"Energy Efficient Refrigeration system for Dairy Plant"

By

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AAR WEBINAR - 20-05-2020

CONTENTS:

- REFRIGERATION LOAD IN DAIRIES
- TYPES OF CHILLED WATER GENERATION SYSTEM
- ENERGY EFFICIENT COMBINATION OF CHILLED WATER GENERATION SYSTEM
- USE OF PRE CHILLER (PHE & FALLING FILM CHILLERS)
- SELECTION OF EQUIPMENTS
- USE OF ENERGY EFFICIENT MOTORS, VFD STARTERS AND AUTOMATION

THE AVERAGE ENERGY CONSUMPTION OF REFRIGERATION SYSTEM IN A DAIRY PLANT OF SIZE 5 TO 30 LAKHS LTR/DAY IS 60 TO 65 %

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CHILLED WATER LOAD

DIRECT REFRIGERATION LOAD

HEAT LOAD

Refrigeration load will be sum of the following for Cold Room such as Storage, Blast, Deep Freezer etc.,

- Wall heat load
- Air change load
- Product load
- Supplementary load or Miscellaneous load

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COLD ROOMS DESIGN

1. Optimum room height of cold rooms to reduce heat load
2. Ante rooms is a must for negative temperature cold room.
3. Sizing of ACU with drain pan heater and heat tracing of drain pipes.
4. Proper hot gas defrosting controls

COLD ROOMS DESIGN

PUF PANELS & LED ENERGY SAVING LIGHTING
SLIDING DOORS

CHILLED WATER LOAD

Milk Chiller
- Raw Milk Chiller: 34 Deg C to 4 Deg C
- Tanker Milk Chiller
- Milk Pasteurization: 14 Deg C to 4 Deg C
- Butter Milk Chiller: 45 Deg C to 4 Deg C
- Ageing Tanks: 8 Deg C to 4 Deg C

CHILLED WATER LOAD - CALCULATION

<table>
<thead>
<tr>
<th>Capacity (TR)</th>
<th>Load Distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>500.00</td>
<td></td>
</tr>
<tr>
<td>600.00</td>
<td></td>
</tr>
<tr>
<td>700.00</td>
<td></td>
</tr>
</tbody>
</table>

Load distribution

CHILLED WATER LOAD - GRAPH

Calculation of refrigeration capacity
Plotting a Histogram
Decide a base load for the refrigeration
Design an optimum system
CHILLED WATER LOAD- PLOTTING HISTOGRAM

CHILLED WATER LOAD- LOAD SUMMARY

- Total Load = 5,292 TR / day
- Average Load / 20 Hrs = 264.6 TR
- Peak load = 483.38 TR

HISTOGRAM

CHILLED WATER LOAD- LOAD SUMMARY

- Total Load = 5,292 TR / day
- Average Load / 20 Hrs = 264.6 TR
- Peak load = 483.38 TR

CHILLED WATER GENERATION

- IBT SYSTEM:
  This is conventional system
- ICE SILO:
- IBT + PRE CHILLER SYSTEM (PHE / FFC):
  A combination of IBT and Pre Chiller depending upon load histogram.

TYPES OF CHILLED WATER GENERATION

- PHE Chiller / Falling Film Chiller:
  i. Chilled Water PHE / FFC
  ii. Chilled Glycol System for Deep Chilling

IBT SYSTEM: This is conventional system

ADVANTAGES OF IBT SYSTEM:
- THERMAL STORAGE OF ENERGY AVAILABLE
- REFRIGERATION PLANT CAPACITY SMALLER
- LATENT HEAT AVAILABLE
- SAFE DURING POWER CUTS / BREAK DOWNS

DISADVANTAGES
- MORE SPACE REQUIRED
- LOW SUCTION (-10 DEG C) INCREASES POWER CONSUMPTION

PHE / FALLING FILM CHILLER WITH IBT SYSTEM

The concept of Pre (PHE/FCC) Chiller and IBT combination i.e. return water from process will be pre-chilled in the PHE/Falling film chiller and fed into IBT for further chilling.

