Design method for solar control

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Design Method for Solar Control

Méthode d'évaluation de la protection solaire

Methode zur Beurteilung von Sonnenschutz-Massnahmen

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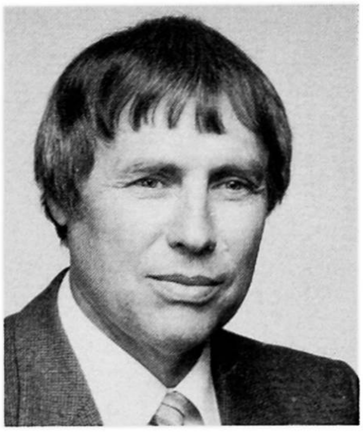
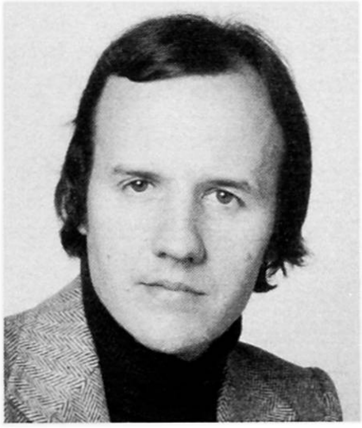
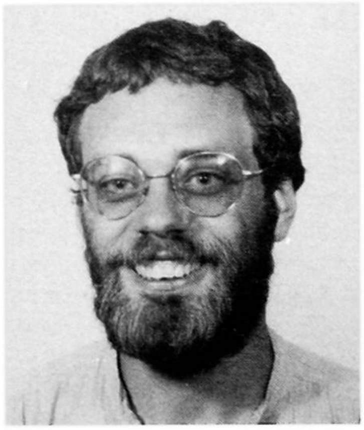


Ralph Sagelsdorff, born 1929, got his civil engineering degree at the Swiss Federal Institute of Technology in Zürich. After 4 years of design work in the United States and Switzerland he entered the Swiss Laboratories for Materials Testing and Research (EMPA). He became 1968 section head of the section building physics.



Th. Frank, born 1950, got his civil engineering degree 1975 at the Swiss Federal Inst. of Technology (ETH) in Zürich. Since 1978 he is working on research projects at the Swiss Federal Laboratories for Materials Testing and Research (EMPA) dealing with measurements and calculation methods on energy consumption of buildings.



Toni W. Püntener, born 1959, got 1983 his bachelor of science at the college of Engineering (Department of HVAC Engineering) in Lucerne. Since then he is working at the Swiss Federal Laboratories for Materials Testing and Research (EMPA) on calculation models for energy consumption in buildings.

SUMMARY
Solar control for residential and commercial buildings is important to maintain thermal comfort and reduce energy consumption. The comfort criteria for summer conditions must be considered carefully, especially in passive solar buildings with high solar gains. A nomogram for the rapid determination of the critical maximum indoor air temperature is given, based on a parametric analysis, considering solar transmission factor, shading devices, window area, internal heat source and building mass.

RESUME
La protection solaire dans les bâtiments résidentiels et commerciaux est importante pour le maintien du confort thermique et la réduction de la consommation d'énergie. Le critère de confort pour les conditions en été doit être considéré soigneusement, spécialement pour certains bâtiments à énergie solaire passive. Une abaque pour la détermination rapide de la température de l'air intérieur maximal critique, basée sur une analyse paramétrique considérant le facteur de transmission solaire, les dispositifs d'ombrage, la surface des fenêtres, la source intérieure de chaleur et la masse du bâtiment, est donnée.

ZUSAMMENFASSUNG
Das Festlegen von Sonnenschutzmassnahmen bei Wohn- und Geschäftsbauten ist wichtig zur Aufrechterhaltung der Behaglichkeit und für Energieeinsparungen. Besonders bei Bauten mit einer hohen passiven Sonnenenergienutzung sind die sommerlichen Behaglichkeitskriterien sorgfältig zu überprüfen. Es wird ein Nomogramm vorgestellt für die rasche Bestimmung der kritischen maximalen Raumlufttemperatur. Das Nomogramm basiert auf einer Parameterstudie und berücksichtigt Gesamtenergiedurchlassgrad, Beschattungseinrichtungen, Fensterfläche, innere Wärmequellen und Gebäudespeichermasse.

