इंटरनेट मानक

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Mazdoor Kisan Shakti Sangathan
"The Right to Information, The Right to Live"

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IS 14443 (1997): Polycarbonate sheets [PCD 12: Plastics]

"ज्ञान से एक नये भारत का निर्माण"
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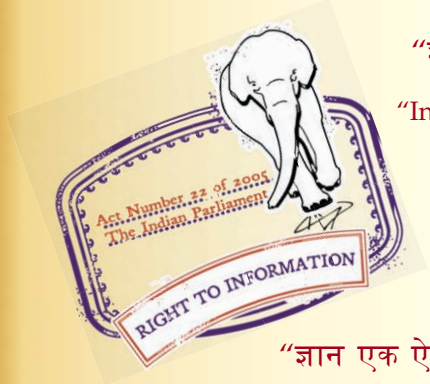

"ज्ञान एक ऐसा खजाना है जो कभी चुराया नहीं जा सकता है"
Bhartṛhari—Nītiśatakam
"Knowledge is such a treasure which cannot be stolen"

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IS 14443 : 1997

(Reaffirmed 2003)

भारतीय मानक

पॉलीकार्बोनेट शीटें — विशिष्टि

Indian Standard

POLYCARBONATE SHEETS — SPECIFICATION

ICS 83.140

BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

September 1997

Price Group 8

FOREWORD

This Indian Standard was adopted by the Bureau of Indian Standards, after the draft finalized by the Plastics Sectional Committee had been approved by the Petroleum, Coal and Related Products Division Council.

Polycarbonate extruded sheets and films form one of the major end product segment accounting for over thirty percent of the world polycarbonate consumption. Due to the excellent combination of mechanical strength, temperature resistance, thermal and electrical insulation, optical clarity, wide usability temperature range and virtual unbreakability offered by polycarbonate sheets and films, they found wide usage in building and construction industry, green houses, safety and security applications and instrument dials and panels. The utility of these products is further enhanced by easy formability, cold bending possibility, easy machinability and amenability to standard fabrication practices.

From a very small application base a couple of years back, the consumption of polycarbonate sheets and films is growing steadily in the country. Two manufacturing facility for sheets are already established in the country offering a very wide range of products. In the absence of any available standard the increasing number of users find it difficult to ensure quality of products during procurement. These considerations led the Committee to formulate this Indian Standard on polycarbonate sheets.

Since polycarbonate sheets and films are relatively new in India and their performance in use condition depends on fabrication techniques adopted, it was also decided to include a code of good fabrication practices in this standard (*see* Annex A).

Considerable assistances have been derived from the following publications while preparing this standard:

ISO 6603-1 : 1985 Plastics — Determination of multiaxial impact behaviour of rigid plastics — Part 1 Falling dart method. International Organization for Standardization (ISO).

DIN 52290-2 : 1988 Testing of security glazing of bullet resistance. Deutsches Institut für Normung e.v (DIN).

DIN 52290-3 : 1984 Attack block glazings: Testing of the resistance against break by mean of a cutting striking tool and classification. Deutsches Institut für Normung e.v (DIN).

DIN 52290-4 : 1988 Testing of security glazing of impact resistance. Deutsches Institut für Normung e.v (DIN).

DIN 52290-5 : 1987 Security glazing: Testing of the resistance against explosive effect and classification. Deutsches Institut für Normung e.v (DIN).

Indian Standard

POLYCARBONATE SHEETS — SPECIFICATION

1 SCOPE

1.1 This standard covers the requirements, methods of sampling and tests for polycarbonate sheets of solid section as well as multi-wall variety and also thinner gauge sheets (films), multi-layer composite laminates of polycarbonate compact sheets and composites of polycarbonate compact sheets and glass sheets. Sheets containing glass fibre or any other reinforcement are, however, not covered by this standard.

1.2 This standard establishes a system for designating various possible polycarbonate sheets and films. Since the system is not based on application, end use condition and performance requirement, it cannot be used for selection of any sheet or film for specific end use. For selection of material for specific use, experts well versed with the application, design and performance criterion as well as polycarbonate sheets and films should be consulted. Similarly the code of good fabrication practices covered in this standard is intended to act as a guide. For specific end use and type of sheet or film, expert opinion should be sought for fabrication details.

1.3 The classification system for various types of polycarbonate sheets and films is based on important properties like:

- Weight per sq. metre,
- Dart drop impact strength,
- Light transmission, and
- Surface texture, surface coating, colour, profile and some specific performance requirements.

2 NORMATIVE REFERENCES

The following standards contain provisions which through reference in the text, constitute provisions of this standard. At the time of publication the editions indicated were valid. All standards are subject to revision and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent edition of the standards indicated below:

IS No.	*Title*
4905 : 1968	Methods for random sampling
14434 : 1997	Polycarbonate moulding and extrusion materials — Specification

3 DESIGNATION/CLASSIFICATION SYSTEM

3.1 This standard adopts a data block system consisting of five blocks — each block, describing specific information about the product. Each block is separated from the other by an asterisk mark. In case a block is not used, the skipped block will be indicated by an additional asterisk mark.
Block 1 * Block 2 * Block 3 * Block 4 * Block 5

3.2 Information given in individual blocks shall be as given below.

3.2.1 *Block 1*

Contains this IS specification number to indicate that the classification is according to this standard.

3.2.2 *Block 2*

This block is used to describe the product in general. This block consists of four letters and one digit. The first two letters are invariably 'PC' to denote that the product under specification is made out of polycarbonate. The digit that comes next indicate the number of layers or walls (in case of hollow sheets). The letter following the digit indicates whether the product under consideration has a solid or hollow cross-section and the type of profile in case of hollow product. And the last letter indicates the surface texture of the product. Codes for Block 2 are described in Table 1.

Table 1 Codes for Block 2
(*Clause* 3.2.2)

3rd Position		4th Position		5th Position	
Code	No. of Layers/Walls	Code	Profile	Code	Texture
(1)	(2)	(3)	(4)	(5)	(6)
1	One	S	Solid section	R	Ribbed
2	Two	N	Hollow N profile	F	Fine grain
3	Three	R	Hollow rectangular profile	C	Coarse grain
4	Four	T	Hollow tunnel profile	P	Polished
0	Not specified	O	Not specified	O	Not specified

Example: For a twin wall hollow sheet with N profile and polished surface texture the Block 2 will be represented by PC 2 NP.

3.2.3 *Block 3*

This block accommodates four letters. The first letter indicates whether the material used to manufacture the sheet is light stabilized or not. The next letter indicates whether any special coating has been applied on the sheet or not. Third letter is to indicate whether the sheet is transparent, transluscent or opaque and the last letter takes care of colour. Table 2 describes the codes for Block 3.

Example:

An opaque coloured sheet made out of polycarbonate grade containing UV stabilizer and having a hard abrasion resistance surface coating is designated by LHQC in Block 3.

3.2.4 *Block 4*

Combination of four digits form this block. Each digit indicates the following properties in order:

a) Weight per sq. metre of the sheet/film as per the codes given in Table 3.
b) Dart drop impact strength at 27°C when tested as per Annex B and the codes listed in Table 3.
c) Light transmission when measured as per Annex D of IS 14434 : 1997 and the codes listed in Table 3.
d) Flammability rating as per Annex C of IS 14434 : 1997 and the codes listed in Table 3.

Example:

For a sheet with 1.3 kg/m^2, dart drop impact value of 12 J, light transmission of 55 percent and flammability rating not specified, the Block 4 will be represented by 1530.

3.2.5 *Block 5*

This block is provided for any additional specific performance requirement, if required to be specified. These specific performances include resistance to vandalism, resistance to forced entry, resistance to bullet and resistance to explosion. In case, there is no specific requirement for the sheet

Table 2 Codes for Block 3
(*Clause* 3.2.3)

1st Position		2nd Position		3rd Position		4th Position	
Code	Light Stabilization	Code	Coating	Code	Transparency	Code	Colour
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
L	Yes	H	Hard	T	Transparent	C	Coloured
X	No	U	UV	R	Transluscent	N	Natural
O	Not specified	O	Not specified	Q	Opaque	O	Not specified
				O	Not specified		

Table 3 Codes for Block 4
(*Clause* 3.2.4)

1st Position		2nd Position		3rd Position		4th Position	
Code	Wt./Sq. metre (kg/m^2)	Code	Dart Drop Impact (J)	Code	Light Transmission, percent	Code	Flame Retardancy
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1	Up to 1.5	1	Above 150	1	Above 85	1	UL 94 HB
2	Above 1.5 up to and including 3.0	2	Above 100 up to and including 150	2	Above 70 up to and including 85	2	UL 94 V2
3	Above 3.0 up to and including 4.5	3	Above 60 up to and including 100	3	Above 50 up to and including 70	3	UL 94 V1
4	Above 4.5 up to and including 6.5	4	Above 15 up to and including 60	4	Above 35 up to and including 50	4	UL 94 V0
5	Above 6.5 up to and including 8.5	5	Up to 15	5	Up to 35	5	UL 94 5V
6	Above 8.5 up to and including 12.0	0	Not specified	0	Not specified	0	Not specified
7	Above 12.0 up to and including 15.0						
8	Above 15.0						
9	Not Specified						

the designation ends at Block 4 with an asterisk mark.

