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A MODERN CONCEPT FOR OFFICE BUILDINGS: ENERGY SAVING AND GOOD INDOOR CLIMATE ARE NO LONGER CONTRADICTORY

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ABSTRACT

An up-to-date design concept for office buildings results in a very low energy consumption and provides a better indoor climate at the same time. This new concept is based mainly on two design features: An *extremely well insulated building envelope* decouples the indoor climate from the outside climate to a high degree during all seasons and weather conditions. The second element of this new design concept is the HVAC-system: The *source-dominated displacement ventilation* provides a better comfort and, as a cosequence of its high effectiveness, is very economical.

Normally windows are the thermal leaks of the building envelope. In order to overcome this deficiency, Geilinger Ltd in Winterthur, Switzerland developped the *High Insulation Technology (HIT)*. Typical glazing-U-values are around **0.65 W/m²K**. The consequences on natural air flow and on the energy balance are enormous: radiator heaters are not anymore necessary in a HIT room and the air change rate of a mechanical ventilation can be reduced considerably compared to the requirements of conventional air conditioning installation.

Modern office buildings usually produce considerable internal loads (occupants, lights, computers, office equipment) which compensate the heat transmission losses in winter. In summer, the excellent insulation protects the building from outside heat during the day. At night free cooling can be used.

Measurements of energy consumption and investigations on thermal comfort were made at different HIT-buildings. One case is presented in this paper.

1. INTRODUCTION

During the last few years it has become widely accepted, that new ways for energy saving in building management must be found. Many people do automatically associate this requirement with a decrease of the user comfort. In this paper it will be shown that the contrary can be achieved. A *new concept*, combining high insulation windows and displacement ventilation, leads to a *higher user comfort and at the same time reduces the energy consumption*. Several office buildings have already been constructed following this concept. Comfort and energy *measurements have been made* [1]. One case is presented on the next pages.

2. A MODERN CONCEPT FOR OFFICE BUILDINGS

2.1. High Insulation Windows

A few years ago, Geilinger Ltd in Winterthur, Switzerland, has developed a new window system which is called *High Insulation Technology (HIT) window*. Glazing-U-values of **0.65 W/m²K** are typical. The basic idea is to minimize all possible heat transfer mechanisms. Considering the glazing, this means to keep the heat conduction by air as well as the convective and the radiative (infrared) transfer rates at low levels.

Measurements and calculations have shown, that the surface temperature of the inner glas pane of a HIT glazing unit is only slightly below the mean indoor air temperature [2]. This gives a rather symmetrical radiation field and only a small deviation of the radiative temperature from the inside air temperature. A second effect of the small difference between room air temperature and surface temperature of the window is the absence of downdraft. As a matter of fact, HIT-buildings do not need radiators at all. (The small amount of heat, which has to be supplied at cold winter nights can be transported by air).

2.2. Mechanical Ventilation and Displacement Principle

Present office work is characterized by relatively high internal heat loads from equipment (computers, copying-devices) and lights. Typical values range from 20 to 50 W/m². It will be shown in the following, that this covers the heat transmission loss, provided that the whole façade is highly insulated. During winter time working hours, the mechanical ventilation has only one task: to supply the office user with fresh air. Heat recuperation is used in the ventilation system for energy saving. During the warmer periods of the year excess heat may be removed by the ventilation system (other means are also possible). But still, the maximum *air exchange rate can be reduced considerably* compared to earlier requirements. This point is of major importance since investment and operating costs are determined mainly by the rate of air changes.

