensing a leak event with a concentration reaching 25 percent of the lower flammable limit for the refrigerant or reaching the upper detection limit for the detector (whichever is lower), must now automatically trigger the emergency shutoff, as described above.

Sections 606.10.1.1 and 606.10.2.2 Overpressure Limit Setpoint: The buffer between the pressure relief valve rated operating pressure and the emergency pressure control system's operating pressure has been revised from 15 psi to 10% of the PRV rated operating pressure. This provides a greater factor of safety to prevent weeping of a PRV in an overpressure condition before the EPCS operates.

Section 606.13 Discharge Location for Refrigeration Machinery Room Ventilation: The previous requirement for room exhaust from ammonia machinery rooms to be routed through a treatment system before release to atmosphere has been deleted.

International Mechanical Code

Section 1101.10 Locking Access Port Caps: A requirement has been added to have all refrigerant access ports located outdoors to be equipped with locking, tamper-resistant caps. This provision was not targeted at industrial refrigeration systems, but the way the code change proposal was worded didn't exclude these types of facilities. This change was made at the last code hearing of the 2009 cycle, which did not allow time for any "fixes" to be made to address concerns. However, in the current code cycle, which will ultimately impact the 2012 IMC, IIAR was successful in getting a revision to this section approved that permits "other means" of ensuring that access ports are protected from unauthorized access.

Section 1104.2.2(6) Industrial Occupancies and Refrigerated Rooms: The requirement to use classified (hazardous) location electrical equipment in process and storage areas where ammonia refrigeration is provided was deleted. This change makes the IMC consistent with requirements of ASHRAE 15.

Code Update continued on page 35

By Lowell Randel, IIAR Government Affairs Director

Update on OSHA's National Emphasis Program for Chemical Facilities

The Occupational Safety and Health Administration (OSHA) launched a National Emphasis Program (NEP) focused on Process Safety Management in chemical facilities at the end of July 2009. With the NEP pilot now over eight months into its implementation, it is time to examine the program and see what can be learned.

NEP Pilot Program Background

First, it is useful to briefly review the background of the NEP and how it was designed to operate. The NEP was announced as a one year pilot with programmed inspections planned for Federal OSHA states in three OSHA regions: Region 1 (New England – Connecticut, Massachusetts, Maine, New Hampshire, and Rhode Island), Region 7 (Midwest – Kansas, Missouri and Nebraska), and Region 10 (Pacific Northwest – Idaho). Facilities participating in the OSHA Voluntary Protection Programs (VPPs) are not subject to programmed NEP inspections.

The NEP is also being used nationwide for Federal OSHA unprogrammed inspections of chemical facilities subject to PSM. State plan states have the option to participate in the pilot. Currently, eight state plan states have formally adopted the NEP. They are: Alaska, Arizona, Hawaii, Kentucky, Michigan, Minnesota, South Carolina, and Washington. There is also anecdotal evidence that additional states have taken parts of the NEP and incorporated them into their ongoing state inspection programs.

Programmed inspections conducted through the pilot program will be unannounced. A team of OSHA inspectors will arrive at the facility and ask to speak with the highest ranking official on site. The inspectors will confirm that the facility is covered under PSM and if so, will begin the inspection. It is worth noting that the OSHA directive establishing the NEP states that for ammonia refrigeration inspections, at least one member of the team must have completed several OSHA Training Institute courses related to PSM and the chemical industry and have prior experience with the chemical industry or ammonia refrigeration. IIAR has been working with the OSHA Training Institute to help ensure that inspectors are better informed about ammonia systems.

OSHA indicates that inspections will place more emphasis on PSM implementation than on the program "on paper." Inspectors will have a list of approximately 15 questions that will be administered during the inspection. The questions are designed to gather facts related to requirements of the PSM standard, and include guidance for reviewing documents, interviewing employees, and verifying implementation. For ammonia facilities, approximately ten of the questions will focus on ammonia specific PSM components and approximately five questions will address general PSM issues. Inspection questions will not be published, and will change periodically.

Four major types of processes are being targeted for inspection: ammonia refrigeration, chlorine in W&WWT, chemical processing/manufacturing, and other (storage, distribution, etc.) The list of facilities targeted for programmed inspections is drawn from the following four categories: EPA Risk Management Program (RMP) Program 3, NAICS codes known to be PSM but not covered by RMP (limited), facilities identified by local (Area and Regional Office) knowledge, and facilities identified in OSHA's IMIS database. Facilities are selected randomly from each category, and OSHA's initial intent was for roughly 25 percent of all inspections to be of ammonia facilities. OSHA anticipates between 70 and 140 programmed inspections will be conducted during the pilot, with an equal number of unprogrammed inspections. As will be shown below, the actual number of inspections conducted by OSHA is lagging well behind these projections.

Current Results of the NEP

Now that the one year pilot program is well over halfway to completion, what can we learn from the results? OSHA Process Safety Engineer Jim Lay participated in the recent IIAR Annual Conference and presented attendees with an update on the results of the NEP pilot. According to Mr. Lay, as of March 16, 2010, OSHA had opened 46 inspections under the NEP. Six of these did not result in a full inspection because the facility was no longer covered by PSM. Of the 40 remaining inspections, 24 were programmed and 16 were unprogrammed. Fifty-eight percent of the programmed inspections were at ammonia facilities, while 38 percent of unprogrammed inspections were at ammonia facilities. When programmed and unprogrammed inspections are combined, ammonia facilities represent 44 percent of all inspections.

It is interesting to note that none of the inspections were at chlorine facilities. This came as a surprise to OSHA, as they had expected roughly 25 percent of inspections to be at chlorine facilities. However, OSHA has since learned that many chlorine facilities have altered their processes and are no longer covered by PSM. This has resulted in a higher than expected percentage of ammonia facilities in the overall total of those being inspected.

NEP inspections have been geographically dispersed across many of the various OSHA regions. It is not surprising that the two regions with the most inspections are Region 1 (New England–14 inspections) and Region 10 (Midwest–7 inspections), both pilot regions. Regions 3 (Mid-Atlantic) and 5 (Upper Midwest) have both conducted 5 NEP inspections. The remaining regions have conducted fewer than five inspections, with Regions 6 and 9 not having conducted any to date.

The average inspection is consuming roughly 100 hours of time for the OSHA teams to complete. By comparison, this total is about 10 percent of the time required by OSHA to conduct inspections under the NEP for Petroleum Refineries. Anecdotally, facilities are also using significantly fewer resources to deal with inspections under the Chemical Facility NEP.

Thirteen of the inspections under the Chemical Facilities NEP have closed, resulting in an average of six citations per inspection. On average, 3.5 of the citations issued were related to PSM, resulting in approximately $5300 in penalties per inspection. Facilities should be aware that non-PSM related infractions of OSHA regulations will also be cited during NEP inspections (currently averaging 2.5 out of every 6 citations).

For PSM related citations, the PSM element cited most frequently is "*(j)* – Mechanical Integrity," with 13 citations. Elements "*(d)* Process Safety Information" and "*(e)* – Process Hazard Analysis" are the second most cited elements, with 9 citations apiece. A detailed breakdown of PSM-related citations and proposed penalties is below.

PROCESS SAFETY MANAGEMENT ELEMENT (First 13 Inspections)	NUMBER OF CITATIONS	PROPOSED PENALTIES
(d) Process Safety Information	9	$14,150
(e) Process Hazard Analysis	9	$12,700
(f) Operating Procedures	5	$5,750
(g) Training	2	$1,400
(h) Contractors	1	$1,000
(i) Pre-startup Safety Review	1	$2,500
(j) Mechanical Integrity	13	$20,325
(k) Hot Work Permit	1	$2,500
(l) Management of Change	2	$3,900
(m) Compliance Audits	3	$4,650
TOTAL	46	$68,875

These results provide some valuable insight into areas where industry can improve its overall safety and compliance.

It is important to remember that safety is good business. This remains true regardless of what happens with the NEP. Facilities are encouraged to revisit their PSM plans to ensure that they are up-to-date and being implemented properly. And, help is available for those who need additional PSM information through IIAR materials, the use of private consultants, and the OSHA On-Site Consultation Program.

OSHA's plans for the program after the initial pilot period are not yet clear. OSHA has indicated that it will examine the results of the pilot, and take into consideration feedback from industry, while determining whether to transform the NEP into a nationwide program. IIAR will closely monitor the status of the program and continue to communicate with OSHA suggestions and concerns regarding the future of the NEP.

Low Charge Systems May Be the Answer

By John Ansbro, GEA FES

Businesses seek to provide income to their shareholders or "bottom line." Safe facilities are more profitable than unsafe facilities. When accidents such as ammonia leaks occur, sometimes people get hurt and even killed; and typically, at least in warehouses, large amounts of product are also destroyed. When ammonia leaks occur, business is severely disrupted; service to customers is impossible. The cost of managing a major accident, even with the protection afforded by workmen's compensation laws and insurance, is still extremely high. Additionally, the process is very painful for the managers involved. Many customers of ammonia-containing facilities understand that a major ammonia leak will adversely affect them and seek to make sure that such plants are well designed and safe.

Recently, the IIAR conducted a 12-question survey about ammonia releases from 700 respondents from the IIAR, RETA, and IARW. Nearly 80% of the respondents reported that their facility had more than 10,000 pounds of ammonia, thus requiring PSM. Cold storage warehouses (33%), frozen food producers (16%), and dairies at (8%) were the largest responders.

Of the 471 responses to the question of where most ammonia releases occurred, 23% reported flanges and joints, 20% manual or control valves, 12% pumps, 9% pressure relief valves, 9% compressors, and 8% oil pots.

WHERE MOST AMMONIA RELEASES OCCURRED

	Responses	Percentage
Flanges/Joints	110	23
Manual Control Valves	96	20
Pumps	58	12
Pressure Relief Valves	43	9
Compressors	41	9
Oil Pots	40	8
Piping	35	7
Charging Transfer	21	5
Evaporators	19	4
Sight Glass	7	1
Storage Tank/Receiver	1	–
	471	

Obviously, valves and joints were the largest leak sources. Human error counted for 60% of the releases, mechanical 37%, other 3%. Obviously, businesses can always do a better job of training people, but people make mistakes.

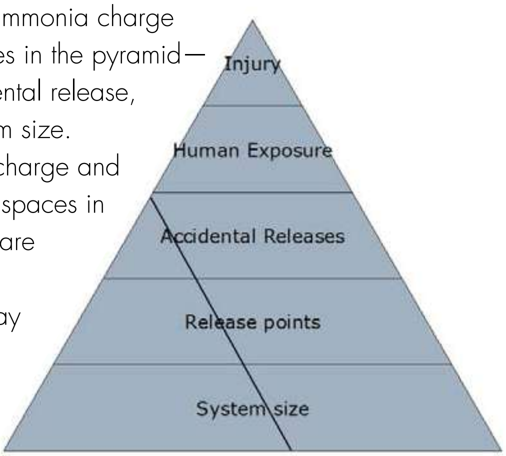
THE MOST FREQUENT CAUSES OF RELEASE, RELATING TO QUESTION #7, CAN BE CATEGORIZED IN FOLLOWING:

Designing a system which minimizes the interface between ammonia and people is probably the best way to reduce ammonia releases and the adverse consequences associated with them.

A full 37% of accidental ammonia releases were mechanical failures, which could be minimized by aggressive preventive maintenance programs. Mechanical failures can never be completely eliminated, but a well-maintained refrigeration system will not only function more efficiently, that is, consume less power, but will also result in fewer ammonia releases. Mechanical seals and corrosion dominated the mechanical failures, so these are two areas on which maintenance should be focused.

