L-DCS Technology
System configuration for humid and tropical climate

For individual information please visit our web site
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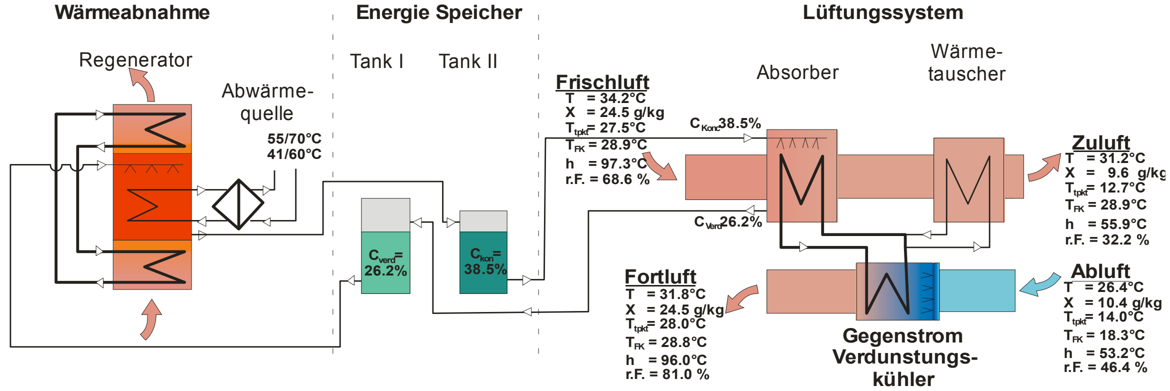
L-DCS Technology GmbH
Kirchenstr. 6
85630 Grasbrunn
Germany
Tel: +49 (0)89 96998197
Mail: Info@l-DCS.com
Web: http://www.L-DCS.com/

Air dehumidification systems

L–DCS
Liquid Desiccant Cooling Systems



L-DCS System: Configured as a high humidity fresh air supply system with energy recoveryy from the exhaust air flow

Base process

A Liquid Desiccant Cooling System (L-DCS) is used for dehumidification and/or cooling of the fresh air intake of air conditioning systems.. These systems are based on the absorption of water vapour by a hygroscopic fluid (sorbent), mostly highly concentrated aqueous solution of Lithium Chloride (H2O-LiCl). The sorbent absorbs water from the air and gets diluted. The absorbed water can be stripped from the sorbent by heating it up with low temperature heat at a supply temperature range in between about 55-75°C (temperature change about 15-20°C). Afterwards the sorbent can be used again for the absorption process In doing so the sorbent is not used up or deteriorated in any way and can be reused for an unlimited time. Possible heat sources are i.e.:

- Low temperature heat from solar collectors, (T_1=75°C;T_2=65°C)
- Waste heat from CHP Technology (preferably coolant only) , (T_1=80°C;T_2=60°C)
- Waste heat from district heating systems (return flow) , (T_1=80°C;T_2=60°C)
- Waste heat from compressed air compressors, (T_1=65°C;T_2=45°C)

The innovative part within the process is the actual air dehumidification step. A subsequent cooling of the airflow is optional and can be done by any cooling technology, i.e. adiabatic or indirect evaporative cooling.

The overall system and its components, functional description

The system described blow complies with the configuration recommended by L-DCS Technology for humid and tropical climates. It consists of the following subsystems:

1. **Ventilation**, consisting of:
   Fresh air supply system:
   - Absorber, for dehumidification and Pre-cooling of the fresh air intake
   - Subsequent heat exchanger, to post-cool the dehumidified fresh air flow coming from the absorber

   Exhaust air system
   - Indirect evaporative cooler, for energy recovery from the exhaust air.

   The units of the supply- and exhaust air subsystems are connected through a closed cycle system preferably containing pure water.
2. **Energy storage system**, consisting of two independent tanks the for storage of the liquid sorbent:
   - Tank I, for diluted sorbent
   - Tank II, for concentrated sorbent
3. **Heat intake system** consisting of:
   - Regenerator, for stripping the sorbent of water picked up during the dehumidification process
   - Heat recovery system, to preheat the regenerator air intake to increase the thermal efficiency of the process (COP_{th}).

The ventilation system consists of an absorber and a heat exchanger in the supply air flow and a Counter-flow-evaporative cooler in the exhaust air flow. Before entering the building the fresh air intake from the ambient is dehumidified in the absorber at almost constant air temperature and subsequently cooled in the heat exchanger. The heat, released during the dehumidification- and the cooling process, is picked up in the absorber by cooling water and transferred to the evaporative cooler in the exhaust air section. The evaporative cooler transfers the heat into the exhaust air flow, which is finally released into the ambient. The special feature of this evaporator is its counter-flow characteristic, the prerequisite of maximum recovery of cooling potential from the exhaust air flow.

