Best Practices for Energy Conservation in ACR

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. This article presents a compilation of some of the best practices in vogue in Indian industries.

- G. Subramanyam & R. Virendra

A sizable portion of electricity (to the tune of 40-50%) is consumed by utilities like refrigeration and air conditioning alone, in most hotels, hospitals, commercial buildings and dairy units. This article presents a compilation of some of the best practices in vogue in Indian industries, with energy saving potential of the order of 20-40%. Best practices like incorporation of SCADA & BMS, Variable Speed Drives (VSD's), Vapour Absorption Refrigeration (VAR) system, Wind Towers (WT), Earth Air Tunnels (EAT), Waste Heat Recovery (WHR) etc. are a few among them. The best practices discussed here are already in practice and Implemented in India and show great promise for large-scale adoption in the near future.

Performance Assessment of the Refrigeration & A/c system

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 & 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 benchmarks, for inter-se comparison amongst a bank of machines & for performance trend analysis. It speaks of the conversion efficiency in broad terms and an upward trend warms 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 measurement, i.e. the input power to the drives of the refrigeration compressor, chilled & condensor water pumps, cooling tower fan, is an easy task involving use of portable power analyzer or panel mounted power/energy meters. In contrast, the TR or 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 sense 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: TR = Q x Cp x (T4-T0) / 3024

Where:

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

Flow measurement is the most tricky and difficult part in the overall assessment of the refrigeration system. Generally, flow measurements and indicators are not provided for in a majority of the cases. Only in recently installed new systems, off late are we finding online flow meters. Ultrasonic flow meters are now available in the market, which can be used for measuring liquid flows. Magnetic flow meters are also widely used though these have to be installed in the pipeline. For measuring airflows, (in cooling towers and A/c ducts) anemometers are good bet. A pitot tube can also be used for airflow, measurements in A/c ducts.

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

The relation ship between kW/TR, COP & EER is feature below:		
COP = 0.293 EER	or	EER = 3.413 COP
KW/TR = 127 EER	or	EER = 12 / (KWATR)
KW/TR = 3.516/COP	or	COP = 3.5 16 / (KW/TR)

Typical normative kW/TR values, for different Vapor Compression refrigeration machines are:			
	Reciprocating	**Centrifugal**	**Screw**
Air Conditioning Temp. Range (chilled water at 4-5 ^{0}C)	0.7-0.9 kW/TR	0.63kW/TR	0.65kW/TR
Subzero Temp. Range (-5 to –25 ^{0}C)	1.25 to 2.5 kW/TR	--	1.25 to 2.5 kW/TR

The above figures include 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 Vapor Absorption Refrigeration (VAR), systems the energy performance indicator is Kcal/TR instead of kW/TR. The typical Kcal/TR values as follows:

	LI-Br			Ammonia
	Single Effect	Double Effect	Triple Effect	Single stage
	Above 6 ^{o}C			Upto – 33^{o}C
Air Conditioning Temp. Range	5000 kcal/TR	2575 kcal/TR	2000 kcal/TR	4615 kcal/TR
Subzero Temp. Range				6666 kcal/hr

In their endeavor to retain their competitive edge in the fiercely competitive market place, most of the business enterprises are readily adopting best practices in pursuit of energy conservation and energy cost reduction. Some of the popular and notable ones in the cooling / refrigeration field are discussed below:

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

- SCADA system for Air Conditioning Plants
- Optimized running of cold & hot water pumps
- Optimized running of Cooling Tower fans
- Optimized running of Air Handling Units (AHU's) through FDD controls & VFD's
- Installation of VAR Systems in process industries including Hotels & Hospitals
- Adoption of air ambiator for low cost air – cooling requirements
- Replacing old inefficient window A/C's with the latest energy efficient 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 analyze and instantaneously take corrective action. The optimized utilization of equipment running time manifests as reduced energy consumption. The real time consumption trend, by individual departments, helps in overall optimization, leading to energy savings. Several pharmaceutical and dairy units have implemented SCADA and have achieved overall energy savings of the order of 5-10%. Many commercial building are also going for Building Management Systems (BMS).

Optimized running of cold water and hot water pumps

Very often one finds the cold well and hot well concept being followed, in chilled water / brine centralized 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 precious 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 as well as 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 Rs. 2 lakhs annually, with an investment of Rs. 4 lakhs. The investment has been paid back in less than 2 years.

Optimized running of cooling tower fans

CT fan operation can be optimized by installing temperature controllers for the cooling tower and Variable Speed Drives (VFD's) 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 optimizes 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 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.

Optimized running of Air Handling Units (AHU'S) through PID controls & VFD's

Optimization of Air Handling Units (AHU'S) can be achieved by installing controllers and Variable Speed Drives for the AHU blowers. The controller installed in the AHU's continuously tracks & monitors the temperature inside the air-conditioned area, and accordingly, the speed of the blower motor is varied by the variable frequency drives (VFD's) resulting in lower power consumption. These types of controls and VFD's have become common now a days in most of the commercial buildings like hotels and hospitals. In industries also they are gaining importance and they have potentials to save energy to the tune of 15-20%.

