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Energy and Environmental Protection Aspects of Desiccant Cooling

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ENERGY AND ENVIRONMENTAL PROTECTION ASPECTS OF DESICCANT COOLING

1. Synopsis

Ventilation and air conditioning systems mainly use fossile primary energies as gas, oil and coal for the heating and cooling processes.

Air conditioning means heating and humidifying the supply air during the winter season and cooling and dehumidifying the supply air in the summer season. For these summer operations the supply air in general is cooled down lower than the dew point in order to dehumidify the air by condensation. Afterwords the supply air is reheated again to reach the required temperature level for room inlet. For this air treatment process cooling and heating energy are used simultaneously. The cooling energy thereby is generated in general in a conventional cooling compressor unit based on CFC-refrigerants.

Due to the threat of an atmospheric ozone depletion leading to a "Greenhouse Effect" mainly caused by CO_2 from burning fossile primary energies and the CFC-based refrigerants (1) used as cooling vapour in compressor chillers new developments of cooling equipment have a realistic chance to enter the HVAC market.

Today it is necessary to operate air conditioning systems with a minimum of primary energy consumption and low pollutant emissions. At the same time the requirements for the indoor air quality are increasing.

Therefore alternative and new air conditioning systems are now introduced using "Desiccative and Evaporative Cooling" (DEC) air treatment processes (2). These units can be operated all over the year and have to be compared under energy and environmental operation aspects with traditional air conditioning systems.

2. Desiccative and Evaporative Cooling (DEC)

In order to separate the summer operations "cooling" and "dehumidifying" in different air treatment steps a rotating desiccant wheel (3) and a rotating heat transfer wheel (4) are combined in a DEC unit. The related processes were proposed already in the early 1940's and granted in the Pennington patent (5). Since that time many contributions have been added to this improvement, but only energy saving activities have brought the breakthrough a few years ago. Today DEC systems are operated with very good results in the USA, Japan and Germany and a broad range of components is available with extremely high efficiencies for adsorption technologies and heat exchangers (6)(7).

According to Fig.1a the DEC unit consists of three well-known air processors: a desiccant air dehumidifier, evaporative coolers and a rotating sensible heat exchanger. The individual function of these principal components is as follows (Fig.1b): the desiccant wheel "A" rotates within the outdoor air stream and removes the moisture from it (1→2). The most suitable rotor is fabricated of silica gel reinforced with inorganic fibres and formed into a honeycomb shape. Active silica gel is synthesized and combined in the honeycomb shape by chemical reaction. It has an excellent water adsorbing ability. The adsorption of moisture on the silica gel causes the temperature of the air to rise. The heat generated during the drying step is removed from the air by a rotating heat recovery wheel "B" with high efficiency (2→3). This heat recovery wheel is non-hygroscopic and fabricated of corrugated aluminium. The evaporative cooler "C" humidifies the dried air to further reduce the dry bulb temperature of the supply air stream (3→4).

