INTERNATIONAL ENERGY AGENCY
energy conservation in buildings and
community systems programme
Annex XII
Windows and fenestration

Step 1

Building Regulations, Standards and Codes concerning Thermal and Solar Performance of windows; a survey of eight countries

September 1986

Ann 12 1986:5

INTERNATIONAL ENERGY AGENCY

Energy Conservation in Buildings and
Community Systems Programme

Annex XII, WINDOWS AND FENESTRATION

Report from Step 1

BUILDING REGULATIONS, STANDARDS AND CODES CONCERNING THERMAL AND SOLAR PERFORMANCE OF WINDOWS;

A survey of 8 countries

This report is part of the work of the IEA Energy Conservation in Buildings & Community Systems Programme

Annex XII - Windows and Fenestration

Participants in this task:

Belgium, FR-Germany, Italy, The Netherlands (Operating Agent), Norway, Switzerland, United Kingdom, United States of America.

The complete list of representatives who have contributed to this report is given in Chapter 5.

Document : Report from work carried out under Step 1 of the project.
Distribution : Unrestricted.
Editor : H.A.L. van Dijk
TNO Institute of Applied Physics
P.O. Box 155
2600 AD DELFT
The Netherlands.
Additional copies: TNO Institute of Applied Physics.
Approximate price: Dfl 15.--.

Delft, September 1986 .

CONTENTS Page

PREFACE

INTERNATIONAL ENERGY AGENCY

In order to strengthen co-operation in the vital area of energy policy, an Agreement of an International Energy Programme was formulated among a number of industrialized countries in November 1974. The International Energy Agency (IEA) was established as an autonomous body within the Organization for Economic Co-operation and Development (CECD) to administer that agreement. Twenty-one countries are currently members of the IEA, with the Commission of the European Communities participating under special arrangement.

As one element of the International Energy Programme, the Participants undertake co-operative activities in energy research, development and demonstration. A number of new and improved energy technologies which have the potential of making significant contributions to our energy needs were identified for collaborative efforts. The IEA Committee on Energy Research and Development (CRD), assisted by a small Secretariat staff, co-ordinates the energy research, development and demonstration programme.

ENERGY CONSERVATION IN BUILDINGS AND COMMUNITY SYSTEMS

As one element of the Energy Programme, the IEA encourages research and development in a number of areas related to energy. In one of these areas, energy conservation in buildings, the IEA is encouraging various exercises to predict more accurately the energy use of buildings, including comparison of existing computer programmes, building monitoring, comparison of calculation methods, as well as air quality and inhabitant behaviour studies.

THE EXECUTIVE COMMITTEE

Overall control of the R & D programme energy conservation in buildings and community systems is maintained by an Executive Committee, which not only monitors existing projects but identifies new areas where collaborative effort may be beneficial. The Executive Committee ensures all projects fit into a predetermined strategy without unnecessary overlap or duplication but with effective liaison and communication.

ANNEX XII

In June 1982 the Executive Committee approved Annex XII, 'Windows and Fenestration' as a new joint effort project, with the Netherlands acting as 'Operating Agent' to coordinate the work.
The following countries are participating in the project:

BELGIUM, FEDERAL REPUBLIC OF GERMANY, ITALY, THE NETHERLANDS, NORWAY, SWITZERLAND, UNITED KINGDOM, UNITED STATES.

The project consists of 5 steps:

Step 1: Survey the state of the art in all types of existing windows and future designs (including glazing and combination of glazings and insulating and/or sunshading systems).

Step 2: Survey the state of the art in thermal and solar properties of windows and compare definitions, test methods, calculation procedures and measured, calculated or assumed data, wherever possible converted into one or several sets of standardized conditions. The aim: to try and cover all existing (and sometimes conflicting) information in this field in an extensive report for 'expert groups'.
A separate report contains summarized information for general use among architects, consultants and manufacturers.

Step 3: Review and analyze existing simplified steady-state calculation methods dealing with heat gains and losses through window systems. These methods can provide a preliminary and global figure for the influence of the window on energy consumption without considering the interaction with the building, occupants and climate in a detailed way.

Step 4: Adapt and compare existing dynamic calculation methods dealing with the influence of window type, size and orientation on energy consumption and thermal comfort in buildings.

Normally, a good window design will often be treated with a global approximation, with the consequence that specific features of the design cannot be revealed properly. With a study specifically focussed on windows complex systems also can be simulated, like multilayer systems with foils, coatings and/or gas-fillings and e.g. systems in which the control of an openable window, insulation panel, or sunshading is associated with indoor temperature and/or time and/or intensity of solar radiation. A thorough consideration of the effect of windows calls for a calculation model that can handle such simulation.

Step 5: Apply unsteady state models in a series of selected, general sensitivity studies and thereby produce extensive information on optimal window design from an energy point of view for different buildings (mass, insulation), occupants" behaviour schemes (control of equipment, internal heat) and climatic zones. The results are aimed at groups like architects, manufacturers and policy makers.

1. INTRODUCTION

This report presents some of the results from the first step of the project.

The aim of this report is to get a rough view on how regulations, standards and codes are used as tools to guide the application of energy efficient windows in the respective countries participating in the research project.
For more extensive and precise information on the subjects covered in this report one should refer to the relevant literature sources listed in this document.

In a separate report the state-of-the-art in existing windows and new window designs is described.

2. SURVEY OF AVAILABLE REQUIREMENTS

2.1. Global review

A global review of available requirements, standards and guidelines is presented in table 1a for the residential sector, in table 1b for other building types.

2.2. Graphical presentation

2.2.1. Introduction

The figures on the next pages present a comparison of the maximum or minimum values which are mandatory or recommended in the various countries.

In many cases the requirements are not so simple that they can be presented by a single curve in a graph. In these cases typical examples were selected to allow for a more or less quantitative comparison.

In other cases regional differences occur. Also in these cases typical examples were selected.

In the notes next to the graphs the meaning of each of the curves is explained.

For the USA additional general remarks are presented in chapter 3.

Table 1a: Survey of available requirements.
A: Residential buildings.

	COUNTRY							
SUBJECT	B	D	I	NL	N	CH	UK	USA(3)
Minimum daylighting (e.g. min. window area	r	R	r	R	-	R(1)	r	R
Reference [Number] *	B1	D1	I21	NL1,2		CH1	UK1	US1
Max. thermal transmission thr. windows or façades (U-value)	S	R	-	R	R	R	R	R
Reference [Number]	B2	D2,3		NL2,3	N1	CH2,3	UK2	US2
Max. net heat loss thr. windows (e.g. equivalent U-value)	-	r	-	-	R	S	-	-
Reference [Number]		D7			N1,2	CH3		
Max. overall transmission or energy consumption (e.g. mean U-value or G-factor)	R	R	R	R	-	S	-	-
Reference [Number]	B3,4	D2,3	I5,6,7	NL2,3		CH3		
Max. thermal load in summer (e.g. max. window area)	R	R	r	r(2)	-	-	-	R
Reference [Number]	B10	D2	I21	-				US2
Min. airtightness of windows (e.g. max. leakage factor)	R	R	S	R	R	R	S	R
Reference [Number]	B5,6,7	D3,4	I9,10,11	NL4	N1	CH5,2	UK7	US2
Min. airtightness of building (e.g. max. leakage factor)	-	R	-	-	R	-	-	-(4)
Reference [Number]		D8			N1			US2
Min. acoustic insulation (e.g. dB attenuation)	S	R	-	E	-	R	R	-
Reference [Number]	B8,9	D5		NL2,5,6		CH4	UK5	
Min. safety requirements	-	R	S	-	-	-	S	R
Reference [Number]		D6	I18				UK6	US1
Fire	-	R	S	-	-	-	R	-
Reference [number]		D9	I19				UK4	

R : Mandatory requirements available
S : Model standard or equivalent (e.g. generally used national or regional guidelines available)
r : Other sources with recommendations available
E : Requirements and/or guidelines only applicable for exceptional cases.

