Building envelopes in "high insulation technology"

Building Envelopes in "High Insulation Technology"

"Haute isolation thermique" pour les fenêtres et façades

"Hochisolationstechnologie" für Fenster und Fassaden

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SUMMARY
The main features of "High Insulation Technology" are presented. The extremely low values of the coefficient of heat transfer for windows completely change the comfort conditions as well as the energy management. Results from measurements in occupied rooms are presented and future perspectives discussed.

RESUME
Les principes de la "Haute Isolation Thermique" pour fenêtres et façades sont présentés. Les valeurs très faibles du coefficient de transmission thermique pour les fenêtres influencent beaucoup les conditions de confort et le budget énergétique d'un bâtiment. Les résultats de mesures dans des locaux ainsi que des développements possibles sont présentés.

ZUSAMMENFASSUNG
Die Prinzipien der "Hochisolationstechnologie" für Fenster und Fassaden werden vorgestellt. Die extrem tiefen Werte des Wärmedurchgangskoeffizienten für Fenster haben weitreichende Konsequenzen sowohl für den Komfort als auch für den Energiebedarf und die Haustechnik. Diese werden anhand von Messungen in realen Räumen diskutiert.

1. INTRODUCTION

The two companies: Sulzer Bros, Heating and Air Conditioning Division and Geilinger Ltd, Metal Work Division, both located at Winterthur (Switzerland), have been doing research and developmental work for better energy- saving solutions in the area of building envelope and HVAC-systems since 1978.

The analysis of energy use in conventional buildings led to the following conclusions:
1. Most of the energy is used for heating and/or cooling.
2. This is done through the HVAC-system in order to guarantee comfort for the inhabitants.
3. That is so, because the building envelope itself does not suffice for this job.
4. A substantial improvement of the building envelope should result in less energy use and smarter and more economical HVAC-systems.

The reaction to the oil-crisis, the super-insulation and the passive solar "waves" both intended to reduce the energy demand, but partially at the cost of human comfort. They both yielded a certain reduction but still remained far from a real breakthrough. Moreover, both had severe drawbacks [1,2]:

Super insulation:
- Too small windows
- High sensitivity to the care of the workmen on the building site.
- Condensation and air leakage, air quality problems.

Passive solar:
- Large temperature- and power swings.
- Severe restrictions of the internal freedom in order to keep the storage material accessible.
- Almost no use of the north side (only side with no glare problems).
- Heavy discomfort at cold and dull days due to draught from large windows etc.

In all these cases, the window plays the key role: for daylighting, for draught, for gain and for loss.

For a breakthrough, we concluded a window to be necessary that will no more need any HVAC-installations in its vicinity to compensate for comfort and that will of course transmit enough daylight.

Investigations in one of our companies showed, that the minimum value for the inner surface temperature should not be lower then about 3° C below mean air temperature, to avoid draught and asymetric radiation cooling. This temperature drop is given by

$$\Delta\vartheta_{sa} = \frac{U}{h_i} \Delta\vartheta_{io}$$

U : U-value h_i: inner surface coefficient
thus, to keep it within 3° C the U-value must be

$$U \leq 0.68 \ W/m^2K$$

for $\vartheta_o > 15$ ° C. Hence we had to develope such windows.

2. HIGH INSULATION TECHNOLOGY

In order to create a well-balanced window system of very low thermal transmittance, new design principles had to be developed for the glazing as well as for the sealing and the framing.

2.1 HIT-Glazing

The three mechanisms of heat transfer between two glass panes: conduction, convection and radiation had to be minimized simultaneously. This was done by:
- augmenting the overall air gap to 80-90 mm,
- subdividing this gap into three parts by means of two panes or suspended films,
- coating the surfaces with infrared reflecting coatings.

Although this set-up could be realized with coated glass panes as well, we decided for reasons of weight, price and also transport and storage volume to use suspended polyester (PET) films with heat mirror coatings: HEAT MIRROR (TM). The suspension technique allows an independent, durable and wrinkelfree suspension of the films and is protected by patents (figure 1). Of course we have developed computer programs for the heat transfer in such stacks in order to optimize the set-up: emissivities, position of the films, and to determine the properties with and without solar irradiation: U-values, solar and luminous transmittances, temperature of the films etc.