In the above system, power saving will be substantial

PHE / FALLING FILM CHILLER WITH IBT SYSTEM

In a 1 Lakhs Lit/ Day Dairy, 60,000 liters of milk will be processed in 4 Hours in the morning and 40,000 liters of milk will be processed in 2 1/2 Hours in the evening.

For a 15,000 LPH milk process PHE chilled water flow of 30,000 LPH shall be circulated with a temp range of 12 to 0.5 °C. 12 Deg C return water shall be pre-chilled to 2 Deg C in a PHE chiller and fed into IBT for further chiling down to 0.5 °C.

PHE / FALLING FILM CHILLER WITH IBT SYSTEM
### POWER COMPARISON

<table>
<thead>
<tr>
<th>IBT SYSTEM</th>
<th>IBT CUM PRE CHILLER</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Handling of Milk</td>
<td>2.00 Lakhs</td>
</tr>
<tr>
<td>No. of compressor</td>
<td>2 NOS Screw (1w+1s)</td>
</tr>
<tr>
<td>Comp. connected motor working</td>
<td>1 no. x 160 Kw</td>
</tr>
<tr>
<td>Suction Discharge temp</td>
<td>-10°C / 20°C</td>
</tr>
<tr>
<td>System Details</td>
<td>IBT Pre Chiller with IBT</td>
</tr>
<tr>
<td>Condenser Type</td>
<td>Evaporative Condenser</td>
</tr>
<tr>
<td>Refrigeration Capacity</td>
<td>150 TR</td>
</tr>
<tr>
<td>Screw Comp. BkW/ TR</td>
<td>0.93</td>
</tr>
<tr>
<td>Heat Comp. BkW/ TR</td>
<td>0.77</td>
</tr>
</tbody>
</table>

### ONLY PHE CHILLERS WITH HOT AND COLD WELL TANK

- The concept of only (PHE) Chiller has also been introduced without ice bank tank but with a hot and cold well or buffer tank
- The compressor size increases
- Better for peak loads and chilling centers.

### POWER COMPARISON

- The PHE / FFC Chiller System
  - For the PHE / FFC chilling, the heat load works out to 135 TR (approximately).
  - A screw compressor selected @ -5°C SST & 40°C SDT delivers refrigeration capacity of 137.6 TR which consumes 103.3 BkW
  - Power Consumption in a day: 137.6 TR x 0.75 BkW/ TR x 6.5 Hrs = 671 Units

**Evaporative IBT System**

- The BkW/ TR of a Screw compressor for an IBT application at -10°C SST & 40°C SDT will be 1.00
- Total Refrigeration capacity required: 137.6 TR x 6.5 Hrs = 894 TR Per Day
- Considering 20 Hrs of Operation: 894 TR / 20 Hours = 44.7 TR
- BkW/ TR @ -10 SST and 40 Deg C SDT will be = 1.00
- Power Consumption: 44.7 TR x 20 Hours x 1.0 BkW/TR = 894 Units

- From saving of approx. 25 to 30 % with the above, you will notice a unit (power) Pre-Chiller system

### SELECTION OF REFRIGERANT

**Ammonia – A Natural Refrigerant**

- Ammonia is a colourless gas that liquefies under pressure and has a pungent odour.
- Ammonia is considered a natural refrigerant because it occurs in nature’s material cycles.
- Ammonia is also an ideal refrigerant from a climate protection point of view.
- It contributes neither to ozone depletion nor to global warming.
- Ammonia has no ozone depletion potential (ODP = 0) and no direct greenhouse effect (GWP = 0).
- Ammonia is combustible only to a limited degree; its ignition energy is 50 times higher than that of natural gas.

### HEART OF THE REFRIGERATION SYSTEM

**COMPRESSORS**

**TYPES OF COMPRESSORS IN AMMONIA**

- **RECIPROCATING OR SCREW COMPRESSORS**

### RECIPROCATING COMPRESSORS

- Reciprocating Comp are selected if the refrigeration capacity is less than 350 kW (100 TR).
- Latest developments for energy optimization in reciprocating compressors:
  - High speed compressors
  - Direct drive.
  - PLC control panel
SCREW COMPRESSORS

SPECIAL FEATURES OF SCREW COMPRESSOR

• Less Space for big plants (Number of compressors less)
• Adapts better for power saving in large plants running at part load.
• Dual capacity control system monitors volume as well as compression control.
• Total installed horsepower reduces.
• Easy to automate
• Very low maintenance.

