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A New Development for Total Heat Recovery Wheels

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normal cost : 1.5-2 DM / m^3/h air

A NEW DEVELOPMENT FOR TOTAL HEAT RECOVERY WHEELS

1. Synopsis

Total energy exchangers with a rotating heat storing matrix have been applied to airconditioning systems for more than 25 years with very good results for saving both heating and cooling energy. The efficiency of the hygroscopic coating of the rotors is very important to recover the latent energy, but there is the risk of cross contamination. To prevent odor transfer, the mechanism of the sorption and desorption process has to be investigated in detail. Selecting the adsorbant accordingly, the rotating heat exchangers can meet the new ventilation requirements in buildings for a high indoor air quality.

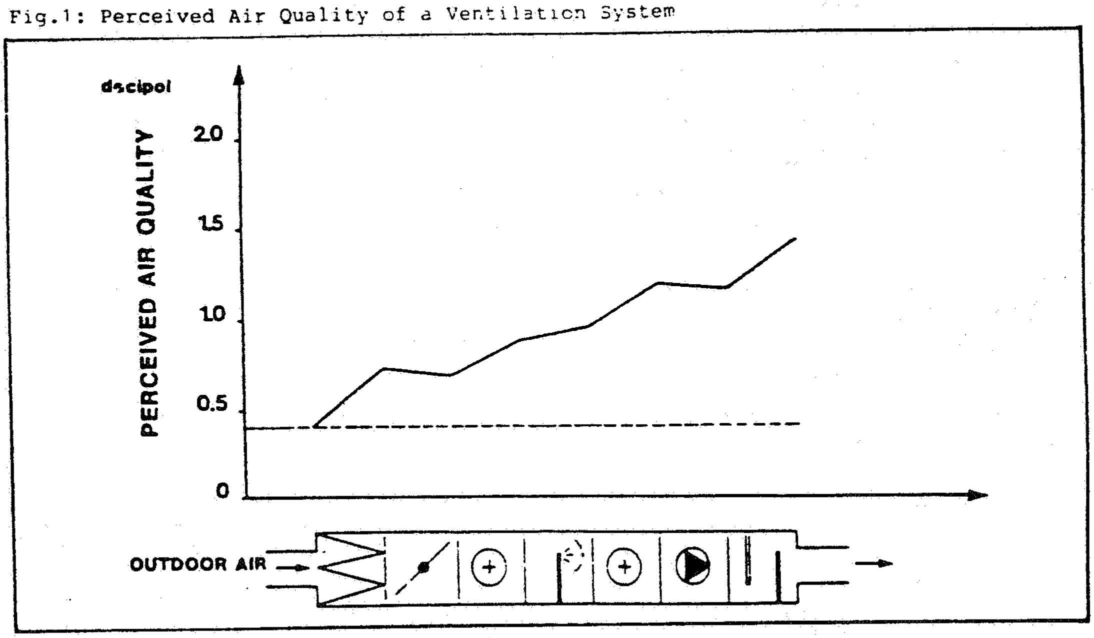
2. Indoor Air Quality

For more than a hundred years ventilation standards for buildings have been based on Pettenkofer's theory that the CO_2-concentration in rooms is an acceptable scale for the indoor air quality. It was assumed, that the human being is the main pollutor, and therefore the required outdoor air rate was specified per room occupant only. Unfortunately, these existing standards do not prevent serious complaints on air quality in many buildings, referring to odors and the perception of stale and stuffy air. During the past years, these dissatisfactions have been investigated systematically in detail in all types of buildings in Europe, North America and Japan.

In 1988, Fanger started to publish results of those studies, which had been carried out to identify the various pollution sources in buildings. This marked the beginning of a new philosophy in ventilation (1). Fanger related the pollutions, such as human bioeffluences, tobacco smoke, odor emissions from building materials, furniture, carpets, papers, office machines and the ventilating system, to the strength of the pollution source by the unit "olf", and defined the perceived air quality by the unit "decipol". These studies started in Copenhagen, randomly selecting 15 existing office buildings (2). As a surprising result, it had been found, that a non-neglectable contribution of the pollutions came from the ventilation system itself. Therefore, further experiments had been carried out to evaluate the contribution of each component of the ventilation system to the total pollution of the air passing the ventilating system by measuring the air quality before and after each component. A typical value of the perceived air quality as increment, caused by each component, is shown in Fig.1 for one of the 15 investigated ventilation systems in Copenhagen. The overall increment shown is 1,0 decipol and mainly caused by filter, heat exchanger coils and sound absorber.