Notes:

(1): Different per region
(2): Requirements exists for government buildings
(3): Typical situation, see chapter 3
(4): Caulking and weather stripping required

---

*) see list of references on final pages.

Table 1b: Survey of available requirements.
B: Other buildings.

	COUNTRY							
SUBJECT	B	D	I	NL	N	CH	UK	USA(3)
Minimum daylighting (e.g. min. window area	r	R	r	-	-	R(1)	r	R
Reference [Number] *	B1	D1	I17,23			CH1	UK1	US1
Max. thermal transmission thr. windows or façades (U-value)	S	R	r	r(2)	R	R	R	R
Reference [Number]	B2	D2,3	I17,23		N1	CH2,3	UK3	US2
Max. net heat loss thr. windows (e.g. equivalent U-value)	-	r	r	-	R	S	-	-
Reference [Number]		D7	I21		N1,2	CH3		
Max. overall transmission or energy consumption (e.g. mean U-value or G-factor)	R	R	R	r(2)	-	S	-	-
Reference [Number]	B3,4	D2,3	I5,6,7			CH3		
Max. thermal load in summer (e.g. max. window area)	R	R	r	r	R	-	-	R
Reference [Number]	B10	D2	I17,23	NL7	N1			US2
Min. airtightness of windows (e.g. max. leakage factor)	R	R	S	R	R	R	S	R
Reference [Number]	B5,6,7	D3,4	I9,10,11	NL4,8	N1	CH5,2	UK7	US2
Min. airtightness of building (e.g. max. leakage factor)	R	R	-	R(2)	R	-	-	-(4)
Reference [Number]	B5,6,7	D8		NL8	N1			US2
Min. acoustic insulation (e.g. dB attenuation)	S	R	r	-	-	R	-	-
Reference [Number]	B8,9	D5	I22			CH4		
Min. safety requirements	-	R	r	-	-	-	S	R
Reference [Number]		D6	117,18				UK6	US1
Fire	-	R	S	-	-	-	R	-
Reference [number]		D9	I19				UK4	

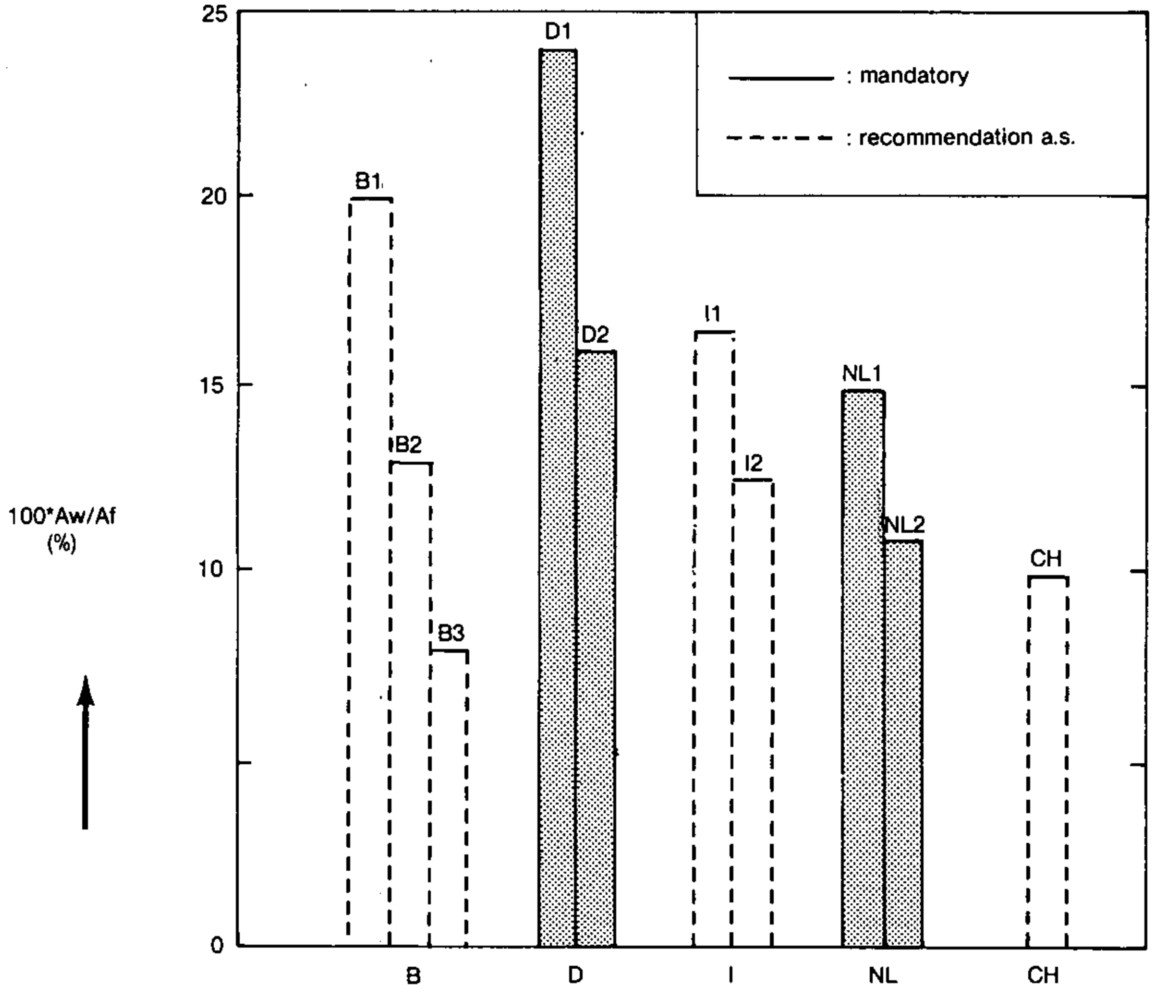
R : Mandatory requirements available
S : Model standard or equivalent (e.g. generally used national or regional guidelines available)
r : Other sources with recommendations available
E : Requirements and/or guidelines only applicable for exceptional cases.

Notes:

(1): Different per region
(2): Requirements exists for government buildings
(3): Typical situation, see chapter 3
(4): Caulking and weather stripping required

---

*) see list of references on final pages.



100*Aw/Af: minimum window area as percentage of floor area

Figure 1: Minimum window area for daylighting.

2.2.2. Minimum window area for daylighting

See figure 1.

Notes:

B: Ref [B1] is a draft proposal text for the local authorities. Each municipality can accept, change or refuse the text as part of the requirements for obtaining a building permission.
B1: for office buildings.
B2: dwellings: vertical windows.
B3: dwellings: horizontal windows.

D: Examples for unobstructed view, dwellings:
D1: room h x b x d = 2.8 x 3.5 x 6.0 m^3
D2: 2.8 x 6.0 x 3.5 m^3

For obstructed view higher minimum window areas are required. DIN 5034 fixes the minimum window area dependent on the room geometry (width, length and height).