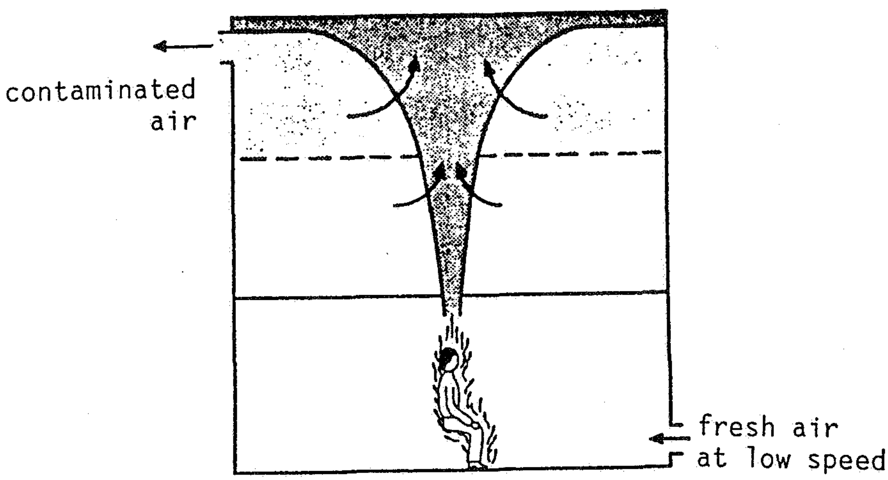

Figure 1: Displacement ventilation. Schematical picture of the air flow with air supply at the bottom, user in the fresh air zone, natural convection of polluted air, entrainment of ambient air, upper zone with polluted air, outflow near the ceiling.

Since the early eighties, a new type of air flow in rooms has been developped in the Skandinavian contries. Fresh air is introduced at low velocity near the bottom. A stable stratification from the bottom to the top devloppes (figure 1). Yet the temperature difference in the occupied zone remains small. The polluted air is removed from the source by natural convection to the polluted zone at the top of the room and from there to the outlet near the ceiling. This system is called *"displacement ventilation"* [3,4]. It combines the advantage of low air change rates and a high level of comfort: fresh air comes directly to the zone where it is needed and draft does not occur.

2.3. Control Concepts

Modern concepts of building management include control facilities which precisely match the features of the HVAC system, the heat production in the offices and the heat transfer through the envelope.

An optimum in comfort and energy consumption may be attained with a hierarchical system ending up with a variable, room individual air volume control. During winter days, heat recovery is applied. At night, the ventilation system is kept in operation only, if heat must be transported: either supplied (cold winter night: internal circulation) or removed (summer night: free cooling).

3. CASE STUDY: ONE YEAR OF REGULAR PERFORMANCE OF A HIT-PROJECT

Detailed investigations were made in 1988 at an office building in Winterthur, Switzerland.

3.1. A conventional building extended with a HIT-part

Up to the fourth floor, the building is built in a conventional way (insulated double glazing windows), with natural ventilation. On top of this building, two floors were erected in 1987 based on the HIT concept (high insulation windows produced by Geilinger Ltd., displacement ventilation with roomindividual control). Geometry is identical for the new and the old part. All windows can be opened and effective sun shades can be lowered individually. - The situation is ideal for comparisons.

3.2. Mechanical ventilation

The ventilation system of the HIT-part of the building operates with temperature demand controlled variable air volumes of 1.0 ... 5.0 air changes per hour. The outside air is heated up to 19°C by heat recuperation and by a water heater (connected to the central heating system of the older part of the building). On top of this, the air can be heated by a room individual electrical unit, if necessary. During summer nights, the excess heat is removed by free cooling. Since the system is not equipped with a cooling unit, the mechanical ventilation is turned off at outside temperatures over 22°C in order to prevent unwanted heating. Users are then recommended to make a reasonable use of the openable windows.

3.3. One year of observations

The energy consumption was investigated by weekly readings of different meters for electricity, heat supply and operating hours.

Further, two campaigns were conducted during winter 1987/88 and summer 1988, respectively. 30 parameters were recorded at time intervalls of 10 minutes. The objectives were:

- user comfort in a HIT room with displacement ventilation and comparison with a conventional room
- efficiency of free cooling
- suitability of the control concept of the ventilation system
- monitoring of the mechanical ventilation

Both rooms (HIT and conventional) were oriented to the east.

