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Session 9 : Building Performance Specifications

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REQUIREMENTS ON INSTALLATION PERFORMANCE

ABSTRACT

The paper deals with two main items:

* Important parts of the installation in the Process of Design, Contracting, "Commissioning", Use and Maintenance of the Installations in the building.

* Social Factors in the Process. The Built Environment in the Commercial Market. Parties involved, and their power. A proper balance of quality and price?

The paper will conclude into white spots in the knowledge which could bring us to a specification of future research in the field of the built environment.

CONTENTS.

REQUIREMENTS ON INSTALLATION PERFORMANCE

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1. INTRODUCTION

Indoor Air Quality and the Management of it, is certainly an important part of the complicated and much wider **Quality of the Indoor Environment.** This indoor environment is the result of a complex interaction between the Building itself, the Installations and the User and its specific qualities. The User (human beings, an industrial process or both) determines the specification of the Building-and-its-Installations as **one single unity.**

The results can be judged by factors as **Thermal Comfort** [ambient temperature, (mean) radiant temperature, mean value of the air velocity and degree of turbulency, (relative) air humidity], **Sound and Noise, Daylight and Artificial Lightning,** and **Indoor Air Quality.**

During this workshop we will focus on **Indoor Air Quality Management,** but we will have to realize that IAQ is not an effect on itself but also the result of a complex of factors. And in this presentation there will be an emphasis on the **Installation and its Requirements** in a close relation to all other factors involved.

2. CLEAN AIR

A good Indoor Air Quality begins with a good Outdoor Air Quality. The best we can have is good outdoor air, generally spoken. If the outdoor environment is totally satisfying, we have no problem at all for the location of the air intake in the building. If the outdoor air is not perfect, we can have gaseous and particulate pollutants, and odours. The pollutants can cause "only" comfort problems (harmless odours), or we can have pollutants causing possible health risks. The removal of particulate pollutants from the outdoor air may be not too complicated, but the removal of gaseous pollutants and odours can be very complicated and costly, specially if there is a severe health risk. Normally spoken, the situation of a building in such a risky environment should be avoided. Exceptional cases can be covered by closing the building fully air tight and give the air a special processing: In military applications, NBC-filters (Nulear, Bactereological, Chemical) are used; airport buildings are protected by processing of the outside air over active coal filters to avoid a kerosine smell in the indoor air. But under normal conditions this is an impossible option from an operational and an economical point of view.

If there are differences in the level of air pollution around the building, we can optimise the situation of the air intake. In a built environment, the air at ground level (car park!) can be much more polluted than at roof level. Even a stack for the intake of fresh air is an option.

From the 1980's the discussion of the quality of the indoor environment got an emphasis to the **Sick Building Syndrome.** In these days, the research to this new item had priority, but from 1988 we switched over to a more positive approach and started to talk about **Healthy Buildings,** trying to get practical solutions for our problems. Certainly the IAQ is one of the main items of the Healthy Building, but we must be aware that HB quality is much more complicated than IAQ alone. But there is a strong interaction.

3. THE BUILDING AND THE USER

Other contributions in this workshop will certainly report in detail about the building and the user, but some basic remarks have to be made now, to provide a background for the discussion of **Requirements on Installation Performance**.

If we look at the **Building** and focus to an occupied area, a room, we will find an air volume separated from the surroundings. By a number of factors, this volume of air will be (or at least can be) polluted. All building materials, giving the room its partition, can show an emission of pollutants in the form of particals, gases and odour. Also paint, wall paper and tapestry must be noticed.

The **User** of the building will bring other elements in the room, such as furniture, equipment, animals, plants and don't forget: themselves! All these elements cause their specific pollution.

The **HVAC-Installation** as a third main parameter is supposed to satisfy not only the thermal specifications but also to maintain the level of IAQ within given restrictions, interacting with the Building and the User. The ventilation (i.e. the supply of "new" air to the occupied space) could be used to **dilute** the pollution, and will be in many cases, but it is better to think of the labor-hygienic philosophy in which we first try to **avoid** a pollution, then **restrict** it, further attack the **source** of the pollution directly, before giving the pollution a free way to the ambient air so that dilution is the only way to go.