Evaporative condenser is a water conservation device and in effect, a condenser and a cooling tower combined into a single unit.

Most of the refrigeration plants in dairies are having open type atmospheric condensers, which mean indirectly getting affected by power penalty.

Power penalty by way of running the make-up water pump continuously due to water wastage by splashing, high wind velocity etc.

ADVANTAGES OF EVAPORATIVE CONDENSER OVER OPEN TYPE CONDENSERS

<table>
<thead>
<tr>
<th>Condenser Water Pump</th>
<th>Cooling Tower Fan</th>
<th>Fan Motor</th>
<th>Pump Motor</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.00</td>
<td>6.00</td>
<td>6.00</td>
<td>6.00</td>
</tr>
<tr>
<td>19.00</td>
<td>7.50</td>
<td>9.00</td>
<td>3.70</td>
</tr>
<tr>
<td>114.00</td>
<td>45.00</td>
<td>54.00</td>
<td>22.20</td>
</tr>
<tr>
<td>26.50</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Condensing Temp:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>38 Deg C</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>40 Deg C</td>
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</tbody>
</table>

Certified as per the Indian Standards, 2015 etc. Evidences for adherence

Table shows the saving per year

For 100 TR:

• To cool down the superheated discharge gas from the compressor before entry into the condenser

• It is usually used in heat recovery, to generate hot water (30 to 60 DegC.) which can be used in crate washing and floor cleaning.

• Temperature range: 0°C to 130°C

Desuperheater System

Ammonia Pumping Re-circulation System

Superb refrigerant distribution

Lower inlet liquid temperature

Cut down capital costs

High system efficiency

Reduced operating expenses

Low maintenance

Protection of compressors from liquid slugs

Tremendous power saving in operation.

Reduce Equipment size

Eliminate individual accumulators
Priority Vessel And Thermosiphon Oil Cooler

ADVANTAGES OF THERMOSIPHON OIL COOLING SYSTEM

- There is no possibility of contamination of the cooling water circuit.
- The water in the cooling circuit does not require to be diverted to produce free cooling.
- The free cooling is produced by evaporation of a relatively small flow of refrigerant. Thereby,
- Thermosiphon system might require 80 mm refrigerant piping and valves whereas a free cooling
- system, in which the water to be cooled is circulated directly through an ambient cooler might require 150 mm piping and valves.

Compressor Motor & its Drives.

Motor should select based on the efficiency. The efficiency of an electric motor is defined as the ratio of usable shaft power to electric input power.

Motor Efficiency [%] = shaft Power [kW] / electrical input [kW]

Based on the Efficiency level, Motor are classified as Efl1, IE1, IE2, IE3/IE4 Motors.

VFD & Vertical in line pump for chilled water circulation

- Installed HP of pump will be reduced.
- Speed will vary depending upon load means reduce power cost.
- Increase overall efficiency.

Types of Drives

Soft Starter
Variable frequency drive (VFD) is a motor control device that protects and controls the speed of an AC induction motor. VFD can control the speed of the motor during the start and stop cycle, as well as throughout the run cycle.
Total Plant Control. Centralized temperature recorder and interlocking electric circuit for various process controls can be interlocked to your PC/PLC.

**NEW INNOVATIONS/CHALLENGES**

- Low Charge Ammonia Refrigeration System
- CO2 Refrigeration Systems

**LATEST TRENDS**

- PHE/Falling Film Chiller + IBT
- Screw Compressors
- Evaporative Condensers
- Liquid Ammonia pumping system
- Thermosiphon Oil Cooling system
- Introduction of VFD for compressors.
- Chilled water pump automation with VFD
- Energy efficient motors (IE3)
- Automation of the complete plant

**THANK YOU**

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