Each requirement is codified by a combination of one letter and one digit. The letter indicates the type of resistance under consideration and the digit indicates the level of resistance. The scheme is elaborated below:

V = Resistance to vandalism (*see* Annex C)
F = Resistance to forced entry (*see* Annex D)
B = Resistance to bullet (*see* Annex E)
E = Resistance to explosion (*see* Annex F)

Tables 4 to 7 give the codification for level of resistance under the above categories in order and when tested as per Annexes C, D, E and F of this standard respectively.

Table 4 Codes for Vandal Resistance
(*Clause* 3.2.5)

Level of Resistance	Drop Height (mm)	Striking Energy per Drop (J)	Total Striking Energy per Level (J)
(1)	(2)	(3)	(4)
1	3 500	141	423
2	6 500	262	786
3	9 500	383	1 149

Table 5 Codes for Forced Entry Resistance
(*Clause* 3.2.5)

Level of Resistance	Kinetic Energy per Stroke (J)	Total Kinetic Energy per Level (J), *Min*
(1)	(2)	(3)
1	300 – 350	9 000
2	300 – 350	15 000
3	300 – 350	21 000

Table 6 Codes for Bullet Resistance
(*Clause* 3.2.5)

Level of Resistance	Weapon/Calibre	Ammunition/Mass, *Max*	Striking Velocity (m/s)	Striking Energy (J)
(1)	(2)	(3)	(4)	(5)
1	Pistol 9mm × 19	Parabellur — 8.10	365	540
2	Revolver 0.35/magnum	Pointed Jacket — 10.35	425	935
3	Revolver 0.44/magnum	Full Jacket — 15.65	445	1 550
4	Rifle 7.62 × 51	Ball, Soft Core — 9.55	795	3 018
5	Rifle 7.62 × 51	A.P. — 9.85	810	3 231

Number of strikes : 3 Pattern of strike : Equilateral triangle
Distance of strike : 125 mm
Range 1, 2, 3 : 3 metres
4 : 10 metres
5 : 25 metres

Table 7 Codes for Explosion Resistance
(*Clause* 3.2.5)

Level of Resistance	Positive Maximum Pressure of the Reflected Pressure Wave (Bar)	Time Duration of the Positive Pressure Phase (m/s)
(1)	(2)	(3)
1	0.5	12
2	1.0	10
3	2.0	8
Average resistance levels of:		
a) 3 Brickwall		— 0.5 bar
b) Concrete wall		— 1.0 bar
c) Steel reinforced concrete wall		— 2.0 bar

NOTES

1 The above system of designation offers unlimited theoretical possibilities. While using the system the user should be aware of practical limitations offered by the raw material and processing technology and should preferably consult the supplier.

2 Dimensions of sheets,that is, length, width and thickness and the colour should be agreed upon between the purchaser and the supplier and should be mentioned separately. Usually following variations in dimension are acceptable if not otherwise agreed upon between the purchaser and the supplier:

a) Width +10 mm
−0 mm
b) Length +50 mm
−0 mm
c) Thickness ±15 percent up to and including 2 mm nominal
±10 percent above 2 mm

3 Measurements of dart drop impact strength is not possible below a thickness of 0.75 mm due to lack of rigidity in the sheet/film. Also impact strength is not of much importance in thinner gauges. In such cases the impact strength requirement in block 4 should be mentioned as not specified.

Example 1

IS | PC 2 NP | LORC | 1530

Block 1
(Indian Standard)

Block 2
(Polycarbonate twin wall sheet N profile and polished surface)

Block 3
(UV stabilized, surface coating not specified, transluscent and coloured)

Block 4
(Weight 1.3 kg/m^2,Dart drop impact strength of 14 J, Light transmission of 58 percent and flammability not specified)

Example 2

IS | PC 1 SP | LHTN | 7124 | E3

Block 1
(Indian Standard)

Block 2
(Polycarbonate single layer solid plain surfaced sheet)

Block 3
(Light stabilized resin, hard coated transparent, natural colour sheet)

Block 4
(14 kg/m^2, dart drop impact strength of more than 150 J, light transmission 79 percent and UL 94 VO rating)

Block 5
(Explosion resistance of level 3)

4 CONFORMANCE TO THE STANDARD

4.1 All property limits specified in this standard are considered to be absolute in nature.

4.2 To check conformity of any material with this standard observed or calculated values of properties have to be directly compared with the specified limits without recourse to rounding off.

4.3 Conformance or non-conformance is decided based on this comparison.

5 SAMPLING

Representative samples of the material shall be drawn as prescribed in Annex G.

6 CONDITIONS OF TEST SPECIMEN AND CONDITIONS FOR TESTS

All test specimens are to be conditioned for a minimum period of 48 h at 27 ± 2°C under 65 ± 5 percent relative humidity and the tests are also to be carried under same conditions.

7 PACKING AND MARKING

7.1 Packing

7.1 Unless otherwise agreed between the purchaser and the supplier, all polycarbonate sheets shall usually be masked on both sides by use of adhesive paper or plastic film which can be peeled off easily without damaging the surface or leaving any mark of the adhesive. In case, however, one surface is having ribbed or coarse grain structure, the use of masking is redundant for that surface.

All these masked sheets, depending upon the ease of handling, shall be packed suitably as agreed to between the purchaser and the supplier.

7.2 Marking

7.2.1 Each masked sheet shall be legibly and indelibly marked with the following information:

a) Indication of the source of manufacture and recognized trade-mark, if any;
b) Name, grade designation and colour of the sheet material;
c) Nominal thickness in mm;
d) Size (width and length) in mm;
e) Date of manufacture; and
f) Batch No. or Code No.

7.2.2 Each packages of the masked sheet shall also be legibly and indelibly marked with the following information:

a) Indication of the source of manufacture and recognized trade-mark, if any;
b) Name, grade designation and colour of the sheet material;
c) Nominal thickness of the sheet in mm;
d) Dimension of the sheet;
e) Number of sheets in the package;
f) Date of manufacture; and
g) Batch No. or Code No.

7.3 BIS Certification Marking

The packages may also be marked with the Standard Mark.

7.3.1 The use of the Standard Mark is governed by the provisions of the *Bureau of Indian Standards Act*,1986 and the Rules and Regulations made thereunder. Details of conditions under which a licence for the use of the Standard Mark may be granted to manufacturers or producers, may be obtained from the Bureau of Indian Standards.

ANNEX A

(Foreword)

CODE OF GOOD FABRICATING PRACTICES

A-1 Polycarbonate sheets are amenable to practically all sorts of forming and fabricating techniques in comparison to other thermoplastic sheets. Adoption of improper practices, however, can lead to unacceptable performance level at the end use. This code of good fabricating practices highlights the areas of critical importance in forming and fabrication of polycarbonate sheets. It cannot, however, be treated as a complete guide to fabricating or forming. Experts in this field should invariably be consulted on various aspects especially when the end use is of critical importance.

A-2 FORMING

For production of limited number of large simple parts with uniform wall thickness, forming of plastic sheets has been found most economical route of production. Polycarbonate sheets are readily adoptable to standard forming techniques. Polycarbonate sheets, however, cool very rapidly and to achieve good results the forming machines should invariably be equipped with its own heating devices. To avoid blistering and consequent brittleness in the end product, polycarbonate sheets must be pre-dried especially if the forming operation is carried out at temperature over 160°C. The clamping frame should preferably be heated to prevent heat loss of heated sheets through the frame. Since polycarbonate sheets cool very fast, the forming should be done rapidly as soon as the sheets reach desired temperature. Demoulding should also be carried out quickly as soon as the material is rigid but still hot to touch.