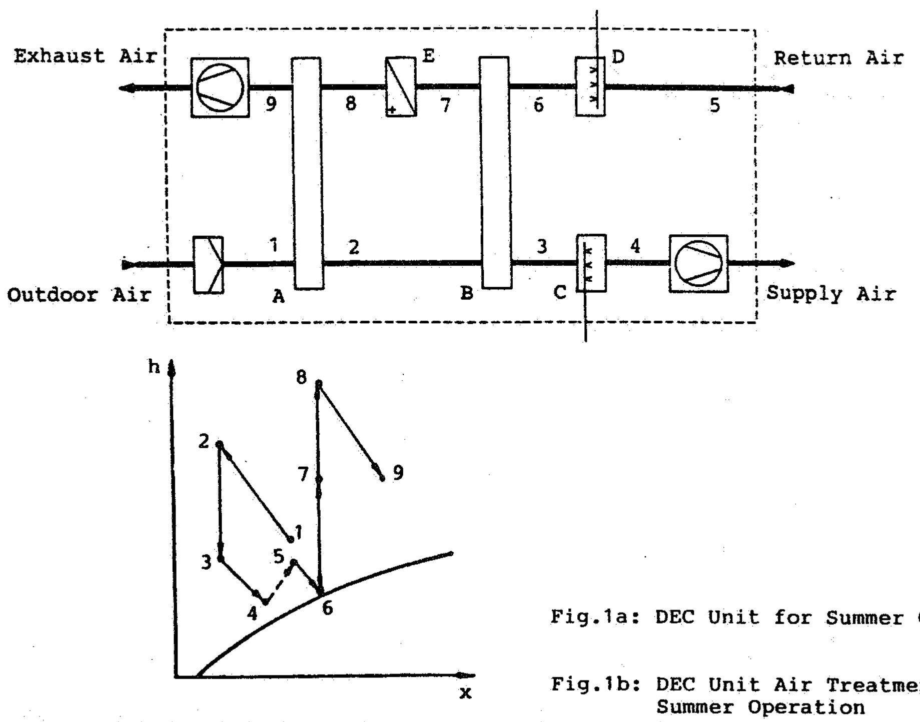


Fig.1a: DEC Unit for Summer Operation

Fig.1b: DEC Unit Air Treatment in Summer Operation

For the reactivation cycle the return air is used by first reducing the dry bulb temperature in the evaporative cooler "D" (5→6). The heat originally generated during dehumidification of the supply air is then removed and transferred back into the reactivation cycle by the heat recovery wheel "B" (6→7). In the heat exchanger "E" external heat energy brings the reactivation air to the required temperature for desorbing the desiccant wheel "A" (7→8). Due to the synthesized silica gel this temperature could be set at a minimum of 50 °C which allows to use low level waste heat available from many heat processes, cogeneration processes and also solar energy. When desorbing the desiccant wheel "A" the exhaust air temperature is reduced with increasing the absolute humidity (8→9).

3. Facts and Figures

The new DEC units (8)(9) can operate during winter and summer seasons for heating, humidifying, cooling and dehumidifying the supply air in the same way as a traditional air conditioning device according to a DEC based control equipment (Fig. 2a,b). Therefore the customer and his consultant engineer can compare both air handling units not only on investment costs and on operation and maintanance costs but also on the thermal and electrical energy consumption together with the emissions of pollutants which are referred to thermal and electrical energy generation.

In the following such a comparison is presented. The specific results are based on the calculations of energy consumption according to the German Standard VDI 2067/3 (10). For the emissions of pollutants the specific figures of a German study on environmental protection (11) are used according to Fig.3.