I: Recommended values for residential buildings are: A_w/A_f = 1/6 - 1/8. Regulations for public sector residential buildings [I21] require "daylight factor" = 0.05 for different types of rooms. For non residential buildings (mainly schools and hospitals) different values of "daylight factor" are required for different types of rooms.

NL: NL1: living room.
NL2: other rooms.

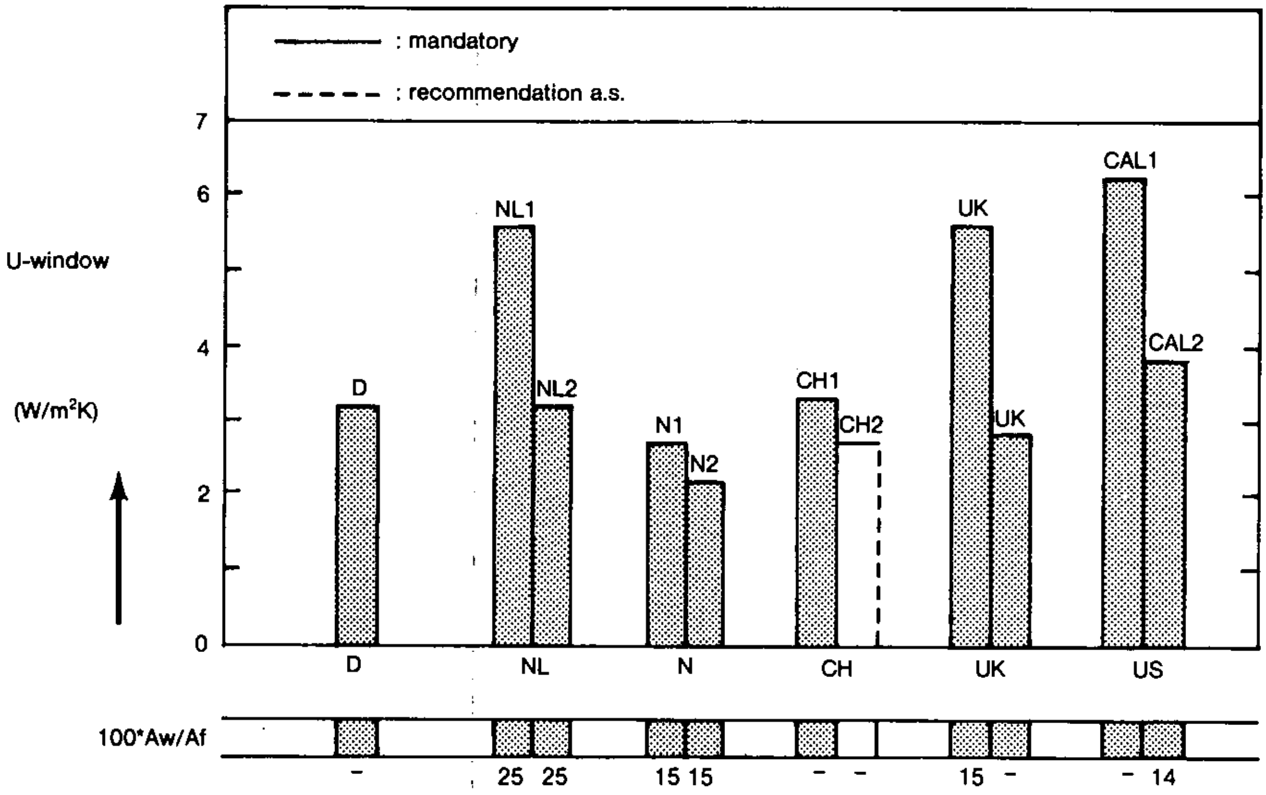
For obstructed view higher minimum window areas are required; the same for windows with a basis below 0.85 m height from the floor. Alternative: more complex calculation ([NL1]).

N: --

CH: Typical minimum value is 10% of the floor area; different per building regulation community.

UK: Minimum daylight factors recommended ([UK1]).

US: --



U-window: maximum U-value of windows
100*Aw/Af: maximum window area as percentage of floor area for windows with maximum U-value

Figure 2: Maximum U-value of windows.

2.2.3. Maximum U-value of windows

See figure 2.

Notes:

B : --

D : The requirements in the "Wärmeschutzverordnung 1.1.84" are in any case:
Maximum U-value window = 3.1 W/m^2K
(buildings with normal indoor temperatures).

NL: NL1: bedrooms, etc.
NL2: living room.
A_w/A_f must be less than 0.25.
Alternative: see U-building.

N : Residential buildings.
N1: U-value must not exceed 2.7 W/m^2K,
if walls have U = 0.25 W/m^2K.
N2: U-values must not exceed 2.1 W/m^2K,
if walls have U = 0.35 W/m^2K.

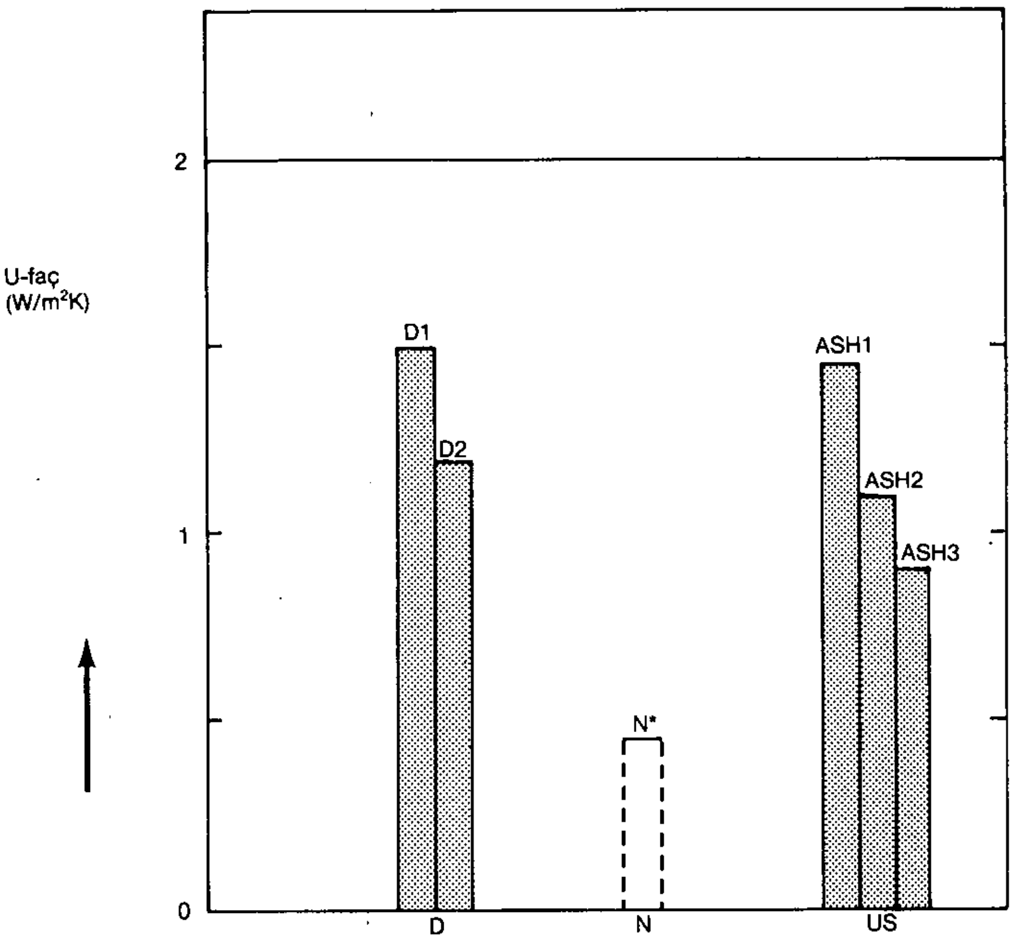
Above ratio 0.15 more insulation is needed either in windows or other parts of the building.

