Ammonia Air Conditioning to the Fore

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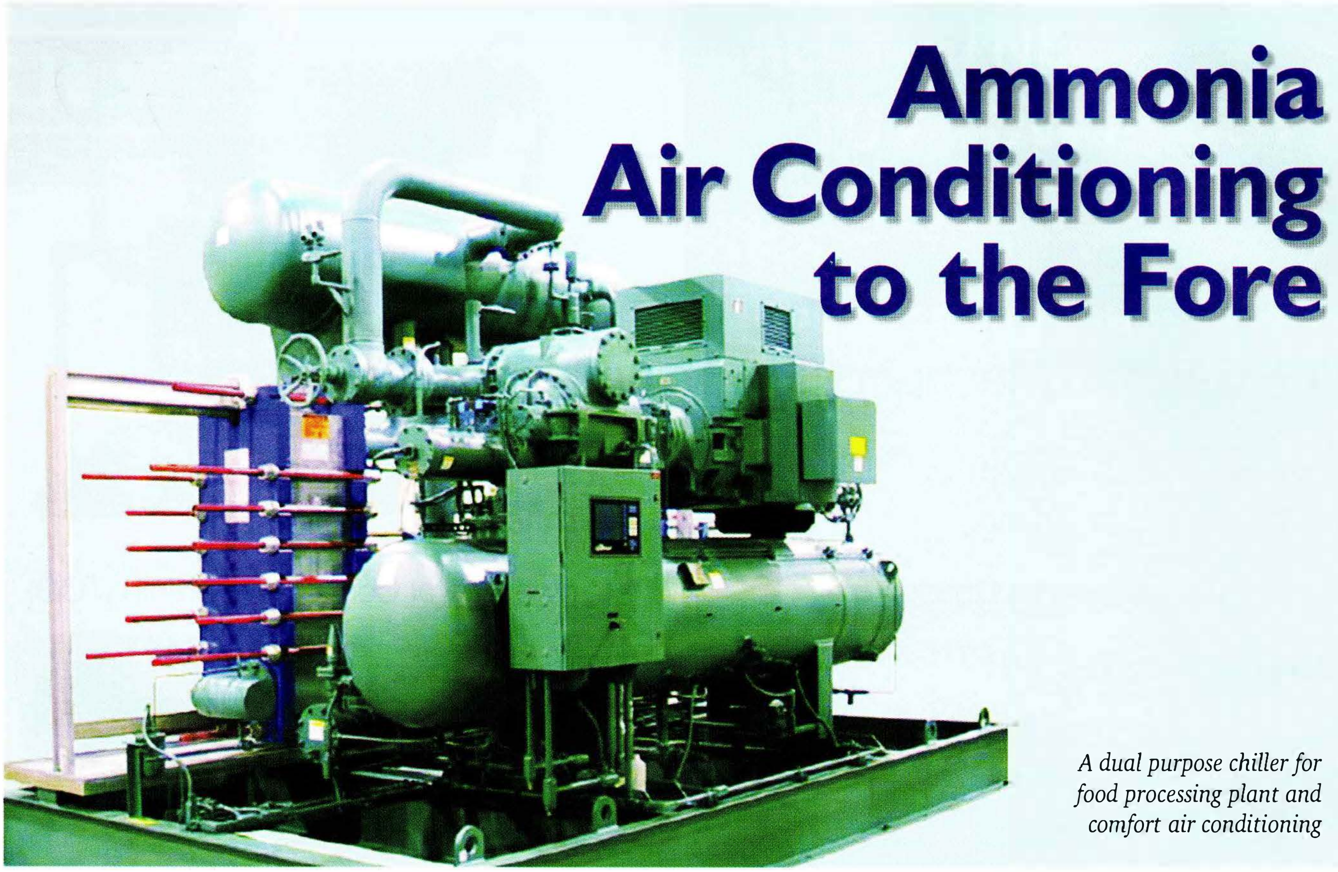

A dual purpose chiller for food processing plant and comfort air conditioning

By Ramesh Paranjpey Fellow ASHRAE Life Member, Pune

Introduction

I had authored an article titled *Use of Ammonia for Air Conditioning Applications*, published in the April-June 1999 issue of *Air Conditioning and Refrigeration Journal* (p 63).