A-2.1 Moulds

Wood, filled or unfilled polyesters, epoxies and metal can be used as mould material. To avoid thermal shock to polycarbonate sheet, materials which are not good conductor of heat are preferred tooling materials. If use of metal is must, the mould should be heated to 120-125°C. Generous radii of at least equal to wall thickness of the product should be provided in the tool. Draft angles of 5-7° for male moulds and 2-3° for female moulds are recommended. A shrinkage factor of 0.5 - 1 percent should be considered while designing the tool. To avoid air entrapment and consequent marks on the product surface, too smooth a mould surface should be avoided. Minute air channel can be provided on the mould surface by use of medium sand paper or fine steel wool. Adequate number of vacuum holes of 0.5 to 0.75 mm diameter should be provided in the mould to facilitate removal of air from between mould surface and polycarbonate sheet. To speed up air evacuation, back drilling of the holes with larger diameter drill can be adopted. Normally, release of product from a properly designed mould should not pose a problem. If, difficulty is encountered, release agents like silicone spray, polytetrafluoroethylene spray, zinc stearate, talcum powder, etc, can be used. However, when the part has to undergo finishing operations like painting, printing or bonding, silicone or teflon spray should not be used.

A-2.2 Pre-drying

Polycarbonate sheets are to be pre-dried before forming in hot air circulating oven maintained at 125 $\pm$ 3°C. The air volume in the oven should be exchanged six times in an hour to remove water vapour. Polycarbonate sheets, after removal of masking, should be hung vertically or be placed in horizontal racks with a separation of about 25 mm. After pre-drying the sheets should be used within few hours depending on sheet thickness and local atmospheric condition. Drying time varies with sheet thickness as given in Table 8.

Table 8 Drying Time
(*Clause* A-2.2)

Sheet Thickness (mm) (1)	Drying Time (h) (2)
0.75	0.50
1.00	1.00
1.50	1.50
2.00	3.00
3.00	4.00
4.00	10.00
5.00	16.00
6.00	24.00
8.00	36.00
9.50	40.00
12.00	48.00

A-2.3 Heating

Production of good parts depends on controlled and uniform heating of polycarbonate sheets. Sandwich type heaters are recommended. Normal forming temperature are between 185-210°C range. Best result is achieved at around 200°C. Heating rate is usually affected by power fluctuation and air draught and should be controlled. To avoid hot spots and to achieve forming temperature at the edges, slower heating is recommended. Clamping frame should be pre-heated to 120-130°C.

A-2.4 Cooling

Due to high heat distortion temperature of polycarbonate, products formed from polycarbonate sheets retain sufficient rigidity even at 125°C and can be demoulded at this temperature. This enables to achieve lower cycle time in the forming process.

A-2.5 Techniques

All thermo-forming techniques like plug assisted and unassisted vacuum forming, free blowing, pressure forming or snap back forming can be used to give desired shapes to polycarbonate sheets.

Polycarbonate sheets can also be cold formed at relatively lower temperature of about 160°C by techniques like drape forming, matched mould forming, hot line bending, etc. In such cases predrying of sheets can be avoided. Polycarbonate sheets are heated in an oven on felt covered supports. Tools are to be pre-heated to 80°C. Since embossing of polycarbonate thin sheets is widely employed in fabrication of membrane switches this technique is discussed in slightly more detail in the next section.

A-2.5.1 *Embossing*

Embossing is used to form raised areas in thin polycarbonate sheets. Thickness of up to 0.25 mm is readily amenable to embossing while thickness up to 0.50 mm can be embossed only in certain configuration. Due to high stress build up during embossing operation, life of membrane switch could be affected significantly and life testing is always recommended. Embossing dies can be made from metals like zinc, magnesium, aluminium and steel and non-metals like polyesters, silicone rubbers, etc. The clearance between male and female portions of the die should be approximately equal to sheet thickness. Draft angle of minimum 3° on both male and female tools is recommended. To reduce fatigue and impact failure possibilities all corners should have radii of equal or greater than the sheet thickness. The embossing width should be equal or greater than 5 times the sheet thickness. The embossing height should not exceed 2.5 times the sheet thickness (excluding adhesive and liner) with sheet thickness included in the measurement. Spacing between embossed areas should be 1.5 mm minimum to limit distortion after embossing.

A-2.6 Annealing

Stress relaxation through annealing in formed products should preferably be avoided. Frozen in stress can be reduced by adopting better processing parameters and good machines. In certain cold formed products the stress can be relieved by heating at 130-135°C for 1 h per 2.5 mm of sheet thickness. The impact strength of the products, however, might be reduced after this operation. Since the products tend to deform while releasing stress, they should be kept in forms during the process.

A-3 MACHINING

Polycarbonate sheets can be machined using ordinary workshop equipments. Cooling is not necessary under normal conditions, but at higher cutting speeds, cooling with air or water is recommended. Oil emulsions should not be used for cooling purposes. No sharp corners or notches should be left on the sheet after machining as they may lead to part failure.

A-3.1 Sawing

Ordinary band saws and circular saws can be used to cut polycarbonate sheets. Due to heat resistance characteristics of polycarbonate, blade speed and cutting rate are not very critical. Tungsten carbide tipped saw blades should be used. To achieve clean cut following recommendations should be observed (*see* Fig. 1).

	Circular Saw	*Band Saw*	
Clearance angle	20-30°	20-30°	For single sheet less than 3 mm, thick, band saws routers or shears are preferred to circular saws
Rake angle	1-5°	0-5°	
Shaft speed	2 500-4 000 rev/min		
Blade or band speed	1 800-2 400 m/min	600-1 000 m/min	
Tooth spacing	9-15 mm	1.5-2.5 mm	

NOTE — Polycarbonate sheets should be clamped to the support table to avoid vibration and rough cutting.

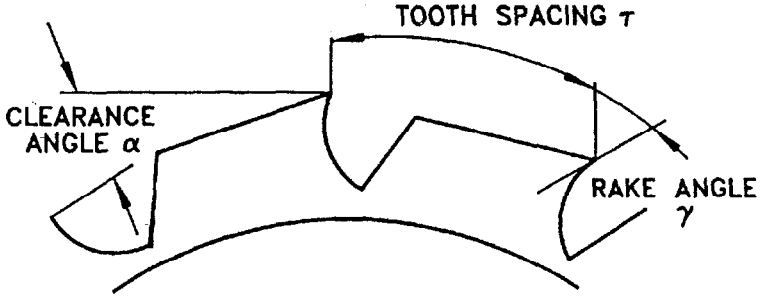

FIG. 1 DETAILS OF SAW BLADES

A-3.2 Drilling

Carbon steel twist drills have been found suitable for drilling polycarbonate sheets. To achieve best results, however, high speed carbide tipped twist drills should be used under conditions given in Table 9.

Table 9 Conditions for Drilling
(*Clause* A-3.2)

Hole Diameter (mm)	Speed rev/min	Feed rev/min	Recommended Drill Angles
(1)	(2)	(3)	(4)
3	1 750	0.035-0.075	Clearance Angle 15°
6	1 000-1 500	0.035-0.075	Rake Angle 0-5°
9	600-100	0.012-0.074	Included tip angle 160-180°
12	325-650	0.075	
18	350	0.075	

To drill larger holes, special drill bits with rake angle of at least 5° should be used (*see* Fig. 2). Sheets should be clamped to the drilling table to avoid vibration and to minimize friction in the drill hole. Swarf should regularly be removed.

A-3.3 Shearing and Punching

Shearing or punching of polycarbonate sheets up to 3 mm thickness is quite easy. To obtain smooth cuts shear blades with rake angle of 45° or more and a clearance between the bed and the blade of 0.015-0.030 mm should be used (*see* Fig. 3). Shrinkage allowance of up to 5 percent should be made while punching holes.

A-3.4 Turning

For turning of polycarbonate sheet following tool parameters (*see* Fig. 4) are critical:

Clearance angle	20°
Rake angle	0-5°
Tip radius	0.5 mm
Speed	500-1 000 m/min
Cutting speed	0.1-0.5 mm/rev

Tough swarf is produced during turning of polycarbonate sheet and this should not build up on machine or the tool. At higher cutting speed, turning should be stopped periodically to cool the work piece with air or water.

A-3.5 Milling

Universal milling machine can be used for polycarbonate sheets. Apart from ordinary metal working tools high speed knife cutters can be used also. To achieve good results following parameters are important.