Some pollutions may be so dangerous that even a strong rate of dilution is not tolerable; some odours (even if not risky to the health) could be so strong that dilution is practically not possible from technical or economical points of view.

Apart from the hygienic behavior of people and the development of social habits in this field, the odour caused by human beings is a given fact; it can not be avoided nor restricted, it can only be diluted. So the **lowest possible airflow** for this dilution will be determining for the ventilation. It is preferable not to increase this flow more than necessary, and look for alternative ways for the supply of heat or cold than by the air alone. The improvement of such means is under development: supply by radiation and/or convective heat transfer (see chapter 5.2).

4. NATURAL VENTILATION versus MECHANICAL VENTILATION.

With the application of **natural ventilation** we cause a **direct exchange** of air from outside the building and air from inside the building. There is no interference from an installation whatsoever. Only an aperture in the facade of the building is needed to provide the possibility of the air exchange.

Supposed that the outside air is of good quality, we have an unlimited reservoir for the exchange of fresh air. If a window is totally opened, the velocity of the exchange is almost unlimited. We can provide a sudden effect of freshness. This is a very positive factor on human experience.

To control the natural ventilation, the window can be closed more or less. But the flow of ventilation is progressively dependent on a variable wind force and direction. ((1))

It is an old proposition that natural ventilation in a multi-story building is only acceptable up to a certain height of the building. A limit of 4 to 15 stories is often stated. Recent studies give a contrary opinion.[1]

The control of the indoor temperature is difficult. The temperature difference outside-inside can easily be more than 30 K, so a limited flow can cause an extreme thermal load, positive or negative. The mixing of cold and warm air can be difficult; therefore inacceptable differences in indoor air temperarure can occur. The mixing process is poor.

The natural exchange of cold and warm air makes it impossible to exchange heat between the two air flows. So the thermal efficiency of the heating system will be extremely low.

The wind force on the facade can cause an important pressure-difference over two opposite facades of the building. So an unacceptable air flow through the building can occur. If the window is open, the door to the corridor must be closed. It is impossible to operate a landscape office.

The size of the building, perpendicular to the facade, is restricted with natural ventilation. Often a depth of 6 meters for an occupied space is stated as a maximum.

Natural ventilation shows many positive features, as simplicity, low cost level and direct accessability for inhabitants, but the possibilities for application are rather restricted. But in moderate climates it will be possible to open the windows when the outside conditions are near the preferred inside conditions. Slightly lowered outside temperatures can provide cooling in case of excess sun radiation.

The application of **mechanical ventilation** shows other advantages. The system provides the possibility for a perfect **control** of air flow, thermal conditions and IAQ conditions of the ambient air.

If the outside air conditions are poor or cause health risk, and the windows must be kept closed, the air can be processed in the installation before the supply into the interior. If the acoustical conditions outside are unacceptable, the windows can also be kept closed.

Apart from health risk, other than chemical properties of the air can be controlled by mechanical ventilation, and can't by natural ventilation. That applies to the filtering of dust and the control of the humidity. The HVAC installation can raise or reduce the humidity level to satisfy any specification. ((2)),((3))

Only with mechanical ventilation, the level of thermal comfort can be assured at any level of heat load or heat gain of the office. With the present (high) level of specifications for indoor climate and use of buildings (i.e. a high density of people and machines, reduced story height and a design of extended buildings), mechanical ventilation gives enlarged possibilities in the design. But this statement does not give the way free to unlimited variation of parameters. Only if there is a proper balance between the building, the use and the installation, a really satisfying indoor climate and good IAQ can be realized.