Since then, a lot of water has flown under the bridge, and my objective in writing a second article on the topic is to update the readers on developments since my first article.

Ammonia has received considerable negative publicity from the man-made refrigerants lobby that is keen to recover, as quickly as possible, their huge investments made in developing these refrigerants such as HFCs and HCFCs. We, in India, have a long tradition of following what the multinationals advocate. This is true especially in the field of air conditioning technology and products. During the last 20 years we abandoned many products that were being manufactured in India, as imports became more economical. The new thrust on *Make in India* should prompt us to seriously think about what is good for us and our country, rather than blindly following others.

About the Author

Ramesh Paranjpey is a mechanical engineer with an M. Tech. in refrigeration from IIT Bombay, having over 35 years' experience. He has worked in very senior positions with Kirloskar Pneumatic in Pune, Carrier Transicold in Bangalore and Singapore and Voltas-Air International in Pune. Presently, he works for himself as a technical advisor and consultant. He is an ASHRAE Fellow, past president ASHRAE W.I. Chapter and past president ISHRAE Pune Chapter. He can be contacted at ramesh.*paranjpey@gmail.com*

Current Scenario

Use of CFC refrigerants is now banned, due to their high Ozone Depleting Potential (ODP), all over the world. Many countries have also stopped the use of HCFC22 refrigerant due to its limited ODP, and its use will not be allowed even in developing countries after 2020. New man-made refrigerants such as HFC134a, R404A, and R410A are currently being used for domestic appliances and for comfort air conditioning applications as well as in the automobile sector and various other applications as substitutes for CFC and HCFC refrigerants.

Table 1: GWP of currently used refrigerants (Reference: CO_2=1kg)

Refrigerant	GWP
R404A	3700
R410A	2100
R407C	1700
R22	1790
R134A	1370
Ammonia R717	< 1

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The man-made refrigerants introduced recently have high Global Warming Potential (GWP) (see *Table 1*), besides the currently unknown dangers they may pose in future. People the world over are reaching the conclusion that these should also be banned. The so-called harmless man-made CFC refrigerants needed nearly 50 years for their harmful effects on the environment to be realized, and the choice of natural refrigerants as a 'no regret' solution is, therefore, finding renewed interest by the refrigeration and air conditioning community.

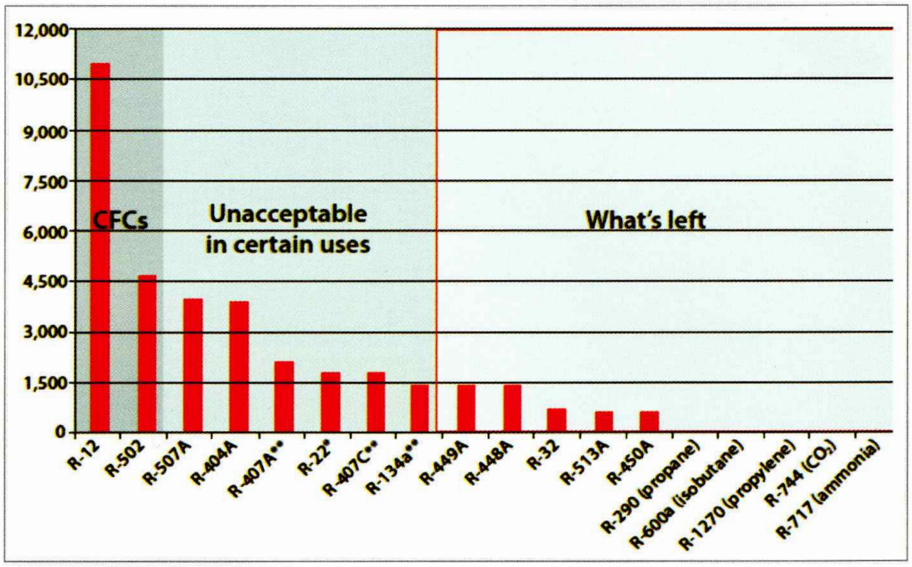

Figure 1: SNAP Rule 20 - phasing out of HFC refrigerants

Natural refrigerants are inexpensive, available in abundance and can cover nearly every refrigeration application. Furthermore, they have very low GWPs compared to synthetic refrigerants. This alone is reason enough to recommend their use. Besides, it is also just as important to note that they are highly energy-efficient. After all, more than 80 percent of the GWP posed by refrigeration and air conditioning systems results from system energy consumption and not from refrigerant leaks.