Clearance angle	20-25°
Rake angle	0-5°
Speed of milling cutter	100-500 rev/min
Cutting speed	0.1-0.5 mm/rev

A-3.6 Tapping

Standard metal working taps are recommended for polycarbonate sheets. Taps that produce threads with root diameters slightly rounded are preferred. To avoid excessive heat build up tapping should be done gently. Cutting oils or emulsions should preferably not be used.

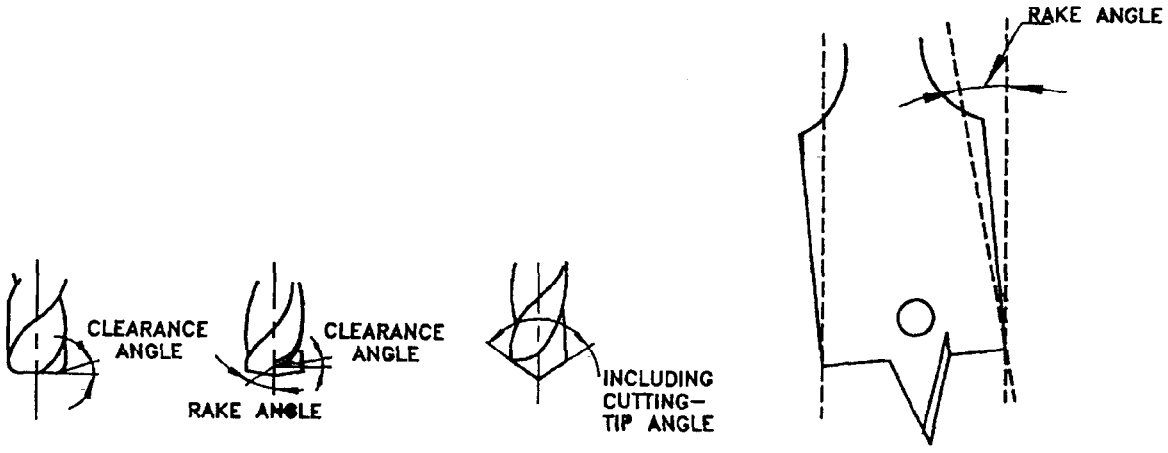

FIG. 2 DETAILS OF SPECIAL DRILL BITS

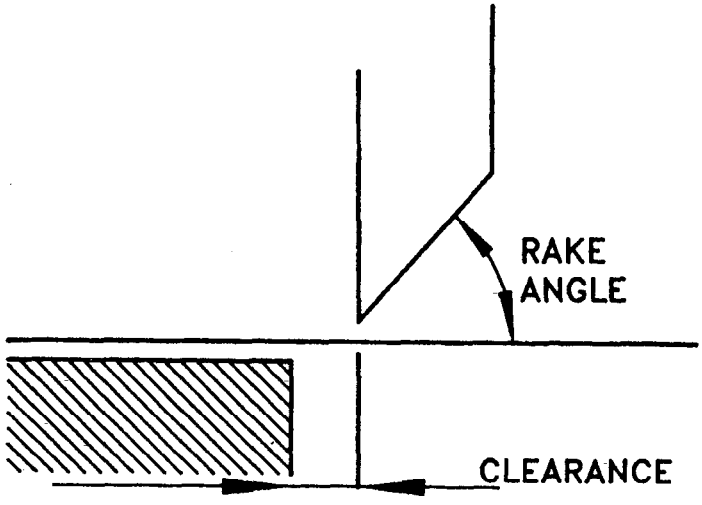

FIG. 3 DETAILS OF SHEAR BLADES

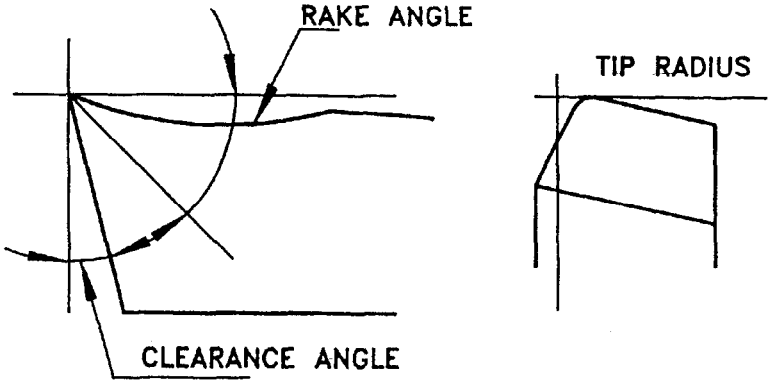

FIG. 4 DETAILS OF TOOL PARAMETERS USED FOR TURNING

A-4 BENDING

A-4.1 Cold Bending

Practically all polycarbonate sheets excepting those with abrasion resistance special hard surface coating can be installed with a curve under stress. The minimum radius of curvature recommended for compact polycarbonate sheets is 150 times the sheet thickness while the same for multi-walled hollow structured sheets is 175 times the sheet thickness. With this minimum recommended radius, impact resistance, transparency or

weatherability of polycarbonate sheets remain unaffected.

A-4.2 Cold Line Bending

Sheet thickness, tool edge and angle of bending determine the mechanical cold bending results. Blunt tool edges should be avoided. Sufficient time (about 2-3 s) for immediate sheet relaxation after bending should be allowed. Assembling should be undertaken only after relaxation for 5 to 10 days. During installation any forced reduction of bending angle must be avoided. Since cold bent sheets are under internal stress, the impact resistance of sheets is reduced. This limits use of cold bent sheets in less demanding applications.

A-4.3 Hot Line Bending

Polycarbonate sheet is locally heated to 155-160°C in this method by an electrical resistance wire. With single heating the sheet must be turned over several times. After desired heating level is achieved, the sheet is bent to the required angle. For better tolerance and higher productivity, bending machines with temperature controlled heaters on both sides should be used.

A-5 ASSEMBLY

In the process of fabricating parts from polycarbonate sheet, it might be required to bond it with another piece of plastics including polycarbonate or glass or metal. The bonding technique that can be adopted depends on the part configuration, strength requirement, flexibility, heat resistance, etc. Ease of bonding and appearance also have major role to play. Adhesive bonding, mechanical fastening or welding can be successfully used to bond polycarbonate sheet.

A-5.1 Adhesive Bonding

Inherent stress level, temperatures, time of exposure and nature and concentration of chemicals determine the chemical resistance behaviour of polycarbonate sheets. Many of the usual solvents used in manufacture of adhesives are known to cause stress cracking of polycarbonate. Selection of adhesive, should therefore, be made on the basis of practical data pertaining to the actual stress conditions and end-use requirements. Many of the epoxy and polyurethane based adhesives and polycarbonate solutions in methylene dichloride have widely been found useful in polycarbonate sheets fabrication.

A-5.2 Mechanical Fastening

Pop rivets are widely used in fastening polycarbonate sheets mechanically. Only aluminium rivets are recommended. The rivet head should be 2.5-3 times the diameter. Drilling of oversized holes is recommended to accommodate thermal expansion of rivets. Aluminium and neoprene washers should be used to spread out the load. Application of small amount of silicone fluid in the hole reduces chance of stress cracking and environment attack. Even spreading of rivets helps to minimize possibility of localized overstressing. The above recommendations are also true if nut and bolts are used. Non-rusting type nuts and bolts should be used and nuts should not be tightened too firmly.

A-5.3 Welding

Traditional welding is not a recommended technique as a large scale production method for jointing of polycarbonate sheet based parts. For small volume or proto-type part production, however, it can be used successfully. The parts and the welding rod (a strip cut from polycarbonate sheet) must be predried as per standard practice. The parts are put next to each other with minimal separation. The hot air temperature should be set around 475-500°C.

Ultrasonic spot welding technique when used to join polycarbonate sheets results in high mechanical performance and low residual stress. More than 70 percent of tensile strength of polycarbonate sheet can be attained in the bonded areas using this fast and effective technique. Use of high ultrasonic amplitude is recommended. A fillet radius should be included at the root of the stud to reduce stress concentration and to prevent possible breakage in this area caused by high vibrational energy.

A-6 FINISIIING

Most common finishing operations that are conducted on polycarbonate sheet parts are painting and printing. Since both paints and printing inks are largely based on organic solvents which are known to have adverse effects on polycarbonate, selection of these should be based on stress level in the parts and practical experience of efficiency of a particular paint or ink system in similar conditions of use.

A-6.1 Painting

Standard spray painting technique can be adopted; cleaning of the surface is a must prior to painting. Both single and two component epoxy and polyurethane paint systems have been developed for painting on polycarbonate surface. Single coat and multi-coat systems are available within the available range of paints. If cut and spray technique is employed, care should be taken to avoid deep cuts in the sheet surface while cutting through the

masking layer. Notches created by deep cuts may cause impact failure in the parts.