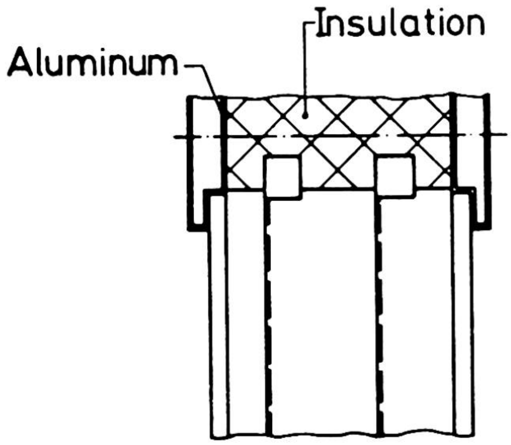
The thick air gap must be vented to the outside to avoid breakage by thermally induced pressure differences. The pressure equalization goes through a protective filter, which keeps humidity and air pollutants out. The service period of this replaceable filter will be at least 3-5 years according to our experience. In addition, the replaceable filter yields a repairability of the window in contrast to the "all or nothing" insulating glazings. It makes the window much more robust and tolerant to rough handling.
Beside the low U-values of 0.6 W/m^2K (even 0.5 in a combination with one coated glass pane), the HIT-S glazing reaches values of up to 63 % for the luminous transmittance and 50 % for the total solar energy transmittance (42 % radiative direct, 8 % at the surface) (all values for perpendicular incidence). This values can be lowered by the combination of different available coatings to meet sun protection needs. They also show a high selectivity τ/g = 1.26 compared to ordinary glass panes with 1.08. Arbitrary combinations with roller blinds, stores or reflecting glasses are possible.

2.2 HIT-Framing and Sealing

To avoid the well known thermal short-cuts in the sealing of insulating glazings [3], we made the sealing to be the framing. Thus the glazing and the framing became an integrated and rigid unit without thermal short cuts. The thick framing allows two rigid metallic parts to be separated by a thick insulating zone, which also contains a water vapor barrier. This design yields local U-values of 0.9 W/m^2K for the framing (figure 1).

The above mentioned filter is integrated into the framing and can easily be replaced within a few minutes by unlocking two screws.

Figure 1: Schematic cross section through HIT-glazing (lower part) and framing.



One further advantage of this integrated and thermally broken design is the high sound insulation of more then 45 dB (measured at the building).

Figure 2 demonstrates the ordinary appearance of a HIT-S-window installed at the LESO test Building of the Federal Institute of Technology at Lausanne.

Figure 2: Outlook through a HIT-S-window at the LESO test building.

3. RESULTS

We have tested this new technology in many different ways:

- accelerated thermal, mechanical and UV-radiation tests of the film material in the lab,
- accelerated corrosion tests of the coating and the films in the lab,
- field tests of the suspension technique since 1979 at many different locations, up to mountain huts at 2500 m above sea level,
- 22 windows in the Sulzer Energy House since March 1981,
- 3 test windows in the restaurant on the Jungfraujoch at 3500 m above sea level, instrumented and measured through the Swiss Federal Institute for material Testing (EMPA) since March 1982,

- 6 windows in an occupied and fully instrumented test office at the LESO test building [5] of the Swiss Federal Institute of Technology at Lausanne since November 1982 in a research project sponsored by the Swiss Energy Research Foundation (NEFF).

The experiences in these tests are very good and let us expect a life time of at least that of usual insulating glazings.

Figure 3 shows some measured temperatures during a cold and cloudy week on the Jungfraujoch for the HIT-S as well as for a double glazing as reference. It clearly demonstrates the superiority of the HIT-S, as even in the joints between glazing and framing the temperature never falls more then about 3-4 ° C below air-temperature. The Jungfraujoch represents a very valuable test site with large temperature swings down to -30 ° C, wind velocities of up to 200 km/h and a rapidly changing very intensive solar irradiation of up to 1200 W/m^2 and a high UV-part.