CH: CH1: Recommendation SIA 180/1 (1980).
CH2: Recommended minimum value SIA 380/1 (1984).

UK: Building regulations: energy trade off will be permitted; in revision; estimated for 100 m^2 floor area house.
Scotland slightly different.

US: CAL: Alternative component package for the energy budget requirements in California, for residential buildings.
Schematized situation for coastal zones:

	either:	CAL1 or:	CAL2
glazing:			
max. U-value	W/m^2K	6.2	3.7
max. total area	% of floor area	-	14
max. non-south facing area	"	9.6	-
min. south facing area (or horizontal)	"	6.4	-



U-faç: maximum U-value of façades
*: U-façade calculated with U-equiv. for the window, see notes

Figure 3: Maximum U-value of façades.

2.2.4. Maximum U-value of façades

See figure 3.

Notes:

B: Only maximum U-value of opaque walls, as a function of the weight.

D: In the German "Wärmeschutzverordnung" there are two alternatives as prove methods:

Alternative 1: Only prove about overall U-value building.
Alternative 2: The maximum U-value façade (wall and window) must be between 1.2 - 1.5 W/m^2.K (Bars D1 and D2), depending on the size of the building.

I : Only for opaque part, as a function of the weight ([I17, I21, I23]).

NL: --

N : Commercial and appartment buildings.
Mean U-values of façades less than 0.45 W/m^2, including windows with or withhout equivalent U-value.

Equivalent U-values can be used for calculation of mean U-values until 0.15 window/floor areas. Above 0.15 normal U-values must be used.
Equivalent U-values W/m^{2}K from [N1] and [N2]:

	double	triple
south	0,0	-0,6
east, west	0,8	0,4
north	2,3	1,5

A revision of the regulations is underway in which U-equivalent no longer appears.

CH: --

UK: --

US: CAL: --
ASH: ASHRAE Standard ([US2]); see chapter 3: Curves as function of degree days. Examples for residential buildings:
ASH1: for locations with 1100 degree days (18 °C base): U = 1.45 (more than 3 stories: 2.0);
ASH2: for locations with 2800 degree days (18 °C base): U = 1.1 (more than 3 stories: 1.6);
ASH3: for locations with 4400 degree days (18 °C base): U = 0.9 (more than 3 stories: 1.3).
Examples of degree days: Chicago: 2300; Seattle: 2400; New York: 2700; S. Francisco: 1700; Houston: 800.

2.2.5. Maximum equivalent U-value of windows

See figure 4.

Notes:

B: --

D: Concerning a maximum equivalent U-value of windows Germany only has recommendations with respect to the calculation procedure. Moreover, there is no dependence of Aw/Af to U-eq in the German recommendations.
The equivalent U-value windows is defined as ([D10]):

$$U_{eq} = U_{window} - S_F \cdot g_w$$

with : S_F: see table
g_w: total solar transmittance of the window

	S_F (W/m² K)
North	1.2
West/East	1.8
South	2.4

D1: north oriented window.

NL: See note on overall U-value buildings.

N : No maximum value on U-equivalent itself; the U-equivalent is used in the calculation of the U-value façade (see note there).
A revision is underway in which the U-equivalent no longer appears.

CH: --

UK: --

US: --

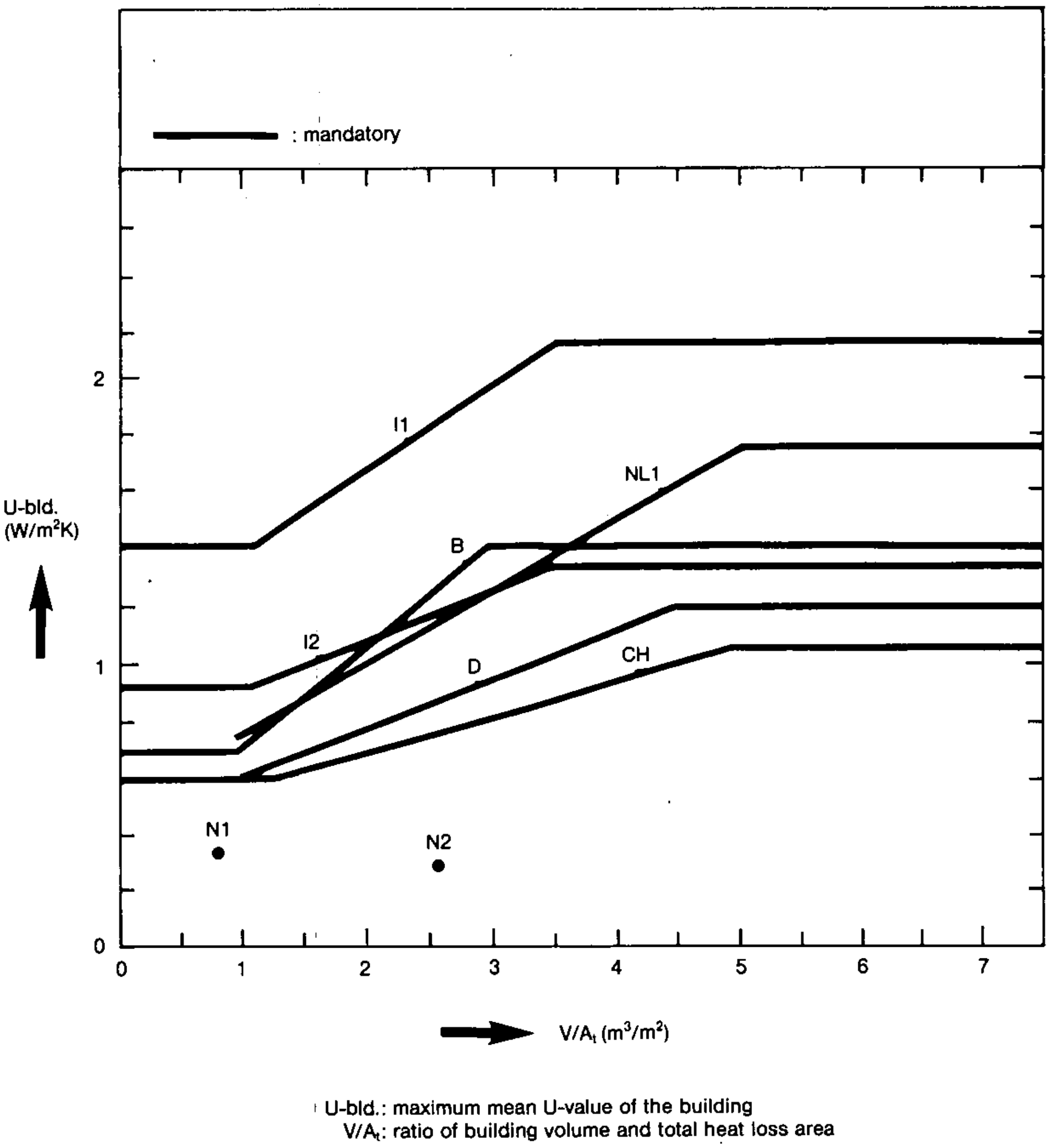


Figure 5: Maximum overall U-value of the building.

2.2.6. Maximum overall U-value of buildings

See figure 5.