4. USER COMFORT DURING THE SUMMER

4.1. Comparability of measurements under real conditions

The temperature and energy performance of a room is up to a certain degree influenced by the user behavior and the weather. In general, with high insulation envelopes the overall energy consumption is very low, but the relative importance of the users influence is more important compared to conventional buildings. (This aspect has clearly been demonstrated by our computer simulations. The model calculation is based on hourly weather data for one year and includes building features as well as the user behavior.)

Nevertheless, observation of real buildings has important advantages compared to laboratory modelling (e.g. influence of thermal mass, long term run, real weather and solar radiation, users). General conclusions can be drawn and give important information to engineers and architects.

Fortunately, in summer 1988 several distinct warm weather periods occurred. The users were instructed *not* to take special care of the measurements, but to behave as they normally do. A reasonable use of sun protection and window opening could be stated in both rooms under observation. The internal heat loads were also comparable.

4.2. Room air temperatures during working hours

Figure 2 shows the statistical distribution of the room air temperatures of the HIT-room and the conventional room, respectively. The statistics includes a periode of 12 summer weeks (530 working hours). The time average doesnot give much information, but the **number of hours with "high" room temperatures** is of importance for the user comfort: there are 4 times less in the HIT-room then in the other one (t > 27°C during 19 hours in the HIT-room, 111 hours in the conventional room).

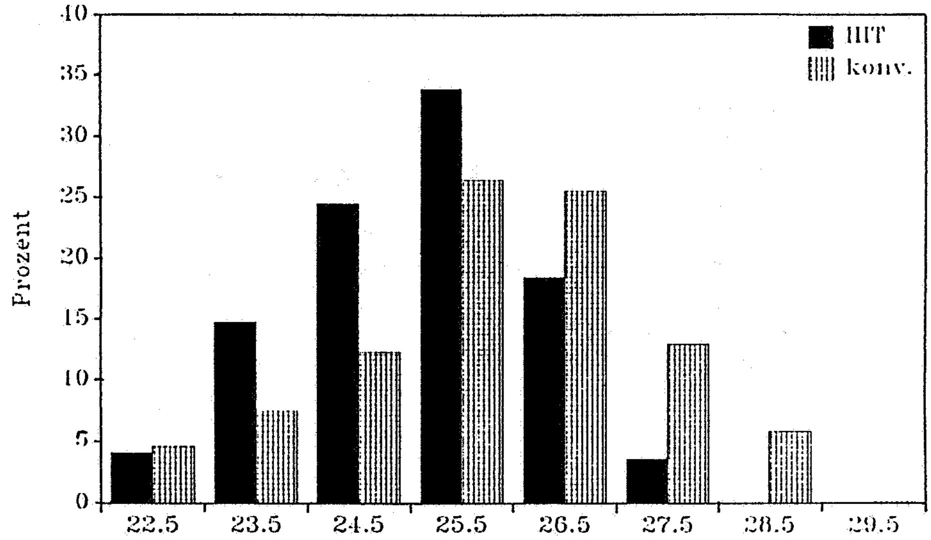

Figure 2: Statistical distribution of the room air temperatures during working hours.

