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Specification for

Safety glass for land transport

UDC 665.155:629.11

Co-operating organizations

The Glass Industry Standards Committee, under whose supervision this British Standard was prepared, consists of representatives from the following scientific and industrial organizations:

British Glass Industry Research Association*
Glass Manufacturers' Federation
Society of Glass Technology*
University of Sheffield (Department of Glass Technology)

The organizations marked with an asterisk in the above list, together with the following, were directly represented on the committee entrusted with the preparation of this British Standard:

Automobile Association
British Plastics Federation
Chief Fire Officers' Association
Flat Glass Manufacturers' Association
Ministry of Technology
Ministry of Transport
Ministry of Transport — Road Research Laboratory
Society of Motor Manufacturers and Traders Ltd.
An individual manufacturer

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Foreword

This standard makes reference to the following British Standard:

BS 354, *Recommendations for photometric integrators.*

This British Standard was first published in 1939 and revised editions were published in 1949 and 1954. A major amendment to the 1954 edition was issued in 1961 when the zoned type of toughened glass windscreen was introduced. This was followed in 1964 by a separate publication of Parts 1 and 2 covering, for the first time, optical requirements for all windscreens and also a further revision of the toughened glass specification including both uniform and non-uniform wide-zone windscreens.

The representative technical committee which is responsible for this standard under the authority of the Glass Industry Standards Committee, continued its revision work on the laminated glass sections of the 1954 specification and in particular modified these to include a more severe impact test for windscreens, thus ensuring that only so-called "high performance" laminates will be used for this purpose. At the same time the impact requirements for all laminated glass have been made more stringent by increasing from 16 ft (4.9 m) to 30 ft (9.15 m) the height from which the ball is dropped in the fracture and adhesion test. A light stability test is included, in which the visual transmission of the laminate is measured both before and after exposure to ultraviolet radiation.

The toughened glass specification has also been reviewed in the light of technical advances made since 1964 and the following main changes are incorporated in the new edition.

1) Only zoned glass is now included for windscreens as it is felt that the uniformly toughened glass, which may obscure the driver's vision if it fractures, should no longer be used for windscreens.

NOTE By amendment in January 1973, the application of the above provision regarding zoned glass was limited to windscreens for the general run of road vehicles, and it was recognized that uniformly toughened glass is acceptable for the windscreens of railway locomotives and of relatively slow-moving agricultural and industrial tractors.

2) For purposes other than windscreens, provision has been made for the use of glass toughened by chemical treatment, instead of heat treatment, provided it meets the requirements of the standard.

3) The requirements for zoned windscreens have been made more stringent by defining the maximum size of individual particles after fracture and the test procedure for the non-uniform zone glass (Type Z2) has been modified so as to encourage the manufacture of windscreens which give better visibility in the event of fracture.

In keeping with the general changeover of the British industry to the metric system, dimensional requirements have been given in metric units throughout this revision, with the corresponding inch-lb units given also for information. The committee has studied the latest standards and proposals for safety glass in vehicles, prepared in the USA and on the continent of Europe, and where considered appropriate the specification requirements and test procedures of this standard have been harmonized with such overseas standards.

The testing equipment and procedure described in Appendix A to Appendix F are substantially unchanged from the earlier editions, except that Appendix F now covers the requirements of the more severe impact test referred to above. Data are also given in Appendix G, for information only, indicating the effect of windscreen design features (e.g. rake angle and designed curvature) on the optical characteristics.

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

Summary of pages

This document comprises a front cover, an inside front cover, pages i to iv, pages 1 to 31 and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

1 General clauses, and optical requirements for windscreens

1.1 Scope

This British Standard specifies requirements and tests for flat and curved safety glass for land transport, of thicknesses from 2 mm (0.08 in) to 13 mm (0.5 in).

1.2 Definitions and general requirements

For the purposes of this British Standard the following definitions apply. Mandatory general requirements, where applicable, are also given.

1.2.1
safety glass (general definition)

a glass which, if fractured, is less likely to cause severe cuts or serious physical injury than ordinary glass

1.2.2
safety glass for windscreens

a glass as defined above which in addition does not cause any appreciable distortion of objects ahead of the vehicle seen through it; and which, if fractured, permits a sufficient view ahead to enable the driver to control the vehicle whilst bringing it to rest

1.2.3
toughened safety glass (also known as tempered safety glass)

glass which has been converted to a safety glass by subjection to a process of pre-stressing so that, if fractured, it disintegrates into small pieces. In general, its liability to fracture under the action of external forces or changes of temperature is greatly reduced by this process. Unless otherwise specified the pre-stressing is substantially uniform over the whole area of the glass

pre-stressing may be carried out by heating and rapid cooling or by chemical treatment

1.2.4
heat-treated safety glass for windscreens

heat-treated safety glass having a zone of modified heat treatment in which the fragmentation, if the glass is fractured, comprises sufficient pieces of larger size than elsewhere to afford better vision through the zone than through the remainder of the glass

at least the marginal part of the glass, of a width not less than 6 cm (2.5 in) shall disintegrate upon fracture into small pieces. The dimensions and location of the zone shall be agreed between the vehicle maker and the manufacturer of the safety glass; even in the case of half-screens the dimensions of the zone shall be not less than 40 cm (16 in) × 15 cm (6 in)

three types of zoned windscreen are covered by this British Standard:

a) *Uniform small zone, Type Z,* in which the stresses in the glass are substantially even throughout a zone in front of the driver (see Figure 1A).

b) *Uniform wide zone, Type Z*1, in which the stresses in the glass are substantially even throughout a zone extending across the greater part of the windscreen (see Figure 1B).

c) *Non-uniform wide zone, Type Z*2, in which the stresses in the glass vary in intensity over the zone so that, if the glass is fractured, alternate areas break into fine and coarse particles respectively.

NOTE Uniformly toughened safety glass complying with the requirements of Section 2 of this standard is permitted for the windscreens of railway locomotives and of relatively slow-moving agricultural and industrial tractors capable of a speed not exceeding 20 mile/h (32.2 km/h) on level ground.

in general, the alternate areas shall be arranged in a regular pattern over the zone and the stresses in corresponding areas shall be substantially the same (see Figure 1C and Figure 1D)

1.2.5
laminated safety glass

a product made of two or more pieces of glass firmly united to, and alternating with, one or more pieces of reinforcing material (known as “interlayer” or “interleaf”). Fracture does not cause the glass to separate from the interlayer to any substantial extent and in general the product does not break into large fragments

1.2.6
primary vision area

that part of the windscreen through which the principal field of view is obtained (see Figure 2A and Figure 2B)

NOTE Figure 2A excludes from the primary vision area a band round the edge of the glass 6 cm (2.5 in) wide at top and bottom and 9 cm (3.5 in) wide at the sides. Compliance with the optical requirements in **1.3** implies the avoidance of sharp curvatures throughout the primary vision area.

1.2.7
consignment

the whole of the safety glass delivered at any one time in connection with an order or contract

Table 1 — Conditions of acceptance for windscreens (optical requirements)

	Conditions for passing group	Conditions for rejecting group	Conditions for retest	Conditions for passing group after retest	Conditions for rejecting group after retest
Number of specimens tested (for each shape)	5	5	5	10	10
Number of specimens satisfying requirements of **1.3.2** to **1.3.4**	5	3 or less	4	9	8 or less

1.3 Optical requirements

1.3.1 General. The requirements detailed in **1.3.2** to **1.3.4** are specified only for windscreens and apply only to the primary vision area of the windscreen as defined in **1.2.1** 6). Since this area necessarily varies, with different models of land transport vehicle according to the rake angle of the windscreen, seated height, distance from the windscreen and lateral placement of the driver, the vehicle manufacturer should define for each model the "eye position" to which the primary vision area is related[1)].

1.3.2 Optical deviation. When the windscreen is tested in accordance with Appendix A:

1) Using the "ring and spot" target, there shall be no displacement of the secondary image[2)] beyond the point of tangency of the central spot image with the inside edge of the circle; this limits the secondary image separation to a maximum of 15 minutes of arc.

2) Alternatively, using the "ring" target, the primary and secondary images of the circle shall either overlap or touch; this also limits the secondary image separation to a maximum of 15 minutes of arc.

3) There shall not be more than one secondary image.

4) From point to point in the test area there shall be no abrupt change in the displacement of the secondary image.

1.3.3 Distortion of vision. When the windscreen is tested in accordance with Appendix B:

1) It shall not cause breaks in the projected lines, easily seen by the un-aided eye.

2) Projected lines may be bowed relative to the lines on the screen provided that these projected lines do not overlap the lines on the screen. This is equivalent to a maximum primary deviation of ± 8.4 minutes of arc.

1.3.4 Visual transmission. When the windscreen is tested in accordance with Appendix C the visual transmission for light emitted by Standard Illuminant A shall be not less than 75 % for the primary vision area.

1.3.5 Acceptance requirements (see Table 1). If all the windscreens tested (see **2.5.2** and **3.4.3**) satisfy the requirements of **1.3.2** to **1.3.4**, the consignment shall be deemed to comply with this section of the standard. If one windscreen fails to satisfy these requirements, a further five windscreens of the same shape (and group if applicable) shall be tested and if all the windscreens in the second batch satisfy the requirements, the consignment shall be deemed to comply. If two or more windscreens of a given shape (and group if applicable) fail in the first test, or if one or more fail in the second test, all the windscreens of that shape (and group if applicable) in the consignment shall be deemed not to comply with this British Standard.

2 Requirements specific to toughened safety glass (including both heat-treated and chemically-treated glass)

2.1 Properties and quality

Toughened safety glass shall:

1) be transparent, translucent or coloured as required;

2) be free from faults which will interfere with vision, appearance[3)] or service.

NOTE The production of small indentations in heat-treated safety glass within 13 mm (0.5 in) from the edge of the glass is a feature inherent in most processes at present used in the manufacture of a heat-treated safety glass. Such indentations are permissible, but any crack or vent from these indentations extending from the surface towards the interior of the glass, and/or any surface vent of length exceeding 1.6 mm (0.06 in), is contrary to the requirements of this standard.

[1)] Standard procedures are available for this purpose, as recommended by the Society of Motor Manufacturers and Traders Ltd. (UK) and the Automobile Manufacturers Association (USA).
[2)] The secondary or "ghost" image is a spurious image, usually seen at night when the object being viewed is very bright in relation to its surroundings, e.g the headlights of an approaching vehicle.
[3)] Standard of appearance to be agreed between the customer and the manufacturer.

3) have surfaces resistant to abrasion likely to be encountered in service and to the effects of exposure to the atmosphere;

4) be capable of withstanding normal treatment in the service for which it is supplied.

