Vol. 10 No. 10 May 2015 ₹ 100

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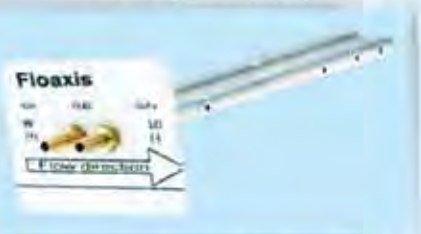

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Publisher's Letter

Transitioning Beyond HFCs

Since, he came to power, our present prime minister Narendra Modi has been facing one after another challenges. The latest challenge is phasing down the Hydro Fluorocarbons (HFCs). These are Green House Gases (GHGs) but do not possess Ozone Depletion Potential (ODP). As a signatory to the Montreal Protocol, India has to cut down Hydro Chloro Fluoro Carbons (HCFCs), which have both ODP and GWP (Global Warming Potential). More than one-third of the India's air-conditioner units are still brought from abroad charged with HCFCs. But as per guideline after July 1, 2015, all these units should be imported without the refrigerant inside.

India has submitted an amendment proposal to the Montreal Protocol proposing a phase-down of HFCs. According to Clare Perry, Head of Climate, Environmental Investigation Agency (EIA), "India's proposal comes as countries are about to participate in a special meeting of the Montreal Protocol to address HFCs. It is a major opportunity to begin negotiations on the most immediate, cost-effective, and tangible global measure to address climate change."

Avipsa Mahapatra, EIA International Climate Policy Analyst, says, "It is refreshing to see India come to the negotiating table for these potent greenhouse gases, as India has historically been opposed to such an amendment."

Like most other developing nations, India has just started to transition to HFC. Yet another transition is not possible immediately. So, India's recent amendment proposal to the Montreal Protocol that states – in industrially advanced countries, production and consumption of HFCs should reach 15% of their 2013-2015 reference levels by 2035. Developing countries would have until 2050 to reach the 15% level of their 2028 to 30 use and consumption reference levels – is quite justified.

Please send your comments at pravita@charypublications.in

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Pravita Iyer
Publisher & Director

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Contents

Vol. 10 No. 10, May 2015

New Project

24

Excellent Purpose, Strategic Location And Best-In-Class Engineering

Danfoss has engineered India's first model green cold storage facility at Roshan Frozen and Cold Storage in Sonipat, Haryana. The storage owned by Sabharwal Food Industries Pvt. Ltd., is an ideal model of the next generation cold storages that India will see shortly...

Articles

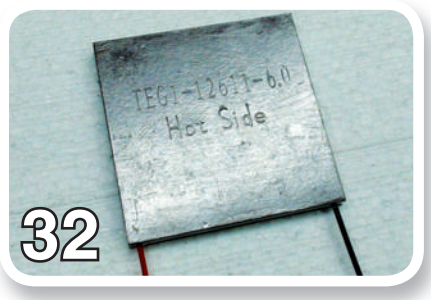
Cover Image Courtesy: Gensler

28

Embracing Intelligent Green Technology

30

Office Building Earns LEED Platinum Designation



32

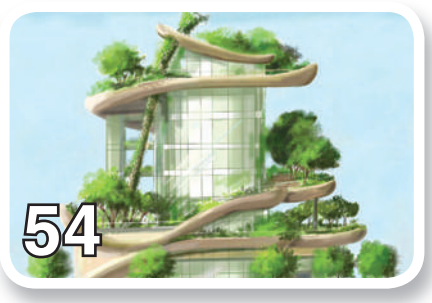
Thermoelectric Cooling
- Dr OmPrakash G Kulkarni

48

Bringing Comfort To Chase Tower with Titus' EOS

50

Cooling Supermarkets Efficiently
- Dr J Sarkar



54

Designing Green Buildings
- Dr S S Verma

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Typical case study data of a 1200 TR Chiller

Sr. No.	Parameter	Cooling Tower (Induced Draft)	LTMCS
1	Wet Bulb Temperature	29°C	29°C
2	Chilled Water Temp in °C (Assumed)	5°C	5°C
3	Supply Temp. from CT / LTMCS	33°C	30°C
4	Approach to WBT	4°C	1°C
5	**ΔT for Chiller**	**28°C**	**25°C**
6	Chilled Water Compressor Motor Kw for 1200 TR	720	643
7	Energy Saved in %	-	10.7%
8	**Energy Saved in Kw**	**-**	**77 Kw/Hr**
9	Total Running Hours per Annum	8640	8640
10	**TOTAL POWER SAVED PER ANNUM**	**-**	**6,65,280 Kw**

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CTI MEMBER

Contents

Vol. 10 No. 10, May 2015

Articles

Energy Efficiency In Hotels And Buildings
- G Subramanyam

Maintenance Of Building HVAC Electrical Systems
- Aneesh Kadyan

One Degree Chiller
- P Babu

Case Study

Combining The Best Of Both Worlds

Managing With A Hired Solution

Interview

'We Need To Understand The Market Opportunity...'
- Sandeep Das
Strategy and Business Development, Intertek, South Asia

Departments

Publisher's Letter....04
Editorial....10
Newsline....12
Opinion....18
Appointment....20
Market Projection....22
Hospital Refrigeration....61
Outdoor Cooler....65
Event Report....71
Special Feature....72
Product Profile....74
Facts & Figures....76
Index to Advertisers....77
Cooling Museum....78

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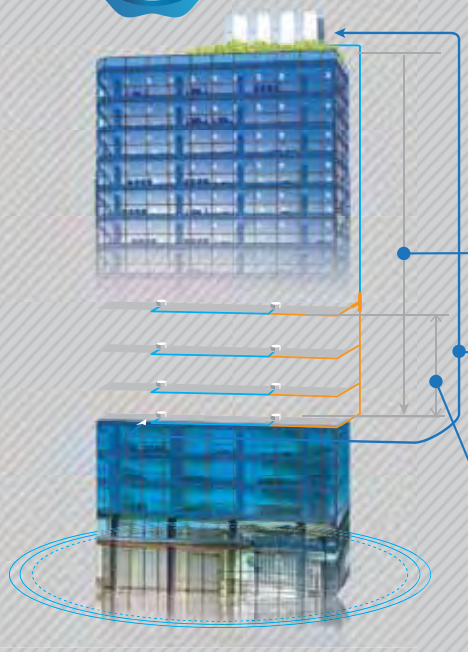

110m
Max.110m level difference between IDU~ODU

175m
Max.175m actual piping length

30m
Max.30m level difference between IDU~IDU

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FROM THE EDITOR

Further Growth Is Obvious

As per the latest available statistics, the domestic penetration of refrigerators in India is still less than 10%. If we see volume wise, the size of the refrigerator market is estimated to be 3.5 to 4 million units, and it is expected to grow at a CAGR of 25.7% during 2012 to 2015. Also, urban versus rural demand ratio of the refrigerators stands at 3:1. Considering a population of around 128 crore at present in our country and when it is forecast to touch 148 crore mark by 2030 – i.e., the highest in the global (population) rank, obviously the durable has an immense growth potential in this sub-continent. Also, rapid ubanisation focused on building self-content type of apartments and fast changing life style of the Indians are showing green signal to its growth path. Climate change is yet another factor to be considered in this context. Even a few years back, those who used to think that having a fridge at home is a luxury, today most of them are thinking exactly in the reverse way. The demand today is not uniform in all regions, it is higher in northern and western regions – next comes the southern region and then the eastern region.

Although, region-wise still there are variances in growth of demand, there are some emerging factors that are boosting the demand in all regions. Because of better employment opportunities, the disposable income levels are increasing. Also, demographically the median age of the Indian population being 26.6 years, there is a shift in the buyer's paradigm. Thus, replacement of the old machines with modern, double door and highly energy efficient fridges is also giving a good impetus to the market growth of the refrigerators. Prominent players in the Indian refrigerator market are LG, Panasonic, Kelvinator, Videocon, Haier, Samsung, Blue star, Godrej and Whirlpool, but in 2014 LG was at the leading position of refrigeration appliances market with a 22% volume share. Efforts toward more market penetration in the rural areas will stimulate further growth in this segment.

Pl. send your views at pkchatterjee@charypublications.in

P. K. Chatterjee

> *Demographically, the median age of the Indian population being 26.6 years, there is a shift in the overall buyer's paradigm...*

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F&S recognises the HLR solution of enVerid Systems

enVerid Systems has received Frost & Sullivan's (F&S's) 2015 North American HVAC Technology Innovation Award for its HVAC Load Reduction (HLR) solution. The solution significantly reduces HVAC energy consumption.

enVerid Systems has received this award for their HLR system...

Frost & Sullivan recognized enVerid's HLR system for its ability to deliver substantial energy savings by innovatively solving a major cause of HVAC energy waste in commercial buildings. "enVerid's ingenuity in minimising the HVAC system's outside air intake by cleaning and recirculating indoor air has produced a solution that dramatically reduces HVAC energy consumption. This technology offers building owners and managers a smart, practical solution to save energy, and provides the HVAC industry with a breakthrough capability to achieve new levels of energy efficiency," says Jennifer Tan, Analyst, Frost & Sullivan.

One of the leading causes of HVAC energy waste in commercial buildings is replacing indoor air with outside air in order to maintain air quality that meets regulatory standards – an inefficient process that happens up to 20 times a day. enVerid's HLR system incorporates patented 'intelligent scrubbers' that directly remove all molecular contaminants from indoor air, including CO_2 and VOCs, reducing the need for costly air replacement and delivering double-digit energy savings.

"We're honoured to receive this recognition from Frost & Sullivan, as it underscores the tremendous energy-saving capability of our technology that can be readily used in both existing HVAC systems and new construction," said Udi Meirav, CEO of enVerid Systems. "Our HLR solution is currently delivering substantial, measurable energy savings at commercial sites worldwide, and we hope this award will help accelerate market awareness and adoption." ■

Letter to the Editor

Sir,

I'm M.G. Rohithraj from UDUPI, Karnataka, a regular subscriber of Cooling India magazine. I'm engaged in production of ice blocks. My ice plant is capable of producing 100 tons of ice per day.

I want to know about new technologies in block ice plant. We've more than 150 ice plants in this coastal belt, which're working to fulfil the need of the ice required for fishing activities. We're making 100kg and 150kg blocks of ice. Is there any new technology to reduce power consumption and enhance production?

In your last issue, you discussed about Bio Chillers. In our ice plants, heat is generated in discharge line. If this heat can be converted to chilling of water, then it will be a large saving for us. Our plants are working 24 X 7, so heat can be converted to chilling of water.

I hope, you will help me in decreasing power consumption and increasing production.

RESPONSE

Dear Mr. Rohithraj,

Thanks for your enquiry.

I request the author and other writers and readers, if anybody has a solution, please come forward to take up this project. Based on your response, we wish to take it forward.

Regards to all.

Pl. reply at: pkchatterjee@charypublications.in

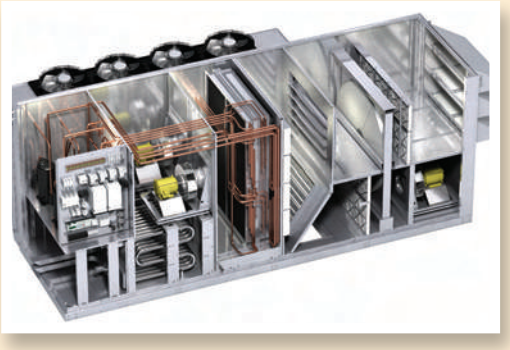
Thermal energy storage market to witness growth

A recent research report titled, "Global Thermal Energy Storage Market 2015-2019," states that revenue-wise this industry will cross US$1300 million by 2019. Europe, Middle East and Africa (EMEA) are expected to witness high growth followed by the APAC region.

This research also recognises some companies as the key players in the market from 2015-2019, namely: Baltimore Aircoil Company (BAC), Caldwell Energy, CALMAC and Chicago Bridge & Iron Co. Other prominent vendors in the market are: NEST and Sunwell Technologies.

One of the trends for this market is the increased investment in storage technology. Rapid advances in storage technology such as electric vehicles or solar-powered storage technologies will pave the way for the growth of the market in the future. The US and China are investing in efficient storage batteries, power grid capacitors, and CAES to increase the development of these storage technologies. ■

Greenheck rolls out Model RV(E)-120



Greenheck has rolled out model RV(E)-120...

Greenheck, a global company in manufacturing and distributing air movement and control equipment, has expanded its packaged rooftop ventilation line with the addition of model RV(E)-120. This is a pre-engineered system featuring increased performance capabilities for larger dedicated outdoor air systems, multi-zone VAV systems, and single-zone VAV systems. Model RV(E)-120 has a two-inch R13 foam panel construction and thermally broken design. Its low sound condenser fans offer an average of 5 to10 dB less than the standard condensing fans for quieter operation, while dual supply and exhaust fans deliver improved performance as well as reduced unit electrical loads.

Four independent cooling circuits allow for excellent cooling turndown and control. On indirect gas-fired furnaces, 10:1 modulating turndown is available for increased operating performance. With performance capacities up to 12,000 cfm, up to 45 tons of cooling and up to 800 Mbh heating, Model RV(E)-120 meets the demands of today's heating, cooling, dehumidification & ventilation requirements. ■

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Safety-enhancing cooling towers for Loviisa nuclear plant

The construction of Fortum's Loviisa nuclear power plant's new cooling system, that is the Cooling Towers (CTs) that're independent of seawater cooling, has been completed. The new air cooling system enhances safety at the Loviisa power plant in the improbable extreme situation when seawater wouldn't be available to cool the plant's reactors.

The use of seawater for cooling could be prevented by, e.g., a wide-spread oil spill in the Gulf of Finland, or by exceptional natural phenomena, such as excessive, wind-borne algae colonies. The power plant has already had back-up systems in place for the seawater cooling.

Installation of the cooler in one of the new standby cooling towers of the Finnish nuclear power plant Loviisa... (photo: Fortum)

The new air-cooled system further supplements the back-up systems. The new air-cooled heat exchangers, the cooling towers, are located in three buildings that have no impact on the landscape. Two cooling towers have been built for each plant unit. One tower is used for removing decay heat from the reactor, the other for removing decay heat from the spent fuel pools as well as for cooling off other equipment critical for safety. The towers used for removing decay heat from the reactors are located in the same building. "Air-cooled systems have been used before in other types of power plants, but the kind of cooling towers used at Loviisa are the first in the world at a nuclear plant. The solution is a cost-efficient way to further enhance safety of the seawater-cooled nuclear power plant," says Group Manager Samuli Savolainen from Fortum. The CTs were designed by Fortum and supplied by the Hungarian GEA EGI Contracting/Engineering. The towers were completed for their intended use in February 2015, and the final capacity and warranty testing will be conducted during the annual outage in summer. ■

Beijer Ref acquires Patton

Per Bertland
CEO, G&L Beijer

The Swedish refrigeration group, Beijer Ref AB, one of the largest refrigeration wholesalers in the world, is acquiring all the shares in the refrigeration wholesale company called, Patton. Patton has its head office in Auckland, New Zealand; and operations in New Zealand, Australia, India and Thailand. This acquisition is a significant step forward in the company's strategy to continue its growth outside Europe.

CEO of Beijer Ref, Per Bertland says,"This is a key acquisition, which gives us a foothold in the important markets like New Zealand, Australia and India, and at the same time, strengthens our existing operation in Thailand. Patton is an established company with a long tradition and a strong growth potential in its markets. The company eminently fits our profile." ■

A survey to identify refrigerant container content

The Chemicals and Refrigerant Reclaimers Product Section of the AHRI is conducting a survey to determine the needs of the market regarding refrigerant labeling – and the current color scheme for refrigerant containers as more refrigerants are approved for use. The U.S. Code of Federal Regulations (CFR) Title 49 for Hazmat Transportation regulations and CFR Title 29 for occupational safety and health regulations require that all hazardous material containers, which include refrigerant cylinders and drums, be properly labeled to clearly identify their contents. These container labels and markings should always be used as the primary means of identifying hazardous materials, including refrigerants. "AHRI Guideline N offers another layer of identification by assigning specific colors to refrigerant containers based on their contents," said AHRI Senior VP, Henry Hwong. This survey is intended to solicit information from the industry, specifically from end users, regarding common practices in use today to identify refrigerant container contents. ■

WorldGBC gets new knowledge partner for GB Awards

Official logo of the WorldGBC's award programme...

WorldGBC has declared that ICLEI Europe has been its newest knowledge partner for its 2015 Europe Leadership in Green Building Awards. The new partnership extends ICLEI's partnership with WorldGBC's global Govt. Leadership Awards to the regional level, and ICLEI now joins the Architects Council of Europe, European Council of Engineers Chambers, and Royal Institute of Chartered Surveyors on the awards panel.

ICLEI is a network of 12 mega-cities, 100 super-cities and urban regions, 450 large cities, and 450 small and medium-sized cities and towns in 84 countries. The organisation facilitates local govt. input to United Nations processes – such as the UN Framework Conventions on Climate Change, and Biodiversity, alongside many other activities. The network's Europe Leadership Awards has opened for nominations in April 2015, covering awards for leadership in building design, business leadership and excellence in city policy. The award winners will be announced at Greenbuild EuroMed in Verona on 14-16 October 2015. "Cities and GB Councils are natural partners in the mission to ensure that all citizens can enjoy a sustainably built environment. ICLEI will help us ensure that the most innovative city policies out there are being held up as examples for others to follow," said Dr Christine Lemaitre, Chairman of WorldGBC's Europe Regional Network.

ICLEI's Regional Director Wolfgang Teubner added, "With cities set to expand as the urban population rises, promoting sustainability in the construction sector is an increasingly pressing topic. Through rewarding and highlighting cities and organisations that have shown leadership in implementing green building policies, we can inspire others to do the same, creating a more resilient and sustainable Europe." ■

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Eversource, Massachusetts DCR offer innovative award for recycling refrigerators

Massachusetts DCR offers park passes to promote recycling of used refrigerators...

With an innovative plan to promote recycling of used refrigerators, the Massachusetts Dept. of Conservation and Recreation (DCR) is partnering with Eversource Energy to offer DCR Annual Parks Passes to the first 100 customers who participate in the utilities' refrigerator recycling programme between May 4 to 25, 2015. Any Eversource customer who recycles his/her old, second fridge or freezer will receive a $50 rebate and free unit pick up. Plus, the first 100 participants will also receive a 2015 MassParks Pass. The MassParks Pass grants holders unlimited day-use parking at Massachusetts state parks pools and beaches – where parking fees are charged, with the exception of Quabbin Reservoir fishing areas. "DCR is always interested in working with innovative partners to advance our mission to protect, promote and enhance the Commonwealth's natural, cultural and recreational resources for the well-being of all. We're excited to partner with Eversource and encourage folks to save energy and reduce waste at home and spend their personal energy and time outdoors in our parks," said Priscilla Geigis, Director of State Parks. "Recycling old refrigerators and freezers that consume as much as four times more energy than newer, efficient models will help preserve the environment for generations to come. We hope our unique partnership with Massachusetts DCR will give our customers incentive to send their old refrigerators and freezers on a 'hike' by having them properly recycled," says Tilak Subrahmanian, Vice President of Energy Efficiency at Eversource Energy. To qualify for the recycling programme, refrigerators and freezers must be clean, empty and in working order with an inside measurement of 10 and 30 cubic feet, standard for most units. ■

Johnson Controls displays its products in China Ref Expo

The HVAC&R technologies from Johnson Controls use refrigerants with low Ozone Depleting Potential (ODP) and Global Warming Potential (GWP). Recently, the company has showcased its Heating, Ventilation, Air-Conditioning and Refrigeration (HVAC&R) technologies using green refrigerants for a wide temperature range of -55 to 15^{0}C at the China Refrigeration Expo 2015. The company also shared the latest trends and technological developments in the industry with participants at the Ozone Climate Industry Roundtable 2015 held during the exhibition.

"We believe that it is crucial to push the boundaries on research for environmentally friendly HVAC&R technologies to address pressing environmental issues like climate change," said Song Wu, Vice President and Managing Director, Johnson Controls Building Efficiency, China. ■

R-22 allocations cause price hikes for larger customers

Facing a phase out of refrigerant R-22, major manufacturers DuPont, Honeywell and Arkema have all raised prices and set allocations for larger customers this spring. Airgas Refrigerants is helping customers plan their allocation use based upon historical consumption and anticipated needs to ensure that they manage inventory properly, and can navigate a year that many expect to be punctuated by price spikes, and perhaps some more shortages."We're hearing that companies are taking their entire allocations," Jay Kestenbaum, Senior Vice President, Sales and Purchasing for Airgas Refrigerants, said.

He further continued, "It's clear that people are nervous about R-22 and what the phase out may cause." Between 2014 and 2015, the EPA reduced the production allowance for R-22 by 57%, which has caused a steady rise in R-22 pricing since Fall, 2014. Airgas is one of the leading reclaimers of R-22, purifying used R-22 refrigerant gas to AHRI-700 standards. ■

California to host zero net energy homes

ZERO NET ENERGY

Meritage Homes, BIRAenergy, Itron and Southern California Edison (SCE) will work with the Electric Power Research Institute (EPRI) and the California Public Utilities Commission (CPUC) in evaluating and building a project that has a target to build 20 zero net energy homes. The EPRI led project will evaluate the energy use and grid integration of a new community, it will be the first development of a community of highly-efficient houses in the state of California.

Results from this project support EPRI's work with utilities in the United States and abroad on a more integrated power system – while propelling CPUC's objectives to increase energy efficiency and renewable energy in the state of California. California is aspiring to meet its 'big bold goal' for all new houses in the state to be zero net energy by 2020, and meet the state's stricter limitations of carbon emissions.

Zero net energy houses, with help from the grid, are designed to generate the same amount of energy that they consume. They have been a central goal of California strategies aimed at increasing energy efficiency and reducing carbon dioxide emissions. However, they were neither cost-effective nor available for most homebuyers until recently.

Zero net energy houses still rely on the grid, both to absorb excess solar generation during the day and to deliver power at night. Over the next several years, the project team will study how these houses and their advanced technologies can be effectively integrated into the utility's electric grid. Simultaneously, researchers will investigate avenues that improve the scalability and economic feasibility of these communities across the state. Meritage Homes designed these houses. The dwellings feature such items as high-efficiency solar panels, HVAC systems, water heating equipment, heat pumps and integrated fresh air ventilation. Also, each will have spray foam insulation, highly insulated windows, energy-efficient lighting and smart chargers & appliances. ■

Voltas releases fresh-air coolers with new features

Voltas range of fresh air coolers...

Voltas has launched its range of Fresh Air Coolers. The new range comes with attractive features, such as exclusive honeycomb cooling pads, carbonised dust filters and powerful air throw. In parallel, the company has rolled out its new range of 'All Weather Smart' ACs, offering an array of choices, and a number of distinctive features.

The features include SmartInverter Technology that saves up to 63% power; SmartMobile Application that provides direct AC control from handset; and the SmartSense Technology that recommends the best AC settings. ■

EIC Solutions rolls out coolers to meet the NEMA 4X standards

The Auto-Ranging Series (M105) cooler...

EIC Solutions, a company specialising in the design and manufactue of thermoelectric cooling systems, air conditioned electronic enclosures and transit cases for a wide range of applications, has introduced the auto-ranging (M105) product line. The ThermoTEC 141, 145, and 151 Series features an auto ranging power capability. This is an advanced circuit design, which allows the units run on 120 or 240 AC power. The auto ranging feature automatically tracks and optimises available voltage to provide unimpeded cooling. This offering is particularly useful in mobile applications – where available voltage may vary. It is also applicable for OEM's manufacturing systems in both voltages. "The coolers are a rugged, durable unit designed for a variety of applications. The flexibility of these auto ranging units makes them the ideal choice for virtually any power scenario, eliminating the need for transformers. This design is also a great fit for the early phases of a project – where the AC power supply is undefined," said Lori Galdo, Sales Engineer, EIC.

Operating at temp of up to 140^{0}F, the ThermoTEC Auto-Ranging (M105) units are manufactured to NEMA 4X standards to provide maximum protection against environmental variables. ACs are easily integrated into existing enclosures or can be configured with an enclosure, as a complete solution by EIC Solutions. The unit keeps the temperature inside the enclosure at safe operating levels – to help assure accurate and effective performance of a variety of electronics such as sensors, computers, telecommunication systems, surveillance devices and control panels. ■

Haier launches new product in India for modern homemakers, bags 'Product of the Year' award

Product of the year, Haier's Bottom Mounted Refrigerator...

Haier, has been honoured with 'Product of the Year' award for its revolutionary new Bottom Mounted Refrigerator, in India. The 'Product of the Year' is an international standard of consumer recognition, and is the largest consumer voted award. It highlights unique innovations and rewards the best customer centric product innovations across categories.

Haier Bottom Mounted Refrigerator has won the award in the refrigerator category resulting through a multi-step process, which initiated with a judging panel conducting extensive review tests of the product, which was followed by a door-to-door research facilitated by Nielsen, the world's largest research company, with 18,000 consumers in over 24 markets in India. The survey was conducted keeping into consideration consumers' understanding of the product and its appeal to the users.

Commenting on the achievement, Eric Braganza, President, Haier India, said, "It is a moment of great pride for the brand to be recognised by the largest consumer-voted award – 'Product of the Year' for our range of BMRs as it reflects the trust our consumers have in this unique concept that comes as a solution to them. Over the years, Haier has continually invested to make design and technology enhancements in the Bottom Mounted Refrigerator – keeping in mind the changing requirements of a modern homemaker."

The new Haier Bottom Mounted refrigerator is a revolutionary product, which caters to modern households, meticulously designed considering the Indian requirements and usage of the refrigerator and freezer compartments. ■

Emerson releases tool that helps limit CO_2 emissions

Emerson Climate Technologies has released its Life Cycle Climate Performance (LCCP), an online calculator for supermarket designers and engineers. This is a web-based tool that allows users to compare different supermarket system architectures with various refrigerants. It calculates annual power, total annual CO_2 emissions and peak power, and is also able to provide recommendations to users.

"The LCCP software will be a valuable tool for supermarkets interested in limiting their CO_2 footprint and will be able to provide an apples-to-apples comparison on the environmental impact of a given supermarket system," said Mike Saunders, Director, End User Technical Sales and Support, Emerson Climate Technologies.The configurable tool allows the user to enter operating conditions in which to compare. Multiple system types can be analysed, including centralised direct expansion, distributed, cascade, secondary and booster CO_2. Refrigerant comparison can be made among R404A, R407A, R410A, R134a and CO_2. ■

Getting a Handle on 'Your' Overhead

The practical method recognises the weakness of the 'Guess Method' and the impractical aspect of the 'Proper Method' while maximising profitability and reducing errors or omissions...

Did you know that the Small Business Administration (SBA) estimates that Restaurants have the highest failure rate of all businesses? Did you know that HVAC contractors run a very close second? Restaurants might fail because of lack of sales, after all there are simply so many of them. But did you know that HVAC contractors typically fail in the year of their greatest (sales) revenue? That is right! They typically fail when they experience their greatest sales (or income). Now while I know this to be a statement of fact, I believe the reason is because HVAC contractors do not typically capture all of their costs in their selling price.

The guess method

Think about the last job (estimate) that you figured for a replacement system. If you are like the typical HVAC contractors, you simply thought back to the last job like this one and tried to remember how it went. Maybe it took a little longer than you thought it should – so you add a couple of dollars more and give the homeowner a price. After all, the homeowner is not going to wait around while you get your equipment costs, estimate your labour, add in overhead, a profit and possibly commission. They want to know the 'bottom line,' and they want to know it right now!

Let us look at this approach a little closer. Did you actually check the last similar job to see how well you did? Do you actually have a way of checking completed jobs to see if you recouped your over head or made a profit?

Most contractors do not have a system in place to accomplish this, but when I demonstrate how easy it really is to my clients, they are amazed. One program I offer shows what they should make before the job is even started and then compares that with what is actually made upon completion of the job. Now that is running your business instead of your business running you.

The proper method

To properly price an estimate for a homeowner, you need the following:

- Equipment & Material Costs
- Your Labor Estimate
- Your Overhead
- Your Desired Profit
- Commission

All of these items are required to obtain a selling price. You should have no trouble with equipment or material costs after all you could call your supplier and get the costs. Now labour is something else. You are always estimating your labour costs on how long you think it will take to complete the installation, or how many hours at your

Combined Replacement Pricing (ABC Htg & AC)					
AC Units w/"A" Coil	**Ultra High Efficiency**	**Super High Effiency**	**High Efficiency**	**Standard Efficiency**	
1. 1/2 Ton	$ 0	$ 0	$ 2,960	$ 2,187	Does Not Include Stat
2. Ton	$ 4,673	$ 3,655	$ 3,057	$ 2,223	
2. 1/2 Ton	$ 0	$ 4,072	$ 3,409	$ 2,392	
3. Ton	$ 5,220	$ 4,291	$ 3,578	$ 2,500	
3. 1/2 Ton	$ 0	$ 4,769	$ 3,942	$ 2,754	
4. Ton	$ 5,756	$ 5,183	$ 4,292	$ 2,886	
5. Ton	$ 6,112	$ 5,670	$ 4,716	$ 3,329	
Remove and re-install down flow furnace for AC Installation				601-D	$ 842
Air Handlers w/Coil (Does not include Stat or Electric Heaters)					
1. 1/2 - 2 Ton	$ 2,117	$ 1,917	$ 1,241	$ 852	
2. 1/2 - 3 Ton	$ 2,277	$ 2,060	$ 1,362	$ 972	
3. 1/2 - 4 Ton	$ 2,535	$ 2,290	$ 1,641	$ 1,293	
5. Ton	$ 2,755	$ 2,488	$ 1,847	$ 1,508	
Thermostats: Intelligent Stat			$ 410		
Programmable Stat	$ 313	Digital Stat	$ 211	Standard Stat	$ 133
Electric Htrs 10 KW	$ 170	15 KW	$ 189	20 KW	$ 225
Indoor Air Quality Package	Best	Better	Good	Standard	w/New System
	$ 1,957	$ 1,498	$ 957	$ 407	
Indoor Air Quality Items					
24 Volt Electronic Air Ceaner		$ 611	Power Humidifier		$ 860
UV Light		$ 885	Outside Air Intake		$ 276
Media Filter		$ 315	By-Pass Humidifier		$ 722
Additional Installation Considerations				Element #	Price
New drain pan with trap and overflow switch				603	$ 241
Cat walk/Service Platform in Attic				605	$ 320
Provide & Install New Disconnect & Whip				607	$ 90
Service Light in Attic/Crawl w/new 115 Volt Circuit				609	$ 233
Install New Line Set **per foot**				611	$ 6
Install Condensate Pump & Drain line				610	$ 155
Up to 40 AMP electric circuit 230 Volts **per foot**				623	$ 15
Up to 60 AMP electric circuit 230 Volts **per foot**				624	$ 22
Line set cover -One Story (specify White or Brown)				625	$ 93

employee's labour rate. But did you check your "OVERHEAD" and include that, and did you actually include your desired profit and commission? Yes! I know that this would not be practical to accomplish while right in front of the home owner – but it is the proper way.

The practical method

The practical method recognises the weakness of the 'Guess Method' and the impractical aspect of the 'Proper Method' while maximising profitability and reducing errors or omissions. The 'Practical Method' uses a price sheet or 'Price Book' that has already included equipment and material costs, labour estimates, overhead, profit and commission. All of the preceding items are fixed costs with the exception of the labour estimate.

Overhead can also be considered as a fixed cost or adjusted annually. The real issue is that most contractors do not know where to find it or how to calculate it...

Let us face facts about the labour estimate; most installations are not that different, to install an AC basically requires the same labour if it is a three 3 or 5 ton or a 13 or 16 SEER. Yes! There might be some additional labour for a programmable thermostat or whatever. But, it is a simple matter of including it on your price sheet. The point is, you will not forget it when you give the homeowner the price. I realise that there are some differences, like a longer line set or a new pad – but that can be listed as additional items on your price sheet (sample beside).