Mechanical ventilation will also have its negative consequences. The total investigation for a HVAC installation can be as high as 40% to 50% of the cost level of the project. And the life cycle of the technical installations is normally much shorter (15 to 20 years) than the life cycle of the building. The HVAC installation with its duct system takes an important part of the volume of the building, which also increases the total cost of the project.

As to the IAQ, there can also be a negative effect from the air handling part of the installation. Caused by a wrong selection of materials or parts, or a lack of maintenance, the installation itself can produce a certain level of pollution or odour.

5. THE HVAC INSTALLATION

The choice of the elements of the HVAC installation and their interaction determine the quality of the indoor climate, and specially the Indoor Air Quality in the building. Fig.1 shows the main parameters of the building and the installation.

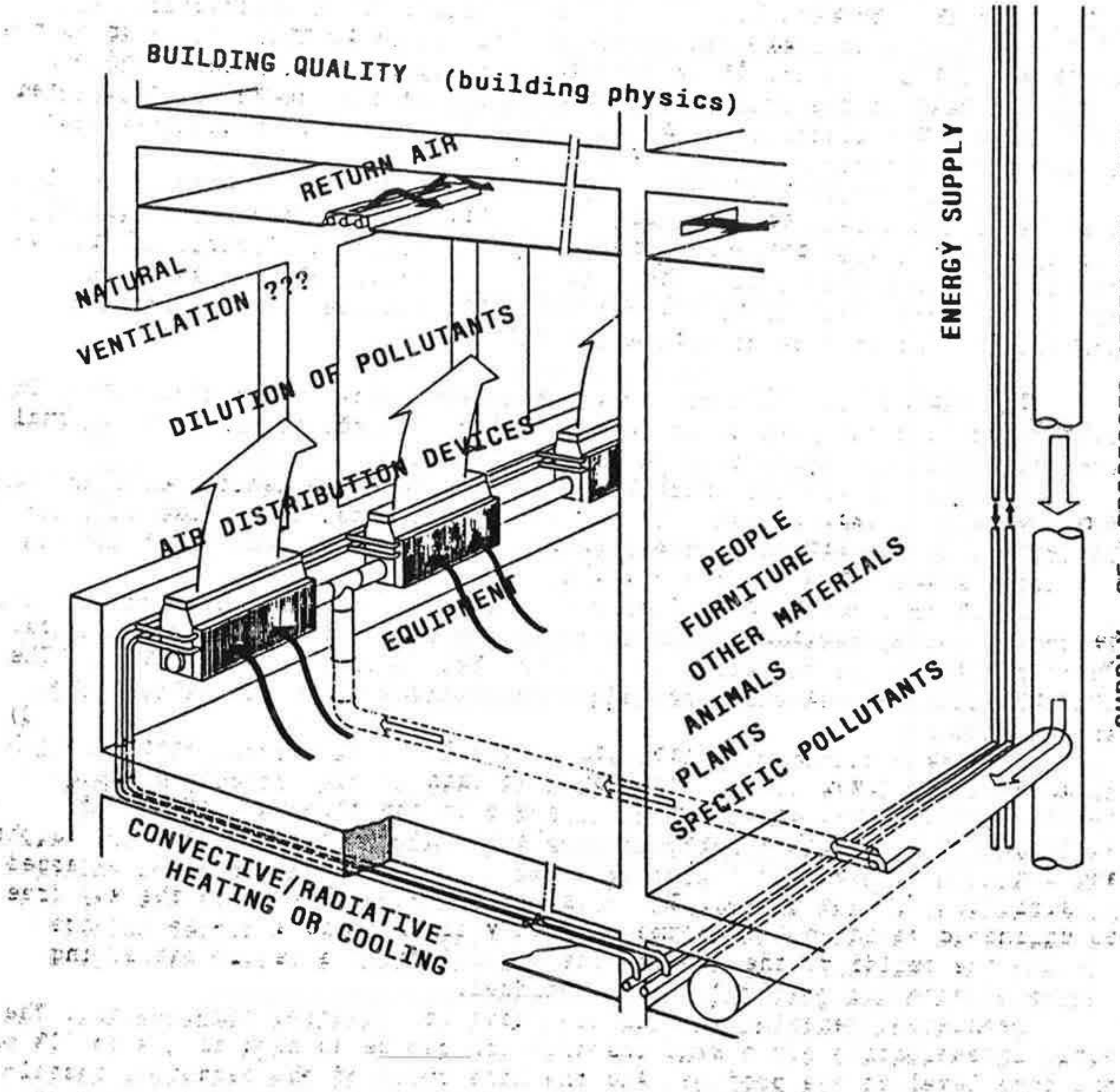

Fig.1. The building and the HVAC installation

5.1 Elements of the HVAC Installation

A traditional HVAC installation will normally content the following elements (see fig.2):