1. INTRODUCTION

Typical of central Europe, the climate of Switzerland calls for many days of heating in winter. Excluding buildings with high internal heat sources, no cooling is normally required in summer.
However, the summer season can present problems since a period of sunny summer days can produce excessive indoor temperatures which severely reduce the thermal comfort and working capacity of the occupants.

Architects and engineers must therefore design the building for effective solar control to avoid overheating. This is especially true for buildings designed for high solar gains in winter to reduce heating loads. Good solar control for summer conditions may also preclude the need for air conditioning and reduce the total energy consumption.

The architect would benefit from a simple tool to check his designs concerning solar protection, to compare different alternatives and to be alerted to critical situations in which more sophisticated calculations by specialists are necessary.

The maximum indoor temperature during a typical period of sunny summer days is chosen as criterion for the thermal response of the building. The critical maximum indoor temperature depends on the following parameters:
- solar gains (influenced by window size, solar transmittance of the glass and the shading devices),
- internal heat sources (lighting, office machines and installations, occupants),
- thermal storage capacity of the internal building mass,
- air infiltration rate.

2. ASSUMPTIONS AND METHOD

The proposed method employs a nomogram for the rapid determination of the critical maximum indoor temperature $\vartheta_{i,max}$ in a chosen room. It is usually possible to select one or a few critical rooms in a building, check these with the nomogram and then apply this solar control to the entire building.

The nomogram gives estimated values and is subject to the following limitations:

- room geometry: ratio of room width-to-depth 1/2 to 2
- window area: orientation from east, south to west
  (the nomogram is not valid for roof windows)
- thermal insulation: U-value, roof < 0.4 W/m^2 K
  walls < 0.6 W/m^2 K
  windows 1.4 to 3.0 W/m^2 K
- no heat absorbing window glass
- air infiltration rate: 0.5 per h, daily mean value
- internal heat sources: 0 to 50 W/m^2 floor area

Thus, the method applies to residential and commercial buildings, offices up to moderate size.

The nomogram is based on a parametric analysis with a computer program considering the varying ambient air temperature, solar radiation and the dynamic behavior of the building.

3. EXTERNAL CLIMATE

A typical period of 5 summer days was selected from the available data [1].
Fig. 1 and 2 give the fluctuations of ambient air temperature and solar radiation.

These diagrams can be considered valid for Swiss climatic conditions up to an elevation of about 800 m above sea level. This covers most of the populated area. The maximum ambient air temperature is 33°C and the daily amplitude, 14 to 16 K.

Higher altitudes can also be checked by reading the overheating ($\Delta\vartheta$) from the nomogram. This overheating is defined as the temperature difference between maximum indoor air temperature ($\vartheta_{i,max}$) and maximum ambient air temperature ($\vartheta_{a,max}$) occuring during the 5 day period. The maximum ambient air temperature, decreasing with increasing altitude, can be taken from Fig. 6.
Extrapolation to altitudes up to about 1600 m is acceptable because the measured data show that solar radiation in summer does not vary greatly with altitude.