Fanger's philosophy of ventilation stated that the total pollution strength in a space can be calculated by addition of the strength of each single source. This brings a new method to calculate the required air volume of outdoor air for a ventilating system (3)(4). This new method will cause a significant increase of the outdoor air rate for so-called "low olf buildings" with 0,2 olf/m^2 with a high indoor air quality. According to the present standards this increase can lead to a five times higher outdoor air rate. Following this statement energy recovery systems will become much more important than in the past. But at the same time, when following Fanger's philosophy, it is also very important to know in detail the pollution emission of every type of the energy recovery systems as a main component of ventilating systems.

Fig.1: Perceived Air Quality of a Ventilation System

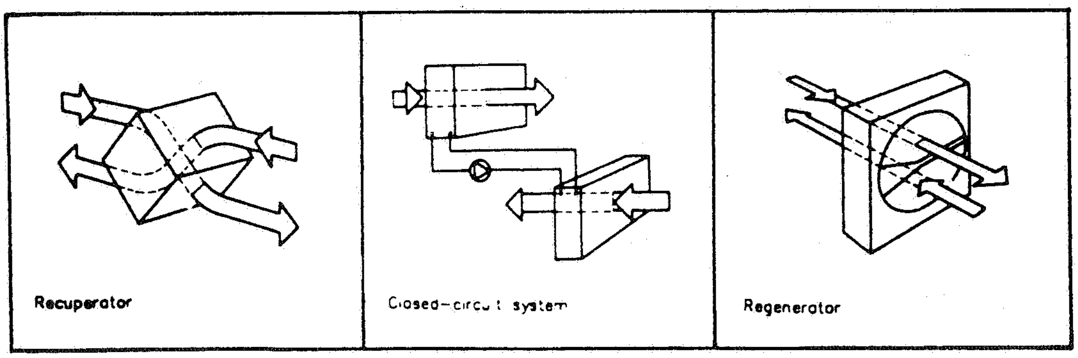


3. Energy Recovery Systems

In accordance with Eurovent 10/1 standards (5) energy recovery systems are devided into 3 categories (Fig.2):

- Recuperators with plates or tubes, preferably for small systems and with sensible energy recovery only,
- Closed circuit systems with finned heat exchangers connected by pipes, used primarily for modification and retrofit of existing buildings with sensible energy recovery only,
- Regenerators with rotary heat storing matrix and combined transfer of heat and humidity for all fields of application with total energy recovery. The matrix of the rotor is fabricated in a honeycomb structure of corrugated aluminum or ceramic fiber material with hygroscopic surface.

Fig.2: Types of Energy Recovery Systems



As shown in (6) the rotor type (Fig.3) has the best total energy efficiency, and it is the only type which can be applied to the combined transfer of sensible and latent heat worldwide under all climate conditions.

The ability to recover latent energy is of great importance in both the heating and the cooling seasons. During the cooling season, when the latent load is typically greater than the sensible load, the outdoor air is dehumidified. In the heating season the costly humidification load is reduced through moisture recovery (Fig.4). Latent recovery doubles the energy saving potential compared with the use of merely sensible recovery technologies. It also allows for sizable cuts to be made in chiller and boiler capacity which reduce the initial costs of the total ventilation and heating installation.

Fanger reports from ventilation system testing that an odor emission has also been noticed in rotating heat exchangers (2). So several manufacturers have studied the reasons for odor transfer in total heat exchangers. It had been found that the main sources of odor transfer are linked to the types of the desiccants used as hygroscopic surface for exchanging the latent energy.