Ammonia systems have a surprisingly good record; for the preceding five-year period, over 2/3 of the respondents said that they had not experienced any ammonia releases. In those instances where a release did occur, nearly 20% reported that their facility was evacuated. Obviously, those occurrences were quite costly both in direct monetary terms and also in customer service.

How can the risk of releases be reduced? Figure 5, courtesy of General Mills, is a risk pyramid for ammonia releases. Reducing the ammonia charge addresses all of the issues in the pyramid—human exposure, accidental release, release points and system size. Reducing the ammonia charge and confining that charge to spaces in which people generally are not permitted is the most obvious and effective way to reduce injury and the high financial cost of ammonia releases.



Industrial Refrigeration Systems

Direct Ammonia Refrigeration Systems

The vast majority of ammonia refrigeration systems in the country use evaporative condensers with ammonia charged evaporators in occupied spaces. These systems certainly produce a very high level of thermal efficiency, resulting in the lowest power costs.

Indirect Ammonia Refrigeration Systems

Indirect ammonia systems have again gained popularity because the charge size can be dramatically reduced by the use of a cooling tower for heat rejection or condensing and secondary coolants, such as brine or glycol, in lieu of ammonia-containing evaporator coils. Recently, CO_2 coils have been used with the CO_2 acting as a volatile secondary or "evaporating brine." The coils contain CO_2 but not ammonia.

An excellent example of an indirect system is a typical, large, commercial air conditioning system, in which condensing takes place with chilled water from a cooling tower, and the refrigerant is distributed to the occupied spaces with a chilled water loop. Obviously, in a case of below-freezing temperatures, the chilled water must be replaced with a fluid which does not freeze at the required temperatures. But the concept is simple; air conditioning systems have very low charges and keep the charge away from people.

Heat exchanger technology has improved dramatically, providing designers with the ability to cool a fluid with ammonia or cool the ammonia with another fluid such as water, much more efficiently and cost effectively than in the past. Welded plate heat exchangers, along with cooling towers, compete effectively with an evaporative condenser. Plate and frame heat exchangers are now economically available with very close approaches (3°F or 4°F) so that the loss of system efficiency can be minimized.

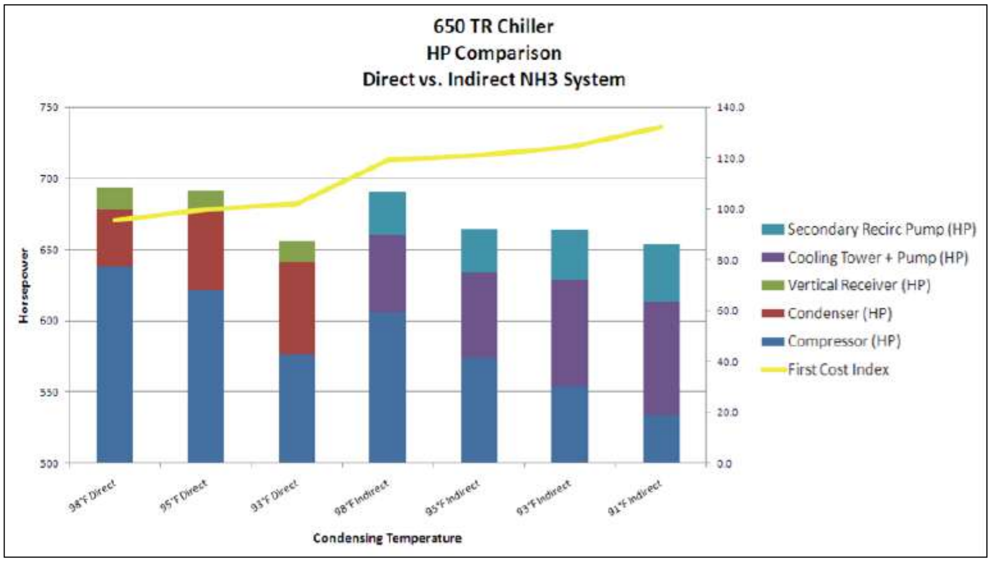
Heat Rejection Paradigm

Advances in cooling tower design, together with a modern heat exchanger, will permit a 13°F approach between wet bulb temperature (78°F) and the ammonia condensing temperature (91°F). This temperature difference is comprised of a 4°F approach between the leaving cooling tower water (82°F) and the air wet-bulb temperature (78°F), a 3°F approach between the water-cooled condenser exiting water temperature (88°F) and the ammonia condensing temperature (91°F). This can also be stated as a 4°F difference between the ambient air wet–bulb temperature and the leaving cooling tower water, a 6°F rise for the water in the water-cooled condenser, and a 3°F approach across the heat exchanger.

Chart A, below, compares a direct and an indirect ammonia system at about 650 tons. Referring to the chart, a system condensing at 95° F., with an evaporative condenser (Direct System), will cost about 20% less with a condenser than an Indirect System, that is, a cooling tower plus heat exchanger, but the cooling tower plus heat exchanger will consume 3% less horsepower. With a cost premium of 30%, the indirect system can be driven down to 5% less horsepower than a direct system at 95° F. condensing.

Low-Charge Ammonia Systems

Indirect systems using modern heat exchangers result in refrigerant charges as low as 1 lb. of ammonia per ton of refrigeration, and that 1 lb. per ton is in the compressor room and not in occupied spaces. The thermal efficiency of the low-charge ammonia systems is somewhat less than that of a direct ammonia refrigeration system but maintenance tends to be simpler and less frequent.



Low Charge Systems continued on page 16

COMPARATIVE COST$ OF LATENT LOADS

By Jerry Von Dohlen, Newark Refrigerated Warehouse

Two systems are generally available to remove moisture from the air in a low temperature refrigeration process. The defrost costs and refrigeration loads of each system are compared in this analysis. The first alternative is a frosted fan-coil evaporator. The assumptions are that the coil is operated at –20° F and condensing takes place at 90° F. For this comparison, a Vilter 16-cylinder R-22 compressor is being used. The second alternative is a liquid desiccant system.

Beginning with frosted coils, the first demand on the refrigeration system is the creation of the frost on the coil.

Energy Cost to Produce One Lb. Frost (COIL)

	BTU
Latent heat of condensation	1076
Sensible heat reduce vapor from 50° F to 32° F	10
Sensible heat of frost (32° F to –15° F)	23
Latent Heat of Frost	144
Total BTU cost to produce frost	1253

Assuming that the air entering the refrigerated space is approximately 50° F, then one pound of water entering with that air is also 50° F. The first cooling effort reduces the vapor temperature and then the phase change from vapor to liquid and the latent heat of condensation is 1076 BTUs per pound at –15° F. The water will now be converted to frost requiring 144 BTUs per pound. That frost must now be reduced in temperature to the coil temperature of –15° F which requires an additional 23 BTUs. Therefore, the amount of heat which must be removed from 50° F water vapor, in the process of being converted to –15° F frost, is 1253 BTUs.

How much energy in the form of electric power is consumed in removing those 1253 BTUs from the refrigerated space? The compressor is operating at about 2 HP per ton and other electric power consumers (evaporators, condenser, pumps, etc.) represent approximately an additional 33% for a total HP per ton of about 2.7. This implies the equivalent of approximately 0.57 kilowatt of electric power to transfer one kilowatt of heat from the refrigerated space. Therefore, for the above calculation (1253 BTUs divided by 3413 BTUs or 0.367 kilowatt hours of heat), it will require 0.57 x 0.367 kilowatt hours or 0.21 kilowatt hours of electric power to be used by refrigeration system to convert the one pound of water to –15° F frost. Obviously, that one pound of frost must now be removed from the coil.

Heat Required to Defrost One Lb. (COIL)

Raise frost temperature (–15° F to 32 F)	24	
Latent heat of frost	144	
Ineff. of defrost (20%) (144 x 4)	576	
Raise water temperature from 32° F to 42° F	10	
Subtotal		754
Sublimation (generally 16%) 0.16 x 754	121	
Evaporation (generally 14%) 0.14 x 754	106	
Subtotal		227
Total defrost heat required		981

Most systems use hot gas defrost; hot gas is supplied to the coil through a piping system. The hot gas must raise the frost temperature from –15° F to 32° F which requires 24 BTUs. The frost is then converted through the application of the latent heat of frost to water at 144 BTUs per pound. According to Stoecker, that process is 20% efficient, at best. Therefore, an additional 4 x 144 BTUs must be applied. This heat is used to heat pipes, the evaporator itself, maintain the water temperature as it drains out of the room, etc. Therefore, an additional 576 BTUs must be applied to the coil. Coils are generally defrosted at around 42° F and the water must be raised from 32° to 42° F which requires 10 BTUs. Therefore, defrosting the frost requires about 754 BTUs. Unfortunately, both sublimation (conversion from frost to vapor) and evaporation (water to vapor) occur in the process of defrosting a coil. According to the Ned Hoeckler paper presented at the 1994 IIAR Annual Meeting, approximately 16% of the frost sublimes and 14% of the frost evaporates into the surrounding air space, so heat for those loads must also be supplied. Obviously, this vapor is returned to the room, so approximately

30% of 754 BTUs (or 227 BTUs) must be supplied to this process. Therefore, a total of 981 BTUs of defrost heat must be supplied to the coil. At this point, only .7 pounds of water vapor has been removed.

How much did the 981 BTUs cost? Compressors are relatively efficient heat pumps; in this case moving 3.31 BTUs for each BTU of input energy. Some argue that the hot gas is free but this author believes that this assumption is incorrect because the vapor condensed into liquid is returned to the low side of the system at defrost pressure and therefore propagates flash gas which is an additional load on the compressor. This parasitic load can be significantly higher in defrost piping designs which rely on a simple back pressure regulator instead of a float drainer to remove the condensed defrost hot gas from the coil. Unnecessarily long defrost cycles plus the addition of unnecessary defrost cycles can add significantly to the parasitic load on the refrigeration system.

Cost of Defrost Heat

	BTU
138 HP produces 67.6 tons	
67.6 tons x 12,000 BTU/Hr. =	811,200
138 HP x 0.745 kw/HP x 3413 BTU/kwh =	350,890
Total heat in hot vapor	**1,162,090**

$$\text{Heat pump effect} = \frac{1{,}162{,}090 \text{ (total heat)}}{350{,}890 \text{ (heat contained in electricity)}} = 3.31 \text{ BTUs/BTU}$$

Sixty-seven point six refrigeration tons (67.6) is the transfer of 811,200 BTUs. The energy of the motor itself (138 HP) is also transferred to the refrigerant vapor: 138 HP x 0.745 (to convert to kilowatts) x 3413 (to convert to BTUs) or 350,890 BTUs for a total of 1,162,090 heat infused into the gas by a 138 HP compressor. 350,890 BTUs of energy in the form of electric power transfers 1,162,000 BTUs or 3.31 BTUs of heat is contained in the refrigerant vapor for each BTU applied to the electric motor. Therefore, 296 BTUs (981 BTUs divided by 3.31) of electric energy is required to produce the 981 BTUs of defrost heat. At 3413 BTUs per kilowatt hour (296/3413), 0.09 kilowatt hours are required to produce the defrost heat. Therefore, the cost of defrost heat is approximately 40% of the refrigeration cost of creating the frost. Remember, the system is operating at one kilowatt of energy transfer for each 0.57 kilowatts of electric energy and the defrost heat of 983 BTUs must be removed from the space. Therefore, on a per hour time basis, 559 BTUs (981 BTUs x 0.57) of energy must be applied at 3413 BTUs per kilowatt hour or 0.16 kilowatt hours must be used to remove the heat which defrosted the coil.