There is an additional 'BONUS,' when using a printed price sheet, creditability! 'Getting a Handle on Your Overhead' If you accept the 'Practical Method', you are well on your way to not participating in the high failure rate of many HVAC contractors. However, as I stated in the opening, the main reason for failure is having not including all your costs. Equipment and material are relatively fixed costs, labour estimates are variable but now you know how to incorporate them in your price sheet (Book), profit and commission are also relatively fixed costs.

However, overhead can also be considered a fixed cost or adjusted annually. The real issue with overhead is that most contractors do not know where to find it or how to calculate it. Overhead can be found on your income statement, and then calculated as a percentage to be included in your price sheets. Now do not expect to see a line item labeled 'Overhead!' If you look at the next to last section of your income statement you will see a list of costs such as rent, utilities, postage, and on and on, this is your overhead cost. Now, simply divide the total figure by your gross revenue (or Income) and this is the percentage of overhead that must be included in all of your pricing. Example:

- Gross revenue $1,000,000.00
- Overhead cost $430,000
- Divide $430,000 by $1,000,000 = 43% overhead.

This means that 43% of any selling price must be included just as you would do for any other cost. The failure to examine and include this cost, when pricing, is what I believe to be the greatest contributing factor to the failure of HVAC contractors. So, do not become a statistician, become a more professional and profitable contractor. Use the 'Practical Method' of selling... ■

Albert Ciuffreda
Founder
Customer Choice
(A Consulting Firm)

Paul T Norman
President, Kellogg North America

"His recent work to establish the new Global Category teams, make this the right time for Paul to take the lead for North America..."

Norman's thirteen years of experience to ensure smooth transition for morning food

Paul T. Norman began his career at Kellogg Company of Great Britain. With his thirteen years of experience with global Kellogg, Norman recently served as the Chief Growth Officer of Kellogg and led the U.S. food business on an interim basis. And now, he has been selected as the President of Kellogg North America at Kellogg Company since April 2015 reporting directly to Chairman and CEO, John Bryant. "The combination of Paul's successful track record and extensive experience, including leading our U.S. morning foods and our international businesses, positions him as the ideal leader for the North America region. His recent work to establish the new Global Category teams while leading U.S. morning foods for the past several months, make this the right time for Paul to take the lead for North America" said Bryant.

Norman will be managing a portfolio of businesses within the region, including the U.S. morning foods, snacks, frozen foods, specialty channels and Canada. "With more than two decades of demonstrated experience working in general management and functional marketing leadership roles, I'm confident Craig will help return our U.S. morning foods business to sustainable growth," said Norman, who will work closely with Bahner to ensure a smooth leadership transition for U.S. morning foods. ■

Ian Gabrielides
HVAC Manager Pickerings Lifts

" I'm extremely excited by this role, and look forward to developing the business stream..."

Pickerings Lifts welcomes new HVAC manager

Pickerings Lifts North West office in Manchester will see a significant growth in Heating, Ventilation, and Air Conditioning (HVAC) business stream. The company is excited to appoint their new senior Ian Gabrielides who will be the new HVAC Manager.

Ian Bowers, Managing Director at Pickerings Lifts said, "While our core business is lift maintenance and repair, in recent years we have diversified into new business streams with a great deal of success. HVAC is a growing area for us, and presents huge potential. Without a doubt, Ian is the right person to deliver this for us, and we're extremely happy to be welcoming him to the team."

With his two years of experience at the cutting edge of the heating and cooling industry, working across both public and private sectors in a variety of senior positions, the new role will see Ian lead a multi-skilled team of engineers to help businesses across the country keep their heating, ventilation and air conditioning systems legally compliant and operationally efficient, as well as avoid costly, unplanned breakdowns and critical failures through effective maintenance regimes.

Speaking of his new role, Ian Gabrielides, said, "With 160-years of history, Pickerings Lifts has tremendous heritage, but also ambitions to continually grow and diversify in response to evolving customer demands. As such, I'm extremely excited by this role, and look forward to developing the business stream." ■

Hakan Erdamar
President Emerson Climate Technologies, Asia and Middle East

"I believe it can be a strong foundation for sustained growth in the region..."

Hakan will improve service levels to gain a higher level of growth

Erdamar Hakan (on his joining) will be supervising all operational affairs for Emerson Climate Technologies including sales, marketing, engineering R&D, production, quality management and financial operations for Asia, Middle East and Africa. Hakan has been appointed by Emerson Climate Technologies as President of Asia and Middle East.

He most recently served as Vice President, Asia Pacific, and Flow. A 15-year veteran of the Asia market, Erdamar has gained deep insights into the region's business, and will continue to drive growth opportunities and operational excellence for Emerson Climate Technologies. "I'm honoured to be appointed President of Emerson Climate Technologies, Asia and Middle East," said Erdamar.

"Emerson Climate Technologies maintains a leadership position in the heating, ventilation, air conditioning and refrigeration (HVACR) industry, and represents a significant portion of Emerson's business in this region as well. The company has a comprehensive strategy for the market, which I believe, can be a strong foundation for sustained growth in the region. My first priority is to enhance communications with our Asian and Middle East regions' customers, as well as with our employees, to explore – how we can further promote technology innovation and improve service levels to gain a higher level of growth," continued Erdamar. ■

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- Sudha Shankarnarayan, Head QA and R&D for India, Middle East & Africa, **Papa John's International**
- Arun Manjeshwar, Director – Logistics & Quality Assurance (IMC), **Roche Scientific Company (I) Pvt. Ltd.**
- Rajiv Sharma, General Manager – Supply Chain, **Panacea Biotec Ltd.**
- Prasad Deshpande, Head – Procurement, Global Supply Chain & Contract Management, **Biocon Ltd.**
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The Air Conditioning Products Market In India: Frost & Sullivan

Energy efficiency is one of the crucial factors for sustainable economic development. Energy consumption is on the rise globally and a fast-developing country like India is no different. One of the major energy consuming systems among various user segments is the Heating, Ventilation and Air Conditioning (HVAC) system. Within the HVAC systems, air conditioning products consume almost one-third of the total electricity used in a building and is the second-most electricity-guzzling equipment after lighting.

The HVAC systems' market has witnessed high growth because of steady construction sector activities. The air conditioning products market has been on a steady growth trajectory, which is proven by the change in end user's perception towards air conditioning products from being a luxury to a necessity, because of India's hot climatic conditions.

Growing concerns about the energy demand-supply gap have made companies aware about energy efficiency, and emphasize appropriate air conditioning product selection to save on energy bills.

Key demand influencers

- **Growing Urbanization:** Due to rapid urbanization, the construction industry is witnessing high growth. This has enabled the growth of commercial (office complexes, healthcare, hospitality, and retail), residential, and industrial buildings; as air conditioning products have become essential in these buildings, hence driving market growth.
- **Increase in Penetration of Green Buildings:** The growing awareness about energy saving and the environment is expected to drive the green buildings' market; which will create more opportunities for energy-efficient and environment-friendly air conditioning products.
- **Low Penetration Level of Air Conditioning Products**: The air conditioning products market (especially, in-room Air Conditioners (ACs)) was considered a luxury product, which led to low penetration levels. As customer awareness increases, it is expected to throw open huge opportunities for energy-efficient products, addressing both new and retrofit demand in the market.

Air conditioning products market overview

Other than the above mentioned demand drivers, increase in disposable incomes, high standards of living, and rising preferences for world-class infrastructure have led to the growth of the air conditioning products market in India. Air conditioning products are classified as Air Handling Units (AHU), packaged units, ducted units, fan coil units, chiller units, Variable Refrigerant Flow (VRF), Vapour Absorption Machine (VAM), ACs, and refrigeration products as showcase refrigerators (these are open type display units showcasing either chilled food items like milk, butter, etc. or frozen products like raw meat, processed food, etc.), freezers (used to store products below 0 degree Celsius), and visicoolers (used to store products in the temperature range of 2 to 8 degree Celsius). The market for air conditioning products was INR 130 Billion in 2014, and catered to the cooling needs of office complexes, industrial, healthcare, hospitality, infrastructure, retail, and residential segments.

Sales of window ACs have fallen sharply in the last two years. The recent trend is the inverter type of split ACs that consume less energy and carry a 5-star rating as compared to the 2- and 3-star non-inverter ACs...

Chiller units have proved to be the most effective way of cooling and are also efficient in saving electric power, compared to other air conditioning products, especially in the commercial and infrastructure segments. Chiller units are meant for wider application areas – and have larger cooling capacity than other air-conditioning products, typically ranging from 15-1,000 Tons of Refrigeration (TR).

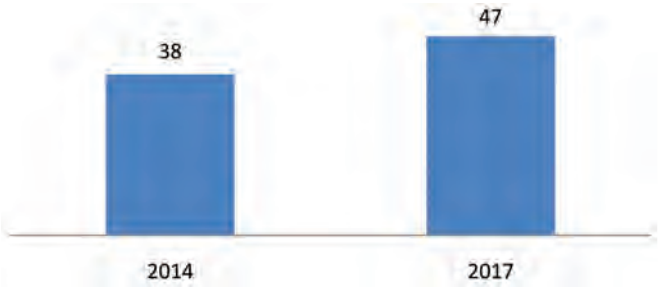
VRF, because of its energy efficiency and environment-friendly design, is gaining market share, and this segment is in the development stage. It is widely used in commercial buildings, hospitality, and premium residential segments – because of its capability to control capacity output based on load factor.

The AC segment comprises split and window ACs, but is dominated by the split ACs because of less noise and high energy efficiency. Until a few years ago, window ACs dominated the market with a share of around 40% owing to the high cost of split ACs. But now, with the shrinking price gap, sales of window ACs have fallen sharply in the last two years. The recent trend is the inverter type of split ACs that consume less energy and carry a 5-star rating as compared to the 2- and 3-star non-inverter ACs.

Opportunity hot-spots

- **Cold Chain Warehousing:** The Indian cold chain warehousing capacity was 38 Million Tonnes (MT) in 2014. Uttar Pradesh, West Bengal, Punjab, Gujarat, Bihar, Andhra Pradesh, Madhya Pradesh, Maharashtra, and Karnataka are the major locations for warehousing in India. Almost 75% of the current cold chain warehousing capacity is meant for potato storage and the remaining 25% of the space is for multi-purposes.

Growth in organised retail, processed food, pharmaceuticals, and horticulture will drive the demand for cold chain storage space in the future. Future demand for warehousing is expected to be in multi-product commodities as the rents are higher, thus margins as well.

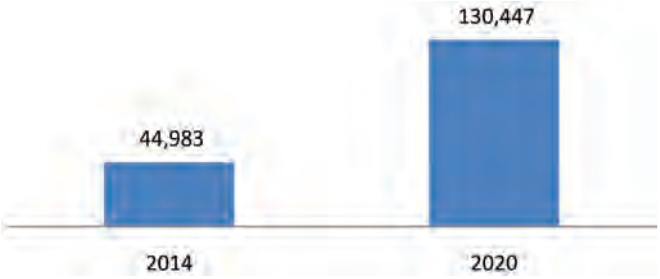


Total Cold Chain Warehousing Capacity (MT), India, 2014 and 2017

Source: The Associated Chambers of Commerce and Industry of India (ASSOCHAM)

- **Data Centres:** Data centres require massive cooling facilities and are a major market for chiller units. In India, increasing Information Technology (IT) business process outsourcing from across the globe has resulted in phenomenal growth of data centre facilities. Data centres are of two types: fixed and modular. Fixed data centres do not have flexibility to expand depending on demand, whereas modular data centres can. Data centres are meant for captive and commercial use (leasing to customer). According to Frost & Sullivan analysis, total third party data centre capacity in India is expected to touch 9.14 million square feet by 2018 as compared to 3.15 million square feet in 2012. Majority of the data centres are located in Mumbai and the National Capital Region (NCR), followed by Chennai and Bangalore.

It is essential to ensure adequate, energy efficient, on-demand cooling in a data centre, which constitutes an average of 40 to 45% of its total operating costs. Cooling in data centres is required mainly for rack and electrical equipment. The largest power consumers are IT racks, followed by air-conditioners, and then lighting systems. Precision air-conditioner technology is predominantly used in data centre applications due to its cooling and energy efficiency, low price, availability of product, service support, and low maintenance costs.



Total Demand for Chiller Units (in TR) from Data Centers, India, 2014 & 2017

Source: Frost & Sullivan Analysis

- **Residential Air Conditioning:** This segment is witnessing high growth and is backed by high disposable incomes, large base of middle-income groups, and the propensity of the young workforce or Generation Y to spend on electrical and electronic goods. Approximately 3 to 4 million ACs are sold in a year owing to the soaring summer temperatures and affordability of the product. Easy financing is supplementing the purchasing power and affordability of ACs to those who initially feared the high upfront cost. Apart from new product sales, the replacement market is driven by changing lifestyles & improving technology.

Market penetration of ACs, considering the middle- and high-income households who can afford to buy ACs, stood at 54.4% in 2014 and is expected to reach 62.3% by 2018. ACs' market penetration is way lower than other consumer durables such as washing machines, refrigerator, and air coolers. Apart from the metros, Tier II and Tier III cities such as Ahmedabad, Surat, Indore, Bhopal, Lucknow, Mysore, Vijayawada, Nagpur, Madurai, and Coimbatore would be the major growth areas in the coming days.

- Supermarkets/ Hypermarkets: India's now among the top five fastest growing markets globally for retail development. Currently, organized retail constitutes about 7 to 8% of the Indian market – but it is likely to grow much faster. As per various industry experts, it is expected to gain a significant share estimated to be about 20% by 2020. Lack of awareness about energy efficient lighting and HVAC controls hampers the market as even big retail chains often want to reduce their capital expenditure – and do not rank energy efficiency highly.

Organized sector growth is one of the key demand drivers for refrigeration and air conditioning from large stores format like hypermarkets/ supermarkets and mini markets. The proposed Foreign Direct Investment (FDI) policy in multi-brand retail, if approved, is likely to bolster retail development by attracting foreign investments. The market is expected to grow at a CAGR of about 14% during 2013 – to 2018.

Way forward

With the growing pace of commercial sectors such as offices, hotels, hospitals, and retail, the need for comfortcooling is also expected to grow. Comfort and changing lifestyles are also driving the demand for ACs in the residential segment. Likewise, if effectively tapped, precision cooling for data centres, refrigeration for retail and cold chain storage, turbine inlet air cooling and shipping, can offer promising growth for air conditioning product manufacturers and suppliers in India.

Urban planning in India is set to incorporate smart concepts and greater use of IT to monitor usage, reduce leaks/slippages, and aid in efficient delivery mechanisms through effective demand management. In this trajectory, toward building sustainable cities, district cooling – a concept prevalent in the Middle East and other developed nations in Europe – may soon find takers in India as well. One of the 7 proposed smart cities to be developed along the 1,500-kilometre long Delhi-Mumbai Corridor could be a start to test the concept of district cooling. If it succeeds in the Indian context, it can be expanded to other cities.

The bulging base of middle-class families represents an immediate opportunity to majority of Air Conditioning product manufacturers in India. It is estimated that 331 million households would be added to the middle class segment between 2010 and 2020. This economic uplift would provide buying powers to the middle class segment, which, in turn presents lucrative business opportunities. ■

Nideshna Naidu
Industry Analyst
Environment & Building Technologies Practice
Frost & Sullivan
South Asia, Middle East and North Africa

Excellent Purpose, Strategic Location And Best-In-Class Engineering

Danfoss has engineered India's first model green cold storage facility at Roshan Frozen and Cold Storage in Sonipat, Haryana. The storage owned by Sabharwal Food Industries Pvt. Ltd., is an ideal model of the next generation cold storages that India will see shortly...

India's cold chain industry is still evolving. It is not only scattered but also operating below capacity. As per ASSOCHAM reports, the Indian cold chain market is highly fragmented with more than 5000 cold storages in the whole value system. The report also indicates that temperature controlled warehouse cold chain market is expected to reach INR 624 billion by 2017 – with an approximate capacity of 46.6 MTs. However, most equipment in use is out dated and single commodity-based – contributing to the below capacity utilisation of the stores.

Growth in the organised retail and food service industry, coupled with rising export demand for processed and frozen foods have contributed towards the interest in reviving the cold storage sector. Increasing demand for improved food quality, freshness, better hygiene standards, temperature controlled delivery, and year-round availability is crucial for the food industry.

Multi-commodity cold stores, especially in areas closer to consumption centres, will be able to cater to different fruits and vegetables – depending on the supply and demand and reduce food loss. These losses cost India both in terms of food inflation and lower export volumes. For example, while 11% of world's total vegetables production is accounted by India, our share in global vegetable trade is only 1.7%.

However, this scenario stands to improve with government's efforts in reviving this sector by encouraging increased investments by providing the sector with infrastructure status – and allowing 100% FDI through the automatic route. Increasing collaboration with the private sector, and backed by NABARDs fund infusion, modernisation of existing facilities is underway – and establishment of new ventures via private and government partnerships are being considered.

Image Courtesy: Danfoss India

(L2R) K. Sabharwal, Sabharwal Food Industries (SFI); R. Purushothaman, President, Danfoss India; R. Sabharwal and Anil Sabharwal of SFI, along with F. Svane, Ambassador of Denmark to India; N. Ryan, President, Commercial Compressors, Danfoss; C. Dahlgaard, Global Marketing Director, Industrial Refrigeration, Danfoss; Rajesh Sabharwal (of SFI), during the inauguration of the Model Green Cold Storage in Sonipat, Haryana...

While it's encouraging to see the government's thrust towards making India a global sourcing hub, it is important to acknowledge the subsequent rise in urbanisation levels with the demographic shift from rural to urban – putting tremendous pressure on the state to provide for food and energy...

Image Courtesy: Danfoss India

Noel Ryan, President, Danfoss Commercial Compressors and Freddy Svane, Ambassador of Denmark to India are inaugurating the Green Cold Room in Sonipat, Haryana...

Under such circumstances in the country, cold storage company Sabharwal Food Industries teamed up with Danfoss India, a global provider of climate and energy solutions, to set up India's first 'green' cold storage model at Roshan Frozen and Cold Storage (a group company of Sabharwal Food Industries), facilitating high-quality food safety and minimal food loss from farm to consumer. This multi-commodity cold storage is yet another initiative towards bridging the demand-supply gap in the cold chain industry that has led to major food loss over the last decade abetting food inflation.

The facility

The facility is designed to European standards, and has palletised storing capability. It is equipped with material handling devices – keeping in mind the hygiene norms to minimise human intervention. In addition to ensuring superior food quality, this facility has hosted the most cost effective and energy efficient solution in the market – catering to some of India's renowned and established companies in the food retail, processed food and frozen food market like HUL, Nestle, Mother Dairy etc.

Capacity and construction

With a capacity of 5000 MT, the facility is compliant with FSSAI/ food safety norms. At this state-of-the-art facility, six vehicles can be docked at a time at the entries to the cold storage chambers. Delivery from the vehicle to the storage rooms is a sealed process, controlling the entire area and temp. to avoid food loss. Most of the functions are mechanical to ensure food safety unlike in a conventional cold room – where workers move the stocks.

The entry is swipe card controlled to minimise human contact with the food products, thereby improving the hygiene quotient in handling food. Being equipped with tracking and traceability function, the cold storage is capable of operating the cold store all-round the year with varying loads – allowing customers to stock and cater to the demand as required.

Workers' hygiene

The well-being of the workers and the environment has a high priority for Anil K Sabharwal, Director, Sabharwal Food Industries. In practice, this translates as – no uncontrolled refrigerant emissions – and for that very reason maximum welded connections have been used to couple the piping to all kind of valves and similar components.

Technology partnership

"We have been a Danfoss customer since 1996, and this facility we see today is a result of the efficient technology and people behind it. Danfoss has offered and installed their best in class controls, valves, VFDs and system manager – allowing us a seamless operation experience, and we expect energy savings of 15 to 25%. However, being a new project – we are expecting full utilisation of capacity in 6 to 9 months by when the detailed results will be known," informed Sabharwal.

Danfoss and Indian food industry

As a key enabler in the sustainable farm-to-fork process, Danfoss plays a crucial role in saving energy and operational costs in refrigeration, food processing & retail and dairy sectors across packaging, processing and transport. To cite an example, the Danfoss technology; which finds application in the Indian dairy sector with respect to refrigeration, processing and storage; helps the industry save almost 34% on milk chilling costs.

While addressing the gathering at the inaugural function, Ravichandran Purushothaman, President, Danfoss India and Chairman of CII National Task Force for Cold Chain Management, said, "Energy consumption for cold stores is highly influenced by the design criteria of the refrigerating system. Studies have revealed that 60 to 70% of the total consumed electricity in cold stores is used for the refrigeration plant. We have closely worked with customers in India and have engineered innovative solution that helps companies like Sabharwal Food Industries cut down their OPEX by 20% with energy efficient solutions. This has not only just direct benefit to cold storage owners but also it helps farmers to maintain right storage conditions – and reduces weight losses for produces – thereby increasing their pricing realisation."

Danfoss' solutions in this project

Customised solutions by Danfoss ranging from VFDs to industrial refrigeration applications – like valves and electronic controllers (such as liquid level & defrost controllers, pulse & extension modules) among others have been instrumental in realising this green cold room.

Working philosophy

Danfoss India aims at lowering the negative impact of energy consumption on the environment. It believes that energy efficiency as an alternate fuel can help achieve the desired levels of sustainability across industries.

"Danfoss applications, globally, have helped the food retail industry lower their OPEX considerably and further profitability. In India, while energy costs are not as high due to the differentiated energy policies, capital costs are among the highest. So, while it's encouraging to see the government's thrust towards making India a global sourcing hub, it is important to acknowledge the subsequent rise in urbanisation levels with the demographic shift from rural to urban – putting tremendous pressure on the state to provide for food and energy. In light of this, it is important that concerted efforts are made by the private sector in collaboration with the govt – to ensure that the country reaches a certain level of self-sufficiency with respect to its own energy requirements," said Noel Ryan, President, Danfoss Commercial Compressors. ■

Sandeep Das
Director, Strategy and Business Development
Intertek, South Asia

"We Need To Understand The Market Opportunity…"

***Intertek** is a wellknown quality solutions provider to industries worldwide. The company adds value to its customers by helping improve the quality and safety of their products, assets and processes. It supports companies by facilitating their efforts for testing, inspection, certification, auditing, outsourcing, advisory, training and quality assurance. In an exclusive interview with **Cooling India**, during ACREX 2015, **Sandeep Das, Director, Strategy and Business Development, Intertek, South Asia** talks about the company's plans for India. Excerpts…*

Q How important is participation in events and have you participated in other events also besides ACREX 2015 here in Bangalore?

A We feel that participation in such shows is of extreme value. We have participated in ACREX before. Last year, we were one of the key sponsors and this year we are exhibitor. Apart from ACREX, we also participated in the TDE show, ELECRAMA and the renewable energy show. We have also been part of a few conferences. I do believe that trade shows – such as ACREX are very effective, as not only do we meet our existing customers but we also get to reach out to potential customers. These platforms are very crucial for us as they help in exchange of ideas and build better relationships.

Q What does the certification mark stand for?

A The certification signifies that the products perform on safety and performance parameters, based on some standards, which the certification mark represents. Different countries in the world follow diverse marks and certifications; therefore there is a need of a set standard for quality that can be accepted globally. The product needs the quality that would meet the customer's satisfaction.

The industry is huge and we believe this is just the beginning for us in India. We aim to be the most accepted company and become the preferred partner for those seeking quality solutions and certification in South Asia.

Q Where are Intertek's testing labs situated in India?

A We are situated across the country, and we have about 20 labs situated in India. Specifically for the electrical market, we have three labs in Delhi, Mumbai and Bangalore. For HVAC sector we have a lab in Delhi which had been setup for partnering Bureau of Energy Efficiency (BEE) around 2004.Without a lab there can be no certification programme. So in any sector, if you want to say 'Make in India' you will have to underpin that to quality. India's manufactured product has to compete with products made in developed nations. So, if you have to compete on the bases of quality, quality needs to be seen as an investment and not as expenditure. We can see innovations in this segment with the government's intervention.

Q 'Make in India' is an entirely different concept from 'Made in India.' What is your priority for certification?

A 'Make in India' is a campaign to invite companies to manufacture their goods in India. Once these goods have been manufactured, they are called as 'Made in India.'

As of today there is a mix of certification for manufacturers, who want to export and for those who manufacture for the

domestic market. There isn't a lot of regulation for people who want to make in India, and this really needs to change. Currently with the new BIS scheme for IT and AV, any IT/AV manufacturer who wants to sell its products in India needs to test its products for safety on Indian soil.

All the globally renowned brands have their own certification marks, but if they want to sell their product in India, they need to ensure that their products comply with the specific standards and testing norms set up by DeitY.

Today, we are talking about IT/AV, tomorrow the government is going to extend it to other product categories that are manufactured in India – either for export or for the domestic market. For 'Make in India' to take root, the domestic manufacturing sector has to embrace quality not as a liability but as a weapon. This will take shape only when the government mandates minimum quality standards.

Q Do you have some standard certification marks like CE, ISI?

A Intertek's commitment to the electronic and electrical sector has a very strong legacy, because the company started with the lab of Thomas Alva Edison, the father of the electric bulb. Edison Testing Lab., or Electrical Testing Lab., as it was known at that point of time evolved into the ETL (Electrical Testing Lab.) mark. The ETL mark of testing that emanated from his lab., is one of the two important marks for the export of products to the US. Similarly, there is CRS and ASTA in the UK and the GS mark in EU.

When IT/AV products are registered under the BIS, it means that the product has conformed to the specifications and has been tested on the Indian soil. Going forward, the domestic manufacturers will also have to get the BIS mark – for their products ensuring that the product functions the way it is supposed to.

WE AIM TO BE THE PREFERRED PARTNER FOR THOSE SEEKING QUALITY SOLUTIONS AND CERTIFICATION IN SOUTH ASIA...

Q How will your standardisation help in the 'Make in India' campaign, and which sectors are you going to target?

A The 'Make in India' campaign will involve manufacturing work for domestic as well as the export market. For the export market, Indian manufacturers are competing with the manufacturers in other countries, and they all have to go through the stringent quality procedures, checks and balances – and all the certification processes. One cannot compete unless you adopt the same approach.

Today in our country, there is a lot more spending on power, and a huge amount of awareness. The younger generation of these days questions the quality of products whether they are manufactured in India or in any other country. The psychology has changed and demand for the best has increased.

Q Who all are your competitors in this area?

A For the electrical segment, Underwriters Laboratory (UL) is our largest competitor. Otherwise, for the general quality services industry, there are two large competitors – SGS and BureauVeritas.

Q Finally, what should be your contribution for the electrical sector?

A HVAC&R is going to be a major focus area for us. If you tabulate the energy consumption at home, HVAC&R has a huge amount of contribution. In future, there is going to be a lot of guidance and mandates from the government in terms of pushing it to be a more efficient group. Even now, there is a talk that the government is introducing a new standard called the Indian Chiller Standard, this is for energy efficiency in the commercial air-conditioning sector. Whatever the government does, we support them by providing them with the testing package.

From domestic air-conditioning testing, we are venturing into commercial air conditioning testing. For Intertek there is going to be an increase in operations on HVAC, but we are also looking at a major movement towards the commercial aspect. The domestic sector is already regulated because of the star rating. Across the globe, we have worked with agencies to regulate these industries and we want to bring that global knowledge to India and partner with the government.

Q What is your vision in the next four years?

A Our vision over the next four years is to significantly grow our business. We will deploy both organic and inorganic routes to increase our scale in this market, and our market process. We need to understand the market opportunity in the overall set up – and deploy our resources. The idea is to invest heavily in India, be it in terms of capability building or in terms of capability buying – and gain market position by the turn of the decade. We hope that over the next few years we will be market leaders in quality services and will be able to deliver best at our end. ■

Embracing Intelligent Green Technology

The maintenance free EnOcean based sensor solution offers significant advantages to the Indian branch office of FirstRand Bank…

A view from outside of the FirstRand Bank's office in Mumbai…

In the scope of an international expansion strategy, the South African FirstRand Bank identified India as an important market for future economic growth – and opened a new branch in India. The FirstRand Bank is the first South African bank to be represented in India further to receiving their commercial bank license from the Indian government.

The bank occupies 6000 square metres – spread over three floors at the newly constructed TCG financial administrative building in the centre of Mumbai. FirstRand Bank appointed Sara Interiors as the architect for their modern office design.

The challenge

The challenge was to achieve optimum energy savings, whilst remaining cost effective and flexible to the future alterations of the office layout. The investors decided to use a modern building automation system and appointed 'Energy Automation' as the system integrator to equip the rooms with the energy efficient 'EnOcean' based technology from Thermokon.

The solution

The wireless transmitters and receivers of the 'EasySens' product line, which operate without batteries or wires or an external power supply, enable a smart control of heating, cooling, ventilation, lighting and CO_2 levels using energy harvesting technology.

'Thanos' the multi-functional room operating panel, is installed on the executive floor is a state-of-the-art design and a highlight of this modern building. 'Thanos' acts as a control centre and detects the current room temperature and humidity – as well as control the light and blind control.

The wireless transmitters and receivers of the 'EasySens' product line, which operate without batteries or wires or an external power supply, enable a smart control of heating, cooling, ventilation, lighting and CO_2 levels using energy harvesting technology…

Wireless temperature sensors model SR04 with an integrated solar cell are installed in the employees' offices for the room temperature set point adjustment...

Wireless temperature sensors model SR04 with an integrated solar cell are installed in the employees' offices for the room temperature set point adjustment.

Occupancy detection for an energy efficient lighting control is achieved by the wireless motion sensor SR-SDS.

Conventional light switches have been replaced by the wireless 'EasySens' switches (based on EnOcean Motion technology) that send a wireless telegram by means of a simple mechanical switch.

To achieve an optimal network of all manufacturers, a wireless EnOcean based Thermokon gateway is used to convert the RF telegrams into a RS485 signal.

The SAIA controller provides a centralised control, and enables the intelligence of the complete system onto a special communications bus of both KNX and S-Bus.

The advantages

The maintenance free EnOcean based sensor solution offered significant advantages – such as reduced installation costs due to less installation time and no cabling costs. Also, flexibility of the mounting positions of the sensors and gateways provided an attractive design of the interior architecture and flexibility for future changes.

A low investment, a considerable energy cost saving of approx 40% provides an environmentally friendly infrastructure. ■

Refrigeration technology for any application

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As a leading manufacturer of components for refrigeration engineering and air conditioning, Güntner provides qualified technical assistance and personal support from the beginning. Different products must be cooled and stored in commercial cooling. This makes high demands on selecting the right air cooler.

Güntner offers a wide range of heat exchangers for all application areas, which are suitable for all current coolants and refrigerants. Our competent employees advise you with professional Güntner know-how by phone and in person on site.

Office Building Earns LEED Platinum Designation

The San Diego office building of LPL Financial LLC is believed to be the largest net-zero energy commercial office building in the US. Typical floors, within the 13-story 415,000-square-foot office, reflect the commitment to wellness and sustainability by providing an abundance of natural light, sit-to-stand workstations and individual thermal controls at each workspace…

US Green Building Council (USGBC), which recognises the best-in-class building strategies and practices in green buildings, offers LEED certification. As per USGBC, "Leaders across the globe have made LEED the most widely used green building rating system in the world with 1.7 million square feet of construction space certifying every day. LEED certification provides independent verification of a building or neighborhood's green features, allowing for the design, construction, operations and maintenance of resource-efficient, high-performing, healthy, cost-effective buildings. LEED is the triple bottom line in action, benefiting people, planet and profit."

Also, "LEED certification means healthier, more productive places, reduced stress on the environment by encouraging energy and resource-efficient buildings, and savings from increased building value, higher lease rates and decreased utility costs. In fact, 88 of the Fortune 100 companies are already using LEED," as staed by USGBC.

LPL Financial LLC, the USA's largest independent broker-dealer (As reported by Financial Planning magazine, June 1996 - 2014, based on total revenue), a top RIA (Registered Investment Advisor) custodian, and a wholly owned subsidiary of LPL Financial Holdings Inc., maintains an office in San Diego. The office building has recently earned the LEED Platinum certification for its interior design and construction. Platinum is the highest level of certification possible from LEED, or Leadership in Energy & Environmental Design.