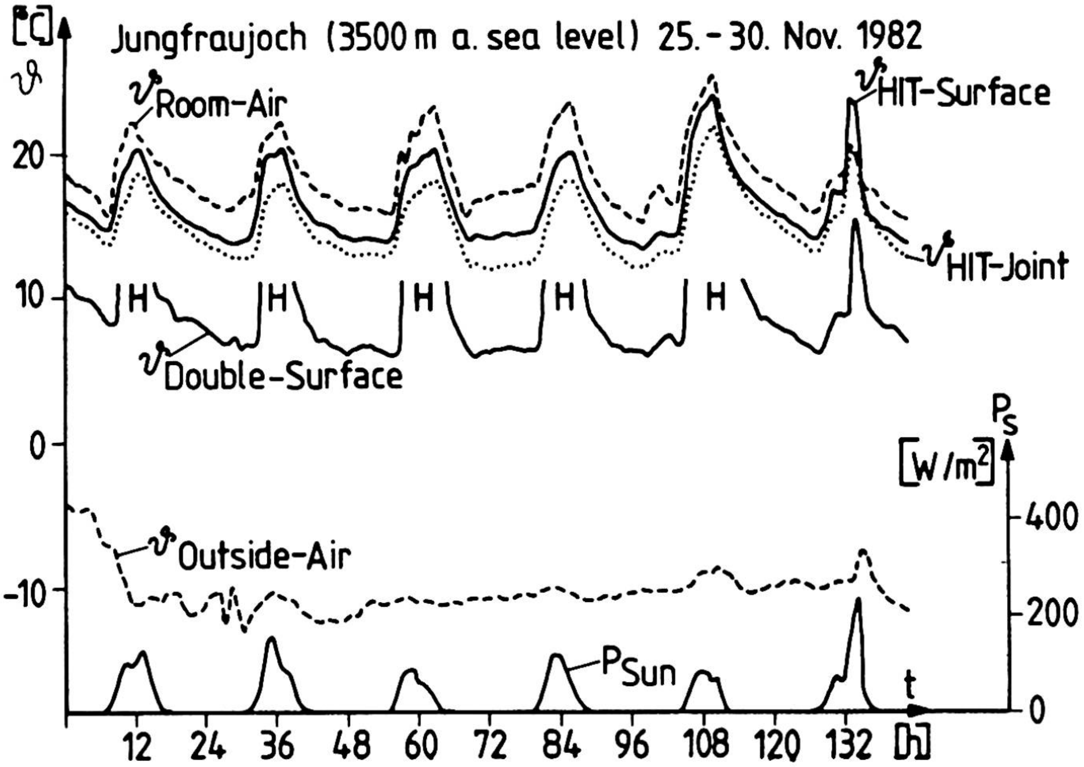


Figure 3: Temperatures measured on a HIT-S window at the Jungfraujoch by the Swiss Federal Institute for Material Testing in November 1982.

The measurements at the LESO by flux meter (during one week) and by the energy balance over some weeks gave

U-values of 0.59±.03 W/m^{2}K and 0.65±.08 W/m^{2}K [4]

respectively. The completely measured energy balance of an office of 36 m^2 floor and 92 m^3 volume is shown in table 1 as an example for one cold and cloudy week from February 14 to 21 in 1983. The values are measured for the HIT-S at the south-side and compared by analog calculations with double and triple glazing and the north side. The results clearly show, that the net losses are mainly compensated by internal sources, allmost all the time on the south and even mostly on the north side. In fact a small heating had mainly to compensate for the additional losses through the ceiling and one outer wall, because the office was located in a corner of the building. A complete report on this measurements over one year at the LESO will appear in summer 1984.

Table 1: Mean Power of Gains and Losses through 22.5 m^2 of Curtain Wall including 9 m^2 Glazing.

Date: 2/14 - 2/21/1983, LESO Test Building, Lausanne
Weather: Mean $\Delta\vartheta$ = 22.8° C, Sun South $\overline{Q}$ = 8 MJ/m^2d Sun North $\overline{Q}$ = 2.1 MJ/m^2d

	Mean Power of		
South	Gain	Loss	Net Loss
HIT-S (measured)	274 W	- 304 W	- 30 W ***
Triple Glazing (calc)	390 W	- 670 W	- 280 W
Double Glazing (calc)	481 W	- 846 W	- 365 W
North			
HIT-S (calc)	74 W	- 304 W	- 230 W ***
Triple Glazing (calc)	105 W	- 670 W	- 565 W
Double Glazing (calc)	130 W	- 846 W	- 716 W

Values: U: 0.6 / 2.2 / 2.8 W/m^2K, solar energy transmittance averaged over hemisphere for diffusive irradiation: 0.33 / 0.47 / 0.58

