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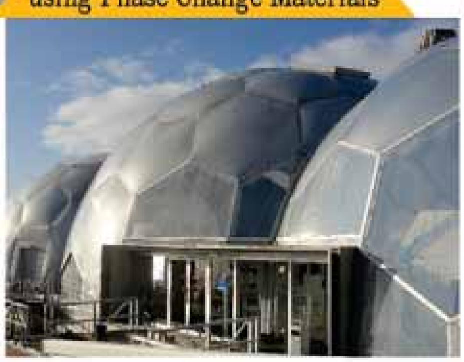
Cooling India

India's foremost Monthly dedicated to the growth of HVACR Industry

Natural Choice – Ammonia

Cooling of Electronics using Phase Change Materials



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Natural Choice – Ammonia

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Often, I hear people refer to ammonia as an alternative refrigerant, like they are settling for second best. I don't understand that kind of thinking. Recently, many people started talking about ammonia, ammonia is back etc. I don't agree with them. In fact, Ammonia is one of the first widely used mechanical refrigerants. Other industrial refrigerants to come along since actually are alternatives to ammonia. Ammonia has been used as a refrigerant for more than 160 years; Ammonia was used for refrigeration in 1876, for the first time in a vapour compression machine by Carl Von Linde.Other refrigerants like CO_2, SO_2 also were commonly used till 1920s.

1980s the harmful effects of CFC refrigerants became apparent and it was generally accepted that the CFC refrigerants are contributing to depletion of ozone layer and to global warming. Finally, resulting in Montreal protocol (1989) where almost all countries agreed to phase out CFCs in a time bound program. In view of seriousness of damage to atmosphere and resulting dangers due to CFC/HCFC emissions as also due to global warming effects, the revisions in Montreal protocol (1990), 1992(Copenhagen) and 1998 Kyoto Japan demanded accelerated phase out schedule. Even HCFC's are also to be phased out and Europe has taken the lead.

Many countries in Europe have stopped use of HCFC refrigerants, and new refrigerants as well as well-tried and trusted refrigerants like Ammonia and Carbon Dioxide are being considered for various new applications as well.

Ammonia as refrigerant has been popular in India for more than 100 years. In India Association of Ammonia Refrigeration (AAR) was formed in 2012. The association started promoting safe and efficient use of Ammonia and immediately become popular. This has attracted many organizations to promote Ammonia Refrigeration, who were dead for Ammonia Refrigeration for years. Now everyone is talking about Ammonia as a Natural Refrigerant: Natural choice. All credit goes to AAR activities.

Please refer to table 1 for refrigerant time line graph in figure 1. The graph shows Ammonia as refrigerant exist for almost 160 year and going to continue for years ahead because of following advantages of Ammonia.

Advantages of Ammonia

Ammonia Is Less Expensive

Ammonia is one of the natural refrigerants. It exists in nature here on earth and on many of the known planets. Of its many uses, fertilizer is by far the largest. Because ammonia is manufactured

Table 1: Ammonia COP (Efficiency) Comparison with Other Refrigerants for Various Applications (*New Equipment banned from 2016)

Refrigerant	Condensing Temperature + 40°C			
	Evaporating Temperature 2°C	Evaporating Temperature -5°C	Evaporating Temperature -25°C	Evaporating Temperature -40°C
Ammonia - R717	6.2	4.965	2.91	2.06
R410A	5.43	4.8	2.5	1.75
R134a	5.88	4.67	2.7	Not Used
R404A	5.18	4.07	2.26	1.52
R22*	5.93	4.74	2.79	1.98

in huge quantities, it is by far the least expensive alternative refrigerant and it will remain that way. The cost of ammonia (cost/kg) is significantly less than CFC, HFC & HCFC refrigerants.

Ammonia Is an Efficient Refrigerant

Thermodynamically, ammonia is the most efficient refrigerant with the application range from high to low temperatures. With the ever increasing focus on energy consumption, ammonia systems are a safe and sustainable choice for the future. Typically, a flooded ammonia system would be 15-20 % more efficient than a DX R404A counterpart. Please refer to table 1. The table shows that for various operating conditions ammonia has best COP (Coefficient of Performance) as compared to all HFC & HCFC refrigerants.