Summary of Electric Cost—
Defrost and Heat Removal of One Lb. (COIL)

	KWH
Produce frost	0.21
Defrost frost	0.09
Remove defrost heat	0.16
Total	**0.46**

In total, approximately 0.46 kilowatt hours are required to remove 0.70 of one pound of water, remembering that .30 of the pound was re-introduced as water vapor into the room, or approximately 0.66 (0.46/0.7) kilowatt hours are required to remove one pound of moisture from air. If a kilowatt hour costs ten cents, the cost to remove one pound of water from 50° F air is about $.066.

A second way of removing the moisture is with a brine/liquid desiccant system. Generally, liquid desiccant systems require about a 20 percent premium (energy) to remove vapor from the air and about 1.65:1 premium to remove the moisture from the brine solution. The water is never converted to frost so the latent heat of condensation of 1100 BTUs (at –20° F) plus approximately 35 BTUs to reduce the vapor from 50° F to –20° F, or 1143 BTUs, is required by the system. With 20 percent inefficiency (heat of absorption and higher temperature of regenerated brine), a total of 1362 BTUs is required to remove one pound of water vapor using a liquid desiccant. At 0.57 kilowatts of electric usage per kilowatt of heat transferred, it requires 776 BTUs of electric power at 3413 BTUs per kilowatt or approximately 0.23 kilowatts would be required to remove vapor from the air and reduce it to –20° F. At 10 cents per kilowatt hour that is approximately .23 cents per pound.

Liquid Desiccant
Cost to Remove One Lb. of 50° Vapor

Latent heat of condensation	1100
Reduce water to –20° F (50 to –20° F)	35
x 20% inefficiency	1.2
Energy to remove vapor	**1362**

At this point in the process, the brine contains the additional 1lb of water and 1362 additional BTUs. This pound must be vaporized by a heating process with 60% efficiency. Therefore, regeneration (returning the brine to its original concentration) will require 1683 BTUs (1020 x 1.65 at 150° F). If natural gas is used, then 1683 BTUs costs about $.017 with natural gas costing $1 per therm (100,000 BTUs).

The refrigeration system must remove the 1362 BTUs from the brine at a cost of .23 kwh (.57 X 1284 / 3413 BTU) at $.10 per kwh or $.023 on a per hour time basis.

Summary of Cost of One Lb. of Water (DESICCANT)

Refrigeration cost to remove vapor	$.023
Natural gas cost to remove water from brine	.017
Total Cost	$.040

The refrigeration system will experience the entire $.066 (.66 kwh) for the coil system but only $.023 (.23 kwh) in the desiccant system. The remaining $.017 is purchased natural gas. If waste heat is available from any source including compressor oil cooler, engine block heat, process heat, etc., the cost advantage of a desiccant system goes from about 40% to 65%. Sufficient heat is available from a screw compressor oil cooler. If the system is properly designed, the regeneration cost would be zero.

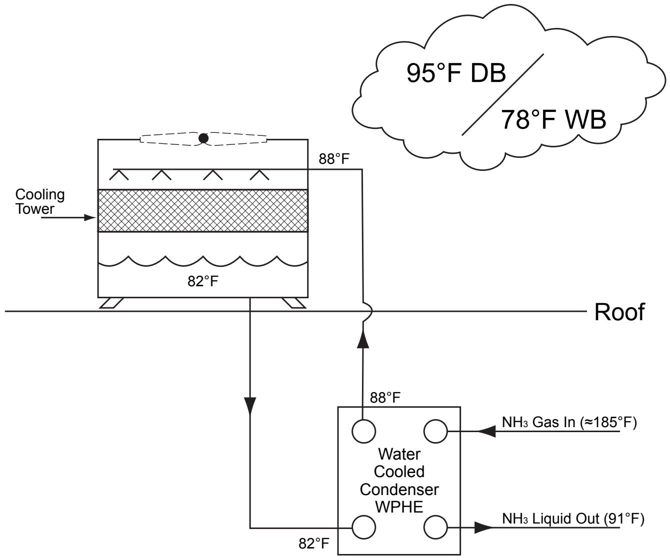
If typical warehouse infiltration loads in a building are 15%, and 33% of that is latent, that 5% will be accomplished at about a 40% cost advantage with a liquid desiccant system when paying for regeneration heat. So about 2% of the cost disadvantage of a desiccant system versus a traditional fan coil air cooler is recovered.

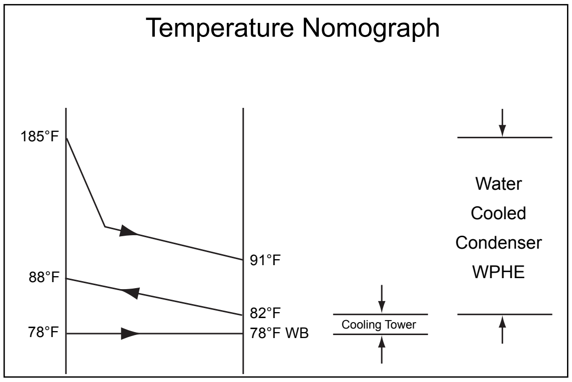
If heat from the screw compressor oil cooler is used for regeneration, the cost advantage of 65% translates to a system cost efficiency improvement of over 3%. The assumption was that each evaporator was only defrosted when needed and exactly the correct amount of heat applied to it. The adverse effect of frost on the coils has been ignored. In practice, the coil system will be less efficient than this analysis assumes.

Several conclusions emerge:

1) Frosted coils are very inefficient for moisture removal.
2) Liquid desiccants below freezing are much more efficient.
3) If regeneration heat is available from a waste heat source, such as a screw compressor oil cooler, liquid desiccant systems significantly outperform those with frosted coils.
4) Systems with frosted coils would benefit from a liquid desiccant removing the latent load to whatever extent possible, usually on the docks.
5) Using a liquid desiccant system as a primary refrigeration technique imposes an energy premium because of the additional fluid and heat exchange (refrigerant to brine) but the higher latent efficiency will at least partially offset that disadvantage.

Low Charge Systems continued from page 13





IIAR Survey Conclusion

Sixty percent of the releases were due to human failure. Improved training can reduce the failure rate, but probably not significantly. Mechanical systems, no matter how well maintained, will leak. Corrosion takes place, mechanical wear adversely affects equipment, as does vibration, etc. To the extent that the ammonia charge can be reduced and located away from people, system safety can be materially improved. Several alternative indirect systems exist, with reasonable thermal efficiency, together with reduced maintenance, cost and skill requirements which also improve safety. These systems deserve virtually every designer's consideration.

Editor's Note: Reduced charge ammonia refrigeration systems will reduce the opportunity for the accidental release of ammonia, as the author suggests. However, the reduction of ammonia charge can only be accomplished in 3-to 5-percent of all refrigeration systems because that is the number of new systems. The greatest improvement in safety and system operating efficiency is through improved training. This means every facility can improve its operational performance. And, as the author states, "safe facilities are more profitable than unsafe facilities."

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Rex Brown Named Honorary Life Member at 2010 IIAR Conference

Rex Brown received IIAR's highest honor when he was given an Honorary Life Membership at the Association's 2010 IIAR Industrial Refrigeration Conference and Exhibition in San Diego, California.

Noting that "Honorary Life Memberships aren't given out every year," 2009-2010 IIAR Chair Don Stroud emphasized that these awards are "reserved for members whose service extends well beyond their term of office and who have made extraordinary contributions to IIAR and the industry."

In presenting the award, Stroud described Brown as "a tireless worker who has served on the IIAR Standards Review Committee for many years and has also been a key participant on the ventilation task force."

Rex Brown has 45 years of experience in industrial refrigeration. Over the years, he has championed code changes that better serve the industry. He has been active in training and R&D, has served on the IIAR Board of Directors and the Frick Advisory Council. He has served on IIAR's Standards Review Committee since 1988 and has written many technical papers and training materials for the industry.

Most recently he presented a session, *Purging the Mystery of Purgers*, at the 2010 IIAR Industrial Refrigeration Conference in San Diego, California. He also has hosted a hydraulic shock research project at ALTA Refrigeration, his business in Atlanta, and represented the industry at meetings with the insurance industry.

Rudy Nechay is IIAR 2010 Member of the Year

Outstanding services to the industry and to the success of IIAR are the primary criteria for selecting a member of the year. Rudy Nechay's many involvements in critical projects, his willingness to give generously of his time and expertise, and his enthusiasm and depth of knowledge made him the natural choice for this honor.

Don Stroud, IIAR Chair (2009-2010), had special praise for Rudy Nechay's multi-faceted approach to advancing the cause of ammonia.

In his speech presenting the Member of the Year Award to Mr. Nechay at the 2010 IIAR Industrial Refrigeration Conference & Exhibition in San Diego, California, Don described Rudy, who is the president of Industrial Refrigeration Service, as:

"…An active supporter of the ammonia safety day program who also headed up a survey research project to gain insight into the common causes of ammonia releases. And he was the chair of the real estate task force that LED the effort to locate and purchase new office space for IIAR."

IIAR Board of Directors

Seated: Don Stroud, Joe Mandato, Peter Jordan, Adolfo Blasquez, Bob Port

Middle Row: Harold Streicher, Kem Russell, Tim Facius, Dennis Halsey, Don Hamilton, John Collins, Bruce Nelsen, Bent Wiencke, Gary Webster, Doug Sweet

Back Row: Bob Czarnecki, Paul Bishop, Jim Adler, Tom Leighty, Mark Stencel, David Blackhurst, Ron Miller, Bruce Badger

Absent: Marcos Braz, Nick Kawamura, Jim Marrella, Joe Paul

Bob Port Elected to IIAR Executive Committee

Bob Port, Lead Mechanical Engineer, Target, Co. has been elected to IIAR's Executive Committee where he will serve as treasurer. The election was held at the 2010 IIAR Industrial Refrigeration Conference & Exhibition in San Diego, California.

Port has over 25 years of experience in the refrigeration industry, as a Contractor, Consulting Engineer, and End User. He has been a member of IIAR since 1991. He served for six years on the IIAR Board of Directors, (2004-2010). He was Chair of the Ventilation Taskforce and was involved with the work of the Standards Review Committee since the mid-1990s.

Port says this position as a leadership chair on the Executive Committee will give him an opportunity to use his experience as an end-user to help IIAR align itself with the evolving industry.

Port will serve a Treasurer during his first year on the Executive Committee. He joins Peter Jordan, Chairman; Adolfo Blasquez, Chair Elect; Joe Mandato, Vice Chair; and Don Stroud, Immediate Past Chair.

Bruce Nelson, Tom Dosch and Doug Scott Win 2010 Andy Ammonia Award of Excellence

The Andy Ammonia Award was created in 1996 to recognize excellence in the IIAR annual meeting program. It is given annually to the two highest-ranking presentations at the IIAR Industrial Refrigeration Conference & Exhibition. The presentations are ranked by the scores they receive on evaluation forms submitted by session attendees.

This year's "Andy" was presented at the 2010 IIAR Ammonia Refrigeration Conference & Exhibition in San Diego, California to Tom Dosch, C&L Refrigeration and Doug Scott, VaCom Technologies, for their joint technical presentation, *Ammonia Refrigeration Design for LEED Certification*, and to Bruce Nelson, President, Colmac Coil Manufacturing, Inc., for his presentation, *Thermodynamic Effects of Water in Ammonia on Evaporator Performance*.

