Dehumidification to eliminate ice, condensation and microbial growth
Key facts

- Munters began trading in 1946 and incorporated in 1955
- 3,000+ employees
- 16 major Manufacturing Plants
- 5 Logistics and Assembly Hubs
- 53 sales and service centres serving customers in more than 30 countries
- Headquarters in Stockholm, Sweden
- Over 300,000 air treatment systems installed
Global Manufacturing & Logistics Support

- 16 Manufacturing Plants
- 5 Logistic & Assembly Hubs
- 53 Sales & Service Centres
Munters Core Competencies

- Dehumidification
- Humidification
- Evaporative cooling
- Refrigeration

- Heating
- Energy recovery
- Mechanical separation liquid from gas
Pharma - Packaging of Effervescent Tablets
Pharma - Manufacturing of Gelatine Capsules

- Drying of gelatine
- Production of capsule shape
- Capsule content
- Packaging
Pharma - After freeze-drying
Pharma - Cleanrooms
Pharma – Chilled and Cold Storage
Humidity
The Composition Of Air

**Air Pressure**
- 101 kPa
- 1013 mbar
- 760 mm Hg

**Partial Pressures**

<table>
<thead>
<tr>
<th>Partial Pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td>~1% Noble gases Ar, etc.</td>
</tr>
<tr>
<td>~21% O₂ Oxygen</td>
</tr>
<tr>
<td>~78% N₂ Nitrogen</td>
</tr>
<tr>
<td>0-3% H₂O Water Vapour</td>
</tr>
</tbody>
</table>

**Earth Surface**
How To Quantify Humidity

• Absolute Humidity (or "Humidity Ratio")
  —The amount of (kilo)grams of water vapour per kilograms of (dry) air (g/kg)

• Relative Humidity
  —The ratio (in %) between the actual quantity of water vapour in the air and the maximum quantity of water vapour that the air can contain at a certain temperature
Warm air can contain more water vapour than cold air.

Air at a certain temperature will have a corresponding maximum content of water vapour.

When too much water vapour is in the air (at a certain temperature), the air is “saturated” and the excess moisture will condense out.

This can happen when the temperature falls.
Outdoor Relative Humidity
## Typical summer temperature and humidity conditions

<table>
<thead>
<tr>
<th>Location</th>
<th>Dry temp</th>
<th>X-value g/kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stockholm</td>
<td>19,8</td>
<td>12,2</td>
</tr>
<tr>
<td>Riyadh</td>
<td>22,9</td>
<td>13,0</td>
</tr>
<tr>
<td>Sydney</td>
<td>24,8</td>
<td>16,4</td>
</tr>
<tr>
<td>New York</td>
<td>26,8</td>
<td>17,8</td>
</tr>
<tr>
<td>Tokyo</td>
<td>28,0</td>
<td>20,4</td>
</tr>
<tr>
<td>Rio de Janiero</td>
<td>30,1</td>
<td>21,5</td>
</tr>
<tr>
<td>Singapore</td>
<td>28,9</td>
<td>21,7</td>
</tr>
<tr>
<td>Shanghai</td>
<td>31,0</td>
<td>23,0</td>
</tr>
<tr>
<td>Caracas (We)</td>
<td>31,7</td>
<td>27,2</td>
</tr>
<tr>
<td>Raufahofn (Isl)</td>
<td>13,9</td>
<td>8,9</td>
</tr>
</tbody>
</table>
The average daily high (blue) and low (brown) relative humidity with percentile bands (inner bands from 25th to 75th percentile, outer bands from 10th to 90th percentile).

Over the course of the year the average relative humidity ranges from 92% (very humid) to 27% (dry).

Rarely drops below 15% (very dry).

Reaches as high as 100% (very humid).