At present, around 15 percent of global electricity consumption is used by the AC&R industry, and there is, thus, a huge power saving potential. Measures to save energy during the entire service life of AC&R systems are, therefore, acquiring increasing importance and can help considerably to relieve the burden on the environment.

Here, the use of natural refrigerants offers a double incentive for companies: by reducing their energy consumption, they not only cut back on costs, but also help protect the environment. So in future, everything points towards the use of natural refrigerants for both ecological and economical reasons, in order to safeguard both capital expenditure and the environment in the long term.

In October 2016 in Kigali, all nations agreed to drastically phase down the use of hydrofluorocarbons (HFCs) over the next 30 years. This will lead to a major change in refrigeration and air conditioning systems, for which we must all be prepared.

EPA SNAP Program

The U.S. Environmental Protection Agency's (EPA) Significant New Alternatives Policy (SNAP) is a program to evaluate and regulate ozone-depleting and high GWP chemicals as authorized by the Clean Air Act (CAA). As part of the SNAP program, EPA both approves new and delists (i.e. deems unacceptable for use) existing refrigerants used in various end-use applications in the U.S.A., including the food retail and food service sectors.

On July 2, 2015, EPA issued its final rule on the delisting of certain HFC refrigerants for use in specific end-use refrigeration applications and communicated alternative refrigerants approved for use. The final rule became effective on August 19, 2015. It spells out phasing out of certain HFC refrigerants as per the time schedule in *Table 2*.

Table 2: Schedule for phasing out certain HFC refrigerants

End Use	Substitutes	Decision
Retail food refrigeration below 2200 Btu/hr.	R404A, R407C, R410A, R505A	Unacceptable as of January 1, 2019
Retail food refrigeration above 2200 Btu/hr.	R404A, R407C, R410A, R505A	Unacceptable as of January 1, 2019
Retail food refrigeration – low temperature	R404A, R407C, R410A, R505A	Unacceptable as of January 1, 2019
Retail food refrigeration standalone retrofits	R404A, R407C, R410A, R505A	Unacceptable as of July 20, 2016

The well tried and trusted refrigerant ammonia is a natural refrigerant. Due to its unmatched thermodynamic properties, it has been extensively used by the refrigeration industry from the beginning and is now finding increasing use in many other applications where it was not considered before, and in areas of application where it was unthinkable earlier.

There is, therefore, an increasing trend to explore the use of natural refrigerants like ammonia, water, air, carbon dioxide as well as hydrocarbons, because these refrigerants have been in the atmosphere since the earth's existence, and their properties and effects on the human body and the environment are fully known to mankind. Ammonia naturally leads the race.

Many articles have been written about the advantages of ammonia over other refrigerants, and I will not repeat their contents. It is a well-known fact, understood by the entire air conditioning and refrigeration community, that ammonia has far superior thermodynamic properties than other refrigerants.

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Current Popular Applications of Ammonia

Currently, ammonia is used for the following applications, though its use is not restricted to them:

1. Cold storages for potatoes, fruits, vegetables and other commodities like chillies, seeds, grains and turmeric.
2. Ice plants for conventional block ice, flake ice, tube ice, slurry ice and plate ice.
3. Skating ice rinks for amusement parks.
4. Fish freezing plants – spiral freezers, plate freezers, individual quick freezers, blast and trolley freezers.
5. Slaughter houses and meat processing plants.
6. Dairies using ice bank systems, ice reserve units, chilled water systems, cold rooms and other such requirements.
7. Ice cream making plants.
8. Air conditioning of processing halls for cold chain facilities like grading, sorting and ante-room areas.
9. Process refrigeration plants using chilled water or low temperature brine chilling systems for chemical and dyestuff industries.
10. Breweries.
11. Bottling plants for Coca-Cola, Pepsi and other soft drinks.
12. Concrete cooling applications for river dams, airport runways and concrete expressways.
13. Fertilizer plants.
14. The maximum use of ammonia is in the agricultural industry as a fertilizer with a minimum of 99.5% ammonia content in commercial grade.
15. Many supermarkets have started using ammonia/carbon dioxide (R717/R744) or ammonia/secondary fluids like propylene glycol systems.
16. Liquefaction of gases like chlorine and carbon dioxide.
17. Pharmaceutical plants for process cooling.
18. In the metallurgical industry, ammonia is used as a source of inert gas, and for nitriding of metal surfaces.
19. In environmental protection, ammonia plays an important role in removing nitrogen oxides and sulpher dioxide from the smole emitted by power plants.
20. Air conditioning of large complexes like airports, telegraph and other office premises.
21. Space shuttles.
22. Heat pumps.

Use of Ammonia for Air Conditioning

To use ammonia refrigerant for air conditioning, many options are available.

1. For large commercial installations, water is circulated in the coils as the secondary fluid and not the refrigerant, which is contained in the plant room in a water chiller. Hence, ammonia in water chillers has no possibility of coming in contact with humans in occupied areas.
2. For supermarkets, ammonia-CO_2 cascade systems are becoming popular the world over. The standalone equipment located inside the shopping area uses CO_2, and ammonia refrigerant stays in the machine room and not in the occupied area.
3. Thermal storage system installed in the machine room, using ammonia ice banks, can be used for central air conditioning, generating ice during the night and melting it into chilled water and using it for air conditioning during the day. This also saves power cost where there is differential tariff between day and night operations.
4. Air cooled ammonia low charge chilled water generating packages are available and can be installed on the roof top. In case of leaks ammonia, being lighter than air, would escape to the atmosphere without causing any harm to humans.
5. Small capacity plants using semi hermetic, hermetic or open type compressors have already been developed for ammonia, and small DX systems with synthetic oils are possible.

In large capacity air conditioning projects, where ammonia refrigerant is used in the machine room to generate chilled water, system efficiency is the best compared even with HFC or HCFC centrifugal or screw chiller packages. Ammonia refrigerant is, therefore, finding increasing use in large air conditioning projects, some of which are mentioned below (source: *Eurammon* issues 2012-16).

i. Oslo Airport, Norway
ii. Heathrow Airport Terminal 5, London
iii. Changi Airport, Singapore
iv. Dusseldorf Airport, Germany
v. Zurich Airport, Switzerland
vi. Christchurch Airport, New Zealand
vii. Stuttgard Airport Terminal 3, Germany
viii. Telephone Exchange, Copenhagen
ix. KWN Greenpeace Headquarters, Vienna, Italy
x. Saab, Linkoping
xi. Ostbanhof Train Station, Berlin
xii. Roche Headquarters, London
xiii. Mulligen Letter Sorting Centre, Switzerland
xiv. Ozeaneum, Switzerland

These examples strengthen the case for ammonia as a refrigerant for air conditioning, dispelling the myths about its safety and fire hazard issues.

Some Prominent Ammonia AC Installations

Oslo Airport, Norway

- Oslo is one of the world's largest and most advanced airports, with a capacity to handle 16 to 18 million passengers per annum with 64 check-in counters, handling 80 aircraft per hour.
- The operational building area is 18,000 sq m, and commercial area is 2.7 sq km. Total area is 13 sq. km.
- The air conditioning plant at the airport was commissioned in October 1998, with a total refrigeration capacity of 6,300 kW.
- The plant uses ammonia refrigerant in an indirect cooling chilled water system, using three reciprocating 16-cylinder compressors in one area and two reciprocating 8-cylinder compressors in another area.

