• Humidity & Customer Problems
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 – Air Treatment for Tablet Manufacturing
Pharma - Air Treatment for Effervescent Tablet Packaging
Pharma - Air Treatment for Gelatine Capsule Manufacturing

- Drying of gelatine
- Production of capsule shape
- Capsule content
- Packaging
Pharma - Air Treatment After freeze-drying
Pharma - Air Treatment for Cleanrooms
Design Considerations

GMP Manufacturing Environment

Product Protection
- Contamination (product & staff)
  - Protect from product cross-contamination
  - Correct temperature and humidity

Personnel Protection
- Prevent contact with dust
- Prevent contact with fumes
- Acceptable comfort conditions

Environment Protection
- Avoid dust discharge
- Avoid fume discharge
- Avoid effluent discharge

Systems

System Validation
• Contamination (product & staff)
  — Ensure air flows are not mixed between production areas unless the proper precautions have been taken
  • Risk assessment – carried with the customer
  • Filtration

• Protect from product cross-contamination
  — Ensure air flows are not mixed

• Correct temperature and humidity
  — Based on customer’s specifications for the product being made and comfort conditions
• Prevent contact with dust
  — Very low probability in clean areas

• Prevent contact with fumes
  — Ensure that fume extraction is working as specified and alarms are properly configured

• Acceptable comfort conditions
  — Based on customer’s specifications – and will be influenced by the product’s temperature and humidity requirements
GMP requirements for air treatment - Environment Protection

• Avoid dust discharge
  — Use dust collectors and filters
  — Ensure correct disposal of used filters

• Avoid fume discharge
  — Assess the content of fumes, are they harmful to the environment? If so, consider adding a treatment system to the exhaust airflow
Air Treatment in Pharmaceutical Applications

- Control of airflow between different areas
- Specific ventilation requirements to avoid cross contamination
- Different demands on temperature and humidity
- Reliable projects that meet the requirements for control and air quality
- Operational cost
Pharmaceutical - Clean Zones Criteria (GMP HVAC)

Finishing and building structure

- Infiltration of air
- Air exchanges
- Room pressure
- Airflow
- Temperature
- Moisture
- Material flow

- Flow of people
- Procedures
- Outdoor conditions
- State occupation
- Type of products
- Cleaning procedures
Humidity
### The Composition Of Air

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

**Partial Pressures**
- ~1% Noble gases (Ar, etc.)
- ~21% O$_2$ Oxygen
- ~78% N$_2$ Nitrogen
- 0-3% H$_2$O Water Vapour

**Vapour Pressure**

**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

- April: 50%
- Juli: 70%
- Oktober: 100%

Levels: 90%
Which is the driest condition?

30 °C and 50% R.H.

or

24 °C and 70% R.H.
Psychrometric Chart or Mollier diagram is one method for showing the thermodynamic qualities of humidity and water vapour.
30°C Dry Bulb Temperature
50% Relative Humidity
22°C Wet bulb Temperature
18.4°C Dewpoint Temperature
13.3g/kg Absolute Humidity
Psychrometrics – Calculated values

- 30°C Dry Bulb Temperature
- 50% Relative Humidity
- 22°C Wet Bulb Temperature
- 18.4°C Dewpoint Temperature
- 13.3g/kg Absolute Humidity
24°C Dry Bulb Temperature
70% Relative Humidity
20°C Wet bulb Temperature
18.2°C Dewpoint Temperature
13.1g/kg Absolute Humidity
Psychrometrics – Calculated values for driest condition

- 30°C Dry Bulb Temperature
- 50% Relative Humidity
- 22°C Wet Bulb Temperature
- 18.4°C Dewpoint Temperature
- 13.3g/kg Absolute Humidity

- 24°C Dry Bulb Temperature
- 70% Relative Humidity
- 20°C Wet Bulb Temperature
- 18.2°C Dewpoint Temperature
- 13.1g/kg Absolute Humidity
<table>
<thead>
<tr>
<th>City</th>
<th>Dry temp °C</th>
<th>Absolute Humidity 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</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>
</tbody>
</table>
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
Does Humidity Cause Problems?

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-betoablak.hu

Source: www.steliozettes.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 (25-30°C) and high humidities.

Below 70% Relative Humidity mould growth is virtually ZERO.
High Humidity Speeds Up Mould Growth – Hanoi Example

Hanoi, Hoàn Kiêm, Hanoi, Vietnam
Wednesday 8:00 AM
Mostly Cloudy

Temperature: 25°F | ≈ 7°C
Precipitation: 8%
Humidity: 74%
Wind: 16 km/h

Relative Humidity by month

<table>
<thead>
<tr>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
<th>Ave.</th>
</tr>
</thead>
<tbody>
<tr>
<td>68</td>
<td>70</td>
<td>76</td>
<td>75</td>
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<td>72</td>
<td>75</td>
<td>73</td>
<td>69</td>
<td>68</td>
<td>67</td>
<td>71.1</td>
</tr>
</tbody>
</table>
Materials and substances will have changing properties at different humidities.

Storage and production in the right, constant climate will optimise quality of the product and the production process and reduce cost.
Some manufacturing and curing processes require a product to be dried. Product drying is a delicate process, especially if heat is a concern.
Relative Humidity and Comfort Feeling

Human comfort feeling depends on a combination of room temperature, air speed, wall temperature and RELATIVE HUMIDITY

At lower RH less cooling is required to maintain a comfortable climate

Other benefits are no condensation and mould growth is the duct system…. much healthier!
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.

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### Moisture Removal Cost Comparison

<table>
<thead>
<tr>
<th>Typical Energy Cost to Remove 120 Pounds of Water Per Hour</th>
<th>Cost</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
Desiccant vs Cooling - Dehumidification Capacities at 50% RH

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

- Process air
- Wet air
- Dry air
- Reactivation air
- Drive motor
- Air heater
Silica Gel

- A non-crystalline (amorphous) silicon dioxide based material which has water molecules in its composition. Adsorption takes place in cavities and pores.
• Humidity is present in all environments

• Humidity control and proper HVAC techniques maintain correct GMP conditions

• 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

In closing
Thank you for your attention
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