The water vapour removed from the supply air flow is picked up by the sorbent. To achieve this concentrated sorbent is intermittently pumped from tank I of the energy storage to the absorber. A specially developed, proprietary *Ultra-Low-Flow©* sorbent distribution system in the absorber then only supplies a minimal amount of sorbent to the process. Subsequently the diluted sorbent leaving the process is pumped back to tank II of the energy storage. As long as tank I holds dehumidification energy in form of concentrated sorbent, fresh air can be continuously dehumidified. Only through the application of the L-DCS *Ultra-Low-Flow ©* technology it is possible to store dehumidification- and cooling energy with a storage density of up to 280 kWh/m³ at extremely low cost. The capacity of this energy storage system is adapted to the customer needs simply by adjusting the tank size. The dehumidification energy is only released in case the sorbent gets in contact with humid air. Therefore this energy storage- and transport system is free of any losses as long as the tanks and pipelines are air tight. Consequently dehumidification energy can be stored over unlimited time, for hours, weeks, month or even seasonal. To be able to reuse the diluted sorbent after the dehumidification process the sorbent has to be stripped of the excess water. This desorption process takes place in the regenerator of the heat intake system. The diluted sorbent, supplied to the regenerator from storage tank I, is being internally heated up in the regenerator by hot water of about 55°-80°C and brought into contact with the regenerator air flow. During the contact of the two media the excess water is evaporated, whereupon the heating water gets cooled down by 15-20°C. The evaporated water is then released into the ambient by the regenerator air flow. The concentrated sorbent laves the regenerator for storage tank II and that way it is available again for the dehumidification process. The heat recovery in between the regenerator supply air- and exhaust air flow limits the thermal losses, hence increasing the thermal efficiency of the overall system (COP_{th}).

The following graphics and diagrams document the performance of the L-DCS Technology under tropical conditions. The measurements were taken by the *Centre for applied Energy Research* (ZAE Bayern e.V.) on the 1.8.2014 on their own 6000m³/h L-DCS system at the *Energy Efficiency Center* in Würzburg, Germany. The tests and measurements were conducted within the framework of a research and developement project supported by the German government (BMWI). The tropical conditions for the tests were artificially created by a climate simulator. The following pages show the measured values taken of the states of all mass flows in- and out of the absorber and the counterflow-evaporative cooler of the system described above during the performance test under tropical conditions on the 1.8.2014. Along the perpendicular line through the diagrams at t=13:53 [hh:mm the respective values for each mass flow are shown exemplarily.

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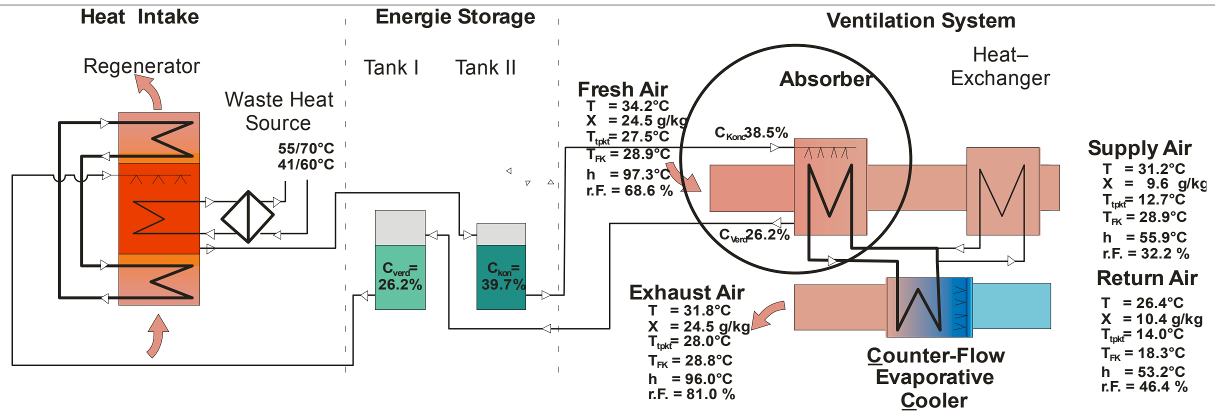