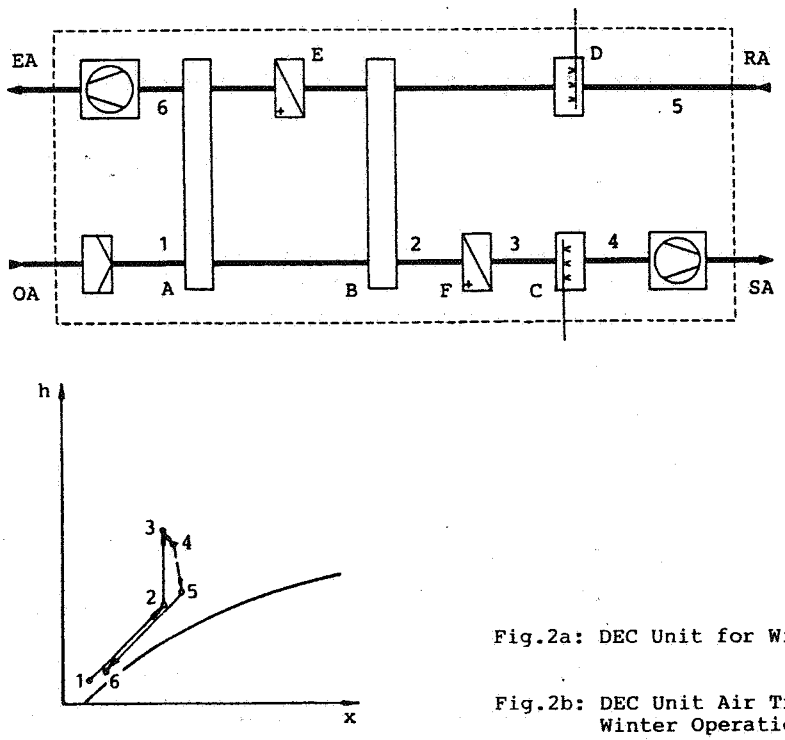


Fig.2a: DEC Unit for Winter Operation

Fig.2b: DEC Unit Air Treatment in Winter Operation

	SO_2	NO_x	Dust	CO_2
Oil fired Boiler	0,4	0,31	0,01	370
Electricity (Coal)	0,75	0,71	0,09	929
District Heating } Coal fired Cogeneration	0,1	0,1	0,01	345
Electricity } Coal fired Cogeneration	0,19	0,28	0,08	438

Fig.3: Specific Emissions kg/MWh Final Energy

The calculations are carried out for

- System A: Air conditioning system with adiabatic humidification and dew point control and CFC based refrigeration (Fig.4).
- System B: Air conditioning system with adiabatic humidification and dew point control, CFC based refrigeration and total energy recovery wheel with sensible and latent heat recovery (Fig.5).
- System C: Air conditioning system as a DEC unit operating the sensible heat recovery wheel and bypassing the dehumidification wheel in the winter season (Fig.6).
- System D: Air conditioning system as a DEC unit operating the dehumidification wheel as total energy recovery wheel with increased rotation speed in the winter season (Fig.7).

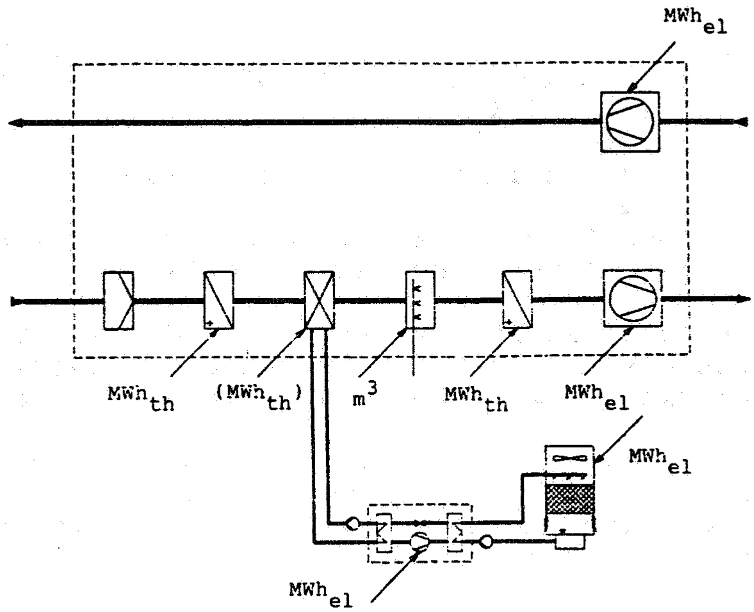
The total annual energy consumption for air treatment is calculated for the systems A, B, C and D for

- Thermal Energy (MWh_{th}): Heating and regeneration
- Electric Energy (MWh_{el}): Motors of blowers for internal and external pressure drops; conventional cooling compressor; cooling tower
- Water Supply (m^3): Humidification and cooling tower

The total annual emissions of pollutants based on primary energy consumption for heating energy and electricity are calculated according to traditional energy supply systems:

- Systems A, B: Heating with oil, electricity from coal fired power plant
- Systems C, D: Heating and electric energy from a coal fired cogeneration power plant.