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- Refrigerant charge (ammonia) is 2,500 kg.
- Electrical motors have a total capacity of 1,720kW (5x280 + 2x160).

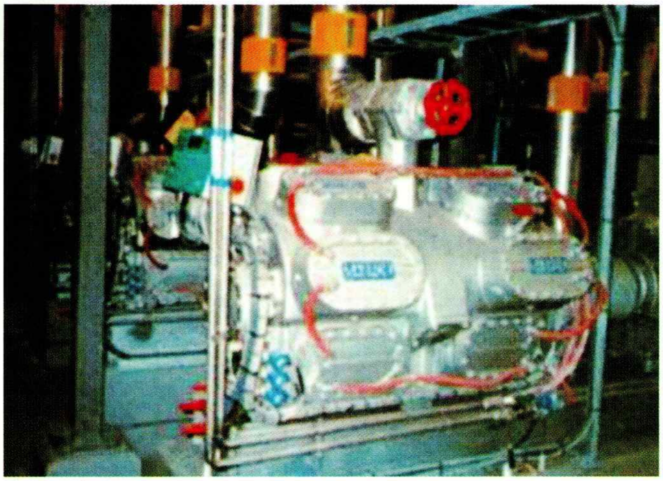

Photo 1: Plant room at Oslo airport

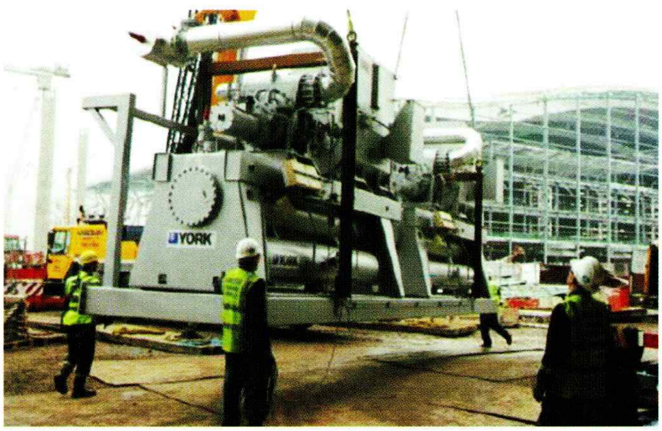

Photo 2: One of the four package ammonia chillers being installed at Heathrow airport

Stuttgart Airport, Germany

Photo 3: Stuttgart airport

Stuttgart airport changed over to ammonia refrigeration system in 2004. Grasso (part of GEA Refrigeration Technologies) installed an ammonia system for Terminal 3, using two liquid chilling packages with a total of 2,300 kW capacity. Its ice bank system is designed to work along with the existing refrigeration circuits to get maximum efficiency even in low load conditions.

Copenhagen P&T Building, Denmark

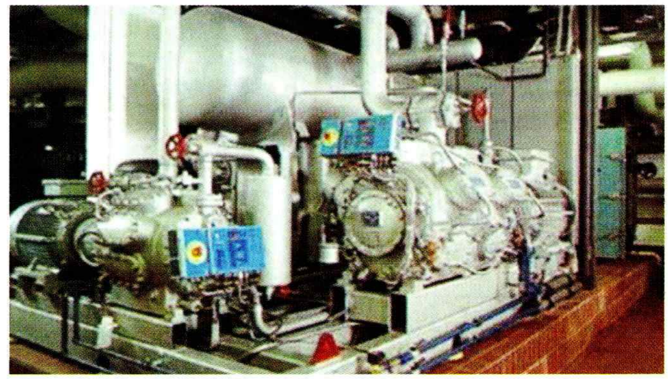

Photo 4: Ammonia chiller package at P&T Building, Copenhagen

This plant uses ammonia reciprocating compressors with plate heat exchangers for the evaporator as well as the condenser side. A particular mention of this plant is made in this article to stress the point that with the use of plate heat exchangers, the refrigerant charge reduces to nearly 20% and thus handling of refrigerant and dangers due to possible leaks are substantially reduced. Welded plate heat exchangers have opened up innumerable opportunities to AC&R professionals for various applications in air conditioning, where the use of ammonia was unthinkable earlier. Obstacles to the use of ammonia need to be understood thoroughly and care taken while designing and installing the plants, so that the false sense of security created through some 50 years of promotion of the now banned, so called safety refrigerants is understood and appropriate measures taken.