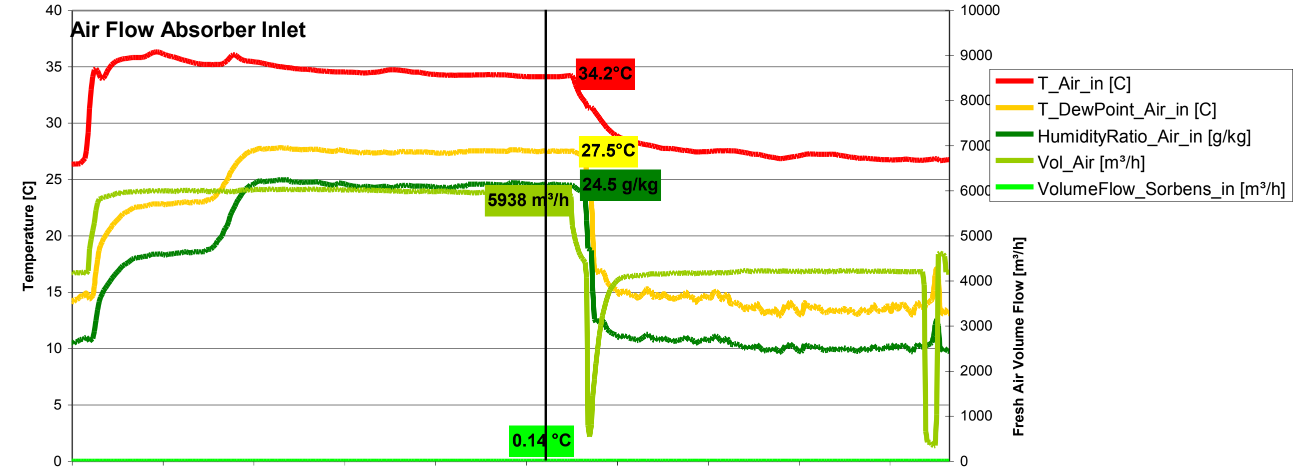

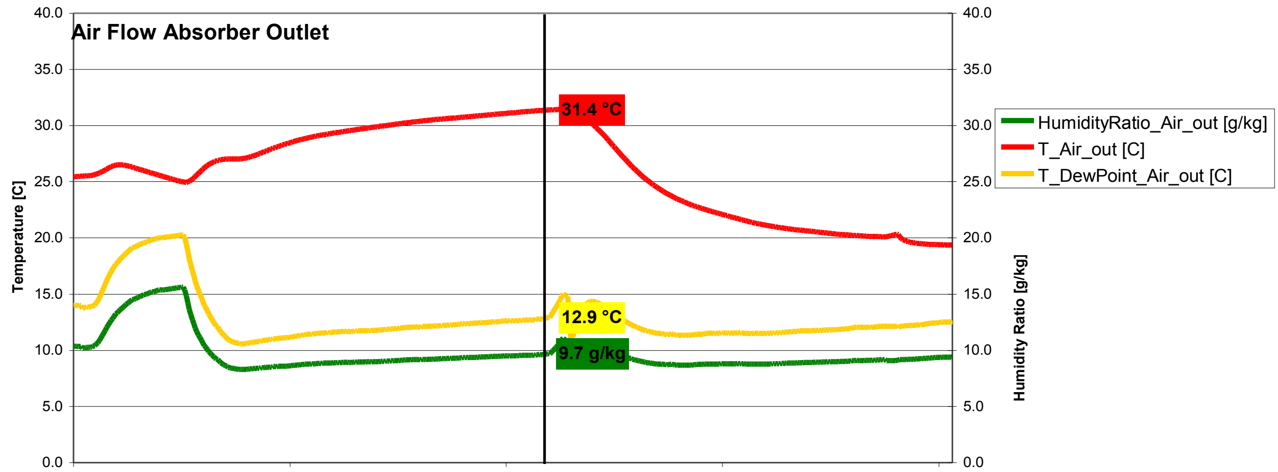