Fig.3: Total Energy Recovery Wheel

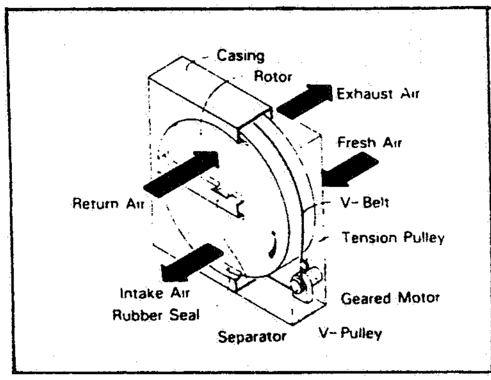
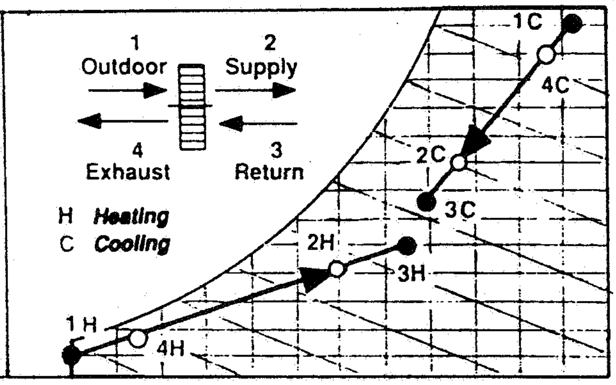