A-6.2 Screen Printing

Screen printing of polycarbonate sheets is similar to the technique adopted for other materials. Vinyl and acrylic based inks are found suitable. However, selection of ink should be based on similar judgement as recommended in case of paints. Thinner, if used, should be as per manufacturer's recommendations.

A-6.3 Anti-Static Treatment

Polycarbonate sheets are good electrical insulator. Machining or handling of polycarbonate sheets usually result in accumulation of static charge on the surface. Surface treatment with proper antistatic agents reduces the possibility of static charge build up in polycarbonate sheets. Proprietory antistatic formulations are available from chemical manufacturers like American Cynamide Co. AKZO and BEE Chemical Co.

A-6.4 Cleaning

Surface cleaning of polycarbonate sheets is required before and/or after various finishing operations. Sometimes this might be required even before forming. Recommended clearing agents are mild detergent dissolved in water, isopropyl or isobutyl alcohol and clean water. Use of soft cloth or sponge helps in cleaning. Paint splashes, greases, dirt, etc, can be removed easily before drying by rubbing lightly with cotton moistened with methylated spirit or petroleum ether. A wash with mild soap solution and clean water should follow. To avoid water spots the surface should be dried thoroughly with a chemois or moist cellulose sponge. Abrasive or highly alkaline cleaners should never be used on polycarbonate sheets. Surface should also not be scrapped with razor or any other sharp tool. In case of heavy dust build up, an ionising airgun should be used to remove the dust. It should be followed by wiping with soft cloth dipped in water or 45 percent iso propyl alcohol.

A-7 INSTALLATION

Polycarbonate sheets of both compact and multiwalled hollow varieties are extensively used in building and construction industry. Architectural and engineering design for any installation should be guided by factors like wind load and snow load (wherever applicable) on the installation. Data related to span width, radius of curvature and sheet thickness, etc, in relation to loading are available from sheet suppliers and should be used judiciously. Depending on sheet thickness and possible loading the edge engagement of sheet is determined. Since thermal expansion of polycarbonate sheet is relatively higher, the rebate depth (depth of fixing profile) should be calculated and maintained accurately to avoid deformation of sheet after installation. Rain water drainage should be ensured in case of horizontal installation by maintaining a slope of 9 cm per metre length of sheet. Wood or metal profiles can be used as structural support. General recommendations given below should be followed during installation of sheets:

a) Edge engagement and expansion allowance should be calculated.
b) Sheets are to be cut to exact size and edges should be free from cuts and notches.
c) 50 mm of masking should be removed from all edges.
d) Suitable gaskets or sealants should be used at the edges.
e) Masking should be completely removed soon after completion of installation.
f) Sheets should be cleaned with mild soap solution and soft cloth after installation is over.
g) In case of UV coated sheets, the coated side should always face the outside. No solvent should be used to clean this coated surface.

Sealant should be used not only to secure the sheets properly with the supporting frame but also to eliminate possibility of leakage. Keeping the expansion and contraction the sheet undergoes due to temperature fluctuations, the sealant should accommodate certain amount of movement without loss of adhesion with frame or sheet. Silicone and polysulfide sealants and polybutene tapes have been found suitable in this respect and are used quite often. However, chemical compatibility of the sealing system with polycarbonate sheet has to be established before use during installation. Where expansion and contraction of sheet exceeds the limitation of such sealants, Neoprene or EPDM rubber gaskets of about 65 shore hardness can be used. The gasket is snap fitted into the glazing bars to allow free movement of the sheet during thermal expansion or contraction. Moreover, use of such gasket has aesthetic value as well.

ANNEX B

(*Clause* 3.2.4)

DART DROP IMPACT STRENGTH

B-1 A Gardner Impact Tester (*see* Fig. 5) is used for testing dart drop impact strength of polycarbonate sheets. The specimen is placed over a hole of 25.4 mm diameter in a die mounted on the anvil. A round nosed dart, 12.7 mm diameter is placed upon the specimen. A dart with a variable mass of up to 15.0 kg is raised to the desired height in a 1.25 m calibrated tube and dropped. The maximum applied impact energy is given as:

$M \times n = 15.0 \text{ kg} \times 1.25 \text{ m} = 18.75 \text{ kg. m } (187.5 \text{ J})$

A slight reduction in the maximum energy may occur due to the zero adjustment necessary for the various thicknesses of the specimen. The test specimen considered to have passed the test if the sample shows no visible signs of surface cracking around the impact area.

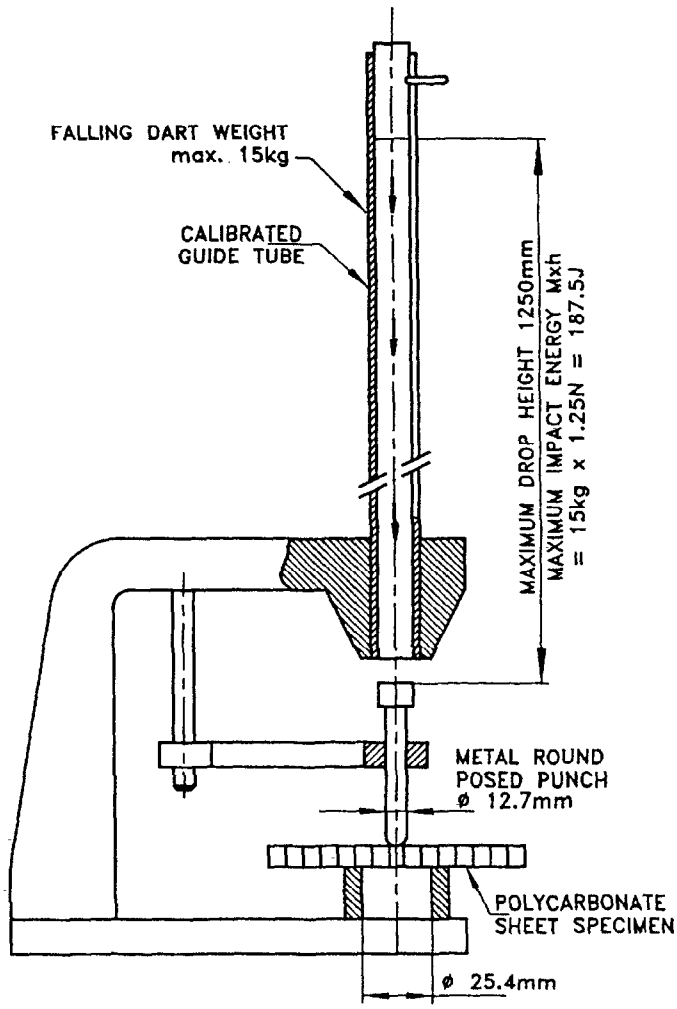

FIG. 5 GARDNER IMPACT TESTING MACHINE

ANNEX C

(*Clause* 3.2.5)

TEST FOR VANDAL RESISTANCE

C-1 PRINCIPLE

A steel ball is dropped three times onto a test piece. It is checked whether the ball penetrates the test piece. Glazing is then classified according to its impact resistance established on the basis of test results.

C-2 APPARATUS

C-2.1 Falling Body

A steel ball, with a nominal diameter of 100 mm (with a mass of about 4 110 g).

C-2.2 Ball Holder

A device to hold the steel ball in place before it is dropped (for example, an electromagnet). The device shall permit the drop height to be adjusted within the specified tolerance (*see* Table 10) and shall not exert a propelling force on the ball as it falls, that is, the ball shall accelerate only due to gravity and fall vertically (*see also* **C-4.2**).

C-2.3 Test Piece Holder

The test piece holder (*see* Fig. 6) shall consist of a steel clamping frame and a catch box for splinters and the ball. The holder shall:

a) be rigid;
b) be inflexibly connected to a rigid base;
c) ensure that the test piece is uniformly clamped in a horizontal position;
d) be designed so that the test piece is only supported by the clamping frame during the test;
e) permit the test piece to be clamped on all sides, the clamping width being 30 ± 5 mm;
f) have upper and lower clamping faces fitted with a 30 mm wide; 4 mm thick rubber strip having an IRHD hardness of 50 ± 10;
g) ensure that the test piece is clamped with a surface pressure of 14 ± 2 N/cm^2; and
h) have an energy-absorbing catch box such that the ball is not damaged and does not rebound, should it strike it.

