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Air Conditioning with Double Air Flow

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AIR CONDITIONING WITH DOUBLE AIR FLOW

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A full air conditioning system implies the automatic control of an atmospheric environment either for the comfort of human beings or for the proper performance of some industrial or scientific process. The adjective "full" demands that the purity, movement, temperature and relative humidity of the air be controlled, within the limits imposed by the design specifications.

But, for human comfort, in temperate climates (Europe), the control of relative humidity is not necessary : human beings are comfortable within a fairly large range of humidities, from about 60 per cent to about 20 per cent ! As we want a good comfort for low investment and running costs, we don't control humidity in a double air flow system : it is not full air conditioning.

1. PURPOSE

We want to show that it is possible, for a very low investment cost, to get a very comfortable air conditioning system with very good running costs. This system can be settled in hospitals, nursing homes, hotels, offices, department stores, ... and so on. Its main competitors are (in Europe) :

- Water to air heat pumps on a water loop.
- Air ejectors (with two or four pipes).
- Convectors with fans (with two or four pipes).
- Variable air volume systems.

With such a system, the local air temperature is 20°C in winter, and lower than 24°C in summer.

2. GENERAL PRESENTATION

An air conditioning system with double air flow includes :

- a double mechanical ventilation, one for fresh air intake (heated in winter and cooled in summer), an another one for exhaust air,
- a heat pump or a cooling unit and a heat transfer equipment for energy savings,
- a complementary heating system (a direct electric heating system)
- a good thermal insulation,
- an optimized control, according to the use of building, the location, the timetable of the people, and the cost of energy (dependent of the time in France for instance).

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1.1. Centralized system

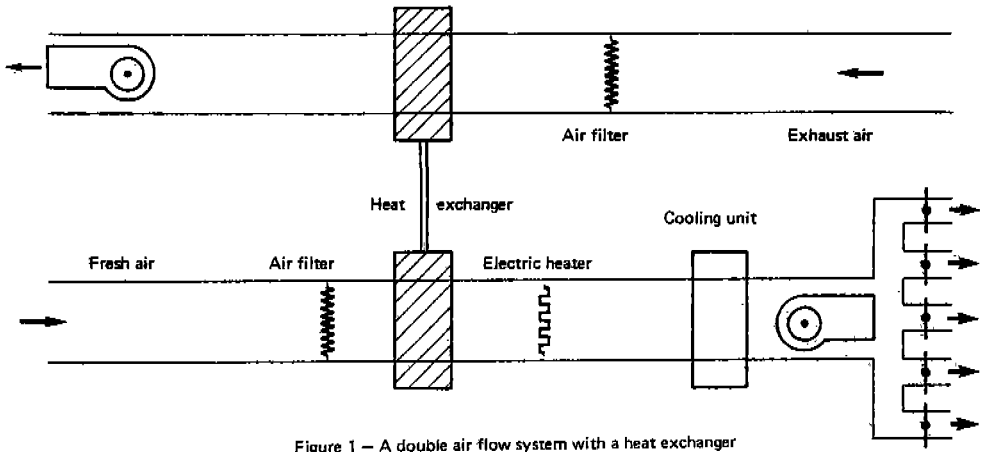


Figure 1 – A double air flow system with a heat exchanger (plate exchangers or heat pipes).

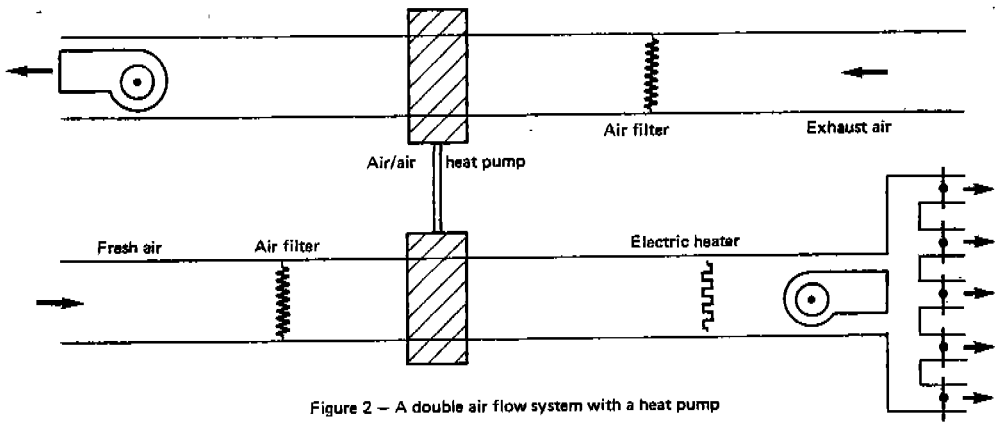


Figure 2 – A double air flow system with a heat pump

It is possible to use a air handling unit with a heat exchanger and a cooling unit (figure 1), or a reversible air to air heat pump (figure 2).

