An Overview of Indian Refrigeration and Cold Chain Industry

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Introduction

Refrigeration is a wonderful technology, and is an integral part of our lives today. Ron Vallort, Past President, ASHRAE called refrigeration the 'Technology for Survival', and he was 100% right.

Today, refrigeration technology acts as the heart of many processes, systems and applications. Refrigeration has vast applications spanning air conditioning (both for process and comfort), chemical, pharmaceutical, construction, dairy, fertilizer and ice making to food processing and cold chain related facilities.

The Refrigerant Scenario

The refrigeration industry has faced several challenges due to environmental issues like ozone depletion and global warming, and the selection of an appropriate refrigerant for any particular application has been a vital factor for ensuring environment safety. Refrigerants have come and gone, e.g.:

- Chloro-fluoro-carbons (CFCs) used in the past have already moved out because of ozone depletion problem.
- The next were hydro-chloro-fluoro-carbons (HCFCs), which also have now been phased out in stages in most countries and are in the phase-out mode even in India.
- Hydro-fluoro-carbons (HFCs) like R134a, R404a and R407c are currently in use but have global warming issues and eventually have to move out.
- Hydro-fluoro-olefins (HFOs) have been developed with zero ODP and very low GWP; but their commercial production is very low and cost is high.

Refrigerants that are here to stay are the natural refrigerants:

- Hydrocarbons (HCs): R-290 (propane) is already being used in Europe, India and elsewhere for smaller plants and appliances. R-600 (isobutene) is being used for refrigerators, etc. Hydrocarbons are effective refrigerants, but the major challenge to their application is high flammability. HCs are now being extensively used in European countries due to their zero ODP and negligible GWP. They have excellent thermodynamic properties. Hydrocarbons are being used as refrigerants in ice cream freezers also.
- Ammonia: R-717 (ammonia) is a trusted refrigerant and has been used for industrial refrigeration for more than a century. It is the refrigerant used in nearly 90% of the plants in the Indian cold chain industry. Ammonia has been in continuous use for longer than any other refrigerant and is perhaps the most effective refrigerant available today. Despite the high toxicity of ammonia, the safety record of ammonia refrigeration systems is good, much better than the safety record of ammonia installations used for production of fertilizers. Solutions to the challenge of ammonia toxicity include technically sound design, manufacturing, testing, installation, operation and maintenance of the system in accordance with current safety standards. Today, apart from industrial refrigeration, ammonia has also made inroads into air conditioning, and some of the large installations like airports and food processing halls have been implemented with ammonia chillers.
- Carbon dioxide: R-744 (CO_2) has been used in the past, but is now becoming popular as a primary as well as secondary refrigerant. The challenges presented by CO_2 include high operating pressures, toxicity and low critical pressure. All these challenges can be overcome with proper technology, which will lead to increased utilization of CO_2 systems.

Emerging Technologies in Refrigeration

New designs have been introduced both in HFC and ammonia refrigeration units. In addition, systems with CO_2 as the primary or secondary refrigerant would also enter the Indian market in the near future.

Low Charge Ammonia Systems

Ammonia has been extensively used for medium and large size plants, but the toxicity factor restricts its usage in many city corporation areas and working places. These systems generally need large quantities of ammonia charge, which is considered a matter of concern.

A lot of development has taken place in this field and as a result, ammonia systems have been developed with much lower charge. These systems are:

Ammonia Low Pressure Receiver (LPR) Systems

These systems have been developed using high pressure float valves, with or without refrigerant pumping. The systems are fairly simple and have the advantage of very low charge of ammonia refrigerant. Their major advantage is that the system does not need a high pressure receiver. Such plants are very common in Germany and other European countries.

