Refrigeration, Politics, and 'The Donald Effect'

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ABSTRACT

The International Institute of Ammonia Refrigeration (IIAR) has historically been dedicated to promoting the safe use of ammonia as a refrigerant through the development of safety standards, education, advocacy, publication of technical information, and research promotion. More recently, the IIAR has expanded its scope of activities to include CO_2 by developing the CO_2 Handbook and initiating work on development of CO_2 safety standards. It is also recognized that IIAR can play an important role in the development of practical safety standards for the safe use of hydrocarbons in commercial and industrial refrigeration systems. The recently launched IIAR Academy of Natural Refrigerants was created with the goal of training and certifying participants to be proficient with the contents of IIAR Standard IIAR-2[1]. The future application of synthetic refrigerants in the USA will be determined by the politics of climate change while the future application of natural refrigerants will be determined by the politics of health and safety regulations. We suddenly find ourselves in a shifting political landscape - there is an expectation that the politics of both climate change and safety regulations will be impacted by 'The Donald Effect'. Regardless of pending political changes new developments with low charge ammonia refrigeration represents inherently safer technology that can also significantly reduce power consumption.

BACKGROUND

The International Institute of Ammonia Refrigeration (IIAR) was founded in 1971 by a group of engineers who saw a need for ammonia refrigeration industry-specific education, advocacy, and best practice standards that did not exist at the time. The predominant HVACR engineering society at the time, ASHRAE, was not actively interested in or advocating for the expanded use of ammonia as a refrigerant. IIAR grew quickly and has become recognized as the authoritative source for information on the safe use of ammonia in refrigeration systems (see www.iiar.org). More recently IIAR has expanded its mission and scope to include promotion of the safe use of all natural refrigerants including CO_2 and hydrocarbons. IIAR finds itself well suited to this task having been founded and sustained in its activities without the support and influence of funding from chemical companies involved in the development and supply of synthetic refrigerants.

Discovery in the 1970's that the synthetic CFC refrigerants were responsible for the destruction of stratospheric ozone was a game-changing event for the refrigeration industry. A new school of thought relating to the use of "natural refrigerants" came into prominence, pioneered by Prof. Gustav Lorentzen, Prof. Horst Kruse, Forbes Pearson, and others, which promoted the idea that if we wanted to make our refrigeration systems environmentally friendly then we should use working fluids that occur in nature. That is, working fluids (refrigerants) that occur in nature are by definition benign and we, as good mechanical engineers, should design our refrigeration systems to take advantage of the properties of these natural refrigerants rather than trying to be chemical engineers designing synthetic fluids to fit existing refrigeration machinery.

At the same time, chemical companies went to work developing new synthetic refrigerants having zero ozone depleting effects - the HFC's. Atmospheric research continued and soon the term "Global Warming" came into our common vocabulary along with the discovery that the new HFC refrigerants are potent "greenhouse gases" and contribute significantly to warming the troposphere, accelerating climate change.

Most recently, development of synthetic refrigerants has focused on chemicals having zero ozone depletion potential (ODP) and "low" global warming potential (GWP) - the HFO refrigerants. The synthetic refrigerants had always been characterized as being "non-toxic" and "non-flammable". The conundrum now faced by synthetic refrigerant producers and proponents is that the low-GWP refrigerants, like HFC-32 and HFO-1234yf, display varying levels of flammability. In addition there are specific environmental concerns with HFO-1234yf, which when released to the atmosphere break down to produce trifluoracetic acid (TFA) which accumulates in aquatic ecosystems like fresh water bodies[2].

All of these developments and discoveries have reinforced the commitment and conviction within IIAR that our environment and society at large will be well served by the safe and orderly transition of all air-conditioning, refrigeration, and heat pump machines to operate with natural refrigerants as quickly as possible. This will be a tall task given the need for research and development of new equipment, new safety standards, adequate training, and marketplace adoption, based on the various properties of the natural refrigerants. If well managed and executed, the result of this transition will be a new generation of safe, environmentally friendly, energy efficient, and cost effective heating and cooling technologies.