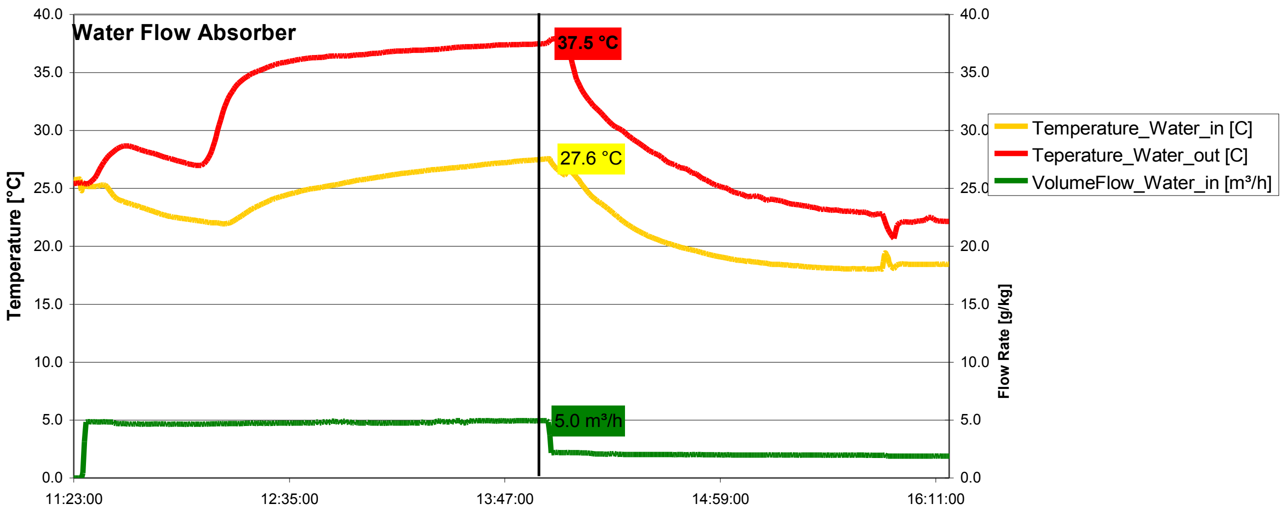

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