Ammonia Has High Heat Transfer Characteristics

Ammonia has better heat transfer properties than most of chemical refrigerants and therefore, allow for the use of equipment with a smaller heat transfer area. Thereby, plant construction cost will be lower and these properties also benefit the thermodynamic efficiency in the system. Ammonia has higher heat transfer coefficients other than water. The latent heat comparison @ 4°C is given in table 2.

Ammonia Has No Effect on 'Ozone Layer' 0 ODP &<1 GWP

Since, ammonia is biodegradable when properly vented it combines with carbon dioxide and other components in the atmosphere to form an innocuous compound. It has about a two-week life according to the EPA. Please refer to table number 3 for effects of various refrigerants

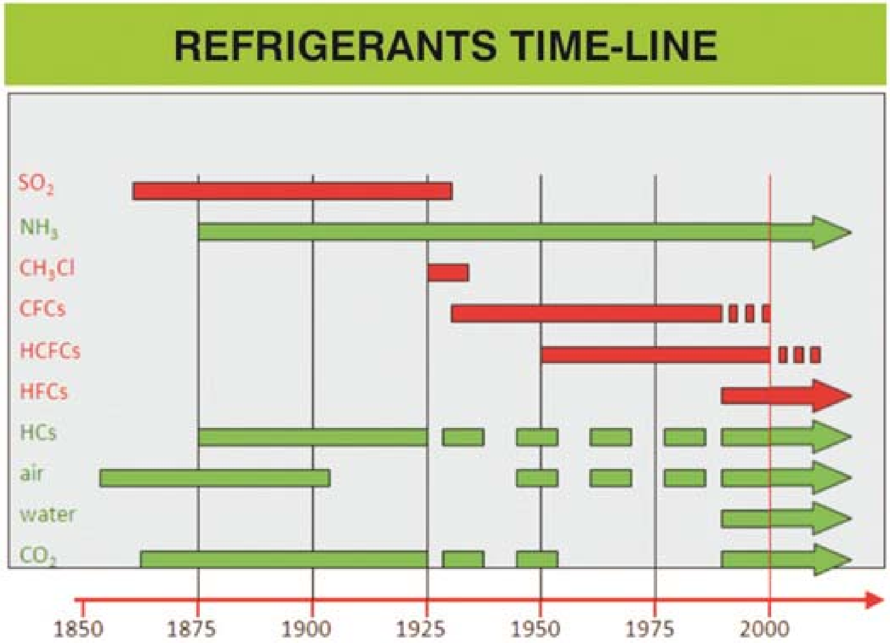

Figure 1: Ammonia as refrigerant exist for almost 160 year

i.e. Global Warming Potential and Ozone Depletion Potential

Ammonia Leaks are 'Self-Alarming'

Ammonia leaks to the atmosphere are easily detected. Many people refer to ammonia as "self-alarming" - you don't need a leak detector to determine that there is ammonia present. This is an important advantage over HCFC, HFC refrigerants where large quantities could escape without detection. Ammonia leaks are found quickly and repaired.

Ammonia Systems can Tolerate Moisture

When refrigeration systems operate in a vacuum, air is drawn into the system, where HCFC & HFC are used and the system operates below freezing (0°C), this moisture must be removed promptly as it will freeze and block control valves. In an ammonia system, the water forms aqua ammonia (ammonia hydroxide) which, being heavier than ammonia will migrate to the coldest spot in the system (evaporator) and remain at that point until drained from the system. The freezing point of this solution is below -73°C. Of course, moisture should be removed from the system as it will affect the thermodynamic properties of the refrigerant effectively reducing the system capacity. Simple to use Ammonia Dehydrators can separate and remove water online. Please refer to figure 2.

Ammonia is Thermodynamically Stable Refrigerant

As a single component refrigerant, ammonia is thermodynamically stable, condensing and evaporating at constant

Table 2: Refrigerant Latent Heat Comparison

Refrigerant	Latent Heat kJ/Kg
Water R-718	2489.04kJ/kg
Ammonia – R717	1247.85kJ/kg
R410A	214.48kJ/kg
HCFC 22/R22	201.79kJ/kg
HFC 134a/R134a	195.52kJ/kg
R404A	162.03kJ/kg

temperatures. Many new refrigerant blends are not as thermodynamically stable, complicating heat exchanger and system design.