2.2 Thickness

2.2.1 The available nominal thicknesses of heat-treated safety glass are listed in Table 2 which also gives for information the approximate limits of these thicknesses. The thicknesses generally used in the automobile industry together with their approximate limits are listed for information in Table 3.

Table 2 — Limits of thickness for heat-treated safety glass

Nominal thickness	Limits of thickness	
	mm	in
1/8 in (including 3 mm, 24 oz and 26 oz)	2.75 to 3.5	0.108 to 0.138
5/32 in (including 4 mm and 32 oz)	3.8 to 4.8	0.150 to 0.189
3/16 in (including 5 mm)	4.8 to 5.5	0.189 to 0.217
7/32 in (including 1/4 in bare)	5.15 to 6.35	0.203 to 0.250
1/4 in (including 6 mm)	5.6 to 7.1	0.221 to 0.280
5/16 in	6.75 to 7.93	0.266 to 0.312
5/16 in to 3/8 in	7.93 to 9.52	0.312 to 0.375
3/8 in	9.12 to 10.32	0.359 to 0.407
1/2 in	11.9 to 13.5	0.468 to 0.532

Table 3 — Limits of thickness usual for heat-treated safety glass for the automobile industry

Nominal thickness	Limits of thickness	
	mm	in
Sheet glass:		
24 oz	2.75 to 3.05	0.108 to 0.120
26 oz	3.2 to 3.4	0.126 to 0.134
32 oz	3.8 to 4.2	0.150 to 0.165
3/16 in	4.8 to 5.2	0.189 to 0.205
Plate glass:		
5/32 in	3.8 to 4.3	0.150 to 0.169
3/16 in	4.8 to 5.2	0.189 to 0.205
1/4 in	6.0 to 6.4	0.236 to 0.252
Float glass:		
3 mm	2.8 to 3.2	0.110 to 0.126
4 mm	3.8 to 4.2	0.150 to 0.165
5 mm	4.8 to 5.2	0.189 to 0.205
6 mm	5.8 to 6.2	0.228 to 0.244

2.2.2 Chemically toughened glass is available within the range 1.8 mm to 2.5 mm (0.07 in to 0.10 in).

2.3 Marking

The following particulars shall be indelibly and distinctly marked by the manufacturer on every piece of toughened safety glass intended for glazing in a land vehicle:

1) The name, registered trade mark or licence number of the manufacturer.

2) In the case of heat-treated toughened safety glass, the letter "T", or the word "Toughened", or the word "Tempered".

3) In the case of chemically toughened safety glass, the letters "CHT".

4) In the case of a heat-treated safety glass windscreen having a uniform small zone of modified heat-treatment of Type Z, the letter "Z".

5) In the case of a heat-treated safety glass windscreen having a uniform wide zone of modified heat-treatment of Type Z1, the symbol "Z1".

6) In the case of a heat-treated safety glass windscreen having a non-uniform wide zone of modified heat-treatment of Type Z2, the symbol "Z2".

7) In the case of a uniformly toughened safety glass windscreen [see Note to **1.2.4** c)], the letter "W".

8) In the case of toughened safety glass made from float glass, either the letter "F" or the word "Float".

9) In the case of toughened safety glass made from plate glass, either the letter "P" or the word "Plate".

10) In the case of toughened safety glass made from sheet glass, either the letter "S" or the word "Sheet".

11) An indication that the glass complies with the requirements of this British Standard. It is strongly recommended that in view of the nature of this specification, manufacturers and purchasers should make use of the scheme operated by the British Standards Institution (see below) whereby the product may bear the registered certification trade mark of the BSI. Alternatively, compliance shall be indicated by the use of the inscription "BS 857:1967".

12) Toughened glass windscreens complying with the requirements of this standard as amended by Amendment No. 1 (AMD 1088) and Amendment No. 2 (AMD 3402) shall be marked with the inscription "BS 857-2:1967".

NOTE The mark BS 857 on or in relation to the product is a claim by the manufacturer that it complies with the requirements of the standard.

The British Standards Institution is the owner of the registered certification trade mark shown below. This mark can be used only by manufacturers licensed under the certification mark scheme operated by the BSI. The presence of this mark on or in relation to a product is an assurance that the goods have been produced to comply with the requirements of the British Standard under a system of supervision, control and testing operated during manufacture and including periodical inspection at the manufacturer's works in accordance with the certification mark scheme of the BSI.

Further particulars of the terms of licence may be obtained from the Director, British Standards Institution, 2 Park Street, London, W.1.

2.4 Sampling and acceptance

Unless otherwise agreed, 5 %, but not less than five safety glasses, of the same nominal thickness, substantially equal in size and similar in shape, shall be taken at random from each consignment, grouped as described in **2.5.2** and tested for compliance with **1.3** (if applicable) and with **2.6**.

If all the glasses tested of a group comply with all the requirements specified in **2.6.4** all the glasses in that group shall be deemed to comply with this section of the standard. If only one glass of a group fails to satisfy one or more of these requirements, five additional glasses shall be taken from the same group and tested for compliance with **2.6.4**; if all the additional glasses satisfy all these requirements, all the glasses of that group shall be deemed to comply with this section of the standard. If in any group two or more of the original glasses, or one or more of the additional glasses, fail to satisfy one or more of these requirements, all the glasses of that group in the consignment shall be deemed not to comply with this British Standard.

2.5 Uniformity test

2.5.1 Apparatus. The apparatus shall be as described in Appendix D.

2.5.2 Procedure. All the glasses taken for test in accordance with **2.4** shall be illuminated by polarized light falling approximately normally on one face and examined from the opposite side through the analysing device. The whole area of each glass shall be examined and the glasses divided into groups having reasonably similar strain patterns[4)]. If any group contains less than five glasses, additional glasses shall be taken at random from the consignment until the group contains not less than five glasses. If new strain patterns are noted, sufficient glasses shall be taken at random from the consignment to obtain five glasses for each new strain group. If, after examining all the glasses, any group contains less than five, the glasses of this group shall be deemed not to comply with the requirements of this British Standard.

Five glasses from each group shall be taken for the optical test (**1.3**) (if applicable), followed by the fragmentation test (**2.6**). One of each set of five glasses shall be set aside as a standard of strain pattern and the four remaining glasses tested for fragmentation.

If the optical properties (if applicable) of any one of the five glasses proves to be unsatisfactory, five additional glasses of the same strain pattern group shall be taken from the consignment and the tests described in **1.3** shall be repeated.

If the fragmentation of any one of the four glasses proves to be unsatisfactory, four additional glasses of the same strain pattern group shall be taken from the consignment and the tests described in **2.6** shall be repeated.

If, in obtaining the additional glasses for the retest, further strain patterns are found, additional groups shall be formed. Each group of glasses shall be subjected to the optical test (if applicable) and the fragmentation test.

2.6 Fragmentation test

2.6.1 General. Notes on methods of supporting the specimens and of carrying out the particle count determination are given in Appendix E. The procedures for carrying out the test and interpreting the results are set out below and are summarized in Table 4 and Figure 3A to Figure 3D. Conditions for acceptance are set out in Table 5.

2.6.2 Procedure for test. Of each set of five glasses (see **2.5.2**) four shall be supported as far as practicable over their whole area, means being provided to prevent any substantial spreading of the fragments (see Appendix E).

The four glasses shall be broken by means of a centre punch, the point of impact being:

1) In the case of a uniformly toughened safety glass, 13 mm (0.5 in) from the longest edge of the glass at the mid-point of that edge.

2) In the case of a small-zone heat-treated safety-glass windscreen or half-windscreen Type Z, on the longitudinal line passing through the centre of the vertical axis of the zone and 13 mm (0.5 in) from the intersection of that line with the end of the glass further from the zone.

3) In the case of a wide-zone heat-treated safety-glass windscreen of Type Z1 or Z2, in the centre of the zone.

4) In the case of a half-screen of Type Z1 or Z2, as near the centre of the zone as possible consistent with the requirements for the position of the first assessed area given in **2.6.3.5**. In no case shall the point of impact be less than 7.5 cm (3 in) from the inner end of the zone.

2.6.3 ***Particle count and size determinations***

2.6.3.1 All particle count determinations on any one piece of uniformly toughened glass shall be completed within 3 minutes of the fracture of that glass.

All particle count and size determinations on any one piece of glass that contains a zone of modified heat treatment shall be completed within 10 minutes of the fracture of that glass.

No magnifying lens or other aid to vision (except spectacles if normally worn) shall be used when making the particle counts described below.

2.6.3.2 When a uniformly toughened safety glass has been broken in accordance with **2.6.2** 1), (see Figure 3A), the particles in a square of side 5 cm (2 in) shall be counted. The particle count shall be made in the region of coarsest fracture excluding the following regions:

1) A segment of radius 7.5 cm (3 in) centred on the point of impact.

2) Two further segments (S) of radius 7.5 cm (3 in) centred on the opposite edge, in the regions of coarsest fragmentation.

[4)] Chemically toughened glass will show only a very slight pattern close to the edge of the glass. The major portion of the glass will be completely free from pattern.

If the count is between the limits stated in **2.6.4.1**, i.e. less than 60 but not less than 40 per 25 cm^2 (4 in^2), a further particle count shall be made in an area of 100 cm^2 (16 in^2) embracing the former area and the area of coarsest fracture adjacent. The counts shall be made in squares of side 5 cm (2 in) and 10 cm (4 in) respectively except that, in cases where such squares would encroach upon the periphery of the glass or any of the segments of radius 7.5 cm (3 in), the counts shall be made in rectangles of equivalent area.

A further count shall also be made in a square of side 5 cm (2 in) in the coarsest fragmentation area (S) defined in **2.6.3.2** 2) above.

2.6.3.3 When a small-zone heat-treated safety-glass windscreen of Type Z has broken in accordance with **2.6.2** 2), (see Figure 3B), a count shall first be made of the particles in a square of side 10 cm (4 in) in the region of the coarsest fracture of the zone.

If the count in this square satisfies the requirements of **2.6.4.2** below:

1) A further count shall be made in a square of 5 cm (2 in) side in the region of the coarsest fracture of the glass outside the zone, excluding a segment of 7.5 cm (3 in) radius centred on the point of impact and extending to the margin, and two further segments (S) of radius 7.5 cm (3 in) centred one on each of the two long edges (if coarser particles occur in these regions).

2) The whole windscreen shall be examined for pointed or flanged long particles, and the number of such particles exceeding 7.5 cm (3 in) in length shall be noted.

3) The presence of any individual particle, of area exceeding 20 cm^2 (3 in^2), shall also be noted.