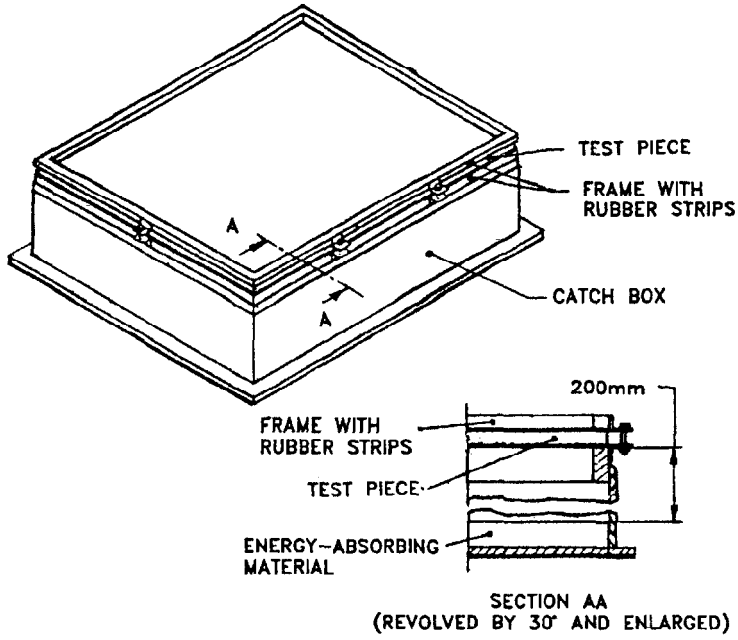

FIG. 6 EXAMPLE OF TEST PIECE HOLDER

C-3 TEST PIECES

C-3.1 Type, Dimensions and Marking of Test Pieces

Test pieces 1 100 ± 5 mm long and 900 ± 5 mm wide, shall be prepared from the same materials, and processed under the same conditions, as the glazing which they represent. They shall be edged. A marking on the test piece shall indicate the side to face the impact.

C-3.2 Number of Test Pieces

Three test pieces shall be used per type of glazing and level of attack.

C-3.3 Conditioning of Test Pieces

The test pieces shall be conditioned in a vertical position, at a temperature of 27 ± 2°C, for atleast 12 h immediately prior to testing.

C-4 PROCEDURE

C-4.1 Testing shall be carried out at a temperature of 27 ± 2°C.

C-4.2 The test piece shall be placed horizontally in the test piece holder. The drop height (clear distance between falling body and test piece) shall be adjusted to comply with the specifications given in Table 10.

Table 10 Drop Height
(Clauses C-2.2 and C-4.2)

Level of Attack	Drop Height (mm) (± 50)
(1)	(2)
1	3 500
2	6 500
3	9 500

C-4.3 The ball shall be dropped three times onto each test piece from the same height. The drop shall be made to form an equilateral triangle, in the centre of the test piece, with a side length of 130 ± 20 mm. Any loose splinters shall be removed from the test piece after each drop.

C-5 EVALUATION

C-5.1 Inspection for Penetration and Dislodgement

After testing, each test piece shall be inspected for penetration or, if no penetration has occurred, for dislodgement from the frame. A test piece shall be deemed to have been penetrated if at least one ball has passed through it.

A test piece shall be deemed to have been dislodged from the frame if one of its edges has been displaced by more than 5 mm. If so, the test shall be repeated with a new test piece.

C-5.2 Establishing Impact Resistance Class

The resistance to impact of each test piece, for each level of attack, shall be established in accordance with Table 11 on the basis of the evaluation described in **C-5.1.**

Table 11 Impact Resistance Classes
(Clause C-5.2)

Level of Attack	Impact Resistance Class
	None of the Three Test Pieces was Penetrated by the Ball or Dislodged from the Frame
(1)	(2)
1	A 1
2	A 2
3	A 3

Table 11 specifies three resistance classes. The resistance class increases as the level of attack increases (that is, greater drop heights are used).

The glazing shall be classified according to the lowest class for which test conditions have been met.

ANNEX D

(Clause 3.2.5)

TEST FOR RESISTANCE TO FORCED ENTRY

D-1 GENERAL

The procedure serves as a test to prove the rupture resisting feature of rupture resistant glazings against attacks with cutting/striking tools and for classification of glazings into groups of resistance against penetration.

NOTE — Glazings whose rupture resistant features are below the resistance class B 1 according to this norm, can be tested and classified in accordance with Annex C of this standard.

The procedure is to be applied only for testing of ruptured glazings which have identical cross-section relations across the whole area.

D-2 SUMMARY OF THE PROCEDURE

Tests are performed under defined conditions by means of an installation that simulates the requirements when an axe is used by hand. This allows the determination of the minimum number of axe-impacts required for a defined fracture. Depending on the test results, the class of resistance of a glazing-type is defined.

D-3 APPARATUS

D-3.1 Figure 7 shows the principle sketch of a device for testing the rupture resistant quality of rupture resistant glazings.

D-3.1.1 *Supporting Device*

The supporting device for testing purposes shall:

- be rigid in itself;
- have an unyielding connection with a solid base and/or sturdy walling;
- secure a plan-parallel gripping of the test material in a vertical position;
- be constructed in such a manner that the material, during testing, is supported against the frame attachment only;
- allow to clamp the testing material on all sides with a border margin of 30 ± 5 mm;
- be padded on the front and rear clamping area with 30 mm wide rubber strips, 4 mm thick, hardness 50 ± 10 IRHD; and
- guarantee that the edges of the testing material are mounted with a surface pressure of 14 ± 1 N/cm^2.

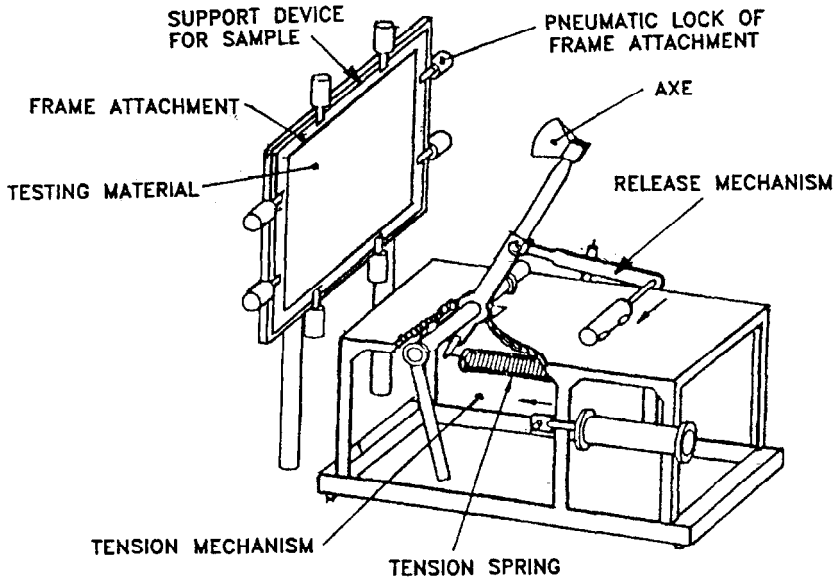

Fig. 7 DEVICE FOR TESTING OF RUPTURE RESISTANT QUALITY OF RUPTURE RESISTANT GLAZING (PRINCIPLE SKETCH FOR AN EXHIBITION SAMPLE)

D-3.1.2 *Axe*

The axe-edge shall have a 'qualified sharpness', a wedge angle of the blade of 35 ± 5°, a slightly convexed flank, as well as a standard normed bending radius and a standard normed hardness 51- 56 HRC.

After 10 impacts the wedge shall be resharpened and checked for standard normed sharpness.

An axe shall not be reused for testing if

- the axe-wedge has been reduced during resharpening by a maximum of 30 mm; and
- the standard norm of hardness of the axe-wedge does not exist anymore.

D-3.1.3 *Installation for Simulation of the Stress Condition by a Hand-Used Axe*

The installation for simulating the requirements when a hand axe is used shall:

- be in itself rigid;
- have an unyielding connection with a solid base and/or sturdy walling; and
- guarantee that the axe is tested according to **D-3.1.2** (cutting edge of the axe) with the velocity of impact V-impact according to Table 12, that the energy of impact E-impact according to Table 12, and that the angle of impact A-impact, relates to the areal-norm of the sample and to the tangent of the cutting edge at the point of impact 65 ± 3.5° onto the testing material.

D-3.1.4 *Measuring Device for the Determination of the Impact Velocity of the Axe V-Impact*

The measuring device shall allow determination of the impact velocity of the axe V-impact on 0.05 m/s.