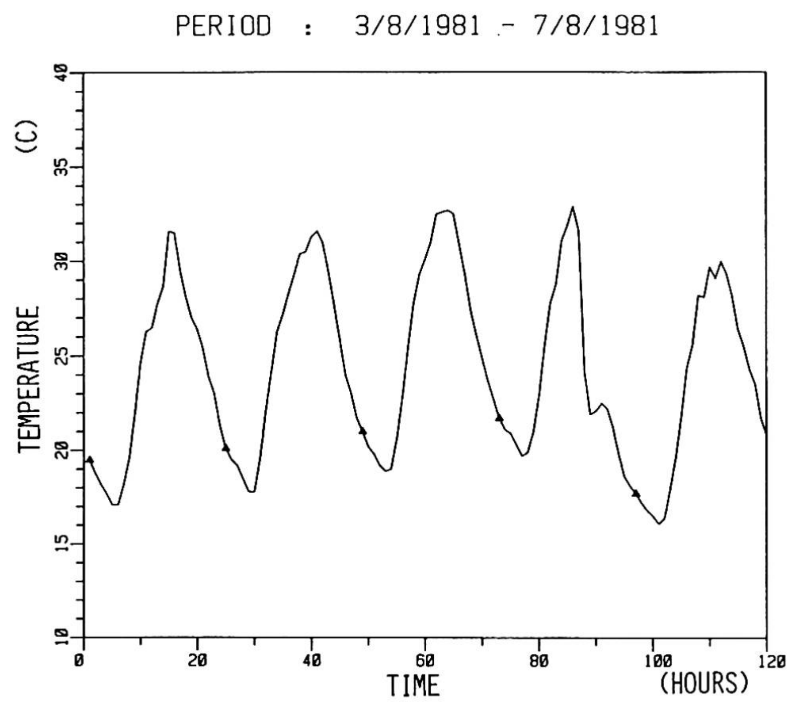


Fig. 1: Typical summer ambient air temperature for Swiss climatic conditions (Geneva 420 m).

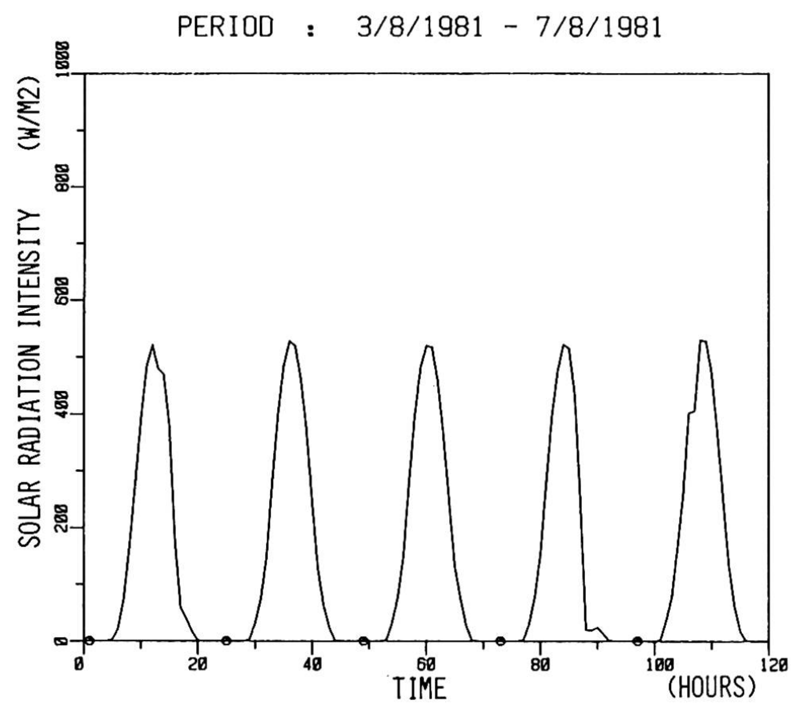


Fig. 2: Global solar radiation intensity on south facade for summer conditions.

4. SIMULATION MODEL

The parametric analysis was performed with the computer program HELIOS 1 [2, 4]. This program calculates the thermal behavior of the building and indoor air temperature in hourly intervals on the basis of weather data, i.e. ambient air temperature, wind velocity, solar and atmospheric long-wave radiation. The building interior is considered as one zone, here one selected room. The calculation of the heat transfer through the walls and the window area uses the ASHRAE procedure [3].

This program has been verified and evaluated by measurements and gives an estimated accuracy of about 1 K in air temperatures and 10 % in daily heating loads (non-existent in summer). Fig. 3 gives a typical result of the evaluation.