2.6.3.4 When a wide-zone heat-treated safety-glass windscreen of Type Z1 or Z2 has been broken in accordance with **2.6.2** 3), (see Figure 3C), a count shall be made of the particles in each of two circles of area 160 cm^2 (25 in^2), i.e. diameter 14.3 cm (5.64 in), the centres of which shall be located within 2.5 cm (1 in) of two points central in the height of the zone and 23 cm (9 in) from and on each side of the point of impact; except that in the case of a small windscreen containing a zone of length less than 76 cm (30 in) but not less than 58 cm (23 in), the position of the assessed areas shall be such that no part of them shall be less than 7.5 cm (3 in) from the ends of the zone or from the point of impact. Within the permitted limits of location, the two circles of area 160 cm^2 (25 in^2) shall be so placed that the fragmentation requirements of **2.6.4.3** are most likely to be satisfied. In the case of a heat-treated windscreen containing a non-uniform zone Type Z2, a count shall first be made in each circle of the number of disks of diameter 12.7 mm (0.5 in) which may be placed on particles or included portions of particles without overlapping the edges of the particles. One or two disks may be placed on any one particle but if two disks are placed on one particle they shall not overlap.

If the count in each circle satisfies the requirements of **2.6.4.3** below:

1) A further count shall be made of the particles in a square of side 5 cm (2 in) situated in the region of coarsest fracture in the marginal area of the glass of width at least 6 cm (2.5 in) (excluding three small segments (S) on both top and bottom edges opposite to and on either side of the point of impact). Additionally, if any of the small segments show a markedly coarser fracture than in this square, a further count shall be made in the coarsest of them.

2) The whole windscreen, excluding a circle of radius 7.5 cm (3 in) centred on the point of impact, shall be examined for pointed or flanged long particles, and the number of such particles of which a length exceeding 7.5 cm (3 in) is outside this circle shall be noted.

3) The presence of any individual particle of area exceeding 20 cm^2 (3 in^2) shall also be noted.

2.6.3.5 When a heat-treated safety-glass half-screen of Type Z1 or Z2 has been broken in accordance with **2.6.2** 4), (see Figure 3D), the first assessment shall be in a single circle of area 160 cm^2 (25 in^2), located so that no part of this area is less than 7.5 cm (3 in) from the point of impact or from the outer end of the zone. Except only that this single circle of area 160 cm^2 (25 in^2) is used for part of the assessment, the particle count and size determinations shall be carried out as described in **2.6.3.4** for full windscreens of the corresponding type of zone.

2.6.4 ***Test requirements (see also Table 4 and Figure 3A to Figure 3D)***

2.6.4.1 For each uniformly toughened glass the following requirements apply:

either there shall be not less than 60 particles in a square of side 5 cm (2 in) in the coarsest area (as defined in **2.6.3.2**),

or there shall be less than 60 particles but not less than 40 particles in this square of side 5 cm (2 in), and not less than 240 particles in the embracing square of side 10 cm (4 in) (as defined in **2.6.3.2**).

There shall be not less than 40 particles in a square of side 5 cm (2 in) in the two segments defined in **2.6.3.2** 2).

2.6.4.2 For each small-zone windscreen glass of Type Z the following requirements apply:

In the case of glasses having a nominal thickness (see Table 2) of 6 mm ($^1/_4$ in or $^7/_{32}$ in nominal), the particle count in the coarsest area of the agreed zone shall be not less than 80 nor more than 160 per square of 10 cm (4 in) side [i.e. an average of not less than five nor more than ten per 6.5 cm^2 (1 in^2)] and the particle count in the coarsest area outside the agreed zone, excluding the three segments referred to in **2.6.3.3** 1), shall be not less than 60 per square of 5 cm (2 in) side, [i.e. an average of not less than 15 per 6.5 cm^2 (1 in^2)]. There shall be not less than 40 particles in a square of 5 cm (2 in) side in the two segments (S) defined in **2.6.3.3** 1). No individual particle shall exceed 20 cm^2 (3 in^2) in area. There shall not be more than five pointed or flanged particles of length exceeding 7.5 cm (3 in).

In the case of glasses having a nominal thickness of 5 mm ($^3/_{16}$ in), the conditions specified in the preceding paragraph shall apply except that the particle count in the coarsest area of the zone may exceed 160 per square of 10 cm (4 in) side provided it does not exceed 200 per square of 10 cm (4 in) side.

2.6.4.3 For each wide-zone heat-treated safety-glass windscreen of Type Z1 or Type Z2, the following requirements apply:

In the case of glasses having a nominal thickness (see Table 2) of 6 mm ($^1/_4$ in or $^7/_{32}$ in nominal), the particle count in each of the two circles of area 160 cm^2 (25 in^2) shall be for Type Z1 not less than 125 nor more than 250 [i.e. an average of not less than five nor more than ten per 6.5 cm^2 (1 in^2)] and for Type Z2 not less than 125 nor more than 400 [i.e. an average of not less than five nor more than 16 per 6.5 cm^2 (1 in^2)]; the particle count in the marginal area shall be not less than 60 in a square of 5 cm (2 in) side [i.e. an average of not less than 15 per 6.5 cm^2 (1 in^2)] except in the six segments (S) referred to in **2.6.3.4** 1) where the particle count shall be not less than 40 in a square of 5 cm (2 in) side; the fragmentation in any area between the marginal area and the zone of modified heat treatment shall be of a character not coarser than that of the zone; there shall be not more than five pointed or flanged long particles of a length exceeding 7.5 cm (3 in) outside a circle of radius 7.5 cm (3 in) centred on the point of impact; and there shall not be any individual particle exceeding 20 cm^2 (3 in^2) in area.

In the case of glasses having a zone of modified heat treatment of Type Z2, the number of disks of diameter 12.7 mm (0.5 in) which can be placed on particles or included portions of intersected particles in each circle of area 160 cm^2 (25 in^2), not more than two disks being placed on any one particle, shall be not less than eight.

In the case of glasses having a nominal thickness of 5 mm ($^3/_{16}$ in), all the conditions specified in the preceding paragraphs shall apply except that for glasses having a Type Z1 zone the particle count in each of the two circles of area 160 cm^2 (25 in^2) may exceed 250 provided that it does not exceed 300.

2.6.4.4 For each heat-treated safety-glass half-screen of Type Z1 or Z2, the appropriate requirements of **2.6.4.3** shall apply, except that the particle count in the first assessment relates to one circle only, of area 160 cm^2 (25 in^2).

2.6.5 Glasses with worked surfaces. Safety glasses with etched, sandblasted, engraved or otherwise "worked" surfaces shall be subjected to the appropriate fragmentation test described above. The pre-stressing of the glass shall be such that upon fracture by centre punch both the "worked" portion and the remainder of the glass shall show a particle count of not less than 60 per square of 5 cm (2 in) side. In no case shall the depth of "working" exceed 20 % of the thickness of the glass.

Table 4 — Summary of requirements for fragmentation tests for toughened safety glass

Number of specimens for test: 4. Number of specimens for retest: 4.

	Type of toughened safety glass			
	Uniform	**Uniform small-zone (Type Z) windscreen**	**Uniform wide-zone (Type Z1) windscreen**	**Non-uniform wide-zone (Type Z2) windscreen**
Point of impact	Centre of longest edge	Short edge furthest from zone	Centre of zone	Centre of zone
First area(s) assessed	Square of side 5 cm (2 in)	Square of side 10 cm (4 in)	Two circles of area 160 cm^2 (25 in^2) centred within 2.5 cm (1 in) of points 23 cm (9 in) each side of point of impact and at mid-height of zone	Two circles of area 160 cm^2 (25 in^2) centred within 2.5 cm (1 in) of points 23 cm (9 in) each side of point of impact and at mid-height of zone
Location	Coarsest area — excluding a segment of radius 7.5 cm (3 in) centred on point of impact and two further segments of radius 7.5 cm (3 in) centred on edge opposite point of impact	Coarsest area of zone		
Number and size of large particles in each area	—	—	—	Not less than eight disks of diameter 12.7 mm (0.5 in) placed on particles or intersected particles (not more than two disks on any one particle)
Number of particles required in area(s)	Minimum of 60 Minimum of 40 in two segments on edge opposite point of impact	For glass of nominal thickness 6 mm ($^1/_4$ in or $^7/_{32}$ in) Minimum 80 Maximum 160 For glass of nominal thickness 5 mm ($^3/_{16}$ in) Minimum 80 Maximum 200	For glass of nominal thickness 6 mm ($^1/_4$ in or $^7/_{32}$ in) Minimum of 125 Maximum of 250 For glass of nominal thickness 5 mm ($^3/_{16}$ in) Minimum of 125 Maximum of 300	Minimum of 125 Maximum of 400

Table 4 — Summary of requirements for fragmentation tests for toughened safety glass

	Type of toughened safety glass			
	Uniform	**Uniform small-zone (Type Z) windscreen**	**Uniform wide-zone (Type Z1) windscreen**	**Non-uniform wide-zone (Type Z2) windscreen**
Relaxation	If particles number 40 or more but less than 60, embracing square of side 10 cm (4 in) shall contain at least 240	—	—	—
Second area assessed	—	Square of side 5 cm (2 in)	Square of side 5 cm (2 in)	Square of side 5 cm (2 in)
Location	—	Coarsest portion outside zone excluding a segment of radius 7.5 cm (3 in) centred on point of impact and two further segments of radius 7.5 cm (3 in) centred one on each long edge	Coarsest portion of marginal band excluding three small segments on top and bottom edges opposite to and on either side of the point of impact	Coarsest portion of marginal band excluding three small segments on top and bottom edges opposite to and on either side of the point of impact
Particles required in area	—	Minimum of 60 (minimum of 40 in the two small segments on long edges)	Minimum of 60 (minimum of 40 in the six small segments)	Minimum of 60 (minimum of 40 in the six small segments)
Third area assessed	—	Complete glass	Complete glass	Complete glass
Maximum length of particles	—	Not exceeding 7.5 cm (3 in)	Not exceeding 7.5 cm (3 in)	Not exceeding 7.5 cm (3 in)
Relaxation	—	There may be not more than five pointed or flanged long particles of length exceeding 7.5 cm (3 in)	There may be not more than 5 pointed or flanged long particles of length exceeding 7.5 cm (3 in) outside a circle of radius 7.5 cm (3 in) centred on the point of impact.	There may be not more than 5 pointed or flanged long particles of length exceeding 7.5 cm (3 in) outside a circle of radius 7.5 cm (3 in) centred on the point of impact.
Maximum area of particles	—	No particle to exceed 20 cm^2 (3 in^2)	No particle to exceed 20 cm^2 (3 in^2)	No particle to exceed 20 cm^2 (3 in^2)
Fourth area assessed	—	—	Between zone and marginal band	Between zone and marginal band
Character of fragmentation	—	—	Not coarser than zone	Not coarser than zone

Table 5 — Conditions of acceptance for toughened safety glass (fragmentation test)

Number of specimens for test: 4. Number of specimens for retest: 4.