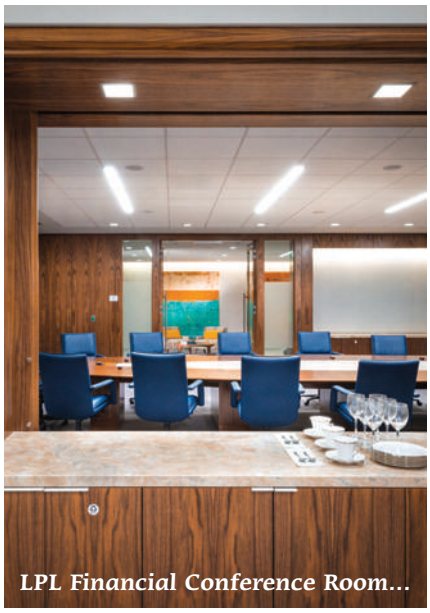
"We are proud to have received this designation for our San Diego office building. From the start of this project, we committed to leveraging technology

LPL Financial Lobby...

LPL Financial Lounge...

LPL Financial Open Office...

LPL Financial Fitness...


LPL Financial Conference Room...

LPL Financial Reception...

The design strategies were shaped from early consulting work, which included metrics pulled from seat sensor studies, surveys and focus group workshops...

LPL Financial Servery...

All Images Courtesy: Gensler

and advanced materials to minimise our impact on the environment, while creating a positive work environment for our employees. The result is an innovative workspace that has become a source of pride for LPL, the San Diego community and the more than 1,600 LPL employees who work here. We made an investment in our employees when we created this building, understanding that by being an employer of choice to the top talent in our industry, we can continue to be the leading service provider to our clients,"says Mark Casady, LPL Chairman and CEO.

Highlights from the LEED scorecard include:

- 39.04% reduction in potable water use
- 100% and 71.82% reductions in site landscaping and irrigation systems potable water usage for irrigation and total water usage for irrigation, respectively
- 52.46% reduction in lighting power density from that allowed by code
- 87.25% of the project's connected lighting load installed with occupancy sensors
- 77.68% of the on-site generated construction waste diverted from landfill
- 19.41% of the total building materials content, by value, that has been manufactured using recycled materials
- 67.62% of the wood-based building materials that are certified in accordance with the principles and criteria of the Forest Stewardship Council (FSC)
- 94.55% of occupants with lighting controls enabled to be able to make adjustments to suit individual task needs and preferences
- 99.56% of the tenant occupants with enabled thermal controls to be able to make adjustments to suit individual needs and preferences
- 94.83% of all regularly occupied spaces with direct line of sight views to the outdoors

"We approached LPL's San Diego tower as an opportunity to usher in a new era of workplace innovation that enhanced the user experience while reinforcing the firm's commitment to wellness and sustainability. Our design strategy centered on creating an agile, adaptable work environment that sets the standard in San Diego for performance, wellbeing and efficiency," says Shawn Davidson Dixon, Design Director at Gensler, the interior architect for the building.

"We thank Gensler for their commitment to excellence on the interior design. They truly pushed the envelope and delivered a workspace that demonstrates our values as a socially responsible company," says Casady.

The design strategies were shaped from early consulting work, which included metrics pulled from seat sensor studies, surveys and focus group workshops with employees at all levels, according to Dixon. Typical floors within the 13-story 415,000-square-foot office reflect the commitment to wellness and sustainability by providing an abundance of natural light, sit-to-stand workstations and individual thermal controls at each workspace.

In addition, the building includes a health clinic, fitness centre, cafeteria and outdoor amenities, some of which are branded to share health and sustainability facts that promote healthy choices. In addition, employees champion a sustainable workplace through employee education on recycling, onsite composting and carpooling. ■

Thermoelectric Cooling

Many researchers and companies are trying to develop Peltier coolers that are both cheap and efficient. A Peltier cooler can also be used as a thermoelectric generator...

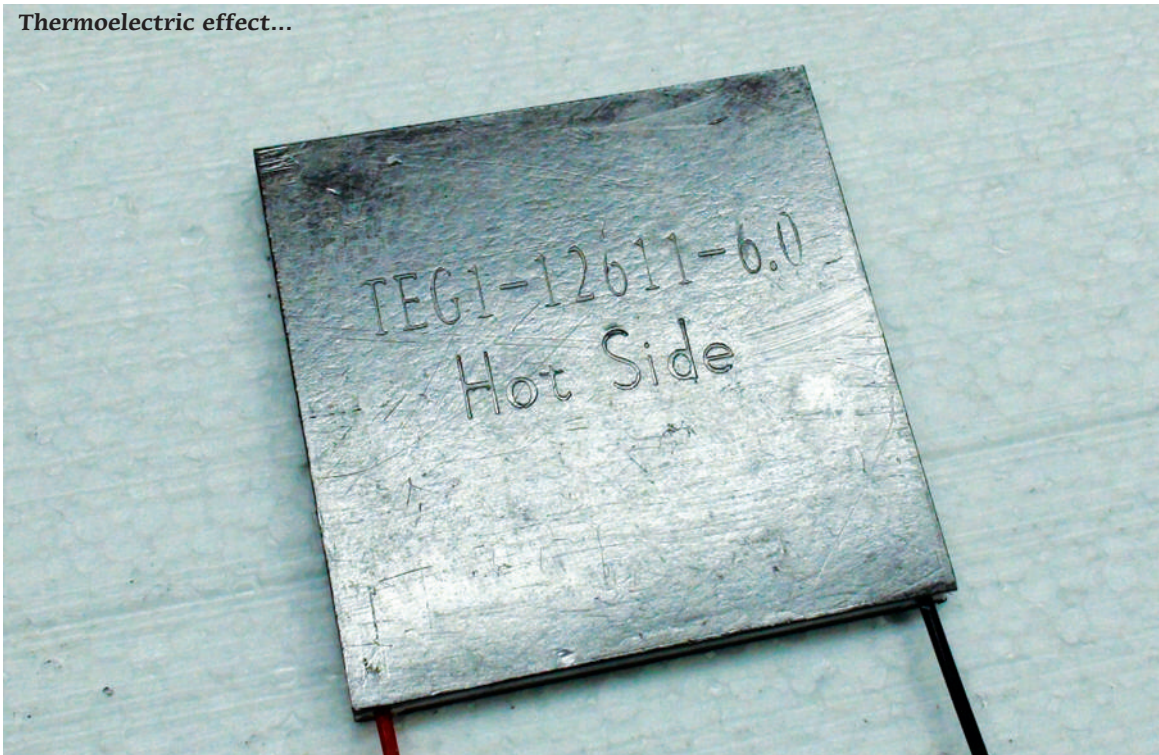
Thermoelectric cooling uses the Peltier effect to create a heat flux between the junction of two different types of materials. A Peltier cooler, heater, or thermoelectric heat pump is a solid-state active heat pump that transfers heat from one side of the device to the other, with consumption of electrical energy, depending on the direction of the current.

Such an instrument is also called a Peltier device, Peltier heat pump, solid state refrigerator, or Thermoelectric Cooler (TEC). It can be used either for heating or for cooling, although in practice the main application is cooling. It can also be used as a temperature controller that either heats or cools.

This technology is far less commonly applied to refrigeration than vapour-compression refrigeration is. The primary advantages of a Peltier cooler compared to a vapour-compression refrigerator are its lack of moving parts or circulating liquid, very long life and invulnerability to potential leaks, and its small size and flexible shape. Its main disadvantage is high cost and poor power efficiency. Many researchers and companies are trying to develop Peltier coolers that are both cheap and efficient.

A Peltier cooler can also be used as a thermoelectric generator. When operated as a cooler, a voltage is applied across the device, and as a result, a difference in temperature will build up between the two sides. When operated as a generator, one side of the device is heated to a temperature greater than the other side, and as a result, a difference in voltage will build up between the two sides (the Seebeck effect). However, a well-designed Peltier cooler will be a mediocre thermoelectric generator and vice versa, due to different design and packaging requirements.

Thermoelectric effect...



Thermoelectric effect

This article is about the thermoelectric effect as a physical phenomenon. For applications of the thermoelectric effect, see thermoelectric materials and thermoelectric cooling. The thermoelectric effect is the direct conversion of temperature differences to electric voltage and vice versa. A thermoelectric device creates voltage when there is a difference in temperature between the two sides. Conversely, when a voltage is applied to it, it creates a temperature difference. At the atomic scale, an applied temperature gradient causes charge carriers in the material to diffuse from the hot side to the cold side.

This effect can be used to generate electricity, measure temperature or change the temperature of objects. Because the direction of heating and cooling is determined by the polarity of the applied voltage, thermoelectric devices can be used as temperature controllers.

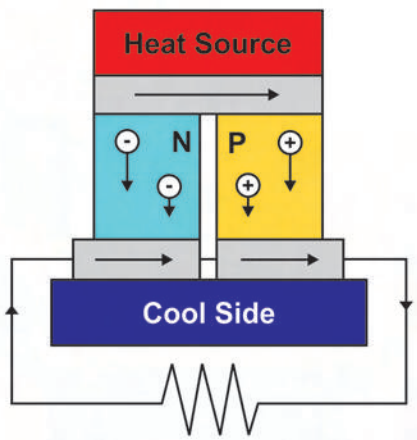
The term 'thermoelectric effect' encompasses three separately identified effects: the Seebeck effect, Peltier effect, and Thomson effect. Textbooks may refer to it as the Peltier–Seebeck effect. This separation derives from the independent discoveries of French physicist Jean Charles Athanase Peltier and Baltic German physicist Thomas Johann Seebeck. Joule heating, the heat that is generated whenever a current is passed through a resistive material, is related, though it is not generally termed a thermoelectric effect. The Peltier–Seebeck and Thomson effects are thermodynamically reversible, whereas Joule heating is not.

Seebeck effect

A thermoelectric circuit composed of materials of different Seebeck coefficients (p-doped and n-doped semiconductors), configured as a thermoelectric generator. If the load resistor at the bottom is replaced with a voltmeter, the circuit then functions as a temperature-sensing thermocouple.

Seebeck, in 1821, discovered that a compass needle would be deflected by a closed loop formed by two different metals joined in two places, with a temperature difference between the junctions. This was because the metals responded to the temperature difference in different ways, creating a current loop and a magnetic field. Seebeck did not recognise that there was an electric current involved, so he called the phenomenon the thermomagnetic effect. Danish physicist Hans Christian Ørsted rectified the mistake & coined the term 'thermoelectricity.'

The thermoelectric effect is the direct conversion of temperature differences to electric voltage and vice versa. A thermoelectric device creates voltage when there is a difference in temperature between the two sides...emperature difference. At the atomic scale, an applied temperature gradient causes charge carriers in the material to diffuse from the hot side to the cold side...



A phenomenon in which a temperature difference between two dissimilar electrical conductors or semiconductors produces a voltage difference between the two substances...

The Seebeck effect is a classic example of an Electromotive Force (EMF), and leads to measurable currents or voltages in the same way as any other EMF. Electromotive forces modify Ohm's law by generating currents even in the absence of voltage differences (or vice versa); the local current density is given by

$$J = \sigma(-\nabla V + E_{emf})$$

where V is the local voltage and σ is the local conductivity. In general, the Seebeck effect is described locally by the creation of an electromotive field

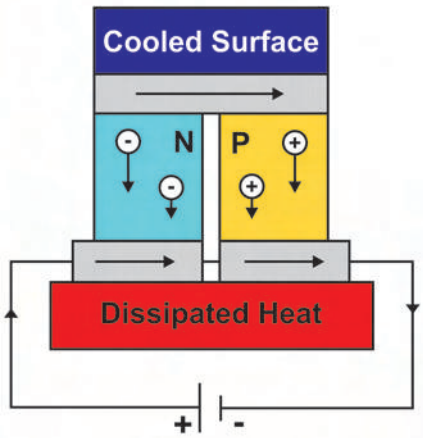
$$E_{emf} = -S\nabla T$$

where S is the Seebeck coefficient (also known as thermopower), a property of the local material, and ∇T is the gradient in temperature T.

The Seebeck coefficients generally vary as function of temperature, and depend strongly on the composition of the conductor. For ordinary materials at room temperature, the Seebeck coefficient may range in value from $-100\ \mu V/K$ to $+1{,}000\ \mu V/K$

If the system reaches a steady state where $J=0$, then the voltage gradient is given simply by the emf: $-\nabla V = S\nabla T$. This simple relationship, which does not depend on conductivity, is used in the thermocouple to measure a temperature difference; an absolute temperature may be found by performing the voltage measurement at a known reference temperature. A metal of unknown composition can be classified by its thermoelectric effect, if a metallic probe of known composition is kept at a constant temperature – and held in contact with the unknown sample that is locally heated to the probe temperature. It is used commercially to identify metal alloys. Thermocouples in series form a thermopile. Thermoelectric generators are used for creating power from heat differentials.

Peltier effect



The Seebeck circuit configured as a thermoelectric cooler...

The Peltier effect is the presence of heating or cooling at an electrified junction of two different conductors and is named after French physicist Jean Charles Athanase Peltier, who discovered it in 1834. When a current is made to flow through a junction between two conductors A and B, heat may be generated (or removed) at the junction. The Peltier heat

generated at the junction per unit time, Q, is equal to

$$\dot{Q} = (\Pi_A - \Pi_B)I$$

where Π_A (Π_B) is the Peltier coefficient of conductor A (B), & I is the electric current (from A to B). Note that the total heat generated at the junction is not determined by the Peltier effect alone, as it may also be influenced by Joule heating and thermal gradient effects (see next).

The Peltier coefficients represent how much heat is carried per unit charge. Since charge current must be continuous across a junction, the associated heat flow will develop a discontinuity if Π_A and Π_B are different. The Peltier effect can be considered as the back-action counterpart to the Seebeck effect (analogous to the back-emf in magnetic induction): if a simple thermoelectric circuit is closed then the Seebeck effect will drive a current, which in turn (via the Peltier effect) will always transfer heat from the hot to the cold junction. The close relationship between Peltier and Seebeck effects can be seen in the direct connection between their coefficients: $\Pi=TS$ (see next).

A typical Peltier heat pump device involves multiple junctions in series, through which a current is driven. Some of the junctions lose heat due to the Peltier effect, while others gain heat. Thermoelectric heat pumps exploit this phenomenon, as do thermoelectric cooling devices found in refrigerators.

Thomson effect

In many materials, the Seebeck coefficient is not constant in temperature, and so a spatial gradient in temperature can result in a gradient in the Seebeck coefficient. If a current is driven through this gradient then a continuous version of the Peltier effect will occur. This Thomson effect was predicted and subsequently observed by Lord Kelvin in 1851. It describes the heating or cooling of a current-carrying conductor with a temperature gradient.

If a current density J is passed through a homogeneous conductor, the Thomson effect predicts a heat production rate q per unit volume of:

$$\dot{q} = -KJ.\nabla T$$

where ∇T is the temperature gradient and K is the Thomson coefficient. The Thomson coefficient is related to the Seebeck coefficient as $K=T\ dS/dT$ (see next). This equation however neglects Joule heating, and ordinary thermal conductivity (see full equations next).

Full thermoelectric equations

Often, more than one of the above effects is involved in the operation of a real thermoelectric device. The Seebeck effect, Peltier effect, and Thomson effect can be gathered together in a consistent and rigorous way, described here; the effects of Joule heating and ordinary heat conduction are included as well. As stated above, the Seebeck effect generates an electromotive force, leading to the current equation.

$$J = \sigma(-\nabla V - S\nabla T)$$

To describe the Peltier and Thomson effects, we must consider the flow of energy. To start we can consider the dynamic case – where both temperature and charge may be varying with time. The full thermoelectric equation for the energy accumulation, e is

$$\dot{e} = \nabla.(k\nabla T) - \nabla.(V + \Pi)J + \dot{q}_{ext}$$

where k is the thermal conductivity. The first term is the Fourier's heat conduction law, and the second term shows the energy carried by currents. The third term q_{ext} is the heat added from an external source (if applicable).

In the case where the material has reached a steady state, the charge and temperature distributions are stable so one must have both $e = 0$ and $\nabla.J = 0$ Using these facts and the second Thomson relation (see below), the heat equation then can be simplified to

$$-\dot{q}_{ext} = \nabla.(k\nabla T) + J.(\sigma^{-1}J) - TJ.\nabla S$$

The middle term is the Joule heating, and the last term includes both Peltier (∇S at junction) & Thomson (∇S in thermal gradient) effects. Combined with the Seebeck equation for J, this can be used to solve for the steady state voltage and temperature profiles in a complicated system.

If the material is not in a steady state, a complete description will also need to include dynamic effects such as relating to electrical capacitance, inductance and heat capacity.

Thomson relations

In 1854, Lord Kelvin found relationships between the three coefficients, implying that the Thomson, Peltier, and Seebeck effects are different manifestations of one effect (uniquely characterised by the Seebeck coefficient).

The first Thomson relation is

$$K \equiv \frac{d\Pi}{dT} - S$$

where T is the absolute temperature, K is the Thomson coefficient, Π is the Peltier coefficient, and S is the Seebeck coefficient. This relationship is easily shown given that the Thomson effect is a continuous version of the Peltier effect. Using the second relation (described next), the first Thomson relation becomes

$$K = T\frac{dS}{dT}$$

The second Thomson relation is

$$\Pi = TS$$

This relation expresses a subtle and fundamental connection between the Peltier and Seebeck effects. It was not satisfactorily proven until the advent of the Onsager relations, and it is worth noting that this second Thomson relation is only guaranteed for a time-reversal symmetric material; if the material is placed in a magnetic field, or is itself magnetically ordered (ferromagnetic, antiferromagnetic, etc.), then the second Thomson relation does not take the simple form shown above.

The Thomson coefficient is unique among the three main thermoelectric coefficients because it is the only one directly measurable for individual materials. The Peltier and Seebeck coefficients can only be easily determined for pairs of materials; hence, it is difficult to find values of absolute Seebeck or Peltier coefficients for an individual material.

If the Thomson coefficient of a material is measured over a wide temperature range, it can be integrated using the Thomson relations to determine the absolute values for the Peltier and Seebeck coefficients.

This needs to be done only for one material, since the other values can be determined by measuring pairwise Seebeck coefficients in thermocouples containing the reference material and then adding back the absolute Seebeck coefficient of the reference material. (for more details on absolute Seebeck coefficient determination, see Seebeck coefficient)

Applications

Thermoelectric generators

The Seebeck effect is used in thermoelectric generators, which function like heat engines,

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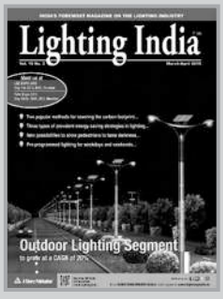

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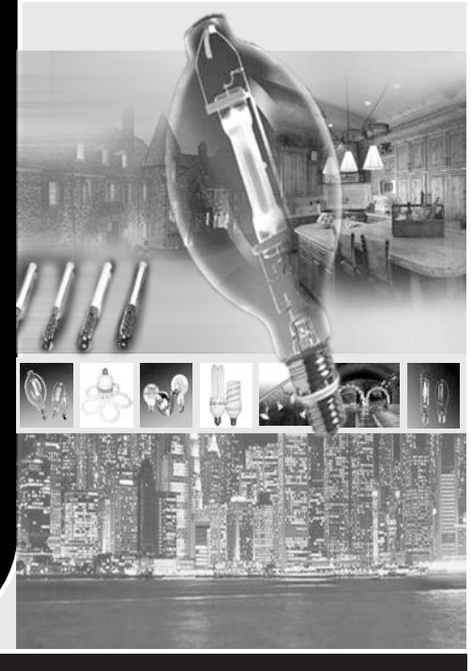


but are less bulky, have no moving parts, and are typically more expensive and less efficient.

They have a use in power plants for converting waste heat into additional electrical power (a form of energy recycling) and in automobiles as automotive thermoelectric generators (ATGs) for increasing fuel efficiency.

Space probes often use radioisotope thermoelectric generators with the same mechanism but using radioisotopes to generate the required heat difference.

Peltier effect

The Peltier effect can be used to create a refrigerator that is compact and has no circulating fluid or moving parts. Such refrigerators are useful in applications where their advantages outweigh the disadvantage of their very low efficiency.

Temperature measurement

Thermocouples and thermopiles are devices that use the Seebeck effect to measure the temperature difference between two objects, one connected to a voltmeter and the other to the probe.

The temperature of the voltmeter, and hence that of the material being measured by the probe, can be measured separately using cold junction compensation techniques.

Thermal cyclers for polymerase chain reaction

The Peltier effect is used by many thermal cyclers, laboratory devices used to amplify DNA by the polymerase chain reaction (PCR). PCR requires the cyclic heating and cooling of samples to specified temperatures.

The inclusion of many thermocouples in a small space enables many samples to be amplified in parallel.

Thermoelectric materials

(From Wikipedia, the free encyclopedia)

This section is about materials that are used or could be used to exploit the thermoelectric effect in practical applications. For the definition of the thermoelectric effect and its underlying physics...

Thermoelectric materials show the thermoelectric effect in a strong or convenient form. The thermoelectric effect refers to the phenomena by which either a temperature difference creates an electric potential or an electric potential creates a temperature difference. These phenomena are known more specifically as the Seebeck effect (converting temperature to current), Peltier effect (converting current to temperature), and Thomson effect (conductor heating/cooling). While all materials have a nonzero thermoelectric effect, in most materials it is too small to be useful. However, low-cost materials that have a sufficiently strong thermoelectric effect (and other required properties) could be used in applications including power generation and refrigeration.

A commonly used thermoelectric material in such applications is bismuth telluride (Bi_2Te_3).

Applications

Power generation

Approximately 90% of the world's electricity is generated by heat energy, typically operating at 30 to 40% efficiency, losing roughly 15 terawatts of power in the form of heat to the environment.

Thermoelectric devices could convert some of this waste heat into useful electricity. Thermoelectric efficiency depends on the figure of merit, ZT. There is no theoretical upper limit to ZT, and as ZT approaches infinity, the thermoelectric efficiency approaches the Carnot limit. However, no known thermoelectrics have a ZT>3. As of 2010, thermoelectric generators serve application niches – where efficiency and cost are less important than reliability, light weight and small size.

Internal combustion engines capture 20 to 25% of the energy released during fuel combustion. Increasing the conversion rate can increase mileage and provide more electricity for on-board controls and creature comforts (stability controls, telematics, navigation systems, electronic braking, etc.) It may be possible to shift energy draw from the engine (in certain cases) to the electrical load in the car, e.g., electrical power steering or electrical coolant pump operation.

Cogeneration power plants use the heat produced during electricity generation for alternative purposes. Thermoelectrics may find applications in such systems or in solar thermal energy generation.

Refrigeration

Thermoelectric materials can be used as refrigerators, called 'thermoelectric coolers', or 'Peltier coolers' after the Peltier effect that controls their operation. As a refrigeration technology, Peltier cooling is far less common than vapour-compression refrigeration.

The main advantages of a Peltier cooler (compared to a vapour-compression refrigerator) are its lack of moving parts or circulating fluid, and its small size and flexible shape (form factor). Another advantage is that Peltier coolers do not require refrigerant fluids, such as chloro fluoro carbons (CFCs) and related chemicals, which can have harmful environmental effects.

The main disadvantage of Peltier coolers is that they cannot simultaneously have low cost and high power efficiency. Advances in thermoelectric materials may allow the creation of Peltier coolers that are both cheap and efficient. It is estimated that materials with ZT>3 (about 20 to 30% Carnot efficiency) are required to replace traditional coolers in most applications. Today, Peltier coolers are only used in niche applications. Materials selection criteria

Power factor

The Seebeck coefficient is not the only number that determines the usefulness of a material in a thermoelectric generator or a thermoelectric cooler. Under a given temperature difference, the ability of a material to produce useful electrical power is quantified by its power factor,

$$\text{Power Factor} = \sigma S^2$$

where S is the Seebeck coefficient, and σ is the electrical conductivity. Materials with high power factor are able to generate more energy in a space-constrained application, but they are not necessarily efficient.

Device efficiency

The efficiency of a thermoelectric device for electricity generation is given by η, defined as

$$\eta = \frac{\text{energy provided to the load}}{\text{heat energy absorbed at hot junction}}$$

The ability of a given material to efficiently produce thermoelectric power is related to its dimensionless figure of merit given by:

$$ZT = \frac{\sigma S^2 T}{\lambda}$$

which depends on the Seebeck coefficient S, thermal conductivity λ, and electrical conductivity σ, and temperature T.

In an actual thermoelectric device, two materials are used. The maximum efficiency is then given by

$$\eta_{max} = \frac{T_H - T_C\sqrt{1+Z\overline{T}} - 1}{T_H\sqrt{1+Z\overline{T}} + \frac{T_C}{T_H}}$$

where T_H is the temperature at the hot junction and T_C is the temperature at the surface being cooled. ZT is the modified dimensionless figure of merit, which takes into consideration the thermoelectric capacity of both thermoelectric materials being used in the device and, after geometrical optimisation regarding the legs sections, is defined as

$$Z\overline{T} = \frac{(S_p - S_n)^2 \overline{T}}{[(\rho_n k_n)^{1/2} + (\rho_p k_p)^{1/2}]^2}$$

where ρ is the electrical resistivity, T is the average temperature between the hot and cold surfaces and the subscripts n and p denote properties related to the n- and p-type semiconducting thermoelectric materials, respectively. Since thermoelectric devices are heat engines, their efficiency is limited by the Carnot efficiency, hence the T_H and T_C terms in. η_{max} Regardless, the coefficient of performance of current commercial thermoelectric refrigerators ranges from 0.3 to 0.6, one-sixth the value of traditional vapor-compression refrigerators.

Phonon-glass, electron-crystal behavior

In the efficiency equations above, thermal conductivity & electrical conductivity compete. G. A. Slack proposed that in order to optimise the figure of merit, phonons, which are responsible for thermal conductivity must experience the material as they would in a glass (experiencing a high degree of phonon scattering—lowering thermal conductivity) while electrons must experience it as a crystal (experiencing very little scattering—maintaining electrical conductivity). The figure of merit can be improved through the independent adjustment of these properties.

Semiconductors

Semiconductors are ideal thermoelectric devices because of their band structure and electronic properties at high temperatures. Device efficiency is proportional to ZT, so ideal materials have a large Z value at high temperatures. Since temperature is easily adjustable, electrical conductivity is crucial. Specifically, maximizing electrical conductivity at high temperatures and minimising thermal conductivity optimizes ZT.

Thermal conductivity

$$K = K_{electron} + K_{phonon}$$

According to the Wiedemann–Franz law, the higher the electrical conductivity, the higher $K_{electron}$ becomes. Therefore, it is necessaryto minimize K_{phonon}. In semiconductors, $K_{electron} < K_{phonon}$, so it is easier to decouple K & σ in a semiconductor through engineering K_{phonon}.

Electrical conductivity

Metals are typically good electrical conductors, but the higher the temperature, the lower the conductivity. This tendency can be explained (approximately) in terms of the Drude conductivity formula:

$$\sigma = ne^2T/m$$

- n is charge carrier density
- e is charge per carrier (elementary charge)
- T is carrier mean free time between scattering events
- m is carrier mass

As temperature increases, T decreases while the other numbers stay constant, thereby decreasing σ_{metal}.

In contrast, the electrical conductivity of a semiconductor generally increases with temperature. In semiconductors, carrier mean free time decreases with increasing temperature, however carrier density increases faster with increasing temperature, resulting in increasing $\sigma_{semiconductor}$.

State density

The band structure of semiconductors offers better thermoelectric effects than the band structure of metals.

The Fermi energy is below the conduction band causing the state density to be asymmetric around the Fermi energy. Therefore, the average electron energy of the conduction band is higher than the Fermi energy, making the system conducive for charge motion into a lower energy state. By contrast, the Fermi energy lies in the conduction band in metals. This makes the state density symmetric about the Fermi energy so that the average conduction electron energy is close to the Fermi energy, reducing the forces pushing for charge transport. Therefore, semiconductors are ideal thermoelectric materials.

Materials of interest

Strategies to improve thermoelectrics include both advanced bulk materials and the use of low-dimensional systems. Such approaches to reduce lattice thermal conductivity fall under three general material types:

- **Alloys:** create point defects, vacancies, or rattling structures (heavy-ion species with large vibrational amplitudes contained within partially filled structural sites) to scatter phonons within the unit cell crystal.
- **Complex crystals:** separate the phonon-glass from the electron crystal using approaches similar to those for superconductors. The region responsible for electron transport would be an electron-crystal of a high-mobility semiconductor, while the phonon-glass would be ideal to house disordered structures and dopants without disrupting the electron-crystal (analogous to the charge reservoir in high-T_c superconductors).
- **Multiphase nanocomposites:** scatter phonons at the interfaces of nanostructured materials, be they mixed composites or thin film superlattices.

Materials under consideration for thermoelectric device applications include:

Bismuth chalcogenides and their nanostructures

Materials such as Bi_2Te_3 and $B_{i2}Se_3$ comprise some of the best performing room temperature thermoelectrics with a temperature -independent thermoelectric effect, ZT, between 0.8 and 1.0. Nanostructuring these materials to produce a layered superlattice structure of alternating Bi_2Te_3 and Sb_2Te_3 layers produces a device within which there is good electrical conductivity but perpendicular to which thermal conductivity is poor. The result is an enhanced ZT (approximately 2.4 at room temperature for p-type). Note that this high value of ZT has not entirely been independently confirmed due to the complicated demands on the growth of such superlattices and device fabrication; however the material ZT values are consistent with the performance of hot-spot coolers made out of these materials and validated at Intel Labs.

Bismuth telluride and its solid solutions are good thermoelectric materials at room temperature & therefore suitable for refrigeration applications around 300 K. The Czochralski method has been used to grow single crystalline bismuth telluride compounds. These compounds are usually obtained with directional solidification from melt or powder metallurgy processes. Materials produced with these methods have lower efficiency than single crystalline ones

due to the random orientation of crystal grains, but their mechanical properties are superior and the sensitivity to structural defects and impurities is lower due to high optimal carrier concentration.

The required carrier concentration is obtained by choosing a nonstoichiometric composition, which is achieved by introducing excess bismuth or tellurium atoms to primary melt or by dopant impurities. Some possible dopants are halogens and group IV and V atoms. Due to the small bandgap (0.16 eV) Bi_2Te_3 is partially degenerated and the corresponding Fermi-level should be close to the conduction band minimum at room temperature. The size of the band-gap means that Bi_2Te_3 has high intrinsic carrier concentration. Therefore, minority carrier conduction cannot be neglected for small stoichiometric deviations. Use of telluride compounds is limited by the toxicity and rarity of tellurium.

Lead telluride

In 2008 Joseph Heremans and his colleagues demonstrated that thallium-doped lead telluride alloy (PbTe) achieves a ZT of 1.5 at 773 K. Later, Snyder and his colleagues reported ZT∼1.4 at 750 K in sodium-doped PbTe, and ZT∼1.8 at 850 K in sodium-doped PbTe1-xSex alloy. Snyder's group determined that both thallium and sodium alter the electronic structure of the crystal increasing electric conductivity. They also claim that selenium increases electric conductivity and reduces thermal conductivity.

In 2012 another team used lead telluride to convert 15 to 20 percent of waste heat to electricity, reaching a ZT of 2.2, which they claimed was the highest yet reported.

Inorganic clathrates

Inorganic clathrates have a general formula $A_xB_yC_{46-y}$ (type I) and $A_xB_yC_{146-y}$ (type II), in these formulas B and C are group III and IV atoms, respectively, which form the framework where 'guest' atoms A (alkali or alkaline earth metal) are encapsulated in two different polyhedra facing each other. The differences between types I and II comes from number and size of voids present in their unit cells. Transport properties depend on the framework's properties, but tuning is possible through the 'guest' atoms. The most direct approach to the synthesis and optimisation of thermoelectric properties of semiconducting type I clathrates is substitutional doping, where some framework atoms are replaced with dopant atoms. In addition, powder metallurgical and crystal growth techniques have been used in clathrate synthesis. The structural & chemical properties of clathrates enable the optimisation of their transport properties with stoichiometry. Type II materials' structure allows a partial filling of the polyhedron enabling better tuning of the electrical properties and therefore a better control of the doping level. Partially filled variants can be synthesised as semiconducting or even insulating.

