AN AIR HANDLING UNIT FOR THE NEXT CENTURY - PART 1
The Factor 4 in Air Conditioning

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Abstract

"Air Conditioning consumes lots of energy and can make people feel sick"
Of course this is a popular generalization, but unfortunately not quite untrue. The energy consumption of many air-conditioning systems is indeed considerable and there is much statistic evidence that air-conditioning is a risk factor for the indoor environment [1]
Conscientious Heating, Ventilating and Air-conditioning (HVAC) engineers have therefore to battle on two fronts. On the one hand the energy consumption of air-conditioning systems has to be reduced, on the other, the air quality has to be improved. This applies especially in urban regions where the outdoor air is often seriously polluted.
The heart of all air-conditioning systems is the Air Handling Unit (AHU). It should deliver healthy, clean and vital air at far less energy consumption than usual. The air handling unit described in this paper meets these requirements.
Our goal was to double the air quality and to halve the energy consumption, thus building the *Factor* 4 *in Air Conditioning.* The study presented here demonstrates that this goal can he achieved. A test of a prototype, to be constructed in early 1998, has to prove that the results of this study can indeed be put into practice.

What is Factor 4 ?

The notion *Factor* 4 has been taken from the book "Factor Vier, Doppelter Wohlstand - halbierter Naturverbrauch" [2] (Factor Four, Doubled Prosperity - Halved Use of Resources) . We misused the notion *double prosperity* a little by changing *prosperity* into *weIl-being,* thanks to the improved I.A.Q. The development of better air-conditioning systems could also raise prosperity however, thanks to the additional employment in the industry and improved productivity of employees.

Introduction

Ventilation works on the principal that stale and bad quality indoor air is replaced by fresh, good quality outdoor air. In large urban conglomerations, however, and in areas where there is much traffic and/or industry, the outdoor air is often heavily polluted,
particularly during the day.

Table 1 shows the most frequently occurring kinds of pollution in urban areas.

Pollution	Gaseous	Dust	Precursor
SO_2 - Sulphurfioxide	★		★
CO - Carbondioxide	★		
VOC - Volatile Organic Compounds	★	★	★
PAH - Polycicl. Arom. Hydrocarbons	★	★	
Fine Dust – PM_{10} – $PM_{2,5}$		★	★
"Black Smoke"		★	
NO_x - Nitrogenoxides	★		★
Heavy Metals (arsenic – cadmium – copper – lead – zinc)		★	

Table 1 - Primary pollution of outdoor air

Various kinds of pollution, so called precursors, also engender secondary pollution, such as summer- and winter smog, ozone and fine dust (PM_{I0}- $PM_{2,5}$). Fine dust can penetrate deeply into the lungs and cause irritation. High concentrations of fine dust reinforce the irritating effect of S02' Moreover, the fine dust fraction, in particular, will contain noxious substances like PAH and heavy metals. In short, fine dust must be considered as a serious pollutant, especially in urban areas [3,4,5].

Mechanical air cleaners cannot effectively remove fine dust particles from the air. However, electrostatic air cleaners are very suited for this purpose, which is demonstrated by the numerous applications of this principle in smoky rooms.
When using a superior air cleaner for the outdoor air, we can make use of it for cleaning the indoor air as well. By increasing the amount of return air and reducing the outdoor air supply, a considerable reduction in energy consumption can be achieved.

How much outdoor air do we need?

The proposed BSR/ASHRAE Standard 62-1989R [6] prescribes for office spaces a minimum ventilation rate of 3 L/s per person + 0,35 *L/s* per sq mtr nett floor area, in total app. 6 L/s per person (at 8,5 sq mtr per person). This requirement applies for adapted persons .

The proposal CEN pr ENV 1752 (96) [7] prescribes for office spaces the following ventilation rates:

- Class A - 15% dissatisfied - 10 L/s.person + 1,0 L/s.m 2 - in total 18,5 L/s.person
- Class B - 20% dissatisfied - 7 L/s.person + 0,7 L/s.m 2 - in total 13,0 Lls.person
- Class C - 30% dissatisfied - 4 L/s.person + 0,4 L/s.m 2 - in total 7,4 L/s.person.

These requirements apply to unadapted persons.

Class C corresponds approximately to the ASHRAE requirement ("only 23% higher"), the latter to be considered as the absolute minimum under normal outdoor air conditions.

Approximately 50% of the ventilation air is intended for diluting human odours and 50% for the building odours. If we can clean the exhaust air very effectively it must be feasible to reduce the amount of outdoor air to 50% of the above values, not only for normal weather conditions and good outdoor air quality but especially for extremes in outdoor air conditions and quality.

There is no danger of too high CO_2 concentrations. At the ventilation rate of 3 L/s.person the CO_2 will reach a value of app. 2200 PPM and this is far below the MAC value of 5.000 PPM. This MAC-value is indeed very safe; under 8500 PPM there is no single influence of CO_2 on the human metabolism [8]. And in aircraft cabins, the standard for the maximum allowable CO_2 concentration bas recently been set at 5.000 PPM by the Federal Aviation Administration [9].