1.2. Complementary heating system

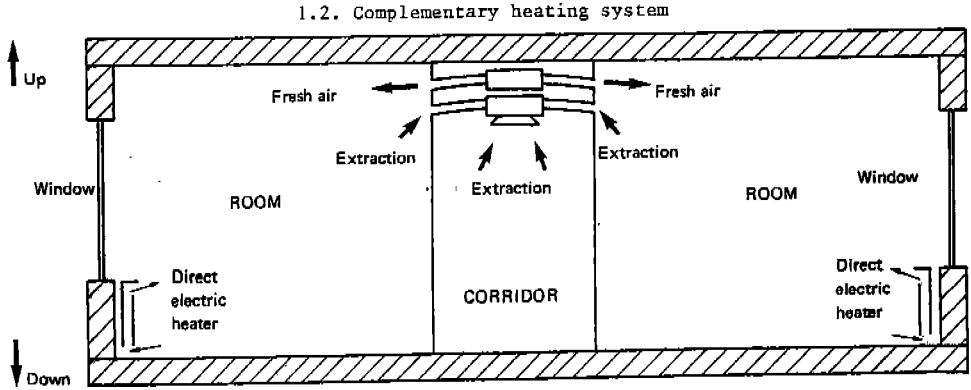


Figure 3 – Air distribution

- The direct electric heaters are stopped when the cooling system is on (central regulation).

- Each direct electric heater has its own thermostatic control.

3. HOW TO DESIGN AND CONTROL A DOUBLE AIR FLOW AIR CONDITIONING SYSTEM

First of all, it depends on the type of building, and on the type of use : in offices, the air conditioning system must be on for about 50 hours a week, and can be stopped by night. In hotels, it is the opposite : the local air temperature has to be controlled by night. But hospitals, nursing homes, dwellings must be comfortable 24 hours on 24 hours. As it is impossible to develop here all the subjects, we will handle the case of offices.

3.1. The constraints

- Winter working temperature : 19°C (from 7 A.M. to 6 P.M., excepted on saturdays and sundays).

- Summer working temperature : less than 24°C (for the same hours).

- Individual comfort in winter : according to the type of activity (meeting room, room for typists), and to respect individualism, it is interesting to master the temperature between 16°C (when it is unoccupied for instance) and 23°C (for chilly people !).

3.2. The means

Such a system is both centralized and decentralized :

- A heat recovery exchanger or heat pump, for the main heating (central system).
- Individual electric convectors, to top up.
- The central cooling system.
- A variable air flow (two levels).