D-4 SAMPLES

D-4.1 Means, Dimensions and Identification of Samples

The samples shall correspond with material and design of the type of glazing to be tested.

Length of sample 1 100 ± 5 mm
Width of sample 900 ± 5 mm
The impact side of each sample shall be marked.

D-4.2 Number of Samples

Three samples of the glazing type to be tested for each testing condition.

D-4.3 Condition of Samples and Preparation

D-4.3.1 The samples are required to have hemmed edges.

Directly before the test each sample must be stored horizontally, self-supporting, at least for 12 h , at a temperature of 27 ± 2°C.

D-4.3.2 The test conditions for the various means of stress are given in Table 12. Testing temperature is 27 ± 2°C.

D-4.3.3 The sample shall be fastened into the supporting device in such a manner that it is completely anchored to the front and rear clamping zone.

D-4.3.4 The velocity speed V-impact of each axe stroke shall be determined.

D-4.3.5 It should be tried, with each sample, to produce a square penetration with a side-length of 400 ± 10 mm in such a manner that

- — the diagonal point of penetration is identical with the sample; and
- — as a penetration, the ejected material has no relation (bridge) to the other remaining sample (glazing) (entire separation).

One should relinquish an entire detachment if the material (as a penetration) that has to be detached, in spite of a connnection, folds up due to its own weight into a horizontal position, and thereby releases the opening.

Should the producing of a square penetration on account of the corresponding break-picture be not meaningful, or not possible, a different penetration can be provided. The penetration however, has to have an inner circle of 510 ± 15 mm in diameter. The request for an entire penetration and related exeption are still valid.

The required number of axe-strokes for the rupture is determined. Loosening strokes and separation strokes are identical and both are axe-strokes.

Without having achieved a penetration, the test can be stopped, if the definite allocation to a resistance group, requiring a minimum number of axe-strokes, has been reached.

D-4.3.6 During tests with silicateglass-objects, the preceding are to be destroyed within the separation area, by the dull edge of the axe with so called loosening-strokes. The forward feed of the loosening-strokes shall be selected in such a way, that the areas, in which the silicateglass-objects are split into fine and finest parts (called 'grey-zones'), at least touch each other. After the loosening-strokes, blows with the sharp edge of the axe (called separation-knocks) shall be performed.

With the other tests shall be initiated immediately with separation-strokes.

D-4.3.7 The first separation-strokes are to be lead on the same spot until the axe-blade has penetrated the sample for the first time. Thereby it is allowed to dislocate the axe slightly in both directions along the frame line in order that the first point of separation is larger than the length of the axe's blade. The forward feed following thereafter has to be selected less than or equal to cutting length of the axe.

Table 12 Testing Conditions
(*Clauses* D-3.1.3 *and* D-4.3.2)

Key for Type of Stress	Simulation of Stress Condition by a Hand-Used Axe				
	Loosening Strokes		Separation Strokes		Axe Strokes *Min*
	Impact velocity of axe V-impact m/s +0.3	Impact energy of axe E-impact Nm+15	Impact velocity of axe V-impact m/s +0.3	Impact energy of axe E-impact Nm +15	
(1)	(2)	(3)	(4)	(5)	(6)
1	12.5	350	11.0	300	30-50
2	12.5	350	11.0	300	Over 50-70
3	12.5	350	11.0	300	Over 70

Separation-strokes are not to be conducted on accrued glass powder.

D-5 EVALUATION

D-5.1 Evaluation of the Test Results

For each test is to be decided, if means and dimensions of the penetration, including velocity of impact of the axe, are or were according to norm.

D-5.2 Establishment of the Class of Resistance Against Penetration

Based on the load spectra under service conditions and the number of executed axe-strokes for each test, the resistance-class must be determined against penetration according to Table 13.

Table 13 Distribution of Rupture Resistant Glazings into Resistance-Classes Against Penetration
(*Clause* D-5.2)

Key to Load Spectra	Axe-Strokes *Min*	Resistance-Class Against Penetration
(1)	(2)	(3)
1	10-50	B 1
2	Over 50-70	B 2
3	Over 70	B 3

The lowest resistance-class determined against penetration is to be allocated to the tested glazing type. According to Table 13, three resistance-classes exist against penetration. The resistance-class increases with intensifying load (higher means of stress).

ANNEX E

(*Clause* 3.2.5)

TEST FOR BULLET RESISTANCE

E-1 PRINCIPLE

Shots are fired at test pieces under defined conditions. The test pieces are inspected for bullet penetration or, if no penetration has occurred, for splintering. Glazing is then classified according to its bullet resistance established on the basis of test results.

E-2 APPARATUS

The following apparatus are required:

a) A frame to mount the test piece in accordance with **E-4.1**;

b) Firearms or other ballistic testing equipment (*see* Table 14);

c) Ammunition which permits compliance with the test conditions specified in Table 14 for the level of attack to be applied. If necessary, the ammunition shall be specially conditioned and tempered for the test;

d) A suitable system for measuring the bullet velocity, $V_{2.5}$, with a limit of error of 10 μs. The reference distance, not to exceed 1 m, shall be such that its midpoint is 2.5 m from the barrel muzzle; and

e) A 500 ± 5 mm cube-shaped splinter collector with one open side, made of a material on or in which glass splinters cannot stick.

E-3 TEST PIECES

E-3.1 Type, Dimensions and Marking of Test Pieces

Test pieces, 500 ± 5 mm square, shall be prepared from the same materials, and processed under the same conditions as the glazing which they represent. They shall be edged.
A marking on the test piece shall indicate the side to face the attack.

E-3.2 Number of Test Pieces

Three test pieces are required per type of glazing and level of attack.

E-3.3 Conditioning of Test Pieces

All test pieces shall be conditioned in a vertical position, at a temperature 27 ± 2°C, for at least 12 h immediately prior to testing.

E-4 TEST ASSEMBLY

E-4.1 Mounting the Test Piece

The test piece shall be mounted in a vertical position with all four edges clamped in a fixed, rigid frame (with parallel clamps), so that:

a) the clamping width is 30 ± 5 mm;

b) the test piece is not damaged by the mounting procedure (*see* below); and

c) the test piece is not dislodged from the frame, either partially or completely, by the shot.

Table 14 Test Conditions
(*Clauses* E-2 *and* E-5.1)

Level of Attack	Type of Weapon and Calibre	Ammunition			Firing Range (m)
		Type of Bullet[1)]	Mass of Bullet, (g)	Striking Velocity, $V_{2.5}$, (m/s)	
(1)	(2)	(3)	(4)	(5)	(6)
1	9 mm × 19	VMR/Wk	8.00 ± 0.10	355 to 365	3
2	357 Magnum	VMKS/Wk	10.25 ± 0.10	415 to 425	3
3	44 Magnum	VMF/Wk	15.55 ± 0.10	435 to 445	3
4	7.62 mm × 51	VMS/Wk	9.45 ± 0.10	785 to 795	10
5	7.62 mm × 51	VMS/Hk	9.75 ± 0.10	800 to 810	25

[1)] VMR/Wk full jacket, round nose, soft point.
VMF/Wk full jacket, flat nose, soft point.
VMKS/Wk full jacket, conical nose, soft point.
VMS/Wk full jacket, pointed nose, soft point.
VMS/Hk full jacket, pointed nose, hard point.

The test piece shall lie flush on the front and rear clamping faces, which have been fitted with a rubber strip approximately 35 mm wide and 3 mm thick, having an IRHD hardness of 50 ± 10. The bottom face of the test piece shall also be cushioned by a rubber strip having the same dimensions and IRHD hardness.

E-4.2 Positioning the Splinter Collector

The splinter collector shall be positioned and installed at a distance of no more than 50 mm behind the test piece so that:

a) its open side faces the rear of the test piece, and
b) the normal to the test piece surface at its centre coincides with the horizontal centre axis of the collector.

E-5 PROCEDURE

E-5.1 The test conditions, as a function of the level of attack, are summerized in Table 14.

Immediately before testing, the velocity of the bullets shall be measured for each level of attack, using the prescribed firearm or ballistic equipment, as follows: a random sample of ten shots shall be fired from a batch of no more than 50 catridges, and the standard deviation, S_{10}, of the average bullet velocity, $V_{2.5}$, at a distance of 2.5 m from the barrel muzzle, calculated.