Ammonia DX Systems

Ammonia DX systems have now been developed and are being installed on projects in India. The systems use electronic expansion valves (EEVs) and have the capability to run in an automated mode similar to HFC systems. As a further development, these systems can also incorporate air cooled condensers. The ammonia charge is also reduced to around 30-35% of a conventional gravity feed system. However, in a country like India with high ambient temperatures, it is advisable to provide condenser air pre-cooling systems using the principle of evaporative cooling to achieve low condensing temperature and thereby reduce energy consumption. Such systems have also been developed.

The first two DX ammonia projects in India

Ammonia Liquid Chillers

Systems using liquid ammonia chillers have the lowest ammonia charge because the charge remains only within the body of the chiller. The chilled water or the brine serves the purpose of distributing the refrigeration effect. Such systems are also used now for a number of installations including air conditioning installations.

Carbon Dioxide Refrigeration Systems

Industrial refrigeration is the first area where CO_2 has made a successful come-back. CO_2 in industrial refrigeration is used either as the primary refrigerant or as a secondary coolant. Due to very small vapour volume, CO_2 systems are very dynamic. CO_2 can be used in cascade systems with CO_2 as a refrigerant at the lower stage and ammonia or another refrigerant at the higher stage. Thermal performance of CO_2 is better at the lower stage. CO_2, when used as a secondary coolant, has the advantage that the pumping power required is only 5-10% of that for chilled water or glycol brine.

Vapour Absorption Systems

Apart from the vapour compression systems mentioned above, vapour absorption systems are also used for low temperature industrial refrigeration. They are particularly useful where a low cost thermal heat source is available, as these systems work on a thermal energy source. These systems are available in the following types:

a) Lithium bromide/water systems for applications up to -5°C liquid.
b) Ammonia/water systems for low temperatures, say up to -30°C.

These systems can be used with any kind of low cost fuel, natural gas or biogas. Systems have also been developed to work with solar thermal generated steam or hot water.

New Developments in Plant and Equipment

Compressors

Gone are the days of robust slow speed compressors. Today, energy efficient higher speed reciprocating compressors are used in a majority of plants. Scroll HFC compressors are available for smaller installations. Screw compressors are available for both ammonia and HFC refrigerants and offer the advantage of step-less capacity control to match varying load requirements. Compressor racks are finding good demand for larger sized HFC based plants.

Condensers

The current trend is to mainly use evaporative condensers in ammonia plants as they perform the combined function of condensers and cooling towers. They offer some saving in water consumption and have excellent energy performance among all types of condensers.

Evaporators

Liquid Chillers

Among the various types available for liquid chilling, plate heat exchanges (PHEs) have become the most popular due to their excellent thermal performance. In many applications like dairies, where ice bank type thermal storage systems have been employed in the past, PHEs are now replacing them with the clear advantage of better energy performance and space saving.

Air Coolers

Modern day air coolers are forced air finned coil type coolers with copper coil and aluminium fins, stainless steel coil with aluminium fins and aluminium coil with aluminium fins, and can be selected as per the application. The fans used are more efficient with SS or GRP impellers with lesser power requirement.

Automation

Being the key word in any engineering system today, industrial refrigeration systems also use PLC based and other control systems. Even web control of operation is possible with the current technology. The main objective is to ensure proper performance and achieve better energy efficiency.

Industrial Refrigeration Applications

Refrigeration is widely used in the following industries:

- Cold Chain (food processing and preservation)
- Dairy Industry
- Beverages Industry
- Pharmaceutical and Bulk Drugs Industry
- Fertilizers and Chemicals Industry
- Petrochemicals and Refinery Industry
- Ice Making Industry
- Other Industrial Processes

Apart from the various applications mentioned above, newer applications have emerged such as the Entertainment Sector where ice rinks and snow houses are being created in metro cities and malls.

While the growth of the refrigeration industry was dependant on the growth of the respective application sectors, there was one avenue which opened the flood gates of growth – the Cold Chain.

Over the years, technology has taken great strides, and today India can stand tall with its remarkable progress in the field of refrigeration and cold chain. Let us discuss the most important application of refrigeration, i.e. the cold chain.

Cold Chain has Turned Hot!

