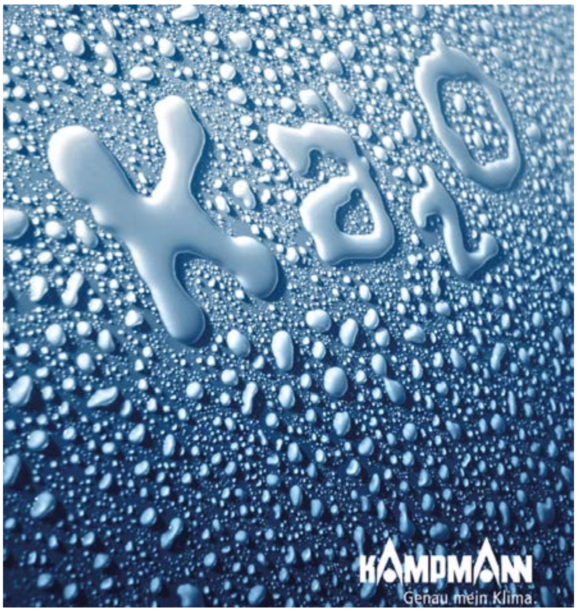
Ka₂O

An air volume independent H_2O cooling system

With the support of the Executive Agency for Small and Medium-sized Enterprises (EASME) by means of the ECO-innovation instrument, Kampmann and NOVA have brought a new, highly efficient and powerful system for indirect evaporative cooling in the central air handling units to the European market.



1. The Reasoning

Climate control is necessary for many buildings, from offices to shops, the gastronomy and residential buildings and many more – these climate systems are commonly known as ventilation and air conditioning units (VAC). The bulk of the VAC in use today utilize chemical cooling agents, the so called F-gases, which are environmentally hazardous due to their high impact on the greenhouse effect and the potential to deplete ozone in the upper atmosphere.

What is *evaporation cooling*?

Water needs heat to vaporize from liquid into vapor. When evaporation occurs, the heat is taken from the environment of the vaporizing liquid, resulting in a cooler environment.

The most common example we all experience is perspiration, or sweat. When sweat evaporates, it absorbs heat from your body.

In addition, the need for climate control systems has gone up in the last few years due to increasing building sizes, in which the natural air ventilation becomes more and more limited. Further, there is a trend to isolate buildings more and more from the natural environment to minimize heat loss and cooling need and therefore to lower energy consumption. These near zero energy buildings also need a climate control system because natural ventilation (open windows etc.) counteracts against the buildings isolation.

Kampmann and Nova have developed a highly innovative counterflow indirect *evaporation cooling* system called Ka_2O, which allows for the first time 86 % heat recovery, nearly unlimited scaling to different air volumes, independence from environment temperatures and a Coefficient of Performance (COP or EER/Energy Efficiency Ratio) of at least 30 by using water as the only cooling agent. Furthermore the water used as cooling agent can easily be reused. This system can be used as an air refrigerator in e. g. summer and to recover 86 % of the building heat while venting in winter only with the need of water as cooling agent and very little energy compared to existing VAC.

2. The Opportunity

The main ecological effect of this technology is the possibility to save huge amounts of environmentally hazardous cooling agents and instead using water as a renewable cooling agent. The Ka_2O system is a regenerative cooling innovation which is based on the principle of indirect evaporation cooling. Until now evaporation cooling has not been powerful enough for a widespread use: for example only a maximum cooling of about 12 Kelvin, depending on the outdoor temperature, has been possible. Therefore Kampmann GmbH and Nova Apparate GmbH elaborated the Ka_2O technology. With this new technology we achieved a record setting cooling of 20.1 Kelvin during a use case, realized within the Eco-innovation project.

What are *F-gases*?

F-gases or HCFCs are short terms for hydrochlorofluorocarbons, a large group of compounds that belong to the group called VOCs – Volatile Organic Compounds. F-gases are widely used for their low evaporation temperature and their otherwise fairly stable and unreactive behaviour. They are applied as refrigerants for air-conditioning systems, propellants in sprays or insulating foams and as agents in fire extinguishers for example. F-gases are completely synthetic – there are no natural sources for these compounds.

They have an equivalent climate impact ranging from 100 to 24.000 times higher than CO_2.

3. The Future-Proofness

Cooling technologies face a plethora of challenges in the near future – Ka_2O addresses these issues now, so that buildings equipped with Ka_2O will be future-proof.