3.3. Outlet temperature

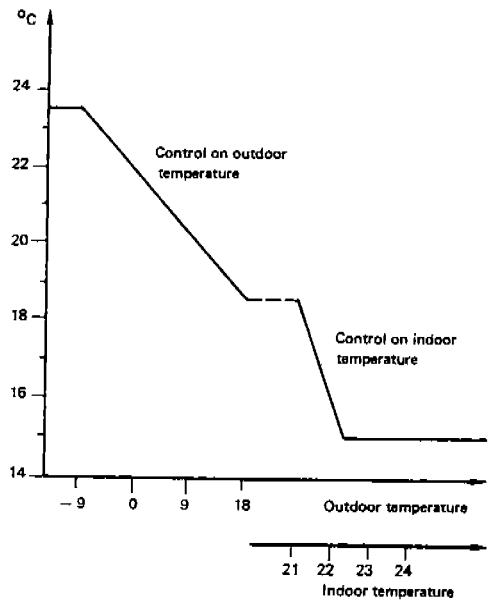


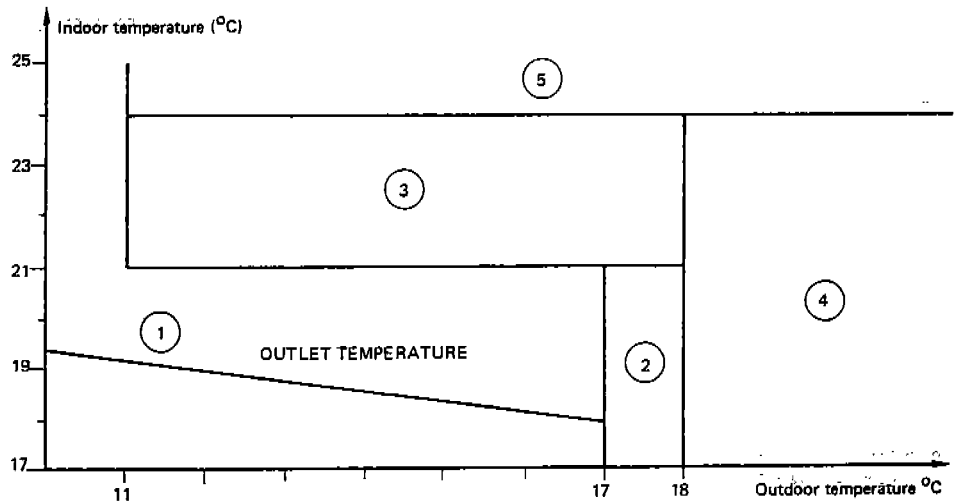
Figure 4 — Outlet temperature as a function of outdoor and indoor temperatures

We determined this curve thanks to an experimentation in an office building near Paris. For low outdoor temperatures (less than 18°C), we control the outlet temperature as a function of the outdoor temperature. If the outdoor temperature is greater than 18°C, we use the indoor temperature to control the outlet temperature.

- The outdoor temperature is corrected to take the sunlight into account.
- The indoor temperature is the average value of eight sensors (exhaust air).

All this implies that we must pay attention to the orientation of the building : it is necessary to control separately, for instance, the eastern and western sides of a building, the "second light" rooms, ... all this must be taken into account at the building of the office block.

3.4. Control in occupation hours



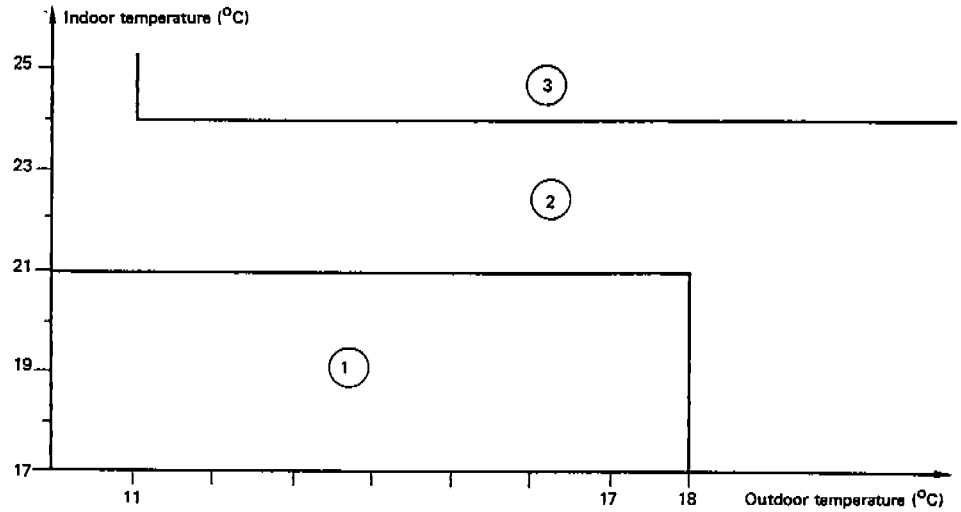
	1	2	3	4	5
HEAT RECOVERY SYSTEM	YES			NO	
CENTRAL ELECTRIC HEATERS	YES	NO			
ELECTRIC CONVECTORS	YES		NO		
COOLING UNIT	NO		YES		
VENTILATION	1				2

Figure 5 — Permits and interdictions in occupation hours (7 AM to 6 PM)

In this case, two ventilation levels are available (1/2) : level 1 means nearly one volume per hour, and level 2 two volumes per hour.

The figure 5 is only an example : of course, all these values depend on the type of building (insulation), of climate...

3.5. Control in unoccupied hours



	1	2	3
HEAT RECOVERY SYSTEM	NO		
CENTRAL ELECTRIC HEATERS	NO		
ELECTRIC CONVECTORS	YES	NO	
COOLING UNIT	NO		YES
VENTILATION	NO		(1) OR (2)

Figure 6 — Permits and interdictions in unoccupied hours (6 PM to 7 AM and week-ends)

4. EXAMPLE

It is an office building near Paris. A new air conditioning system with a double air flow was settled in 1983, and we have recorded all the energy consumptions between december 1984 and november 1985 (heating, cooling, auxiliaries, lighting).