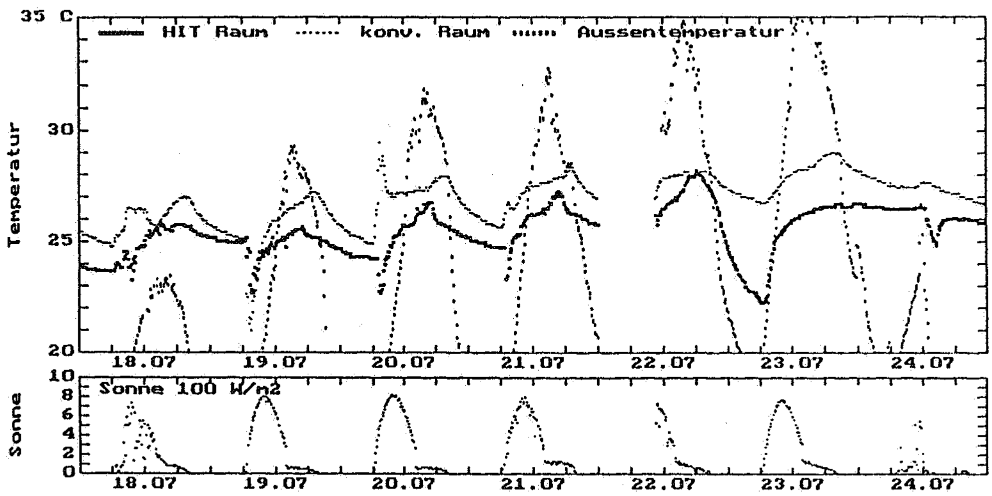

Figure 3: Air temperatures in the HIT-room (exceptionaly no free cooling), the conventional room and outside. The sun protection (louvers) were used every day. AT the bottom: solar radiation (global, vertical).

Room air temperatures during a hot summer week are shown in figure 3. Due to an operating error, the free cooling did not work during that week, which in turn reveals the dynamical characteristics of the room itself. At all times the room air temperature in the HIT-room was lower then in the other one. Quickly after the end of the working time, the room air temperature of the HIT-room began to drop, although the outside air temperature still remained higher. The reason is the effectiveness of the thermal mass (floor, walls, furniture). Contrary, the conventional room is strongly influenced by the course of the outside air temperature and can, therefore, only cool down if the temperature of the outside lies below.

The summer dynamics of a room with HIT-windows is characterized by two important factors:

- The high insulation also protects the interior against midsummer heat.
- The type of HIT-window used in the observed building show selective properties: a comparably large difference of light transmission rate (τ_{vis} = 58%) and total solar energy transmission rate (g = 42%). This results in an effective protection against the unwanted solar heat and, at the same time, an efficient day light.

Generally speaking, the HIT concept means that *inside and outside climate are separated as much as possible.*

4.3. Free Cooling

A mechanical ventilation system offers the opportunity to run a free cooling mode during summer nights: the excess heat, which has been accumulated in the thermal masses during the day, is being removed by the cold nocturnal air. Figure 4 demonstrates the effect of free cooling during a warm week at the end of August 1988: the temperature drop in the HIT-room is quite distinct.

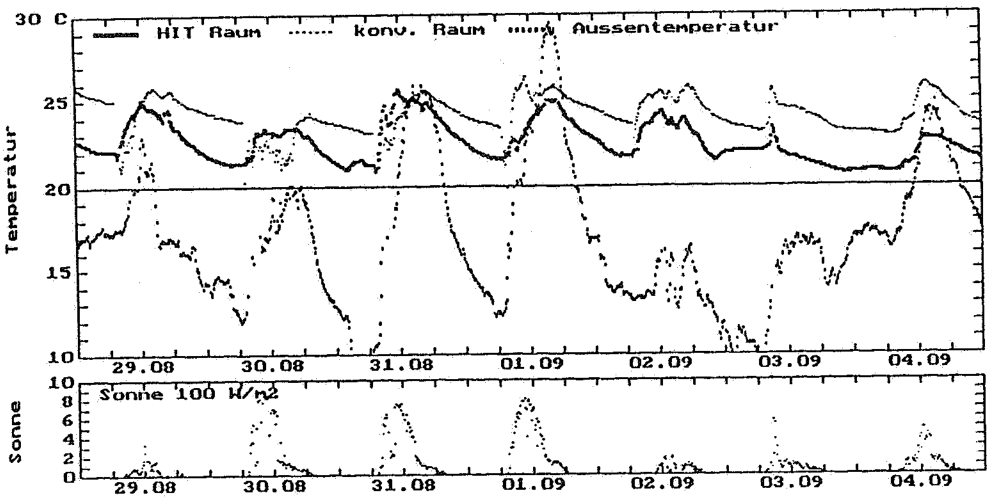

Figure 4: Air temperatures in the HIT-room (with free cooling), the conventional room (no mechanical ventilation) and outside. The sun protections were used every day. At the bottom: solar radiation (global, vertical).