Fig.4: Psychrometric Chart with Energy Recovery



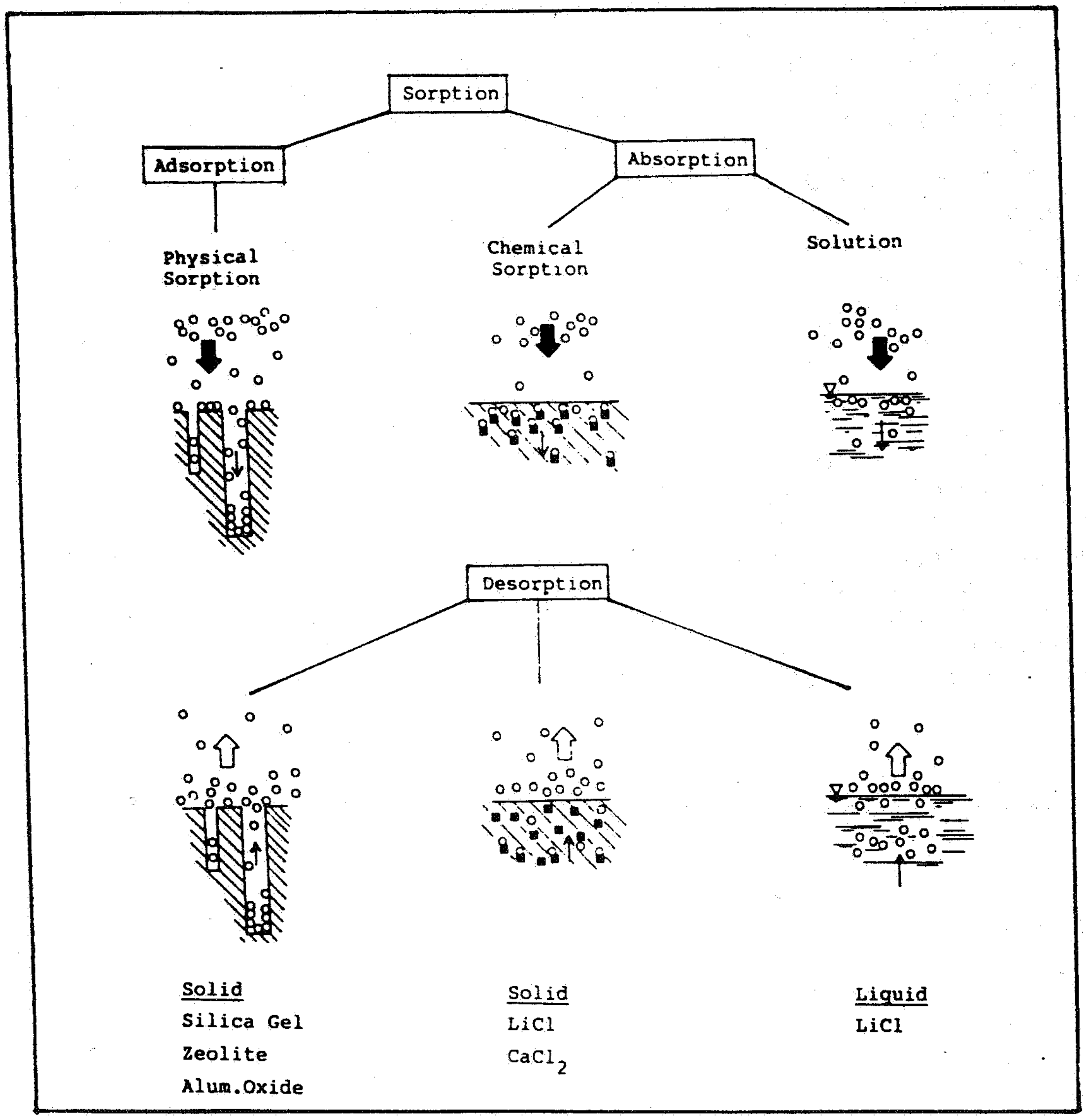
4. Latent Heat Exchanger

There are various types of desiccants for latent heat exchange. Silica gel, molecular sieves (zeolites) and aluminum oxide have an internal pore structure with a specific surface of 400 - 800 m^2/g comprising micropores, mesopores and macropores for binding the water molecules of the air streams. Lithiumchloride or calciumchloride can be used either as solid or liquid desiccant to accumulate humidity. In general, the sorption has to be distinguished between adsorption and absorption of binding water molecules in order to transfer latent heat (Fig.5). Adsorption means trapping the water molecules in the pore structure of silica gel or zeolites by physical sorption. Absorption is the way of binding water molecules by a chemical compound on a solid or liquid desiccant like lithium chloride by a chemical reaction or chemical solution.

The difference of the vapor pressure at the surface of the desiccant versus the vapor pressure in the surrounding air stream serves as the driving force for sorption (adsorption/absorption) and desorption.

The sorption capacity of the desiccants is shown in equilibrium sorption isotherm curves. In the past the type of desiccant to be applied in a total energy recovery wheel had been selected according to the basic material of the rotor and the technical know-how of fixing the desiccant on the rotor surface. Several manufacturers have ceramic glass fiber paper or aluminum sheets formed into a honeycomb structure as basic rotor material and are using all above mentioned desiccants.

Fig.5: Mechanism of Sorption and Desorption



5. New Technology for Adsorption preventing Odor Transfer

Generally all desiccants have a very good sorption capability for water, but can also adsorb or absorb airborne odorous contaminants of outdoor air or exhaust air. To prevent odor emission or odor transfer via the desiccant the odor desorption has to be eliminated under all operation conditions of an air conditioning system.

From the point of view of the latent heat exchange efficiency it may be advantageous to use the desiccants containing many mesopores as they have large specific pore volume. However, moisture adsorption by mesopores is very different from adsorption on micropores. In mesopores capillary condensation occurs. Capillary condensation can be estimated from the equilibrium isotherms of the desiccant. For example in Fig.6 the adsorption and desorption process is shown for two types of silica gel (A-type and B-type). As mentioned in the isotherms in the B-type silica gel the adsorption ratio during increasing relative humidity from low level to high level and during decreasing from high level to low level do not correspond with one another. This phenomenon is so-called "hysteresis" and it means that capillary condensation is occuring. When relative humidity is high the adsorbed water vapor on B-type silica gel condenses in the mesopores and is staying as bulk water in them. Then, if the odorous chemicals adsorbed in the wall of pores (adsorbed as monolayer adsorption) were water-soluble those odorous chemicals solute in the bulk water in liquid phase. (Fig.7). Also, when the odorous chemicals are insoluted in the bulk water those are desorbed from the wall of the pore and disperse into the water. This is the situation in which odorous chemicals are easily desorbed from the pores. Eventually, at the stage of desorption those odorous chemicals have been evaporated with the water, emitted as well as moisture, and mixed into the supply air which is delivered to the inside of the room. This is the mechanism of the odor emission.