4.1. The building and its double air flow system

It is a six-storey building, the total surface is 3500 m^2 and the air volume is 9500 m^3. There are two main frontages (east-side and west-side).

The windows represent 31 % of the walls (49 % on the west-side, and 43 % on the east-side).

The global heat loss coefficient of the building is 0.5 $W\ m^{-3}\ K^{-1}$ (without dynamic losses due to air renewal) : this level of insulation is a very good one in France, and is possible in new buildings, or in old ones which are entirely renovated (as in our example).

The heat recovery system is a plate heat exchanger (figure 1). The technical characteristics of the different generators, cooling unit, fans, ... are the followings :

TABLE I – CHARACTERISTICS OF THE DIFFERENT UNITS

	Total power (kW)	Power/m^2 (W)
Central electric heater	72	20,6
Auxiliaries	36	10,3
Cooling unit	45	12,9
Electric convectors	115	32,9
Lighting	70	20,0

TABLE II – METEOROLOGICAL DATA (Paris/december 1984 - novembre 1985)

	D	J	F	M	A	M	J	J	A	S	O	N	Total
Degree-days (réf. : 18°C)	409	598	434	390	233	128	98	16	40	54	220	420	3040
(°C)*					15	18,5	20	25	23	23	17		

*Maximum temperatures (monthly average value)

TABLE III – YEARLY BALANCE SHEET

	Total yearly consumption kWh	Total yearly consumption MJ	Consumption/m^2 kWh	Consumption/m^2 MJ	Cost F/m^2
Convectors	231 822	834 559	66.23	238.45	27.85
Central electric heater	47 009	169 232	13.43	48.35	7.37
Auxiliaries (winter)	7 917	28 501	2.26	8.14	1.24
Auxiliaries (summer)	20 573	74 063	5.88	21.16	0.97
Cooling unit	25 447	91 609	7.27	26.17	1.20
Lighting	181 470	653 292	51.85	186.65	21.44
Sanitary water	5 688	20 477			0.67
Others	7 628	27 461			0.44
Total	527 554	1 899 194	151	544	61.18
Recovered energy	31 119	112 028			
Fixed cost (F)					31.26
Total cost (F)					92.44

Winter means 5 months : from november to march.

Summer means 7 months : from april to october.

(This is due to the price of electricity in France).

The investment cost was about 600 F/m^2.

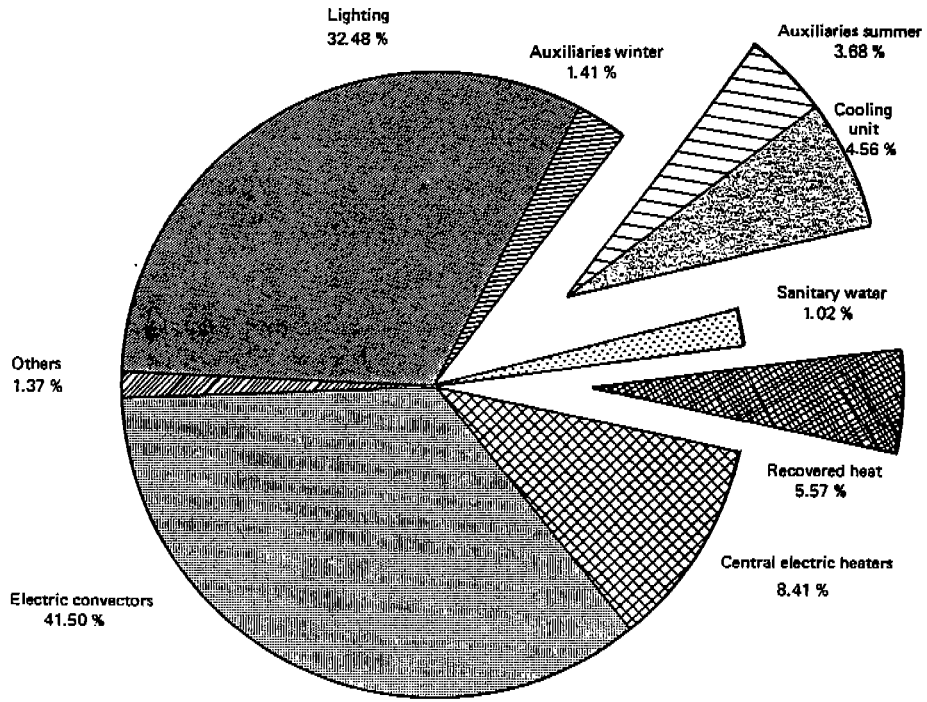


Figure 7 – Distribution of energy consumptions (MJ)