Ammonia is not Miscible with Paraffin 1c and Napthenic Lubricants

This characteristic of non-miscibility makes lubricant management in ammonia systems quite simple. The very small amount of lubricant that escapes the lubricant separator will be released by the ammonia in the evaporator and it can be removed (drained) easily. This characteristic is ideal for industrial systems. Oil return from the evaporator to the compressors can be automatic or semiautomatic.

Figure 2: Ammonia Dehydrator Installation

Ammonia System Components may be smaller than those employed In HCFC, HFC systems

Due to the high latent heat capacity of ammonia less mass of refrigerant is circulated in the system. Thus, the piping, stop valves, and control valves are smaller. Due to the high heat transfer characteristics of ammonia, the heat exchangers may be smaller. For "a one of a kind" industrial refrigeration system installation where an HCFC, HFC system is compared to an ammonia system, the ammonia system cost could be as much as 20% less.

Refrigeration Grade Ammonia is Available throughout India

Ammonia is available in cylinders, and in bulk transports throughout India. Since ammonia is employed throughout the food processing and distribution industry, the ammonia distribution system is in place.

No Need to Write off Investment of Ammonia Plant due To Environmental Concerns

In most cases, a company using an ammonia refrigeration system will not have to write off the investment due to environmental concerns and high costs. Companies using chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs) will have to face these issues as a these refrigerants are phased out of production under the Montreal Protocol and become even more expensive.

Smaller System Component for Ammonia as Compared to CFC, HCFC and HFC systems

Generally speaking, ammonia system components are smaller than those used in CFC, HCFC and HFC systems. Ammonia's high latent-heat capacity means that less refrigerant circulates in the system; thus, the piping, stop valves and control valves are smaller. And, because of ammonia's heat transfer characteristics, heat exchangers usually are smaller. Based on system component cost alone, ammonia system installation costs typically are 10 to 20% less than an identical HCFC/HFC system. Ammonia refrigeration system components are reliable. They are built to industrial standards, and must be designed to run continuously (8,760 hrs/yr). Most CFC, HCFC, and MFC systems have components built to commercial-grade standards, which means they are designed to run only 2,000 hours per year. When used in industrial cooling applications, these commercial-grade components will break down or wear out more frequently.

Table 3: ODP/ GWP of Refrigerants

Refrigerant		Atmospheric Lifetime (Years)	Ozone Depletion Potential (ODP) (100 Year)	Global Warming Potential (GWP)
Ammonia	R-717	–	0	<1
CFC (no more)	CFC-11 (Baseline ODP)	50	14000	
	CFC -12	102	1	10900
HCFCs	HCFC-22	13.3	0.055	1820
	HCFC-123	1.4	0.02	93
	HCFC-141b	9.4	0.11	630
HFCs	HFC-134a	14.6	0	1300
	HFC-245fa	7.3	0	820
	R-32	–	0	675
HCs	HC-290 (Propane)	–	0	3
	R-1270 (Propelene)	–	0	<2
HFC Blends	R-404A	–	0	3260
	R-407A	–	0	1770
	R-407C	–	0	1530
	R-410A	–	0	1730
CO2	R-744	–	0	1
HFOs	1234yf, 1234ze	–	0	4,7

Table 4: Informal Test Of Reactions To Short-Term Exposures To Ammonia Concentration

AMMONIA CONCENTRATION, PPM	EFFECTS
150 to 200	Affected eyes to a limited extent after about a 1 -minute exposure, but vision not seriously impaired; breathing not affected.
440	Affected eyes more quickly, but not sufficiently to impair vision seriously.
600	Eyes streamed within about 30 seconds; still breathable.
700	Tears to eyes in a few seconds; still breathable.
1000	Eyes streamed instantly and vision impaired but not lost; breathing intolerable to most subjects; skin irritation after several minutes.
1500 or greater	Instant reaction was to get out of the area.

Present Users of Ammonia

The sale of ammonia refrigeration systems has continued to increase each year, for many years. Why? Because of all the advantages previously listed.

Some 80 to 95% of the following industries use ammonia as their refrigerant: wineries; cold storage warehouses; vegetable and fruit freezing plants; meat processing plants; fresh vegetable processors; shrimp processors; fish (seafood) processors; commercial ice plants; dairy and ice cream plants; prepared food processing plants; concrete cooling plants (ice and water); breweries and beverages, condensing carbon dioxide in merchant carbon dioxide plants; barges and ships used to transport ammonia.