* registers for outside air and return air
* mixing box
* pre-filter
* fine filter
* fin-pipe heat exchanger for heating
* fin-pipe heat exchanger for cooling and de-humidifying
* humidifier
* ventilator

* sound attenuator
* duct system
* valve, constant/variable volume box
* air distribution device (grille, air terminal)
* device for radiative/convective heating or cooling
* device for heat recovery

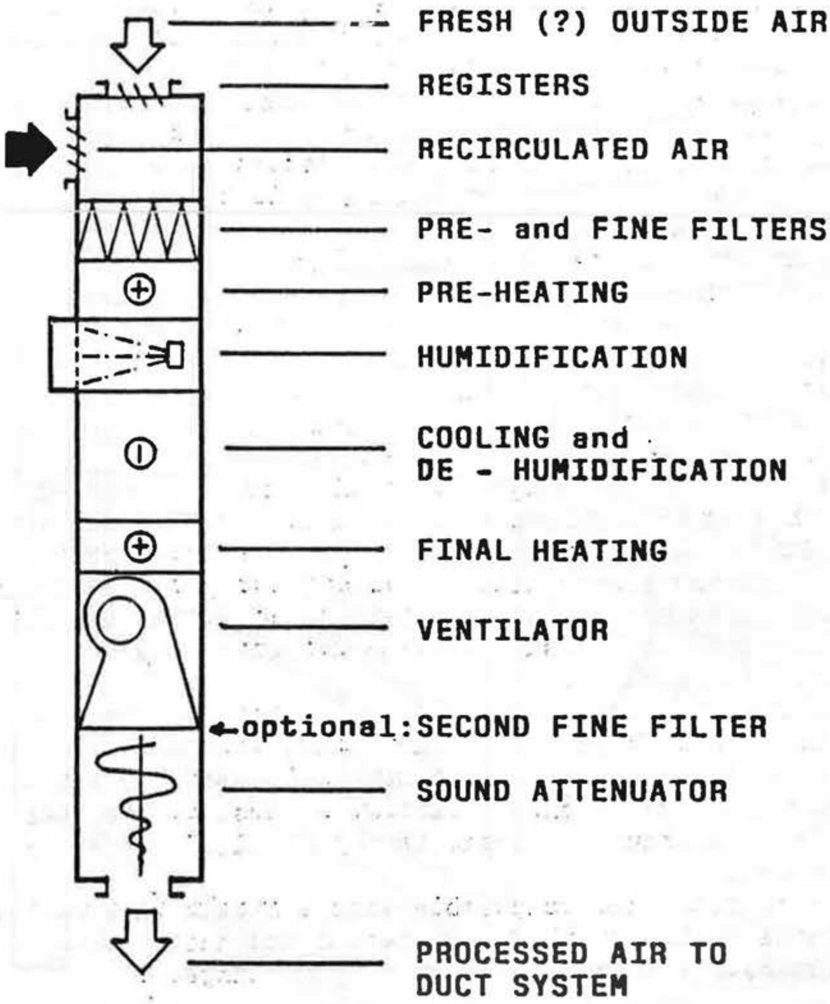

Fig.2. Elements of a traditional air-processing installation

These elements themselves could be a source of pollution.((4)) Porous materials can easily emit odours from their (own) material or absorb/adsorb and desorb gaseous pollutants or odours. This mechanism applies for filter material, for the baffles in a sound attenuator, for the thermal isolation inside ducts (better don't use internal isolation), for the heat recovery "wheel" especially if porous material is used for the "latent" recovery. (5)) For many other elements sheet metal is used. During the processing of this sheet metal in special machines additional materials are often used, for instance oily fluids, adhesives or plastic materials for tightening of seams. This applies specially for fin pipe heat exchangers.