[*see also* **E-2**(d)]. The maximum permissible standard deviation shall be 5 m/s. If the test conditions specified in Table 14 and the specifications given in E-2 are satisfied, the remaining cartridges in the batch shall be deemed suitable for use in the test. If conditions and specifications are not satisfied, the procedure shall be repeated with a random sample from another batch.

Note also that the test temperature is not to differ by more than 2°C from the used during the measurement of $V_{2.5}$.

E-5.2 Three shots shall be fired at each of the three test pieces so as to form an equilateral triangle, in the centre of the test piece, with a side length of 125 ± 10 mm at a firing range up to and including 10 m or 125 ± 20 mm at a firing range of 25 m.

E-5.3 Both the firearm barrel and the test piece shall be arranged so that the barrel axis coincides with a line normal to the surface of the test piece at its centre (that is, the centre point of the equilateral triangle). Relative to this reference position, the shots shall be fired so as to produce the required triangular pattern.

E-6 EVALUATION

E-6.1 Inspection for Bullet Penetration and Splintering

After testing, each test piece shall be inspected for bullet penetration (*see* **E-6.1.1**) or, if no bullet has penetrated, for splintering (*see* **E-6.1.2**).

E-6.1.1 Penetration is defined as:

a) the penetration of the bullet or bullet fragments into the test piece;
b) the lodging of the bullet or bullet fragments into the rear surface of the test piece;and
c) a hole resulting from complete bullet penetration, even if it recloses.

E-6.1.2 The rear side of the test piece shall be inspected for splintering,that is, for the appearance of splinters in the collector. The test piece shall be assigned class SF if no splinters are found and SA if splinters are found.

E-6.2 Establishing Bullet Resistance Class

The bullet resistance of each test piece, for each level of attack, shall be established in accordance with Table 15 on the basis of the evaluations described in **E-6.1.1** and **E-6.1.2.**

Table 15 specified ten resistance classes. The resistance class increases as the level of attack increases and for each level of attack, differentiation is made between splintering (SA) and no splintering (SF).

The glazing shall be classified according to the lowest class for which test conditions have been met in order for this classification to be valid, the glazing must also fulfil the requirements of any lower resistance class.

Table 15 Bullet Resistance Classes
(*Clause* E-6.2)

Level of Attack	Bullet Resistance Class	
	No Penetration no Splintering	No Penetration Splintering
(1)	(2)	(3)
1	C 1 - SF	C 1 - SA
2	C 2 - SF	C 2 - SA
3	C 3 - SF	C 3 - SA
4	C 4 - SF	C 4 - SA
5	C 5 - SF	C 5 - SA

ANNEX F

(*Clause* 3.2.5)

TEST FOR EXPLOSION RESISTANCE

F-1 GENERAL

The method according to this standard serves for testing the resistance against explosive effect property of security glazing and classification of glazings in resistance classes. This method is determined only for testing security glazings that have already been assigned the resistance class A as per Annex C or a resistance class B or C as per Annex D and Annex E, respectively.

The resistance class assigned to a glazing type applies only to that type of glazing with an area of 1.00 m^2 or less.

F-2 PRINCIPLE

Samples are tested under defined conditions in order to determine which positive maximum pressure of a reflected blast wave a glazing type resists for a set time (impulse). The class of resistance against explosive effect is determined on the basis of the test result.

F-3 APPARATUS

F-3.1 Specimen Holder

Required properties:

- intrinsicly rigid;
- unyielding connection to rigid background and/or solid masonry;
- ensurance of plane parallel specimen gripping in vertical position;
- designed to ensure that the specimen is only supported by the frame during the test;
- it shall permit the specimen to be clamped on all sides with 50 ± 10 mm edge width;
- its front and rear pressure surfaces shall be covered with 50 mm wide rubber strips 4 mm thick, 50 ± 10 IRHD hardness;
- it shall ensure that the specimen edges are clamped with 14 ± 3 kg/cm^2 surface pressure;
- facing on all sides 1 000 mm *Min*, wide or to the wall of the detonation tube or detonation dugout;
- on the side of attack the facing shall be flush with the surface of the specimen holder; and
- the specimen shall be clamped so as to ensure that the specimen surface does not protrude from the specimen holder or has a recess of not more than 20 mm.

F-3.2 Device for the Demonstration of the Explosive Effect

Required features:

- simulation of a vertical areal effect of a spherical non-shattering explosive charge equivalent to Trinitrotoluol (TNT) on the attack side surface of the specimen (detonated in the specified distance); and
- it shall permit the realization of the test conditions as per Table 16.

F-3.3 Measuring device to determine the magnitude and timely development of the positive pressure of the blast wave reflected from the attack side surface of the specimen.

Device tolerance: 5 percent

F-4 SPECIMENS

F-4.1 Type, Dimensions and Marking of Specimens

Materials and structure of the specimen shall conform to the glazing type to be tested.

Specimen length: 1 100 ± 5 mm
Specimen width: 900 ± 5 mm

The side of attack of each specimen shall be marked.

Table 16 Test Conditions
(*Clauses* F-3.2, F-5.1, F-5.4 *and* F-6.1))

Code No. of Type of Stress	Demonstration of the Effect of a Spherical, Non-shattering TNT-Equivalent Explosive Charge (Detonated in Specified Distance)	
	Positive Maximum Pressure P_r of the Reflected Blast Wave, (bar), ± 5 percent	Duration t_o of Positive Pressure Phase (ms), *Min*
(1)	(2)	(3)
1	0.5	12
2	1.0	10
3	2.0	8

F-4.2 Number of Specimens

Three specimens of the glazing type to be tested for each type of stress to be tested.

F-4.3 Specimen Condition and Preparation

The specimens shall have tarried edges.

For a minimum of 12 h prior to the test each specimen shall be stored vertically freestanding at test temperature.

F-5 PROCEDURE

F-5.1 The test conditions for the various stresses are listed in Table 16. The test temperature shall be between 10 and 30°C.

F-5.2 The specimen shall be clamped in the specimen holder so as to ensure that its front and rear pressure surfaces have a full contact with the supporting surface (*see also* **E-5.1**).

F-5.3 Determine the duration t_o of the positive pressure phase and the maximum pressure P_r of the blast wave reflected on the attack side of each specimen (pressure-time-development).

F-5.4 Each of the three specimens shall be tested once under the test conditions specified in Table 16 for the type of stress to be tested.

F-6 TEST RESULTS

F-6.1 For each specimen the following shall be determined:

- duration t_o of the positive pressure phase and the positive maximum pressure P_r of the percussion wave reflected from the attack side surface under the test conditions in Table 16 for the type of stress to be tested;
- the specimen shall not have any through-holes;and
- There shall be no opening between the clamping frame and the specimen edges (maintenance of the 'sealed space').

F-6.2 Determination of the Class of Resistance Against Explosive Effect

Determine for each specimen the class of resistance against explosive effect as per Table 17 depending on type of stress and test results as per **F-6.1**.

The tested glazing type shall be assigned the lowest class of resistance against explosive effect determined for the three specimens.

Table 17 shows three classes of resistance against explosive effect. The resistance class increases with increasing stress (higher type of stress).

Table 17 Classification of Security Glazing in Resistance Classes Against Explosive Effect
(*Clause* F-6.2)

Code No. of Type of Stress	Positive Maximum Pressure P_r of the Reflected Blast Wave (bar)	Resistance Class Against Explosive Effect
(1)	(2)	(3)
1	0.5	D 1
2	1.0	D 2
3	2.0	D 3

ANNEX G

(*Clause* 5)

SAMPLING OF POLYCARBONATE SHEETS

G-1 SCALE OF SAMPLING

G-1.1 Lot

In a single consignement all the sheets of identical dimensions belonging to the same batch of manufacture shall be grouped together to constitute a lot.

G-1.2 For judging conformity to the specified requirements each lot shall be considered separately.

G-1.3 The number of sample sheets from a lot for determining the conformity shall be in accordance with col 1 and 2 of Table 18.

G-1.4 The sample sheet shall be taken at random from the lot. In order to ensure randomness of selection, random number tables may be used (*see also* IS 4905).

G-2 NUMBER OF TESTS AND CRITERIA FOR CONFORMITY

G-2.1 Each of the sample sheets selected according to **G-1.3** shall be tested for all the requirements of this specification. The lot shall be declared to be in conformity if each sample sheet individually meets the specified requirements.

Table 18 Number of Sample Sheets
(*Clause* G-1.3)

Number of Sheets in a Lot *N* (1)	Number of Sample Sheets *n* (2)
Up to 25	1
26 to 150	2
151 to 300	3
301 to 500	4
501 and above	5

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