THE POLITICS OF CLIMATE CHANGE

In 1974 the researchers Molina and Rowland published a laboratory study demonstrating the ability of CFC's to catalytically break down Ozone in the presence of high frequency UV light. Further studies estimated that the ozone layer would be depleted by CFC's by about 7 per cent within 60 years and based on such studies the US banned CFC's in aerosol sprays in 1978. In 1984 British Antarctic Survey scientists Farman, Gardiner, and Shanklin, discovered a recurring springtime Antarctic ozone hole. In the 1980's the first measurements of this loss were actually documented and in 1984, when the British first reported their findings, October ozone levels were about 35 per cent lower than the average for the 1960s. The U.S. satellite Nimbus-7 confirmed these results, and the term Antarctic ozone hole entered our popular language.

Ultimately this research led to the Montreal Protocol on Substances that Deplete the Ozone Layer, an international agreement to phase out the production of numerous substances that are believed to be responsible for ozone depletion. The Montreal Protocol was agreed to in September 1987, and entered into force on January 1, 1989. All of these events triggered intense research activity throughout the 1980's to find alternate refrigerants with lower Ozone Depletion Potential (ODP) and resulted in the development of various HCFC and HFC type refrigerants.

The Clean Air Act (CAA) of 1970 was amended in 1990 to include Title VI – "Stratospheric Ozone Protection" which began putting into law regulations requiring the phase-out of the ozone depleting substances identified by the Montreal Protocol .The enforcing body for these regulations is the Environmental Protection Agency (EPA). Section 608 of Title VI of the CAA establishes the National Recycling and Emission Reduction Program. The purpose of this program is to:

- Prohibit the release of CFCs, HCFCs, their blends, and substitute refrigerants during service, maintenance and repairs, and at end of life.
- Reduce the use and emission of CFCs and HCFCs.
- Maximise the recapture and recycling of CFCs and HCFCs.
- Ensure the safe disposal of CFCs, HCFCs, and their blends.

Section 608 prohibits individuals from intentionally venting ODS refrigerants (including CFCs and HCFCs) and their substitutes (such as HFCs), while maintaining, servicing, repairing, or disposing of air conditioning or refrigeration equipment. EPA is responsible for enforcement and may perform random inspections, respond to tips, and pursue potential cases against violators of the Section 608 regulations. EPA is authorized to assess fines of up to $37,500 per day for any violation of these regulations.

Section 608 includes a number of requirements for users of regulated ozone depleting substances - and now greenhouse gases including HFC's. Regulatory requirements cover:

- Technician Certification
- Refrigerant Recovery and Recycling Equipment
- Refrigerant Leaks
- Refrigerant Sales Restrictions
- Major Recordkeeping Requirements
- Safe Disposal Requirements
- Reclamation
- Service Practice Requirements

Enforcement by the EPA has been very aggressive since 2010 with a number of large fines issued to various companies, individuals, and even government entities. A few examples include [3]:

Table 1: EPA Fines under CAA Sec. 608

Year	Entity Fined	Penalty	Comments
2010	City of Tacoma, WA	$525,000	Releasing CFCs from appliance disposal service.
2011	Seafood processor, OR	$27,000	Failing to keep proper records for HCFC equipment.
2011	Food manufacturer, MA	$108,320	Failing to repair leaks, conduct follow up tests, and keep service records for R-22 equipment.
2012	Two Seattle-based seafood companies	$700,000	Required to improve shipboard refrigeration systems at cost of $9 million related to improper release and illegal import of ODS.
2013	Safeway Corp.	$600,000	Required to implement $4.1 million plan to reduce ODS emissions at its 659 grocery stores.
2014	Costco Wholesale Corp.	$334,000	Fix leaks and make repairs at 274 stores totaling $2 million. Failure to keep service records also cited.
2015	E.I. DuPont	$531,000	Improper maintenance and repair of two large refrigeration units.
2015	U.S. Navy	$83,900	Not performing leak rate calculations when servicing AC units at Norfolk Naval Station.
2016	Trader Joe's Company	$500,000	Also agreed to spend $2 million to reduce leaks and improve compliance at 453 grocery stores.

Under Section 612 of the Clean Air Act, EPA's Significant New Alternatives Policy (SNAP) program reviews refrigerant substitutes within a comparative risk framework. The SNAP program periodically issues final rulings which define what are acceptable substances for use in various refrigeration and air conditioning applications as well as for use as blowing agents. The latest SNAP final ruling number 21[4] effectively adds the regulation of greenhouse gases to ozone depleting substances identified at the Montreal Protocol Conference of Parties (COP21) held in Paris in October 2015.

One year after the the Paris COP21 agreement the 197 Parties to the Montreal Protocol adopted the Kigali Amendment, agreeing to phase down production and consumption of Hydrofluorocarbons (HFCs) worldwide in response to their contribution to climate change.