Moore insight into the cooling process can be gained through the calculation of the energy transport. The night of the 1./2.9.88 is selected as a typical case (table 1). The calcuations are based on the measurement of the air temperatures and velocity in the air ducts (energy transport by free cooling) and the air temperatures in the rooms and outside (transmission). With transmission and free cooling, an amount of 10864 kJ was removed from the HIT-room. This means a drop of the floor temperature of around 0.7 K. Besides, the case shows that free cooling (9102 kJ) is more efficient than the cooling by natural transmission (7373 kJ) in a conventional room.

	HIT-room	conv. room
transmission free cooling	1762 kJ 9102 kJ	7373 kJ -
total	10864 kJ	7373 kJ

Table 1: Removal of the excess heat from the two observed rooms, both with 24 m², during the night of 1./2.9.88, from 20.00 to 05.00.

In this case, the energy consumption of the ventilators was 6000 kJ (related to the office room). This amount should be seen as part of the total, extremely low energy consumption (see chapter 6).

5. WINTER PERFORMANCE

5.1. Working hours

During working hours, HIT rooms are supplied with fresh air at a temperature of 19°C. Normally, the air change rate is at a minimum rate of 0.6 to 1.0 air changes per hour. In case of excess heat, the air volume is increased.

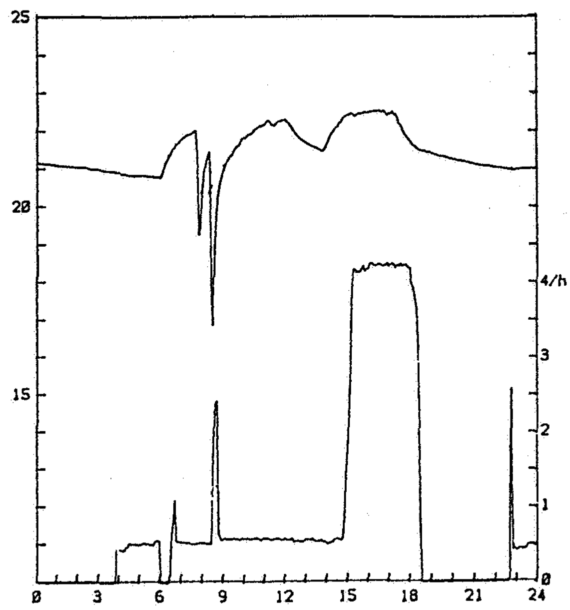

Figure 5: Room air temperature and air change rate of the mechanical ventilation during an overcast winter day (13.1.88).

Figure 5 shows the room air temperature and the air change rate of the mechanical ventilation during an overcast winter day with outside temperatures around 0°C. The user obviously left his office several times for shorter or longer intervalls (temperature drops). In the afternoon, the ventilation reacted to the room air temperature of 22°C with an input of the maximum air volume rate. This means that a larger amount of heat is removed (cooling).

Regarding the user comfort, the advantages of the HIT-concept during the winter working time may be summarized as follows: the surface temperatures of the HIT-windows are only a few degrees below the temperatures of the interior walls and the room air temperature. Consequently, the thermal radiation field is well-balanced: an important factor for comfort. As a second effect, the surface boundary layer at the window has approximately the same temperature as the room air. Therefore, downdraft does not develop and radiators below the window are not necessary. The comfort gain of the displacement ventilation results from the constant supply with fresh air without any draft (low air speed *and* low turbulence degree).