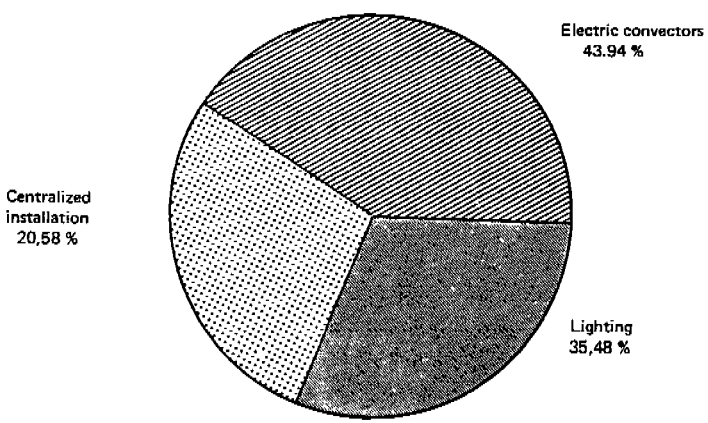


Figure 8 – Importance of lighting consumptions (MJ)

5 . THE MAIN ADVANTAGES OF AN AIR CONDITIONING SYSTEM WITH DOUBLE AIR FLOW

5.1. Comparison with other systems

TABLE IV – INVESTMENT AND RUNNING COSTS (without maintenance)

	INVESTMENT COST F/m^2	RK	RUNNING COST F/m^2	RK
DOUBLE AIR FLOW	300 to 600	1	40 to 120	1
HEAT PUMPS ON A WATER LOOP	700 to 1200	4	50 to 150	2
AIR EJECTORS 4 PIPES	900 to 1500	5	> 200	5
CONVECTORS WITH FANS 4 PIPES	690 to 900	2	80 to 200	3
VARIABLE AIR VOLUME	700 to 900	3	100 to 200	4

And our example :

Investment cost : 600 F/m^2
Running cost : 92 F/m^2.

5.2. Other advantages

- Such a system is both centralized and decentralized ; this allows personal comfort in winter, with low energy consumptions.

- A double air flow system is a very simple installation, and the maintenance is not expensive.

- In winter, the running cost is about the same as a direct electric installation if the heat recovery system is a plate exchanger, and the savings are about 15 % in the heat recovery system is a heat pump.

- The noise level is very interesting (no fan or compressor in the room).

AIR CONDITIONING WITH DOUBLE AIR FLOW

SUMMARY : The purpose of this paper is to present the possibilities of the air conditioning systems with double air flow. This type of systems allows low investment and running costs, but we don't control humidity in a double air flow system : it is not full air conditioning, but the temperature levels can be handled in very strong limits.

Both technical and economical point of views are discussed. In the first part, one will find the technical characteristics of a double air flow system (heat recovery system, double ventilation, cooling unit, complementary heating system). The reader will find how to control such a system, in order to have a high level of comfort for very low running costs.

In the second part, a full example is given (an office block near Paris) : one will find all the technical characteristics of the building, the meteorological data, and the energy consumptions for one year.

In the third part, a table allows to compare an air conditioning system with double air flow to its main competitors (variable air volume systems, heat pumps on a water loop, air ejectors, convectors with fans).

CLIMATISATION PAR DOUBLE FLUX RAFRAICHI

RESUME : Cette communication a pour but de présenter les possibilités de chauffage et de rafraîchissement des locaux par la technique dite "de double flux rafraîchi". Il ne s'agit pas d'un vrai système de climatisation car il n'y a pas de contrôle de l'humidité, cependant les niveaux de températures peuvent être maintenus dans des fourchettes très étroites.

Les aspects techniques et économiques sont abordés. Dans la première partie, le lecteur trouvera les principes d'un double flux rafraîchi (récupération des calories de l'air extrait, double ventilation, chauffage d'appoint par convecteurs...). Un exemple de logique de régulation est donné (loi de soufflage, autorisations d'utilisation des différents générateurs de chaleur ou de froid).

Puis une réalisation complète est traitée (immeuble de bureaux en région Parisienne): toutes les caractéristiques de l'installation sont données (puissances installées, données météorologiques, consommations d'énergie sur un an).

Enfin, un tableau permet de comparer les coûts d'investissement et d'exploitation des principaux systèmes de climatisation (pompes sur boucle d'eau, ventilo-convecteurs, éjecto-convecteurs, systèmes à débit d'air variable).