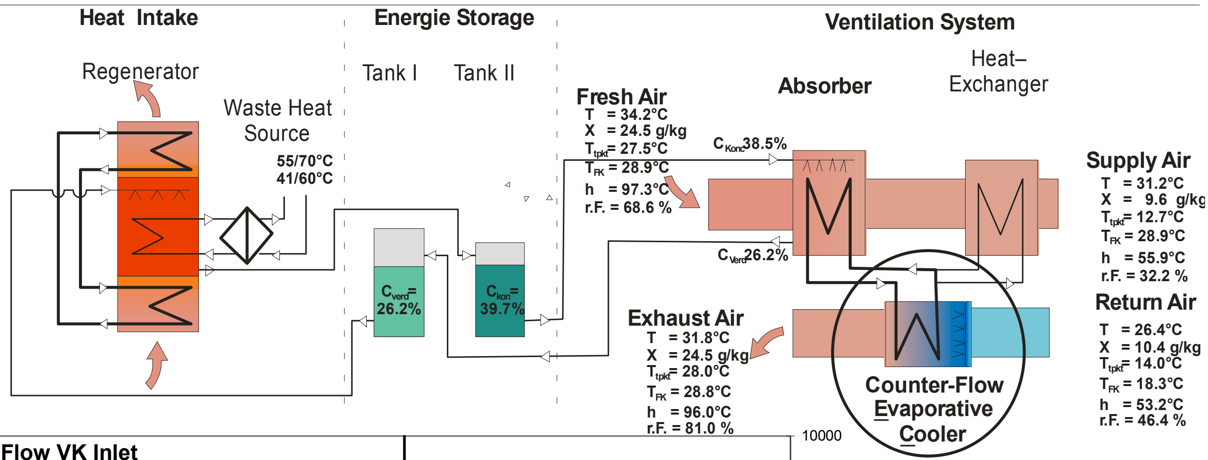
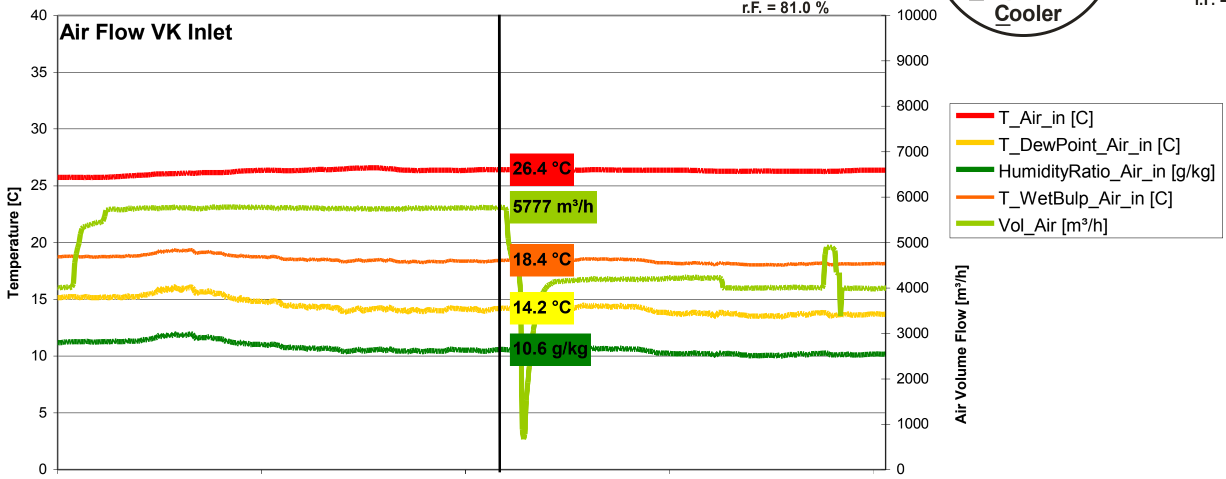
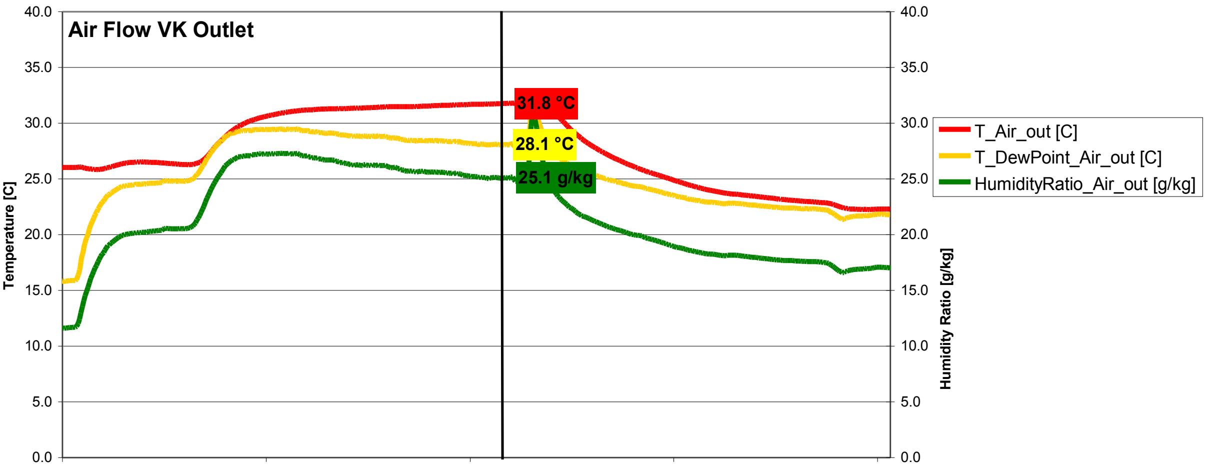