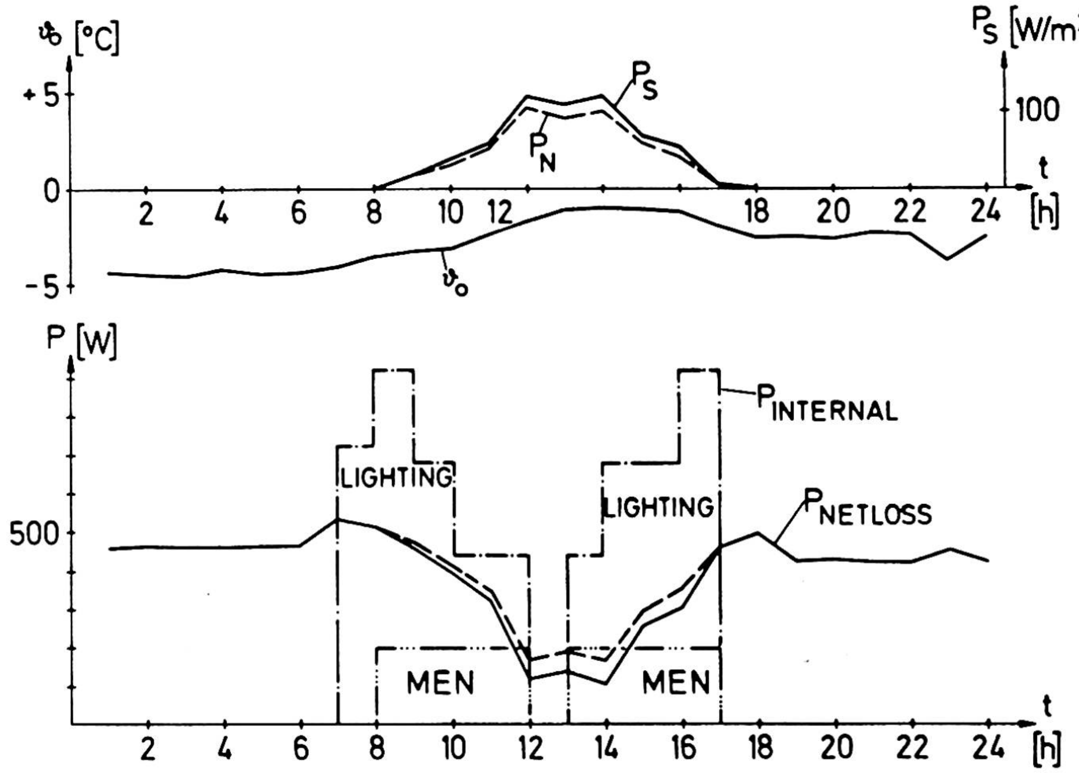


Figure 4: Power need for same office as in table 1. Two men, lighting: 20 W/m^2 in 3 levels, ventilation: night: n = .2h^{-1}, day: n = 1h^{-1} (heat recovery with η = 70 %).

The curves in figure 4 (calculated for the same office as in table 1) for a cold and dull day demonstrate the important change in the energy management: during the whole day, the internal sources, together with the low solar irradiation have more power then it is needed for the compensation of the losses, even at the north side. This yields a small temperature rise even at such a day, giving a reserve for the night. The net heating energy for this day (24 h) turnes out to be 9.5 MJ compared to 52 MJ with a double glazing. Sun and internal sources cover 77 % (double glazing 41 %) of the energy need.

During automn and springtime, no energy is needed for heating or cooling: heating is completely covered by the internal sources and the sun and to much sun can easily be compensated by free cooling or natural ventilation through the open windows.

The reduced solar transmittance and the relatively thick framing act as sun protection in summer. Together with the low U-value (now acting in the reverse direction), they allow a substantial reduction of the cooling load. Moreover, the high attainable selectivity of up to $\tau/g = 1.6$ ($\tau = 0.29$, $g = 0.18$) allows low power for the artificial lighting.

4. CONCLUSIONS

The results shown demonstrate that
- there is no necessity for heating installations in the vicinity of the window, comfort is maintained without additional measures,
- most of the energy need for heating is covered by the solar gain and the internal sources on the south side as well as on the north side and even on cold and dull days,
- in order to keep all losses low and air quality high, the use of a mechanical ventilation with heat recovery is recommended but not necessary. It can also be used for heating purposes because of the low power densities.

Thus, the main feature of this new technology is a reduction of the power amplitudes for heating as well as for cooling. The availability of different coatings on film and on glass allows custom-built windows for the specific situation and climate.

We are building now (spring to summer 1984) a commercial building at Geneva with about 2500 m^2 of HIT-S windows. We found that the additional costs of the new windows were approximately compensated by the reduction of the HVAC-system. Therefore the pay back time becomes zero and the improvement of comfort and the saved energy are a net profit for the owner.

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