Humidifier devices can sometimes use water with special additives for the prevention of corrosion or biologically active substances. These substances can be odourous or chemical active.

The elements of the installation should be prevented for being polluted. The chain of elements should start not only with a pre-filter but also with a fine filter. And, to be sure of preventing the duct system from pollution, another fine filter should be provided at the beginning of the duct system (the part of the system "before" the ventilator is at a lower pressure then the surrounding so could be polluted from outside).

Filters can be a source of pollution. For instance, when moisture plays a role, the collected dust could carry substances which are biologically active, and pass the filter. If mould growth occurs on the filter, the spores can penetrate the filter, and stimulate mould growth on other places if these places are (temporary) moist. ((6))

Humidifiers, if not in a state of perfect maintenance, will be a source of pollution. Specially if liquid water plays a role, pollution is hardly to avoid: "natural" water will develop biologically active substances after some time and bring them in the ventilating system, or when the water is processed for the prevention of these effects, the chemicals which are diluted in the water will disperse in the system. If humidification is an absolute necessity, steam is the best alternative.

Heat exchangers of the fin pipe type could also be dependent of regular maintenance. This applies strongly for batteries with a cooling and de-humidifying task. For de-humidifying the batterie needs many rows of pipes (6 to 10 rows) to attend a dew point low enough for our purpose and of course condensation will occur. These temporarily wet surfaces deep inside the device have a pollution risk. So these batteries must be perfectly accessible for maintenance.

Air distribution devices, as grilles, are in direct contact with potentially polluted room air. These grilles introduce processed air in the room by means of a mixing process, called induction. So room air can penetrate the grill(-box) and cause the collection of dust in the device. Even if the primary air is absolutely clean, supply grilles must be in regular maintenance anyhow. ((7))

In general, machine rooms and comparable spaces should have dimensions that allow a sufficient accessibility for repair and maintenance, and all the components must have a possibility for easy exchange.

5.2 Systems for HVAC

Generally spoken, the building, the use and the installation must be in good balance in the design process. But we must start with a good definition of the use, and avoid to translate our doubts in specifications that double or even triple any normal level. The second step is a provisional building design in which we try to satisfy the specifications from the user as good as possible, within certain limitations. Here we deal with fundamental decisions about the building (i.e. thermal specifications and other decisions in the field of building physics). During this provisional stage in the building design, fundamental discussions about installations must start. From this moment on we should assure the balance between building and installations, looking at the realisation of thermal and other specifications against, on the other hand, the total cost level of the project. This certainly is a circular process. An extreme emphasis on trying to avoid installations, nor an extreme neglect of building physics (which can make the buiding too dependent on installations) will lead us to a well balanced design.

Focussing again on Indoor Air Quality, a number of useful statements on system design can be made.

It seems useful or even desirable to assure the possibility of **windows that can be opened**, and give the inhabitants the option for natural ventilation if they like it. Also the option of combining a HVAC installation and windows to open, must be considered with certain restrictions. Under certain atmospheric conditions it is an attractive alternative, and it gives people the chance to escape from the given indoor climate. But we will have to assure that the system will work even if the wind force changes the air pressure in the room. Dramatic chances for malfunctioning occur. Return grilles can alter to supply grilles at the lee side of the building. ((8))

In traditional system design the principle of **air recirculation** is ofen used. In the machine room a large percentage of the return air from the occupied spaces is mixed with a relatively small percentage of outside (processed) air and supplied to the building again. ((9))

Looking at the energy consumption there is an advantage: The quantity of outside air to be processed is far less (20% to 40%) and specially during winter conditions we avoid the need for heating the air over a span of 30K. The same applies for the latent load. The humidification during winter or the de-humidification under summer conditions takes a lot of energy.