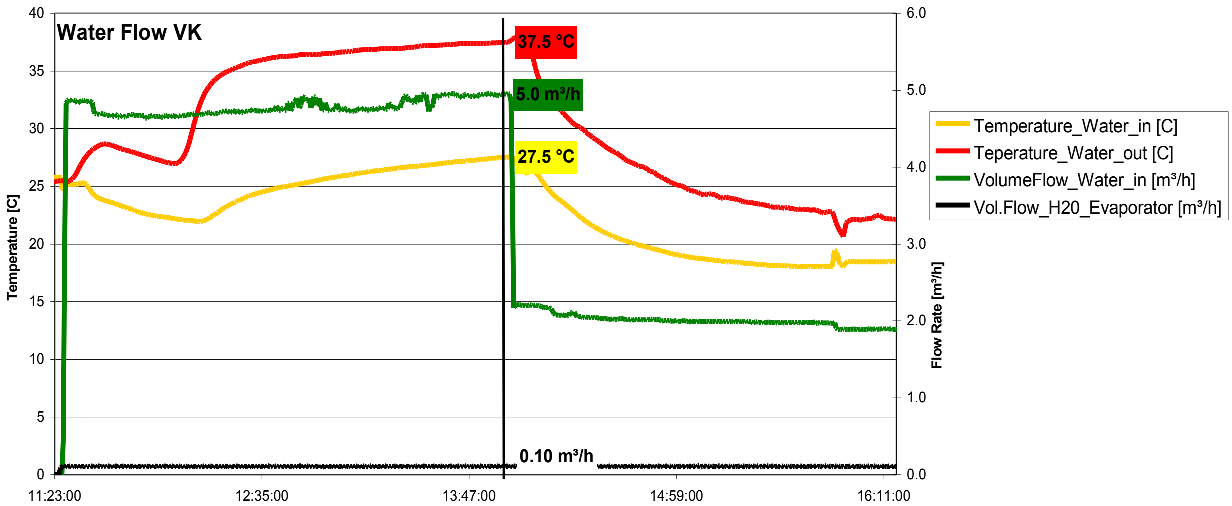
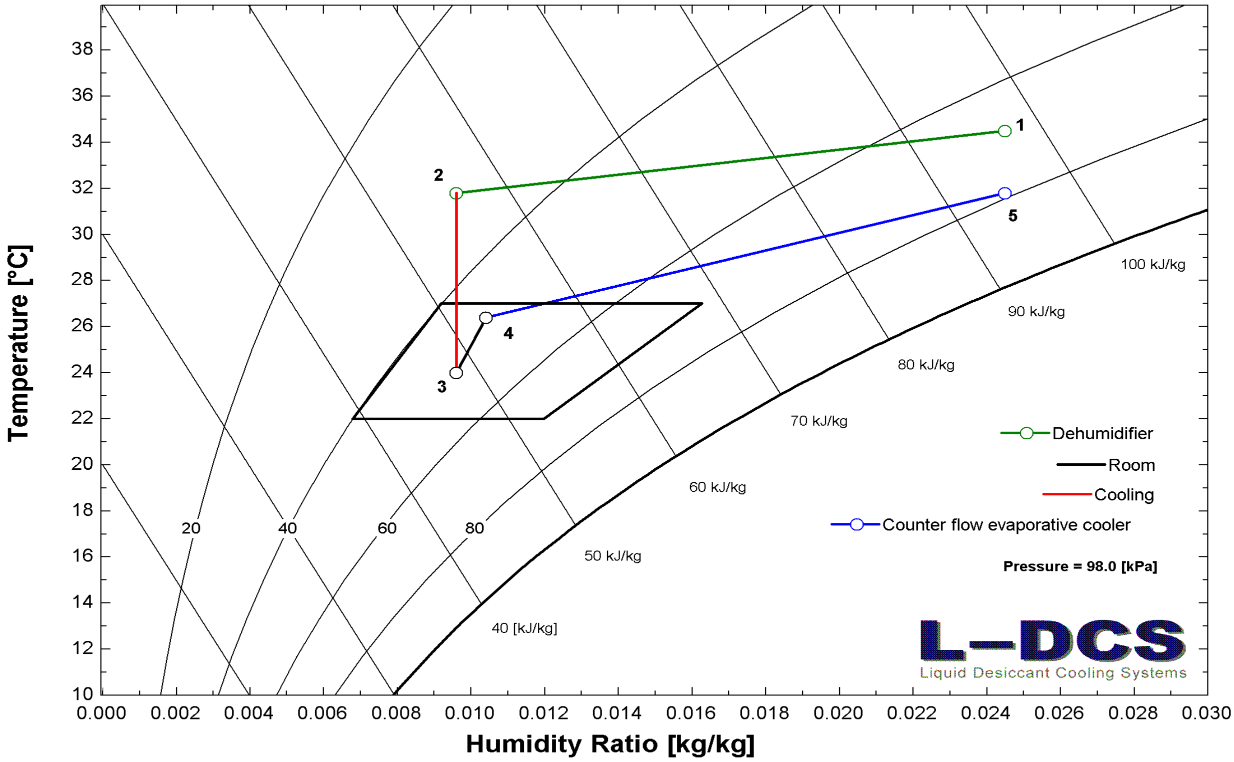