SNAP Rule 21 passed on Dec 1, 2016 effectively enforces the COP21 and Kigali restrictions on emissions of most HFC and HFC blends by changing their status as refrigerants to "unacceptable" as early as 2021. Significant changes of concern to commercial and industrial refrigeration users include:

- Propane is listed as an acceptable alternative in new commercial ice machines, new water coolers, and new very low temperature refrigeration equipment as of 3 Jan 2017.
- A number of flammability Class 3 (HC and HC blends) refrigerants are listed as unacceptable for retrofit residential and light commercial AC and heat pumps— unitary split AC systems and heat pumps, as of 3 Jan 2017.
- Propylene (R-1270) and R443A are listed as unacceptable for new residential and light commercial AC and heat pumps, cold storage warehouses, centrifugal chillers, and positive displacement chillers, as of 3 Jan 2017.
- For new centrifugal and positive displacement chillers, many HFC refrigerants are listed as unacceptable as of 1 Jan 2024 including R-134a, R-245fa, R-404a, R-407c, R-410a, R-410b, and R-507a.
- In new cold storage warehouses, many HFC refrigerants are listed as unacceptable as of 1 Jan 2023 including R-404a, R-407a, R-407b, R-410a, R-410b, and R-507a.
- For new retail food refrigeration, many HFC refrigerants are listed as unacceptable as of 1 Jan 2021 including R-404a, R-407a, R-407b, R-407c, R-407f, R-410a, R-410b, and R-507a.

It is interesting to note the allowed expanded use of the hydrocarbon propane, but the more restricted use of the hydrocarbon propylene.

With the application of the Kigali Amendment to the CAA and SNAP, HFC refrigerants' days are now numbered. This leaves end users of refrigeration systems with a choice between the natural refrigerants which are cheap and energy efficient, but perhaps have toxicity and flammability characteristics to manage, and an increasingly complex set of synthetic HFC, HFO, and HFC/HFO blends which are as yet mostly unproven in equipment, very expensive, and less energy efficient in most cases[5]. Consequently, the natural refrigerants ammonia, carbon dioxide, and the hydrocarbons are increasingly being examined for all types of refrigeration applications. Note that ammonia in vapor compression equipment has had SNAP approval for use in cold storage warehouses since 1996 and carbon dioxide since 2009.

Momentum for the application and adoption of natural refrigerants in refrigeration systems is evident in a survey conducted by the Obama Administration published just after the signing of the Paris COP21 agreement in October 2015. The majority of both manufacturers and end users of refrigeration systems surveyed at that time indicated they were actively developing natural refrigerant solutions for their equipment and facilities. It was interesting to note that the chemical companies and large AC manufacturers in the survey were continuing to focus on development of "low-GWP" synthetic refrigerants and equipment.

While it is true that the recent election has put a Republican in the White House, it is highly unlikely that the United States would withdraw as a signatory to the Montreal Protocol. It is also expected that the Clean Air Act will remain in place with continued enforcement by the EPA. On the other hand, the current President has stated his intention to reduce the size of government - reduce funding to the EPA - and to reduce or remove regulatory burdens on business. It is therefore expected that "The Donald Effect" will allow current regulations to remain in place, but reduce the aggressive level of enforcement of Section 608 of the CAA by EPA. The current President has also stated his opposition to US participation in the Kigali Amendment. However, the author suspects that the President will focus, at least in the next two years, on fulfilling campaign promises relating directly to trade agreements, immigration policy, expanded infrastructure and military spending, and pro-business policies resulting in job creation.

THE POLITICS OF PUBLIC SAFETY

The application of the natural refrigerants ammonia and hydrocarbons to commercial AC and refrigeration systems is effectively prohibited by current government regulations which limit refrigerant charge to extremely small amounts. CO_2 is being widely applied particularly in supermarkets, but poor energy efficiency and high first cost/complexity for transcritical systems is a factor limiting uptake of the technology. The current political landscape (safety standards and codes) still favors the synthetic refrigerants for commercial AC and refrigeration, however, there is growing recognition in the industry that more reasonable safety standards are needed to allow wider use of ammonia and hydrocarbons. One doesn't have to look far to see hydrocarbon-based appliances and machinery safely applied in our automobiles, gas-fired commercial heating equipment, gas water heaters, gas cooking ranges, and propane barbeque grills. Why not natural refrigerants (ammonia and hydrocarbons) in our commercial closed-circuit AC and refrigeration systems? Unfortunately, widespread application of hydrocarbons to commercial and industrial refrigeration systems will have to wait for politics and safety standards to catch up to common sense.