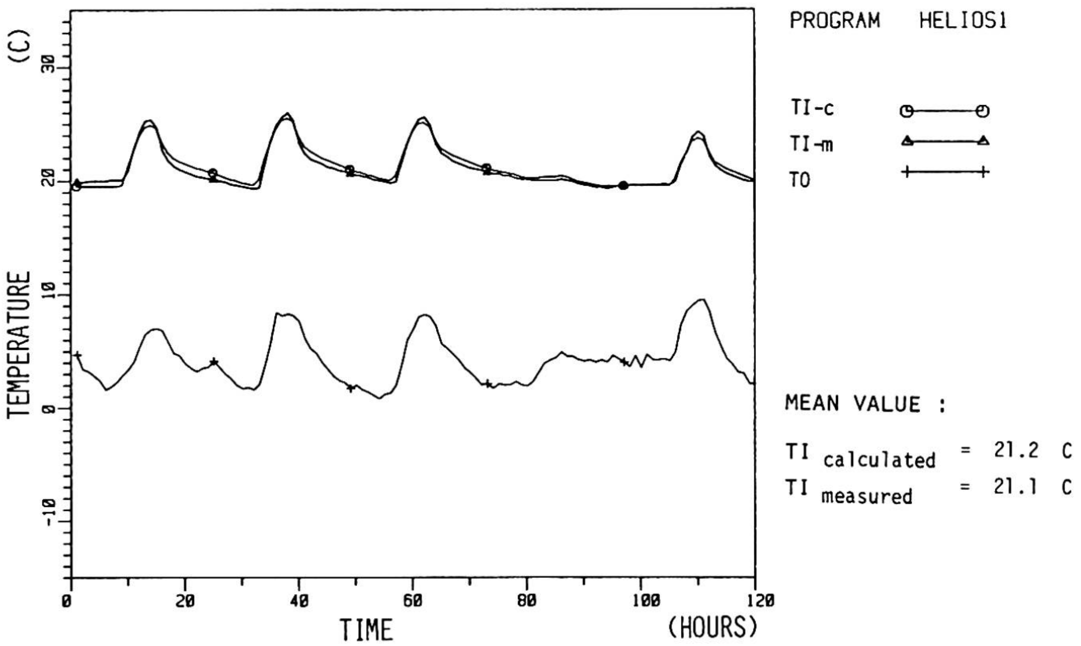


Fig. 3: Comparison of measured and calculated indoor air temperature for a south oriented room.
TI-c: Indoor temperature, calculated
TI-m: Indoor temperature, measured
TO: Ambient air temperature

In Fig. 4 and 5, results from the parametric analysis are given. They show the influence of window area on the indoor air temperature for heavy and light building constructions.

5. NOMOGRAM AS DESIGN TOOL

Fig. 7 and 8 give two examples for the use of the nomogram. One enters the following parameters in sequence:

- solar transmission factor of the window area. This factor includes the standard transmission properties of the glass, the reduction of transmission area by window frames and the shading effect of building parts, shutters or Venetian blinds. The total solar transmission factor must be determined (calculated or estimated) by the designer.
- ratio of window area devided by floor area (A_{window}/A_{floor}). Windows in two different facades are treated additively (Fig. 8).
- internal heat source. The mean daily value per m^2 floor area is used.