It was in the 1970s that a new wave of multiproduct cold stores began in Maharashtra, followed by development in other important avenues in the food processing and freezing sector. This was followed by a shift of outlook from 'Cold Storages' to 'Cold Chain', where the entire food chain from farm to retail was seen as an important aspect of food preservation.

Now, cold chain has emerged as a major area of development and is recognized as the sunrise sector in India.

Current Scenario in India

Recent trends in the cold chain Industry in India show an increase in special types of cold storages like multiproduct cold stores, controlled atmosphere (CA) stores, pack houses with processing and pre-cooling facilities and ripening units. There is also a great potential for frozen food production in the country and distribution facilities for refrigerated foods. Refrigerated transport is an important link in the cold chain and has a large scope for growth.

External view of a pack house

Process hall in a pack house

The various types of cold chain facilities include:

- Bulk cold storages for storing a single commodity of large capacity with only a few chambers.
- Multi-purpose cold stores for storing multiple commodities – a mix of positive temperature cold storages for storing fresh fruits and vegetables, pulses, spices, etc. and negative temperature frozen stores for storing meat, fish, dairy products, processed fruits and vegetables, etc.

A multi-facility project with pack house, ripening chamber and commercial multi-product cold storage at Kappec, Hubli

- Pack house facility with pre-cooling for fresh fruits and vegetables that are required to be pre-cooled close to the source. The facility consists of a processing line including sorting, grading and packing of the produce, a testing lab, pre-cooling and a short-term cold store.
- CA stores are special purpose cold stores mainly for storage of apples, pears, etc.
- Ripening units also are special purpose units for controlled ripening of produce like bananas, mangoes, papaya, etc.
- Frozen food production units with processing, freezing, packing and storage facilities.
- Food distribution centres.

Distribution centre with insulated panel construction and docking facilities

- Refrigerated transport.
- Food malls, retail food stores, etc.

Based on the report of the National Centre for Cold-chain Development (NCCD) on 'All India Cold-chain Infrastructure Capacity Assessment of Status and Gap', as per the recorded data (as on March 31, 2014) and the information collected thereafter, the country has created nearly 33 million MT of cold storage space. The additional requirement as per the report is about 10% of the existing capacity. The other areas where there is a potential for further development are as follows:

- Pack houses: The existing infrastructure is approximately 500 units, while the estimated requirement is 70,000 units. Hence the estimated gap is 69,500 units.
- Reefer vehicles: The existing capacity is 10,000 vehicles, while the estimated requirement is 61,800 vehicles, leaving an estimated gap of 51,800.
- Ripening chambers: The existing capacity is 900, and the estimated requirement is 9,100. Hence the estimated gap is 8,200.

It is also a matter of experience that some of the existing cold stores are non-functional and a large number of the others are based on old and outdated technology. These certainly have to be upgraded with modern technology and this itself is a huge business opportunity.

Growth of Cold Chain

The Cold Chain Industry is developing at a fast pace in India due to the shift in focus from increasing production to better storage and transportation facilities for food products. The industry has now become an integral part of the supply chain industry consisting of refrigerated storage and refrigerated transportation.

Owing to the rising need of infrastructure and to reduce wastage, according to a market research report, the cold chain industry in India is forecasted to grow at a CAGR of 19% during the period 2017-2022. The drivers for growth of the industry include:

- Rising need for cold chain facilities to reduce the cold chain infrastructure gap as stated above.
- Increasing government initiatives and financial support.
- Increasing private sector investments by both domestic and foreign players.
- Changing demographics, lifestyle and food consumption patterns in urban areas with nuclear families.
- Increasing demand for packaged, canned, frozen and ready-to-eat products.
- Increasing interest in the Indian food market and investments by international players like food chains and logistic players.