Using recirculation, there is much more air-**circulation** in the building than **ventilation** (air rate, expressed in airchanges per hour). If the air flow for ventilation is used in a traditional **mixing system** this air quantity can be too low to assure a good air distribution in the room, and a sufficient supply of fresh air and/or a good temperature distribution through the occupied space is not realised. Furthermore the enlarged air quantity using recirculation can be a necessity if the air is the only means of transport of energy for heating or cooling (all air systems).

The transportation of much more air than we need for ventilation has severe disadvantages. All air handling devices will be much larger, and this does not only apply to the machine room, but even worse to the duct system in the building. The installation will cost more, and the enlarged space need is costly in building volume. Besides that, the energy use and cost for air transport (the ventilator) can cover a high percentage of the total running cost for the installation (up to 40%). The reduction of the air volume to the ventilation rate only will cause a severe reduction in energy use and cost for this transport. It will depend on the details of the specific installation, in which direction the energy saving will come out.

But the main disadvantage of recirculation is the mixing of pollutants through the building as a whole. The recirculated air is again filtered from dust, and humidity and temperature will be at a correct level again, but gaseous pollutants and odours will remain. In this way inhabitants of the building are oblidged to breathe the tobacco smoke of their neighboor, be it in a diluted condition. Air recirculation should be forbidden, at least in office buildings and comparable projects.

If we now reduce the air volume to the ventilation rate alone, we intoduce, as said before, two problems. The first problem of the energy transport is easy to solve: if we take water for the energy transport, this liquid is 2000 times better than air, looking at the volumetric heat transport capacity, at normal temperature differences. This argument moves against the all air systems.

The second problem was the air quantity for ventilation being too small to ensure a good mixing and distribution. There are two possible solutions. The first, in the discipline of the traditional mixing systems, is the well known **induction unit** (see fig. 3).

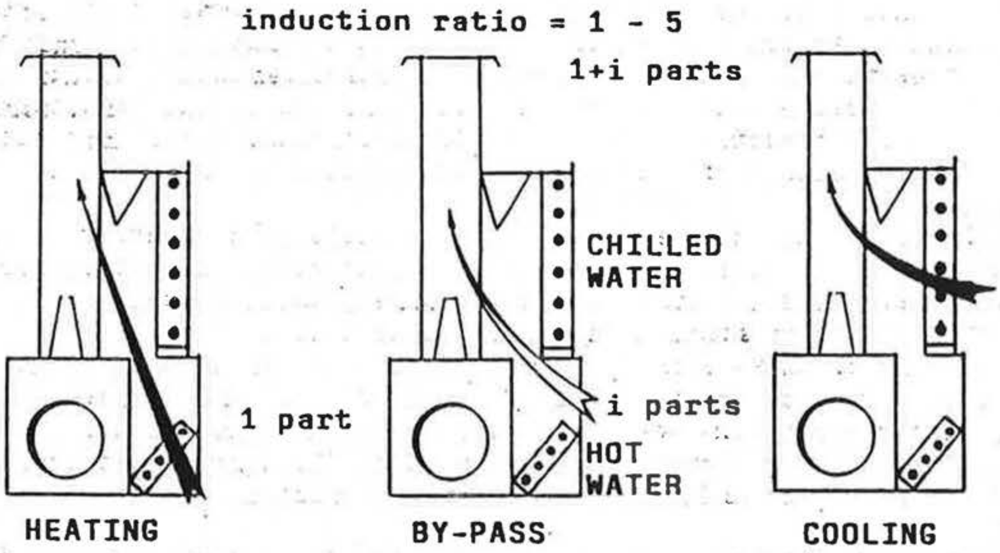

Fig.3. Induction unit (damper operated)