For example, because climate protection ranks as one of the biggest ecological and economical challenges of the mankind, there are governmental efforts to reduce the use of *F-gases*: the regulation (EU) no. 517/2014 stipulates the reduction of the allowed usage gradual to one fifth compared to today's level which corresponds to a value of 35 million tonnes CO_2 equivalent. If the underlying technology of VACs does not change, the use of natural refrigerants such as propane, butane, ammonia and CO_2 will increase dramatically. But they are toxic, highly flammable or need very high air pressures and therefore their use will lead to high energy consumption.

Furthermore the 2010 Energy Performance of Buildings Directive and the 2012 Energy Efficiency Directive are the EU's main legislations when it comes to reducing the energy consumption of buildings. The latest one states for example:

- all new buildings must be nearly zero energy buildings by 31 December 2020 (public buildings by 31 December 2018)
- EU countries must set minimum energy performance requirements for new buildings, for the major renovation of buildings and for the replacement or retrofit of building elements (heating and cooling systems, roofs, walls etc.)

Ka_2O has been categorized as a renewable energy (cooling) by the German Renewable Energies Heat Act (EEWärmeG), because it is generated naturally by addition of water. An additional advantage over cooling units with F-gases is the significant reduction of the power consumption. Due to the changed conditions to achieve climate protection goals the indirect evaporation cooling with Ka_2O will become a technology which can replace or clearly relieve the conventional refrigeration by machine. With the use of Ka_2O all these requirements and regulations can be fulfilled without creating other ecological or health risks.

4. The History

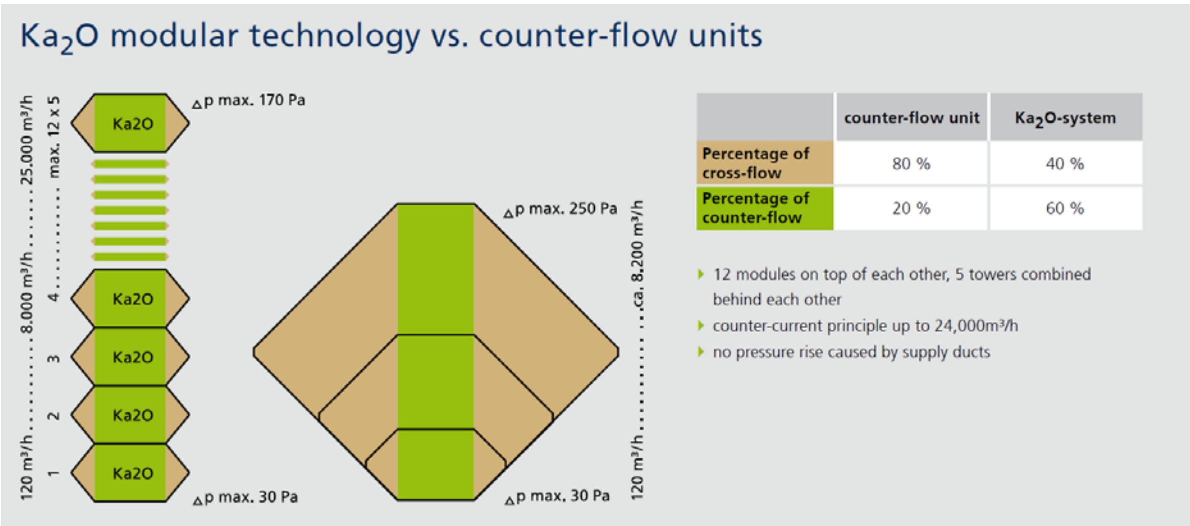
In the past, Kampmann has developed the precursor to Ka_2O, an air-conditioning device called 'Klimanaut' whose technology was also based on the principle of indirect evaporation cooling. At that time there were many market and technology barriers for evaporation cooling firstly because of its hygiene shortcomings which were caused by the use of water. Moreover the maintenance was complex and the device had a low cooling capacity in comparison to its size, due to the need of bigger evaporation areas in comparison to devices that use F-gases. But yet the basic idea of the system was forward-looking.

Since then Kampmann elaborated a new concept of indirect evaporation cooling which now is called Ka_2O. The achievements are a maximum cooling capacity with lower dimensions and a high hygienic standard which includes a simple maintenance. All this achieved through a highly innovative structure of the heat exchanger with new surface coatings and perfectly aligned airflow mechanics.