Blake et al. have predicted ZT∼0.5 at room temperature and ZT∼1.7 at 800 K for optimised compositions. Kuznetsov et al. measured electrical resistance and Seebeck coefficient for three different type I clathrates above room temperature and by estimating high temperature thermal conductivity from the published low temperature data they obtained ZT∼0.7 at 700 K for $Ba_8Ga_{16}Ge_{30}$ and ZT∼0.87 at 870 K for $Ba_8Ga_{16}Si_{30}$.

Magnesium group IV compounds

Mg_2B^{IV} (B^{IV}=Si, Ge, Sn) compounds and their solid solutions are good thermoelectric materials and their ZT values are comparable with those of established materials. Due to a lack of systematic studies about their thermoelectric properties, however, the suitability of these materials and in particular their quasi-ternary solutions, for thermoelectric energy conversion remains in question.

The appropriate production methods are based on direct co-melting, but mechanical alloying has also been used.

During synthesis, magnesium losses due to evaporation and segregation of components (especially for Mg_2Sn) need to be taken into account. Directed crystallisation methods can produce single crystalline material. Solid solutions and doped compounds have to be annealed in order to produce homogeneous samples - with the same properties throughout. At 800 K $Mg_2Si_{2-x}Sn_x$ has been reported to have a figure of merit about 0.9.

Silicides

Higher silicides display ZT levels with current materials. They are mechanically and chemically strong – and therefore can often be used in harsh environments without protection. Possible fabrication methods include Czochralski and floating zone for single crystals & hot pressing and sintering for polycrystalline.

Skutterudite thermoelectric

Recently, skutterudite materials have sparked the interest of researchers in search of new thermoelectrics These structures are of the form (Co,Ni,Fe)(P,Sb,As)3 and are cubic with space group Im3. Unfilled, these materials contain voids into which low-coordination ions (usually rare earth elements) can be inserted in order to alter thermal conductivity by producing sources for lattice phonon scattering and decrease thermal conductivity due to the lattice without reducing electrical conductivity. Such qualities make these materials exhibit PGEC behaviour.

The composition of skutterudites corresponds to the chemical formula LM_4X_{12}, where L is a rare earth metal, M a transition metal and X a metalloid, a group V element or pnictogen whose properties lie between those of a metal and nonmetal such as phosphorus, antimony, or arsenic. These materials could be potential in multistage thermoelectric devices as it has been shown that they have ZT>1.0, but their properties are not well known.

Oxide thermoelectrics

Their layered superlattice structure gives homologous oxide compounds (such as those of the form $(SrTiO3)_n(SrO)m$—the Ruddleson-Popper phase) potential in high-temperature thermoelectric devices. These materials exhibit low thermal conductivity perpendicular to the layers while maintaining electrical conductivity within the layers. ZT is relatively low (∼0.34 at 1,000K), but their enhanced thermal stability, as compared to conventional high-ZT bismuth compounds, makes them superior for use in high-temperature applications.

Interest in oxides as thermoelectric materials was reawakened in 1997 when $NaxCoO_2$ was found to exhibit good thermoelectric behavior. In addition to their thermal stability, other advantages of oxides are their nontoxicity and high oxidation resistance. Simultaneously controlling both the electric and phonon systems may require nanostructured materials. Some layered oxide materials are thought to have ZT∼2.7 at 900 K. If the layers in a given material have the same stoichiometry, they will be stacked so that the same atoms will not be positioned on top of each other, impeding phonon conductivity perpendicular to the layers.

Half Heusler alloys

Half Heusler alloys have potential for high temperature power generation applications especially as n-type material. These alloys have three components that originate from different element groups or combinations of elements. Two of the groups are composed of transition metals and the third group consists of metals and metalloids. Currently only n-type material is usable in thermoelectrics but some sources claim that they have achieved ZT~1.5 at 700 K, but according to other sources only ZT~0.5 at 700 K has been achieved. They state that primary reason for this difference is the disagreement between thermal conductivities measured by different groups. These alloys are relatively cheap and also have a high power factor.

Electrically conducting organic materials

Some electrically conducting organic materials may have a higher figure of merit than existing inorganic materials. Seebeck coefficient can be even millivolts per Kelvin but electrical conductivity is usually low, resulting in small ZT values. Quasi-one-dimensional organic crystals are formed from linear chains or stacks of molecules that are packed into a 3D crystal. Under certain conditions some Q1D organic crystals may have ZT~20 at room temperature for both p- and n-type materials. This has been credited to an unspecified interference between two main electron-phonon interactions leading to the formation of narrow strip of states in the conduction band with a significantly reduced scattering rate as the mechanism compensate each other, yielding high ZT.

Silicon-germanium

Silicon-germanium alloys are currently the best thermoelectric materials around 1000^0 and are therefore used in some radioisotope thermoelectric generators (RTG) (notably the MHW-RTG and GPHS-RTG) and some other high temperature applications, such as waste heat recovery. Usability of silicon-germanium alloys is limited by their price and mid-range ZT (~0.7).

Sodium-cobaltate

Experiments on crystals of sodium cobaltate, using X-ray and neutron scattering experiments carried out at the European Synchrotron Radiation Facility (ESRF) and the Institut Laue-Langevin (ILL) in Grenoble were able to suppress thermal conductivity by a factor of six compared to vacancy-free sodium cobaltate. The experiments agreed with corresponding density functional calculations. The technique involved large anharmonic displacements of Na0.8CoO2 contained within the crystals.

Functionally graded materials

Functionally graded materials make it possible to improve the conversion efficiency of existing thermoelectrics. These materials have a non-uniform carrier concentration distribution and in some cases also solid solution composition. In power generation applications the temperature difference can be several hundred degrees and therefore devices made from homogeneous materials have some part that operates at the temperature where ZT is substantially lower than its maximum value.

This problem can be solved by using materials whose transport properties vary along their length thus enabling substantial improvements to the operating efficiency over large temperature differences. This is possible with functionally graded materials as they have a variable carrier concentration along the length of the material, which is optimized for operations over specific temperature range.

Nanomaterials and superlattices

This section may be too technical for most readers to understand

In addition to nanostructured Bi_2Te_3/Sb_2Te_3 superlattice thin films, other nanomaterials show potential in improving thermoelectric properties. Another example of a superlattice involves a PbTe/PbSeTe quantum dot superlattices provides an enhanced ZT (approximately 1.5 at room temperature) that was higher than the bulk ZT value for either PbTe or PbSeTe(approximately 0.5). Not all nanocrystalline materials are stable, because the crystal size can grow at high temperatures, ruining the materials' desired characteristics. Nanocrystalline materials have many interfaces between crystals, which scatter phonons so the thermal conductivity is reduced. Phonons are confined to the grain, if their mean free path is larger than the material grain size. Measured lattice thermal conductivity in nanowires is known to depend on roughness, the method of synthesis and properties of the source material.

Nanocrystalline transition metal silicides are a promising material group for thermoelectric applications, because they fulfill several criteria that are demanded from the commercial applications point of view. In some nanocrystalline transition metal silicides the power factor is higher than in the corresponding polycrystalline material but the lack of reliable data on thermal conductivity prevents the evaluation of their thermoelectric efficiency.

One advantage of nanostructured skutterudites over normal skutterudites is their reduced thermal conductivity but further performance improvements can be achieved by using composites and by controlling the grain size, the compaction conditions of polycrystalline samples and the carrier concentration. Thermal conductivity reduction is caused by grain boundary scattering. ZT values of ~0.65 and > 0.4 have been achieved with $CoSb_3$ based samples, the former value is 2.0 for Ni and 0.75 for Te doped material at 680 K and latter for Au-composite at T > 700 K.

Due to the unique nature of graphene, engineering of thermoelectric device with extremely high Seebeck coefficient based on this material is possible. One theoretical study suggests that the Seebeck coefficient might achieve a value of 30 mV/K at room temperature and ZT for their proposed device would be approximately 20.

Superlattices can be good thermoelectric materials, but their production is expensive for general use because of their fabrication is based on various thin film growth methods. However, the amount of thin-film materials required for device fabrication is so much smaller, almost one-ten-thousandth, of bulk thermoelectric materials and hence the long-term cost advantage is indeed favorable.

This is particularly true given the limited availability of Tellurium, from competing solar applications. Superlattice structures also allow the independent manipulation of transport parameters by adjusting the structural parameters enabling the search for better understanding of thermoelectric phenomena in nanoscale, by the so-called phonon-blocking electron-transmitting strcutures.

Many strategies exist to decrease the superlattice thermal conductivity that are based on engineering of phonon transport. The thermal conductivity along the film plane and wire axis can be reduced by creating diffuse interface scattering and by reducing the

interface separation distance, both which are caused by interface roughness.

The interface roughness can be natural due to the mixing of atoms at the interfaces or artificial. Many different structure types, such as quantum dot interfaces and thin films on step-covered substrates, can act as source for artificial roughness.

However, while engineering interface structures for reduced phonon thermal conductivity effects to electron transport has to be taken into account because the reduced electrical conductivity could negate the advantage received from phonon transport engineering. Because electrons and phonons have different wavelengths, it has been shown that it is possible to engineer the structure in such a way that phonons are scattered more diffusely at the interface than electrons.

Through proper choice of superlattice structure, and through taking advantage of mini-band conduction across superlattices and avoiding quantum-confinement, one can almost eliminate or reduce the decrease of the electrical conductivity across superlattices.

Second approach is to increase phonon reflectivity and therefore decrease the thermal conductivity perpendicular to interfaces. This can be achieved by increasing the mismatch between the materials. Some of these properties are density, group velocity, specific heat, and the phonon spectrum between adjacent layers. Interface roughness causes diffuse phonon scattering, which either increases or decreases the phonon reflectivity at the interfaces. Mismatch between bulk dispersion relations confines phonons and the confinement becomes more favourable as the difference in dispersion increases. The amount of confinement is currently unknown as only some models and experimental data exist. As with a previous method, the effects on the electrical conductivity have to be considered.

In order to further reduce the thermal conductivity, the localisation of long wavelength phonons can be attempted with aperiodic superlattices or composite superlattices with different periodicities. In addition, defects, especially dislocations, can be used to reduce thermal conductivity in low dimensional systems. Thermoelectric performance improvements in superlattices originate from various sources, usually at least the lattice thermal conductivity in the cross plane direction is very low but depending on the type of superlattice, the thermoelectric coefficient may also increase because the band structure changes. Low lattice thermal conductivity in superlattices is usually due to strong interface scattering of phonons. Electronic band structure in superlattices comprises the so-called minibands, which originate from lack of quantum confinement within a well. In superlattices, electronic band structure depends on the superlattice period so that with very short period (~1 nm) the band structure approaches the alloy limit and with long period (≥ ~60 nm) minibands become so close to each other that they can be approximated with a continuum.

Especially in multi quantum well structures the parasitic heat conduction in the barrier layers could cause significant performance reduction. The impact of this phenomenon can be reduced by choosing the distance between the quantum wells correctly but has never been validated.

The Seebeck coefficient can change its sign in superlattice nanowires due to the existence of minigaps as Fermi energy varies. This indicates that superlattices can be tailored to exhibit n or p-type behaviour by using the same dopants as those that are used for corresponding bulk materials by carefully controlling Fermi energy or the dopant concentration. With nanowire arrays, it is possible to exploit semimetal-semiconductor transition due to the quantum confinement and use materials that normally would not be good thermoelectric materials in bulk form. Such elements are for example bismuth. The Seebeck effect could also be used to determine the carrier concentration and Fermi energy in nanowires.

In quantum dot thermoelectrics, unconventional or nonband transport behavior (e.g. tunneling or hopping) is necessary to utilize their special electronic band structure in the transport direction. It is possible to achieve ZT>2 at elevated temperatures with quantum dot superlattices, but they are almost always unsuitable for mass production. However in superlattices, where quantum-effects are not involved, with film thickness of only a few micrometers (μm) to about 15 μm, Bi_2Te_3/Sb_2Te_3 superlattice material has been made into high-performance microcoolers and other devices. The performance of hot-spot coolers are consistent with the reported ZT~2.4 of superlattice materials at 300 K.

Nanocomposites are promising material class for bulk thermoelectric devices, but several challenges have to be overcome to make them suitable for practical applications. It is not well understood why the improved thermoelectric properties appear only in certain materials with specific fabrication processes.

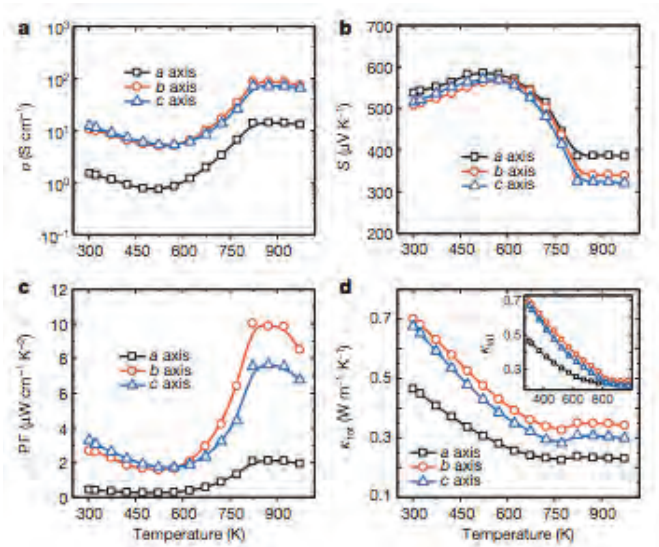
SrTe nanocrystals can be embedded in a bulk PbTe matrix so that rocksalt lattices of both materials are completely aligned (endotaxy) with optimal molar concentration for SrTe only 2%. This can cause strong phonon scattering but would not affect charge transport. In such case, ZT~1.7 can be achieved at 815 K for p-type material.

Tin selenide

In 2014 a research group discovered that tin selenide (SnSe) has a ZT of 2.6 along the b axis of the unit cell. This is the highest value reported to date. This high ZT figure of merit has been attributed to an extremely low thermal conductivity found in the SnSe lattice. Specifically, SnSe demonstrated a lattice thermal conductivity of 0.23 $W \cdot m^{-1} \cdot K^{-1}$, which is much lower than previously reported values of 0.5 $W \cdot m^{-1} \cdot K^{-1}$ & greater. This SnSe material also exhibited a ZT of 2.3±0.3 along the c-axis and 0.8±0.2 along the a-axis. These excellent figures of merit were obtained by researchers working at elevated temperatures, specifically 923 K (650^{0}C). As shown by the figures below, SnSe performance metrics were found to significantly improve at higher temperatures; this is due to a structural change that is discussed below. Power factor, conductivity, and thermal conductivity all reach their optimal values at or above 750 K, and appear to plateau at higher temperatures.

Although it exists at room temperature in an orthorhombic structure with space group Pnma, SnSe has been shown to undergo a transition to a structure with higher symmetry, space group Cmcm, at higher temperatures. This structure consists of Sn-Se planes that are stacked upwards in the a-direction, which accounts for the poor performance out-of-plane (along a-axis). Upon transitioning to the Cmcm structure, SnSe maintains its low thermal conductivity but exhibits higher carrier mobilities, leading to its excellent ZT value.

One particular impediment to further development of SnSe is that it has a relatively low carrier concentration: approximately 1017 cm^{-3}. Further compounding this issue is



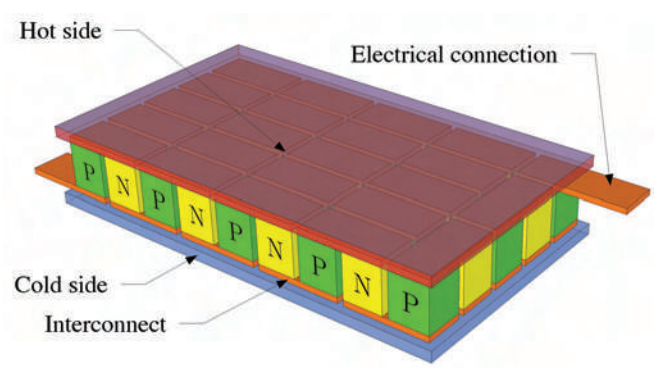
SnSe performance metrics...

the fact that SnSe has been reported to have low doping efficiency. However, such single crystalline materials suffer from inability to make useful devices due to their brittleness as well as narrow range of temperatures, where ZT is reported to be high. Further, polycrystalline materials made out of these compounds by several investigators have not confirmed the high ZT of these materials.

Production methods

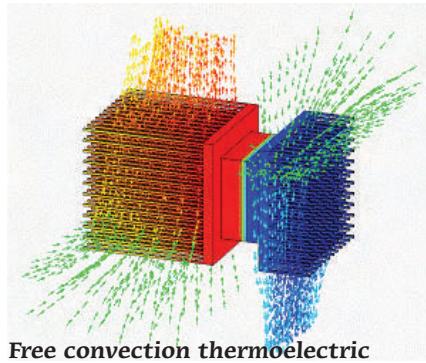
Production methods for these materials can be divided into powder and crystal growth based techniques. Powder based techniques offer excellent ability to control and maintain desired carrier distribution. In crystal growth techniques dopants are often mixed with melt, but diffusion from gaseous phase can also be used. In the zone melting techniques disks of different materials are stacked on top of others and then materials are mixed with each other when a traveling heater causes melting. In powder techniques, either different powders are mixed with a varying ratio before melting or they are in different layers as a stack before pressing and melting.

Operating principle



Peltier element schematic. Thermoelectric legs are thermally in parallel and electrically in series...

Thermoelectric coolers operate by the Peltier effect (which also goes by the more general name thermoelectric effect). The device has two sides, and when DC current flows through the device, it brings heat from one side to the other, so that one side gets cooler while the other gets hotter. The 'hot' side is attached to a heat sink so that it remains at ambient temp, while the cool side goes below room temp. In some applications, multiple coolers can be cascaded together for lower temp.



Free convection thermoelectric cooler (Peltier cooler) with heat sink surface temperature contours, and rising warmer air and falling cooler air flow trajectories, predicted using a CFD analysis package, courtesy of NCI...

Construction

Two unique semiconductors, one n-type and one p-type, are used because they need to have different electron densities. The semiconductors are placed thermally in parallel to each other and electrically in series and then joined with a thermally conducting plate on each side. When a voltage is applied to the free ends of the two semiconductors there is a flow of DC current across the junction of the semiconductors causing a temperature difference. The side with the cooling plate absorbs heat which is then moved to the other side of the device where the heat sink is. TECs are typically connected side by side and sandwiched between two ceramic plates. The cooling ability of the total unit is then proportional to the number of TECs in it.

Some benefits of using a TEC are

- No moving parts so maintenance is required less frequently
- No chloro fluoro carbons
- Temperature control to within fractions of a degree can be maintained
- Flexible shape (form factor); in particular, they can have a very small size
- Can be used in environments that are smaller or more severe than conventional refrigeration
- Has a long life, with mean time between failures (MTBF) exceeding 100,000 hours
- Is controllable via changing the input voltage/current

Some disadvantages of using a TEC are

- Only a limited amount of heat flux is able to be dissipated
- Relegated to applications with low heat flux
- Not as efficient, in terms of coefficient of performance, as vapour-compression systems (see below)

Performance

A single-stage TEC will typically produce a maximum temperature difference of 70^0C between its hot and cold sides. The more heat moved using a TEC, the less efficient it becomes, because the TEC needs to dissipate both the heat being moved, as well as the heat it generates itself from its own power consumption. The amount of heat that can be absorbed is proportional to the current and time.

$$W = PIt$$

where P is the Peltier Coefficient, I is the current, and t is the time. The Peltier Coefficient is dependent on temperature and the materials the TEC is made of.

Thermoelectric junctions are about 4 times less efficient in refrigeration applications than conventional means (they offer around 10 to 15% efficiency

of the ideal Carnot cycle refrigerator, compared with 40 to 60% achieved by conventional compression cycle systems (reverse Rankine systems using compression/expansion).) Due to this lower efficiency, thermoelectric cooling is generally only used in environments where the solid state nature (no moving parts, low maintenance, compact size, and orientation insensitivity) outweighs pure efficiency.

Peltier (thermoelectric) cooler performance is a function of ambient temperature, hot and cold side heat exchanger (heat sink) performance, thermal load, Peltier module (thermopile) geometry, and Peltier electrical parameters.

Requirements for Thermoelectric materials

- Narrow band-gap semiconductors because of room temperature operation
- Heavy elements because of their high mobility and low thermal conductivity
- Large unit cell, complex structure
- Highly anisotropic or highly symmetric
- Complex compositions

Common thermoelectric materials used as semi-conductors include bismuth telluride, lead telluride, silicon germanium, and bismuth-antimony alloys. Of these bismuth telluride is the most commonly used. New high-performance materials for thermoelectric cooling are being actively researched.

Uses

A USB-powered beverage cooler...

Thermoelectric coolers are used for applications that require heat removal ranging from milliwatts to several thousand watts. They can be made for applications as small as a beverage cooler or as large as a submarine or railroad car. TECs have limited life time. Their health strength can be measured by the change of their AC resistance. When a TEC gets 'old' or worn out, the AC resistance (ACR) will increase.

Consumer products

Peltier elements are commonly used in consumer products. For example, Peltier elements are used in camping, portable coolers, cooling electronic components and small instruments. The cooling effect of Peltier heat pumps can also be used to extract water from the air in dehumidifiers. A camping/car type electric cooler can typically reduce the temperature by up to 20^0C (36^0F) below the ambient temperature. Climate-controlled jackets are beginning to use Peltier elements. Thermoelectric coolers are used to replace heat sinks for microprocessors. They are also used for wine coolers.

Science and imaging

Peltier elements are used in scientific devices. They are a common component in thermal cyclers, used for the synthesis of DNA by Polymerase Chain Reaction (PCR), a common molecular biological technique which requires the rapid heating and cooling of the reaction mixture for denaturation primer annealing and enzymatic synthesis cycles.

With feedback circuitry, peltiers can be used to implement highly stable temperature controllers that keep desired temperature within +/-0.01 Celsius. Such stability may be used in precise laser applications to avoid laser wavelength drifting as environment temperature changes.

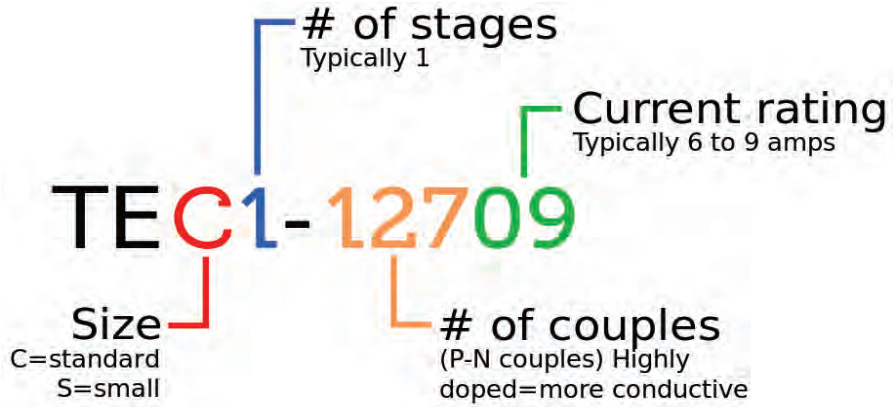
The effect is used in satellites and spacecraft to counter the effect of direct sunlight on one side of a craft by dissipating the heat over the cold shaded side, whereupon the heat is dissipated by thermal radiation into space. Since 1961, some unmanned spacecraft (including the Curiosity Mars rover) utilize radioisotope thermoelectric generators (RTGs) that convert thermal energy into electrical energy using the Seebeck effect, lasting several decades, fueled by the decay of high energy radioactive materials.

Photon detectors such as CCDs in astronomical telescopes, spectrometers, or very high-end digital cameras are often cooled down with Peltier elements. This reduces dark counts due to thermal noise. A dark count occurs when a pixel registers an electron because of a thermal fluctuation rather than because it has received a photon. On digital photos taken at low light these occur as speckles (or 'pixel noise.') Thermoelectric coolers can be used to cool computer components to keep temperatures within design limits, or to maintain stable functioning when overclocking. A Peltier cooler with a heat sink or waterblock can cool a chip to well below ambient temperature.

In fiber optic applications, where the wavelength of a laser or a component is highly dependent on temperature, Peltier coolers are used along with a thermistor in a feedback loop to maintain a constant temperature and thereby stabilize the wavelength of the device. Some electronic equipment intended for military use in the field is thermoelectrically cooled.

Identification

The vast majority of TECs have an ID printed on their heated side. These universal IDs clearly indicate the size, number of stages, number of couples, and current rating in amps, as seen in the above diagram. ■



Peltier elements all conform to a universal identification specification...

Prof Dr OmPrakash G Kulkarni is recognized as a Scientist at global level in the field of Renewable Energy and as the Inventor of World's first Solar Thermal/ Renewable Energy Based Air Conditioning / Refrigeration system.

Combining The Best Of Both Worlds

More than 55% of energy consumed by Groupe Auchan comes from renewable sources. When the company heard about the benefits of a new Honeywell HFO blend – Solstice N13 (R-450A) – they were keen to test its credentials…

When it comes to delivering on environmental promises, Groupe Auchan has an enviable record, having been rated among the greenest supermarket chains – and openly publishing its ambitious annual carbon reduction targets.

Part of this eco-commitment involves finding greener ways of operating its stores – and this includes refrigeration – so when the company heard about the benefits of a new Honeywell HFO blend – Solstice N13 (R-450A) – they were keen to test its credentials. Solstice N13, recently awarded official ASHRAE R-450A, is an alternative to R-134a, offering similar performance but with a superior GWP of ~600, and is suitable for chillers – and MT refrigeration (distributed, CO_2 cascade), offering the best non-flammable replacement for R-134a.

Approval was given to design a combined Solstice N13/ CO_2 refrigeration system for a new large hypermarket opening in Epinaysur-Seine (Paris), with measurement criteria focused on energy efficiency, equivalent CO_2 emissions reduction and refrigeration performance.

The test

The test utilised a new design of low energy refrigeration unit, and involved a team from Auchan, the company's refrigeration partners

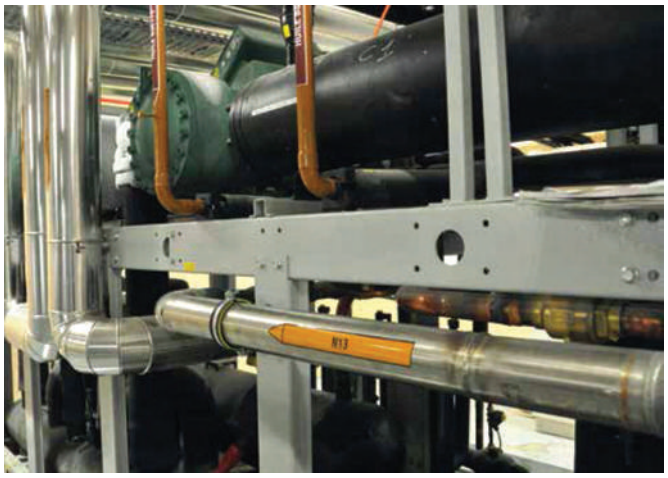
Axima Refrigeration and Honeywell. The test focused on assessing the merits of a system that incorporated an N13 liquefaction unit alongside a CO_2 refrigerated distribution circuit.

The system was then compared with Auchan's current standard set-up that used R-134a and glycol water with CO_2.

The results to date have been encouraging, and include:

- Easy commissioning, with similar energy efficiency as R-134a
- A global saving of 90 tons CO_2 eq / year compared with a secondary Glycol / R-134a / CO_2 system and savings of 960 tons CO_2 eq / year compared to using a standard R-404A DX system.

"Our aim was to successfully trial the new HFO blend N13 in a flagship store and to prove its operational and energy saving credentials. The results speak for themselves," said Jean-Michel Deroo of Groupe Auchan.



A view of the Auchan plant...

Supporting environmental goals

Groupe Auchan is at the leading edge of mitigating the ecological footprint generated by its different activities, and constantly strives to innovate in order to lower energy consumption, contribute to the fight against global warming and promote biodiversity.

All of the group's businesses control their energy consumption by setting ambitious annual reduction targets. The installation of smart meters helps chains identify waste and optimise consumption.

To help meet the European Union's objective of 20% of all energy usage coming from renewable energy by 2020, Auchan has invested in solar and geothermal energy over the recent years. All new buildings include autonomous energy production systems and, as a result, more than 55% of energy consumed by Auchan comes from renewable sources.

The refrigeration pilot project at Epinay-sur-Seine is, therefore, entirely in keeping with the context of building a greener operating environment.

From this start point, the company participated in a wider partnership, involving the end user plus Honeywell (and its Solstice ze technology), L'Ecole des Mines de Paris and Total – Ademe, to build a second prototype machine. The aim was to develop a machine that was not only capable of delivering hot water at 97^0C, but could also immediately cool the product down to 2^0C using chilled water. This second machine would be assessed against key criteria, including environmental performance, process effectiveness and pay-back linked to energy efficiency.

Solstice N13, recently awarded official ASHRAE R-450A, is an alternative to R-134a, offering similar performance but with a superior GWP of ~600, and is suitable for chillers...

Field test and implementation

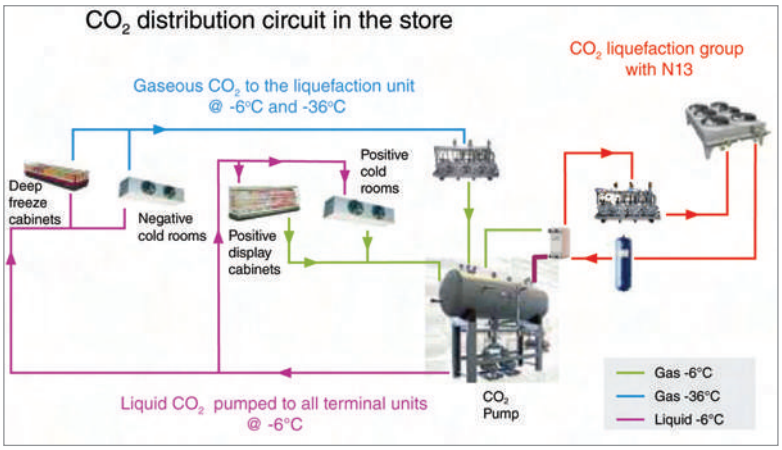
Groupe Auchan worked alongside its refrigeration partner Axima Refrigeration to develop a system for the Epinaysur-Seine store that combined the low GWP and energy efficiency benefits of a new refrigeration HFO blend named Solstice N13 (R-450A) – and the proven performance of pumped CO_2.

The system uses Solstice N13 in a liquefaction unit to convert gaseous CO_2 into a liquid that is then pumped to deep freeze containers, cold rooms and display cabinets. The CO_2 returns in a gaseous form to the Solstice N13 liquefaction unit ready for converting again to liquid.

Feedbacks

"Groupe Auchan places environmental responsibility at the top of its business agenda, and we are very supportive of innovations such as this new approach to refrigeration – that delivers benefits to us as a business, to the customers we serve and to the wider community," said Deroo.

"We are continuously looking to apply more sustainable and lower GWP solutions into supermarkets such as Auchan. With the experience and results of this Solstice N13 trial, we are now confident that we can deliver even greater environmental benefits to the industry. The choice of refrigerant is a fundamental element in our strategy for the reduction of CO_2 equivalent emissions and for maintaining or improving energy efficiency," said Cédric Leroy, Axima Refrigeration.



Schematic view of the system aiming at CO_2 reduction...

Rolling out the benefits

The field test with Groupe Auchan confirms the energy efficiency benefits of using Solstice N13 (R-450A) alongside CO_2 in a cascade system, with additional advantages in terms of CO_2 equivalent emissions reduction and much lower GWP (-58%) over traditional refrigerants such as R-134a. ■

Managing With A Hired Solution

Chiller failure leads to loss of cooling in an air-conditioned zone. When it happens in a hotel, the incident turns into a great matter of concern, as it may stall the entire cooling effect in the comfort zone, and adversely affect the reputation of the hotel. Recently, Carrier Rental Systems (UK) has handled such an emergency situation in Royal Garden Hotel (UK). Read on – what was done there?