Notes:

B: Only for the French region and the National Housing Society.

D: In the German "Wärmeschutzverordnung" there are two alternatives as prove methods:

Alternative 1: Prove about overall U-value building: see curve in figure 5.
Alternative 2: The maximum U-value façade (wall and window) must be between 1.2 - 1.5 W/m^2 K. (See note with figure 4).

I: I1: for mild climates (Degree-days $< 600\,^\circ$C.day)
I2: for cold climates (Degree-days $> 3000\,^\circ$C.day)

NL: Alternative for maximum U-value of windows and other constructions. In fact the alternative is: maximum value on 'thermal insulation index' I_t [NL3],

$$I_t = \frac{80 \frac{At}{V} (1 - \bar{U}) + 30}{4 \frac{At}{V} + 1}$$, in which $\bar{U}$: overall U-value of building

Under preparation is an addition to [NL3] in which a minimum will be required for $(I_t + I_z)$ in which I_z is the 'solar index', taking into account extra solar gains through windows.

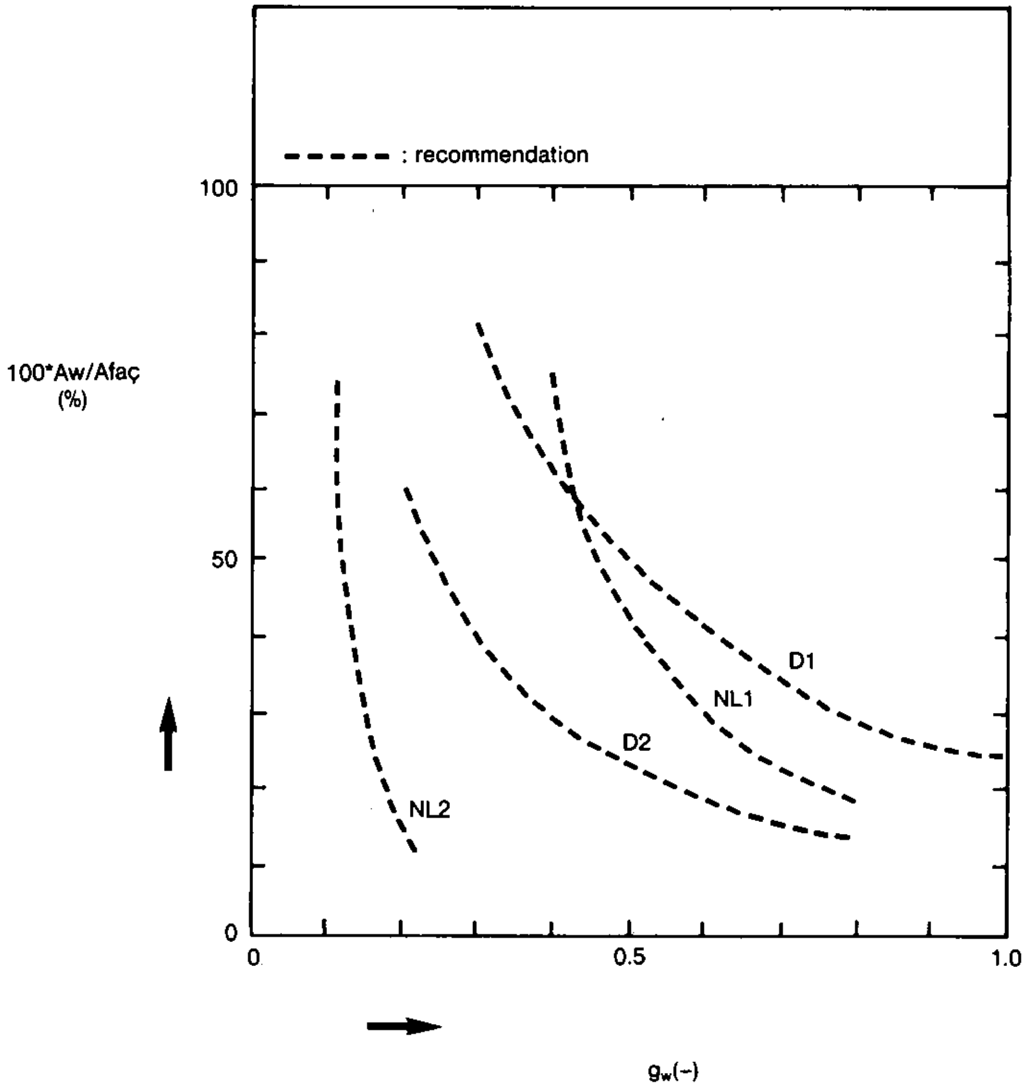
N: No recommendations but 2 examples are presented:

N1: Residential building 120 m^2 $U \approx 0.37$ W/m^2K
N2: Commercial building 1000 m^2 $U \approx 0.33$ W/m^2K

CH: $U_{max} = 0.75 \times C_1 \times C_2 \times C_3$,
with $C_1 = f$ (V/At)
$C_2 = f$ (altitude), example $C_2 = 1$ (alt. = 500 m)
$C_3 = f$ (indoor temp.), example $C_3 = 1$ ($T_i = 20\,^\circ$C).

UK: --

US: CAL: Energy budget requirements, California.



100*Aw/Afaç: maximum window area as percentage of façade area
g_w: solar energy transmission coefficient of the window

Figure 6: Summer situation: maximum window area to prevent overheating.

2.2.7. Maximum window area in combination with solar transmittance for summer conditions.

See figure 6.

Notes:

B: Only for the public building sector.
Acceptable combinations:

	for I =	max. solar transm. g_w	max. window/ floor area
I	< 0.5	0.15	1.0
II	0.5 - 3	0.50	1.0
III	any value	0.80	0.25
IV	< 1.5	0.80	0.15

$$I = \frac{\text{"effective surface" for heat storage } (m^2)}{\text{floor surface } (m^2)} = \frac{A_{ef}}{A_f}$$

$A_{ef} = \sum A.f$

A = surface of each wall
f = coefficient which is a function of the wall type, e.g.:
heavy weight uninsulated layer at the inner side: f = 1;
very light weight and/or insulated layer at the inner side:
f = 0.

D: The German recommendations are:

the maxiumum $g_w \cdot A_w / A_{faç}$ results from the following table:

mass	without raised natural convection	with raised natural convection
light	0.12 (curve D2)	0.17
heavy	0.14	0.25 (curve D1)

The curves D1 and D2 are valid for values of the total solar transmission coefficient g within the range 0,2 to 0,8 [D2].

I: According to [I17], [I21] and [I23] the window shall be provided with an external ventilated shield (rolling shutter meets this requirement) so that the solar heat flux entering the room is less than 30 percent of the corresponding flux without the shield.

NL: Dwellings: under preparation.
Office buildings: NL1: example for single glazing, no indoor blinds, high mass, high air movement.
NL2: example for double glazing, indoor blinds, low mass, low air movement.