5. The Innovative Structure

In contrast to other existing evaporation cooling systems the Ka_2O technology includes a modular structure by the use of different combinations of a countercurrent heat exchanger in one size. A single countercurrent heat exchanger is designed for an air volume flow of up to 400 m^3/h with a pressure loss of 150 Pa. The wide variety of combination ranges from one stack of three modules (1.200 m^3/h) to five stacks of twelve modules each (24.000 m^3/h). Due to this parallel connection the pressure loss stays almost the same, regardless the number of modules. Only due to more complexity in the air distribution with a higher number of modules, there is an increase of 10 Pa at most.

Each heat exchanger module has got five nozzles which spray water into the exhaust air of the heat exchanger. Its hydrophilic coat on the exhaust side causes a capillary action. Along with the special geometrical design of the fins the capillary action effects the water distribution on the whole surface and thereby the best possible water evaporation. When using only one big heat exchanger the water would not spread equally on the whole surface of it, which leads to the formation of drops, that drain off and do not participate to the evaporation cooling. The cooling capacity would decrease.



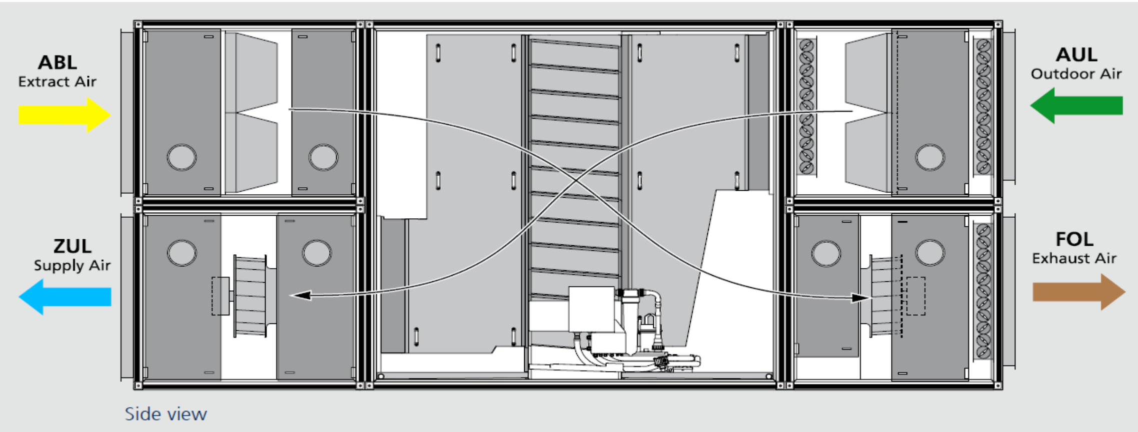
	counter-flow unit	Ka_2O-system
Percentage of cross-flow	80 %	40 %
Percentage of counter-flow	20 %	60 %

6. The Technology

The Ka_2O system achieves an adiabatic efficiency of up to 96 %. This maximum cooling capacity results from heat absorption of the outside air. The air on the exhaust side warms up and raises its capacity to absorb more moisture. Hence the evaporation and cooling capacity increase. Furthermore the *wet bulb temperature* of the extract air is transmitted to the supply air, regardless of the outside temperature, even at as high as 40 °C. The countercurrent principle achieves up to 87 % temperature change, up to 78 % dry in compliance with EN 308.

What is the *wet bulb temperature*?

The wet bulb temperature or also called theoretical limit of cooling is the lowest temperature which can be reached by evaporation cooling. It describes the point where the surrounding atmosphere of a wet surface is fully saturated with water. For the water absorption energy is necessary which is taken from the air as heat energy and so leads to a cooling effect.



7. The Ecological and Hygienic Aspects

1. <u>Low Water Consumption</u>

To keep the water consumption at its minimum the heat exchangers are sprayed with circulation water. There is a water tank under the stacks of modules which collects the surplus, not evaporated water. A circulating pump which is switched by solenoid valves distributes this water again on each stack. The associated, self-developed regulation 'KaControl' controls and monitors the entire system. This includes level monitoring, an automatic feeding and a daily blowdown. The system is not permanent, but cyclical sprayed, which further reduces the water and energy consumption.

Through intense laboratory bench tests the parameters for an optimum of water consumption, cooling capacity and power consumption were discovered - the spraying time of each stack lasts only 10 seconds and the following break has a minimum duration of 240 seconds.

2. <u>Frost Protection</u>

Every component of the system is designed in the way that self-emptying is even possible under power-off condition, thereby no water is left in the module so no harmful ice formation can occur. Furthermore the heat exchanger can be impinged with a surplus quantity of circulating water, so that a high level of water efficiency can be reached.