A reduced volume of ventilation air ("primary air") from the duct system mixes up with room air ("secundairy air"), and the mixed quantity ciculates in the room. The secundairy air passes a heat exchanger in the same device, providing heat or cold transport to the room. In this concept, only original room air circulates through the room; there is no mixing or recirculation through the building. ((10)

A second possible solution for a reduced air quantity is the system of **displacement ventilation**. Fresh air for ventilation is dispersed with low velocity at floor level and with a temperature 2K or 3K below room temperature. A "lake" of fresh air on the floor works as a reservoir, and the driving force for the air transport is the production of heat by people or machines. So the heat production determines the quantity of transported air. A human being is supposed to displace by convection an air quantity sufficient for his ventilation need (say 40 m3/h). The pollution (odour) and the excess heat does not mix up and is directly transported to ceiling level. As there is no mixing, an enlarged **ventilation efficiency** and a better **temperature efficiency** is claimed from the system. This is a contribution to an improved IAQ level; with a reduced air quantity the same level of IAQ can be realized. The thermal capacity, notwithstanding the improved temperature efficiency, is very restricted. So the system has to be completed with some kind of a low velocity thermal system; a cold ceiling is claimed to give an extra thermal capacity by radiation and natural convection. ((11)) It seems that this system provides good possibilities for adequate solutions. But there is not much experience and hardly any laboratory research to prove the claims.

If we reject the air recirculation as an option for energy saving in the system, an other method can be found with **heat recovery**, by which the energy content of the return air is (partially) transferred to the outside air to be processed (see fig. 4). Several systems can be used: direct transfer via a plate heat exchanger, liquid systems with two heat exchangers or heat pipes. The heat recovery by means of a slowly rotating "wheel" could be risky.

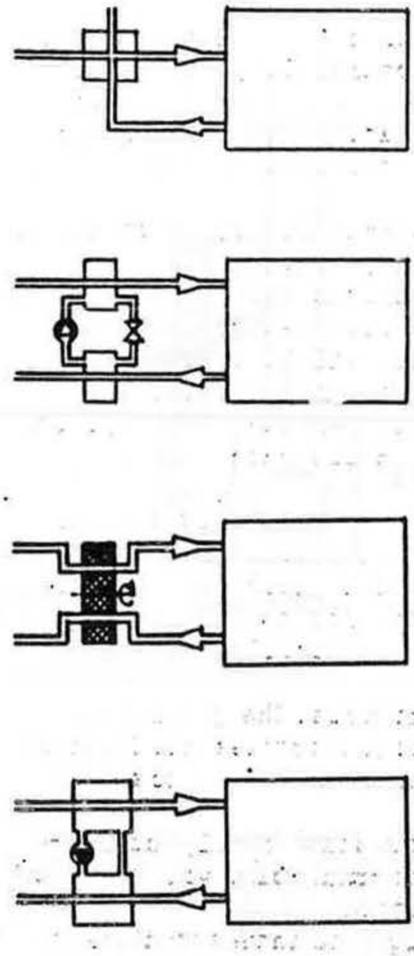

Fig.4. Systems for heat recovery

The surfaces of the wheel itself are in intermittent contact with clean and polluted air; there could be an adsorption effect. If the wheel also recovers the latent load (humidity), the material of the wheel is of a porous nature. The risk of exchange of gaseous pollutants or odours is extended.

6. THE BUILDING PROCESS AND ITS SOCIETAL FACTORS

The realisation of a building with its installations and other equipment is an extremely complicated process. It is much more than the addition of technical specifications. The process assumes the cooperation of concerns and other business units and finally the cooperation of people.

The main parties in the building process are the **principal** (the employer, the owner, the investor), the **architect**, the **consultants, the contractors**, the **commissioner** and the ultimate **user**. There is also a **maintenance** responsability with the owner and/or the user.