	Type of toughened safety glass			
	Uniform (non-windscreen)	**Uniform small-zone (Type Z) windscreen**	**Uniform wide-zone (Type Z1) windscreen**	**Non-uniform wide-zone (Type Z2) windscreen**
Condition for passing group	No failure	No failure	No failure	No failure
Condition for retest	One failure	One failure	One failure	One failure
Condition for passing group after retest	No failure in retest	No failure in retest	No failure in retest	No failure in retest
Condition for rejecting group	Two or more failures in first test or one or more failures in retest	Two or more failures in first test or one or more failures in retest	Two or more failures in first test or one or more failures in retest	Two or more failures in first test or one or more failures in retest

2.7 Visual transmission

When toughened glass is tested in accordance with Appendix C, the visual transmission for light emitted by Standard Illuminant A shall be:

a) not less than 75 % in the case of a windscreen;

b) not less than 70 % for toughened glass other than windscreens.

NOTE The requirements of **2.7** and **3.5.3** of this standard do not relate to safety clauses and safety glazing in windscreen and other windows which are specifically excluded from the Motor Vehicles (Construction and Use) Regulations 1978 (SI No 1017) by paragraphs 10 and 11 of Regulation 26, paragraph 10 of which states that the specified value of visual transmission of light shall not apply to

a) any part of any windscreen which is outside the vision reference zone;

b) windows through which the driver when in the driver's seat is unable at any time to see any part of the road on which the vehicle is waiting or proceeding;

c) windows in any ambulance which are not wholly or partly in front of or on either side of any part of the driver's seat; and

d) windows in any public service vehicle, goods vehicle, locomotive, or motor tractor other than windows which:

i) are wholly or partly in front of or on either side of any part of the driver's seat,

ii) face the rear of the vehicle, or

iii) form the whole or part of a door giving access to or from the exterior of the vehicle.;

and paragraph 11 of which states

For the purposes of this Regulation any window is deemed to face the front of the vehicle or the rear of the vehicle if the inner surface of such window is at an angle exceeding 30 degrees to the longitudinal vertical plane of the vehicle.

3 Requirements specific to laminated safety glass

3.1 Properties and quality

Laminated safety glass shall:

1) be transparent, translucent or coloured as required;

2) be free from faults which will interfere with vision, appearance[5] or service;

3) have surfaces resistant to abrasion likely to be encountered in service and to the effects of exposure to the atmosphere;

4) be capable of withstanding normal treatment in the service for which it is supplied.

3.2 Thickness

The available nominal thicknesses of laminated safety glass are listed in Table 6, which also gives for information the approximate limits for these thicknesses.

Table 6 — Limits of thickness for laminated safety glass

Nominal thickness	Limits of thickness	
in	mm	in
$^3/_{16}$	4.4 to 6.2	0.173 to 0.244
$^7/_{32}$	5.0 to 6.8	0.197 to 0.268
$^1/_4$	5.6 to 7.4	0.220 to 0.292
$^5/_{16}$	7.0 to 9.4	0.276 to 0.370
$^3/_8$	9.0 to 11.4	0.354 to 0.449

3.3 Marking

The following particulars shall be indelibly and distinctly marked by the manufacturer on every piece of laminated safety glass intended for glazing in a land vehicle, except in the case of stock sizes which are supplied for cutting and fitting by stockists when the specified markings may be applied by the manufacturer in the form of a label:

1) The name, registered trade mark or licence number of the manufacturer.

2) The letter "L" or the word "Laminated" indicating that it is a laminated safety glass.

3) In the case of laminated safety glass made with two or more pieces of plate glass, either the letter "P" or the word "Plate".

4) In the case of laminated safety glass made with two or more pieces of sheet glass, either the letter "S" or the word "Sheet".

5) In the case of laminated safety glass made with two or more pieces of float glass, either the letter "F" or the word "Float".

6) In the case of laminated safety glass made with one piece of plate or float glass and one piece of sheet glass, the letter "C", the abbreviation "Compo" or the word "Commercial".

7) In the case of high performance laminated safety glass (meeting the requirements of impact test **3.8**) the symbol HP[6].

8) In the case of laminated safety glass for use as windscreens the symbol W HP[7].

[5] Standard of appearance to be agreed between the customer and the manufacturer.
[6] HP is the symbol selected to indicate "high performance" laminates complying with the additional impact test in **3.8**.
[7] W HP is the symbol selected to indicate "high performance" laminates complying with the additional impact test in **3.8** and optical requirements in **1.3**.

9) An indication that the glass complies with the requirements of this British Standard. It is strongly recommended that in view of the nature of this specification, manufacturers and purchasers should make use of the scheme operated by the British Standards Institution (see below) whereby the product may bear the registered certification trade mark of the BSI. Alternatively, compliance shall be indicated by the use of the inscription "BS 857:1967".

10) Laminated glass windscreens complying with the requirements of this standard as amended by Amendment No. 1 (AMD 1088) and Amendment No. 2 (AMD 3402) shall be marked with the inscription "BS 857-2:1967".

NOTE The mark BS 857 on or in relation to the product is a claim by the manufacturer that it complies with the requirements of the standard.

The British Standards Institution is the owner of the registered certification trade mark shown below. This mark can be used only by manufacturers licensed under the certification mark scheme operated by the BSI. The presence of this mark on or in relation to a product is an assurance that the goods have been produced to comply with the requirements of the British Standard under a system of supervision, control and testing operated during manufacture and including periodical inspection at the manufacturer's works in accordance with the certification mark scheme of the BSI.

Further particulars of the terms of licence may be obtained from the Director, British Standards Institution, 2 Park Street, London, W.1.

3.4 Sampling and acceptance

3.4.1 General. For the purpose of testing a consignment of flat laminated safety glass, specimens may be cut from larger pieces taken at random from the consignment, but only one specimen shall be cut from each sample taken from a consignment. In the case of curved laminated safety glass *either* the specimens shall be cut from the flatter portions of production glasses selected at random, *or* flat samples shall be processed under conditions identical with those employed for the curved laminated safety glass, and the test specimens shall be selected at random from these samples.

In so far as sealing or working of the edges is concerned the test specimens shall be in the condition in which they are ordinarily supplied by the manufacturer to the user.

3.4.2 ***Laminated glass for all positions except windscreens***

3.4.2.1 *Standard laminates.* 18 specimens measuring 30.5 $^{+0}_{-0.5}$ cm (12 in) square are required. These specimens shall be submitted to the tests described in **3.5**, **3.6** and **3.7**. If any of the test specimens fail to satisfy these requirements, other than to the extent laid down in the appropriate clauses, the laminated safety glass under test shall be deemed to have failed to comply with this British Standard. The conditions of acceptance are summarized in Table 7.

3.4.2.2 *High performance laminates.* 28 specimens measuring 30.5 $^{+0}_{-0.5}$ cm (12 in) square are required. These specimens shall be submitted to the tests described in **3.5**, **3.6**, **3.7** and **3.8**. If any of the test specimens fail to satisfy these requirements, other than to the extent laid down in the appropriate clauses, the laminated safety glass under test shall be deemed to have failed to comply with this British Standard. The conditions of acceptance are summarized in Table 7

3.4.3 Laminated glass for windscreens. Unless otherwise specified five wind screens of each shape included in the consignment shall be taken at random from the consignment and tested for compliance with the optical requirements of **1.3**. The conditions of acceptance are summarized in Table 1.

Twenty-eight specimens measuring 30.5 $^{+0}_{-0.5}$ cm (12 in) square are required. These specimens shall be submitted to the tests described in **3.5**, **3.6**, **3.7** and **3.8**. If any of the test specimens fail to satisfy these requirements, other than to the extent laid down in the appropriate clauses, the laminated safety glass under test shall be deemed to have failed to comply with this British Standard. The conditions of acceptance are summarized in Table 7.

3.5 Light stability test

3.5.1 Apparatus. The following apparatus is required:

1) CIE Standard Illuminant A, i.e. a gas-filled incandescent lamp with a colour temperature of 2 854 °K.

2) Equipment for measuring visual transmission.

3) A source of ultraviolet radiation[8)].

3.5.2 Procedure. Three specimens 30.5 cm (12 in) square shall be subjected to the light stability test. The visual transmission of the specimens shall be determined using the light emitted by the Standard Illuminant A (see Appendix C).

[8)] A Hanovia S 500 Lamp operated in accordance with the manufacturer's instructions has been found suitable.

The same three specimens shall be placed 23 cm (9 in) from the source of ultraviolet radiation. A portion of each specimen shall be protected from the radiation.

The temperature of the specimens shall be maintained within the limits 38 °C and 49 °C (100 °F and 120 °F) throughout the test. The surface of each specimen which would be glazed to the outside of the vehicle shall be towards the lamp. The specimens shall be exposed for a period of 100 hours.

The irradiated specimens shall again be tested for visual transmission using the light emitted by the Standard Illuminant A (see Appendix C).

3.5.3 Interpretation of result. In the case of a specimen representing a windscreen, the visual transmission before and after irradiation shall not be less than 75 %.

In the case of laminated glass other than a windscreen, the visual transmission before and after irradiation shall be not less than 70 %.

NOTE See note to **2.7**.

3.5.4 Additional boil test. After the transmission measurements have been made the same three irradiated specimens shall be immersed, vertically on edge, in water at 66 °C (150 °F) for 3 minutes and then quickly transferred to and similarly immersed in boiling water. The specimens shall remain in the boiling water for 10 minutes and shall then be removed.

3.5.5 Interpretation of results of additional boil test. The glass itself may crack but no bubbles or other noticeable decomposition shall develop in the irradiated portion. Any specimen in which the glass cracks to such an extent as to confuse the results shall be discarded without prejudice and the test repeated on another specimen.

3.6 Boil test

3.6.1 Procedure. These specimens 30.5 cm (12 in) square shall be immersed, vertically on edge, in water at 66 °C (150 °F) for 3 minutes and then quickly transferred to and similarly immersed in boiling water. The specimens shall remain in boiling water for 2 hours and shall then be removed.

3.6.2 Interpretation of results. The glass itself may crack in this test, but no bubbles or other defects shall develop more than 13 mm (0.5 in) from the outer edge of the specimen or from any cracks that may develop. Any specimen in which the glass cracks to such an extent as to confuse the results shall be discarded without prejudice and the test repeated on another specimen.