Mollier-Diagram, L-DCS Process 1.8.2014 13:53



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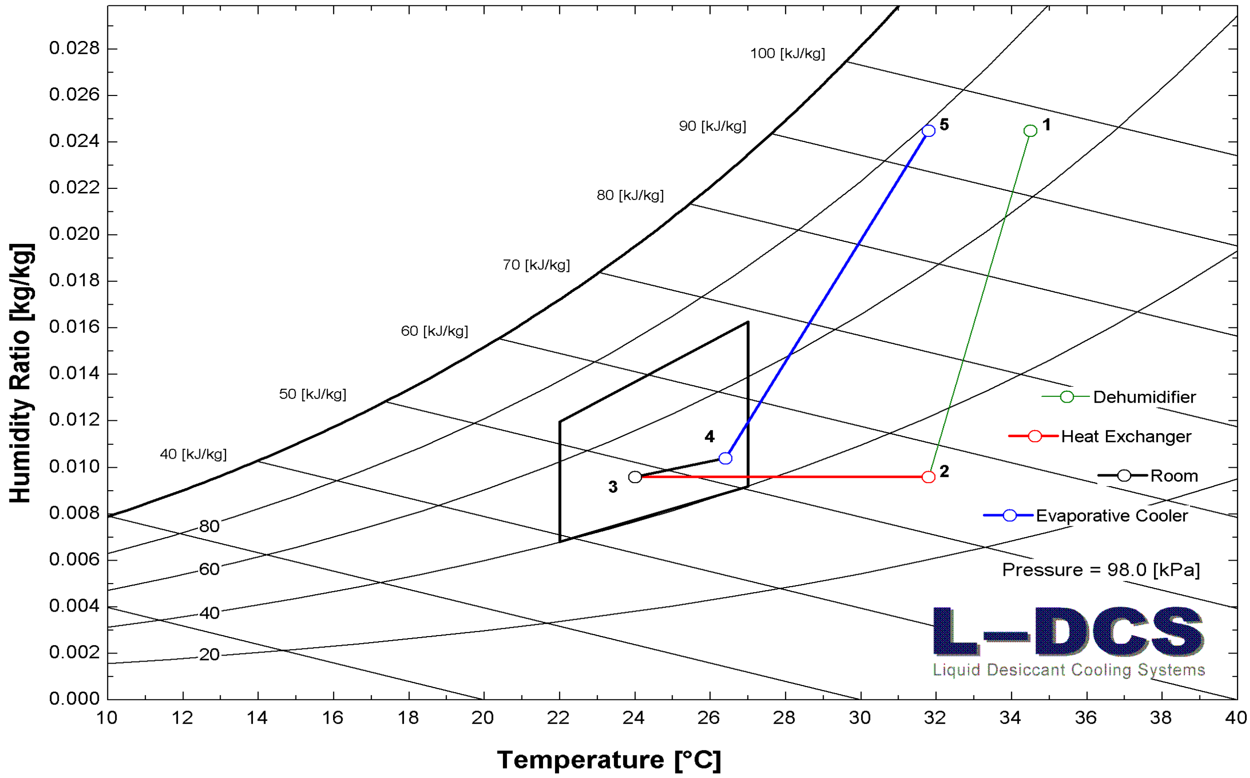
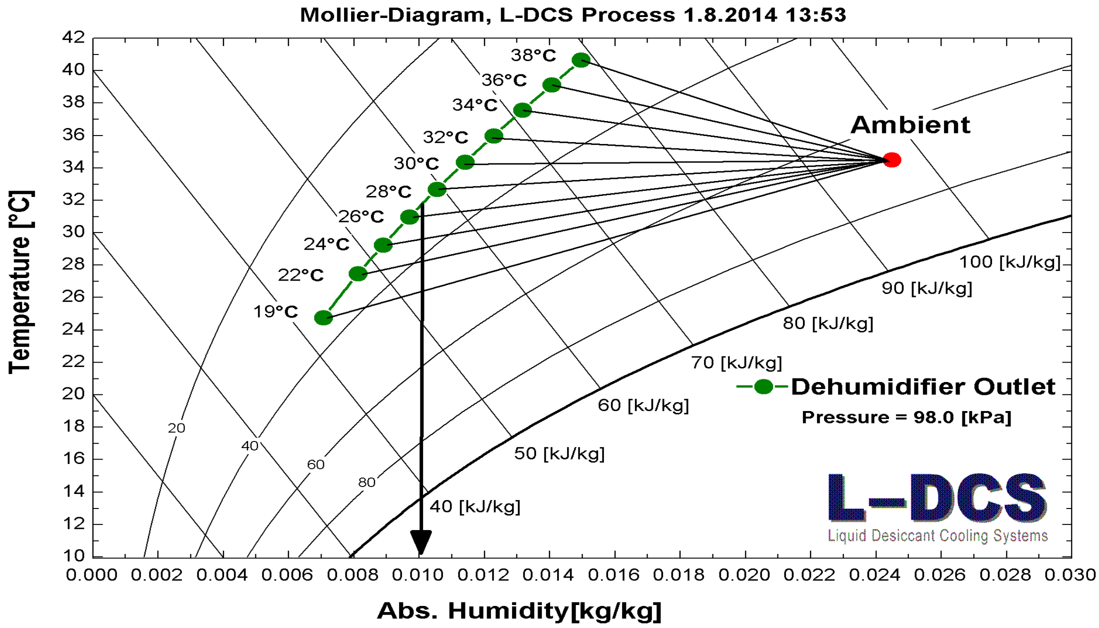
The diagrams on this page show the L-DCS process values at 13:53 in the Mollier-Diagramm used in Europe (above) and the psychrometric chart used in the English speaking world (below).