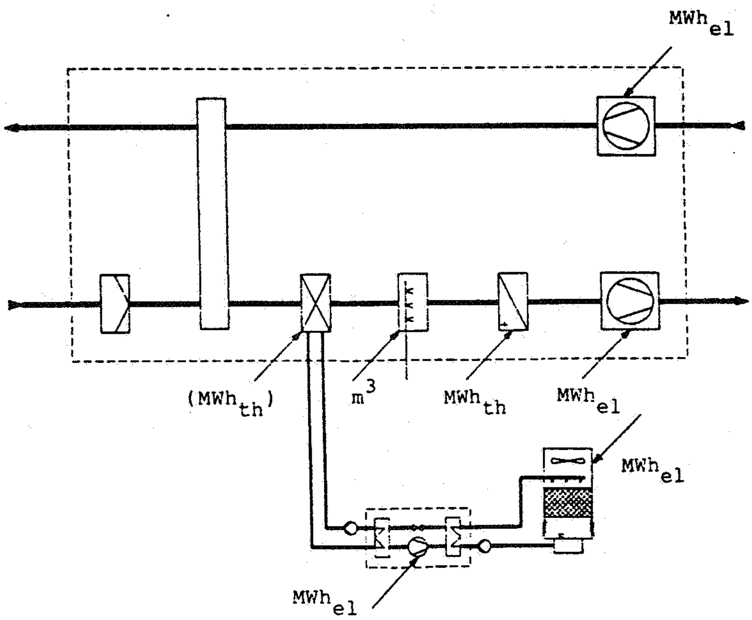
The calculations are derived from a German DEC installation with 25000 m^3/h supply air volume and 22000 m^3/h exhaust air volume for a convention hall operating 12 hours per day at 5 days per week. Supply air conditions are 18^{o}C/10,5 g/kg (16^{o}C after DEC). The results are presented as specific figures based on m^3/s air flow.



Energy Supply per m^3/s		
- Thermal Energy	81	MWh/a
- Electric Energy	14	MWh/a
- Water Supply	120	m^3/a

Emissions per m^3/s		
- SO_2	43	kg/a
- NO_x	35	kg/a
- Dust	2	kg/a
- CO_2	44000	kg/a

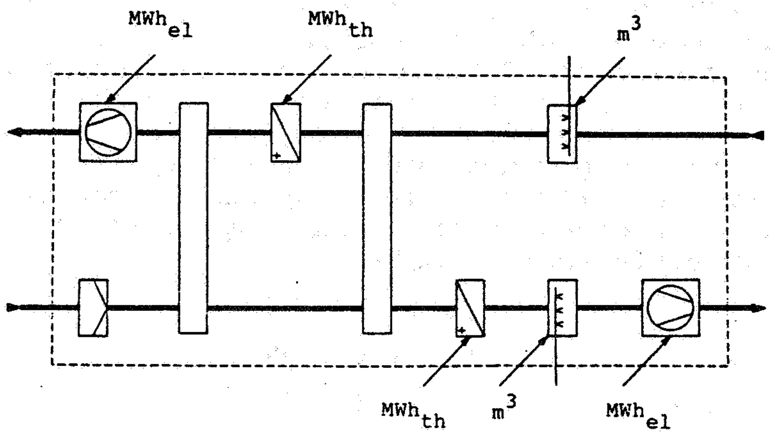
Fig.4: Air Conditioning System A



Energy Supply per m^3/s		
- Thermal Energy	52	MWh/a
- Electric Energy	16	MWh/a
- Water Supply	90	m^3/a

Emissions per m^3/s		
- SO_2	33	kg/a
- NO_x	27	kg/a
- Dust	2	kg/a
- CO_2	34000	kg/a