In their presentation, Dosch and Scott tackled the very timely question of how a refrigerated warehouse with an efficient refrigeration design using ammonia can achieve LEED® certification, while Bruce Nelson's presentation explored how ammonia evaporators can be operated at reduced liquid overfeed rates. Nelson also reviewed and recommended methods for managing and removal of water from these systems.

The first Andy Ammonia Award was presented in 1996. Previous winners include:

2009	Don Faust and Andy Pearson
2008	Bent Wiencke
2007	Rowe Bansch, Heinz Jackmann and Marcus Wilcox
2006	Kem Russell and Andy Pearson
2005	Andy Pearson and Don Faust
2004	Bruce Paulson and Niels Vestergaard
2003	Jeff Welch and Thomas Lund/Per Nielsen
2002	Tom Heisler and Bruce Paulson/Adrian Page
2001	Rex Brown and Mark Dolson
2000	Andy Pearson and Thomas Rajewski
1999	Jeff Welch and Marcus Wilcox
1998	Ron Cole and Joe Pillis
1997	Ted Martin and Robert Miksch
1996	Milt Garland and Douglas Villem

Sight Glass Taskforce Update

In other sections of this magazine, we've highlighted IIAR's role as a standard setting organization and as an association that acts as the voice of the industrial refrigeration industry. IIAR has another key function that is enshrined in our mission statement. We provide information on the safe, reliable and efficient use of ammonia and other natural refrigerants for the benefit of the ammonia refrigeration industry worldwide. In this role, IIAR initiated a Sight Glass Taskforce to investigate recent incidents of sight glass failure, to assess the safety of sight glasses and to make recommendations on steps the industry can take to ensure a higher degree of safety for sight glasses.

The initial findings of the Sight Glass Taskforce were presented at a special session at the 2010 IIAR Industrial Refrigeration Conference & Exhibition. The moderator of the session was Peter Jordan of MBD Risk Management Services, Inc. Three speakers shared the stage with Jordan:

- Doug Reindl, Industrial Refrigeration Consortium
- Rowe Bansch, Refrigeration Valves and Systems Corporation
- Bent Wiencke, Nestlé

Background: Recent Sight Glass Failures

In 2007, two catastrophic sight glass failures occurred in close succession at two separate end-user facilities. These sight glass failures were the catalyst for the formation of IIAR's Sight Glass Taskforce.

The first sight glass failure released 28 lbs of ammonia. The origin of the release was a ruptured sight glass located in a hot gas driven Liquid Transfer Unit (LTU) or pumper drum. Ammonia was released into the air and an employee working in the area where the sight glass failed was engulfed in an ammonia cloud and suffered severe injuries. Findings from the incident investigation suggested two possible causes for the failure — faulty installation or surface damage to the sight glass from external impacts. The sight glass was in an area where workers used a push-out bar. They may have hit the glass with the bar and weakened it. This first failure was considered a fluke that was unlikely to happen again. And then lightning struck twice! A mere 6 weeks later, a sight glass mounted in a plate freezer's suction line failed. Constant "bumping" of the sight glass is suspected to have weakened it leading to its eventual failure. Another possibility was that a gasket wasn't mounted correctly. Decades of wear may have also played a part in that the sight glass in question was over 20 years old.

Rather than ignore these incidents, corporate management and management of the affected facilities decided that they needed to investigate sight glass failures to ensure a safe working environment. They inspected all of their sight glasses and changed out any that seemed damaged. In the process, they discovered that sight glasses used in pumper drums showed signs of cavitation and erosion on the interior side of the glass. This damage is believed to have been caused by the erosive effects of saturated liquid between the gasket and the sight glass housing flashing when the pumper is rapidly depressurized.

The end-user informed IIAR of the sight glass failures and of the results of their initial sight glass inspections. Based on this information, the IIAR Board of Directors created the Sight Glass Taskforce in 2009. The taskforce was led by Marcos Braz, of MRBraz & Associates. It was charged to evaluate the safety of sight glasses and formulate recommendations to improve them.

Sight Glass Basics

Sight glasses are used extensively throughout industrial refrigeration systems. They provide visual access to portions of a system. They give operators an indication of whether ammonia is in liquid or vapor state. They also help operators detect oil in a system.

Doug Reindl described a typical sight glass assembly as consisting of a housing that is installed on the component on which the sight glass is located, vessel, piping etc, a sealing gasket, the glass, a fiber gasket and a retaining ring. The two sight glass design types used in industrial refrigeration systems are bull's-eye and linear. Bull's-eye is the most widely used type. There are two glass composition types, borosilicate and soda-lime materials. Sight glasses made of quartz or sapphire are used in laboratories but are too expensive for industrial refrigeration applications.

Taskforce Findings

Although sight glass failures are rare, they can have a powerful impact on facilities. In most situations, sight glass failures can be avoided through the simple application of common sense and an understanding of the nature of glass.

Sight Glass Taskforce Update continued on page 24

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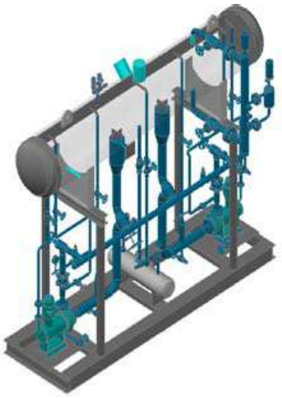

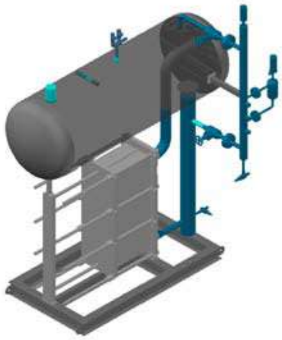

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Sight Glass Taskforce Update continued from page 22

Glass is a material that likes to be in compression rather than in tension. Glass is susceptible to shocks that can weaken it and cause it to fail. The Taskforce found that when sight glasses fail, they don't give much warning. They suddenly fail and that's it. This abruptness is due to the nature of glass — when it breaks, it doesn't do so by degrees, but all at once.

The taskforce also noted that chips or nicks in a sight glass surface will greatly reduce its ability to withstand pressure, and that some of the glass materials used in industrial refrigeration systems is susceptible to corrosion when exposed to alkaline environments including ammonia. When glass corrodes, it becomes cloudy. Glass is also susceptible to latent damage when improperly handled (e.g. glass is dropped) or installed (gaskets not properly arranged).

These findings suggest some basic rules:

- All sight glasses should be inspected regularly for any type of visible damage. Look for surface imperfections using illumination to provide back- and/or oblique lighting.
- Everyone who comes into contact with the sight glass should be strictly prohibited from using sharp, metal objects to remove ice from sight glass.
- Metal wires should not be used to install frost shields.
- Sight glasses should be eliminated where possible.
- Sight glasses should not be used in applications subject to hydraulic shock which includes hot gas driven liquid transfer units ("pumper drums") and any control valve group subject to hot gas defrost.
- The use of sight glasses in portions of the system where they will be subjected to extremes of pressure or temperature should be minimized.
- Proper alignment of sight glasses is critical; make sure glasses are properly aligned during installation.
- When installing sight glasses, strictly follow the manufacturer's recommendations. If the sight glass appears to have sustained any damage, it should be discarded before installation even if it's a brand-new glass just out of the box.
- Since, after an incident, it may not be possible to trace the origin of the failed sight glass, it's a good idea to keep an inventory detailing the glass' manufacturer, pressure rating, and date of installation.

End-User Survey

The Sight Glass Taskforce undertook a survey of 40 end-user plants. Of those 40 end-user plants, 38 percent included visual inspections of sight glass in their mechanical integrity programs. A total of four (10%) of plants surveyed had a refrigerant leak as a result of a sight glass failure in the past. It is important to note that none of the end-user reported failures were catastrophic. All reported failures involved small leaks from hairline cracks in the glass.

The next step for the Taskforce is to administer a manufacturers' survey intended to answer the following questions:

- What changes (if any) to the sight glass fabrication process are being investigated?
- What do they currently do in terms of testing and inspection at their facilities?
- What, if anything, is being done to date on the key issue of traceability?
- What preventive maintenance practices do they recommend?

Codes & Standards

A review of codes and standards and guidelines revealed little information regarding sight glass construction and the use of sight glasses in refrigeration systems.

The Taskforce recommended that the glass used to fabricate ammonia refrigeration system sight glasses comply with specific standards regarding the chemical composition of the glass itself, the process that was used for fabricating that glass, whether or not it was treated after fabrication by tempering or annealing and the required testing of the finished product. A required minimum thickness for maintaining mechanical integrity in an installation also should be established.

The IIAR Sight Glass Taskforce has delivered recommendations to SRC and the Code Committee for incorporation into our standards. It is possible that this will result in a new performance standard for sight glasses. The preventative maintenance standards being developed in IIAR 6 may be another area where these recommendations will be incorporated. There is money available from ARF for potential research projects to fill in gaps where additional testing is needed.

ASME Boiler and Pressure Vessel Code

Because sight glasses are often used in conjunction with pressure vessels, Rowe Bansch explained how the ASME Boiler and Pressure Vessel Code, ("B&PV Code"), treats sight glasses.

Some sight glass manufacturers claim that the sight glasses meet the requirements in UG 11(a) (1) of the ASME Boiler and Pressure Vessel Code, (Section VIII, Division 1). Another common claim is that the sight glasses are in compliance with the intent of the ASME Boiler and Pressure Vessel Code, Section 8, Division 1, and that the housings meet the material requirements for ASME for direct welding into pressure vessels. Moreover, each housing is marked for material traceability and that certifications are available upon request. These claims are of little value since the codes do not really address the actual glass in sight glasses.

Paragraph UG 11 of the B&PV Code actually states that,

"pressure parts shall not require inspection, identification or partial data reports when all of the following apply:

Sight Glass Taskforce Update continued on page 26

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PLC Maintenance & Troubleshooting
Allen - Bradley - Jul 26 & 27, 2010
Oct 12 & 13, 2010
Siemens - Aug 16 & 17, 2010
Nov 1 & 2, 2010
Mitsubishi - Sept 13 & 14, 2010
Dec 6 & 7, 2010

Operator Level I
Aug 9 - 12, 2010 Aug 16 - 19, 2010
Sept 13 - 16, 2010 Sept 20 - 23, 2010
Oct 11 - 14, 2010 Dec 6 - 9, 2010
Dec 13 - 16, 2010

Operator Level III
Oct 25 - 28, 2010

HazMat 8 Hour Refresher
Sept 1, 2010

PSM/RMP
Aug 2 - 5, 2010 Nov 1 - 4, 2010

Fundamentals of PLC's
Aug 30, 2010 Dec 13, 2010

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Sight Glass Taskforce Update continued from page 24

- That the parts are wholly formed by casting, forging, rolling or dye forming;
- That the parts are made to a manufacturer's standard with materials permitted by this division;
- That the materials are certified by the manufacturer to be suitable for service at the rating indicated;
- That the parts are marked with the manufacturer's name or trademark so that it is traceable."

In reality, this paragraph only applies to the sight glass housing itself.