3.7 Fracture and adhesion test

3.7.1 Apparatus. The apparatus for this test shall be as described in Appendix F.

3.7.2 Procedure. Twelve specimens 30.5 cm (12 in) square shall be selected and kept at a temperature of 25 ± 4 °C (77 ± 7 °F) for at least 4 hours immediately preceding the test, thereby ensuring a uniform temperature throughout each specimen when tested. Each specimen in turn shall be supported in a wooden frame, as described in Appendix F, in such a way that the plane of the test specimen when in the frame shall be substantially horizontal.

The 227 gramme (0.5 lb) ball shall be dropped freely from a height of 9.15 metres (30 ft) so as to strike the specimen within 2.5 cm (1 in) of its centre on that surface which would be glazed to the *outside* of the vehicle. The ball shall make only one impact on the specimen.

3.7.3 *Interpretation of results*

3.7.3.1 *Consignment satisfactory.* The impact may produce a large number of cracks in the glass; not more than two of the specimens shall break into separate large pieces. Furthermore, with not more than two of the remaining specimens shall the ball produce anywhere in the specimen a hole or fracture through which it could pass.

Immediately opposite the point of impact small fragments of glass may leave the specimen but the small area thus affected shall not be more than 650 mm^2 in an area of 2 000 mm^2.

Areas in which the glass is delaminated without exposing the reinforcing or strengthening material shall not exceed 2 000 mm^2 on each side. Spalling of the outer glass surface opposite to the point of impact, and also adjacent to the area of impact is permitted.

NOTE Where glass fragments have left the specimen the surface of the reinforcing or strengthening material shall be discontinously covered by tiny particles of tightly adhering glass.

3.7.3.2 *Consignment failed.* If more than four specimens break into separate large pieces or if more than four specimens develop a hole through the body of the specimen, or if more than one specimen exposes more than 6.5 cm^2 (1 in^2) of interlayer at the impact point, or if more than one specimen shows more than 20 cm^2 (3 in^2) of separation of glass and interlayer on either side, the consignment shall be deemed not to comply with this British Standard.

3.7.3.3 *Conditions for retest.* If either three or four specimens break into separate large pieces or if three or four yield a hole through the body of the specimens, or if one specimen exposes more than 6.5 cm^2 (1 in^2) of interlayer, or one specimen shows more than 20 cm^2 (3 in^2) of separation between glass and interlayer on either side, a further 12 specimens shall be tested. The consignment shall then be judged on the basis of the 24 specimens tested.

3.7.3.4 *Consignment satisfactory after retest.* If of the 24 specimens not more than four break into separate large pieces, and if not more than four specimens develop a hole, and if not more than one specimen exposes more than 6.5 cm^2 (1 in^2) of interlayer, and if not more than one specimen shows more than 20 cm^2 (3 in^2) of separation between glass and interlayer on either side, the consignment shall be deemed to comply with this British Standard.

3.7.3.5 *Consignment failed after retest.* If of the 24 specimens more than four break into separate large pieces, or if more than four develop a hole, or if more than one exposes more than 6.5 cm^2 (1 in^2) of interlayer, or if more than one shows a separation of glass from interlayer of more than 20 cm^2 (3 in^2) on either side, the consignment shall be deemed not to comply with this British Standard.

3.8 Impact test for high performance laminates

3.8.1 Apparatus. The apparatus for this test shall be as described in Appendix F.

3.8.2 Procedure. Ten specimens 30.5 cm (12 in) square shall be selected and kept at a temperature of 25 ± 4 °C (77 ± 7 °F) for at least 4 hours immediately preceding the test, thereby ensuring a uniform temperature throughout each specimen when tested. Each specimen in turn shall be supported in a wooden frame, as described in Appendix F, in such a way that the plane of the test specimen when in the frame shall be substantially horizontal.

The 2.27 kilogramme (5 lb) ball shall be dropped freely from a height of 3.65 metres (12 ft) so as to strike the specimen within 2.5 cm (1 in) of its centre on that surface which would be glazed to the *inside* of the vehicle. The ball shall make only one impact on the specimen.

3.8.3 ***Interpretation of results***

3.8.3.1 *Consignment satisfactory.* If eight or more specimens retain the ball for 5 seconds, the consignment shall be deemed to comply with this British Standard.

3.8.3.2 *Consignment failed.* If not more than five specimens retain the ball for 5 seconds, the consignment shall be deemed not to comply with this British Standard.

3.8.3.3 *Conditions for retest.* If either six or seven specimens retain the ball for 5 seconds a further ten specimens shall be tested. The consignment shall be judged on the basis of the 20 specimens tested.

3.8.3.4 *Consignment satisfactory after retest.* If of the 20 specimens tested 16 or more retain the ball for 5 seconds, the consignment shall be deemed to comply with this British Standard.

3.8.3.5 *Consignment failed after retest.* If of the 20 specimens tested 15 or fewer retain the ball for 5 seconds, the consignment shall be deemed not to comply with this British Standard.

Table 7 — Conditions of acceptance for laminated safety glass

	Conditions for passing	Conditions for failure	Conditions for retest	Conditions for passing after retest	Conditions for failure after retest
Light stability test (**3.5**); *Boil test* (**3.6**)					
Number of specimens tested	3	3			
Number of specimens meeting requirements	3	2			
Fracture and adhesion test (**3.7**)					
Number of specimens tested	12	12	12	24	24
Number of specimens breaking into separate large pieces	Up to 2	5 or more	3 or 4	Up to 4	5 or more
Number of specimens developing a hole	Up to 2	5 or more	3 or 4	Up to 4	5 or more
Number of specimens exposing more than 6.5 cm^2 (1 in^2) of interlayer at impact point	None	2 or more	1	1	2 or more
Number of specimens showing a separation of glass from interlayer on either side greater than 20 cm^2 (3 in^2)	None	2 or more	1	1	2 or more
Impact test for high performance laminates and windscreens (**3.8**)					
Number of specimens tested	10	10	10	20	20
Number of specimens retaining ball	8 or more	5 or less	6 or 7	16 or more	15 or less

4 Requirements specific to toughened safety glass for use only in railway rolling stock

4.1 General. Toughened safety glass for use in railway rolling stock shall, in addition to the requirements of Section **2**, comply with the requirements stated in **4.2** to **4.5**.

4.2 Flatness. Applicable only to glasses without intentional bending and where the nominal thickness is equal to, or greater than, 5 mm.

4.2.1 Applications. The applications of glasses to be covered by a flatness tolerance are as follows:

1) side windows including doors with drop windows: single and double glazed, clear, tinted, and translucent;

2) interior doors fitted with fixed and drop windows: single glazed clear and tinted;

3) partitions: single glazed, clear and tinted;

4) shelves: clear;

5) mirrors;

6) miscellaneous applications.

4.2.2 Procedure. Four glasses shall be selected at random from a single production batch and categorized into one of two groups as follows:

Category (a) glasses with an area of less than 1 m^2 and with a maximum dimension less than 1.1 m;

Category (b) glasses with an area equal to, or in excess of, 1 m^2 and/or with a maximum dimension equal to, or greater than, 1.1 m.

4.2.2.1 *Category (a).* Glasses shall be placed horizontally on to a substantially flat surface. Considering each edge in turn, the maximum distance, *d,* from the upper surface of the glass to the supporting surface shall be recorded. During this measurement, no load that could result in a flattening of the glass shall be applied, other than the mass of the glass itself.

4.2.2.2 *Category (b).* Glasses shall be supported vertically without applied load, other than the mass of the glass. Considering each edge in turn, a straightedge shall be held in contact with the surface of the glass as near its edge as possible. The maximum distance, *d,* from the straightedge to the furthermost surface of the glass shall be recorded.

4.2.3 Calculation. The average thickness of the glass, obtained from three measurements along each edge, shall be subtracted from the values of *d* recorded in order to obtain an-out-of-flatness value, *v,* for each edge.

4.2.4 Interpretation of results. The test is considered to have given a satisfactory result if the out-of-flatness value, *v,* determined above does not exceed $^1/_{250}$ of the total edge length under consideration for category (a) glasses for edge lengths greater than 500 mm, and $^1/_{200}$ of the total edge length under consideration for category (b) glasses for edge lengths greater than 400 mm. The maximum permissible out-of-flatness value for category (a) glasses up to 500 mm edge length and category (b) glasses up to 400 mm edge length shall be 2 mm.

In the case of the suspended edge, the above values may be increased by 2 mm to allow for distortion of the glass due to the tong marks.

[Therefore a category (a) glass with an edge 1 000 mm long would be allowed a maximum value, *v,* of $^{1000}/_{250}$ or 4 mm. For the suspended edge only, this figure is increased to 6 mm.]

4.3 Tong marks. Tong marks shall not be permitted on those edges of a glass that are required to slide through a runner, e.g. sliding windows and doors, etc.

4.4 Light transmission. Applicable only to frosted or translucent semi-obscured glass for use where a source of light through the glass is required, e.g. kitchen windows.

4.4.1 ***Apparatus***

4.4.1.1 *Light source,* consisting of an incandescent lamp, the filament of which is contained within a parallelepiped 1.5 mm × 1.5 mm × 3 mm. The voltage at the lamp terminals shall be such that the colour temperature is 2 856 ± 50 K. This voltage shall be stabilized within 1 %. The instrument used to check the voltage shall be of appropriate accuracy.

4.4.1.2 *Optical system,* consisting of a lens with a focal length of at least 500 mm and corrected for chromatic aberrations. The clear aperture of the lens shall be adjusted in order to obtain a light beam that is substantially parallel.

4.4.1.3 *Diaphragm,* inserted to limit the diameter of the light beam to 7 ± 1 mm. This diaphragm shall be situated at a distance of 100 ± 50 mm from the lens on the side remote from the light source.

4.4.1.4 *Measuring system,* consisting of a photoelectric cell with an integrating sphere of diameter of 200 mm to 250 mm. The sphere shall be equipped with an entrance port for the light. The entrance port shall be circular and have a diameter at least twice that of the light beam.

The surfaces of the interior of the integrating sphere shall be of substantially equal reflectance, and shall be matt and non-selective.

The output of the photoelectric cell shall be linear within 2 % over the range of luminous intensity used. The design of the instrument shall be such that there is no galvanometer deflection when the sphere is dark. The whole apparatus shall be checked at regular intervals.

4.4.2 Procedure. Three flat specimens 100 mm square shall be selected. The value of total transmittance for each shall be recorded as the average of three readings taken at various positions on the glass as a percentage of the value recorded with no glass in place.

4.4.3 Interpretation of results. The average total transmittance, when measured in accordance with **4.4.2**, shall not fall below 40 %.