5.2. A HIT-room during winter nights

During moderately cold winter nights, a HIT-room needs not to be heated at all, even if no internal loads are present. An example is given in figure 6. The mechanical ventilation was turned off from 18.30 to 06.30. During this time the mean room air temperature dropped about 0.5°C. Totally different is the behavior of the conventional room. There, the radiator was on during the whole night (at a reduced level). The temperature dropped to 19°C.

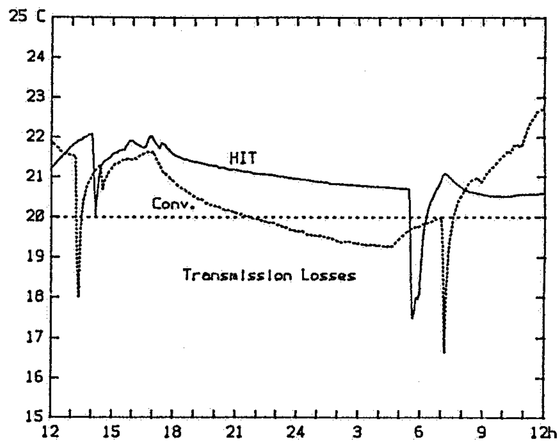

Figure 6
Room air temperature during a winter night in the HIT room and the conventional room, respectively. The mechanical ventilation of the HIT room was off from 18.30 until 06.30. The conventional room was heated at a low level by the radiator.

During very cold and clear winter nights, the situation is slightly different. Computer simulations and practical experience led to the conclusion that a little amount of heat should be added to the HIT room. This can be done by the mechanical ventilation (internal circuit). The idea is, to keep the overall room temperature (air, floor, furniture) at a level of about 20°C in order to have optimal conditions in the morning.

6. ENERGY SAVING

6.1. One year of observation

Some results of the detailed energy readings are presented in table 2 and in figure 7.

In "lights + machines" the direct consumption by the user is given. Monthly deviations are small, which means that the portion for machines is dominant.

For the ventilators more energy has been consumed in summer than in winter. This is partly due to free cooling.

Most of the "heat" energy has been used for central air pre-conditioning. In other words: heat is not used to cover the transmission losses, but for the fresh air supply of occupants.

	MJ/m²a	%
lights + machines	150	45
ventilators	64	19
heat	118	36
total	332	100

Table 2: Energy consumption 1988 at the 5. floor (HIT)

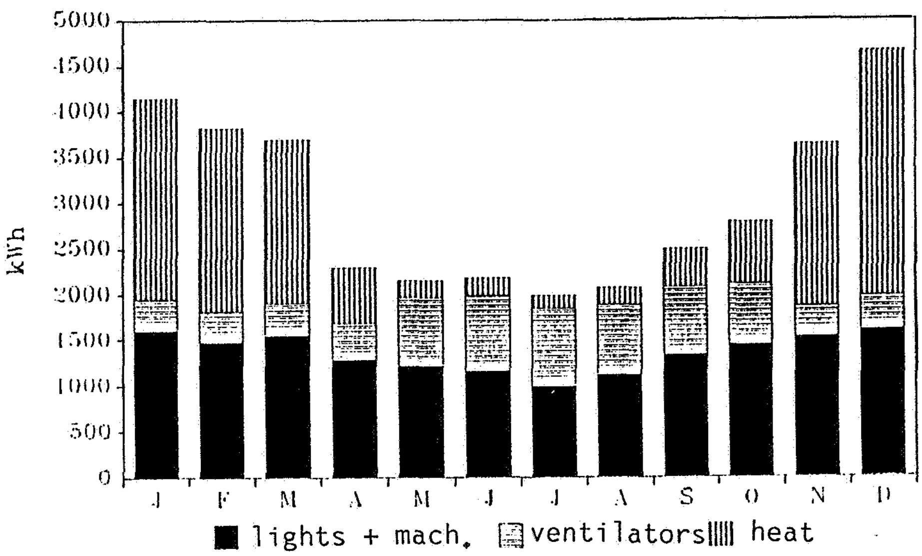

Figure 7: Monthly energy consumption at the 5. floor (HIT).