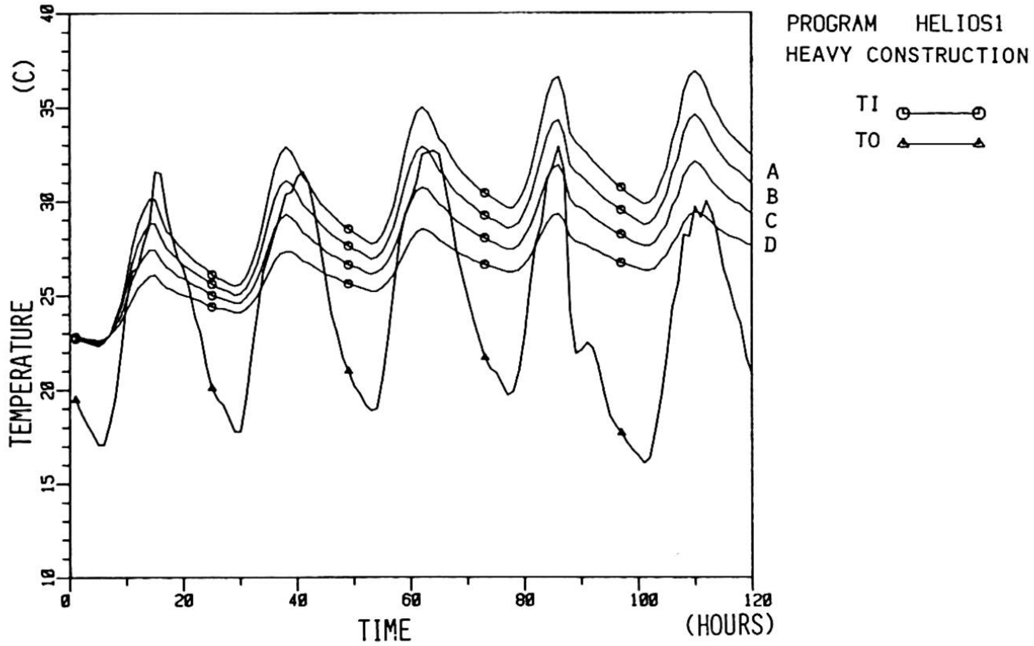


Fig. 4: Calculated indoor air temperatures of a heavy building construction for different ratios of window to floor area A_w/A_f: A=50%, B=40%, C=30%, D=20%.

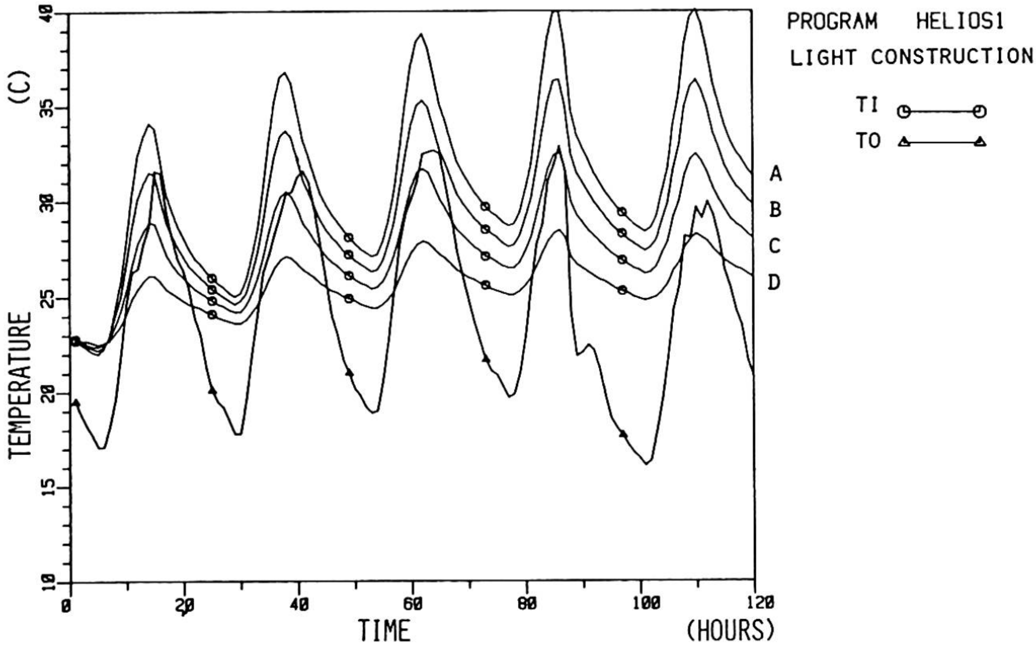


Fig. 5: Calculated indoor air temperatures of a light building construction for different ratios of window to floor area A_w/A_f: A=40%, B=30%, C=20%, D=10%.

- building mass. Three categories are defined:
  I Heavy construction with floor and ceiling of reinforced concrete without thermal or acoustical insulation on the inner surface, textile floor covering not thicker than 10 mm, walls of brick, concrete, porous concrete blocks, etc.

  II medium construction with floor and ceiling as above. A suspended lightweight ceiling and light interior walls are possible.

III light construction using lightweight panels, wood construction, etc. or heavy construction in which the building mass is covered with thermal or accoustical insulation.

If the room is furnished very densely, it must be classified in a lighter category due to the shielding effect.

For these entries the nomogram gives the predicted maximum indoor air temperature $\vartheta_{i,max}$ (Example Fig. 7) or the overheating $\Delta\vartheta$ (Example Fig. 8).