Other users of ammonia as the refrigerant of choice are chemical plants, pharmaceutical plants, and petro-chemical plants.

Ammonia is used in these industrial refrigeration systems with requirements down to -50°C evaporator temperatures. However, most applications employ evaporator temperatures of -40°C up to +15°C. With the proper selection of lubricants, temperatures down upto -50°C presents no lubricant management problems if the system is properly designed and installed.

There is a movement among industrial companies that now use HFC & HCFC to convert their existing systems to ammonia. Many food freezing systems that use HFC & HCFC as a refrigerant are in the process of converting to conventional freezing systems using ammonia as the refrigerant.

Most of the chemical, dyestuff and pharmaceutical companies uses Ammonia as refrigerant for their industrial cooling requirements.

Concerns for Toxicity of Ammonia

Obviously, toxicity must be addressed by any user. However, much of the concern is based on the fear of ammonia that has been generated by ammonia's competitors.

Ammonia has a pungent odor, but that's not all bad. It warns you to take the necessary steps to stop leaks. The American Conference of Industrial Hygienists (ACGIH) publishes a booklet that lists the maximum threshold limit values. The threshold limit values (TLVs) consist of two components- the time weighted average (TWA) concentration and the short-term exposure limit (STEL). The TWA is the time-weighted average concentration for a normal 8-hour work day and a 40-hour work week. The STEL is a 15- minute, time-weighted average exposure that should not be exceeded at any time during a work day, even if the 8-hour TWA is within the TLV. The TWA of ammonia is 25 ppm. The STEL for ammonia is 35 ppm, which is only slightly higher than the TW A Other studies, some of them informal, have been conducted on the reactions of people to ammonia. A typical study is shown in Table 1. These observations were made during short exposures (1 to 3 minutes) of seven volunteer subjects (humans) to ammonia. The concentrations are higher than the TLVs, (recommended by the ACGIH) which are probably intentionally conservative. Please refer to table 4 for details.

Concerns for Flammability of Ammonia

Ammonia is classified as Class B2L

Table 5: Misconception about Ammonia when used as a Refrigerant

Misconception	Fact
Ammonia is Toxic	• Ammonia has a pungent odour and even small leaks as low as 5 PPM is detectable by smell and serves as an early warning, so that the maintenance staff can arrest them. • Almost all human beings can detect levels up to 25 PPM and continuous exposure to 50 PPM levels is permitted in most countries for 8 hours per day per week. • Laboratory trials have proved that continuous exposure levels for 10 to 15 years up to and exceeding 24 PPM has no adverse effect on human beings. • Installation of ammonia leak detection sensors assists in ensuring safe operation.
Ammonia is Flammable	• Ammonia is extremely hard to ignite even up to 650 °c. Ammonia breaks at 450 °c. Flammable limit by volume in air at atmospheric pressure is as high as 16% to 28% concentration. • It is now classified as a B2L, which is less flammable as compared with many hydrocarbons and other fuels which are used in day to day life. • Due to the high affinity of ammonia for atmospheric humidity, it is rated as hardly flammable.
Ammonia cannot be used for air cooled applications	• Ammonia air cooled condensers are available and also hybrid (Evaporative + Air cooled) Condensers are becoming popular around the world.
Ammonia systems are flooded operation and require lot of refrigerant as compared to other refrigerants	• Low charge factory made packaged refrigeration systems of less than 0.3kg of ammonia lTon or Refrigeration are available.
Small capacity & Direct expansion Ammonia systems are not available	• Ammonia compressors with 7kW capacity have been developed for small capacity package units. • Semi hermetic as well as hermetic compressors using aluminum winding motors are now developed. • Direct expansion systems with miscible oils using electronic expansion valves are available.
Ammonia cannot be used for air conditioning	• Due to increased use of natural refrigerants and due to its excellent energy saving properties, many countries are using ammonia with secondary fluids like water, brines and CO_2 in air conditioning plants. • Some of them listed below: - Oslo Airport -Norway - Heathrow Terminal- 5 - Singapore Airport - Stuttgart Airport Terminal-3
Ammonia plants cannot be made automatic and requires team operators	• Fully automatic Ammonia refrigeration plants are being used all over the world and as well in Ind ia since last 30 years. • These plants are remote controlled from central control panel.
Ammonia is going to be banned	• This is a myth. In fact, the man made refrigerants are on the way out in most of the developed countries. • Ammonia is not going to be banned. Manufacturers of synthetic refrigerants and manufacturers of air conditioning and refrigerant systems suitable tor only synthetic refrigerants are trying their best to safeguard their products by spreading drawback of Ammonia. This is a futile attempt hopefully till they are geared up to start using Ammonia. Recently being introduced so called "safe and nature friendly synthetic refrigerants" are petroleum based which have its own drawbacks. • Being natural refrigerant, its use is increasing globally.