Ammonia continues to be the refrigerant of choice in industrial refrigeration systems. Ammonia is an excellent refrigerant with very high operating efficiency, however, when operating an ammonia refrigeration system in the United States there could be as many as three federal agencies who take an interest in what you are doing and how you are doing it. Depending on the size of your facility and the quantity of ammonia in the system, you may have to comply with regulations enforced by EPA, Occupational Safety and Health Administration (OSHA), and Department of Homeland Security (DHS).

For any industrial process that involves toxic materials, flammable materials, or the manufacture of explosive materials, OSHA requires a qualified Process Safety Management (PSM) system to be in place. In addition EPA requires the facility owner to have a Risk Management Program (RMP) which follows certain detailed guidelines. Many PSM and RMP requirements overlap and can be covered with a single controlled and documented safety management system.
For refrigerated facilities having 4,545 kg (10,000 lbs) or more of ammonia on site, both PSM and RMP statutes require that the following elements be covered:

1. Employee Participation
2. Process Safety Information
3. Process Hazard Analysis
4. Operating Procedures
5. Training Program
6. Contractor Program
7. Pre-start-up Safety Review
8. Mechanical Integrity
9. Hot Work Permit
10. Management of Change
11. Incident Investigation
12. Emergency Action and Response Plans
13. Compliance Audit
14. Trade Secrets
    Additional RMP-specific elements include:
15. Hazard Assessment
16. Five Year Accident History
17. Risk Management (Reporting etc.)

IIAR has developed and offers PSM/RMP guidelines designed to satisfy EPA and OSHA requirements. These guidelines are widely used in the ammonia refrigeration industry in the USA.

For ammonia refrigeration systems having less than 4,545 kg (10,000 lbs) of ammonia on site, both OSHA and EPA rules mandate that the owner follow the less stringent “General Duty” clauses which can be summarized as follows:

OSHA – OSH Act Section 5(a)1: “… furnish to each of his employees employment and a place of employment free from recognized hazards that are causing or likely to cause death or serious physical harm to his employees.”

EPA – Sec. 112(r)(1): (a) Identify and assess hazards of releases, (b) Design and maintain a safe facility to prevent releases, and (c) Minimize the consequences of releases.

In order to comply with the General Duty clauses, the following 10 program elements must be documented and practiced:

1. Management System
2. Refrigeration System Documentation
3. Operating Procedures
4. Preventative Maintenance
5. Contractor Program
6. Emergency Response
7. Incident Investigation
8. Training
9. Hazard Review
10. System Change Procedures

Like the politics of climate change, the safety regulations affecting ammonia refrigeration systems will likely remain in place with continued enforcement by the EPA, OSHA, and possibly DHS. As stated above, the current President has stated his intention to reduce the size of government - reduce funding to the enforcing agencies - and to reduce or remove regulatory burdens on business. It is therefore expected that "The Donald Effect" will allow current regulations to remain in place, including the 4,545 kg (10,000 lbs.) threshold quantity which triggers the more rigorous PSM/RMP requirements.

LOW CHARGE AMMONIA SYSTEMS

The 4,545 kg (10,000 lbs) threshold quantity for ammonia has resulted in a high level of motivation in the US to develop low-charge ammonia equipment and system designs. The use of new direct expansion evaporator technology with a central engine room can achieve system ammonia charges in the range of .8 to .9 kg/kW, compared to 3.2 to 3.8 kg/kW for a traditional pumped ammonia system. Close-coupled packaged ammonia refrigeration units for direct air cooling, or use of secondary fluid cooling can achieve ammonia charges as low as .3 to .4 kg/kW.