Newer Technologies in Cold Chain Project Construction

The technology for construction and operation of cold chain projects has undergone a lot of change over the past few years. These include advances in all aspects of cold chain management from construction to material handling equipment. Given below are the major advances in these fields:

Construction

1. PEB structures are now replacing conventional construction practices in the cold chain sector. Pre-engineered steel buildings (PEBs) are those that are fully fabricated in the factory after designing, shipped to site in completely knocked down (CKD) condition, and assembled and erected at site with nuts and bolts, thereby reducing the time for construction.

A PEB structure

2. Use of eco-friendly materials in construction is increasing.
3. Docks used for loading and unloading of products are now more scientifically designed to facilitate easier movement of materials and to ensure safety in operation.
4. Efforts are made for effective use of natural light and natural ventilation to the maximum extent during the design stage itself.

Thermal Envelope

1. Insulated panel technology has largely replaced the old and conventional insulation practices. Sandwich insulation panels ensure high thermal insulation value and high structural strength, and are being used for cold stores as well as process halls.
2. Mechanized insulated cold room and chamber doors and dock doors ensure the least energy loss and effective temperature control.

Refrigeration

1. Use of eco-friendly refrigerants is now being promoted and practiced to take care of the environmental challenges.
2. Refrigeration machinery and systems are now designed with high energy efficiency for optimal use of power, thus reducing operational costs and ensuring minimal water consumption.
3. Cold chain operations are getting more and more automated with state of the art control systems. Capacity control is used with compressors for energy savings.
4. Integrated system design takes care of redundancy and provision for future expansion.

Electrical Installations

Energy efficient equipment is being increasingly used in electrical systems. This includes LED lighting, alarm systems, PLC systems, APFC panels and solar PV panels.

Palletized convertible multipurpose cold storage project (8000 pallets) with fully automated PLC based control system at Boxco Logistics, Sonepat Haryana

Water Management

1. Water recycling and water saving devices are installed at plants.
2. Rain water harvesting is implemented at many plants.

Heat Recovery Systems

Some plants deploy systems to use waste heat from the refrigeration plant to generate hot water for process, cleaning or other purposes. This is a very attractive energy saving proposition.

Use of Renewable Energy

Uses of solar, wind and other sources of renewable energy are finding their place in the cold chain field. Innovative products like solar roofs, energy generating systems with use of biogas and cow-dung cakes, etc. are being introduced in the market.

Material Handling and Storage Systems

Various modern storage systems are being implemented:

- Racks for manual loading and unloading operation.

Palletized storage inside cold chamber with material handling equipment

- Racks with reach trucks.
- Racks with fork lift for pallet loading.

IT and Automation

1. Large cold chain facilities and public warehouses in India are moving away from Excel sheets and in-house software and are deploying Warehouse Managament System (WMS) software. There are two types of deployments for WMS – in-premise (where the software sits on internal servers) or on Cloud (where the software sits on a public network and dedicated domains are created for every client). There has been a rise in Cloud based WMS software providers as well as users in India.
2. Bar coding system is used for marking product boxes. Bar code scanners integrated with WMS software are used for picking and storage.
3. Variable frequency drives (VFDs) are commonly used for capacity control of various equipment.

Fire Safety

There is increasing awareness about provision of dry and wet fire fighting systems that have to be installed as per local norms.

Challenges in Cold Chain

While there is a huge potential for the cold chain industry in India, these growth prospects come with some basic challenges at the facility setup level as well as the environment level:

Facility Setup Concerns

- High initial cost of cold chain projects with rising cost of land
- Land availability at suitable locations
- Insufficient market surveys
- Lack of adequate and reliable power supply
- Non-availability of adequate water of proper quality
- Lack of proper road infrastructure
- Lack of proper reefer transport
- Lack of skilled personal

Environment and Energy Concerns

- Global warming through refrigerant usage
- High electrical energy usage
- Water requirement in large quantities
- Refrigerant leakage
- Damaged/spoilt produce disposal

However, efforts are going on to find solutions to these issues at the levels of the government and technical advisory bodies.