The scope of ASME Boiler and Pressure Vessel code (paragraph U-1(e)) includes the first sealing surface for proprietary components "for which rules are not provided by this division" such as gauges, instruments and non-metallic components. In other words, the ASME code ends at the first gasket face. The glass is NOT included within the scope. The code's scope does include the welding and connection for the first circumferential joint where external devices are to be connected to the vessel. This means that if the sight glass is welded to a pipe nozzle in the vessel rather than into the shell or head of the vessel itself, the code may be stopped prior to the sight glass housing at the joint where the sight glass is connected to the pipe nozzle. In this case, the entire sight glass including the housing can be excluded from the scope of the ASME code.

In paragraph UG-4 of the B&PV Code, the statement is made that "materials subject to stress due to pressure shall conform to one of the specifications given in Section 2." Non-metallic materials are not included in Section 2; therefore, glass is not included in the scope of the code.

Sight glass manufacturers provide a range of ratings for their glass: Manufacturer A gives the maximum working pressure of 500 psi with a temperature rating of –40°F to 250°F. Manufacturer B rates the sight glass at 1,000 psi maximum working pressure, suitable for low-temperature applications to –60°F. Manufacturer C rates the sight glass at a safe working pressure of 400 psi with an operating temperature range of –60°F to 250°F. Although the ratings vary significantly, the actual products are often used interchangeably.

In conclusion, sight glasses are not included in the scope of the ASME B&PV Code (Section VIII Division. 1). There are no specific requirements in ASME for the design, manufacture, inspection or testing of sight glasses. There is no common standard for the design, manufacture, inspection or testing of sight glasses used in industrial refrigeration systems.

Alternatives to sight glasses:

Capacitance probes and magnetic level indicators are technology alternatives that can be used to provide an indication of level in a component such as a vessel. Capacitance probes find widespread and successful use in sensing liquid in level columns connected to vessels.

Magnetic level gauges are a relatively newcomer to industrial refrigeration systems. A magnetic level gauge is an indirect level-indicating instrument whose main components consist of a float, float chamber and a float indicator. The float rests in the chamber and is magnetically coupled to the indicator. The float creates a magnetic field and magnetic flags turn color as the float travels up and down. They utilize a level column with a flag-type indicator that's magnetically coupled to an internal float. These devices are available with optional level transmitters that send a continuous signal indicating where the level is to the control system.

Level switches are another alternative to indicate the presence of liquid. Level switches have no glass pressure retaining parts. They operate by sensing the presence of liquid by a change in capacitance. They can have alarms or level control signals incorporated into their design. One of the advantages of this type of switch is that it's easy to fabricate level columns similar to sight glass columns; it just requires the installation of threaded couplings that the level switches are threaded into. The drawbacks are that wiring is required; you've got to power these devices. A level switch is slightly higher in cost than a typical sight glass. It adds about 25% to the cost of a typical level column with a probe.

Conclusions:

The sight glass failures mentioned earlier should inspire us all to closely examine the design of the sight glasses we use and how we apply them. Make it a habit to consider safer designs along with the development of enhanced mechanical integrity inspection procedures. Challenge when and where sight glasses are installed and consider omitting them from locations where they are not needed. Follow the sight glass manufacturers' installation instructions and avoid possible latent damage that can occur to the glass from an accidental drop. Visually inspect sight glasses and immediately replace them when any external damage is apparent. Damage that should prompt replacement includes surface nicks and scratches.

One big safety consideration is that we are using sight glasses that are not always traceable, once a sight glass is out of the box, there's no way to discover what its pressure rating is, who made it or what material it's composed of. If it fails, it's almost impossible to trace back to the manufacturer. Sight glasses for other industries include information such as manufacturer, pressure rating and model number inscribed on the part. Manufacturers of sight glasses in our industry are encouraged to include similar information on their sight glasses. iiar

New From IIAR

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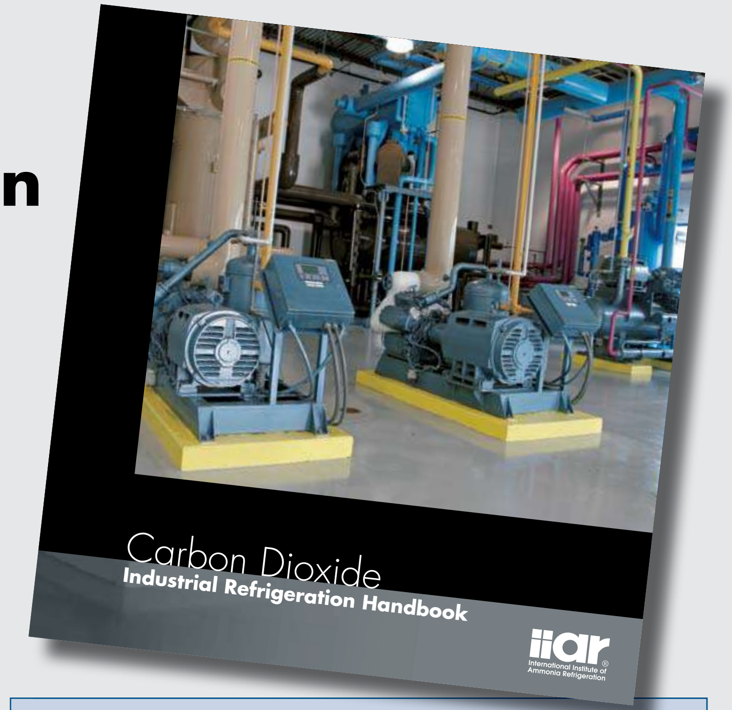
The Carbon Dioxide Industrial Refrigeration Handbook



Ammonia and carbon dioxide (CO_2) are the obvious choices to replace synthetic refrigerants such as R-22. The interest in two-stage, ammonia/ CO_2 systems has reached an all-time high. While there are plenty of technical guidance publications available on ammonia refrigeration, there is a limited amount of published guidance on the use of carbon dioxide as a refrigerant.

To help ensure that the refrigeration industry's transition to natural refrigerants is successful and safe, IIAR has just released a new publication, *The Carbon Dioxide Industrial Refrigeration Handbook*.

The Handbook explains the advantages of CO_2, explores its nature and covers the proper specification, design, installation and operation of safe CO_2 systems. The Handbook is a complete "one-stop" source of information on carbon dioxide refrigeration.

In addition, the Handbook also contains an appendix that presents reprints of technical papers on the subject of carbon dioxide refrigerants from previous IIAR Industrial Refrigeration Conferences.

Areas covered by the Handbook are as follows:

Chapter 1: Fundamentals
Chapter 2: CO_2/NH_3 Cascade Refrigeration Systems
Chapter 3: System Safety
Chapter 4: Pipe Sizing
Chapter 5: Heat Exchangers and Vessels
Chapter 6: Compressors
Chapter 7: Lubricants
Chapter 8: Evaporators
Chapter 9: Defrost
Chapter 10: Installation, Startup and Commissioning

ARF Safety Relief Research Project

Background

Pressure relief valves are engineered safety devices intended to protect pressure vessels and other pressure-containing equipment from catastrophic failure as a result of excessive pressure excursions that may occur during operation or standby conditions. Requirements for the application of pressure relief devices for pressure vessels originate from the ASME Boiler and Pressure Vessel code (Section VIII Div. 1 UG 125). Both IIAR 2 and ASHRAE 15 have specific engineering requirements for sizing of both pressure relief valves as well as relief vent piping systems. Section 6.6.3 of IIAR Bulletin 110 provides guidance for the interval of replacement or recertification of pressure relief valves. Although most end users simply replace their pressure relief valves on a five (5) year interval as identified in Bulletin 110, some are considering the use of an alternate provision for determining a performance-based interval for relief valve replacement. The following is one option for modifying the five (5) year replacement interval provided in Bulletin 110:

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

IIAR has developed a pressure relief valve test procedure to support this alternative interval for replacement. The test procedure includes a design and materials specification for a test rig suitable for use in collecting post-mortem data from relief valves removed from service at the termination of their operating life. The rig design and test procedure are intended for use by end-users (or their contactors) who seek to modify their interval for replacement.

Relief Valve Test Rig

In the fall of 2008, the IIAR relief valve task force completed its development of a draft relief valve bench test procedure, including details on a relief valve bench test rig. In the fall of 2009, the IIAR Ammonia Refrigeration Foundation (ARF) funded the Industrial Refrigeration Consortium (IRC) at the University of Wisconsin-Madison to construct the proposed bench test rig, verify the rig's function and the relief valve test procedure.

At the 2010 IIAR Annual Conference in San Diego, Todd Jekel and Doug Reindl of the IRC reported on the results of the relief valve bench test project. The researchers completed the construction of the relief valve bench test rig earlier this year and have been testing relief valves with varying set pressures, capacities, and connections sizes to assess the fitness of the test rig for functional testing and to validate the test procedure. The rig uses high pressure compressed air cylinders as the source for relief valve testing. Air from the compressed air cylinders is fed into 6.6 ft^3 (0.19 m^3) vessel. The vessel provides a buffer to feed air to the inlet of the relief valve being tested. The relief valve being tested is attached to the vessel by a 1-1/2" (38 mm) connection. A full port ball valve is used to isolate the relief valve for removal without discharging the entire volume of the buffer vessel. A high accuracy bourdon tube pressure gauge sits immediately upstream of the relief valve inlet.

Figure 1: Pressure relief valve test rig (University of Wisconsin-Madison, IRC 2010).

In order to verify the function of the test rig and corresponding procedure, the IRC researchers tested both newly manufactured and used relief valves. The table below shows combinations of valve capacity and set pressure that were tested to validate the bench test rig operation.

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

Table 1: Pressure relief valves tested using the bench test rig.

Preliminary Results

The researchers found that the test rig performed satisfactorily over the entire range of set pressures and capacities. They also confirmed that the pressure vessel feeding air to the pressure relief valve inlet was necessary to enable "pop testing" the relief valves. The vessel also served as a buffer to allow pressure relief valve blowdown to be observed and measured if needed. The researchers recommended that the

AMMONIA REFRIGERATION FOUNDATION

relief valve's pop pressure be used as the primary criteria for valve function (e.g. pass/fail). The rig was not designed nor was the test procedure intended to measure valve capacity (lb/min). During the conference, the researchers showed a series of videos to demonstrate the rig operation.

The researchers are completing revisions to the relief valve test procedure. Additional details on the results from this project will be available as a technical paper to be presented at next year's IIAR annual meeting.

Acknowledgements

The researchers would like to gratefully acknowledge and thank a number of key stakeholders involved with this project – without which, it would not have been possible. Funding and project oversight was provided by the Ammonia Refrigeration Foundation (ARF) and IIAR Research Committee, respectively. Additional generous donations were provided by a number of other companies including:

- 500 psig vessel were provided by Isotherm, Inc.
- High pressure piping, fittings, and construction of the rig was provided by Rhode Brothers
- Newly manufactured pressure relief valves were provided by Hansen Technologies and Refrigerating Specialties
- Used pressure relief valves were provided by Kraft Foods/Oscar Mayer, and Schoep's Ice Cream

ARF Board of Directors

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ARF's 2011 Golf Tournament in Orlando, Florida

Looking for an opportunity to gain your clients' undivided attention and good will? Treat them to a golf outing at the ARF Golf Tournament. Next year's ARF Golf Tournament will be held before the start of the annual IIAR conference on Saturday March 26, 2011, in Orlando, Florida. Please save the date and plan to play. The format for the golf outing differs from the typical "scramble" type of play and allows everyone to play their own ball throughout the match. This unique scoring system for the event will challenge the avid golfers to compete for the prize of individual champion while allowing the more casual golfers an opportunity to have fun while helping their foursome compete for team prizes. Additional information will be posted on the ARF website (www.nh3foundation.org).