When a chiller serving Kensington's renowned Royal Garden Hotel failed during a busy period, on the same day the hotel contacted Carrier Rental Systems to request a fast-track hire solution – until the equipment could be replaced. The hotel asked the company to evaluate whether a temporary solution could be provided, to supply the necessary level of cooling – & quickly replace the lost air conditioning capacity.

Tim Walker, Technical Services Manager, Royal Garden Hotel, says, "We pride ourselves on providing guests with the highest levels of comfort, and air conditioning is obviously an essential element of the five-star experience. It was a particularly busy period with full occupancy during a major international sporting event. A breakdown of one of our long-serving chillers reduced the hotel's cooling capacity by 50%, and presented us with a problem that required immediate action."

Crisis management

Carrier Rental Systems recommended the temporary installation of two high performance Carrier AquaSnap air-cooled 30RB 522 chillers, with rotary scroll compressors. These provided up to 1.2MW of cooling capacity to the hotel, fully replacing lost capacity from the out-of-commission unit with some extra capacity to spare.

With micro-channel condensers and high-efficiency variable condenser fans, the AquaSnap 30RB chillers operate with full load Energy Efficiency Ratio (EER) values of up to 10.3.

As there was one chiller still operating, that was on full duty while the temporary chiller solution was installed.

Image Courtesy: Carrier Rental Systems

Fig. 1: Exterior part of the Royal Garden Hotel (UK) at night...

Logical reasoning

In the words of Marc White, Director, Carrier Rental Systems, "The scroll compressor-based machines have multiple refrigerant circuits, giving excellent resilience – and a high level of assurance for end users in critical applications such as hotels... We were pleased to be able to fast-track the installation – to ensure full service was resumed quickly."

The AquaSnap 30RB chillers are equipped with stand-alone controls, and can also be connected to a building's existing Building Management Systems (BMS), enabling them to operate alongside other systems as part of a fully integrated building.

A hired solution provides time to chalk out a long-term strategy on whether to repair or replace a managed component of the plant...

Logistics management

Carrier Rental Systems is geared to assess onsite, and then supply very rapidly from its hire fleet base on the outskirts of London, at Thorpe. The company holds a comprehensive range of temperature control rental equipment at locations around the UK, enabling a rapid response to HVAC breakdowns.

They delivered, installed and commissioned the AquaSnap 30RB chillers over a weekend, minimising downtime and inconvenience for the hotel. Due to space constraints onsite, the temporary units were installed in the hotel's goods delivery area. Packaged chillers, which were supplied, provided 'plug & play' type connection facility, thus the job became easy.

Walker informed, "Although space was fairly limited in the vicinity of the chillers, the location provided a good solution. While it was close enough to connect into the hotel's existing air conditioning system, it did not create a disturbance for guests – thanks to the quiet operation of the temporary chillers."

Fig. 2: A view of the lobby of the Royal Garden Hotel (UK)...

Techno-commercial angle

The hire package included all maintenance during the 10 month rental period, plus full emergency response and repair service in the event of a problem.

Walker explained, "The hire option provided a swift and effective solution that solved the immediate need, and gave us time to properly assess the requirements for repair or replacement of existing plant. In the end, we decided to replace the previous unit with a new Carrier machine." ■

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Bringing Comfort To Chase Tower with Titus' EOS

During remodeling, the company had to find a way to reuse the dual duct system that included all overhead air distribution. What did they do?

The Qube, formerly known as Chase Tower, has been a landmark of the Detroit skyline since 1959. Standing at 14 stories high, it also occupies the site of Detroit's first skyscraper. Having been purchased by Quicken Loans, the company moved forward on a complete remodel of the facility in 2011. The remodel was intended to bring the building up to date and add designs to match the company's modern style.

MA Engineering was brought in to take on the mechanical engineering aspects of the project. As a firm that incorporates aspects of sustainable design into every project, they were a good fit for ensuring good indoor air quality, comfort and sustainability.

Based in Birmingham, Mich, John Richards at MA Engineering, served as the lead mechanical engineer and project manager of the renovation. His team was tasked with the complete renovation for nine of 14 floors, equaling 280,000 square feet. One of the renovation challenges was that the project did not call for new infrastructure. This meant that MA Engineering had to find a way to reuse the dual duct system that included all overhead air distribution. MA Engineering was concerned about occupant comfort near the windows because the original building design incorporated a slot air distribution device in the base of each window, creating a blanket of air over the building's single pane windows. The new architectural design eliminated the slot at the base of the windows, but the single pane windows remained, creating a challenge to maintain comfort along the windows. In addition, the new office layout included workstations directly along the windows.

Comfort

Richards turned to Fontanesi and Kann, a company committed to providing the very best products, services and support to owners, contractors and design engineers through their variety of professional project and construction management services.

As a result, the two approached Titus HVAC, the world leader in air distribution to help solve the challenge. "Our firm is always watching for new, sustainable technologies to provide additional value to customers – and Titus offers the best technology for perimeter challenges," said Richards. "That is why we decided to look at the Titus EOS for this project," he added.

The EOS is designed to address the imperfect split compromises that are commonly found in the perimeter of a building's system, like the Qube...

The EOS is the industry's first light-powered, energy-harvesting diffuser. With its wireless, energy-harvesting technology, it pushes the HVAC science of air distribution to new heights. It was designed to improve comfort and save energy while providing a solution to challenging building perimeter applications.

Having previous experience with the Titus Dynafuser, Richards and his team were familiar with the overall concept of the new EOS technology. As Richards describes it, "EOS is better than typical diffusers because it has a 'brain' – and can automatically adjust according to the temperature need – so the area by the windows now maintains better comfort in both heating and cooling modes."

The EOS is designed to address the imperfect split compromises that are commonly found in the perimeter of a building's system, like the Qube.

Its smart system delivers both heating and cooling by utilising an auto-changeover function that eliminates wasteful compromise by automatically changing the air distribution pattern. Because comfort was the primary objective, it became clear that the EOS was the right diffuser for the job.

"With the EOS,the air is sent horizontally in the cooling mode and vertically down over the single pane window, creating a blanket in the heating mode. In addition, the unit runs on solar power which makes it more appealing to the client and can also save on energy costs," said Richards.

Advancing the science of air distribution

Another challenge on the project was that the office space featured an open ceiling with exposed ductwork and air diffusers. As a

result, MA Engineering worried that a normal diffuser might not get the cooling flow needed. In order to make sure the cooling mode could project the air out into the space; Joe Fontanesi worked with the Titus HVAC lab to engineer a 'lip' that helped make the air projection horizontal instead of vertical.

The lip would ensure that the EOS distributed air more evenly and throughout the entire building rather than just one area. The Titus HVAClab used videos to show the engineers how the new lip would work.

"Being able to see the demonstrationvideos and the projection the lip would make was incredibly helpful," said Richards. "Tituseliminated the guess work and helped us better understand and explain how it would work in this particular building."

Sustainable

Having been listed as one of the 'Top Places to Work in America' for many years running, the solar aspect of EOS was important to Quicken Loans. As a light-powered energy-harvesting diffuser, the EOS is powered completely by natural light making this smart system cost effective and sustainable.

In fact, the energy harvesting feature on the EOS can provide up to 30 per cent energy savings during heating over a split compromise system.The solar aspect also supports the company's progressive brand image – as solar powered and green systems are popular aspects among the young professionals, the company is looking to attract. Not only does the company win in the eyes of its employees, but Quicken Loans is able to improve their bottom line. Because MA Engineering had so much success with the EOS on the Qube project, they are already incorporating it into other projects as well.

As Richards pointed out, "The EOS and support from both Fontanesi and Kann and Titus far exceeded expectations." He added, "They provided us with the technology that allowed our engineers to be successful on the job. We intend to work with them and use the EOS on future projects."

All engineers want to design the perfect system. But as most young consulting engineers soon find out, HVAC design is a game of compromises. Their goals are occupant comfort, energy savings, system controllability and low installation cost. The air conditioning of perimeter zones in commercial buildings is a perfect example of these compromises. Almost all buildings require heating and cooling at the perimeter during different times of the year. Most commercial buildings in the US are overhead mixed systems.

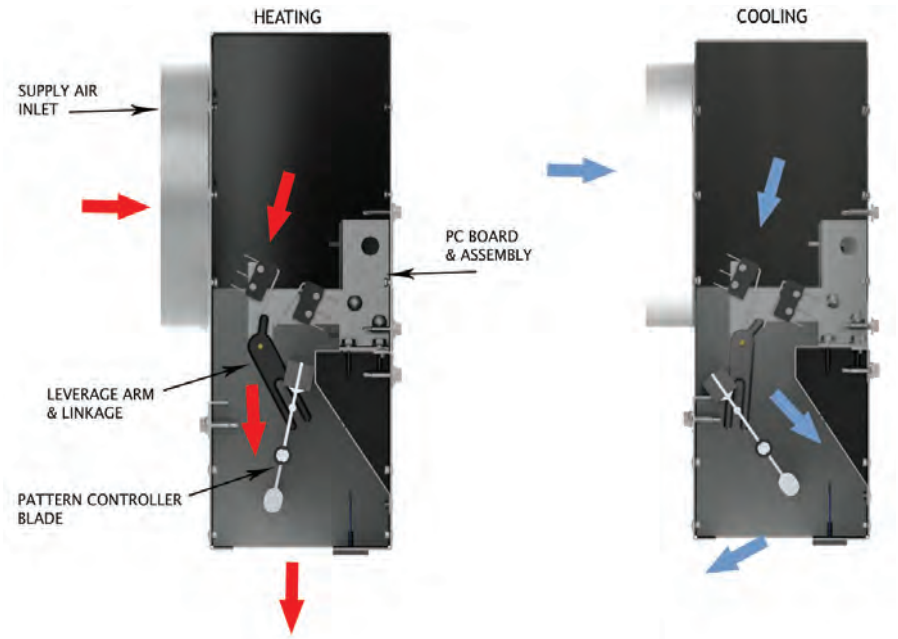
To make sure the cooling mode could project the air out into the space; Joe Fontanesi worked with the Titus HVAC lab to engineer a 'lip' that helped make the air projection horizontal...

Overhead systems work well in cooling with proper diffuser selection. Overhead heating is a different story.

A good solution would be to provide overhead cooling and baseboard heating, but providing two systems is cost prohibitive.

Here the engineer is faced with his/her first compromise. A fairly common compromise is to provide a perimeter slot diffuser with either a dedicated down blow section to provide some heat to the floor or a diffuser with split pattern control, so half of the air can always be directed down while the other half is directed horizontally across the ceiling.

As a compromise, these methods work, but it is not the optimum solution. In both heating and cooling modes, half the supply air is being discharged in the wrong direction for optimal comfort and energy savings. In heating, half of the supply air is discharged horizontally causing stratification along the ceiling. In cooling, half of the supply air is discharged vertically causing unwanted drafts along the floor. The Titus EOS is a plenum slot diffuser designed to address the imperfect perimeter compromises by providing the perfect perimeter solution. The EOS automatically changes the air discharge pattern to horizontal for cooling or vertical for heating.



The Titus EOS is a plenum slot diffuser designed to address the imperfect perimeter compromises by providing the perfect perimeter solution...

When 100% of the supply air is effectively utilised, the room temperature reaches set-point faster allowing the HVAC system to run for a shorter duration of time – which saves energy. Lab tests show the savings to be as high as 30%, which makes it a great choice when designing buildings for LEED certification.

The EOS increases occupant comfort and saves energy without the use of any external power source. The auto-changeover action is powered by a unique energy harvesting system which uses solar or ambient light energy to power a miniature motor/actuator assembly. A PC board with temperature sensor uses smart logic to monitor supply air temperature and quickly change the air discharge pattern.

With the EOS, Titus nowadays continues as the industry leader in innovative design by providing an energy efficient as well as cost effective solution for the perimeter heating or cooling dilemma. ■

Cooling Supermarkets Efficiently

The refrigeration systems produce a large amount of rejected heat that can be recovered and used by heat pumps or other equipment to provide space and water heating for store requirements...

Supermarkets are one of the most energy-intensive types of commercial buildings. Significant electrical energy is used to maintain chilled and frozen food in both product display cases and walk-in storage coolers. Fig. 1 shows a representative layout for a supermarket showing refrigerated display cases and storage areas located generally around the store perimeter.

Typical supermarkets with approximately 2,000 to 11,000 square metres of sales area consume roughly 2 million kWh annually, and roughly half of it is for refrigeration.

Compressors and condensers account for 60 to 70% of refrigeration energy consumption. The remainder is consumed by the display and storage cooler fans, display case lighting, evaporator defrosting, and for anti-sweat heaters used to prevent condensate from forming on doors and outside surfaces of display cases.

The refrigeration systems also produce a large amount of rejected heat that can be recovered and used by heat pumps or other equipment to provide space and water heating for store requirements.

Thus, improvement in energy efficiency of supermarket refrigeration will affect the store's bottom line of profit margin.

Conventional supermarket refrigeration system

The most commonly used refrigeration system for supermarkets today is the multiplex direct expansion system.

Fig. 2 shows the major elements of a multiplex refrigeration system. All display cases and cold store rooms use direct expansion air-refrigerant

coils that are connected to the system compressors mounted on a skid, or rack in a remote machine room located in the back or on the roof of the store. Heat rejection is usually done with air-cooled condensers because these are the least cost to install and maintain.

The hot refrigerant gas from the compressors is cooled and condensed as it flows into the condenser. The liquid refrigerant is collected in the receiver and distributed to the cases and coolers by the liquid manifold.

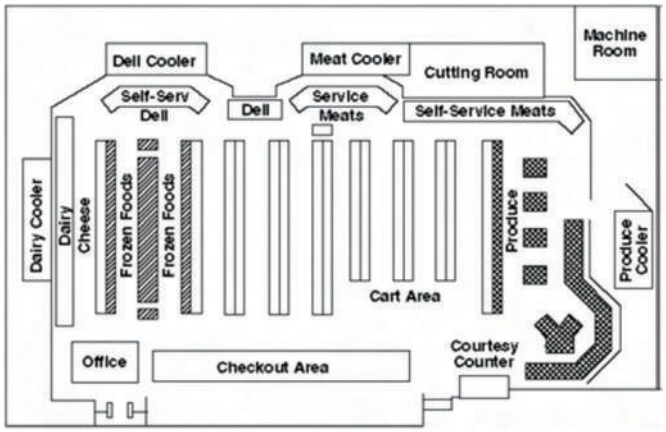


Fig. 1: Layout of a typical modern supermarket...

The refrigerant is expanded turning a fraction of liquid into vapour before flowing into the evaporator. After cycling through the cases, the refrigerant returns to the suction manifold and the compressors.

Supermarkets tend to have one direct expansion system for 'low-temperature' refrigeration (e.g., ice cream, frozen foods and so on) and one or two direct expansion systems for 'medium-temperature' refrigeration (e.g., meat, prepared foods, dairy, refrigerated drinks, etc.).

The large amount of piping and pipe joints required can result in large refrigerant losses – historically 30% or more of the total charge annually.

This system has historically been designed for ease and rapidity of service rather than low leakage. However, this practice is changing for new supermarkets with more emphasis on reducing leakage.

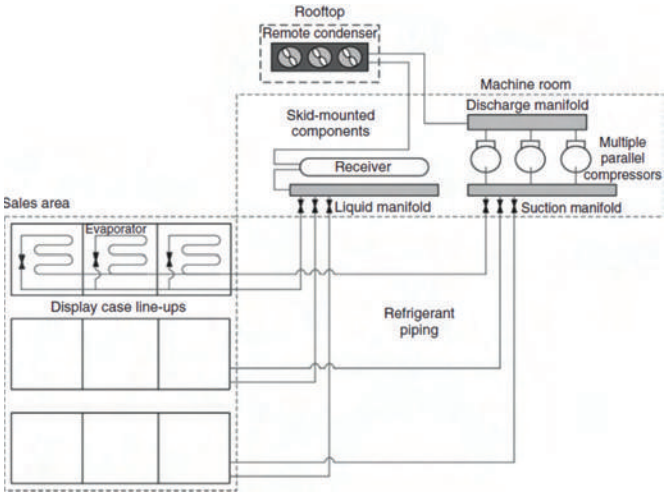


Fig. 2: Multiplex direct expansion system...

Advanced supermarket refrigeration systems

Conventional supermarket refrigeration systems require very large refrigerant charges for their operation, and several new approaches, such as distributed, secondary loop, low-charge multiplex, and advanced self-contained refrigeration systems, are available that utilise significantly less refrigerant resulting in reductions of annual energy consumption and total equivalent warming impact (TEWI).

Several new approaches, such as distributed, secondary loop, low-charge multiplex, and advanced self-contained refrigeration systems are available that utilise significantly less refrigerant resulting in reductions of annual energy consumption and Total Equivalent Warming Impact (TEWI)...

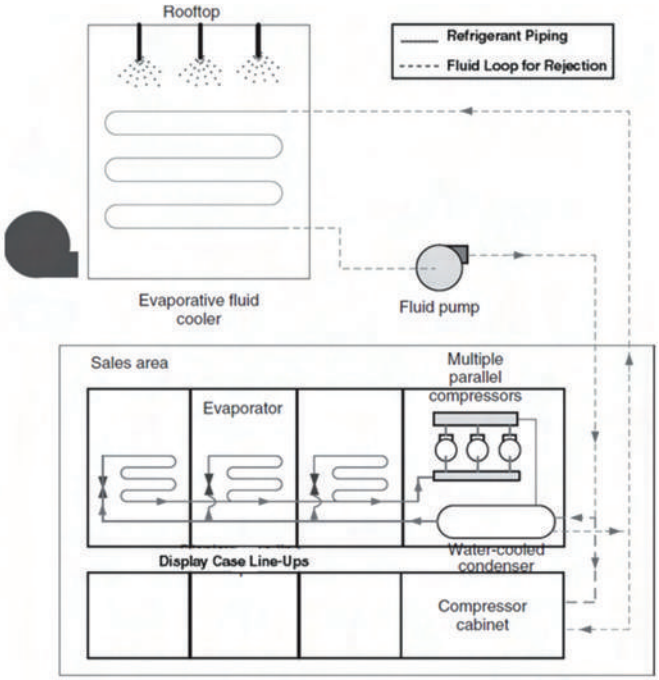


Fig. 3: Distributed refrigeration system...

Distributed compressor systems

Fig. 3 illustrates typical system components. Unlike traditional direct expansion refrigeration systems, which have a central refrigeration room containing multiple compressor racks, distributed systems use multiple smaller rooftop units that connect to cases and coolers, using considerably less piping.

The compressors in a distributed system are located near the display cases they serve, for instance, on the roof above the cases, behind a nearby wall, or even on top of or next to the case in the sales area. Thus, distributed systems typically use a smaller refrigerant charge than direct expansion systems and hence have decreased total emissions.

The refrigerant is compressed in multiple parallel compressors and the superheated refrigerant gas is cooled and condensed in a water-cooled condenser. The refrigerant is then expanded before entering the evaporator. It absorbs heat from the cooled products before returning to the compressors as a vapour.

The water that is heated by the condensing refrigerant in the condenser is sent to an evaporative cooler. It is cooled and pumped back to the condenser to repeat the cycle. To enable the cabinets to be located in or near the sales area, this refrigeration system employs scroll

compressors because of their very low noise and vibration levels. Scroll compressors have no valves and in general are not quite as efficient as reciprocating units for refrigeration applications.

However, this efficiency disadvantage is offset by the fact that the no valve feature allows them to operate at lower condensing temperatures. The refrigerant charge required for a distributed refrigeration system is on the order of 30% or 50% of that required for a conventional air-cooled multiplex system depending upon whether water- or air-cooled condensing is employed, respectively.

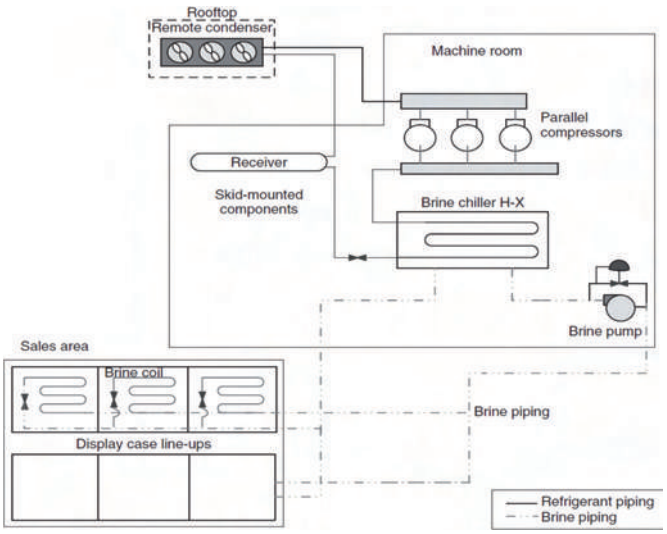


Fig. 4: Secondary loop systems...

Secondary loop systems

Secondary loop systems use a much smaller refrigerant charge than traditional direct expansion refrigeration systems, and hence have significantly decreased total refrigerant emissions.

In secondary loop systems, two liquids are used. The first is a cold fluid, often a brine solution, which is pumped throughout the store to remove heat from the display equipment. The second is a refrigerant used to cool the cold fluid that travels around the equipment. Secondary loop systems can operate with two to four separate loops and chiller systems depending on the temperatures needed for the display cases.

As shown in Fig. 4, the refrigerant is compressed in parallel compressors and the superheated refrigerant gas is cooled and condensed in a remote condenser.

The liquid refrigerant is then collected in the receiver, expanded in a throttling device, and evaporated by absorbing heat from a cold fluid (i.e., brine). The cooled brine is distributed in the sales area (refrigerated area) absorbing heat from the products before returning to the evaporator to repeat the process.

These systems employ chillers located in a remote machine room to refrigerate a brine solution that is pumped to each display case or cold store room.

Lowest energy consumption for secondary loop systems is achieved when the display case heat exchangers are designed specifically for the use of brine, so that the temperature difference between the brine and air is minimised.

Brine selection is also of importance, because energy consumption for pumping is a large component of overall energy consumption. The use of brines with high heat capacity and low viscosity at low temperature is desirable. The number of brine loops employed will also impact energy consumption. Typically, 2 loop temperatures are used, such as -30 and -7^{0}C. If significant portions of the refrigeration load can be addressed by higher temperature loops, energy savings can be obtained.

Each loop requires its own controls and means of maintaining the loop temperature (separate chiller etc.). The central chiller systems are constructed similarly to multiplex racks, using multiple parallel compressors for capacity control.

Use of high-efficiency compressors is highly desirable to help offset some of the added energy consumption associated with brine pumping. Because of the location of the evaporator on the chiller skid, the compressors for the secondary loop system are considered close-coupled to the evaporator.

The pressure drop and return gas heat gain are minimised in this configuration. Both these factors help in reducing compressor energy consumption. These chiller systems can also be equipped with hot brine defrost where brine is heated by subcooling of the chiller refrigerant. Heat rejection can be accomplished with air-, water-, or evaporatively cooled condensers. Like distributed refrigeration, the use of evaporative heat rejection is recommended to reduce energy consumption. The system refrigerant charge will be on the order of 15 to 25% of that required for conventional air-cooled multiplex systems.

Low-charge multiplex systems

Low charge multiplex system (Fig. 5 illustrates typical system components) consists of control systems for condensers that limit the amount of refrigerant charge needed for the operation of multiplex refrigeration. The refrigerant liquid charge is limited to that needed to supply all display case evaporators.

This control technique can reduce the charge needed by the refrigeration system by 1/3 or more. Some liquid charge control approaches can also provide some energy-saving potential by enabling the compressors to operate at lower condensing temperatures. The minimum condensing temperature values suggested are 4.5 & 15^{0}C for low and medium temperature refrigeration, respectively.

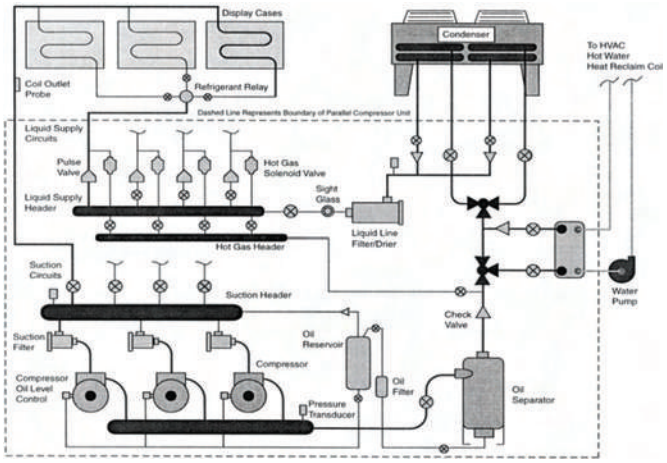


Fig. 5: Low-charge multiplex systems...

Self-contained refrigeration systems

In this type, each display case and storage room has its own compressor and condenser (usually water-cooled). A glycol loop is used to reject heat from the individual refrigeration units to the exterior of the store. For energy-efficient operation of a self-contained system,

capacity control of the compressor is needed. The advanced self-contained system consists of display cases or storage coolers each having their own compressor and water-cooled condenser with warm water pumped to the rooftop fluid cooler for heat rejection.

The self-contained system has advantages in extremely low refrigerant change (one tenth of rack systems), easy and low-cost installation, flexibility in time to order and remodeling. However, the self-contained system has some inherent disadvantages including high equipment cost and low efficiency due to heat transfer penalty of water-cooled condensing.

Cascade refrigeration system

The cascade refrigeration system is shown in Fig. 6. Subcritical CO_2 cycle is used in low temperature circuit. Due to the potentially high system pressure of the carbon dioxide loop during stand still, special precautions have to be taken to avoid excessive pressures.

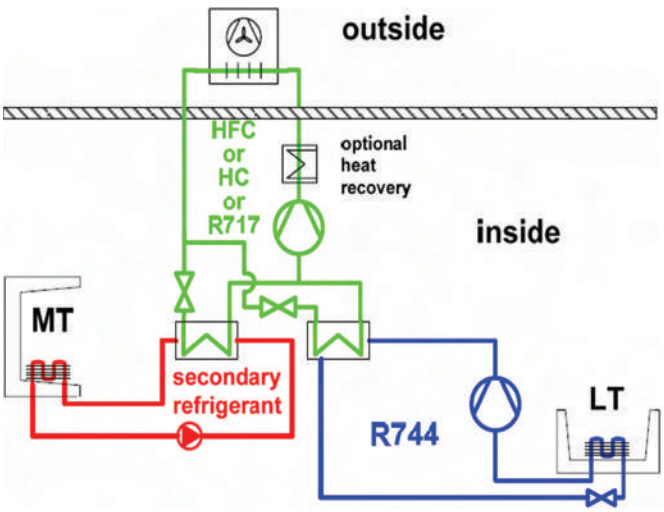


Fig. 6: Indirect cascade refrigeration system...

In a typical supermarket system, which operates 24 hours a day, seven days a week, CO_2 is simply blown off to the atmosphere, if pressures exceed the maximum allowable pressure during stand still. The low temperature loop is built as a cascade system to the Medium Temperature (MT) system. Employing a propylene glycol system for the MT cooling has a few advantages – as compared to direct expansion systems.

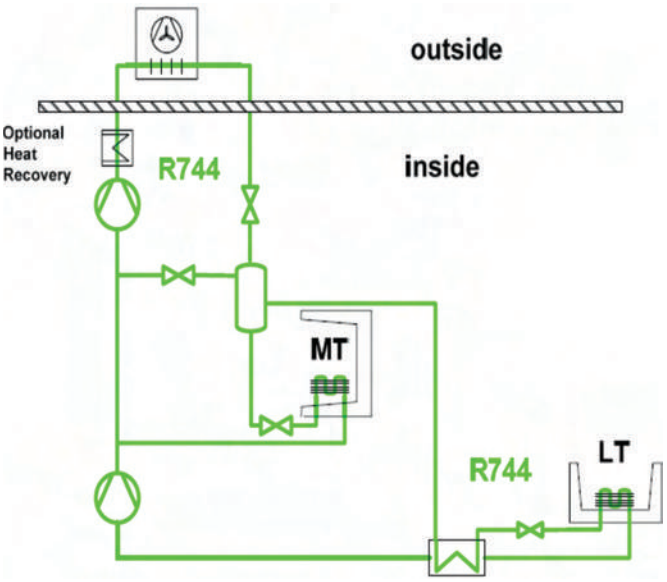


Fig. 7: Central multiplex system with carbon dioxide as refrigerant...

Transcritical CO_2 multiplex system

Fig. 7 shows the various components of transcritical CO_2 multiplex refrigeration system, which uses two-stage compression and evaporations. Due to negative environmental effects of man-made refrigerants, natural refrigerants have been emerged as valuable alternatives.

CO_2 is a strong choice in LT circuit for cascade system. Due to toxicity of ammonia and flammability of propane and isobutene, XP10 is also a good choice in both multi-evaporator and cascade systems due to its comparatively lower GWP (Table 1).

Refrigerant	ODP	GWP	Flammability	Toxicity	NBP (°C)	CT (°C)
Ammonia	0	0	Yes	Yes	−33.3	132.3
Carbon dioxide	0	1	No	No	−78.4*	31.1
Propane	0	3	Yes	No	−42.1	96.7
Isobutane	0	3	Yes	No	−11.7	134.7
XP10	0	500	No	No	−29.2	97.5
R134a	0	1300	No	No	−26.1	101.1
R407C	0	1774	No	No	−43.6	86.2
R22	0.055	1500	No	No	−40.8	96.2
M099	0	1890	No	No	−44.2	85.3
R404a	0	3260	No	No	−46.2	72.1
R507	0	3300	No	No	−46.7	70.6
R502	0.221	4500	No	No	−45.2	80.7

Table 1: Refrigerants for supermarket refrigeration system
ODP – Ozone layer depletion potential, GWP – Global warming potential,
NBP – Normal boiling point, CT – Critical temperature, *Normal sublimation point

Conclusions and future options

Distributed compressor system using CO_2 as working fluid in transcritical cycle or in secondary loop /cascade systems is the best layout for supermarket refrigeration – in term of both minimum energy consumption and environmental effect (TEWI). However the various further improvement possibilities are there, such as use of microchannel heat exchanger, heat recovery and renewable energy sources. Use of distributed system may yield significant power saving and TEWI reduction compared to the baseline multiplex system. ■

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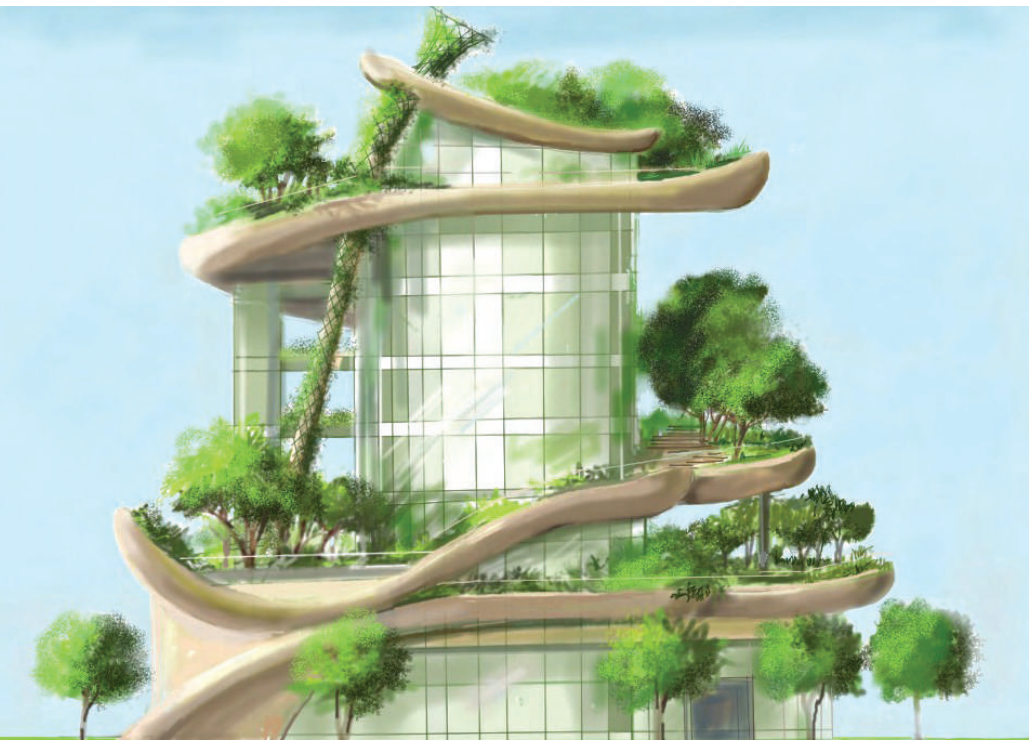

Designing Green Buildings

This article presents a brief summary about the green building designs and the latest scientific and technological developments towards this endeavour...