DX ammonia has been used for some time in medium and high temperature systems (suction temperatures above -6 deg °C) with some success. However, in spite of the charge reduction advantages mentioned above, to date DX ammonia has not been applied successfully at freezer temperatures. At suction temperatures below about -6 deg C, the following particular characteristics of ammonia result in extremely poor performance of evaporators unless effectively addressed:

- Separation of liquid and vapor phases inside evaporator tubes
- Negative thermodynamic effect of small amounts of water in ammonia
- Fouling of evaporator tubes by oil

Separation of liquid and vapor phases inside evaporator tubes. The very high ratio of vapor to liquid specific volume of ammonia at low temperatures combined with its very high latent heat of vaporization causes an unavoidable separation of vapor and liquid phases inside evaporator tubes. This separation of phases is referred to as "stratified flow" and causes the liquid ammonia present to run along the very bottom of the tubes leaving the top of the tubes exposed to only ammonia vapor - i.e. completely "dry". Unless addressed, the result is extremely poor evaporator performance and lower-than-expected suction temperatures during operation. To solve this problem the inside surfaces of the evaporator tubes must have a special enhancement (a "wicking structure") applied to cause the liquid ammonia present to coat the entire inside surface of the tubes by capillary action. Performance with this enhanced tube surface results in good DX ammonia performance even at low temperatures, which heretofore has not been possible[6,7,8,9].

The wicking effect of various types of structures has been studied for some time in relation to heat pipes and their applications[10]. Typical wicking structures for producing capillary pressure on tubing surfaces are available and are show below:

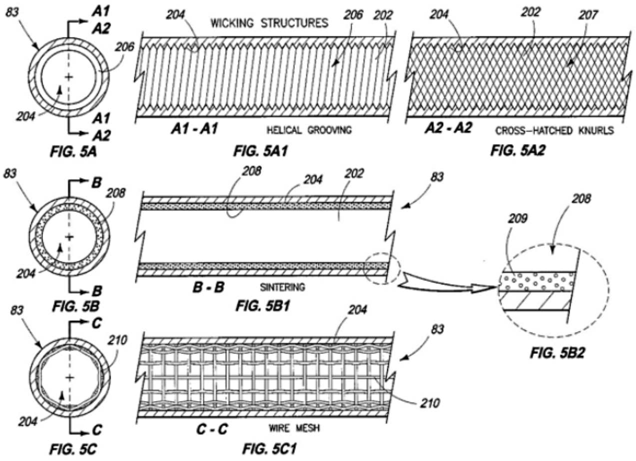

Figure 1: Various Types of Wicking Structures.

Capillary pressure and capillary action (making liquid go uphill) is a function of the structure itself, but also of certain properties of the fluid. As it turns out surface tension is one of the big drivers for capillary pressure and ammonia happens to have very high surface tension. Actually, ammonia is one of the best heat pipe working fluids available because of its very high surface tension! The same properties that make ammonia a good heat pipe working fluid also make it work well when the appropriate wicking structure (that's the trick) is used in evaporator tubes.

Removal of water from ammonia. As explained in detail elsewhere[11], the presence of even small amounts of water in ammonia has a significant negative effect on DX evaporator performance. Unfortunately, water is difficult to entirely keep out of industrial ammonia refrigeration systems for a number of reasons: Residual water in pressure vessels left from hydro-testing, incomplete evacuation of the system prior to startup, leaks in parts of the system which normally operate in a vacuum, etc.

This residual water goes into solution with the ammonia and increases the boiling point (bubble point) temperature. At a concentration of 20% (by mass) water in ammonia, the boiling point rises to approximately 6 deg C above the boiling point of pure ammonia at the same pressure. Figure 2 shows the increase in boiling point (bubble point) for various initial water concentration in ammonia at various pressures.

As the ammonia-water liquid enters the evaporator circuit it begins to boil. Because of the large difference in vapor pressures of ammonia and water, only ammonia vapor is generated during the evaporation process, leaving the water behind in the remaining liquid. So the evaporation process results in an

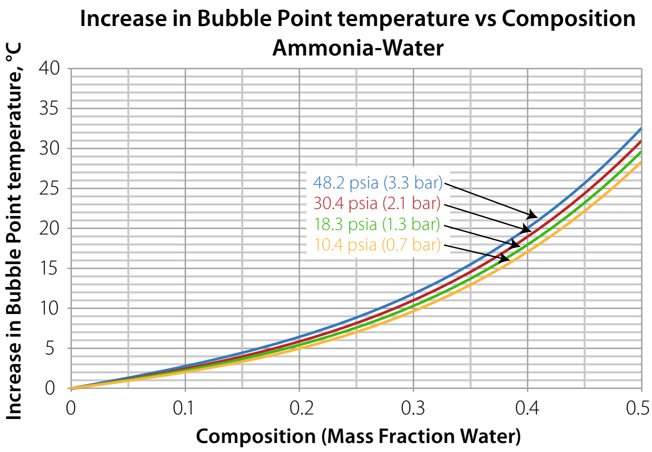

Figure 2: Increase in Bubble Point vs Composition of Ammonia-Water.

increase in water concentration and a corresponding increase in the boiling point of the refrigerant as it passes through the coil circuit. In the case of an evaporator operating with a 6 deg °C temperature difference, the refrigerant will stop boiling once the water concentration reaches about 20% since the boiling point will have risen by 6 deg C. This cessation of boiling will occur at some point along the length of the evaporator circuit, the point at which boiling stops depending on the initial concentration of water and suction pressure. At the point where the increase in the water concentration has caused an increase in the boiling point equal to the coil TD, liquid refrigerant will exit the evaporator and enter the suction line.