4.5 Assessment of visual appearance. The assessment of visual appearance is applicable only to translucent or frosted semi-obscured glass.

4.5.1 Submission. On submission of a series of glasses for test, the manufacturer shall include at least one reference sample with minimum dimensions 100 mm square of a type identical with the glass for which approval is required. This sample shall be indistinguishable from the material of the test glasses, and shall be retained by the customer for submission with subsequent audit tests.

4.5.2 Procedure. Submissions for reapproval, or for audit testing shall be compared with the reference sample retained by the customer.

4.5.3 Interpretation of results. The glass shall be considered satisfactory if there are no significant visual differences between the submission samples and the reference sample.

Appendix A Test for optical deviation

A.1 Test conditions

The test shall be carried out with the test piece at the designed angle of rake from the vertical. It is essential to use a dark room for the test so that any secondary image[9] and the white circle shall be distinctly visible.

A.2 Apparatus

The apparatus shall consist of a box approximately 30.5 cm × 30.5 cm × 15 cm (12 in × 12 in × 6 in) as shown in Figure 4. The front of the box shall have *either* a central hole of diameter 12.7 mm (0.5 in) and a concentric slit of inside diameter 7.92 cm (3.12 in) and width 1.6 mm (0.062 in) forming a "ring and spot" target, *or* a circular slit of outside diameter 3.33 cm (1.31 in) and width 1.6 mm (0.062 in) forming a "ring" target. This front panel may be of glass masked with opaque black paper or of metal sheet painted matt black; in the latter case, the spiders bridging the slit should be small and disposed at 45° to the vertical and horizontal axes. The box shall be illuminated by a 15–25 watt pearl bulb and the central hole shall be covered by a yellow-red filter, e.g. Ilford red 608. The inside of the box shall be coated with white paint as recommended in the appendix of BS 354:1961[10].

A.3 Procedure

The light box shall be positioned so that the centre of the target lies on a horizontal line passing through the centre of the windscreen, which shall be placed 7.6 metres (25 ft) from the light box, either set at the designed rake angle or in a vehicle standing on a level surface facing the light box. The light box shall be viewed through each part of the primary vision area in order to detect the presence of any secondary image associated with the illuminated target. The windscreen may be moved laterally across the projection line, being rotated as necessary to maintain normality of vision in the horizontal plane, still maintaining a distance of 7.6 metres (25 ft) from light box to windscreen and the designed rake angle. A (x2) monocular will assist in viewing and decrease eye strain.

Appendix B Test for distortion of vision

B.1 Test conditions

The test shall be carried out with the test piece at the designed angle of rake from the vertical. It is essential to use a dark room for the test.

B.2 Apparatus

The apparatus shall consist of:

1) A lantern slide projector capable of projecting a sharply defined image on to a screen at a distance of 7.6 metres (25 ft). A 500 watt projector with an object lens of aperture 5 cm (2 in) and focal length 10–30 cm (4–12 in) is suitable for this purpose.

2) A vertical matt white screen approximately 1.2 metres (4 ft) high × 1.8 metres (6 ft) wide, ruled in red lines 1.5 mm (0.06 in) thick at a pitch of 2.16 cm (0.85 in) and inclined at an angle of 30° to the horizontal edge of the screen.

3) A lantern slide bearing lines which shall match exactly with those on the ruled screen [see 2) above] when projected and focused at a distance of 7.6 metres (25 ft) from the lantern. This slide may be produced by photographing the ruled screen itself. It is permissible to adjust slightly the distance between the lantern and the ruled screen in order to achieve coincidence of images.

B.3 Procedure

A piece of flat glass of the highest quality, of the same thickness as that of the windscreen, shall be set at the angle at which the windscreen is to be tested and midway between the lantern and the ruled screen. The ruled screen shall then be adjusted, to compensate for the offset thus introduced, so that the projected lines fall midway between the lines painted on the screen. The piece of flat glass shall then be removed.

The windscreen shall be placed at the designed rake angle and normal to the light source, at a distance of 3.8 metres (12.5 ft) from the ruled screen, in place of the piece of flat glass.

[9] The secondary or "ghost" image is a spurious image, usually seen at night when the object being viewed is very bright in relation to its surroundings, e.g. the headlights of an approaching vehicle.
[10] BS 354, "*Recommendations for photometric integrators*".

The windscreen may be moved laterally across the projection line, being rotated as necessary to maintain normality of vision in the horizontal plane, still maintaining a distance of 3.8 metres (12.5 ft) from light box to windscreen and the designed rake angle.

The image of the lantern slide shall then be projected through the windscreen and the ruled screen shall be examined.

Appendix C Test for visual transmission

C.1 The test shall be carried out with the test piece perpendicular to the incident light by any of the published procedures using the CIE Standard Illuminant A, i.e. a gas-filled incandescent lamp with a colour temperature of 2 854 °K.

Appendix D Apparatus required for uniformity test

D.1 A suitable type of polariscope is shown diagrammatically in Figure 5. The specimen is placed between two sheets of polaroid with their optical axes crossed. Diffused light from a suitable source passes through the sheets of polaroid and the specimen, and the strain pattern is viewed from the side remote from the light source. Other equally satisfactory arrangements are permitted.

Appendix E Notes on fragmentation test

E.1 Suggested methods for supporting the specimens

In the case of flat glass, the specimen may be laid on any convenient flat surface and spreading of the particles prevented by a frame of loose wooden slats held against the edges. In the case of curved glass, the specimen may be wrapped in a sheet of paper, sealed so that the package may be readily opened from one side and placed for breaking on the glass set aside as a standard for the strain pattern; a small piece of steel plate about 0.5 mm (0.020 in) thick should be placed between the glasses under the point of impact to prevent damage to the standard glass.

E.2 Recommended procedures for carrying out the particle count and size determinations

A recommended procedure for particle count determinations is to inscribe a square of side 5 cm (2 in), a square of side 10 cm (4 in) and a circle of area 160 cm^2 (25 in^2) on a thin sheet of transparent plastics material. The appropriate inscribed figure is placed immediately over the area of the glass to be counted and as each particle within the figure is counted an ink spot may be made above it on the plastics sheet. The particle count shall be obtained by adding half the number of particles intersected by the perimeter of the figure to the number of particles wholly contained within that perimeter. For the first area assessment of a glass containing a zone of modified heat treatment of Type Z2, a number of disks of diameter 12.7 mm (0.5 in) are required in order to determine how many such disks may be placed without overlapping on the large particles or included portions of particles within the circle of area 160 cm^2 (25 in^2).

Appendix F Apparatus for fracture and adhesion test and impact test

F.1 A hardened steel ball weighing 227 grammes (0.5 lb) and having a diameter of 3.8 cm (1.5 in).

F.2 A hardened steel ball weighing approximately 2.27 kilogrammes (5 lb) and having a diameter of 8.25 cm (3.25 in).

F.3 A square hardwood frame having dimensions approximating to those shown in Figure 6 so constructed that when the test specimen rests symmetrically on the frame there shall remain unsupported an area 29 cm × 29 cm (11.375 in × 11.375 in) of the specimen. The frame shall be rigidly mounted on a 13 mm (0.5 in) steel plate; the screws or bolts used for attaching it to the steel plate shall not project below the under-surface of the plate. The complete frame shall stand upon a substantial concrete bed.

F.4 A means for dropping freely the 227 gramme (0.5 lb) ball from a height of 9.15 metres (30 ft) or the 2.27 kilogramme (5 lb) ball from a height of 3.65 metres (12 ft) so as to strike the specimen within 2.5 cm (1 in) from its centre. An electromagnet may conveniently be used for this purpose.

Appendix G Optical characteristics of windscreens[11)]

G.1 Introduction

The optical characteristics of windscreens depend on a number of factors, including the angle of rake from the vertical and the curvatures embodied in the car design, the glass thickness, and the parallelism of the two surfaces of the glass, and on combinations of these factors.

The principal defects which may be observed are distortion of vision and the formation of secondary images.

G.2 Definitions

G.2.1 *Optical deviation.* The angle between the true and the apparent direction of an object viewed through the screen, the magnitude of the deviation being a function of the angle of incidence of the driver's line of sight, the thickness and inclination of the screen and the radius of curvature at the point of incidence. If the optical deviation remains constant throughout the screen, or changes gradually, the optical characteristics will generally be satisfactory, but this is not so if the deviation changes abruptly from point to point. Optical deviation is conveniently measured in terms of secondary image separation (see below).

G.2.2 *Wedge.* Departure from parallelism of the surfaces of the screen that may be inherent in the raw material or may result from the bending techniques employed in producing the designed screen curvature.

G.2.3 *Distortion of vision.* Lack of truth in the apparent shape, size or position of objects seen through a screen, caused by changes in the optical deviation due, for example, to changes in glass curvature or to local wedge.

G.2.4 *Secondary image.* A phenomenon in which a distant light source viewed through a screen is seen as a bright primary image with a less bright juxtaposed secondary image. The relative brightness of the secondary and primary image varies with the angle of incidence of the line of sight, being 1 to 500 at 30°, 1 to 400 at 45° and 1 to 100 at 60° incidence, though the difference in brightness appears much less to the human eye because of its response characteristics.

G.3 Formation of images

Figure 7 illustrates the formation of primary and secondary images of an object O by an inclined curved glass. The primary deviation D is the angle between the true direction of O and the apparent direction of its primary image, I_1. The relatively faint secondary image I_2 is seen as a result of light which is reflected by the two inner surfaces of the windscreen before reaching the eye. The angle between the apparent directions of the two images I_1 and I_2 gives the image separation, S.

Figure 8 illustrates the formation of primary and secondary images of an object O by an inclined thin wedge having a wedge angle δ. The primary deviation is again shown as the angle D, and the separation of primary and secondary images as the angle S.

G.4 Magnitude of effects

To enable the optical characteristics of any new design to be determined in advance, a nomogram has been prepared for glass of thickness $^1/_4$ in (6.4 mm) giving the relationship between radius of curvature R, angle of incidence or rake angle of windscreen i, and primary deviation D resulting from the designed curvature, and the associated image separation S. Additional data are also given in the nomogram to enable the radius of curvature to be computed from a knowledge of windscreen height $2x$ and the cross curvature h[12)].

The method of using the nomogram is illustrated by an example (see Figure 9) in which it will be noted that the i_s incidence scale is used to find image separation and the i_d scale for primary deviation. For glass of thickness $^3/_{16}$ in (4.8 mm) the values of D and S should be reduced in the proportion of 4 : 3.

[11)] A more detailed treatment of this subject is given in Gough H. "Curved glass components for the automotive industry: manufacturing techniques, properties, limitations and future trends". The Institute Bulletin. The Institution of Body Engineers, September 1963.