The construction of the proposed Air Handling Unit

The AHU is described in detail in Part 2; it comprises the following functions:

- ***Air cleaning****:* by means of an electrostatic filter at a fractional efficiency ≥ 98 % for particle sizes $\leq 0, 1$ µm. The fine dust fraction ($PM_{2,5} - PM_{10}$), often saturated with VOC's, PAC's and heavy metals is captured in these filters. The power-consumption is at least 40% less compared with traditional bag filter. No odour and microbial pollution is emitted.
- ***Air heating:*** far less than usual because more air can be recirculated through the superior air c1eaning in the electrostatic filter.
- ***Cooling, humidifying an dehumidifying:*** in an multifunctional air washer , thus eliminating the need for a separate cooling coil. The air washer neutralizes possible overproduction of ozone in the electrostatic filter, and improves the air quality .
- ***Pressurization*** by plenum fans, which control the air flow electronically, do not destroy the dynamic pressure as usual, do not pollute the system by rubber particles and can easily be cleaned. Highly efficient electric motors are applied.
- ***Active sound control****:* very effective in the lower frequencies, thus eliminating the passive silencers and reducing the size of the air handling unit as a whole. The acoustical comfort in the space is improved by reducing the low frequency noise.
- ***Active air deodorizing*** (Optional in heavy polluted regions): by adding chemical substances to the air, encasing the odour molecules and thus neutralizing the odour. This system could replace activated carbonfIlters, thus reducing pressure losses and power consumption.
- ***Active air vitalizing*** (Optional for general purpose): by adding natural fragrances to the air in small quantities thus pleasing people's senses and making them feel better by the natural! freshness of the air.

Calculation of the Factor 4

General

As an example, we consider an AHU serving office rooms at a constant air volume of 4,0 m^3/s. The HV AC system could be fan-coil or cooling/heating ceilings (preferably the latter because of the excellent Healthy Building properties).

The outdoor and indoor design conditions are as follows:

Season		Summer	Winter
• Outdoor condition	DB/WB	*28 °/21* °C	-10°/-10 °C
• Indoor condition	DB/WB	*24 °/18,5* °C	*21 °/12* °C

The traditional AHU operates on 100% outdoor air, whereas in the Next Century Unit 50% of the air is recirculated. The air velocity in the AHU is chosen at app. 2,0 m/s.

The pressure losses in both units are estimated as follows:

AHU supply Section:Type>		*Traditional*	*Next Century*
Mixing Section	Pa	18	28
• Bag Filter	Pa	169	-
• ES Filter	Pa	-	50
• Heating Coil	Pa	31	31
• Activated Carbon Filter	Pa	100	-
• Odour Neutralizer	Pa	-	0
• Air Washer/Humidifier	Pa	60	-
• Cooling Coil inc. Eliminator	Pa	119	-
• Cooling Washer	Pa	-	100
• Heating Coil	Pa	19	-
• Sound Absorber	Pa	58	0
• Air Vitalizer	Pa	-	0
• Dynamic Pressure	Pa	36	0
• Total Pressure Drop	Pa	**610**	**209**

AHU Return Section			
• Intake	Pa	13	13
• Sound Absorber	Pa	58	0
• Mixing Section	Pa	36	46
• Dynamic Pressure	Pa	36	0
• Total pressure Drop	Pa	**143**	**59**

Calculation Energy Consumption

The following calculations comprise only the energy consumption of the AHU's themselves due to the typical features of each unit. External static pressures of the connected HV AC system are not inc1uded.

Power consumptions			
AHU - Fan power	*Type ->*	*Traditional*	*Next Century*
• Air volume	m3/s	4,0	4,0
• ΔP supply Fan	Pa	610	209
• ΔP Return Fan	Pa	143	59
• Fan Efficiency	%	75	72
• Electr. Motor Efficiency	%	83	86
• V -belt Drive Efficiency	%	88	-
• Speed Control Efficiency	%	-	98
• Total Efficiency	%	55	60
• Fan Power	kWe	5,5	1,8
Required Electric Power KWe			
AHU - Cooling Energy			
• ΔH – Outdoor/Indoor	KJ/kg	8,5	8,5
• Outdoor Air	%	100	50
• Cooling Capacity	kW th	40,8	20,4
• Required Electric Power	kWe	9,0	4,5
(C.O.P. = 4,5)			
AHU - Heating Energy			
ΔH Outdoor/Indoor	KJ/kg	39	39
Outdoor air	%	100	50
Heating Capacity	kW_{th} h	187	93,5
Heating Plant Efficiency	%	85	85
Primary Heating Energy	kW	220	110
AHU - In Total			
Fan Power	kWe	5,5	1,8
Cooling Power	kWe	9,0	4,5
Electric Power in Total	kWe	14,5	6,3
Aequivalent Primary Energy*	kW	29	13
Primary Heating Energy	kW	220	110
*) conversion factor of 0,5			
Total Primary Energy	kW	249	123
Ditto	%	100	49

This calculation shows that, when applying the Next Century Unit, the energy consumption can be halved.

Pollution loads

Based on the work of Jan Pejtersson [10,11] the sensory pollution of used filters can be estimated at app. 7 decipol. The sensory pollution load of activated carbon filters is negative when the filters absorb odours, and is positive when desorbing odours. We assume that the average pollution is zero.

The non-sensory pollution is hardly to be estimated. It will be clear however that the Next Century Unit offers a much better air-quality than the traditional one.

Investigation of the sensory pollution load in ventilated spaces has shown that 2/3 of the pollution load was caused by the ventilation system [10,11]. We assume that, when applying the Next Century Unit, an improvement of 75% is feasible. The "improvement factor" then is (1/3 + 0,25 x 2/3) -1 = 2.

Conclusion

The conclusion is that by halving the energy consumption and redoubling the I.A.Q. the Factor 4 we aimed at can easily be reached. This conclusion will be validated by testing a prototype of the Next Century Unit in the following phase of the project.

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