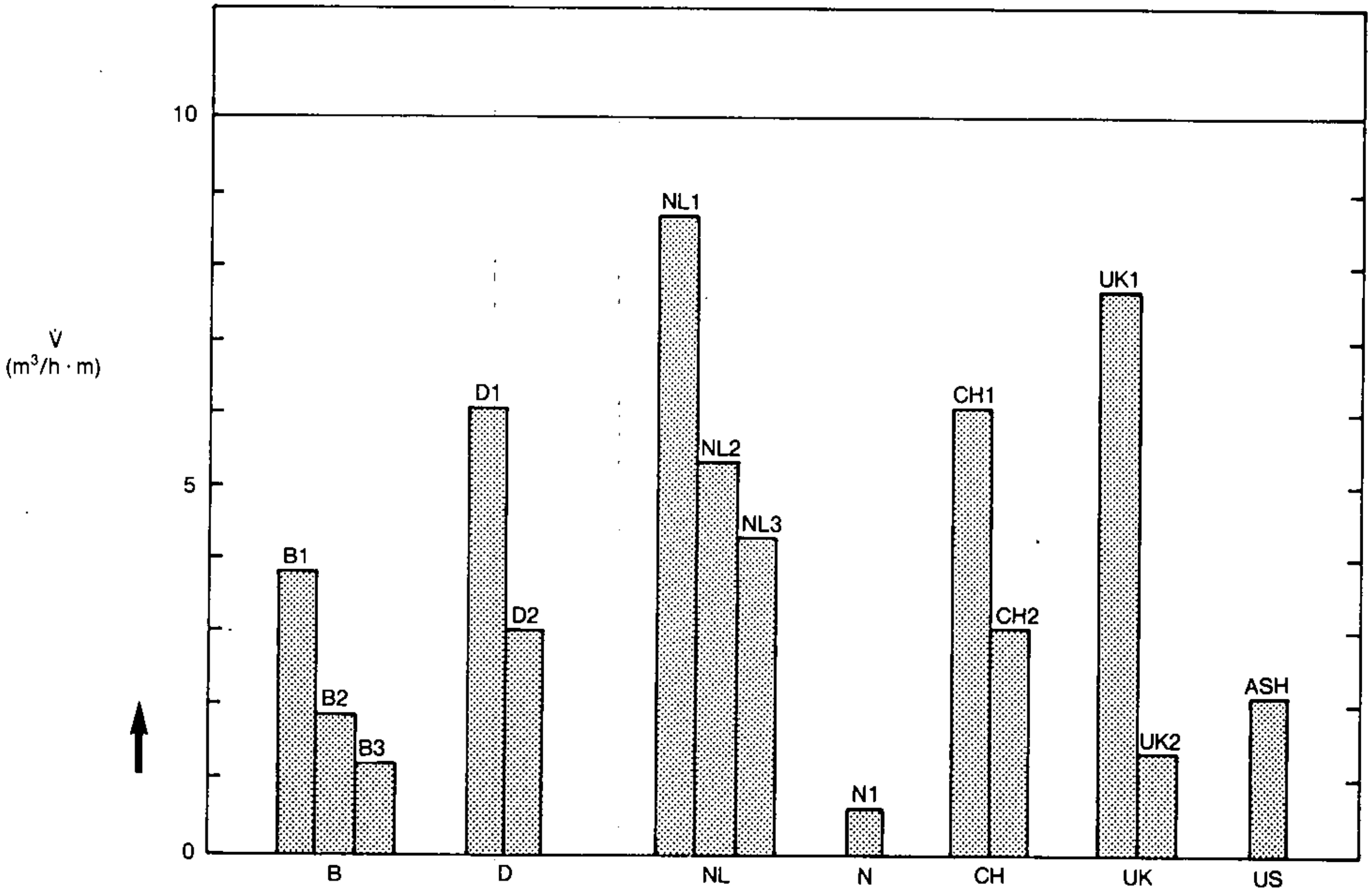
N: No regulations, but installation of cooling power is not allowed.

CH: Standard is under preparation.

UK: --

US: CAL: Alternative Component Package for the Energy budget requirements in California, for residential buildings.

Required: for coastal zones in southern California and inland zones in northern California, south and west facing windows:
fully shaded at August 21 (south: noon; west: 5 p.m.), but fully exposed on December 21 (south: noon; west: 3 p.m.),
or: operable shadings with max. shading coefficient of glazing: 0.36 (solar transmittance g_w = 0.3).
For coastal zones in northern California no requirements.



$\dot{V}$: maximum air leakage per m¹ crack at 50 Pa pressure difference
N.B.: maximum air leakage rates at pressure differences other than 50 Pa have been transformed to 50 Pa, using the relation:
$\dot{V}(50) = \dot{V}(P1) * (50/P1)^n$; in all cases here $n = 2/3$

Figure 7: Maximum window air leakage rates of windows.

2.2.8. Maximum air leakage through windows

See figure 7.

Notes:

B: Mandatory for public building sector [B5]:
Maximum rate of leakage at 100 Pa for different grades of windows:

	B1	B2	B3
Class	PA2	PA 2 B	PA 3
Exposure level-height of building in which the window is situated (m)	0-10	10 - 18	> 18
Air permeability of joints per meter crack-length (m^3/h m)	6	3	2

D: From [D3], [D4]: the maximum air leakage coefficient per m crack-length, a-max, is:

	Building height	a max (m^3/h m Pa 2/3)	test pressure (Pa)	window classif.
D1	< 8	0.44	150	A
D2	8 - 20	0.22	300	B
	> 20	0.22	600	C

NL: The air leakage per m crack-length must not exceed 18 m^3/h m, with a specified test pressure.
Test pressure depends on building height and location ([NL4]).

NL1: Example for building h = 15 m and location inlands: testpressure 150 Pa.

NL2: Example for building h = 15 m and location near coast: test pressure 300 Pa.

For government buildings the maximum air leakage per m^1 cracklength is 9 m^3/h m, for a crack density in the façade of less than 0.6 m^1 per m^2 [NL8]. For higher densities the formula $\dot{V}_{max}$ = 0.6/lc . 9.0 m^3/h m should be applied, with l_c = crack length per m^2 façade.

NL3: Example for government building h = 15 m., location inlands, $l_c < 0.6$ m^1/m^2.

N: Maximum air leakage - expressed as function of the window area - is 1.7 m^3/m^2h at 50 Pa test pressure, both for commercial and residential buildings [N1].

N1: value per m^1 crack-length for a 1.2 x 1.2 m^2 window.

CH: From [CH2]: the maximum air leakage coefficient per m^1 crack-length, a-max, is:

	building height [m]	a-max [m^3/hmPa$^{2/3}$]	test pressures [Pa]
CH1	< 8	0.44	150
CH2	8 - 20	0.22	300
	> 20	0.22	600

UK: From [UK7]: four categories ranging from: maximum air leakage coefficient, a max:

UK1: a-max = 0.56 m^3/hmPa$^{2/3}$ at test pressure 150 Pa (Class I)

UK2: a-max = 0.10 m^3/hmPa$^{2/3}$ at test pressure 600 Pa (Class IV)

3. ENERGY CONSERVATION STANDARDS IN THE U.S.A.

The matter of energy conservation standards in the U.S. is complicated by the great geographic, legal and administrative diversity of the country. There is considerable technical uniformity, in the sense that two technically equivalent guideline standards, ASHRAE 90 and the Model Energy Code, exist - each with periodical updates and modifications. The complications arise when one asks what is mandatory as opposed to voluntary, and where.

Building standards in the U.S. are set for county or municipal level. Historically this sometimes resulted in great disparities in requirements - for example, rural areas may have few or no requirements, wheras other areas may have complex requirements reflecting local economic interests. Prior to 1970 standards were justified on the basis of public safety. Since most counties and cities lack the resources to develop adequate standards, the typical pattern was to make a model code mandatory, such as the Uniform Building Code, the Uniform Plumbing Code and the Uniform Electrical Building Code in those areas where it was considered necessary to have a standard and where there were no compelling local interests to organise things differently. The traditional pattern, therefore, is basically a uniform set of standards with local variances (which may include having the option of no standards what so ever).