If this temperature is too high, the designer can either decrease the solar transmittance (more shading, other glass properties) or decrease the window area.

For Swiss climatic conditions, a maximum indoor air temperature of about 30°C is generally considered as acceptable.

The orientation of the facade is not taken into account in this method because the calculations show only small differences in the maximum indoor air temperature for summer conditions. They occur of course at different hours of the day.

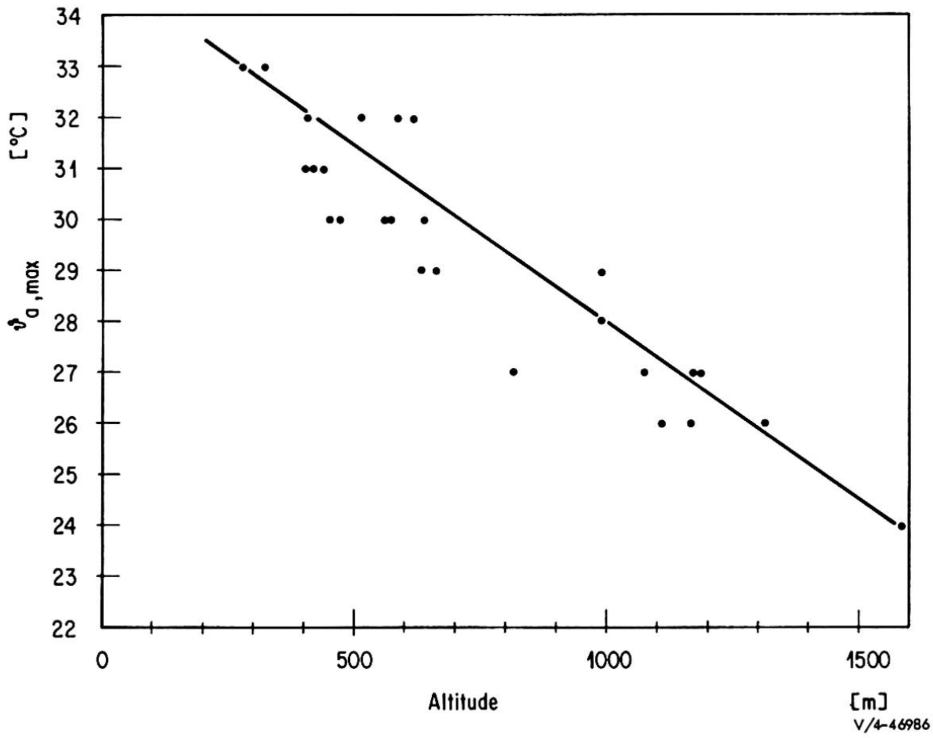


Fig. 6: Correlation between highest summer ambient air temperature and altitude for Swiss climatic conditions.