[12)] The cross curvature h is usually determined for a given vertical plane by laying a straight-edge between the top and bottom inner edges of the windscreen, in that plane, and measuring the perpendicular distance from the straight-edge to the centre of the windscreen.

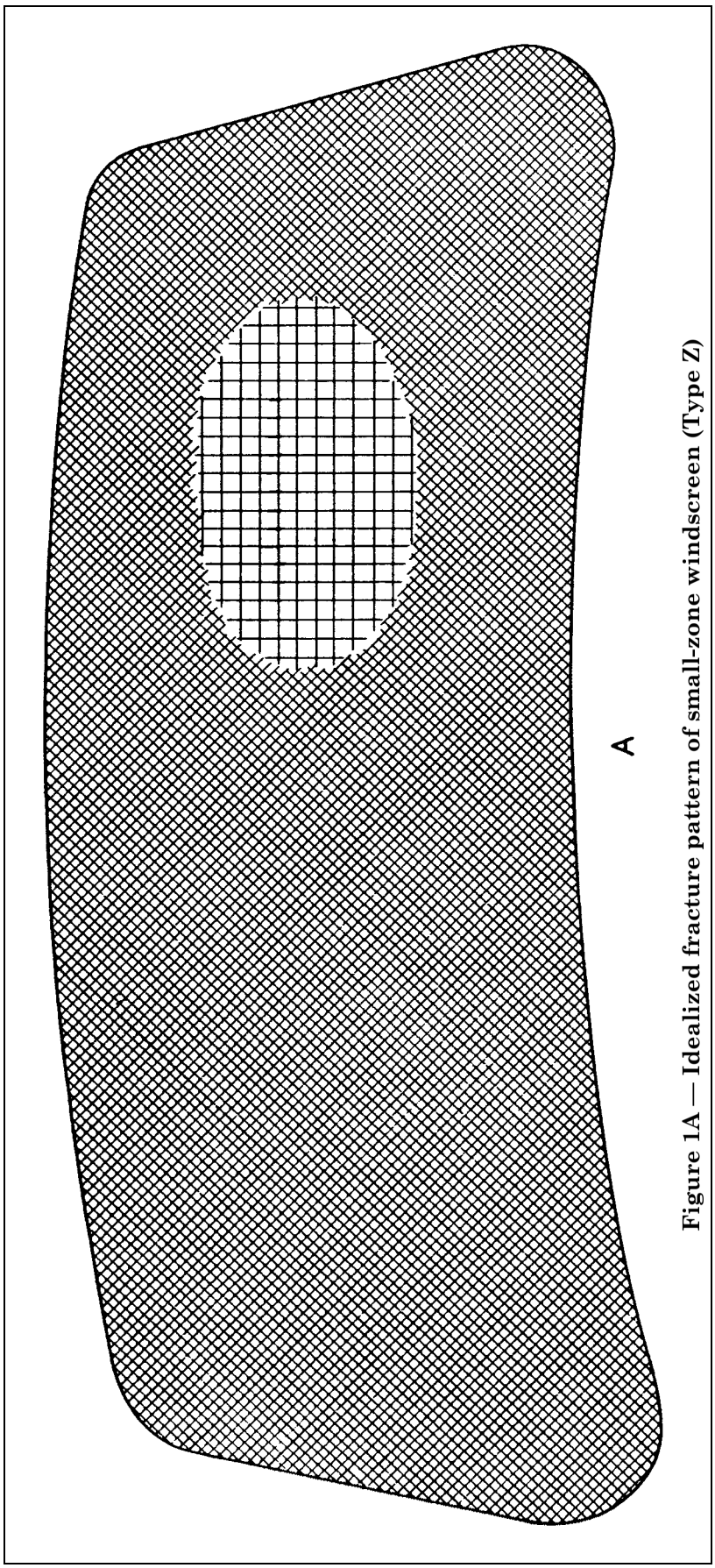
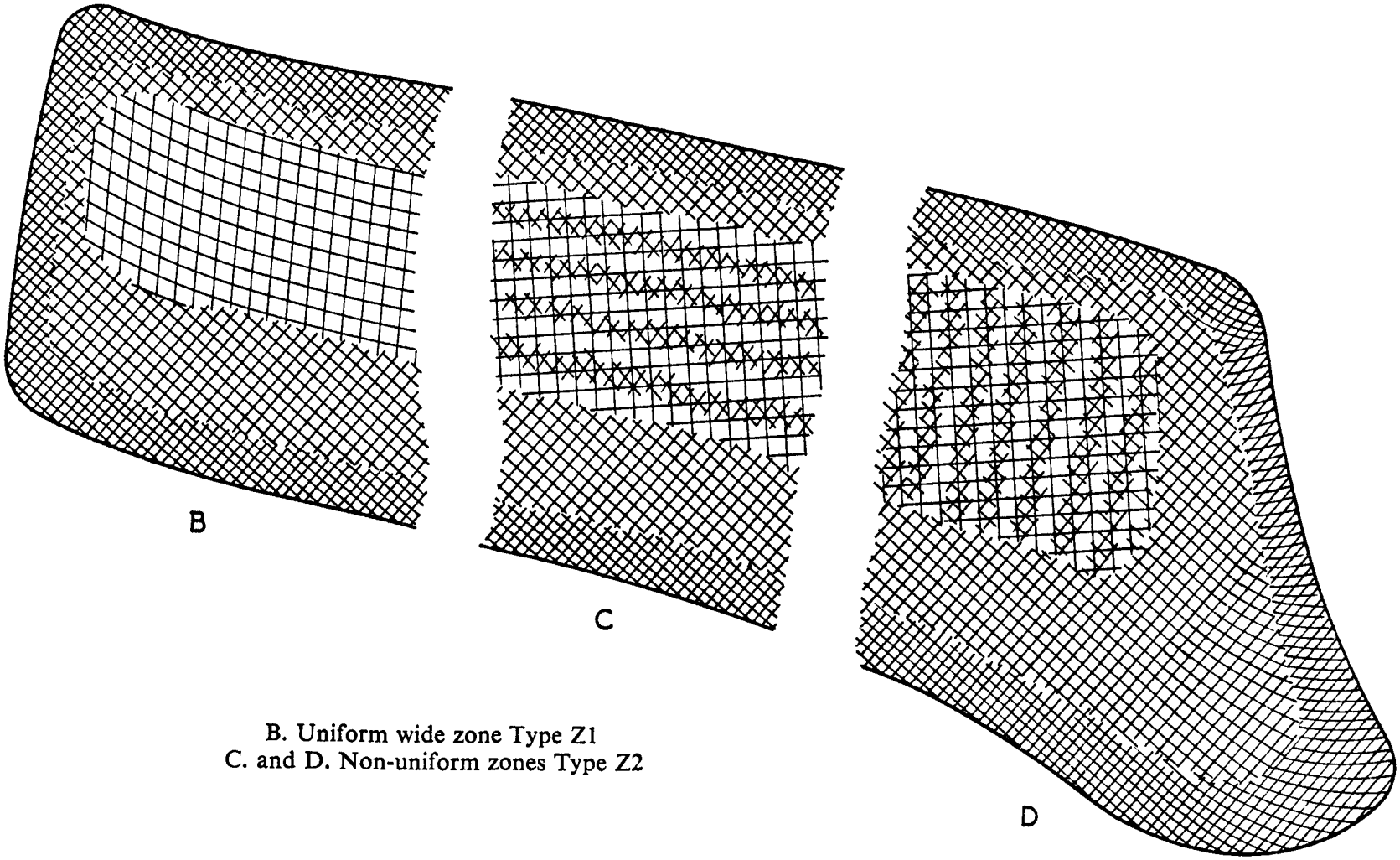


Figure 1A — Idealized fracture pattern of small-zone windscreen (Type Z)



B. Uniform wide zone Type Z1
C. and D. Non-uniform zones Type Z2

NOTE 1 Two variations of Type Z2 are shown; others are permitted.
NOTE 2 The end of a simply curved windscreen is shown at B and the end of a wrap round windscreen at D.

Figure 1B, C and D — Idealized fracture pattern of wide-zone windscreens (Types Z1 and Z2)