An example of the increase in bubble point temperature over the circuit length of an evaporator, represented by the change in vapor quality, is shown in Figure 3 below for an initial water concentration in ammonia of 3% at a pressure of 0.7 bar (-40°C SST). In this example the bubble point (Tbub) has increased by 6 deg °C at a vapor quality of approx. 0.89.

This increase in bubble point significantly reduces the mean temperature difference and therefore the cooling capacity of the evaporator is reduced.

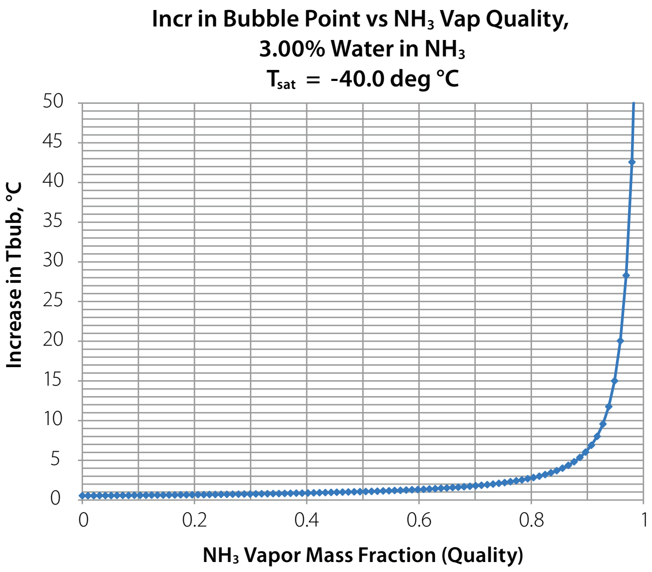

Figure 3: Increase in Bubble Point vs Ammonia Vapor Quality with 3% Water in Ammonia.

The reduction in cooling capacity of a DX ammonia evaporator due to the presence of water is shown below in Figure 4. It is apparent that even small amounts of water in the ammonia, if not effectively captured and removed from the system, will result in significant loss of capacity and increased operating costs.

Fortunately, ammonia piping and accumulator vessels can simply be arranged in a way to capture this water and isolate it such that the refrigeration system "dries itself out" very quickly during the startup and commissioning phase. Proper DX ammonia piping is explained in detail elsewhere[12].

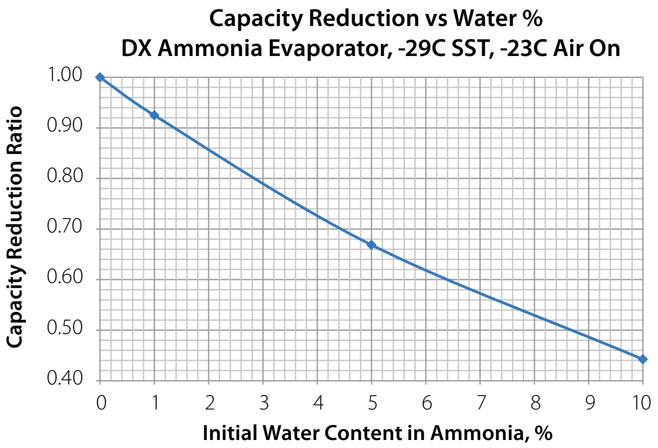

Figure 4: Evaporator Capacity Reduction vs Water Content in Ammonia.

Separation and management of oil.

Immiscible lubricants are recommended over miscible lubricants for large industrial DX ammonia refrigeration systems for a number of reasons:

- Lower cost
- Ease of separation
- Relative insensitivity to contaminants (water, dirt)

Even though immiscible oils are preferred over miscible types for the reasons stated above, any oil reaching the evaporator can potentially coat the inside of the tubes and severely degrade heat transfer performance due to:

a. Added resistance to heat transfer as explained below, and

b. Fouling of the proprietary wicking structure preventing liquid ammonia from coating the inside of the tubes by capillary action.