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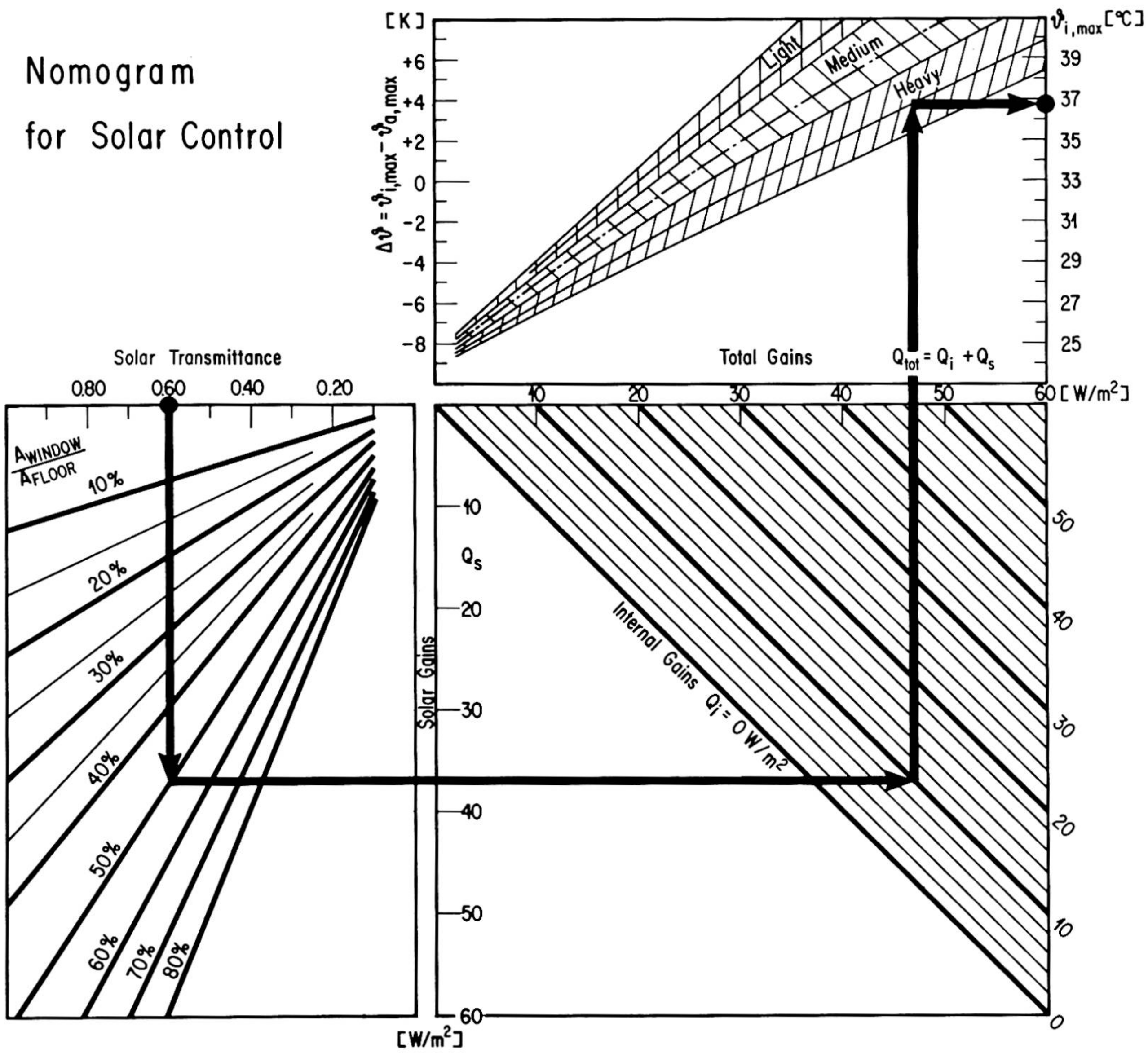

Fig. 7: Nomogram for solar control (Swiss climatic conditions)

Example A: Mid-zone room heavy construction

Location Zurich	$\vartheta_{a,max}$	=	33	°C
Solar transmittance	g	=	0.60	
Window area (south)	A_w	=	20	m²
Floor area	A_f	=	40	m²
Ratio window to floor area	A_w/A_f	=	50	%
Internal heat sources	Q_i	=	10	W/m²
Result:				
Maximum indoor air temperature	$\vartheta_{i,max}$	=	37	°C
	additional shading required			