Living aside the times when human used to live in open with the environment, buildings of homes, offices, market and for many other human activities have been an integral part of ancient to modern civilization with human safety and security. In earlier times (i.e., before modern technological era bestowed with cement and bricks), people used to make buildings with locally and environmentally friendly available raw materials with designs suiting to their day to day needs – with affordable costs as well as suiting to climate changes from time to time.

Traditional buildings were energy efficient because architecture depended on the use and places. Buildings in the hot and dry regions, had corridors directing the wind to cool naturally. In wet regions, structures using natural light and breeze, were used.

Then the use of cement, metal and bricks in the construction of buildings became a way of life, which created enormous energy demand as well as increase in cost. In the present era of energy consciousness, efforts are again being diverted towards making green buildings as a part of civilization, which may be designed and constructed in such a way that not only make human living comfortable but also prove to be in harmony with the nature – and also energy efficient.

Green building

Green building is the practice of creating structures and using processes that are environmentally responsible, and resource-efficient throughout a building's life-cycle from sitting to design, construction, operation, maintenance, renovation and deconstruction. Green building research is being done by national laboratories, private companies, universities and the industry. Further, a green building is one which uses less water, enhances energy efficiency, conserves natural resources, generates less waste and provides healthier spaces for occupants, as compared to a conventional building. This practice expands and complements the classical building design concerns of economy, utility, durability, and comfort. Green building is also known as a sustainable or high performance building.

Green building design and construction provide an opportunity to use resources more efficiently, while creating healthier and more energy-efficient homes and commercial buildings. Successful green buildings leave a lighter footprint on the environment through conservation of resources, while at the same time balancing energy-efficient, cost-effective, low-maintenance products for construction needs. In other words, green-building design involves finding the delicate balance between homebuilding and a sustainable environment.

Green buildings are designed to reduce the overall impact of the built environment on human health and the natural environment by:

- Efficiently using energy, water, and other resources
- Protecting occupants' health and improving employee productivity
- Reducing waste, pollution & environmental degradation

For example, green buildings may incorporate sustainable materials in their construction (e.g., reused, recycled-content, or made from renewable resources); create healthy indoor environments with minimal pollutants (e.g., reduced product emissions); and/or feature landscaping that reduces water usage (e.g., by using native plants that survive without extra watering).

Green building design components

Green building brings together a vast array of practices, techniques, and skills to reduce and ultimately eliminate the impacts of buildings on the environment and human health. It often emphasizes taking advantage of renewable resources, e.g., using sunlight through passive solar, active solar, and photovoltaic equipment, and using plants and trees through green roofs, rain gardens, and reduction of rainwater run-off.

Many other techniques are used, such as using low-impact building materials or using packed gravel or permeable concrete instead of conventional concrete or asphalt to enhance replenishment of ground water. While the

Aspects of Built Environment	Consumption	Environmental Effects	Ultimate Effects
Sitting	Energy	Waste	Harm to human health
Design	Water	Air pollution	Noise
Construction	Materials	Water pollution	Environment degradation
Operation	Natural resources	Indoor pollution	Loss of resources
Maintenance		Heat islands	
Renovation		Stormwater runoff	
Deconstruction		Noise	
Impacts of the built environment			

practices or technologies employed in green building are constantly evolving and may differ from region to region, fundamental principles persist from which the method is derived: siting and structure design efficiency, energy efficiency, water efficiency, materials efficiency, indoor environmental quality enhancement, operations and maintenance optimisation and waste and toxics reduction. The essence of green building is an optimisation of one or more of these principles. Also, with the proper synergistic design, individual green building technologies may work together to produce a greater cumulative effect. On the aesthetic side of green architecture or sustainable design is the philosophy of designing a building that is in harmony with the natural features and resources surrounding the site. There are several key steps in designing sustainable buildings like:

- Energy efficiency and use of renewable energy / Water efficiency
- Environmentally preferable building materials and specifications
- Waste reduction / Toxics reduction
- Indoor air quality enhancement
- Smart growth and sustainable development

Energy efficiency and use of renewable energy: programmes can promote partnerships with homebuilders, office building managers, product manufacturers, and many other organisations to improve the energy efficiency of homes, buildings, and various building components and appliances.

Water efficiency: programmes can promote and enhance the market for water-efficient products and services, and educate home and business owners, and others.

Waste reduction: programs should support projects to reduce, reuse, and recycle waste generated from building construction, renovation, deconstruction, and demolition.

Toxics reduction: programmes should work to provide chemical assessment tools and expertise to inform substitution to safer chemistries and to develop best practices.

Indoor air quality: is a critical component of constructing 'green' homes and buildings. Programmes should be designed to protect occupant health, promote comfort and productivity, and enhance the durability of structures.

Smart growth & sustainable development:

- Community action to organise and take action to reduce toxic pollution in its local environment.
- Approach to storm water management that is cost-effective, sustainable, and environmentally friendly.
- Cost-efficient and environmentally friendly solutions for large-scale landscaping that are designed to help preserve natural resources and prevent waste and pollution.
- To offers individuals, communities and institutions the ability to develop and implement sustainable practices.
- To provide tools to develop healthy communities, promote economic development, build strong neighborhoods and helps to make smart transportation choices.
- To provide information on how to reduce the run-off of pollutants from urban environments into our waters, including low-impact development strategies.

Science of green building

Sustainable building takes us back to the physical properties of energy, air, and water. Green building practices, as well the selection of the appropriate building materials, revolve around a few basic principles of science. Science is what sustainable building relies on, principles that once understood can guide at every step of the way, including:

- A house is a system of interrelated parts
- Energy loses some of its potential each time it is converted from one form to another, which explains why passive solar heat is much more efficient than electric heat
- Form follows function when it comes to design, meaning that construction should be tailored to the environment in which the house is built.
- Air leaks in the building envelope represent a significant loss of energy and open the door to moisture damage inside wall and ceiling cavities.
- Controlling the movement of heat, air, and moisture involves every part of the building and everyone on the building team.

Green building best practices

- Look for designs that use energy as close to its sources as possible to minimise conversion losses: passive solar heat, for example, over electrical resistance heating.
- Consider heat transmissions in all its forms – convection, conduction, and radiation – in selecting building materials and building practices.
- Create an effective air barrier and make sure everyone on the build team understands his/her role in maintaining it through various stages of construction.
- Include some form of mechanical ventilation in the house and strive for a 'pressure neutral' interior as minimum requirement.
- Make sure construction details are able to handle water movement via gravity, diffusion, and capillary action.
- In areas of high noise, consider window upgrades, sound barriers, and alternatives to conventional stick framing.

Green building ideas

Here are some green building ideas that one must consider while designing a green building:

- Build smaller / Cool roofing
- Harness renewable energy
- Rely on recycling
- Use sustainable materials
- Work with the land / Focus on water
- Energise building windows
- Take thermostats to a new level. ■

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Energy Efficiency In Hotels And Buildings

Are you aware of the fact that 40 to 50% of electricity is consumed by utilities like refrigeration and air conditioning alone, in most hotels, hospitals and commercial buildings? Let us see how we can reduce power consumption there just by following some best practices...

Cost of electricity is a major share in the total operating cost of an enterprise. Ever rising energy bills and reduced availability, necessitates the need for efficient use and innovative techniques. A sizable portion of electricity (to the tune of 40 to 50%) is consumed by utilities like refrigeration and air conditioning alone, in most hotels, hospitals and commercial buildings.

However, some of the best practices in vogue in Indian industries have energy saving potential of the order of 20 to 40%. Practices like: incorporation of SCADA & BMS, use of Energy Optimus, Energy Savers for ACs, Variable Speed Drives (VSDs), Earth Air Tunnels (EAT), Waste Heat Recovery (WHR) etc., are few among them. The best practices discussed in this article have shown great promise for large scale adoption in the near future.

Performance assessment

TR? Yes TR or Tons of Refrigeration is a commonly used and familiar term even by non-techies. It is something that even a housewife, barely initiated in technicalities would figure out and understand. However, it clues one, only to the capacity and size of an air conditioning or refrigeration system, but not its performance.

In industry on the other hand, where great footage is accorded to the quantum & quality of the refrigeration effect, and where the power consumption & efficiency of the system are crucial, the term kW/TR has mileage and greater relevance – and is the more apt energy performance related indicator in use. It simultaneously reflects the quantum of power consumed (kW) per unit of refrigeration effect (TR) i.e., the specific power consumption for the

refrigeration system or the machine, as the case may be. Moreover kW and TR in any facility are parameters that are not too difficult to measure.

Like any other specific power consumption indicator, kW / TR can be widely and conveniently used for comparison with bench marks, for intense comparison amongst a bank of machines, and for performance trend analysis. It speaks of the conversion efficiency in broad terms and an upward trend warns of bad performance. Timely intervention to curb the rising trend would be in order, perhaps by restoring to good maintenance & operating practices and / or incorporating appropriate efficient technological changes / retrofits.

To obtain kW / TR value it is obvious, that one needs to measure power consumption in kW and refrigeration effect in TR. Power measurements, i.e., the input power to the drives of the refrigeration compressor, chilled & condenser water pumps, cooling tower fan, are easy tasks involving use of a portable power analyser or panel mounted power/ energy meters. In contrast, the TR of the refrigeration effect or load is a slightly more involved assessment in the sense that, chilled water flow measurements are to be undertaken.

TR in a basic reflects the amount of heat removed or the chilling effect, which would render 1 British Ton of water into ice in a period of 24 hours.

The TR effect can be calculated by the relation: $\mathbf{TR = Q \times C_p \times (T_i - T_0) / 3024}$

Where:

- TR is the cooling duty
- Q is the mass flow rate of the chilled water/ brine coolant in kg/hr
- C_p is coolant specific heat in kCal /kg.^{0}C
- T_i is the inlet temperature of coolant to evaporator (chiller) in ^{0}C.
- T_0 is the outlet temperature of coolant from evaporator (chiller) in ^{0}C.

Flow measurement is the most tricky and difficult part in the overall assessment of the ref. system. Generally, flow meters and indicators are not provided for in most of the cases. Only in recently installed systems, we find online flow meters. Ultrasonic flow meters are now available, which can be used for measuring liquid flows. Magnetic flow meters also find wide use, though these have to be installed in the pipe line. For measuring air flows, (in CTs and AC ducts) anemometers are good bet. A pitot tube can also be used for air flow measurements in AC ducts.

In their endeavour to retain their competitive edge, most of the business enterprises are readily adopting best practices for energy cost reduction...

Once we have a handle on kW/TR values, then it can be expressed, either in terms of Coefficient of Performance (COP) or Energy Efficiency Ratio (EER), and other commonly used energy performance indicators.

The relationship between kW/TR, COP and EER is featured here...		
COP = 0.293 EER	or	EER = 3.413 COP
KW/TR = 12 / EER	or	EER = 12 / (KW/TR)
KW/TR = 3.516 / COP	or	COP = 3.516 / (KW/TR)

	Reciprocating	Centrifugal	Screw
Air Conditioning Temp. Range (chilled water at 4 to 5^{0}C)	0.7-0.9 kW/TR	0.63 kW/TR	0.65 kW/TR
Subzero Temp. Range (-5 to -25^{0}C)	1.25 to 2.5 kW/TR	--------	1.25 to 2.5 kW/TR

Typical normative kW/TR values, for different Vapour Compression refrigeration machines

The above figures includes compressor power alone. If one adds the chilled water / condenser water pumps' power and also the cooling tower fan power, then these kW/TR values may slightly go up. One often encounters the reciprocating compression systems in the field. The typical benchmark overall kW/TR figures including compressor, condenser pump, chiller pump, cooling tower fan, could be 1 to 1.1 for air conditioning systems.

For Vapour Absorption Refrigeration (VAR), Systems the energy performance indicator is Kcal/TR instead of kW/TR. The typical Kcal/TR values are given in the next figure (below).

	LI-Br			Ammonia
	Single Effect	Double Effect	Triple Effect	Single Stage
		Above 6^{0}C		Upto – 33^{0}C
Air Conditioning Temp. Range (Chilled water at 4-5^{0}C)	5000 Kcal/TR	2575 Kcal/TR	200 Kcal/TR	4615 Kcal/TR
Subzero Temp. Range (-5 to -25^{0}C)	-------	-------	-------	6666 Kcal/hr

In their endeavour to retain their competitive edge in the fiercely competitive market place, most of the business enterprises are readily adopting best practices for energy cost reduction. Some notable ones in the cooling/ refrigeration field are discussed hereafter.

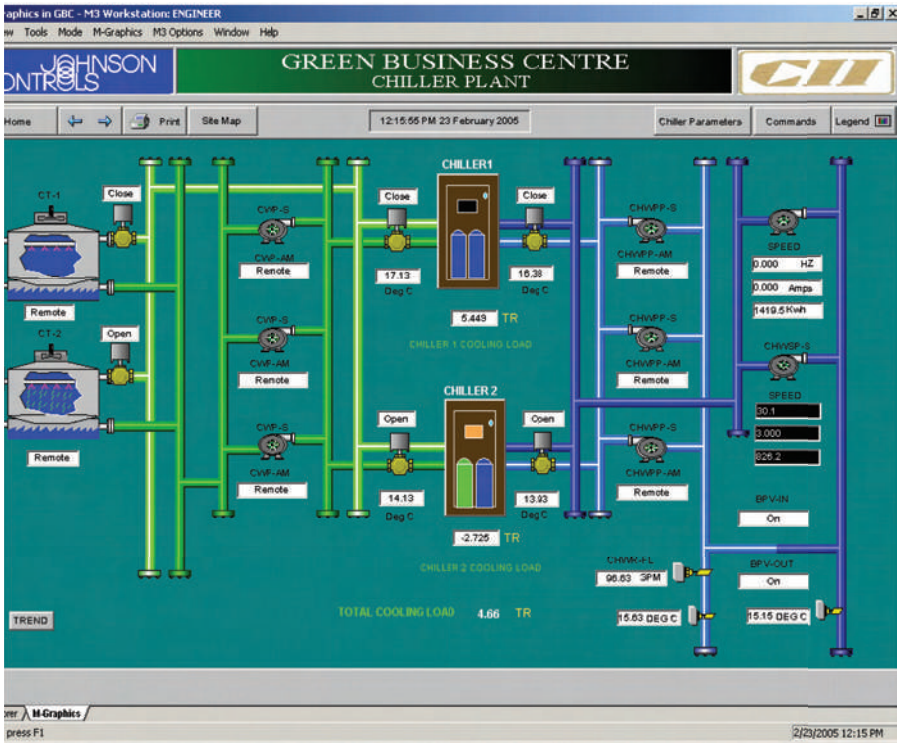
Recent technologies, best practices, systems that have been successfully adopted and implemented are:

- SCADA system for Air Conditioning Plants
- Energy Optimus for Energy savings
- Optimised running of cold & hot H_2O pumps
- Optimised running of cooling tower fans
- Optimised running of Air Handling Units (AHU's) through PID controls & VFDs
- Installation of VAR systems in process industries including hotels and hospitals
- Adoption of air ambiator for low cost air cooling requirements
- Replacing old efficient window A/C's with the latest energy efficient A/Cs
- Use of hybrid water sink energy efficient window AC
- Use of Energy saver for Window A/c's
- Traditional cooling with Wind Towers
- Use of underground Earth Air Tunnel (EAT) to supply pre-cooled air
- Generation of hot water by waste heat recovery through de-superheating

SCADA system for air conditioning plants

Supervisory Control and Data Acquisition (SCADA) system, is a sophisticated automation, data acquisition and data logging tool as well as a control option during operation, thus facilitating operators to effect parameter changes based on actual real time data available at his finger tips.

The facility to view key process parameters like, temperature, pressure and flow of chilled water, cooling water and air, and input power consumption of compressors, pumps, fans, allows the operating personnel to analyse and instantaneously take corrective action. The



SCADA system for air conditioning plants...

optimised utilisation of equipment running time manifests as reduced energy consumption. The real time consumption trend, by individual departments, helps in overall optimisation, leading to energy savings. Several pharmaceutical and dairy units have implemented SCADA and have achieved overall energy savings of the order of 5 to 10%. Many commercial buildings are also going for Building Management Systems (BMS).

Energy optimus

Energy optimus can save energy to the tune of 25 to 30%. Energy optimus can be used in high energy consuming equipments like chillers, HVAV, pumps, air compressors...

Energy optimus is a good energy saver...

Optimised running of water pumps

Very often we find that the cold well and hot well concept being followed, in chilled water / brine centralised systems. Invariably, users encounter the nagging problem of hot water mixing into the cold water by overflow, thus killing the advantage of refrigeration, and losing energy in the process. To overcome this wasteful phenomenon, the speed (RPM) of the cold and hot water pumps can be varied as per need, to control flow and pressure, by installing PID controllers and variable speed drives. Motor speed is varied based on level in the cold/ hot well, and also the pressure in the cold water header.

The power savings that have been achieved by some of the dairy industries are worth more than ₹ 2 lakhs annually, with an investment of ₹ 4 lakhs – i.e., pay back within 2 years.

Optimised running of cooling tower fans

CT fan operation can be optimised by installing temperature controllers for the cooling tower and Variable Speed Drives (VFDs) for the cooling tower fans. The controller provided in the cooling tower pump house keeps track of the temperature of cold water in the header through the sensor provided in the header, and accordingly VFD varies the speed of the CT fans motor. This automatically optimises the CT fan operation and results in sizable power savings, especially for a 24 x 7 type of operation. A majority of modern dairies and pharma industries have implemented this type of system. A good number of industrial units have also implemented ON/OFF controls – actuated based on cooling tower sump water temperature as a low cost solution. The power savings thus achieved by one of the modern dairy, in cooling tower fan alone was around Rs.8 lakhs annually.

Optimised running of AHUs

Optimisation of Air Handling Units (AHUs) can be achieved by installing controllers and Variable Speed Drives for the AHU blowers. The controller installed in the AHUs continuously tracks and monitors the temp. inside the air conditioned area, and accordingly, the speed of the blower motor is varied by the VFDs resulting in lower power consumption.

These types of controls and VFDs have become common nowadays in most of the commercial buildings like hotels and hospitals. In industries also, they have potentials to save energy to the tune of 15 to 20%.

Installation of VAR Systems

Vapour Absorption Refrigeration (VAR) or Vapour Absorption Machine (VAM) are being used by many process industries like pharma, rayon, textiles, fertilizers, refineries and power plants, where steam or waste heat is available

In one of the process industries in India, They've replaced the existing single effect VAM to double effect VAM for cost savings. Recently, one of the leading rayon industry has replaced the existing centrifugal chillers by installing 525 TR single effect vapour absorption chillers. The reported cost benefits are as follows.

Power consumption of centrifugal machines	10,000 kWh/day
Power consumption of VAR	400 kWh/day
Total power savings	9,600 kWh/day
Working days/year	365 days
Annual savings/year (@5.25/kWh)	₹ 184 lakhs
Cost of operation of VAR system by steam	₹ 149 lakhs
Net savings	₹ 35 lakhs
Cost of implementation	₹ 60 lakhs
Payback period	< 2 years.

Towards energy cost reduction, many people are going for direct fired VAR system, where steam is not available. One of the innovative methods adopted by a multi-specialty hospital (Vadodara, Gujarat) is use of solar energy for air conditioning. By generating 3 kg/cm^2 steam by using solar concentric panels, they are able to run the VAR machines and reduce their high power bills.

Adoption of air ambiator technology

We can reduce our air conditioning energy cost by 50 to 60% by adopting air ambiator technology. If you are able to compromise little on humidity, we can go for air ambiator system. We can achieve temps much below the wetbulb temp. using 2-stage cooling. The capital cost of the this system is also less, and this system can be used for outpatient wards of hospitals, canteens, cinema halls, etc., the table (next page bottom) gives the capital cost, operating energy cost of different systems i.e., vapour compression and the air ambiator.

	Ambiator Two Stage Cooling	Vapour Compression System
Machine Capacity	1,50,000 CFM	250 TR
Units per hour	100 units	325 units
Units per day (8 Hours)	800 units	2,600 units
Units per month (30 days)	24,000 units	78,000 units
Units per year	2,88,000 units	9,36,000 units
Cost per unit	₹ 5.00	₹ 5.00
Savings per year	₹ 32.4 lakhs	-

Replacing old inefficient window ACs

The old window ACs are bound to consume more energy. The window ACs, which are designed about 10 years back, the specific energy consumption is around 2 to 2.5 kW/TR. The present genre state-of-the-art, window ACs with scroll compressors are more efficient, and are designed to consume about 1.2 to 1.4 kW/R. With the implementation of standards and labeling programme by the Bureau of Energy Efficiency (BEE), the user has a choice to go for energy efficient window ACs (including split ACs).

Label indicating the energy efficiency of the air conditioner...

Use of hybrid water sink energy efficient window AC

New type of energy-efficient air conditioners are available today, that are more energy efficient (at least 30% when compared to 3-star rated ACs). The fluid that collects heat at the evaporator and releases it at the condenser is called refrigerant. A pump, called the compressor, forces the refrigerant through the circuit of tubing and fins in the coils. Air moves through the tiny spaces between the fins and is cooled by the refrigerant in the coils. This cycle is called vapour compression cycle. The Hybrid AC uses the same compression cycle by adding another stage in condensation. A unique condenser and evaporator design, allowing for faster condensation and evaporation, makes the cycle more efficient than the conventional vapour compression cycle. In most of our installations, we have been able to achieve average power consumption of 0.7 kW/ton.

The Hybrid AC uses the same compression cycle by adding another stage in condensation...

Energy saver for window ACs

MAS is a programmable micro-processor based energy saver window AC. The demonstration at different locations have indicated a savings of 20 to 25%. This is suitable for both window AC and split AC.

MAS is a programmable micro-processor based energy saver window AC...

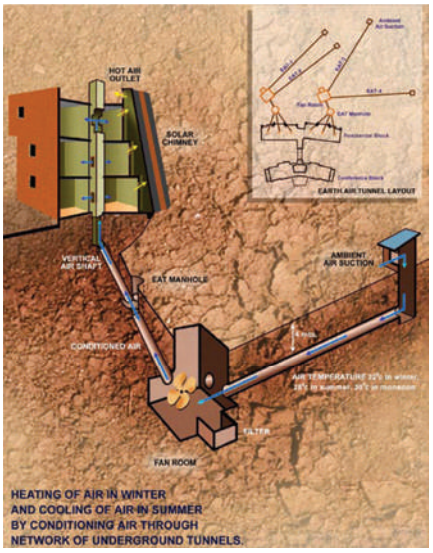
Traditional cooling with wind towers

By constructing wind towers and drawing fresh air intake through the towers and spraying water, similar to air coolers, we are able to reduce ambient air temperature by 5 to 7^{0}C. By passing this cool air through the chiller water fan coil in the AHUs, we can reduce the air conditioning load of the building by 2 to 3%. This is being practised at the CII-Godrej Green Business Centre at Hyderabad, the first building outside USA to get platinum rating by LEED, USA.

Cooling with wind towers...

Use of underground Earth Air Tunnel (EAT) to supply pre-cooled air

The principle of the tunnel is to take advantage of consistency in temperature through out the year at certain depth below ground. At a depth of four metre below the ground, the temperature remains constant, round the year and is equal to the annual average temperature of a place. For instance, Delhi this temperature is between 25 to 26^{0}C. So, if air is passed through such earth tunnel, before funneling into a room, we can expect it to be cool in summer and warm in the winter. In this system air is passed through the underground pipes and then circulated in the rooms by AHU's to reduce heat load. However

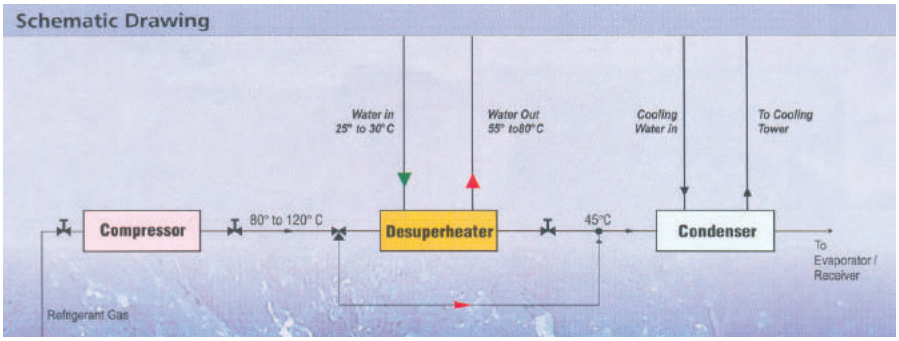


Underground earth air tunnel...

the tunnels cannot remove the excess humidity from the air during monsoon, humid summers. So, additional chillers have to be installed to achieve the required comfort levels. The additional investment required to construct the Earth Air Tunnel can be paid back within a year. The TERI's Gual Pahri campus near Delhi has incorporated this type of system.

Generation of hot water by waste heat recovery through de-superheating

We are more familiar with waste heat recovery from furnaces, boilers, DG sets etc. Waste heat recovery from refrigeration and Air conditioning system has become a reality. By de-superheating the refrigerant from the discharge of compressor, before sending to the condenser, we are able to produce hot water at 55 to 60^{0}C. As a thumb rule, we can generate 20 lit/TR hot water with a ΔT of 30^{0}C. This type of system is more useful for hotels.



Generation of hot water by waste heat recovery through de-superheating...

A check list for energy saving in AC systems and buildings

- Tune up the HVAC control system
- Consider installing a Building Automation System or Energy Management System or restoring an out-of-service one
- Balance the system to minimise flows and reduce blower/fan/pump power needs
- Reduce reheat as much as possible
- Use appropriate HVAC thermostat setback
- Use morning pre-cooling in summer and pre-heating in winter (i.e., before electrical peak hours)
- Use building thermal lag to minimise HVAC equipment operating time
- In winter during unoccupied periods, allow temperatures to fall as low as possible without freezing water lines or damaging stored materials
- In summer during unoccupied periods, allow temperatures to rise as high as possible without damaging stored materials
- Improve control & utilisation of outside air
- Use air-to-air heat exchangers to reduce energy requirements for heating and cooling of outside air
- Reduce HVAC system operating hours (e.g., computer rooms)
- Provide dedicated outside air supply to kitchens, cleaning rooms, combustion equipment, etc to avoid excessive exhausting of conditioned air
- Use evaporative cooling in dry climates
- Reduce humidification or dehumidification where possible
- Use atomisation rather than steam for humidification where possible
- Clean HVAC unit coils periodically and comb mashed fins
- Upgrade filter banks to reduce pressure drop and thus lower fan power requirements
- Check HVAC filters on a schedule (at least monthly) and clean/change if appropriate
- Check pneumatic controls air compressors for proper operation,cycling, and maintenance
- Isolate air conditioned loading dock areas and cool storage areas using high-speed doors or clear PVC strip curtains
- Install ceiling fans to minimise thermal stratification in high-bay areas
- Relocate air diffusers to optimum heights in areas with high ceilings
- Consider reducing ceiling heights
- Eliminate obstructions in front of radiators, baseboard heaters, etc.
- Check reflectors on infrared heaters for cleanliness and proper beam direction
- Use professionally-designed industrial ventilation hoods for dust & vapour control
- Use local infrared heat for personnel rather than heating the entire area
- Use spot cooling and heating (e.g., use ceiling fans for personnel rather than cooling the entire area)
- Purchase only high-efficiency models for HVAC window units
- Put HVAC window units on timer control
- Don't oversize cooling units, (oversized units will "short cycle" which results in poor humidity control)
- Install multi-fueling capability and run with the cheapest fuel available at the time
- Consider dedicated make-up air fir exhaust hoods. (Why exhaust the air conditioning or heat if you don't need to?)
- Minimise HVAC fan speeds
- Consider desiccant drying of outside air to reduce cooling requirements in humid climates
- Consider ground source heat pumps
- Seal leaky HVAC ductwork
- Seal all leaks around coils
- Repair loose or damaged flexible connections (including those under air handling units)
- Eliminate simultaneous heating and cooling during seasonal transition periods
- Zone HVAC air and water systems to minimise energy use
- Inspect, clean, lubricate and adjust damper blades and linkages
- Establish an HVAC efficiency-maintenance programe. Start with an energy audit and follow-up, then make an HVAC efficiency-maintenance programme a part of your continuous energy management programe

Conclusion

The energy bill towards refrigeration and air conditioning alone is contributing to 50 to 60% in majority of the industries such as hotels, hospitals and commercial buildings. The air conditioning loads are increasing day by day – and creating burden on our already overloaded electricity grid. By adopting best practices that are given in this article you will be able to save energy to the tune of 10 to 20% – depending on the application. I remind, the best practices discussed in this article have already been implemented at may places in India, and they show great promise for large scale adoption in the near future. ■

G Subramanyam
Director
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Managing Hospital Cooling

In a replacement project at a hospital, Cool-Therm successfully increased the cooling capacity by around 30% without increasing energy consumption...

In a major replacement project at Swindon Hospital, which has been jointly carried out with Carillion, Cool-Therm has supplied two low temperature Tonon chillers.

The project harnessed the outstanding low temperature performance characteristics of the Italian-made multi-Scroll-based Tonon Galaxy industrial chillers, which operate on a reduced charge of R410A refrigerant.

The quiet nature of the Tonon machines makes them fit to be installed in any hospital environment. Each chiller includes high pressure primary pumps, buffer tank and pressurisation equipment within a compact footprint of 3m x 1.2m.

Image Courtesy: Cool-Therm

An aerial view of the Swindon hospital...

Image Courtesy: Cool-Therm

The Tonon Forty chiller...

The quiet nature of the Tonon machines makes them fit to be installed in any hospital environment. Each chiller includes high pressure primary pumps, buffer tank and pressurisation equipment within a compact footprint...

The units

The units, can operate down to -8^{0}C. They provide chilled water to the hospital's catering department. Each of the two Tonon machines delivers 65kW at -7^{0}C, and replaces ageing chillers rated at 50kW at -2^{0}C.

Additional work

Alongside the chiller replacement, Cool-Therm installed bespoke low temperature fan coils in the cold rooms, to take advantage of the lower water temperatures – and maintain cold rooms at a lower temperature.

Project execution

The chillers were selected to deliver improved performance and energy efficiency, and ensure resilience for the critical hospital environment. The cooling system is designed with a N+1 complete backup system. The chillers were replaced over two weekends, with commissioning taking place during the Christmas week, without the site losing chilled water production.

Project economy

Each of the Tonon chillers is equipped with three high efficiency Sanyo scrolls, replacing the Bristol hermetic reciprocating compressors on the previous chillers.

"It allowed us to increase cooling capacity by around 30% without increasing energy consumption. The system also benefits from a greater capacity turn-down, with much smoother temperature control than that was possible with the original chillers," says Rob Young, Director, Cool-Therm. ■

Rob Young
Director, Cool-Therm

Maintenance Of Building HVAC Electrical Systems

The cost of maintaining the power system is lower than that of repairing other building systems, and hence a focused approach to electrical system maintenance can pay very rich dividends...