The average daily high (blue) and low (brown) relative humidity with percentile bands (inner bands from 25th to 75th percentile, outer bands from 10th to 90th percentile).
Sources Of Humidity In a “Closed” Environment

1. Unintentional ventilation
2. Intentional ventilation
3. Evaporation from water surfaces
4. Emission from people
5. Diffusion
6. Evaporation from hygroscopical materials
7. Emission from combustion engines
Sources Of Humidity In a “Closed” Environment

Humidity emitted depending on activity, clothing and room temperature

Average value at 20 - 25 °C and normal clothing:

- High activity 200 g/h
- Medium activity 125 g/h
- Low activity 40 g/h
We will quickly walk through a list of humidity related processes that cause damages, quality loss and/or cost increases.

- Condensation (water) and frost formation (ice – i.e. condensation below 0°C)
- Corrosion of metals
- Influence of moisture on resistance values (electronic malfunctions)
- Mould affecting hygiene in ducts, systems, buildings and manufacturing processes
- Property and quality change of materials and substances
  - Storage and production processes that require a stable, optimal climate
  - Product drying (deliberate moisture reduction, avoiding too high temperatures)
- Chemical reactions with moisture in the air
- Special cases of humidity impact
  - Comfort impact
  - Energy impact
Visible Humidity - Condensation on cold surfaces or in cold air
Visible Humidity - Condensation on cold surfaces or in cold air

Source: www.myallergo.de
Source: www.teachingengineering.org
Source: www.bontott-tetoablak.hu
Source: www.stellozletes.hu
High Humidity Causes Corrosion

Above 60% Relative Humidity (RH) the speed of corrosion on steel rises exponentially.

Below 45% RH corrosion development on steel is virtually ZERO.

Humidity control can be used to stop or slow down corrosion.
Influence of Moisture on Resistance Values

Electric conductivity increases in moist environments

Over insulation material

But also through air.....
High Humidity Speeds Up Mould Growth

Mould has high growth rates at higher temperatures (20-30°C) and high humidities. They can extract water from moist air.

Below 70% Relative Humidity mould growth is virtually ZERO.
Local Relative Humidity Levels – Kunming Example

The average daily high (blue) and low (brown) relative humidity with percentile bands (inner bands from 25th to 75th percentile, outer bands from 10th to 90th percentile).
Local Dewpoint Levels – Kunming Example

The daily average low (blue) and high (red) dew point with percentile bands (inner band from 25th to 75th percentile, outer band from 10th to 90th percentile).
Some manufacturing and curing processes require a product to be dried

Product drying is a delicate process, especially if heat is a concern
Humidity Control and Energy

Desiccant dehumidification can save a lot of energy.

Depending on the temperature and initial humidity level, moisture removal through condensation can be costly and ineffective.

If applied properly, it is much more cost effective to dehumidify than to heat objects and buildings.

Dehumidification can be combined with cooling to reach the desired climate at optimal energy efficiency.

<table>
<thead>
<tr>
<th>Moisture Removal Cost Comparison</th>
<th>Typical Energy Cost to Remove 120 Pounds of Water Per Hour</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dehumidifier</td>
<td>$1.00</td>
</tr>
<tr>
<td>Air Conditioner</td>
<td>$7.86</td>
</tr>
<tr>
<td>Produce/Dairy Cases</td>
<td>$9.13</td>
</tr>
<tr>
<td>Meat/Deli Cases</td>
<td>$10.62</td>
</tr>
<tr>
<td>Frozen Food Cases</td>
<td>$14.83</td>
</tr>
<tr>
<td>Ice Cream Cases</td>
<td>$16.72</td>
</tr>
</tbody>
</table>

Source: Tyler Refrigeration Advance Development
Humidity Control
The Benefits of Humidity Control

- Condensation prevention
- Corrosion prevention
- Electrical resistance optimisation
- Mould prevention
- Property change optimisation, incl. drying
- Chemical reaction prevention
- Comfort optimisation
- Energy optimisation
- Other reasons (damping, ionisation prevention, etc.)