In the A-type silica gel the pore diameter is smaller than that of the B-type silica gel (Fig.8) and classified in micropores only. The silica gel A-type has a strong adsorption capability and shows monolayer adsorption and, in consideration of the diameter of its micropore size, the multi-layer adsorption cannot occur. Therefore, as shown in the A-type silica gel curve capillary condensation never happens even at high relative humidity and no hysteresis is expected. Namely, unlike B-type silica gel, A-type silica gel does not show a phenomenon such as the odor solution into the water or the emission of odorous chemicals.

Fig.6: Isotherms of Water Vapor Adsorption

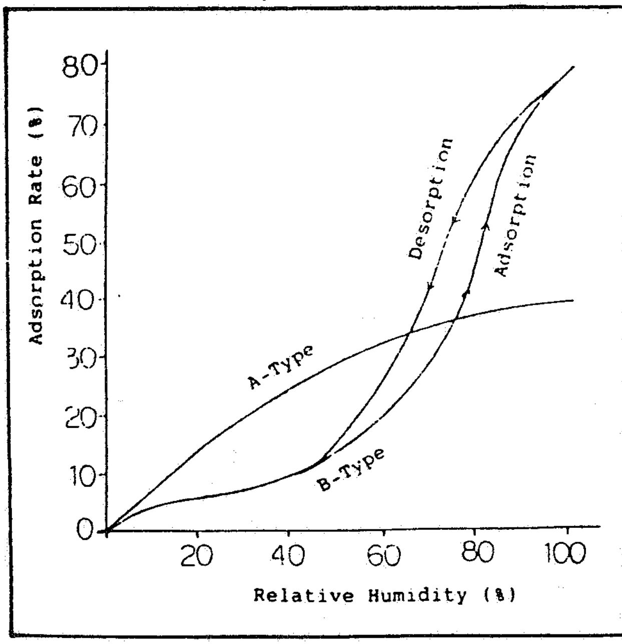
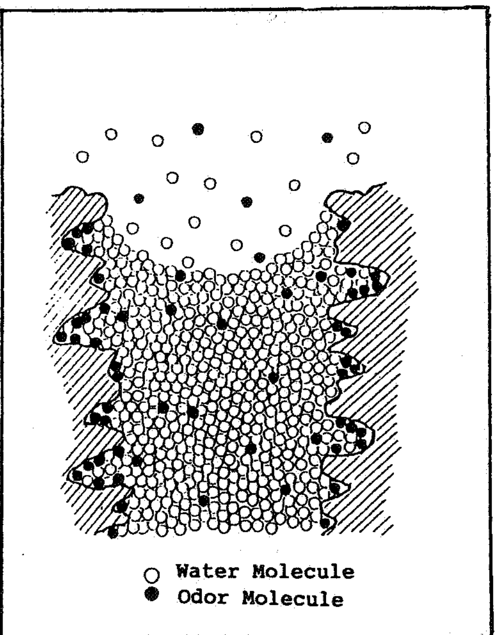


Fig.7: Capillary Condensation of Water Vapor in Mesopore



The explanation of the mechanism of odor transfer is corresponding exactly with field observations that odor emission will be noticed when the relative humidity of outdoor air increases rapidly in rainy seasons or at a time of shower but also at the start up of an air conditioning system at morning time after stop at night, or after weekend start up when exhaust air humidity is rapidly rising.

So only the selective choice of the silica gel A-type with micropores of only 22Å pore size and with no capillary condensation prevents odor transfer and guarantees a high efficiency of latent heat recovery (7)*.