In a busy BPO facility in Delhi, floor operations had just began in the morning, with the employees logging into their systems and getting ready for the shift. The floor air conditioning suddenly stopped and the facility manager took it to be a routine stoppage for a change over but when the Air Handling Unit (AHU) did not start after the normal 3 to 5 minutes, he got worried and enquired with the building manager. The news was not good – the electrical power to the building's central chiller as well as the risers to the floor was down due to a rupture of the bus duct of that section of the building.

The temperature on the floor kept on increasing and the temperature in the server rooms shot up rapidly, leading to the IT team having to shut down the servers. By the time the supply was restored, over two hours had passed, and considerable damage was done to not only business but also the reputation of the company's image with their clients! So, a problem in the building's electrical system brought down the HVAC system and in turn impacted the business operations.

This kind of scenario is played out in buildings and offices all over the country on a very regular basis, and the impact on business operations is usually quite severe as the modern business operations are heavily dependent on IT services – which in turn are dependent on continuous, uninterrupted and quality power.

Electrical system interconnect to the HVAC system – as the chillers are the largest load in the building, and therefore a very important and critical part of a building. The HVAC electrical system thus require the highest level of upkeep

and maintenance, and also effective operations. While this is understood by most building operators and owners, it is quite often a neglected aspect of building maintenance. There are many instances where the electrical systems have not been taken off grid to carry out servicing for over two years - this usually results in a major incident occurring in the third year and of course, someone paying for the loss in business either by getting a reprimand or even getting fired!

Key components of the building HVAC electrical system

All building services and facilities depend on electrical power for their operations, and hence, the electrical system connects to all parts and components of the building. Thus, the system has linkages to all areas of a building such as the HVAC systems, security systems, plumbing systems (for the pumps), vertical transport systems and so on.

While building electrical systems link to all other systems, when the HVAC electrical system is discussed, it typically covers the following:

- High Tension (HT) side distribution switchgear (HT breakers, panels)
- Transformers
- Low Tension (LT) side distribution switchgear for the chillers, primary and secondary pumps, etc (LT breakers, panels, control systems)
- Standby power generation systems (DG sets, synchronizing panels, control systems)
- Electrical cabling/bus ducts to plant rooms and floor tap off points, AHUs etc.

What can go wrong and where?

Each component in a building system is critical to ensure power reaches the users when it is needed. Since the systems are linear in that one component feeds to the next, a breakdown in one of these can lead to a disruption in the system downstream.

Redundancies are built in the system where cost permits or critically mandates, but even then, when a section of the system goes down, the parallel system is again vulnerable till the breakdown is rectified.

Since all components are equally critical, the operators and maintainers need to pay equal attention to the entire system. The most common defects that occur in the various components of the electrical system are:

Failure can occur due to accidental cutting of cabling or degradation of the insulation between the conductors in the bus duct due to moisture...

Breakers: The HT and LT breakers channel the power to the required areas. Vacuum circuit breakers are usually found in the HT section – whereas Air Circuit Breakers (ACBs) are used in the LT side. A typical ACB, which is the most common breaker found in buildings is shown in figure 1. The most common problem encountered with such breakers is their inability to 'engage' or 'disengage' when required.

This results in either supply not reaching the downstream user or power not getting cut off when it is needed to. Modern ACBs have control systems that switch on or off the breaker and problems in the control circuit can often result in the ACB not functioning properly. Flashing of the breaker contacts is also a problem faced that can lead to power disruption. Mechanical interlocks can at times also not function as designed, resulting in the breaker not engaging.

Fig. 1: A typical ACB...

Transformers: The transformer is a capital cost head for a building and usually does not fail, as the design is robust. However, the operating conditions of the transformer affects the life and functioning of the transformer. If the frequency of grid supply failure is very high, the transformer will be cycle between load and no load more frequently, resulting in degradation of the system health. One common defect that occurs in oil type transformer (shown in figure 2) is the contamination of oil due to water ingress. Failure of windings is not very common, but does occur occasionally due to mostly design or mechanical failure.

Fig. 2: A typical transformer...

Power distribution circuits: The weakest link in the electrical systems is the distribution system within the building. The power is distributed through either bus bars or through bust ducts, with the late being seen in most modern constructions. The failures occur mostly at the points where joints are made – such as the lugs at the panel terminations or where the bust duct changes direction.

Failure can occur due to accidental cutting of cabling or degradation of the insulation between the conductors in the bus duct due to moisture. A common problem seen in many buildings is the positioning of the bus ducts or riser cables under plumbing lines leading to water ingress in case of any water leakages from the lines.

Maintaining the electrical system

Like all building systems, a robust and documented Planned Preventive Maintenance (PPM) plan is essential to keep the system functioning as intended.

The staff needs to be trained on the functioning of the electrical system and the limitations of the system – so that it is used correctly. Many breakdowns occur due to incorrect operations or overloading. Some of the best practices that the maintenance team can adopt to increase the life of the electrical system as well as maintain it at high level of efficiency are list below.

Annual shutdowns: As maintenance cannot be undertaken on most components of the electrical system when the system is live, a 'shutdown' is needed where the building operations are stopped and the system is de energized and maintenance work carried out.

This is easier said than done as there is usually pressure from the building business operations team to delay the shut down as it means transferring critical IT data to another location, which is time consuming and costly. A shutdown once a year is an absolute necessity as it gives the operators time to check the system health. Key aspects that are covered in shut down are shown in figure 3.

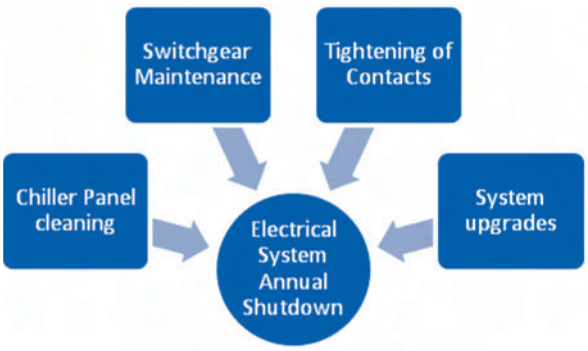


Fig. 3: Key activities covered in shutdown...

Thermography: An efficient way to identify defects in a live system is to use thermography, where a thermal imaging camera is used to map the heat signatures of the various components of the electrical system. Areas that are defective come up as hotter than the surrounding, and can be rectified before a breakdown occurs. For large buildings, an in house thermal camera is recommended so that more frequent (six monthly) test runs can be done. For smaller buildings, third party agencies can be called to undertake the thermography once a year just prior to the shutdown so that rectification can be done when the system is deenergised. Figure 4 shows a typical thermography image of a hot spot in a panel.

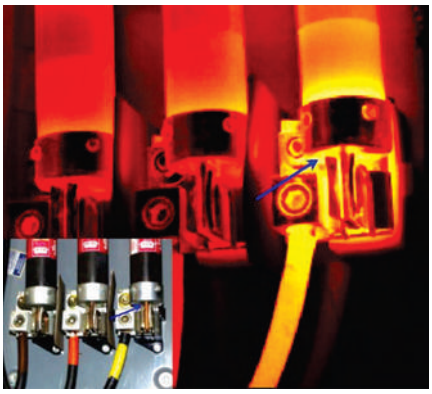


Fig. 4: A typical view of thermography set up...

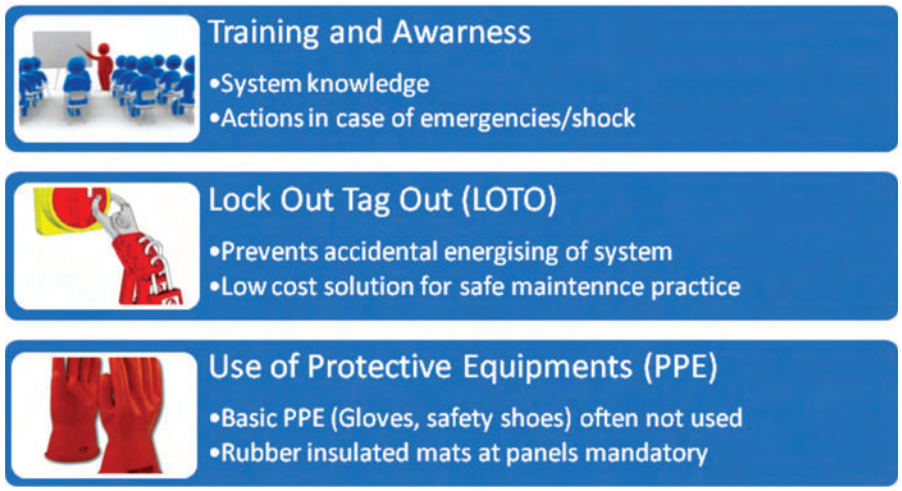
Power quality audits: The quality of power reaching the end users can degrade due to various reasons such as generations of harmonics due to inductive loads, low power factor, improper grounding etc. Poor power quality can lead to various problems like voltage spikes, burnouts, tripping of MCCB etc. A power quality audit will identify the cause of the poor quality and also suggest rectification measures.

An annual power quality audit is recommended for mid to large sized office buildings. Poor power quality can result in failure of motors and frequent tripping of breakers, which in turn put higher cyclical load on the chillers, leading to reduction in their operating life.

Earth resistance checks: One of the easiest ways to keep an electrical system healthy is to ensure that the earth or grounding of the system is good. Typically, the earth resistance should be in the range of 0 to 2 ohms, with a maximum of 5 ohms. Quarterly checking of the earth resistance and maintenance of the earth pits will go a long way in ensuring good power quality and lower defects in the system.

Safety aspects in maintenance of HVAC electrical systems

Anyone who has had a mild electrical shock will vouch that it's not a pleasant experience. 220 V is enough voltage to cause fatal injuries to personnel, and hence there is need for the highest level of safety to be adhered to – when undertaking maintenance of electrical systems. The key aspects of safety when maintaining power systems are shown in demo bands above.



Conclusion

HVAC systems depend heavily on the electrical systems in the building to function effectively, right from the HT breakers to the low voltage control circuits.

The consequences of a poorly maintained electrical system directly impact the air conditioning systems – and eventually lead to loss of business and cost, and can also lead to serious injuries to personnel.

The cost of maintaining the system is however low as compared to other building systems, and hence a focused approach to electrical system maintenance can pay very rich dividends.

With advances in predictive maintenance, technologies such as thermography, it is easier to anticipate failures and assess system health. The maintenance plan should thus include these tools to ensure a healthy system. The last but very critical aspect of electrical system maintenance is the need for adhering to the highest standards of safety. ■

Aneesh Kadyan
Director - Operations
CBRE South Asia Pvt Ltd

Image Courtesy: Laird

Ensuring Reliability Of Cellular Coverage

The battery life in the base stations of cellular antenna towers is significantly reduced by exposure to temperatures outside the optimal range. Laird's new AA-480 series outdoor coolers protect these critical batteries...

Laird (LRD: London) has released its new AA-480 Series Outdoor Cooler, which improves the reliability of cellular coverage, keeping people connected during a power outage by protecting the emergency batteries used in wireless base stations.

When the power to a cellular antenna tower goes out, emergency batteries in the base station turn on to provide power for up to six hours. But battery life is significantly reduced by exposure to temperatures outside the optimal range.

That is why many wireless base station operators take measures to ensure that emergency batteries are kept at the proper temperature extending the life of those batteries – and ensuring more reliable cellular coverage during power outages.

As per the company, the new AA-480 Series Outdoor Coolers protect these critical batteries by providing greater cooling power and increased reliability compared to other units currently on the market. And the AA-480 accomplishes this using less energy and taking up less space compared to the similar units.

With a Coefficient of Performance (COP) rating of 1, they have nearly 50% more efficiency than standard air-to-air units offered today. This saves installation and maintenance costs for users as well as space inside the battery cabinet.

Due to its robust, steady-state construction, Laird's AA-480 series also requires less maintenance, cutting the total cost of ownership as well as the time spent traveling to and from these sometimes remote locations.

"Long life operation is required in wireless base station applications to maximise uptime and maintain low cost of ownership," says Anders Kottenauer, Senior Vice President of Laird's Engineered Thermal Systems Business. "This product has a COP of 1, which is unheard of in our industry. That means it will run longer with less power consumption than previously designed thermoelectric based cooling units."

The AA-480 Outdoor Thermoelectric Cooler is an Air-to-Air Thermoelectric Assembly (TEA) that uses impingement flow to transfer heat. It offers dependable, compact performance by cooling objects via convection. The AA-480 has 480 Watts of cooling power and a COP = 1 at $\Delta T = 0^0C$.

Key system features

- Designed to pass rigorous telcordia testing,
- Input power accommodates a nominal or float voltage of 24/28 or 48/56 VDC
- Power cycle tested up to 100K cycles
- Environmentally friendly solid state operation with no CFC refrigerants
- Fans can be controlled for reduced noise
- Cooling and heating in the same unit to maintain compact form factor.

The AA-480 complements the product family of outdoor coolers for harsh applications but can also be easily retrofitted as a substitute for compressor based air conditioners used in medical diagnostic and analytical instrumentation for cooling and heating applications –where maximising system uptime is required. ■

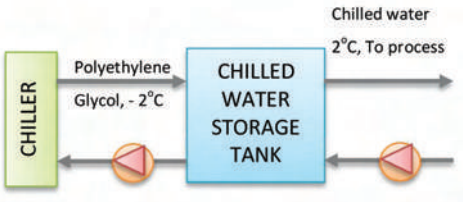
One Degree Chiller

Thermax has established design and control philosophy required for operating at subzero evaporating temperatures. These features too, were integrated and monitored during the 1 Deg concept finalization testing...

In many industries, particularly in food & beverage, dairy and pharmaceutical sector, the required process temperatures are below 5^0C at various points along the manufacturing course. It may involve cooling a process fluid to lesser than 5^0C or maintaining a storage/packaging area at temperatures below 5^0C.

For such cases, the cooling media has to be circulated at even lower temperatures, i.e., lesser than ~3^0C, to enable the heat exchange. Earlier, for temperatures lower than 3.5^0C, glycol solutions were chosen as cooling media to avoid freezing issues associated with use of pure water. However, use of glycol solutions has its own set of drawbacks.

- **Process compatibility:** In many processes, mainly F&B applications, glycol is not acceptable due to toxicity issues. In such cases, indirect heat exchange circuits or ice bank tanks have to be included between the chiller and the actual process.



Indirect heat exchange circuit...

This not only further reduces the outlet temp required from the chiller [to allow approach in the heat exchanger circuit] but also adds to the no. of required accessories ultimately increasing initial and operating costs.

- **Heat Transfer:** Heat Transfer Co-efficient (HTC) observed for glycol is lower than pure

water owing to its thermophysical properties. The reduced HTCs have to be compensated for by providing excess area for heat transfer. Thus, equipment's initial cost increases.

- **Corrosion:** Glycol solutions are more corrosive than water. Also, glycols degrade to acids over a period of use that adds to the corrosive nature. Therefore, on glycol addition, it becomes necessary to use corrosion inhibitors and buffers.
- **Pressure drop:** Due to higher viscosities, required pump head and pumping costs also increase.
- **Recurring cost of glycol solution replacement:** As glycols degrade over a period of time and use, the solution has to be replaced after definite intervals adding to operational costs & maintenance work.

All these glitches can be avoided by using pure water as the cooling media. The question remains, how to tackle the freezing?

Freezing phenomenon

We expect a material to solidify when liquid cools to just below its freezing temperature. However, crystallisation phenomenon follows process of nucleation i.e., initially small crystals, nuclei, are formed by clustering of atoms throughout the body of the liquid. Freezing is observed once these nuclei stabilise and start growing.

The minimum size of a crystal that must be formed by atoms clustering together in the liquid before the solid particle is stable and begins to grow is called as critical radius. This critical radius is a function of undercooling (cooling achieved below freezing temperature). As the extent of undercooling increases, the critical radius also reduces.

When there is continuous flow of liquid, the formation of stable nuclei for freezing is disturbed due to the flow turbulence and the onset of freezing is possible only after a certain amount of undercooling has been attained i.e., when the critical radius is sufficiently reduced.

That is, required undercooling for onset of freezing for certain flow regimes, and velocities can be ascertained by actual testing.

Anomalous expansion of water

Another fear entertained against use of pure water below 3.5^{0}C temperature is the phenomenon of anomalous expansion displayed by water below 4^{0}C. However, the decrease in density of water between 4^{0}C and 0^{0}C is nominal. As can be seen in fig.1, density of water at 1^{0}C is same as that at 7^{0}C.

As such, there is no need to worry about increase in the circuit pressure as long as water is in liquid state.

As for the LiBr-water systems, the refrigerant is water, for these evaporating conditions (being discussed here) the refrigerant itself will freeze...

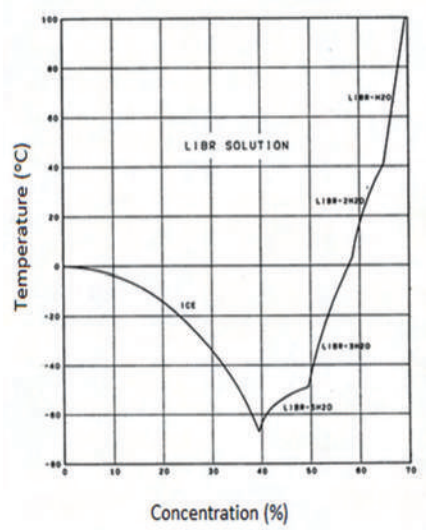


Fig. 3: The fusion curve...

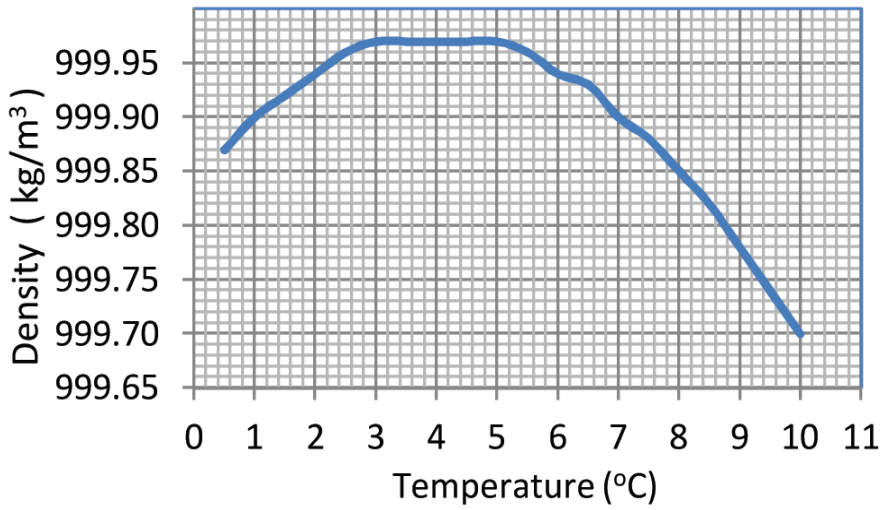


Fig. 1: Water density variation with temperature...

Subzero evaporating temperatures

If the required chilled water outlet temperature is below 3.5^{0}C, the evaporating temperature for the refrigerant will have to be 0^{0}C or even below. As for the LiBr- water systems, the refrigerant is water, for these evaporating conditions the refrigerant itself will freeze. That is, even the refrigerant freezing point has to be depressed. This can be achieved by intentional contamination of the refrigerant – intentional addition of LiBr to refrigerant. However, maintaining the extent of contamination in the desired range is critical for efficient chiller performance:

- Higher concentration – poor transport properties, lower heat transfer, reduction in cooling capacity
- Lower concentration – Freezing of refrigerant

Ground work

Thermax conducted extensive testing to ascertain the acceptable working conditions for hassle free use of pure water below 3^{0}C.

- Freezing point depression of water was determined for different flow velocities in the evaporator tubes and headers
- Increase in circuit pressure in event of freezing was monitored
- Simulation of abnormal operating scenarios and corresponding corrective control actions were determined.

Thermax already has established design and control philosophy required for operating at subzero evaporating temperatures; this was also developed through exhaustive experimentation. These features too, were integrated and monitored during the 1 Deg concept finalization testing.

1 Deg chiller - design

Avoidance of freezing in headers and tubes:

- By ensuring certain minimum velocity of chilled water in the tubes,

freezing point is lowered such that there is safe margin between operating condition and freezing condition

- The required velocities at rated conditions are ensured during heat exchanger design itself
- Online measurement and monitoring of flow velocity in evaporator tubes and headers
- Inclusion of Required corrective actions in control logic in event of deration of flow velocities

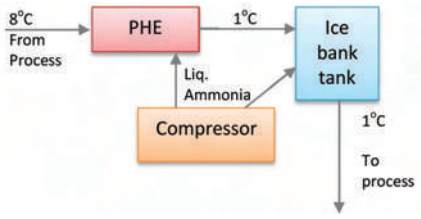
- SS tubes in evaporator for better strength at lower temperature operation
- Online monitoring and accurate control of refrigerant contamination
- Provision of sufficient controls to ensure smooth and efficient operation.

One Deg Chiller - advantages

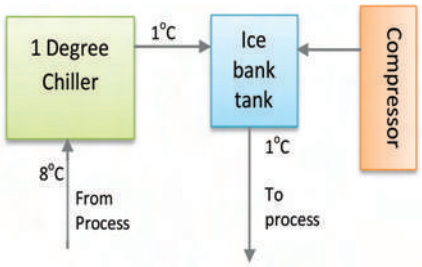
- One Degree Chiller allows use of pure water in chilled water circuit till desired chilled outlet temperatures as low as 1^0C
- As pure water is being used, optimum heat transfer co-efficients are observed in the chiller and cost/ TR reduces
- As the chiller sizing is optimum, COP of the VAM for a given duty is higher by 3 to 5% in 1 Deg Chiller as compared to use of glycol solutions
- Also, as indirect heat exchange is no longer required, the process becomes simple to erect, operate & maintain
- Operational savings would be higher due to better COP, lower pumping and maintenance costs – ensuring a more attractive payback time.

Applications

A typical schematic of chilling systems in dairy



- As seen, the compressor is catering to the chilling load of cooling from 8^0 to 1^0C, with maintenance of ice bank tank
- With 1 Deg chiller, the PHE and associated scheme can be done away with
- Also, the compressor load will be greatly reduced; the compressor operation will be limited to only IBT maintenance as and when required.
- That is, the power consumption will reduce substantially. As a thermally activated vapour absorption machine is catering to a larger portion of the chilling requirement, either steam from biomass boiler or more waste heat recovery will be feasible. The overall operation costs will greatly reduce.



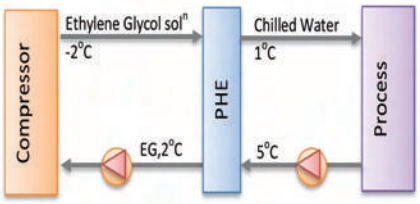
- The above mentioned scheme has already been supplied to a dairy company. The following was the scheme revision:

Equipment	No. of operating units	Chilling capacity (kW)	Operating hours (h)
$Compressor_1$	1	112	9
$Compressor_2$	3	30	72
Chilling system for IBT: Before			

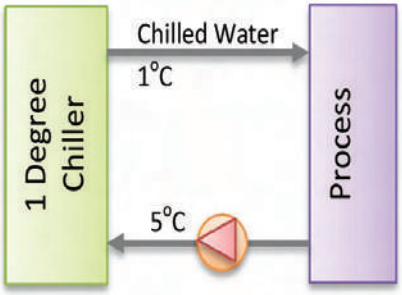
Equipment	No. of operating units	Chilling capacity (kW)	Operating hours (h)
VAM	1	468	16
After			

Food, beverage and pharma industries

In food, beverage and pharmaceutical industries, indirect circuits are added due to toxicity issues of glycols.



- As can be seen, due to an additional indirect circuit with glycol, the required cooling media temperature from the compressor is further reduced.
- As such, the COP of the chiller reduces further and the power consumption increases. The additional pump required for the glycol circuit also adds to the power requirement of the process.
- 1 Deg chiller will make the system very simple.



- Now, as a vapour absorption machine is catering to the chilling requirement, the system will be thermally driven, i.e., steam from biomass boiler or waste heat from any source can be utilised.
- Obviously, the required power and subsequently the optn. costs of the chilling system will reduce greatly.

Description	Unit	Electric chiller	1 Degree Chiller
Capacity	TR	250	250
Power consumption /TR	kW/TR	1.1	0.06
Additional Pump	kW	11	0
Power Consumption	kW	285	15
Steam Consumption	kg/h	0	1125

Similarly, the concept can be used to simplify various chilling systems which have become tedious owing to their lower temp requirements and thus have higher initial and operating costs. ■

P Babu
Head Innovation Dept.
(Absorption Chillers & Heat Pumps)
Thermax
He introduced world's first LiBr double effect chiller.

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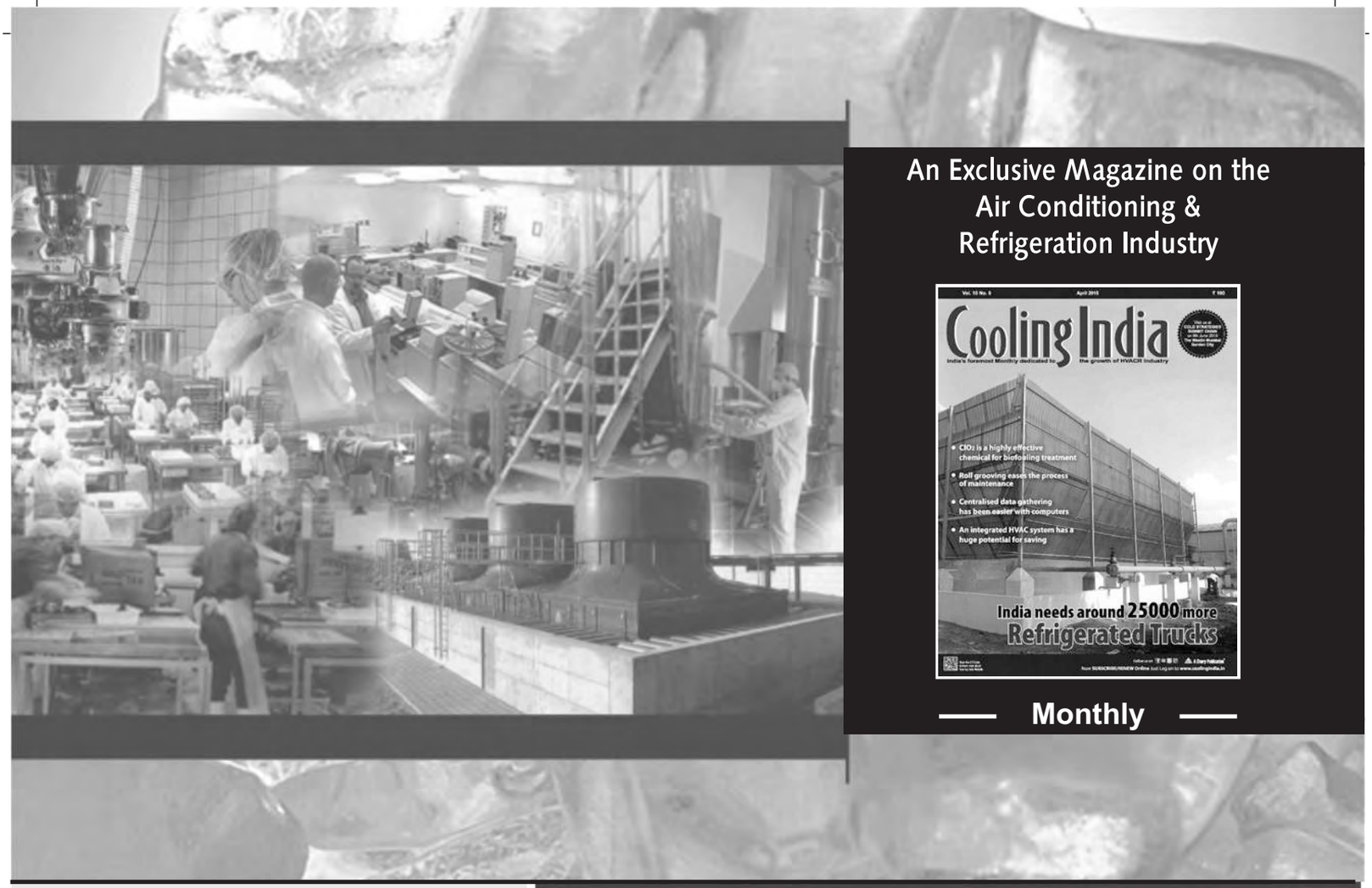

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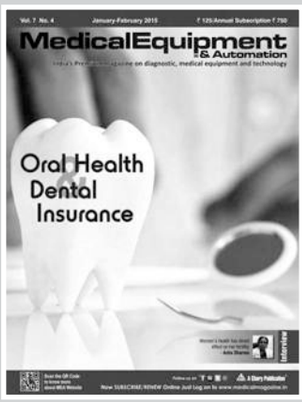

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Siemens Shows Its Building Management Technology At China Refrigeration Expo

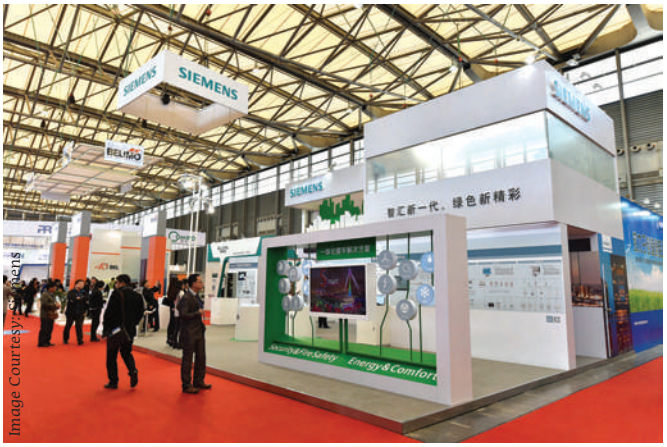


Image Courtesy: Siemens

Siemens' Desigo CC – building management system on display station…

Image Courtesy: Siemens

Desigo TRA Smart Hotel Application helps enhance living experience and hotel management…

Siemens participated in the 2015 China Refrigeration Expo from April 8 to 10. The company showcased advanced technologies such as the new generation building management station Desigo CC, smart office and home building, smart hotel and intelligent lighting etc. As one of the largest professional exhibitions in global HVAC & Refrigeration industry, the 2015 International Exhibition for Refrigeration, Air-conditioning, Heating and Ventilation, Frozen Food Processing, Packaging & Storage (China Refrigeration Expo) was held ceremoniously, in Shanghai New International Expo Center.

Theme of the exhibition

The theme followed in the expo was 'New Generation of Intelligence Technology for New Age of Green Building.' Shao Kangwen, Executive Vice President and General Manager – Building Technologies Division, Siemens, China, said, "As the global leader of intelligent and integrated building solution, Siemens always walks in the technical front, providing diversified and integrated solutions for varied needs – intelligence, integration, energy saving and security - of buildings in China."

"Nowadays, with digitization, technologies play more and more important roles in smart buildings, Siemens dedicates itself in innovation of this field – and launches cutting-edge systems like the Desigo CC, a building management platform able to provide optimal performance, and personalised experience for customers. In future, Siemens will continue to invest in R&D and develop more advanced products and solutions – to address the new challenges of environmental protection, energy efficiency, individualisation, so on and so forth," he added.

Siemens' Desigo CC platform

Siemens' latest high-standard building management platform, Desigo CC leverages the most advanced technology, completely new software architecture and new patents. It provides users the optimal performance and facilitates their convenient and efficient operation, control, optimisation and management of the building system. Moreover, the special features and functions of Desigo CC also make it a value-added platform – and allow customers to personalise the system to satisfy future needs.

For example, it is a highly flexible platform. The interface dedicated for users' workflow simplifies task and operation of buildings, enhances user experience, and allows users to control the building faster, safer and more comfortable. Meanwhile, it is an open system, which can not only access Siemens products, but also supports multiple standard protocols to meet the current and future needs of building control and security.

What's more? It can analyse system data to help users optimise building control or identify hidden malfunction, so as to minimise downtime. Desigo CC also ensures and prepares clients' installed systems for future migrations. And the Web Client options reduce maintenance costs over the entire lifecycle.