Energy standards follow the same pattern, except that the variances tend to be less, and there are more areas where states have chosen to pre-empt localities and apply mandatory state-wide standards. An excellent reference [US5] summarizes this situation.

Some 28 states have mandatory energy standards, derived from some version of either the ASHRAE 90 [US2] or the Model Energy Code [US4]. Another 22 states have mandatory codes for state-owned and/or financed buildings, wheras in 15 states the energy codes are adopted (or not) by local governments. Again, most of these are derived from ASHRAE 90 or the Model Energy Code. At the other end of the scale, Maine has only guideline state standards, Vermont has no standards applying to privately financed buildings, Louisiana has an energy code which has not yet been adopted, and Tennessee has standards applying only to non-residential buildings.

It is therefore justified to say that the ASHRAE 90 standards represent the best approximation of the typical U.S. case. In the reference documents ASHRAE 90-80 is used, although states frequently derive their standards from ASHRAE 90-75 and a newer version, ASHRAE 90P, which is currently being reviewed.

The ASHRAE 90-75 building standard was a prescriptive standard in which minimum or maximum performance levels were specified for many building components and systems. The "envelope" section of the standard set maximum average U-values for walls and roofs, including window and skylight systems. These values varied with location and climate in the U.S., decreasing in value as the climate increased in severity. This part of the standard forced many designers to select double glazing instead of single glazing if reasonable window areas were to be allowed (note that in the early 1970s about 70% of all windows were still single glazed).

A second requirement, for climates where cooling was a more significant problem, limited the overall solar heat gain by placing restrictions on the product of shading coefficients and area, with orientation as a variable. Depending on location, either the U-value or the solar gain term could be the constraint. Air infiltration was addressed by referencing standard industry specifications.
No adjustments were made to offset heat loss for winter solar gain, nor was an allowance made for day lighting benefits in the envelope section.
Designers who wanted to obtain an energy credit for passive solar design, day lighting, or other non-standard energy-saving features, had to prove, using annual energy simulation techniques, that the proposed design required less energy annually than a similar design which met the prescriptive standard. Since this approach involved a significant increase in design time, it was not commonly used.

A recent shift in the approach of standards has been the development of a "performance" approach. In this case, an annual energy budget is alloted to the building and the designer is free to choose any combination of building features provided the final result is less than or equal to the budget. Budgets must be set for each climate zone and each building type. This approach requires that standard occupancy and operating conditions be defined, and that recognized calculation procedures are available. To simplify this further, "alternative prescriptive packages" are created. Which implies that if the requirements of that package are met, it is considered to comply with the annual energy budget without the need for calculations (e.g. California).

ASHRAE is now in the process of revising Standard 90-80 to include many of the features of these performance-based approaches. It should, for example, provide an energy credit for the use of day lighting. There is an increasing notion in the standards development process that requirements for energy efficiency should not reduce environmental quality below "acceptable" levels. This tends to set lower bounds on window size in office buildings, for example.

The California State Energy Code [US3] probably represents the most stringent set of requirements currently in force in the U.S. For both residential and non-residential buildings this code provides a set of climate dependent energy budgets. There are no requirements on individual components, so long as the building can be shown to meet the overall performance requirements. As an alternative to this procedure, for non-residential buildings the thermal characteristics of the envelope are specified, including the maximum overall average U-value of walls including windows. Overall thermal transfer through walls for cooled spaces is also limited and this includes the transfer through windows. Non-residential buildings which derive more than 40% of their annual thermal energy usage for renewable energy sources automatically satisfy the standards.

For residential buildings, as an alternative to the overall energy budget the state is divided into 16 climate zones and three "alternative component packages" are provided for each zone. These may place either U-value or total glazing area limits on fenestration and may also require shading (see relevant graphs and notes in chapter 2).

4. LIST OF REFERENCES

Belgium:

[B1] Model Building Requirements, 2nd part. Association of the Belgian municipalities, 1978.

[B2] NBN B62-001, Hygrothermal characteristics of buildings. Winter conditions.

[B3] Ministerial decision 29-02-1984. Belgian Statute Book 31-10-1984.

[B4] NBN B62-301, Thermal Insulation of Buildings. Global insulation level.

[B5] STS 52.0, External Joinery - General principles. Draft 1983 (*).

[B6] STS 36. Metal-clad woodwork, frames, light, weight façades and window frames (*).

[B7] STS 52, Timber cladding, windows, french-window and leight-weight façades (*).

[B8] NBS S 01-400, Sound insulation.

[B9] NBN S 01-401, Maximal noise levels in buildings.

[B10] STS 23, Wooden structures - addendum and remark (*).

(*) Service for Agreement and Specifications.
Ministry Public Works, Regie des Bâtiments, Brussels.

FR Germany:

[D1] DIN 5034 Tageslicht in Innenräumen
Daylighting in interior rooms
Part 1 Feb. 83/ Part 2 Feb. 85/ Part 4 Draft Dec. 81
Part 5 Draft Sept. 83/ Supplement 1 Nov. 83/
Supplement 2 June 66

[D2] DIN 4108 Wärmeschutz im Hochbau
Thermal insulation in building construction
Part 1/2/3 Aug. 81/ Part 4 Dec. 85/ Part 5 Aug. 81/
Supplement 1 Apr. 82/

[D3] Verordnung über einen energiesparenden Wärmeschutz im Hochbau
(01.01.1984).
Decret about an energy saving thermal protection in building
constructions.

[D4] DIN 18055 Fenster: Fugendurchlässigkeit, Schlagregensicherheit
und mechanische Beanspruchung.
Windows: Air permeability, water tightness and
mechanical demand.
Oct. 81.

[D5] DIN 4109 Schallschutz im Hochbau.
Sound insulation in building construction.
Part 1/2/3 Sep. 62/ Part 5 Apr. 63/ with supplement
Sept. 75/
Part 1/2/3/5/6/7 Draft Oct. 84.

[D6] DIN 52290 Angriffshemmende Verglasung
Attack blocking types of glazing
Part 1/2 May 81/ Part 3/4 June 84

[D7] Gertis K. Passive Solarenergienutzung - Umsetzung von
Forschungserkenntnissen in den praktischen
Gebäudeentwurf,
Bauphysik, 5 (1983), Heft 6, S. 183 - 194.

[D8] DIN 4701 Regeln für die Berechnung des Wärmebedarfs von Gebäuden.
Regulation for the calculation of the heat demand of buildings.
Part 1/2 March 83

[D9] DIN 4102 Brandverhalten von Baustoffen und Bauteilen
Fire characteristics of building materials and compound units.
Supplement 1 May 81/ Part 1 May 81/ Part 2/3 Sept. 77/ Part 4 March 81/ Part 5/6/7 Sept. 77/ Part 7 Draft April 85/ Part 8 Draft Sept. 84/ Part 11 Dec. 85.

[D10] Gertis, K; Hauser, G.; Künzel, H.; Nikolic, V.; Rouvel, L. und Werner, H.: Energetische Beurteilung von Fenstern während der Heizperiode. DAB 12 (1980), H. 2, S. 201 - 202; DBZ 114 (1980), H. 2, S. 66 - 68; Glasforum 30 (1980), H. 1, S. 38 - 44; Glas + Rahmen (1980), H. 4, S. 180 - 186.

ITALY

[I1] UNI 7885 "Tests on glass - Determination of the transmission factors of the solar energy".

[I2] UNI 8034 "Tests on glass - Determination of light transmission by illuminant A, with a spectrophotometer".