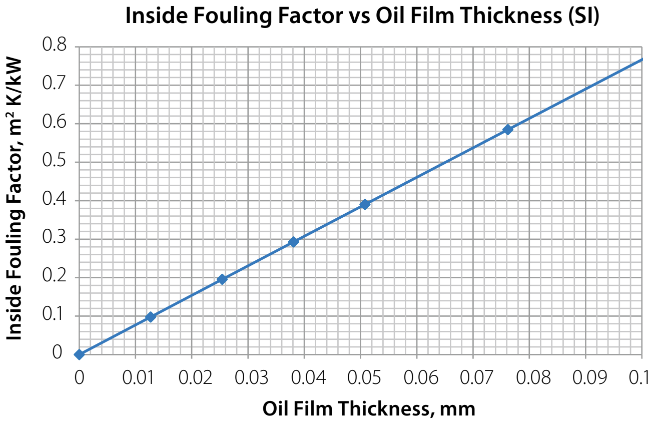

Figure 5: Inside Fouling Factor vs Oil Film Thickness.

Even a thin layer of oil coating the inside of evaporator tubes adds resistance to heat flow as shown in Figure 5.

The reduction in DX ammonia evaporator cooling capacity resulting for this oil film fouling factor is significant and is shown in figure 6.

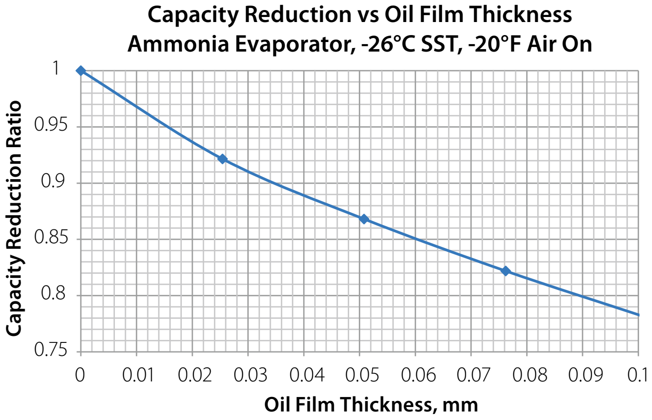

Figure 6: DX Ammonia Evaporator Capacity Reduction vs Oil Film Thickness.

It is apparent from Figures 5 and 6 that it is highly desirable from an energy efficiency standpoint to prevent compressor lubricating oil from reaching the evaporators.

To achieve this, the following should be carefully considered and specified in the system design:

a. Type of compressor lubricating oil

b. Compressor oil separator design and efficiency

c. Oil capture and management at the outlet of the condenser

d. Oil capture in the suction accumulator(s)

e. Oil capture at the evaporator

Type of Oil:

Depending on the type of compressor used (reciprocating or rotary screw), varying amounts of lubricating oil will unavoidably be discharged with the ammonia vapor. Oil will leave the compressor both in liquid droplet form and as oil vapor. The liquid droplets can be captured mechanically in the oil separator vessel by controlling velocity and by incorporating coalescing elements. The oil which is combined with the ammonia in vapor form is more difficult to capture. Generally speaking, as volatility and solubility of the oil increase, separation becomes more difficult. The amount of oil which is not captured in the separator and returned to the compressor is referred to as "oil carryover".

All lubricating oils used in the ammonia refrigeration industry are blends of a base fluid(s) with additives. The base fluid controls volatility and solubilty of the oil. The aromatic content of the base fluid has a large effect on vapor pressure (volatility) and solubility. The higher the vapor pressure of the oil, the more oil vapor will leave the compressor with the ammonia in the discharge gas. Since this oil vapor is difficult to capture in the separator, it is desirable to select an oil which has the lowest vapor pressure possible. Alkyl Benzene and Naphthenic bases have the highest aromatic content, vapor pressure, and solubility. 2-Stage Hydrocracked bases have lowest aromatic content, vapor pressure, and the lowest solubility, and are therefore recommended for use in DX ammonia systems.

Another factor affecting oil vapor pressure is the oil temperature. The higher the oil temperature, the higher the vapor pressure. Reducing the discharge gas (and oil vapor) temperature before it enters the separator will therefore reduce overall oil carryover and increase the efficiency of the separator. For example, desuperheating the discharge gas from 80 deg °C to 35 deg °C reduces the oil vapor pressure, and therefore carryover of oil vapor, by approximately 85%.