Saab Office Rooms, Linkoping, Sweden

Photo 5: Saab office in Linkoping

Johnson Controls uses an ammonia system to air condition 5,000 sq. m. of office area at Saab Group, a Swedish aerospace and defence company founded in 1937, with four ammonia water chilling units of 2 MW capacity each.

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Roche Headquarters In Welwyn, the U.K.

Roche has installed two ammonia chilling units to air condition its office building near London, using 930 kW ammonia refrigeration units installed on the roof top by Star Refrigeration Company.

Photo 6: Roche headquarters

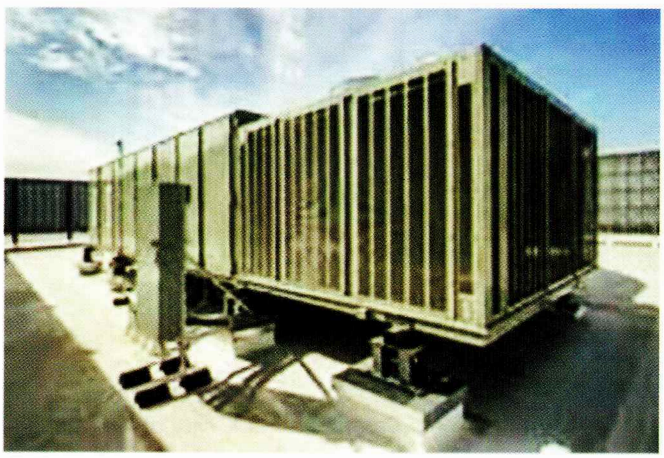

Photo 7 and 8: Roof top units using low charge ammonia systems at Roche headquarters in the U.K.

The Ozeaneum, Stralsund, Germany

This museum with its huge sea water aquarium, having 2.6 million litres of water, offers the visitors a spectacular journey through the underwater world.

The refrigeration system for cooling the water in the aquarium and for air conditioning the building is provided by a refrigeration plant of 900 kW capacity: 400 kW for the aquarium and 500 kW for air conditioning the building. Cold water is supplied at 6°C and returned at 12°C. Johnson Controls designed the refrigeration system using single stage ammonia flooded evaporators. Two Sabroe reciprocating compressors were utilized.

Photo 9 and 10: The Ozeaneum building and aquarium are cooled by an ammonia plant

Features of Modern Packaged Ammonia Systems

- New design packaged ammonia systems use plate heat exchangers (PHEs) or spray type shell-and-tube evaporators.
- They use liquid injection system.
- They have more than 30% better efficiency compared to HFC134a systems.
- They use less charge (0.02 to 0.5 kg/kW) for dry and flooded evaporators.
- They have high discharge pressures (upto 40 bar).
- Their safety levels are significantly higher, approaching zero leakage.
- They are being used in Europe for both display cabinets and space conditioning.

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Photo 11: A modern packaged ammonia system

New Products Developed with Ammonia in Mind

These product developments indicate the direction in which the global refrigeration and air conditioning industry is spending its R&D money to make ammonia a refrigerant of choice for all applications.

The use of ammonia will become even more popular once its toxicity and flammability are tamed and the quantity of refrigerant charge in systems is reduced substantially through advanced design heat exchangers and additives to reduce toxicity, like mixing of DME in a certain proportion with ammonia.