and hence not considered as highly flammable refrigerant. Pure ammonia is considered flammable between the 16% and 27% atmospheric pressure. There have been many experiments performed in this area. Ammonia in vapor state will not sustain a flame. In the industrial refrigeration industry, many engineers believe that the presence of oil in the ammonia is the culprit, where ammonia has been blamed for an explosion. Oil in vapor state is relatively easy to ignite and it will sustain a flame. Modem plants employing highly efficient coalescing separators reduce the amount of oil in the system and thus diminish the possibility of a fire or explosion.

The best deterrent would be a non-flammable lubricant. This would further diminish the possibility. A non-flammable lubricant for ammonia systems is now in the final development stage.

Misconceptions about Ammonia When Used as a Refrigerant

Many misconception about Ammonia as refrigerant exist due its popularity and some of the heavy lobbying of synthetic refrigerant manufacturers and equipment producers. Please refer to table 5.

New Applications

Ammonia for Air-conditioning

Water chillers employing helical screw compressors providing conventional 7°C water for air conditioning. These units would be installed in a building separated from the air conditioned building or possibly on the roof. The chiller would be designed with a minimal ammonia charges low as 0.25 kg of Ammonia for 1 kW refrigeration load. In Europe, many plants are now operational with Ammonia as refrigerant for air conditioning such as KWN Engineering Vienna (1998), Saab Sweden (1999), Frigopol (2000), Berlin Ostbahnh of Train Station (2000), Stuttgart Airport (2004) Roche's HQ London (2005), Dutch ABN Amro Bank London (2006), Mulligan Letter Sorting Center Switzerland (2008), Ozeaneum Stralsund (2010), Heathrow Airport terminal 4, Oslo Airport, terminal 3 and many more.

Thermal Storage

A static ice storage system employing ammonia as the refrigerant. This system freezes ice on tubes (pipe) over a period of 24 hours. The ice accumulated is then melted by water which is recirculated to the air conditioning system. This is a demand leveling system. This unit would be installed in a building that is separated from the air conditioned building.

Secondary Refrigerant

A dual temperature Brine chilling system for supermarkets employing ammonia (minimal charge) as the refrigerant. This could be a package design in an enclosure that would be roof mounted.

Heat Pump

With the increased emphasis on energy savings, market opportunities exist for NH_3 heat pumps. Therefore, the newly identified market and products are primarily for small and medium capacity (~50 to ~2000 kW) liquid and water chillers for air-conditioning, industrial and commercial refrigeration applications, and occasionally including heat recovery. New ammonia products are packaged chillers because indirect cooling systems are safer for small systems. This tendency to indirect cooling is not limited to ammonia. This is a general trend to improve the charge containment with any refrigerant including HFCs.

Each of these systems can be designed in accordance with AAR-01. Since ammonia is a group B2L refrigerant, the safety code is restrictive in the area of refrigerant change and equipment room design.

We can conclude that with increase awareness for energy efficiency, eco friendliness and availability of knowledge through AAR the use of Ammonia as refrigerant is every growing in India. Also, we have to acknowledge Indian Refrigeration industry which is self-reliant and manufacture all equipment & components for Ammonia Refrigeration Industry in India. Unlike other synthetic refrigerant based equipment manufacture who mostly import equipment and components from counties like China. The high-quality standard maintained by these companies has opened doors for Indian products to international markets. I am glad to see many of such companies participating in International show with proudly displaying make in India brand. ■

Anand Joshi
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