Oil Separator;

Use of a properly sized high efficiency oil separator capable of guaranteeing 5–7 ppm carryover is recommended. Also, for reasons mentioned above, it is also recommended that the discharge gas be desuperheated as much as practical prior to entering the oil separator.

Oil capture and management at the outlet of the condenser;

As mentioned above, reducing the temperature of the discharge gas down to the saturated condensing temperature (i.e. fully desuperheating) significantly reduces the vapor pressure of the oil in the discharge gas. This reduction of the oil vapor pressure increases the amount of oil available for capture.

Consequently, most of the oil vapor which has escaped the oil separator vessel will be condensed and held in the liquid ammonia leaving the condenser. It is possible to design the high pressure receiver to collect and separate this oil, now in the liquid phase, and then automatically return it to the compressors. It is also desirable to take the "de-oiled" ammonia vapor from the top of the high pressure receiver rather than using oil-laden discharge gas for hot gas defrost.

Oil Capture at the Evaporator:

As explained above, it is important to prevent fouling of evaporator tubes with oil particularly at low temperatures. Refrigerant distributors are available which effectively separate any oil which has escaped the oil separator and high pressure receiver and prevents it from entering the evaporator. The Tank Distributor shown below incorporates a drop leg in the body of the distributor tank which serves to collect oil and debris where it can be periodically drained and removed from the system at the evaporator.

Unlike conventional orifice plate type distributors, the Tank Distributor operates with very low pressure drop and is well suited to the following applications:

- DX ammonia utilising motorised expansion valves
- Floating head pressure systems
- Evaporators designed for operation with more than one refrigerant

CONCLUSIONS

Since the Clean Air Act was amended in 1990 to include Title VI - "Stratospheric Ozone Protection" the accelerated phase-out of Ozone Depleting Substances has been aggressively enforced by the EPA. Enforcement of Section 608 of Title VI has included the regular assessment of large fines and required remediation measures to a number of US users of refrigeration systems. Under the Obama Administration the US agreed to the Kigali Amendment of the Montreal Protocol which adds the phase-out of high-GWP refrigerants to the list of ODS.

The agreement has already resulted in the SNAP Final Rule 21 (2016) setting "delisting" dates for many HFC refrigerants and blends by as early as 2021. It remains to be seen how the Politics of Climate Change will fare under the new Trump Administration as Mr. Trump has stated his opposition to participating in the Kigali Amendment.

It appears there is sufficient political momentum in the US to ban both Ozone Depleting and high-GWP refrigerants and blends. This has created an interesting conundrum for the refrigeration and AC industry. The Politics of Climate Change favor the application and adoption of the natural refrigerants - they are cheap, highly efficient, and are by definition environmentally friendly. The Politics of Public Safety on the other hand, discourages the wider adoption of natural refrigerants to commercial refrigeration and AC applications because of existing very low threshold quantities for ammonia and hydrocarbons. Until safety standards and regulations are updated and/or replaced by more "natural friendly" ones, there will continue to be commercial forces promoting the use of synthetic HFC/HFO refrigerants and blends which are in most cases much more expensive, will likely be less energy efficient, exhibit some flammability, and could have serious negative environmental effects (TFA into aquafers).

Given its unique ability to develop ANSI-certified safety standards, training materials and programs, and influence code writing bodies and regulatory agencies, IIAR has recognized that it is in a position to actively promote and facilitate the wider use of all natural refrigerants, not just ammonia. IIAR is currently developing safety standards specifically for CO_2 to accompany the other CO_2 publications already in place (CO_2 Handbook). A newly formed task force chaired by the author will be conducting a survey of existing standards and codes relating to the use of hydrocarbons in AC and refrigeration applications and identifying opportunities for IIAR.

Ammonia, CO_2, and Ammonia/CO_2 cascade refrigeration systems offer end users an immediate "natural" refrigerant solution for commercial and industrial refrigeration applications. Due to regulatory pressures in the US the development and introduction of low charge ammonia refrigeration systems has accelerated in recent years. New developments in direct expansion ammonia technology now allow ammonia refrigeration plants to be designed with 1/4 to 1/5th the total ammonia charge in the system compared to traditional pumped ammonia designs. These new low charge ammonia systems can be installed with lower first cost and have been shown to operate with lower operating costs compared to pumped ammonia.

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