All these parties have their responsabilities- and their authority. The ultimate power, in our society, is reserved to the money. The parties involved all try to keep their position in the market, work for their reward and satisfy the given specifications, within their responsability and their span of power.

It is obvious that this process and its management is far from perfect. The technical knowledge often plays a minor role between authority and money. **In a majority of cases the results of the project do not satisfy the given demands, and the total costs exceed the originally given budget.** If we really don't look for the basic reasons of these failures, we will never fulfill the given (technical) requirements, and will not properly use the collected technical knowledge.

If we accept the ultimate power of the money, which is under control of the principal, the principal must, in his turn, accept his ultimate responsability for the project. The full delegation of this responsability must be impossible.

In our current practice, the ultimate goal of the project (a good building) will be **translated** in split responsabilities for different disciplines. Based on these responsabilities, the tasks are specified, and referred to cost levels. What has to be changed, is that all parties involved must not restrict themselves only to their specific task but must overlook the total aim of the project.

Standards and rules, and contracts too, are useful in the prevention of mistakes, but they can not replace the real responsability of parties in a project. The satisfaction of rules do not garantee the perfect result. The recent development of the "performance specification" in contracting will not give the definite solution: it only moves the final responsability to the last party in the process, the contractor.

If, for instance, an important cost reduction in the project comes in the discussion, all parties must have the possibility to report the (negative) consequences of that measure (in their discipline) without being rejected. And, in his turn, the principal must ask for these consequences and take his responsability. The indicated procedure will only be possible if the work is done in the organisation of an open team in which all information is freely exchanged. The principal again has the task organize this open team, in which a thorough base of mutual confidence must be established.

In the field of quality control, an effective commissioning of the project is essential. All parties involved will be convinced about their quality level, but it won't work if parties must check their own work. This statement definitely applies too for the consultant. The commissioner must be absolutely independent, and only have a direct reponsability to the principal.

In many cases, the architect plays a dominant role. The principle must convince him to play a serving role, as the other parties do. It must not be the artistic creation in first order to demonstrate, but to serve human requirements and measures.

The consultant can only be effective if he can stay really independent, specially independent from the architect. The principle will have to provide protection for the consultant in this relation.

Also the contractor needs protection. Normally his interest depends on the answer to the demands of the consultant or the architect, while he uses to have the final responsibility for the performance and costs of the installation.

Again, only the open project team provides the possibility for this approach.

7. PROPOSITIONS: PROPOSALS FOR FUTURE RESEARCH
(the following items are referred to in the text as ((1)), ((2)), etc.)

The following items, derived from the present contribution, are proposed for dicussion in an E.C. Programme for future research in Healthy Building Development, specially directed to Indoor Air Quality. The proposals will focus mainly on installations.

((1)). Control of natural ventilation with an open window.
((2)). Which type of fine filter do we need to avoid pollution of the installation, specially the duct work?
((3)). Is control of air humidity a necessity, supposed the indoor air is clean enough?
((4)). Pollution effects from materials used in airconditioning equipment.
((5)). Pollution risks of a heat recovery wheel, specially if made for latent heat recovery (humidity).
((6)). Health risk of humidifier sections, specially if operated with fluid water.
((7)). Design procedures for installations, looking at the facilities/possibilities for maintenance.
((8)). Design specifications for installations when windows can be opened. Influence of pressurization of the building by wind force.

((9)). Air recirculation should be forbidden in office buildings. Which alternatives do we have for energy conservation. What will be the cost level of this avoidance?

((10)). Displacement ventilation is a hopeful development. But there is still a severe lack of knowledge as design aids. A thorough laboratory research is a necessity to be succesful in the application, and give the system a chance.

((11)). A laboratory research should be made to find out the restrictions for the use of "cold ceilings" as an additional equipment with displacement ventilation. Capacity specifications and consequences for comfort. The combination with displacement ventilation; possible problems with velocity- and temperature distribution.

((12)). The model for the operation of an "open project team" should be thouroughly developed. This societal problem should not (only) be treated by engineers or technical scientists.

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