Safety Issues and Standards

Safety standards are being updated to reflect increasing interest in flammable and mildly flammable refrigerants. Flammability and toxicity requirements have been covered by ASHRAE safety standards 15 and 34 and their international equivalents ISO 5149 and ISO 817. Other organizations adopt ASHRAE technical requirements into codes and regulations. For cold chain projects in India, the National Horticulture Board has published five standards for cold storages and other related projects.

Government Initiatives

In order to promote a technically sound, energy efficient and sustainable cold chain, the government has established the National Centre for Cold-chain Development (NCCD) under the Ministry of Agriculture. The other related institutions are:

- Mission for Integrated Development of Horticulture (MIDH): *www.midh.gov.in*
- National Horticulture Board (NHB): *www.nhb.gov.in*
- National Horticulture Mission (NHM): *www.nhm.nic.in*
- Ministry of Food Processing Industry (MOFPI): *www.mofpi.nic.in*
- Agriculture and Processed Food Products Export Development Authority (APEDA): *www.apeda.gov.in*

In addition, there are state level bodies.

The government has set technical standards for the development of cold chain facilities that give importance to the use of good technology, thereby ensuring energy efficient and environment friendly facilities. These standards were first introduced by NHB as *NHB Guidelines*, and are now being promoted as *MIDH Guidelines*. These guidelines help promotion of good quality cold chain infrastructure in India.

Further, to increase investments and promote entrepreneurship and growth in this sector, the Government provides good financial incentives through the above mentioned bodies. They ensure that financial schemes are relevant to the need of the industry and promote growth in the right direction. The schemes also take into consideration the varied geography of the country and are spread across various states.

Technical support is available from various organizations like ASHRAE, ISHRAE, NCCD, NHB, Global Cold Chain Alliance (GCCA), International Institute of Ammonia Refrigeration (IIAR) and some other institutions. These organizations help promote the cold chain in the country, provide standards for installation, safety and other aspects of the cold chain and organize cold chain events that help increase business and fuel growth at the state, national and international levels.

Green Cold Chain - The Need of the Hour

Industrial refrigeration systems have to operate at very low temperatures, and hence have considerably high energy consumption as well as water consumption. It is, therefore, advisable to design these plants and projects with green design concepts. A green system is based on the following features:

- Use of materials that can be recycled and reused
- High energy efficiency of the system
- Well designed thermal insulation for low temperature vessels, piping and cold chambers
- Equipment design to achieve maximum saving in water consumption
- Efficient electrical system, lighting, etc.
- Use of natural ventilation and lighting
- Use of energy saving devices such as energy recovery units, VFDs and PLC systems for automation
- Heat recovery systems for using waste heat from the refrigeration system for gainful purposes
- Use of recycled water and condensate from evaporators
- Rain water harvesting
- Use of renewable energy such as solar P.V., wind and biomass

Conclusion

An overview of the refrigeration and cold chain industry in India over the past 50 to 60 years shows that the industry has undergone significant transformation in terms of industrial applications, technology, geographical spread, standards and practices followed and support from the government as well as technical organizations. Energy saving and Green cold chain concepts are also being seriously looked at by owners, private players and entrepreneurs.

However, it must be realized that for a country that is No. 1 in terms of milk production and No. 2 in terms of F&V production, the overall food processing, storage and cold transport capacity cannot be considered adequate and there is a good potential for development of modern and energy efficient cold chain facilities.

The concept of Green cold chain needs to be promoted, a rating system for evaluation of projects needs to be formulated and special incentives need to be considered for Green cold chain projects.

To support the government's goal of doubling farmers' incomes, the cold chain will act as a key enabler by improving post harvest management, reducing food waste, maintaining food quality and hence helping to increase sales and market rates of food products.

A scientifically developed cold chain, designed to handle and preserve the substantial quantity and excellent quality of food products grown in the country, has to transform itself into a value chain with value for farmers, processors, cold store owners, transporters, distributors and finally consumers.