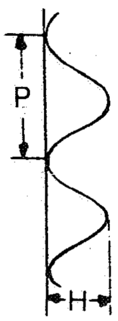
Fig.8: Properties of Silica Gel A-Type and B-Type

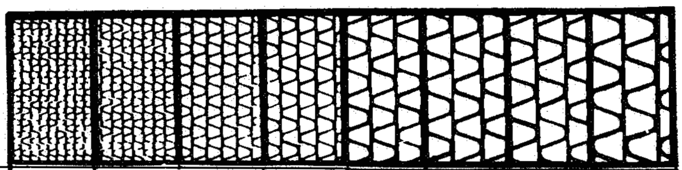
	A-Type	B-Type
Specific pore volume (cm^3/g)	0.36	0.86
Average pore diameter (Å)	22	70
Specific surface area (m^2/g)	650	450

To optimise the total efficiency of an energy recovery wheel (8) it is also necessary to select the right size of the honeycomb structure as well as the depth of the rotor in order to have the highest possible sensible heat exchange obtainable while simultaneously reducing pressure drop parameters by means of the rotor corrugation size (Fig.9,10).
The silica gel powder is fixed on the aluminum sheet (even and corrugated) by heatbaking with a highly porous coating agent

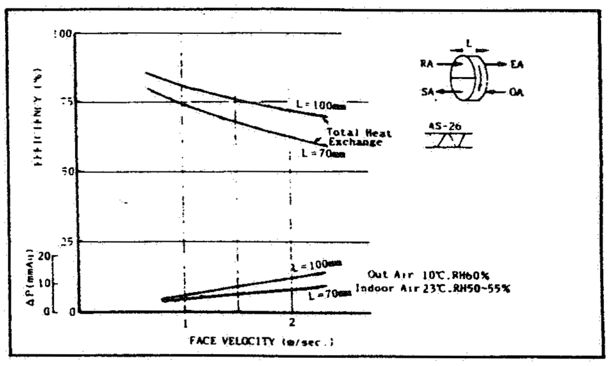
Fig.9: Different Size of Honeycomb Structure

Fig.10: Performance Data of Total Energy Recovery Wheel





	AS-24	AS-26	AS-31	AS-42	AS-50	AS-63	AS-70	AS-85
P(mm)	2.4	2.6	3.4	4.2	5.0	6.1	7.0	8.5
H(mm)	1.2	1.4	1.9	2.5	2.7	3.8	4.5	5.8



6. Summary

Energy recovery today is routinely incorporated into the ventilation systems of office buildings, hospitals, schools, hotels and industrial buildings. Because of the high efficiency for both sensible and latent enenergy recovery the rotating energy exchangers are superior to other types of heat exchangers. The risk of odor transfer in rotating systems had been investigated theoretically and experimentally. A new desiccant had been developped to prevent cross contamination without decreasing the latent enenergy recovery efficiency. The new rotors had been introduced successfully in Japan.

7. References

(1) Fanger, P.O.:"A new Philosophy of Ventilation". XXII. International Congress for Building Services Engineering, Berlin 10/1988

(2) Pejtersen, J., Bluyssen, P., Kondo, H., Clausen, G., Fanger, P.O. (1989): "Air Pollution Sources in Ventilation Systems". Proceedings of CLIMA 2000, Sarajevo 8/1989

(3) Guntermann, K.: "Raumluftqualität-Bewertung und Maßnahmen zur Verbesserung". ISH-Jahrbuch für Gebäudetechnik, Bertelsmann Verlag 3/1993

(4) "Guidelines for Ventilation Requirements in Buildings". Report No.11, European Concerted Action Indoor Air Quality and its Impact on Man, Commission of the European Communities, 1992

(5) Eurovent 10/1 "Heat Recovery Standards", 1985

(6) Dehli, F. (1992): "Energy Recovery in Ventilation Systems - A Worldwide Energy Saving and Environmental Protection Technology". Proceedings of the 13th AIVC-Conference "Ventilation for Energy Efficiency and Optimum Indoor Air Quality", Nice 9/1992

*(7) Kuma, T., Shirahama, N. (Seibu Giken): New Total Heat Recovery Wheel Shutting out Odor Transfer". 58th General Meeting of the Society of Chemical Engineering of Japan, Kagoshima 3/1993

(8) Kuma,T., Hirose, T. (Seibu Giken): "Honeycomb-Shaped Heat Exchanger". 69th Meeting of the Society of Mechanical Engineers of Japan, Nagoya 10/1991

* The "No-Odor Transfer Rotor" is a development of the company

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Patents pending: Japan, Korea, USA, Germany, Sweden, UK.