Ammonia Safety Alert: Transferring Ammonia

There are risks involved whenever anhydrous ammonia is transferred to or from an industrial refrigeration system. Potentially catastrophic ammonia releases could occur if the transfer operations are not performed safely. While catastrophic releases are relatively rare, two ammonia-related incidents occurred in 2009 during transfer operations involving cargo tank trucks. The circumstances surrounding these incidents will be summarized below along with the precautions that should be taken whenever ammonia is transferred to or from a system using a cargo tank truck.

The first incident occurred in July 2009. During a delivery and transfer operation there was an ammonia release at an ammonia storage and distribution facility. The release occurred at approximately 8 a.m. The weather conditions were hot, humid, and overcast; wind speed was about 1 mph. The ammonia cloud from the release hugged the ground for several minutes due to the weather conditions and covered a portion of a two-lane highway adjacent to the facility.

The release occurred when a common carrier cargo trailer was delivering anhydrous ammonia to the ammonia distribution facility. The cargo trailer contained about 40,000 lbs of anhydrous ammonia. The carrier utilized a two-inch transfer hose from the trailer unit to make the delivery via a pump unloading process. The receiving tank was a 30,000 gallon capacity above-ground storage tank. About ten minutes into the delivery, the carrier's transfer hose ruptured creating an opening in the transfer hose through which the ammonia was released. The emergency shut off for the trailer was activated by personnel on site shortly after the release. It was estimated that about 7,000 lbs of ammonia could have been released.

The investigation of the incident subsequently revealed that the carrier's transfer hose that ruptured was not rated for ammonia service. It was an LP gas hose. Carriers using DOT MC 330/331 cargo trailers can haul and transport both ammonia and propane. Even though the cargo trailer itself is suitable for either service, hoses are constructed differently and should be maintained separately for each product. The ammonia deteriorated the LP hose since the hose's material of construction is not compatible with ammonia, and that deterioration eventually led to the failure of the hose.

Since this incident occurred during a transportation transfer operation, the National Transportation Safety Board (NTSB) had the lead in the incident investigation. Other agencies were also involved including Federal DOT, State EPA, State OSHA as well as company officials.

The second incident occurred at a fertilizer plant in Rosemont, MN in November 2009. Anhydrous ammonia apparently was held in large tanks at the plant and then transferred to awaiting cargo tank trucks at various loading stations. At about 6:30 p.m. two drivers were filling a cargo tank truck with anhydrous ammonia when a problem developed in a connection between a pipe delivering the ammonia and the tank on the truck. A driver noticed the problem and tried to fix it. Witnesses then recalled hearing noises followed by a loud "bang." The high-pressure piping dislodged releasing liquid ammonia. One driver died at the scene and a second driver was hospitalized and later died. An employee saw the ammonia vapor cloud and within seconds hit a button shutting down the flow throughout the entire plant. Occupational Health and Safety Administration (OSHA) officials are expected to conduct a full investigation.

Though neither of these incidents occurred at a facility operating an industrial refrigeration system they do demonstrate the importance of following proper procedures whenever ammonia is transferred to or removed from a system using a cargo tank truck. These precautions include:

- Proper training for those involved in the transfer operations. For example, Department of Transportation (DOT) HAZMAT employee training, sometimes called HM-126f training, must be provided to any employee involved in the transportation of hazardous materials. Refresher HAZMAT employee training is required every three years after initial training, or if the employee's duties involving hazardous materials change.
- Proper attendance during transfer operations. 49 CFR § 177.834 establishes the general requirements for loading and unloading cargo tank trucks. This regulation specifies that a motor carrier who transports hazardous materials by cargo tank truck must ensure that the truck is attended by a qualified person at all times during loading or unloading. For a cargo tank with a capacity greater than 3,500 water gallons, excluding delivery hose and piping, the qualified person attending the unloading operation must remain within 150 feet of the cargo tank and 25 feet of the delivery hose when the internal self-closing stop valve is open. A person is qualified if he/she has been made aware of the nature of the hazardous material which is to be loaded or unloaded, has been instructed on the procedures to be followed in emergencies, is authorized to move the cargo tank, and has the means to do so.

- Written operating procedures describing the steps that will be taken when transferring ammonia to or from a system. The procedures should describe:
  - The appropriate personal protective equipment (PPE) that should be worn and when the buddy system shall be practiced.
  - The source of the refrigerant, i.e., charge from a cylinder or from a cargo tank truck.
  - Charging point on the system.
  - Facility safe work practices and emergency response procedures applicable to the charging procedures.
  - Steps required to charge ammonia to the system.
  - Steps required to purge the charging system.
- An eye wash/safety shower capable of providing at least 20 gpm of water for at least 15 minutes should be accessible within 10 seconds or less from the transfer point.
- Ensuring that no ammonia is loaded into or unloaded from any cargo tank truck unless the handbrake is securely set and all other reasonable precautions are taken to prevent motion of the vehicle during the loading or unloading process. In addition no material should be loaded into or from any cargo tank truck with the engine running unless the engine is used for the operation of the transfer pump of the vehicle.
- Proper ammonia hoses must be used whenever transferring ammonia to or from a system. Each hose must contain a label or stamp indicating that it is suitable for ammonia service. Some transfer involving hose connections may also have backflow protection such as a check valve as part of the unloading process.
- Preventive maintenance procedures for transfer hoses. The DOT requires a hose management program for liquid transfer hoses carried on cargo tanks that transport liquefied compressed gases such as anhydrous ammonia. This program should include a visual inspection each time a hose is used (see below), a monthly inspection and an annual hose leakage test.
- Proper inspection before ammonia is transferred. The qualified person performing the transfer should check the components, including the transfer hose and piping, to assure that they are of sound quality, without obvious defects detectable through visual observation and audio awareness, and that connections are secure.

  Ammonia should not be transferred if the transfer hose has any of the following defects:
  - Damage to the hose cover that exposes the reinforcement.
  - Wire braid reinforcement that has been kinked or flattened so as to permanently deform the wire braid.
  - Soft spots when the hose is not under pressure or bulging when the hose is under pressure.
  - Loose outer covering.
  - Damaged, slipping, or excessively worn hose couplings.
  - Loose or missing bolts or fastenings on bolted hose coupling assemblies.

  In addition ammonia should not be transferred if the piping system has any of these defects:
  - Any external leak identifiable without the use of instruments.
  - Bolts that are loose, missing, or severely corroded.
  - Manual stop valves that will not actuate.
  - Rubber hose flexible connectors with any condition outlined above for hose assemblies.
  - Stainless steel flexible connectors with damaged reinforcement braid.
  - Internal self-closing stop valves that fail to close or that permit leakage through the valve detectable without the use of instruments.
  - Pipes or joints that are severely corroded.
- Proper emergency shutdown devices should be provided. Cargo tank trucks used in anhydrous ammonia service during metered delivery service with a capacity of 3,500 water gallons (or greater) should be provided with off-truck remote shutdown equipment per 49 CFR § 177.840. This shutdown equipment should close the internal self-closing stop valve and shut off the engine and auxiliary power upon activation by the person attending the unloading operation. Additional features may be required for obstructed view deliveries.

Chairman's Message continued from page 3

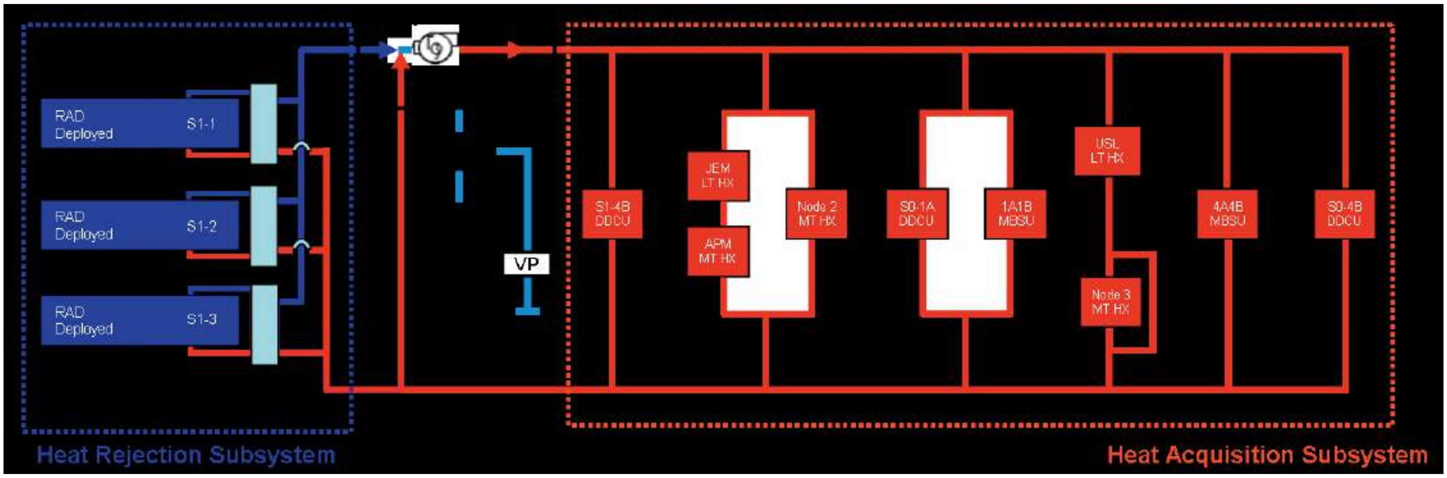
activity with the realization that the attention these inspections focus on our daily activities may ultimately improve our industry.

Over the next few months the IIAR will continue to make additional changes designed to achieve the goals set during the 2010 strategic planning session including:

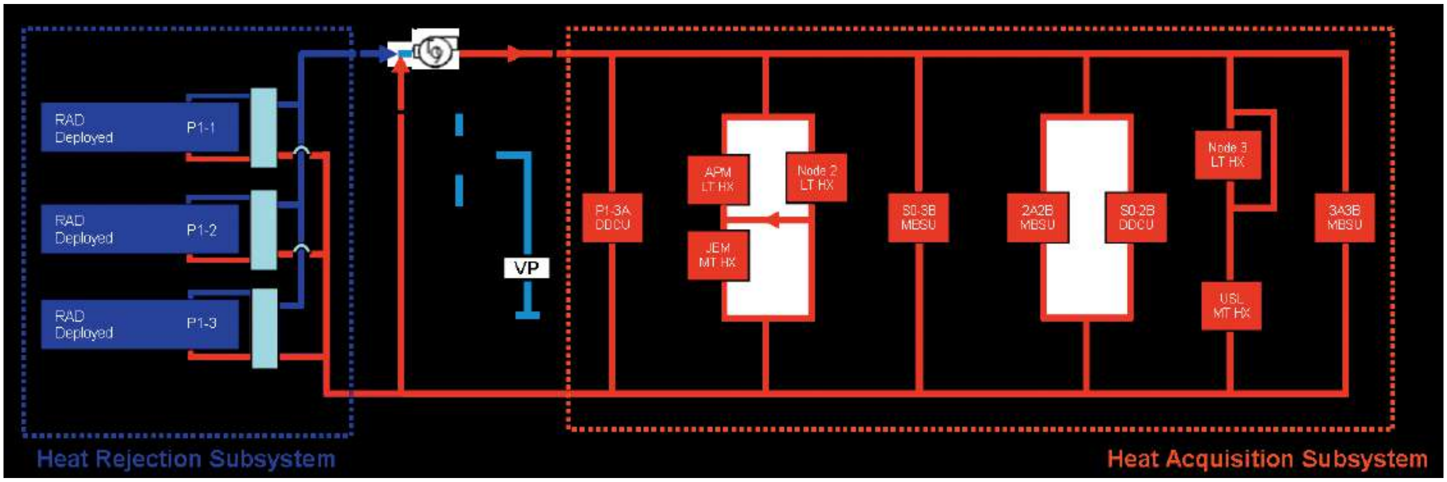
- The formation of an End User's Task Force to identify additional end users' needs related to the design and operation of industrial refrigeration systems.
- The development of a methods to distribute the information which was collected in the Ammonia Incident Survey to promote safety practices in our industry.
- The updating of the IIAR's PSM and Risk Management Program guidelines to reflect lessons learned during the implementation of these programs.
- The development of additional materials to help our members as they implement effective operator training and preventive maintenance programs.