[I3] UNI 6534-74 "Glazing and fixing of glass for building design, materials and laying".

[I4] UNI 7144-79 "Flat glass - Thermal insulation".

[I5] L. 373, 30/4/1976 "Regulations for limiting thermal energy consumption in buildings".

[I6] D.P.R. No. 1052, 28/6/1977 "Rules to enforce Law No. 373, 30/4/1976, concerning thermal energy consumption in buildings".

[I7] D.M. 10/3/1977 "Determination of the climatic zones and of minimum and maximum values of the relative overall heat loss coefficients per unit volume".

[I8] UNI 7357 "Rules for the computation of heat requirements in the buildings's heating".

[I9] UNI EN-42 "Methods of testing windows - Air permeability test".

[I10] UNI CE-0015 "Fenestration classification criteria for air permeability, water tightness and wind pressure resistance".

[I11] UNI EN-86 "Methods of testing windows - Water tightness test under static pressure".

[I12] UNI en-77 "Methods of testing windows - Wind resistance test".

[I13] UNI 7170-73 "Flat glass - Acoustic insulation".

[I14] UNI 8204 "Building - External windows classifications based on acoustical performance".

[I15] UNI 8270/5 "Acoustic measurement of sound insulation in buildings and building elements. Field measurement of airborne sound insulation of façades and façade elements".

[I16] Circ. No. 1769, Ministry of Public Works "Criteria for evaluating and testing acoustical requirements in buildings" (1966).

[I17] D.M. 18/12/1975 "Technical norms concerning educational buildings".

[I18] UNI 7697 "Flat glass in building practice - Safety criteria".

[I19] UNI-ISO 3008 "Fire resistance tests - Doors and other fixtures".

[I20] UNI-ISO 3009 "Glass elements".

[I21] Circ. No. 3151, Ministry of Public Works "Criteria for evaluating thermal, hygrometric, ventilation and daylighting performance in buildings" (1967).

[I22] Circ. No. 3150, Ministry of Public Works "Criteria for evaluating and testing acoustical requirements of educational buildings" (1967).

[I23] Circ. No. 13011, Ministry of Public Works "Technical requirements for hospitals. Thermal, hygrometric, ventilation and daylighting performance" (1974).

The Netherlands:

[NL1] V 1069 'Dagverlichting van woningen', 1953 (Day lighting of Dwellings).

[NL2] Model Bouw Verordening (Model Building Requirements).

[NL3] NEN 1068 'Thermische isolatie van gebouwen', 1981 (Thermal insulation of buildings).

[NL4] NEN 3661 'Ramen, Luchtdoorlatendheid, waterdichtheid, stijfheid en sterkte', 1975 (Windows air permeability, water tightness, rigidity and strength).

[NL5] Wet geluidshinder, 1979 (Noise abatement Act).

[NL6] Woningwet, Art. 3.7 and 85.2 (Housing Act), a.o. calculation and measuring methods on noise reduction by façades.

[NL7] SBR 74, Zon en Ramen, regels voor de keuze van raamgrootte en zonwering voor gebouwen zonder mechanische koeling, 1980 (sun and windows, guidelines for the selection of window area and solar shading for buildings without mechanical cooling).

[NL8] Richtlijn betreffende de aan de luchtdoorlatendheid van gevels te stellen eisen, rapport 262.10/L, Febr. 1984, Rijksgebouwendienst (RGD), (Guideline concerning the requirements on air permeability of façades).

Norway:

[N1] Norwegian Building Code, chapter 54, Thermal insulation and airtightness (revised November 4, 1980).

[N2] Norwegian Standard, NS 3031 "Energy and power demand for heating of buildings". Calculation rules.

Switzerland:

[CH1] Communal building regulations.

[CH2] Norm SIA 180/1 (1980), "Winterliche Wärmeschutz im Hochbau".

[CH3] Norm SIA 380/1 (1984), "Energie im Hochbau".

[CH4] Norm SIA 181, "Schallschutz in Wohnungsbau".

[CH5] Norm SIA 384/2 (1980), Wärmeleistungsbedarf von Gebäude.

United Kingdom

[UK1] BSI CP3, Chapter 1 Lighting. Part 1 Daylighting, British Standards Institution

[UK2] Building regulations April 1, 1982 (housing).

[UK3] Building regulations 1978 (1-6-1979) (other buildings).

[UK4] BS 5588, Part III.

[UK5] The noise insulation regulations 1973.
The control of pollution act 1979, part III, Noise.

[UK6] BS 6262: 1982, Glazing for Buildings. A.7 Safety.

[UK7] BS 6375 Part I, 1983, Performance of Windows: Classification for weather tightness.

[UK8] BS 5925, 1980, Code of practice. Design of Buildings: Ventilation principles and designing for natural ventilation (formerly CP3, CK.1.c).

United States:

[US1] Uniform Building Code, International Conference of Building Officials,
5360 South Workman Mill Road, Whittier, CA 90601, 1985 ed.

[US2] ASHRAE Standard 90-80, Energy Conservation in New Building Design, American Society of Heating, Refrigerating and Air Conditioning Engineering Inc.,
1791 Tule Circle, NE, Atlanta, GA 30329.

[US3] California Administrative Code, Title 24, Chapter 2-53, Office of Administrative Procedure, Dept. of General Services, State of California,
P.O. Box 20191, Sacramento, CA 95820.

[US4] Model Code for Energy Conservation in New Building Construction, 1977 (MCEC), developed by National Conference of States on Building Codes and Standards.

[US5] Directory and Compilation of Technical and Administrative Requirements in Energy Codes of New Building Construction used within the United States, David R. Conover & Carolyn A. Fitch, eds.
National Conference of States on Building Codes & Standards, 481 Carlisle Drive, Herndon, VA 22070.

5. PARTICIPANTS

The following participants were involved in this part of the research project:

NAME	AFFILIATION	ADDRESS	COUNTRY
J. Dubois, F. Henderieckx, R. Liekens, P. Wouters	Belgian Building Research Institute	Lombardstraat 41 B-1000 BRUSSEL	BELGIUM
H. Erhorn, R. Stricker, M. Szerman	Fraunhofer Institut für Bauphysik, Dir.Prof.Dr.-Ing. habil, K.A. Gertis	Nobelstrasse 12 D-7000 STUTTGART 80	FR GERMANY
P. Brunello	Istituto di Fisica Tecnica	Viale Ungheria 43 I-35100 UDINE	ITALY
R. Zecchin	Istituto di Fisica Tecnica Università di Padova	Via Marzolo 9 35100 PADOVA	ITALY
H.A.L. van Dijk	TNO Institute of Applied Physics (TPD)	Stieltjesweg 1 2600 AD DELFT	THE NETHERLANDS
A. Nielsen	Norwegian Building Research Institute	Hogskoleringen 7 N-7034 TRONDHEIM-NTH	NORWAY
J.B. Gay	Ecole Polytechnique Féderale de Lausanne (EPFL)	LESO CH 1015-LAUSANNE	SWITZERLAND
T. Frank	EMPA Dübendorf Section Building Physics	Überlandstrasse 129 CH-8600 DÜBENDORF	SWITZERLAND
P.G.T. Owens	Pilkington Glass Ltd.	Prescot Road, St. Helens, MERSEYSIDE WA10 3TT	UNITED KINGDOM
J.H. Klems, S. Selkowitz	Lawrence Berkeley Laboratory	1, Cyclotron Road BERKELEY, CALIFORNIA	USA