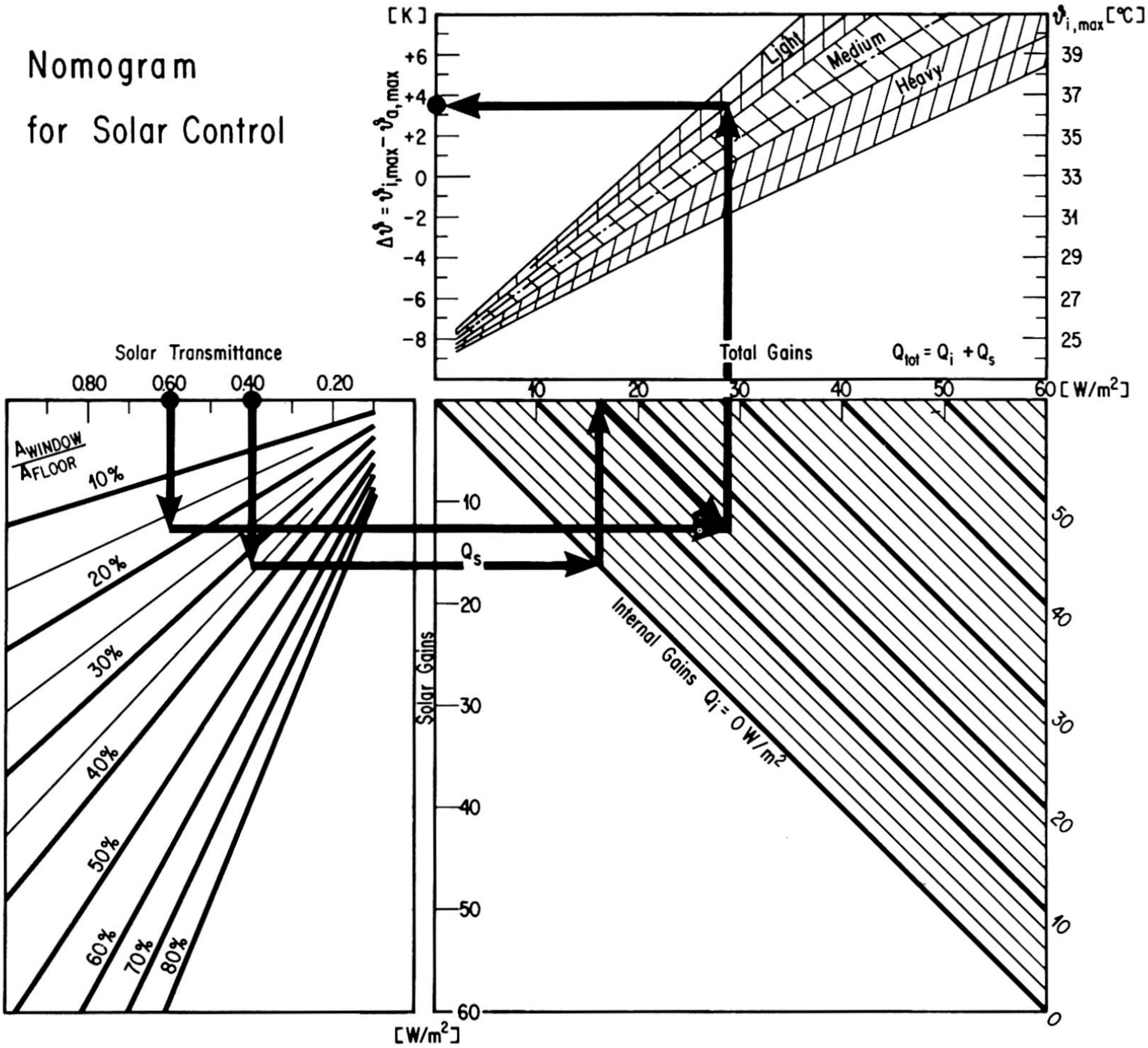

Fig. 8: Nomogram for solar control (Swiss climatic conditions)
Example B: Corner room, lightweight construction
Location 1300 m above sea level

Maximum ambient air temperature (see Fig.7)	$\vartheta_{a,max}$	=	26	°C
Solar transmittance of south windows	g_s	=	40	%
South window area	A_w	=	10	m²
Floor area	A_f	=	30	m²
Ratio window to floor area (south)	A_w/A_f	=	33	%
No internal heat gains	Q_i	=	0	W/m²
Solar transmittance of west windows	g_w	=	60	%
West window area	A_w	=	5	m²
Ratio window to floor area (west)	A_w/A_f	=	17	%

Procedure:

Step 1 - Determine solar gain from south windows	$Q_s(s)$	≅	16	W/m²
Step 2 - Determine solar gain from west windows	$Q_s(w)$	≅	12	W/m²
addition to determine total gain	Q_{tot}	≅	28	W/m²

Result:

Overheating	ϑ_Δ	≅	+3	K
Maximum indoor air temperature	$\vartheta_{i,max}$ = 26+3	≅	29	°C
			acceptable	