The most impressing feature is the extremely low total energy consumption, and besides, the small fraction (36%) used for heat. This is demonstrated with the comparisons in table 3.

	heat MJ/m²a	%	total energy MJ/m²a
average 1988 (*)	575	70	825
nominal value (**)	240	58	415
HIT 5. floor	120	36	332
HIT 5. + 6. floor	170	47	360

Table 3: Consumption of heat and total energy.
(*) Existing swiss buildings (buildings with heavy deficiencies are excluded), [5].
(**) based on the recommendations of the Swiss Society of Engineers and Architects (SIA), [6].

Although conditions for the extension of the reported building were not optimum (certain heat leaks such as outside columns could not be avoided), the energy consumption is far below the nominal value for Switzerland.
At the 6th floor more heat and total energy was consumed than at the 5. floor: reasons are the 67% larger transmission loss factor due to the bulding roof and an accidentally lower consumption of electricity.

6.2. Energy balance during winter

During three winter months (Dec. 87 - Feb. 88) with an avarage outside temperature of 2.8°C, detailed energy measurements were made. Gains and losses were calculated. Comprehensive energy balances for the fifth floor (HIT) and the third/fourth floors (conventional) resulted and are presented in table 4.

Gains/Input	HIT	conv.	
Sun + occupants	2.3	4.0	W/m²
Light + machines	5.5	7.8	W/m²
Heat	10.1	21.0	W/m²
Total	16.9	32.8	W/m²

Losses	HIT	conv.	
Transmission	7.1	21.4	W/m²
others (*)	6.2	-	W/m²
Air	3.6	11.4	W/m²
Total	16.9	32.8	W/m²

Table 4: Energy balance for the periode Dec. 87 - Feb. 88.
(*) Losses due to thermal leaks inherent to the existing building design. For comparison purposes "Transmission" values should be considered only.

Two important conclusions can be drawn from these measurements:

1. *A high insulation office room obtains enough heat energy by machines, lights, sun and occupants to balance the thermal transmission losses.*

2. If an adequate ventilation concept is used, ventilation losses are much lower compared to natural ventilation (crack flow and window opening).

7. CONCLUSION

The High Insulation Technology (HIT) - concept is based on decoupling the inside thermal climate from the outside climate by a high insulation building envelope. This provides a good radiative climate by saving large amounts of energy. The air quality is maintained at a high comfort level running a mechanical ventilation based on the displacement principle. Excess heat can to a certain extent be removed by the mechanical ventilation: free cooling can be recommended.

REFERENCES

1. BRAUN, W., KELLER, B.
Resultate von Energieverbrauchsmessungen bei hochisolierten Bürogebäuden
5. Schweizerisches Status-Seminar "Energieforschung im Hochbau", Zürich, September 1988

2. KELLER, B.
Der Einfluss von hochisolierenden Fenster- und Fassaden-systemen auf Raumklima und Energiebedarf, NEFF-Projekt Nr. 225, 1984

3. MAHISEN, H.M., and SKÅRET, E.
Ventilation efficiency - part 4: displacement ventilation in small rooms
SINTEF-Report Nr. STF15 A84047, Norvegian Institute of Technology, 23.5.1983

4. HESTHAG, B.H.
Ventilation and tehrmal climate in an office equipped with HIT-window and low momentum displacement ventilation
SINTEF-Report Nr. STF15 F85023, Norvegian Institute of Technology, 16.4.85

5. Schweizer Energiefachbuch 1989
M & T Verlag AG, St.Gallen, 6. Jahrgang

6. Swiss Society of Engineers and Architects (SIA)
SIA-Empfehlung 380/1, Energie im Hochbau, 1988