Mostly, the benefits are found in a combination of above reasons
Psychrometric chart
101.32 kPa

Day time condition
25°C @ 50%RH

Night time condition
10°C @ 100%RH
Changing Environment - Methods

- Sorption
- Heating
- Cooling

5 g/kg
15 g/kg

Temperature:
- 0°C
- 10°C
- 20°C
- 30°C
- 40°C

Relative Humidity:
- 30%
- 50%
- 70%
- 100%

Parameters:
- \( t_{WB} = 10^\circ C \)
- \( t_{DB} = 10^\circ C \)
Desiccant vs Cooling - Dhumidification Capacities at 50% RH

4 times more capacity at 10°C!
Sorption Dehumidifier - Munters Rotor Principle
Silica Gel

- A non-crystalline (amorph) silicon dioxide based material which has water molecules in its composition. Adsorption takes place in cavities and pores.
Cold Stores (Below 0°C)
Cold Store problems have two dimensions….

“In Between” area
- Loading dock
- Lock
- Distribution area
- Processing area

Cold Store
- Frost & Ice build up
- Temp -25°C
- Moisture leakage
- Warm air inflow
- Cold air outflow
- Iced floor

Outside the Cold Store
- Temp +5°C
- 85% RH
- 4.5 g/kg
- Moisture leakage
- Fog
- Wet floor

Ambient Outside
Dewpoint and Cold Stores

The line is cutting through the saturation line. Water vapour turns into fog, below 0°C into ice particles.
In the Cold Store

- Snow
- Fog
- "Warm" moist air
- Cold air
- Ice
- Frost on evaporator coil
• High outside humidity causes ice formation inside Cold Store on cold surfaces
  — on the ceiling
  — the evaporator
  — on products, scaffolds and shelves
  — on entry door areas
• Ice formation on the ceiling also causes “snow” which falls down on the floor and on products
  — Ice on the floor (snow compressed by forklifts, pallet trucks, handling equipment)
  — Additional ice formation on products
• Fog around the door area
• Ice on the evaporator forms an insulated layer on the coil (COP degradation)
  — Reduced efficiency of the refrigeration process – increased energy consumption
  — Growing layers will reduce and ultimately block the airflow through the coil – again reducing efficiency of the refrigeration process

• Fog, Ice and Snow
  — SAFETY HAZARD
    • Slippery floors
      — Persons - personal hazard (people can slip)
      — Forklifts collisions with objects such as scaffolds/shelves and doors or with people
    • In the doors - enhanced chance of accident due to reduced visibility
      — Fog
      — Iced up flap doors - collisions with people or other forklifts
  — CONTAMINATION HAZARD - possible contamination of products by dirty snow
    — Accelerated degradation of cardboard packaging materials when it leaves the cold store
    — Decreased readability of bar codes (laser deflection on ice crystals)
Outside the Cold Store

Possible frost on evaporator coil

Possible condensation and droplets

Fog

Moisture leakage

"Warm" moist air

Cold air

Wet floor
• Combination of cold air coming from Cold Store, moisture leakage from outside and refrigeration creates excessive RH%
  — SAFETY HAZARD
    • Wet slippery floors - personnel hazard (people can slip)
    • Fog - reduced visibility leading to collisions with people or other forklifts
  — CONTAMINATION HAZARD
    • Possible condensation compromises hygiene

• Conditions outside the Cold Store drive the problems inside the Cold Store (earlier slides)
Existing customer strategies inside Cold Stores

- Existing solution strategies solve only parts of the problem and are temporary and/or costly
- Defrost cycles for evaporators
  - Costs energy
  - Loss of cold store condition
- Floor heating near the door (up to 8-10 kW)
- Manually removing ice/snow for the cold store (remove from walls, floors, product)
  - Labour intensive
  - Damage to cold store structure
Benefits of dehumidification

• Less damage to the cold store and loading areas
  — No ice scraping
  — Less condensation damage
  — Better performance of automated equipment and sensors
  — Special impact on automated / robotic cold stores
  — Less corrosion damage
  — Cardboard packing boxes remain in better shape

• Higher speed of product movement
  — Better visibility
  — No slippery floors
  — Optimal bar code or label reading
  — Improved picking rates and handling of boxes