Psychrometric Chart, L-DCS Prozess 1.8.2014 13:53

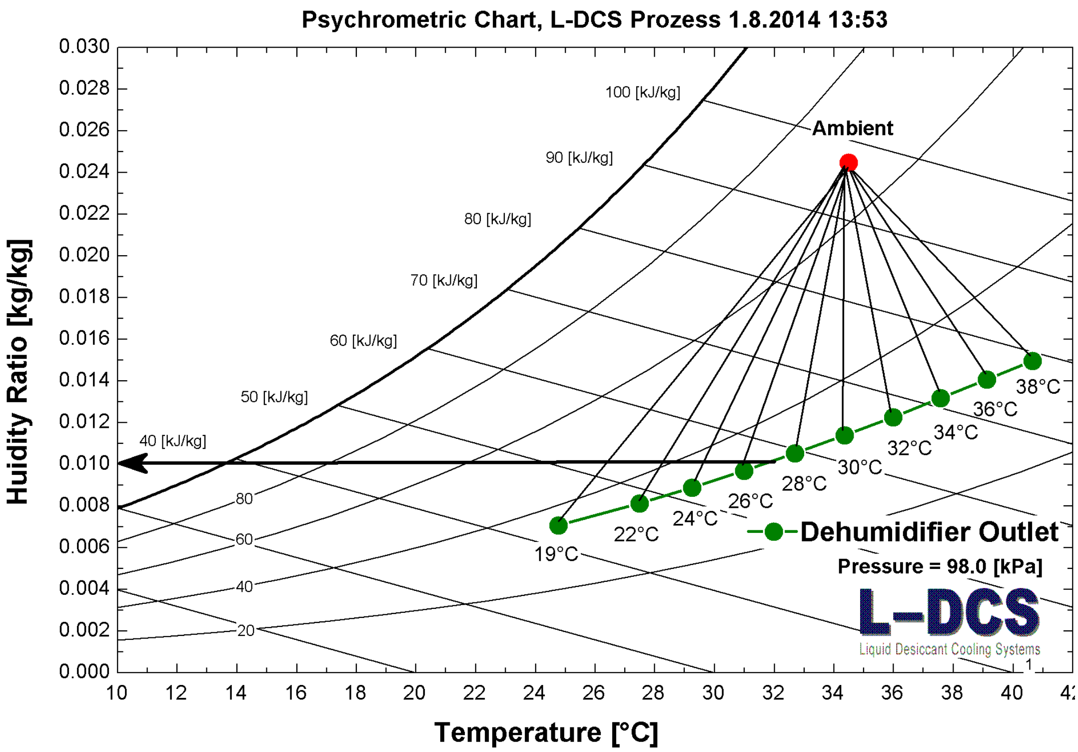


The performance tests show, that the L-DCS Technology easily dehumidifies fresh air of tropical conditions (T=34.5°C; W=24.5g/kg) to humidity levels well under 10g/kg without the use of conventional chiller power. At the same time the change of concentration in the sorbent was about 13.5%, relating to a storage density of 270 kWh of dehumidification energy per m³ of diluted sorbent.

The following diagrams show the the calculated humidity and temperature of the air leaving the absorber at varying temperatures of the cooling water inlet.



The measurements taken from the real life process at 13:53 (see above) are reproduced with high precision. From this parameter variation of the temperature of the cooling water into the absorber the corresponding air temperature and humidity ratio at the absorber outlet can be predicted for different operation conditions respectively for different system configurations. For example using a standard cooling cooling tower rather than a counter-flow evaporative cooler in the exhaust air, as suggested above, results in an absorber outlet humidity ratio of approx. 12.5[g/kg] (assuming the cooling water leaves the cooling tower at 33°C, about 4°C above wet bulb temperature).



Conclusion:
The measurements recorded during the performance tests impressively document the capability of the L-DCS technology under harsh tropical conditions. Nonetheless, they represent only one specific operating point of many possible. The dehumidification performance of the system mostly depend on the following variables:

- **Cooling water temperature** entering the absorber:
  Temperature ↓ Dehumidification performance ↑
- **Sorbent concentration** entering the absorber
  Concentration ↑ Dehumidification performance ↑
  Maximum limit: 42%, usual operation: 38-40% (mass concentration [kg salt /kg sorbent])
- **Sorbent mass-flow** entering the absorber:
  Mass-flow ↑ Dehumidification performance ↑
  Alert! Consequence: Energy storage density ↓, required pumping power ↑

In addition it should be noted that the heat capacity flow within the run-around coil system, supplying the dehumidification process with cooling water from the energy recovery process in the exhaust air, needs to be balanced to yield the best system performance.

Addendum

L-DCS dehumidification system for tropical conditions with values measured during performance tests..