As you can see we have very ambitious goals in 2010 and 2011. Your support of the IIAR will make the completion of these goals possible. Without the active participation and support of our membership, for example, we would not have continued access to experts such as Lowell Randel and Jeff Shapiro as we strive as an industry to comply with the regulations, codes and standards which apply to us. In June, we will be mailing the annual IIAR membership renewal forms. We urge you to remember the valuable services that the IIAR has provided and will continue to provide to you as members.

A Service Call In Space continued from page 7



EATCS Loop A Schematic



EATCS Loop B Schematic

between the two fluids via conduction and convection. The heat exchanger core is a simple flow through device with no control capability.

The Photovoltaic Thermal Control System (PVTCS) consists of ammonia loops that collect excess heat from the Electrical Power System components in the Integrated Equipment Assembly (IEA) and transport this heat to the four PV radiators where it is rejected to space. The Photovoltaic Thermal Control System consists of ammonia coolant, 11 cold plates, two pump flow control subassemblies (PFCS), and one photovoltaic radiator (PVR). The Photovoltaic Thermal Control System can dissipate 6,000 watts of heat per orbit.

Each loop provides cooling to externally mounted cold plates. The cold plates contain electrical equipment that converts and distributes power to downstream ISS loads. Each ammonia loop contains four cold plates, two attached to Current-to-Direct Current Converter Units (DDCUs) and two attached to Main Bus Switching Units (MBSUs). Each cold plate Orbital Replacement Unit (ORU) is connected to the EATCS ammonia loop by self-sealing quick disconnect (QD) couplings and contains a finned cold plate, two or three strip heaters and a temperature sensor. The cold plates are installed such that the fins of the cold plate are positioned adjacent to corresponding fins on either the DDCU or the MBSU to facilitate heat transfer by radiation between the cooled equipment and the cold plate. Each DDCU cold plate measures 35 inches (88.9 cm) by 28 inches (71.12 cm) by 31 inches (78.74 cm) inches and weighs about 96 pounds (43.54 kilograms).

Circulation, loop pressurization, and temperature control of the ammonia is provided by the Pump Module (PM). Each ammonia loop contains a Pump Module Assembly (PM) ORU to provide flow and accumulator functions and maintain proper temperature control at the pump outlet. Each Pump Module consists of a single pump, a fixed charge accumulator, a Pump & Control Valve Package (PCVP) containing a firmware controller, startup heaters, isolation valves, and various sensors for monitoring performance. The accumulator within the Pump Module works in concert with the Ammonia Tank Assembly (ATA) tanks to compensate for expansion and contraction of ammonia caused by temperature changes and keeps the ammonia in the liquid phase through a fixed charge of pressurized nitrogen gas.

The Pump Module (PM) provides fluid pumping, fluid temperature control and system pressure control. The Pump & Control Valve Package (PCVP) provides flow control. A single pump in the PCVP circulates the ammonia. The Flow Control Valve (FCV) located within the PCVP regulates the temperature of the ammonia. The Flow Control Valve mixes "cool" ammonia exiting the radiators with "warm" ammonia that has bypassed the radiators. Loop A typically operates at 8,200 lb/hr and loop B at 8,900 lb/hr with the pumps turning at 14,000 and 14,700 revolutions per minute, respectively.

The accumulator located in the Pump Module provides auxiliary pressure control. The accumulator keeps the ammonia in the liquid phase by maintaining the pressure above the vapor pressure of ammonia and provides makeup ammonia in case of a leak. The accumulator works in conjunction with the Ammonia Tank Assembly to absorb fluctuations in the fluid volume due to varying heat loads through the expansion and contraction of its internal bellows. Nominal operating pressure for the loops is 300 psia at the pump inlet. The maximum system design pressure is 500 psia. Each Pump Module measures 69 inches (175.26 cm) by 50 inches (127 cm) by 36 inches (.91 cm) inches and weighs about 780 pounds (353.8 kilograms).

Flow Control Monitoring Failure Detection, Isolation and Recovery (FDIR) for high and low pressure conditions are monitored by Multiplexer/Demultiplexers (MDMs). For an over pressure, gaseous nitrogen pressure is relieved down to 360 psia when pump inlet pressure reaches 415 psia (active control). The Pump & Control Valve Package Inlet pressure, Radiator return pressure, and Bypass return pressure sensors are part of this system and two of three pressure readings are used to determine if an overpressure condition exists. The pump will shut down when the pump outlet pressure reaches 480 psia.

Low pressure (current limit set at 170 psia) is monitored by two methods to determine a low pressure condition (the higher of the two values to determine the limit). Low pressure conditions are monitored using the PVCP inlet pressure, radiator return pressure, and bypass return pressure sensors.

The Pump & Control Valve Package also maintains temperature set point control of the ammonia supplied to the Heat Acquisition Subsystem. The PCVP has a temperature control capability of 36°F (2.2°C) to 43°F (6.1°C) and it is set at 37°F ± 2 °F (2.8°C). The temperature control method is by a three-way mixing valve that mixes flow from the radiators and the Heat Rejection System (HRS) Bypass. Heaters on the HRS Bypass leg provide an additional level of control. Total heater power of 1.8 kW is split across two heater strips mounted on the HRS bypass lines (900 watts each). Pump outlet over temperature protection is provided by a Firmware Controller (FWC) in the PCVP that uses three PCVP outlet sensors to determine an over temperature condition and issues zero pump speed. Multiplexer/Demultiplexers (MDMs) use the Pump Module outlet sensor to determine an over temperature condition and pull power from the Solenoid Driver Output (SDO) card providing power to the Pump Module. The current limit is set at 65°F (18.33°C). The pump is also shut down when the PCVP firmware detects potential freezing in the IFHX.

Each ammonia loop contains an Ammonia Tank Assembly Orbital Replacement Unit (ATA ORU) to contain the heat transfer fluid (liquid ammonia) used by the EATCS loops. There is one Ammonia Tank Assembly per loop. The ATA ORU is used to supply makeup fluid to the system, to act as an accumulator in concert with the Pump Module accumulator and provide the capability to vent the ammonia loops by way of a connection to an external non-propulsive vent. Each ATA primarily consists of two bellows ammonia tanks pressurized by an external nitrogen source, two internal survival heaters and two sets of quantity, differential pressure, absolute pressure and temperature sensors. The ATAs are isolatable and replaceable on orbit.

The ATA in combination with the Nitrogen Tank Assembly (NTA) provides fluid supply and primary system pressure control. The ATA acts as the primary accumulator for the EATCS in concert with the NTA. If required, it can also be used to replenish the PVTCS fluid lines. Each ammonia loop contains a Nitrogen Tank Assembly ORU to provide storage for the high pressure nitrogen used for controlled pressurization of the ATA.

The NTA is connected to the ATA by self-sealing Quick Disconnects (QDs). Each NTA ORU primarily consists of a nitrogen tank, a gas pressure regulating valve (GPRV), isolation valves and survival heaters. The nitrogen tank provides a storage volume for the high-pressure gaseous nitrogen, while the GPRV provides a pressure control function as well as nitrogen isolation and over pressure protection of downstream components. The NTA provides the necessary pressure to move the ammonia out of the ATA. The single high-pressure tank contains nitrogen at 2,500 psia (@70°F, ground fill) and uses the GPRV to supply continuous pressure up to 390 psia in one psia increments. A back-up mechanical valve limits the maximum nitrogen pressure to 416 psia. The GPRV provides pressure control as well as high-pressure nitrogen isolation and overpressure protection of downstream components. The NTA has venting capabilities and over pressure controls. Each NTA measures 64 inches (162.56 cm) by 36 inches (91.44) by 30 inches (76.2 cm) inches and weighs about 460 pounds (208.65 kilograms).

Fluid Lines and external Quick Disconnects (QDs) provide the transportation path from the truss segments to the IFHXs. Connections between segments are made with flex hoses and QDs.

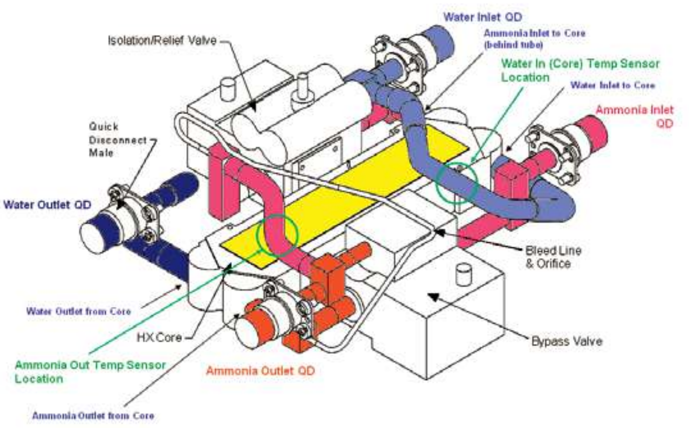
Heat collected by the EATCS ammonia loops is radiated to space by two sets of rotating radiator wings—each composed of three separate radiator ORUs. Each radiator ORU is composed of eight panels, squib units, squib unit firmware controller, Integrated Motor Controller Assemblies (IMCAs), instrumentation, and QDs. Each Radiator ORU measures 76.4 feet (23.3 meters) by 11.2 feet (3.4 meters) and weighs 2,475 pounds (1,122.64 kilograms). Each ammonia loop contains one radiator wing comprised of three Radiator ORUs mounted on the Radiator Beam and six Radiator Beam Valve Modules (RBVM) and one Thermal Radiator Rotary Joint (TRRJ).

Each Radiator ORU contains a deployment mechanism and eight radiator panels. The deployment mechanism allows the Radiator ORU to be launched in a stowed configuration and deployed on orbit. Each radiator ORU can be remotely deployed and retracted. Each individual radiator has two separate coolant flow paths which flow through all eight radiator panels. Each panel's flow path has eleven flow tubes for a total of 22 Inconel flow tubes or passages (11 passages per flow path) per radiator panel; flow tubes are freeze tolerant. Flow tubes are connected along the edge of each panel by manifolds. Flex hoses connect the manifold tubes between panels. Each panel has a white (Z-93) coating which provides optimum thermo-optical properties to maximize heat rejection. The flow tube arrangement is designed to minimize ammonia freezing in the radiator. Each radiator path contains one Radiator Beam Valve Module (RBVM) as a part of the radiator wing. Six RBVMs are mounted on the radiator beams and truss segments. Two RBVMs service each radiator ORU. Each RBVM consists of an isolation relief valve, an isolation valve, an Integrated Motor Controller Assembly (IMCA), QDs, and pressure and temperature sensors. The RBVM controls the transfer of ammonia between the Radiator Assembly ORU and the rest of the EATCS loop. Each RBVM contains sensors to monitor absolute pressure, temperature and valve position within the ORU. Remote control venting of the radiator fluid loop is also available through the RBVM to facilitate radiator replacement and prevent freezing of the ATCS coolant during contingency operations. The RBVM provides flow path isolation in the event that a panel suffers micro-meteoroid damage and also provides automatic pressure relief when the EATCS is over pressurized. Each RBVM weighs about 50 pounds (22.68 kilograms) and measures 24 inches (60.96 cm) by 20 inches (50.8 cm) x 5.4 inches (13.72 cm).