• Spaces faster to clean
  — Drying after cleaning
Benefits of dehumidification

• Keeping ice and condensation away from evaporator coils
  — Higher efficiency of the evaporator (COP)
    • Less latent load for the coils
    • Allows more economic setting for refrigeration system
  — Time between defrost considerably lengthened
  — Less energy loss due to defrost (can take up to 15% of the total energy consumption, in some cases reduced to 3%)

• No floor heating (up to 8-10 kW) needed near door (common in newer cold stores)
• Energy savings are bonus on top of the improvements in safety, hygiene and efficiency
Because of **ACTIVE** moisture removal capacity ice formation is sublimated
(Ice changes phase and turns directly into vapour without passing through the liquid phase)
Chilled Stores (Above 0°C)
Typically in the 2 to 8°C temperature range
If humidity is not controlled then RH within the chilled space can be >90%
Cold surfaces will allow condensation to occur
If this is left untreated additional issues can arise
Easy to treat with dehumidification
Dewpoint and Chilled Stores

The line hits the saturation line. Water vapour turns into water and condenses out on cold surfaces.

Condition outside chilled store:
25°C @ 50%RH

Condition in chilled store:
2°C @ 100%RH
Chillers, Humidity and Cold Surfaces
Water droplets form on the lighting fittings, ceiling or chiller units.

These droplets occasionally drop onto boxes of vaccine below.

Mould, bacteria or yeast growths in the water droplets would be transferred onto the boxes.

If enough droplets were to fall on a particular box in the same location over time, contaminants could enter the box and come in contact with the sealed vaccines inside.
The growth and metabolism of microorganisms demand the presence of water in an available form, which is measured as water activity, $a_w$.

The $a_w$ of a solution equals the ratio of the water vapour pressure of the solution ($p$) to that of pure water ($p_0$) at the same temperature. When a solution becomes more concentrated, vapour pressure decreases and the $a_w$ drops from a maximum value of 1 for pure water.

Many microorganisms, including pathogenic bacteria, grow most rapidly at levels of $a_w$ in the range of 0.99 – 0.98. Below this $a_w$ the growth rate decreases and the length of the lag phase increases.

No microorganisms can grow at an $a_w < 0.50$. 

Water Activity and Microbial Growth
Examples of Water Activity and Microbial Growth

<table>
<thead>
<tr>
<th>Substance</th>
<th>$a_w$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distilled Water</td>
<td>1.00</td>
</tr>
<tr>
<td>Tap water</td>
<td>0.99</td>
</tr>
<tr>
<td>Saturated NaCl solution</td>
<td>0.75</td>
</tr>
<tr>
<td>Typical indoor air</td>
<td>0.5 - 0.7</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Microorganism Inhibited</th>
<th>$a_w$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Most bacteria</td>
<td>0.97 – 0.85</td>
</tr>
<tr>
<td>Most moulds</td>
<td>0.80</td>
</tr>
<tr>
<td>Xerophilic molds and yeasts</td>
<td>0.75 - 0.80</td>
</tr>
<tr>
<td>Yeasts</td>
<td>0.70 - 0.75</td>
</tr>
<tr>
<td>Osmophilic yeasts</td>
<td>0.65 - 0.70</td>
</tr>
<tr>
<td>Xerophilic molds, osmophilic yeasts</td>
<td>0.60 - 0.65</td>
</tr>
<tr>
<td>No microbial proliferation</td>
<td>0.50</td>
</tr>
</tbody>
</table>
• Moisture plays an important role as the base for metabolism and therefore for any growth
• Moulds do not need droplets of water to form - water vapor concentrations of > 80% relative humidity are sufficient.
• Once established, some moulds can transport free water to dry areas. (For example, dry rot)
• Moulds can be highly hygroscopic due to large surface area. The result is that water molecules are filtered from the air (thawing effect). This process is particularly enhanced when mould develops on cold walls.
Humidity is present in all environments

Dehumidification can deliver the following benefits

- Eliminate Condensation (water) and frost formation (ice – i.e. condensation below 0°C)
- Prevent corrosion of metals
- Prevent influence of moisture on resistance values (electronic malfunctions)
- Stop mould formation and improve hygiene
- Prevent property and quality change of materials and substances
Thank you for your attention
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www.munters.com