Installation of VAR Systems in process industries including Hotels & Hospitals

Vapour Absorption Refrigeration (VAR) or Vapor 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 fact in one of the process industry in India had replaced 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	= 10000 kWh/day
Power consumption of VAR	= 400 kWh/day
Total power savings	= 9600 kWh/day
Working days/year	= 365 days
Annual savings / year (@ Rs. 5.25/kWh)	= Rs. 184 lakhs
Cost of operation of VAR system by steam	= Rs. 149 lakhs
Net savings	= Rs. 35 lakhs
Cost of implementation	= Rs. 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 in Vadodara, Gujarat is, by use of solar energy for air conditioning. By generating 3kg/cm^2 steam by using solar concentric panels, they could able to run the VAR machines and reduce their high power bills.

Adoption of air ambiator technology for low cost air cooling

We can reduce our air conditioning energy cost by 50 – 60% by adopting air ambiator technology. If you are able to compromise little on humidity, we can go for air ambiator system. We can able to achieve temperatures much below the wet bulb temperature by using two stages cooling. The following table indicates the expected average temperatures in some of the important Indian cities in summer.

Temperature Attainable At The Mouth Of The Blower At Various Temperatures			
Location	**Dry Bulb OC**	**Wet Bulb OC**	**Temp at Blower**
Ahmedabad	19.96	41.2	23.5
Bangalore	16.72	34	19.6
Bhopal	17.94	40.5	21.7
Hyderabad	19.16	39.2	22.5
Indore	16.64	40.4	20.6
Jaipur	18.84	41.4	22.6
Jodhpur	19.44	40.8	24.8
Kota	18.64	42.4	22.6
Lucknow	21.60	40.8	24.8
Nagpur	20.16	42.6	23.9
New Delhi	20.44	40.6	23.8
Mumbai	21.10	34.3	23.3
Kolkata	24.08	36.2	26.1
Chennai	24.58	37.3	26.7

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 following table 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 kWh	325 kWh
Units per day (8 hours)	800 kWh	2,600
Units per month (30 days)	24,000 kWh	78,000kWh
Power consumption /year	2,88,000 kWh	9,36,000 kWh
Cost per unit	Rs. 5.00	Rs. 5.00
Savings per year	Rs. 32.4 lakhs	-

Replacing old inefficient window A/C's with the energy efficient A/C's.

The old window A/C's are bound to consume more energy. The window A/C's which are designed about 10 years back; the specific energy consumption is around 1.5-2 kW/TR. The present genre state of the art, window A/C's with scroll compressor 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 Bureau of Energy Efficiency (BEE), the user has a choice go for energy efficient window A/C's including split A/C) before he buys. The following table gives the inter comparison of energy consumption of different models of A/C's, which are available in India.

Power consumption in Watts			
Capacity	**1 Ton**	**1.5 Ton**	**2 Ton**
LG	1300-1350	2000	2400-2710
Carrier	1300-1400	1860-2000	2000-2350
Samsung	1170-1300	1850-2000	2400-2600
Voltas	1300	1850-2550	200—2600
Onida	1200	1800-1980	
Whirlpool	1300-1475	1790-1980	2450-2750
Hitachi	1300	1800	2200
Kenstar		1800-1850	
Electrolux	1180-1350	1800-1850	2500-2600
Videocon	1350	1900-1990	2440-2550
Source: VOICE Report			

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 can able to reduce ambient air temperature by 5-7 ^{0}C. By passing this cool air through the chiller water fan coil in the AHU's, we can able to reduce the air conditioning load of the building by 2-3%. This is being practiced at the CH – Godrej Green Business Centre at Hyderabad, the first building outside USA to get platinum rating by LEED, USA.

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

The principles of the tunnel is to take advantage of consistency in temperature through out the year at certain depth below ground. At a depth of 4M 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 25-26 ^{0}C. So, if the 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 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 TERFs 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 can able to produce hot water at 55-60 ^{0}C. As a thumb rule, we can generate 20 lit/TR hot water with a AT of 30 ^{0}C. This type of system is more useful for hotels, hospitals and process industries, where there is hot water requirement. The de-superheating system for 100 TR will cost around Rs. 6 lakhs and the investment can be paid back within a year. A number of hotels in Hyderabad are using this system.

Conclusion

One first needs to measure to be able to peg down one's present performance, towards which, one needs to carry out an energy audit to arrive at key energy performance indicators like kW/TR etc. once we are aware of where we stand, we begin to look for improvements to bridge the gap in performance. Based on field observations and energy audit studies at a number of establishments, we dare-say that, one can easily reduce one's energy bills through proper implementation of some of the above mentioned best practices, either at design stage or by retrofitting into the existing systems.

Reference Book:

Cooling India
Vol. 2 No 1
February - April 2006