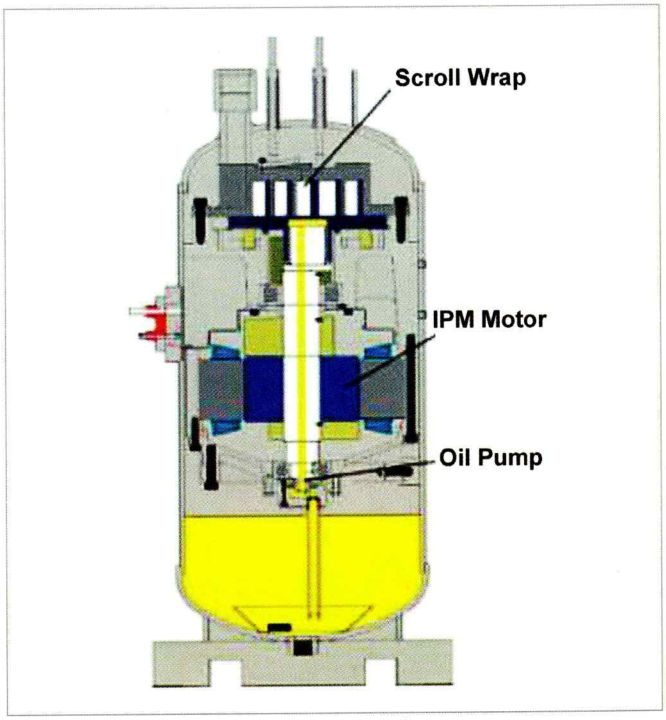

Figure 2: Semi-hermetic ammonia scroll compressor

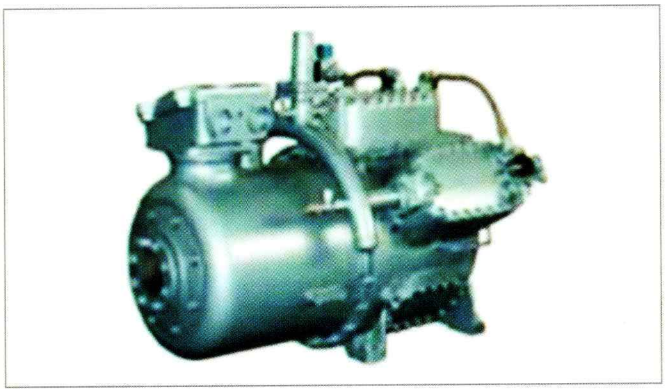

Photo 12: Semi-hermetic ammonia compressor

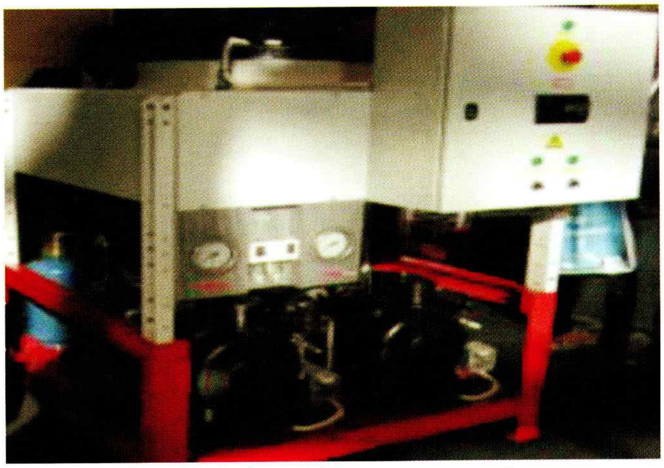

Photo 14: Ammonia reciprocating compressor package

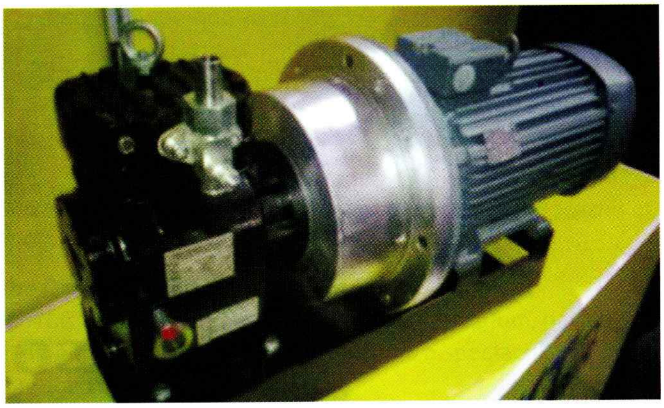

Photo 13: 7 kW ammonia reciprocating compressor

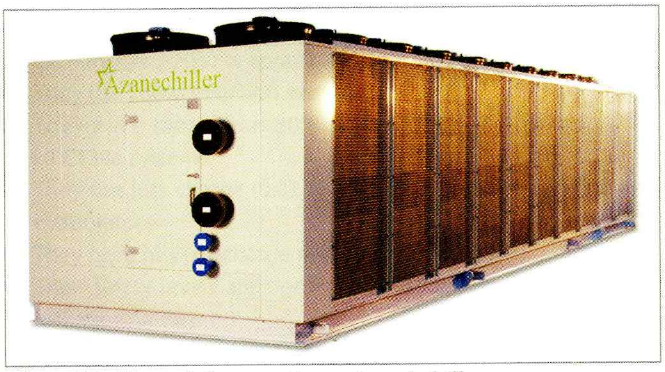

Photo 15: Air cooled ammonia packaged chiller

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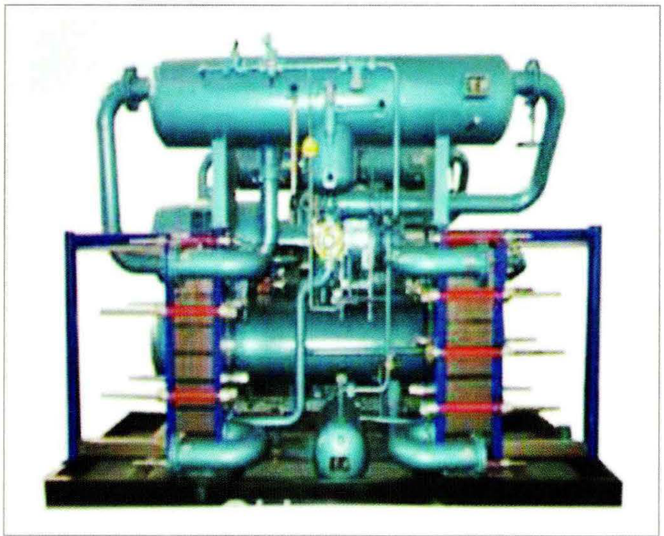

Photo 16: Ammonia packaged chiller

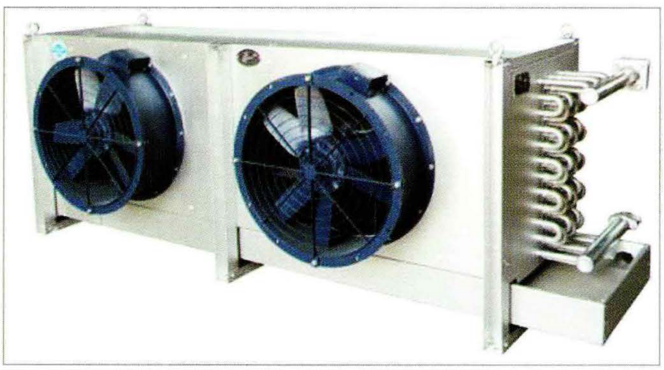

Photo 17: Aluminium cooler for ammonia

Ammonia leakage issues can also be minimised to the extent possible by use of hermetic motors and miscible synthetic oils, and eliminating flanged connections in favour of welded joints.

Conclusion

Since I wrote my first article on the use of ammonia in air conditioning in the year 1999, the entire world has progressed a lot towards using ammonia systems for various air conditioning applications. R&D efforts by multinationals in developing small capacity ammonia compressors in open, semi hermetic and sealed types have been going on with a view to using them in small capacity air conditioning plants. Unfortunately, our own air conditioning companies and experts have not been able to convince end users to use ammonia refrigerant for air conditioning. When restrictions for HFC and HCFC refrigerants come in force, they will have to wake up and start learning how to use ammonia in air conditioning applications.

Rather than depending on multinationals, we should start our own efforts to popularize natural refrigerants in the field of air conditioning in view of their long term benefits, and take a lead, signaling to the world that we are in no way behind others in technology and its applications.