Desigo TRA Smart Hotel Application

Desigo TRA Smart Hotel Application provides perfect function combination for hotel room, and ensures the interaction and cooperation of heating, ventilating, air conditioning, lighting and sunshade. By engaging users in energy-saving function, the system control can satisfy their needs – while save energy based on actual demand. For instance, the Green Leaf Symbol will remind user to take appropriate actions for unnecessary energy consumption. It not only gives the best living experience to hotel guests, but also helps hotel administrator realise the most efficient and energy-saving management.

GAMMA Instabus System

KNX-based GAMMA Instabus System, which focuses on control of office buildings, public buildings and households, provides users professional solutions for lighting, curtain and air conditioning for a more comfortable, energy-efficient and secure environment. Its standardised technology, modular structure, flexible configuration and reliable operation create a comfortable environment while improve system performance and save energy. This system has been widely applied in building projects and is highly recognised by the market. ■

Enhancing Efficiency Of **ACHEs**

For running the Air Cooled Heat Exchanger (ACHE) with the same efficiency in summer as well as in winter months, air has to be cooled to the designed temperature by some external medium. How can that be done?

Globally, there is a growing need for both electric power and water. Due to large scarcity of water, this may lead to conflict between water for power plant cooling requirements and that for other agricultural, residential, or environmental uses. Hence, there is a huge inclination towards use of dry cooling (air cooling), which is supposed to be an attractive alternative to the use of wet cooling – basically on the grounds of water conservation.

It is well known that dry cooling on one hand substantially reduces the need of water in process/ power plants, on the other hand – it may cause reductions in plant efficiency and output during hottest periods of the year.

Mist Ressonance Engg. Pvt. Ltd. has come out with a solution by designing Mist Cooling System for air cooled heat exchangers/ condensers – where air temperatures are reduced by 8 to 10°C during hot period of the year. Water quantity required for doing this is approx 1/10th of what a water cooled cycle would require, and hence it provides a perfect way of running your process /power plants at its designed efficiency throughout the year without any water/ environmental issue.

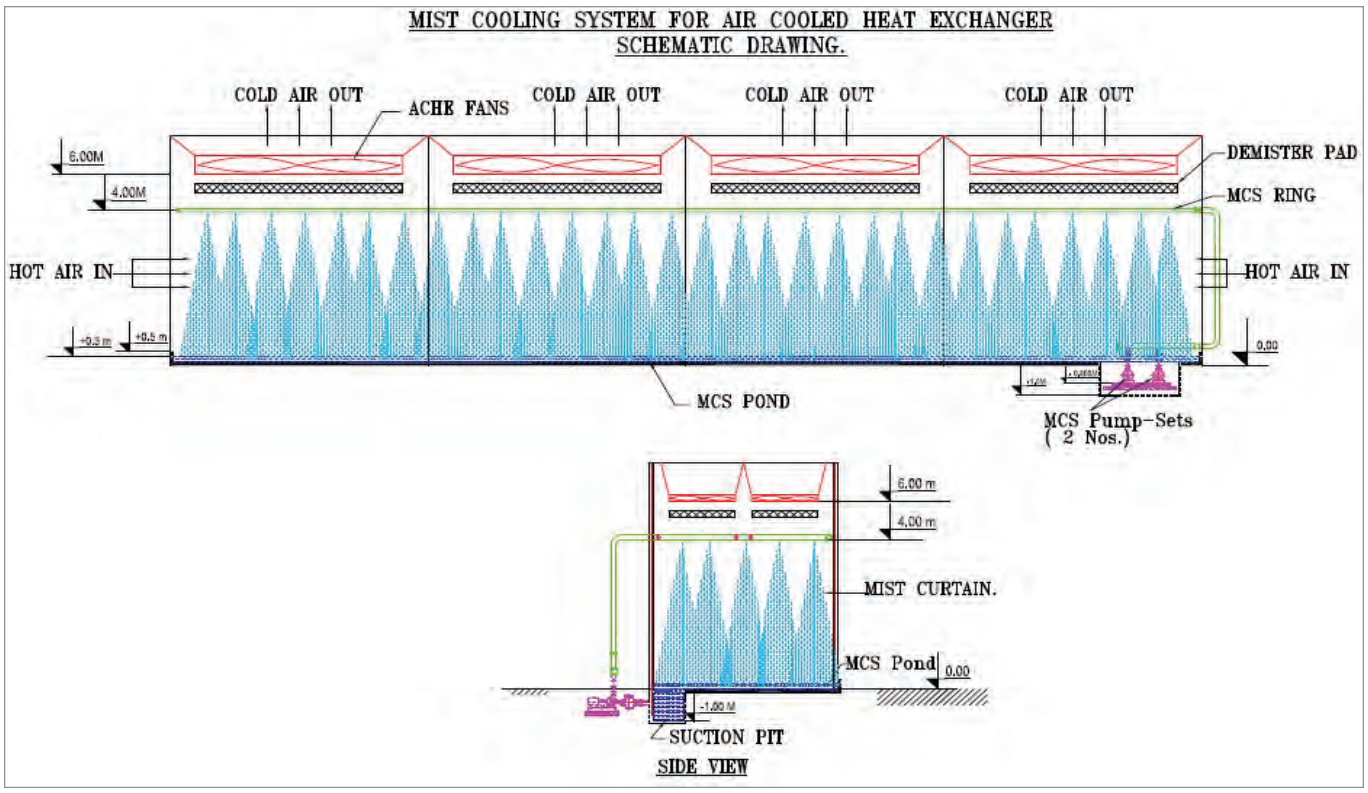
Mist Cooling System (MCS)

MCS induces water to intensive atomisation - i.e., water particles are sub-divided to around five microns. The atomised particles shoot out of 'mist-creator nozzles' at immense speed and form mist.

This ensures extensively large surface area for a longer interval – and at high velocity providing a mist formation. Surface evaporation is very fast – i.e., even faster than the time needed for reaching equilibrium.

Image Courtesy: Mist Cooling System Pvt. Ltd.

The arrangement of the nozzles and the size of the mist are kept in such a fashion that it offers minimum resistance to the air flow through ACHE. Also, mist is not carried over to ACHE tubes thus giving trouble free operation...



A demister pad is placed between the mist curtain and the fan deck in order to arrest fine droplets from going to tube bundle...

This is similar to the phenomenon of formation of hailstone, when rainwater reaches temperatures much lower than wet-bulb. MCS simulates the nature and temperature to as low as wet-bulb temperature. This is just not possible in conventional spray or cooling towers – where ultimate temperatures are 5 to 7^{0}C higher than prevailing wet-bulb temp.

Purpose of installation of MCS for ACHE

ACHE (Air Cooled Heat Exchanger) is designed to cool / condense the product fluid / steam from process plant by air at certain maximum ambient temperature.

Normally, in peak summer, the air temperature exceeds the designed temperature mainly in day time. This reduces the efficiency of ACHE by a considerable amount. Hence, for running the ACHE with the same efficiency in summer as in winter months, air has to be cooled to the designed temperature by some external medium. We propose to do this by passing this inlet air through a water / mist curtain before entering ACHE.

The detailed scheme

As explained earlier while describing the technology, mist creator nozzles induce water to intensive atomisation, thus subdivides it to around five Microns. As shown in the graphic above, a bank of 'mist creator nozzles' are installed at an elevation of +3 metres above ground level or RCC floor all along four sides of the Air Cooled Condenser.

A collection pond has to be constructed at ground level for collection and circulation of water. Depth of the pond could be kept as 1 to 2 feet only. Circulation water pumps are installed at the cold water suction pit of depth 1 to 2 metres created in the MCS pond.

The pump delivery line brings pond water to MCS header at desired elevation. Water pressure is maintained at inlet of 'mist creator nozzles' at 3 Kg/cm^2. Circulation pumps are designed accordingly. 'Mist creator nozzles' are installed in such a manner that they spray water downwards. A mist curtain is prepared all along the Air Cooled Heat Exchanger periphery. Any air entering the ACC passes through this mist curtain, thus getting cooled to the designed air inlet temperature or even lower. A demister pad is placed between the mist curtain and the fan deck in order to arrest fine droplets from going to tube bundle. The Demister Pad is designed in such a fashion that, it offers minimum pressure drop for air flow. Water is collected on the RCC floor / suction pit of MCS pond & the cycle continues.

Nozzle arrangement or design

The degree, at which water sprayed in to inlet air stream evaporates, raises a number of important questions. Incomplete evaporation introduces several problems. Un-evaporated droplets contributes nothing to cooling effects but adds to the plant water use – if they cannot be collected and recycled. If they are carried into the ACHE'S finned tube bundles, there is a danger of scaling and corrosion of surfaces. Extremely fine spray can approach complete evaporation, but results in high pressure. Low flow design of nozzles shall also require a strong back up filtration system. MREPL has developed 'mist creator nozzles' with a bore size of 8 to 10 mm that can produce mist of size up to five microns. Due to such high bore size, it operates with a choke-less design. Also, nozzles are arranged just below fans of ACHE in such a way that they spray water downwards (graphic above). ■

Makarand A Chitale
Director (Technical)
Mist Ressonance
Engineering Pvt. Ltd.

Remotepro – NRGdash from Carel

Energy saving is becoming an increasingly important. The ability to quickly check trends in total energy consumption, analysing the variables that affects system performance, is a need shared by everyone operating in HVAC/R. Comparative analysis between systems with similar operating features and structures is essential in being able to quickly identify energy expense factors and adopt suitable countermeasures. Reducing energy consumption means reducing running and operating costs, thus adding extra value to the solutions supplied. Value that translates into competitive advantage on the market and signifies care for the environment. Carel offers energy saving solutions that exploit control logic developed throughout its extensive experience in the refrigeration and air-conditioning business.The focus is increasingly shifting from control of individual systems to all sites managed. This is where Carel, through its new remotepro – NRGdash solution, can provide a response to all these needs, representing a partner not only as regards technology but also value-added solutions, allowing customers or partners to in turn develops solutions and proposals that generate new business. ■

Website: www.carel.com

Spiral Freezers designed with modular construction for food industry

Spiral freezers are used mainly by food industries and is getting popular day by day. This product is space saving and has high freezing efficiency and wide applications. The freezer is designed with modular construction and utilizing standard design components. A range of multipurpose units are offered for the freezing or chilling of naked, in-tray, or wrapped products rapidly and safely. Engineered for high output and low space requirements. The system utilise a continuous horizontal air flow over and around the moving helical belt. The cooling action is efficient, yet, gentle, thus safeguarding quality of the products. It is suitable for freezing and chilling of medium retention time products like: formed meats, meals in trays, fried and coated meat and potato products, ice cream etc.

Features and Benefits

The product has symmetric air flow design, that allows optimum heat exchange between cool air and food. It has most efficient drain design. The insulation enclosure is lifted above the floor that eliminated the damage to the floor. Its key electronic components and reliable transmission control are of International brand. ■

Website: www.irl.co.in

Float Switch from Manik Engineers

FKS 39 is an electromechanical float switch designed to provide a reliable, electro-mechanical response to liquid level changes. The simple and basic design ensures long lifetime performance and reliable operation for many applications. FKS 39 can control liquid level in vessel and accumulators or can be used as a low or high level safety alarm.

Features and Benefits

- Based on Manik float type 39F.
- DIN, ANSI and FPT/NPT flanges.
- The switch box can be placed in any position top float housing for ease of installation.
- Adjustable liquid level differential switch point.
- Electro magnetic micro switch, mechanically activated.
- The complete switch box can easily be replaced without any interference with the refrigeration system.
- Switch box supplied with a DIN plug for easy installation and service.
- Flanges are also included. ■

Website: www.manikengineers.com

Luvata introduces HGPC

Luvata has launched the new High-Grade Process Cooler (HGPC), which is designed for the most stringent requirements. The HGPC is a high-end quality product that offers flexibility in material choices and numerous ways for customisation to meet the requirements of the world's most complicated installations, including cooling power plants and emergency and standby generator sets for offshore platforms and reactor cooling plants.

When quality and reliability matter most, the HGPC is the answer. Developed specifically for projects where site ambient conditions are harshest and material choice matters, every HGPC is customised to meet the customers' exact specifications. It can be equipped with one or up to 56 fans, depending on the cooler size and other variables such as power supply voltage, frequency variations, sound level, power consumptions and speed regulation.

A new feature of the COILS software is a slider. By moving the slider, the data will change in accordance with the changed fan speed. Based on various factors such as cooling capacity, cooler size, number of fans, tube row and environmental conditions, the software is used to further improve the cooler design.

Website: www.luvata.com

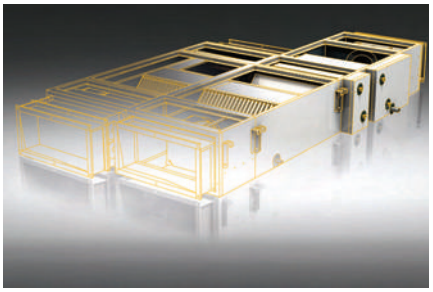
The GEA ATpicco

The GEA ATpicco is a full-capacity air handling unit intended for installation above suspended ceilings, in walls, or in floors. It is characterized by especially flat and compact dimensions.

These units, equipped with a high-efficiency counterflow heat exchanger, are designed for air flow up to 2,400 m^3/h. They already satisfy the criteria of the Ecodesign Directive that will go into effect on January 1, 2016. A choice of three unit cross-sections and two installation heights (355 and 455 mm), as well as the modular design of the series, enable flexible and individual selection of output capacity.

The new counterflow heat exchanger in the climate control version provides heat recovery of up to more than 90%. The heat recovery unit has an integrated bypass that serves for anti-icing protection for outdoor temperatures below -4^{0}C. This is possible by routing part of the outside air around the heat exchanger and directly into the stream of supply air. The bypass module is further subdivided to simplify installation and service work.

Website: www.gea-heatexchangers.com



Ice Make brings Milk Chillers

Ice make, a leading manufacturing of industrial and commercial refrigeration equipment. They offer bulk milk chiller that is used to cool milk at 40^{0}C and to maintain freshness of milk. The most important part of a collecting centre of Bulk Milk Cooler (BMC). When the milk is extracted, it is at around 370^{0}C. If the milk continues to remain at room temperature after extraction, bacterial growth will affect the quality of the milk. The BMC is meant to cool the milk to 40^{0}C in a prescribed time. The BMC is available in different shapes and sizes which depending on the amount of milk to be cooled and the system of cooling.

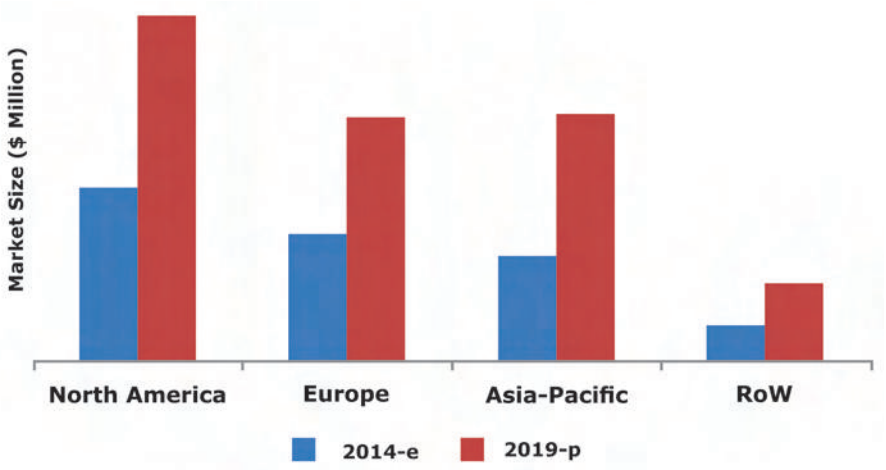
Features and Benefits

- It has faster cooling system owing to direct expansion.
- It is durable and its durable tank made of AISI 304 SS. It has hermetically sealed compressor.
- It also has digital temp controller. It occupies minimum space.
- Also it is designed to be user friendly. ■

Website: www.icemakeindia.com

Global Cold Chain Market

As per the report of marketsandmarkets, the global cold chain market is expected to reach $233,476.7 Million by 2019, at a CAGR of 15.6% from 2014 to 2019...



Cold Chain Market Size, by Region, 2014 vs. 2019 ($Million)

Source: Company Annual Reports, Company Websites, Online Journals, and Markets and Markets Analysis...

A cold chain is a temperature-controlled supply chain for perishable food products, pharmaceuticals and chemicals – in order to maintain their quality and increase their shelf-life. Cold chain infrastructure consists of precooling facilities, refrigerated storage (warehouses), refrigerated transport, packaging and information management systems.

The survey report by marketsandmarkets has divided the market into two main infrastructure types of cold chain, namely – refrigerated storage and refrigerated transport.

The cold chain market is applicable to perishable food products that include two categories chilled and frozen food items.

Application-item-wise, there are fruits and vegetables, bakery and confectionery, dairy and frozen desserts, meat and seafood, and others (sauces, condiments, salad dressings, and dips).

Requirement

A cold chain is essential as it reduces food loss, enhances food safety, balances the supply and demand of food and indirectly helps in the growth of the food industry. The growth of the market is largely attributed to globalisation, which enables the import and export of perishable foods, technological advancements in cold chain storage and transport, growing preference for frozen foods amongst consumers, and the need to reduce food loss in emerging markets such as India, China, and Latin American countries.

Market

North America is one of the largest exporters and importers of perishable foods; therefore garners the largest market share, followed by Europe and the Asia-Pacific region.

China and India are the fastest-growing markets in the Asia-Pacific region. The Indian market is growing due to the rise in organised retail, supportive government initiatives, and a shift in taste and preferences, which has fuelled the growth of frozen foods and Quick Service Restaurants (QSRs).

The cold chain market in China is growing as it serves as a lucrative market for the US-based service providers for investment in cold chain infrastructure, and also due to e-commerce and food safety regulations introduced by the Chinese government.

The global refrigerated transport market is growing at a considerable rate.

In North America and Europe, refrigerated trucks, vans, and trailers are also witnessing a considerable growth in demand – as they provide flexibility to deliver goods in multiple locations at flexible timings.

Consumer demand fresh food through online shopping has also increased, which has triggered the increase in refrigerated transport by road. Reefer containers transported by sea are also contributing to the growth of refrigerated transport due to technological improvements that maintain the shelf-life of perishable foods.

Classification

Chilled, frozen and deep-frozen are the temperature ranges through which products are stored and transported using a cold chain.

The chilled products account for the largest share globally, as most fruits and vegetables are stored and transported through this chain.

The frozen food market is also expected to witness a substantial growth for the next four years.

Trend

Globally, the meat and seafood market has the largest share, by application, followed by dairy and frozen desserts, and fruits and vegetables.

The consumption of these perishable foods is increasing globally, thereby increasing the inter-trading of perishable foods among different countries.

Key players

The key (3PL) players identified in the cold chain industry are AmeriCold Logistics(U.S.), Lineage Logistics(U.S.), Swire Cold Storage (Australia), Preferred Freezer Services (U.S.), and Nichirei Logistics Group (Japan).

These players are investing to expand their refrigerated storage facilities and transport in emerging markets as the demand for cold chain has increased in these markets. ■

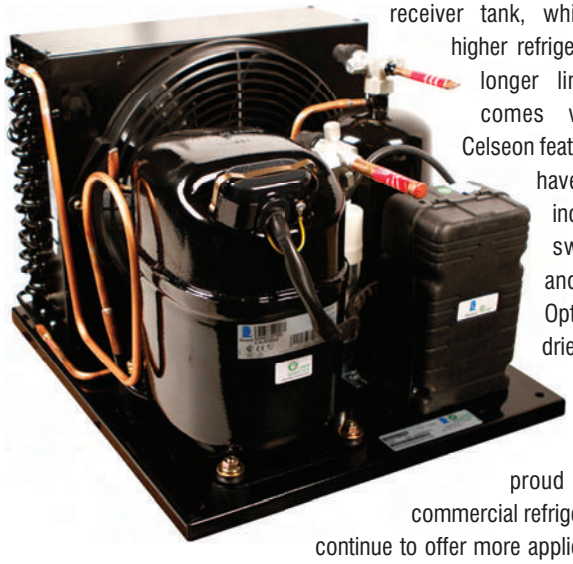
Courtesy: http://www.marketsandmarkets.com

Tecumseh extendes capacity, range of condensing unit

Tecumseh products company continues to expand its wide range of commercial refrigeration condensing units with the introduction of larger capacity VSC Indoor Scroll models and several Celseon AJ series models featuring larger refrigerant pump-down capabilities...

The VSC Indoor Scroll lineup from Tecumseh features Commercial Temperature models ranging from 7-1/2 to 10 HP, perfect for walk-in coolers and larger refrigerated cases. VSC indoor condensing units utilize R404A and R507 refrigerants and have standard features including PSC fan motor, receiver tank, and fan controls, along with optional high/low pressure switches, crankcase heaters and more.

Several AJ large pump-down Celseon ¾ HP models are available for R404A/R507 and R134a refrigerants. The newest feature is a larger receiver tank, which accommodates higher refrigerant charges and/or longer line sets. The unit comes with all standard Celseon features that contractors have come to expect, including power cords, sweat connections and service valves. Options includes filter drier, sight glass and low pressure control.



Tecumseh is proud to extend their commercial refrigeration expertise and continue to offer more application options to the market. The addition of the VSC Scroll Indoor and Celseon AJ large pump-down models offer more capacity and application options with all the reliability and performance Tecumseh is known for. ■

A S Controls Pvt Ltd	15
ALM Engineering & Instrumentation Pvt Ltd	IFC
ATE Enterprises Pvt Ltd	13
Carel ACR Systems India Private Limited	5
Carrier Midea India Private Limited	9
Cold Chain Summit	21
Desiccant Rotors International Pvt Ltd	IBC
ebm-papst India Pvt Ltd	3
Emerson Climate Technologies	11
Encon India	BC
Guntner GmBH & Co. KG	29
Mist Ressonance Engineering Pvt Ltd	7

Companies covered in this issue

Company Name	Page No.
AHRI	14
Beijer Ref AB	14
Carrier Rental Systems	46
Cool-Therm	61
Carel	74
Customer Choice (A consulting firm)	18
CBRE South Asia Pvt Ltd	62
Emerson	17
EIC Solutions	17
First Rand Bank	28
Fortum	14
GEA	75
Greenheck	12
Haier	17
IRL	74
Ice Make India	75
Intertek	26
Johnson Controls	16
Lutava	75
Laird	65
LPL Financial LLC	30
MA Engineering	48
Manik Engineers	74
Markets And Markets	76
Mist Ressonance Engineering Pvt Ltd	72
Siri Exergy & Carbon Advisory Services (P) Ltd	56
Thermax	66
Voltas	17

Energy efficient evaporative cooling orchid house wins best urban design at Solar Decathlon Europe

Evaporative cooling orchid house...

Austrian architects Casati expertly blended the traditional materials of the Italian Alps with modern design in Casa Prè de Sura, a house in Italy's San Martino in Badia. Surrounded by stunning views of the Dolomites mountain range, the wood-clad home is fitted with large boxy windows that project from the facade and frame views of the landscape. In sharp contrast to its wooden exterior, the modern interior is lined with textured limestone aggregate, a material that absorbs moisture and can cool the home during summer months. From afar, Casa Prè de Sura fits the local alpine vernacular with its traditional gable roof and vertically laid wood panels. Upon closer inspection, however, the building's contemporary influences become apparent: boxy windows bordered by light wooden frames jut out of and wrap around the facade and onto the roof at strategic locations. An accessible living roof built atop the garage doubles as a second-story patio. Inside, richly textured limestone aggregate walls, likely mined from the surrounding Southern Limestone Alps, punctuate all three floors of the home. The limestone helps absorb moisture in the area and contributes to passive cooling. White walls and wooden accents complete the clean and contemporary vibe of the interior. ■

Coke is changing beverage cooling with its electricity-free bio cooler

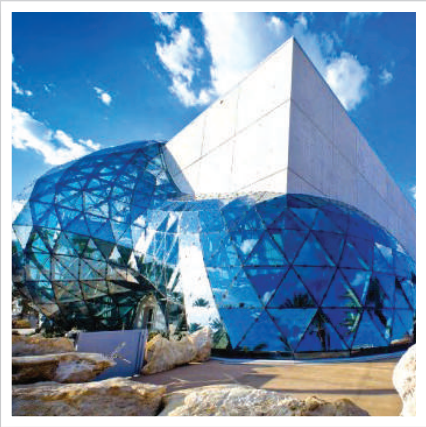
Coca-Cola wants to bring the world icy-cold beverages without the use of electricity or batteries with their new Bio Cooler. The little can dispenser takes advantage of ancient technology that uses evaporation and mirrors to cool things down. Best of all, the technology works better the hotter it gets. Coke brought its cooler to the off-grid town of Aipir, Colombia, where temperatures of 115 degrees are not unheard of – and a frosty drink would no doubt be a nice treat.

The cooler was developed by Leo Burnett Colombia along with the International Physics Centre. The cooler works by watering the plants that sit on top which creates evaporation inside the machine. Then, a mirror on top converts gas into liquid, making things even cooler inside the dispenser. The result is a cold drink without wasting any electricity to do it.

Obviously the dispenser isn't meant to supply needy communities with essential resources. The idea is meant to be more of a luxury in the same feel-good vein that some of Coke's other marketing ideas have followed, like sharable cans and bottles that only open when connected to another bottle. But for the people of Aipir, who have to travel 12 hours just to get some ice, it's a revolutionary way to experience something fun that could change the way we all keep our drinks cool in the future. ■

A new bio cooler...

Resistant and sustainable Salvador Dalí Museum



Salvador Dalí Museum...

The Salvador Dalí Museum in St. Petersburg, Florida by HOK is designed to withstand extreme weather conditions as well as reduce its ecological footprint. The work of the renowned surrealist artist is not only displayed at this museum, it also greatly inspired the design of this sustainable, resistant structure. The rough, unfinished concrete walls of the main structure provide a stark contrast to the sleek elegance of the glass sections, which use geodesic triangulation to mimic the flow of liquids in nature. An imposing, 75-foot-tall spiral staircase rises from the lobby. Hurricane-resistant skylights allow natural light to penetrate the third-floor gallery space, and the glass atrium brings natural light into the lobby. The dehumidification system runs on solar hot water, which also provides domestic hot water. Low-flow fixtures help the building conserve water, and condensate is recycled back into the system. High-efficiency HVAC and ventilation systems also help conserve energy. A cool roof coating coupled with the use of light-colored materials for the building's exterior reduces the heat island effect and therefore the amount of artificial cooling required. The compact, well-insulated envelope – including the glass sections, which are all insulated and laminated – prevents excessive heat loss and heat gain depending on the time of year. An effort was made to use low-VOC construction materials. ■

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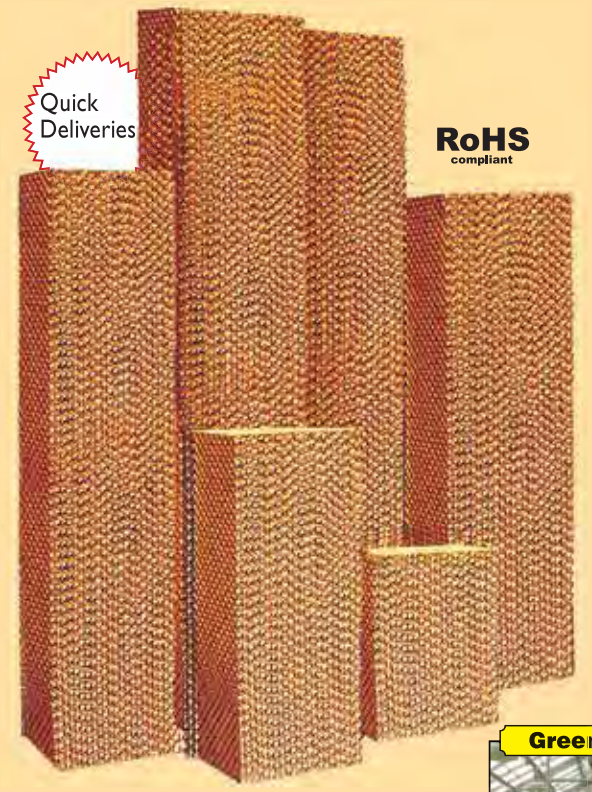

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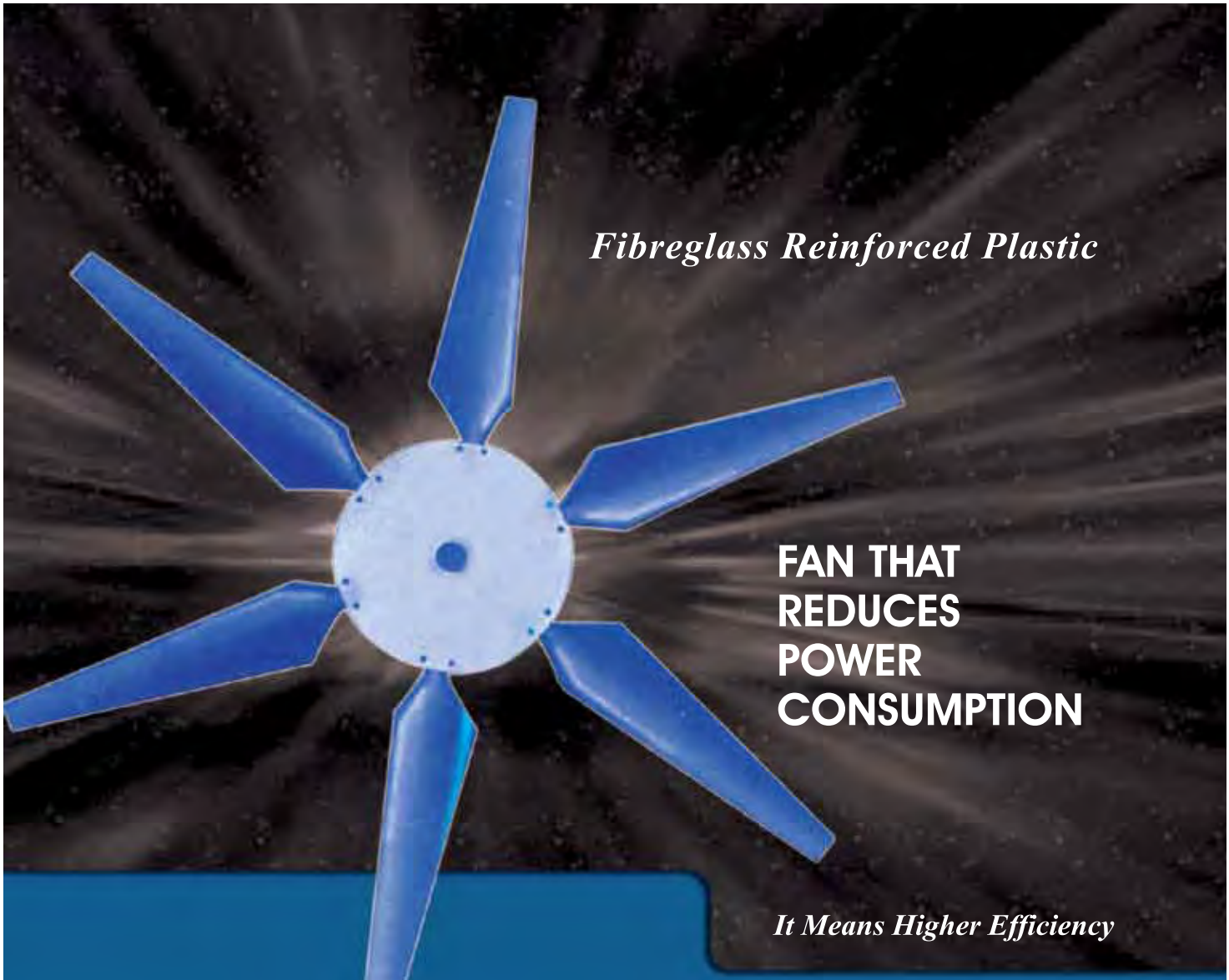

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