3. <u>Cleanliness</u>

An additional advantage of excessive spraying is an increase in cleanliness. Precipitated minerals are washed off the surface of the heat exchanger and collected in the water tank. This also prevents clogging of the modules and inactivation of the evaporation surfaces.

By using soft or pre-treated water the maintenance effort and the need for excessive spraying can be further reduced.

The Ka_2O technology complies with the requirements of the German Hygienic Guideline VDI 6022, which represents the highest standard on this issue. Additionally, due to the shallow geometry of each small Ka_2O register the fins can be cleaned more efficient than bigger heat exchanger systems. The air pipes, which are used for air distribution, can also be removed for the maintenance, so every single module can be inspected and tested.

8. The Use Case Consumer Market

The supermarket at the centre of Haselünne (Lower-Saxony, Germany) is air-conditioned by a VAC which contains 3 stacks of 9 Ka_2O modules each. This results in an air volume flow of 9.600 m³/h for 1.500 m² sales area. In winter mode this system uses heat recovery - the cold outside air is warmed up by the extract air inside the heat exchanger, so that a temperature change of up to 83 % can be achieved.

The remaining heating is managed by an add-on heating register, which is fed with the waste heat of the supermarket's freezers. If the market has to be cooled, the Ka_2O technology activates and transmits almost 100 % of the wet bulb temperature of the extract air to the outside air.

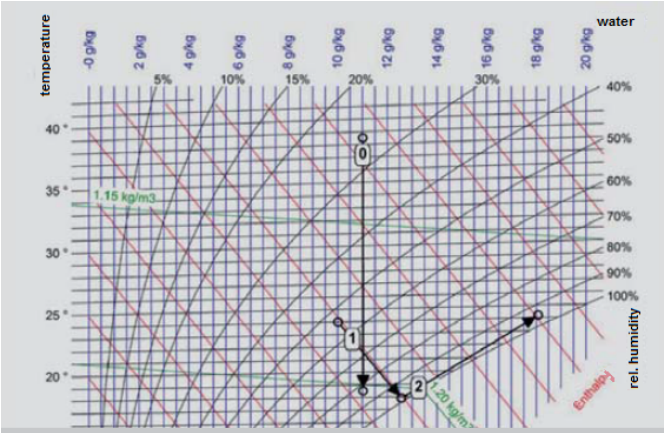
On a particularly hot day in the summer of 2015 Kampmann took measurements at the supermarket. The results exemplary show the efficiency of the Ka_2O technology on the 2nd of July 2015:

- outside air temperature: 38.5 °C
- extract air temperature: 24.0 °C (54 % r.h.)
- supply air temperature: 18.5 °C (measured in the air flow behind the EC-fan)
- spread: 20.1 K

  → cooling efficiency level **Φ: 96 %**

9. The Project Conclusion

The support by the Eco-innovation program allowed us to overcome several barriers that prevented a successful market launch of the new and innovative, environmentally friendly technology. We were able to bring the technology itself to perfection, reduced the production costs and raised the market awareness. The economic and environmental effectiveness could be proofed as well as the hygenic safety.



The curves shown in the h,x-diagramme comply to the following measured values:

Outside air - supply air - flow (curve 0)

	outside air →	supply air
temperature	38,6 °C	18,5 °C
relative humidity	26,0 %	83,0 %
absolute humidity	11,0 g/kg	11,0 g/kg
enthalpy humid	67,1 kJ/kg	46,6 kJ/kg
volume flow humid	9.600 m³/h	8.984 m³/h
mass flow dry	10.680 kg/h	10.680 kg/h

Extract air (humidification to wet bulb temperature) (curve 1)

	extract air →	wet bulb temperature
temperature	24,0 °C	17,9 °C
relative humidity	54,0 %	98,0 %
absolute humidity	10,0 g/kg	12,6 g/kg
enthalpy humid	49,7 kJ/kg	49,8 kJ/kg
volume flow humid	9.600 m³/h	9.440 m³/h
mass flow dry	11.220 kg/h	11.220 kg/h

Extract air - exhaust air - flow (curve 2)

	extract air →	exhaust air
temperature	17,9 °C	24,2 °C
relative humidity	98,0 %	95,0 %
absolute humidity	12,6 g/kg	18,1 g/kg
enthalpy humid	49,8 kJ/kg	70,4 kJ/kg
volume flow humid	9.600 m³/h	9.893 m³/h
mass flow dry	11.410 kg/h	11.410 kg/h

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