Fig.5: Air Conditioning System B



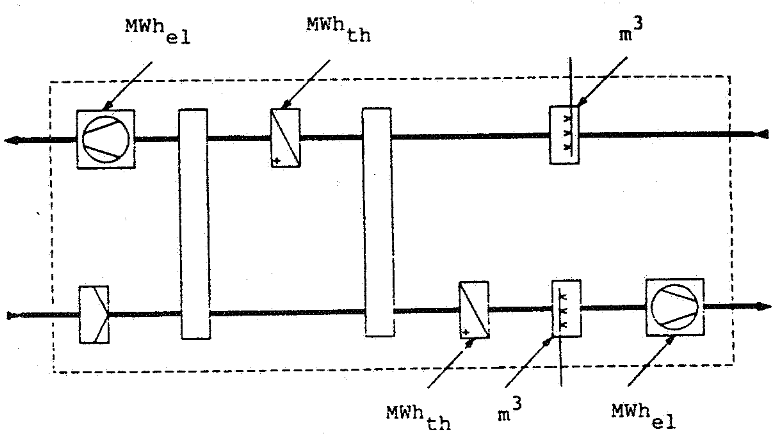
Energy Supply per m^3/s

- Thermal Energy 43 MWh/a
- Electric Energy 14 MWh/a
- Water Supply 90 m^3/a

Emissions per m^3/s

- SO_2 7 kg/a
- NO_x 9 kg/a
- Dust 2 kg/a
- CO_2 22000 kg/a

Fig.6: DEC System C



Energy Supply per m^3/s

- Thermal Energy 33 MWh/a
- Electric Energy 15 MWh/a
- Water Supply 45 m^3/a

Emissions per m^3/s

- SO_2 6 kg/a
- NO_x 8 kg/a
- Dust 2 kg/a
- CO_2 18000 kg/a

Fig.7: DEC System D

4. Comparison

As a new technology the DEC systems have to be compared with conventional air condition systems running with or without energy recovery. Because DEC systems replace the electric driven cooling compressor and CFC's are no longer needed for the cooling cycles the most important comparison is for the total energy consumption including the very attractive application of various cogeneration energy supply systems. As normally for DEC systems the peak electric capacity for summer operation can be reduced the comparison is extended to the annual operation costs with the following specific energy costs:

- Thermal energy 60,- DM/MWh
- Electric energy 180,- DM/MWh
- Electric capacity 250,- DM/kW
- Water 6,- DM/m^3

In Fig.8 the two conventional air conditioning systems A and B are compared with the two DEC systems C and D in relation to 100% for system A. It is evident that the DEC system D with the desiccant wheel operating in the winter season as a total energy recovery wheel in combination with cogeneration energy supply is under every aspect superior to the traditional air conditioning systems.

System	A	B	C	D
Energy				
- Thermal Energy	100	64	53	41
- Electric Energy	100	110	100	105
- Electric Capacity	100	77	29	29
- Water Supply	100	75	75	38
Emissions				
- SO_2	100	77	17	15
- NO_x	100	78	24	22
- Dust	100	100	100	100
- CO_2	100	77	50	40
Operation Costs	100	79	57	50

Fig.8: Comparison of Systems A,B,C,D

Regarding the annual heating energy consumption the DEC heat recovery system D needs only 40% of a conventional airconditioning system. The electric energy consumption is for all systems almost the same, because the DEC systems have higher internal pressure drops. But the DEC electric capacity is only 30% of a conventional airconditioning system. This allows to reduce the tarifs for electric energy.

The water supply can be reduced down to 40%.

Referring the combined application of thermal and electric energy in a cogeneration plant the DEC systems allow a more economical operation of these attractive energy supply systems.

DEC systems can apply solar thermal energy on low temperature level for the regeneration cycle. If 60% of the regeneration energy can be used by solar gains the total annual heating energy of a DEC system can be reduced to 33% of a conventional airconditioning system. This seems to be very attractive.

The total annual operation costs for a DEC system can be reduced to 50%.

Investment costs have to be calculated for every project. In general DEC systems as a total unit can be designed and installed with the same investment costs as traditional systems, because the refrigeration compressor and the cooling tower are no longer necessary. So the benefits of a DEC system of reduced energy consumption and reduced emissions as well as the reduced operation costs can be earned from the beginning.

5. References

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