The rotation capability for each radiator assembly is provided through a Thermal Radiator Rotary Joint (TRRJ). The TRRJ provides power, data, and liquid ammonia transfer to the rotating radiator beam while providing structural support for the radiator panels. Rotation angles are determined via the Radiator Goal Angle Calculation (RGAC) algorithm which commands the Radiator Beam to put the radiators either "edge to the sun" during isolation phase of the orbit or "face to the Earth" during the eclipse phase.

The RGAC ensures the radiators stay cold enough so the heat can be rejected but warm enough so that the ammonia does not freeze. There is a temperature goal of –40 °F at the radiator outlet. The FHRC provides the transfer of liquid ammonia across the rotary joint and is capable of rotating 230 degrees, at ±115 degrees from its neutral position. (software command limit is ±105°); with a variable rotation speed of 0 to 45 degrees-per-minute. Each TRRJ measures approximately 5.6 feet (1.7 meters) by 4.6 feet (1.4 meters) by 4.3 feet (1.3 meters) and weighs 927 pounds (420.5 kilograms).

IFHX Fluid Roadmap



IFHX ORU Model

Software Thermal Control System (TCS) software is used to control and monitor the system. The TCS software executes actions such as system startup, loop reconfiguration, and valve positioning for flow and temperature control automatically or via commands from crew laptops or ground workstations. Telemetry from the various temperature, pressure, flow, and quantity sensors is monitored by TCS software and displayed on crew laptops or ground workstations. In addition, Fault Detection, Isolation, and Recovery (FDIR) software is used to monitor the performance of the TCS and, if there is a problem, alert the crew and flight controllers. In some cases, FDIR software initiates recovery actions.

In addition to the experts mentioned in the article, the author thanks Lupe Gonzales, The Boeing Company–IDS Space Exploration ISS Active Thermal Control Systems Manager, and Adam Morgan, Boeing Space Exploration Communications/ Public Relations, for information and help locating diagrams of the Space Station's Active Thermal Control System.

Code Update continued from page 8

Uniform Mechanical Code

Section 1102.0 General: ASHRAE 15 and IIAR 2 are now referenced as mandatory standards, applying in full except where the UMC specifies a differing requirement, in which case, the UMC prevails.

Section 1105.3.3 Refrigerated Process and Storage Areas: The requirement for ammonia process and storage areas to be classified as Class I, Division 1 hazardous electrical locations, in accordance with the electrical code, has been revised to exclude areas using ammonia as a refrigerant. This change makes the UMC consistent with all other codes that deal with this topic. Also, the requirement for refrigerant detection in process and storage areas to activate automatic valves to stop the flow of refrigerant out of the machine room and stop the flow of refrigerant to evaporators that previously appeared in Section 1121.1 was eliminated when that section was consolidated, in part, with this one.

Section 1108.5 Emergency Control of the Ventilation Systems: The ammonia concentration set point for initiating emergency ventilation has been increased from 150 ppm to 1,000 ppm, which reduces the possibility of unnecessarily triggering emergency ventilation in the event of a small fugitive release, which might occur during routine oil draining or other system service work. Although accidentally activating emergency ventilation might not typically cause a problem, there are cases, such as extremely cold climates, where introducing large volumes of unconditioned air into the machinery room could cause problems.

Section 1108.7 Ventilation Discharge: The previous requirement for room exhaust from ammonia machinery rooms to be routed through a treatment system before release to atmosphere has been deleted.

Section 1120 Ammonia Discharge: The previous requirement for emergency diffusion tanks to be designed on a basis of one gallon of water per pound of ammonia, calculated using the entire system charge, has been reduced. The volume of water required in diffusion tanks is now limited to that required to handle a one-hour discharge from the single largest relief device on the system, still using the one gallon of water per pound of ammonia ratio.

Section 1121.1 Detection and Alarm Systems: Some of the provisions previously located in this section were relocated to Section 1105.3.3. See discussion of that section above.

Section 1122 Emergency Pressure Control System: The requirement to provide an emergency pressure control system for ammonia refrigeration, previously added to the International codes, was added to the UMC for consistency. Those involved in codes over the past few years will recall that the emergency pressure control system was added to codes as a basis for justifying elimination of the archaic requirement for manual emergency control boxes.

Uniform Fire Code

Sections 53.2.1.1.1 and 53.2.1.2.1 Overpressure Limit Setpoint: The buffer between the pressure relief valve rated operating pressure and the emergency pressure control system's operating pressure has been revised from 15 psi to 10% of the PRV rated operating pressure. This provides a greater factor of safety to prevent weeping of a PRV in an overpressure condition before the EPCS operates

Section 53.2.3.1.6 Refrigerant Detector Monitoring and Annunciation: This section was revised to require that refrigerant detectors, when activated, transmit an alerting signal to an "approved" location. The term "approved" refers to whatever the local authority will accept as a reasonable basis of system monitoring. In some cases, this might be a central station service monitoring other alarm signals for the same facility. In other cases, it may make the most sense to have the approved location be a pager carried by the on-duty refrigeration engineer responsible for the facility.

Section 53.2.3.4.5 Refrigeration System Emergency Shutoff: The requirement for an emergency shutoff switch for machinery rooms has been revised in three ways. First, the previous mandate requiring the switch be mounted in a "break glass" enclosure has been changed to allow any tamper-resistant cover that is satisfactory to local authorities.

Second, equipment required to be controlled by the emergency shutoff switch has been clarified. Previously, the code implied that all electrical equipment and devices in the machinery room had to be stopped by the switch, and some jurisdictions interpreted the provision as even requiring shutoff of convenience outlets. The code is now specific in only requiring shutoff of refrigerant compressors, refrigerant pumps and normally-closed automatic refrigeration valves. It is recognized that some owners and designers prefer a complete electrical shunt for machinery rooms in the event of a significant leak, as opposed to what the code now requires. This type of design remains an option for those who chose it, but it's no longer the code mandated minimum.

Third, there is a new requirement for the shutoff control to be integrated with refrigerant leak detectors located in the machinery room. The detection system, upon sensing a leak event with a concentration reaching 25 percent of the lower flammable limit for the refrigerant or reaching the upper detection limit for the detector (whichever is lower), must now automatically trigger the emergency shutoff, as described above.

Section 53.2.3.3.13.2 Ventilation Discharge: The previous requirement for room exhaust from ammonia machinery rooms to be routed through a treatment system before release to atmosphere has been deleted.

More details on individual changes in the International codes can be found in "Code Change Resource Collections" books published by ICC. These books include the complete history of each change made to the 2009 codes.

IIAR continues to work on the model codes to ensure that they specify reasonable, appropriate and consistent regulations and coordinate with ASHRAE 15 and IIAR 2 to the greatest extent possible. Look for an update on proposals to the 2012 codes in an upcoming column.

From the Technical Director

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

New Ventilation Requirements for Machinery Rooms

Standard ANSI/IIAR 2-2008 is being updated soon. As most readers are aware, IIAR 2 is the ANSI/IIAR standard for equipment, design and installation for closed circuit ammonia refrigeration systems. Being an ANSI standard, this document is required to be reviewed, updated and renewed every five years per ANSI's canvassing approval process.

You will notice from its title that the publication was renewed in 2008. When that renewal process was taking place, a great deal of deliberation formed around the topic of machinery room design. Many members and the Standards Review Committee decided that the 2008 renewal would be an opportune time to incorporate some current ideas regarding several aspects of machinery room design and for the revised IIAR 2 to reflect recent changes in the NEC and ASHRAE 15. However, because of the variety of opinions and the lengthy process of the ANSI canvass procedure, the IIAR was compelled to publish the standard in 2008 without changes to Section 13, *Machinery Room Design* and commit to establishing an addendum to the standard that would address the concerns and needs of the industry. This addendum is titled *Addendum A* and it is anticipated that the ANSI process of approval will be complete within the next few weeks.

Much of the debate regarding Section 13 centered on ventilation and methods of calculating the rates required. To this end, a ventilation task force was formed and charged with determining the most appropriate methods to accomplish machinery room ventilation. The most obvious changes are the formulas used to determine "normal" and "emergency ventilation" rates. The way ventilation rates were calculated for many years was based on determining the greater value between engine room heat rejection, and the rate based on the mass of refrigerant in a system. While heat rejection is still a factor that must be considered, it was determined that the mass of refrigerant had little to do with the ability to provide an appropriate ventilation rate, and that the formula for determining the rate was an archaic leftover from the 1920's that predates not only IIAR, but also ASHRAE. The flaw in logic is obvious: after all, a small charge can release rapidly and a large charge can release slowly. Further it was noted by the task force that many different design parameters are not in agreement. IIAR 2, IIAR Bulletin 110, ASHRAE-15, the IMC, the UMC, various fire codes and the European code EN-378 all have conflicting requirements.

So, what are the changes? These are basically shown below, but the actual standard should be reviewed for details and exceptions upon final publication. Further, there are a number of other changes in the standard which should also be reviewed. These pertain to emergency switches, room pressure, signage and more.

- Continuous ventilation is no longer a requirement. This is consistent with the NEC (which both ASHRAE and IIAR reference) that requires ammonia detection if electrical machinery is not Class I, Div. 2.
- Normal ventilation (not to be confused with continuous ventilation) is based on the greater of these: a rate of 20 air changes per hour, or the quantity of air needed to limit the room temperature to 104°F, based on the heat load. Normal ventilation fans need not run continuously, or at full speed except when refrigerant is detected.
- Emergency ventilation is based on 30 air changes per hour.

The normal ventilation rate was determined by considering all of the various code and underwriter requirements that exist already, and the size of a typical machinery room. Subsequently, over 50 typical facilities were surveyed to determine an average machinery room size, and to compare what ventilation rates existing rooms have to what would be required under the new method. It was found that most all of the rooms would have sufficient normal and emergency ventilation based on the new methods.

The emergency ventilation rate was determined by considering what the typical "large release" scenario was found to be based on survey data and historical anecdotes. The amount of ammonia released in a sheared ½" high pressure liquid line at the "choked flow" condition was calculated, and then verified by the Ammonia Safety Training Institute. This rate was then correlated to a ventilation rate that would prevent the Lower Flammability Limit (LFL) of 160,000 parts per million (ppm) from being exceeded. Also, it was determined that this rate would provide an average velocity of 400 ft./min. of fresh air across the floor, and potentially provide lifesaving ventilation for an unconscious person unable to escape the room.

As is typical when getting a large group of people to agree on a plan of action, there are several provisions of the standard that remain contentious. Therefore it should be noted that the entire standard will come up for renewal once again in approximately two years. At this point, the standard will be re-opened to public review and comment. As always, the IIAR encourages you to be involved in the process. This helps to legitimize the standards development process and provides individuals a way to participate in developing the rules and standards upon which our industry is based.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