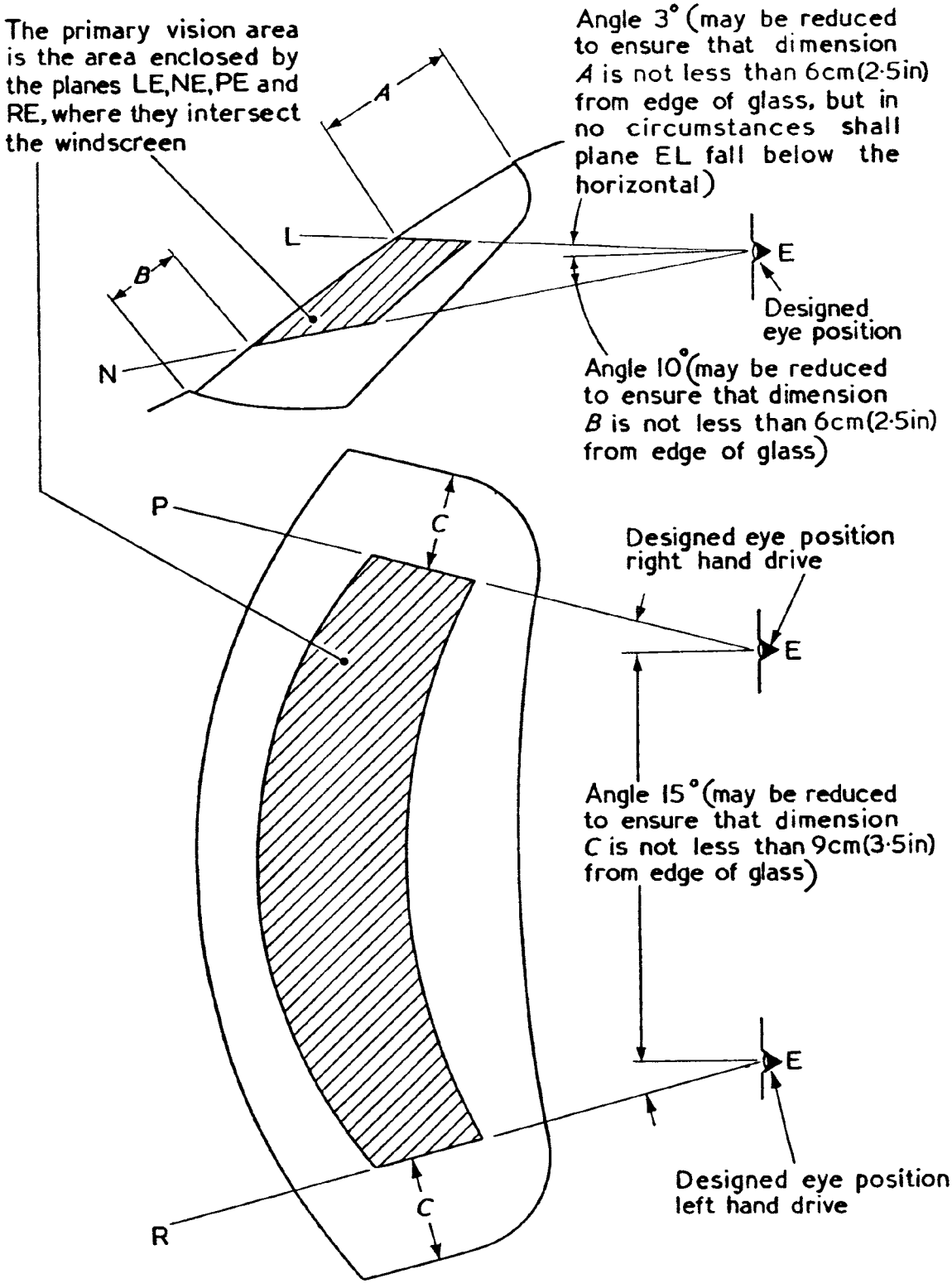
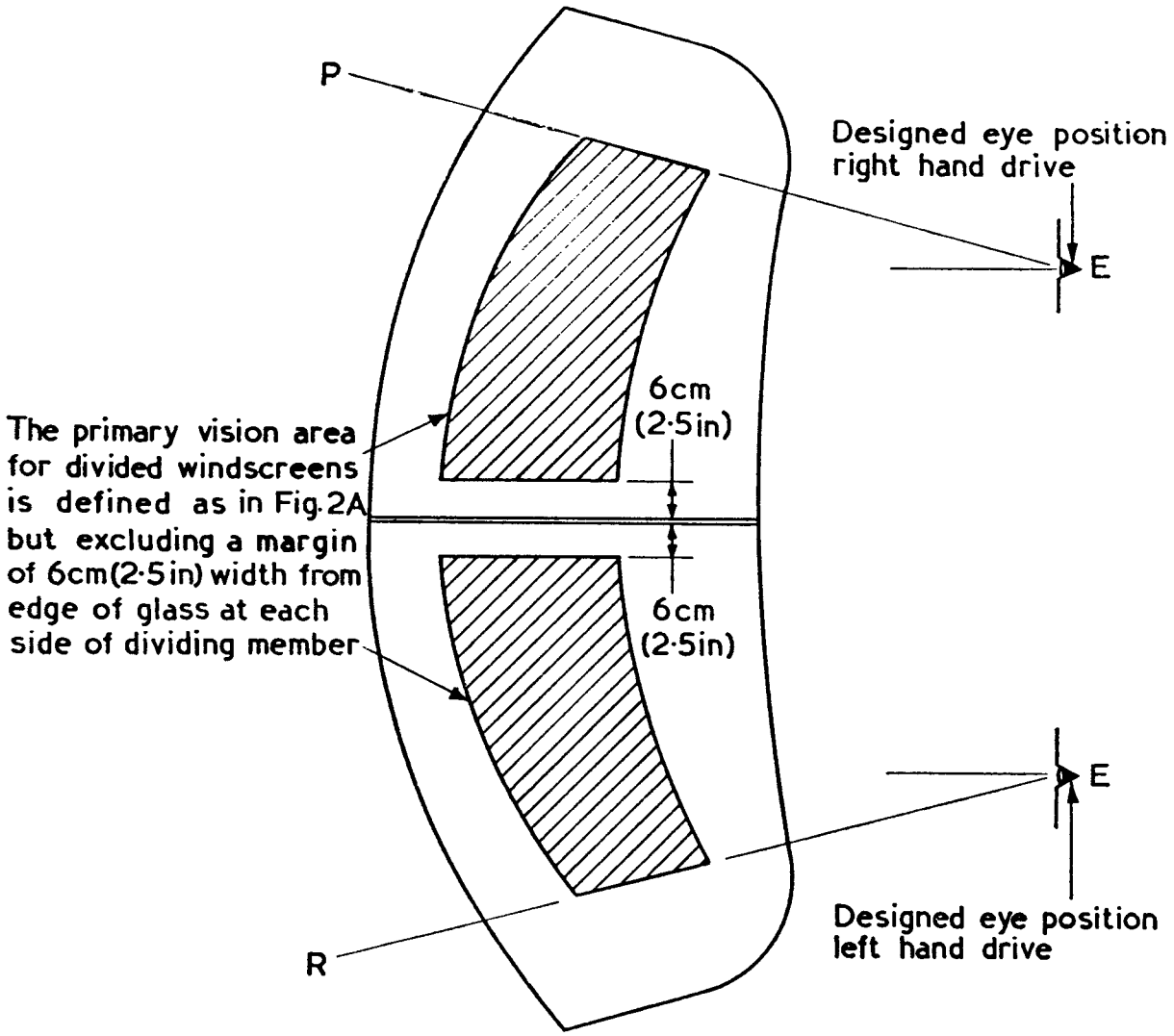
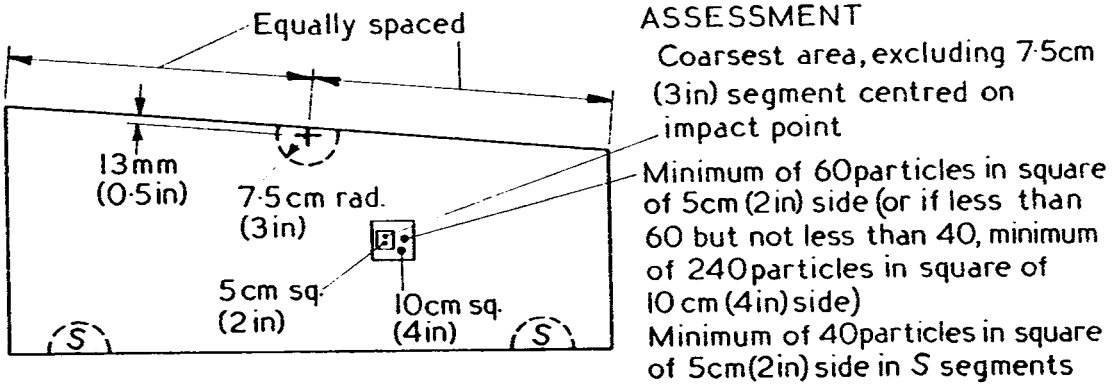


Figure 2A — Primary vision area for optical tests on windscreens

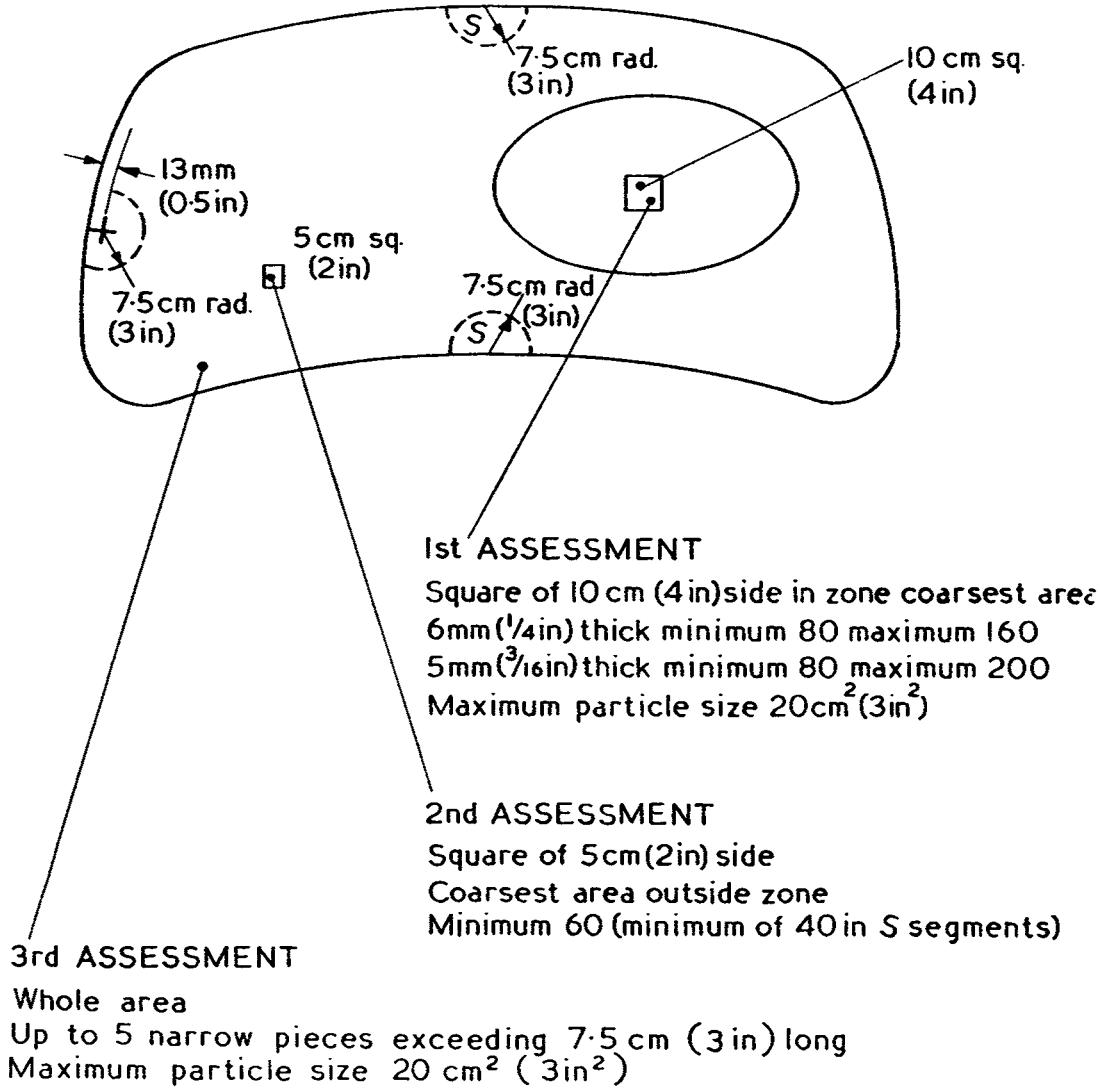


All angles and dimensions as in Figure 2A.

Figure 2B — Primary vision areas for optical tests on divided windscreens

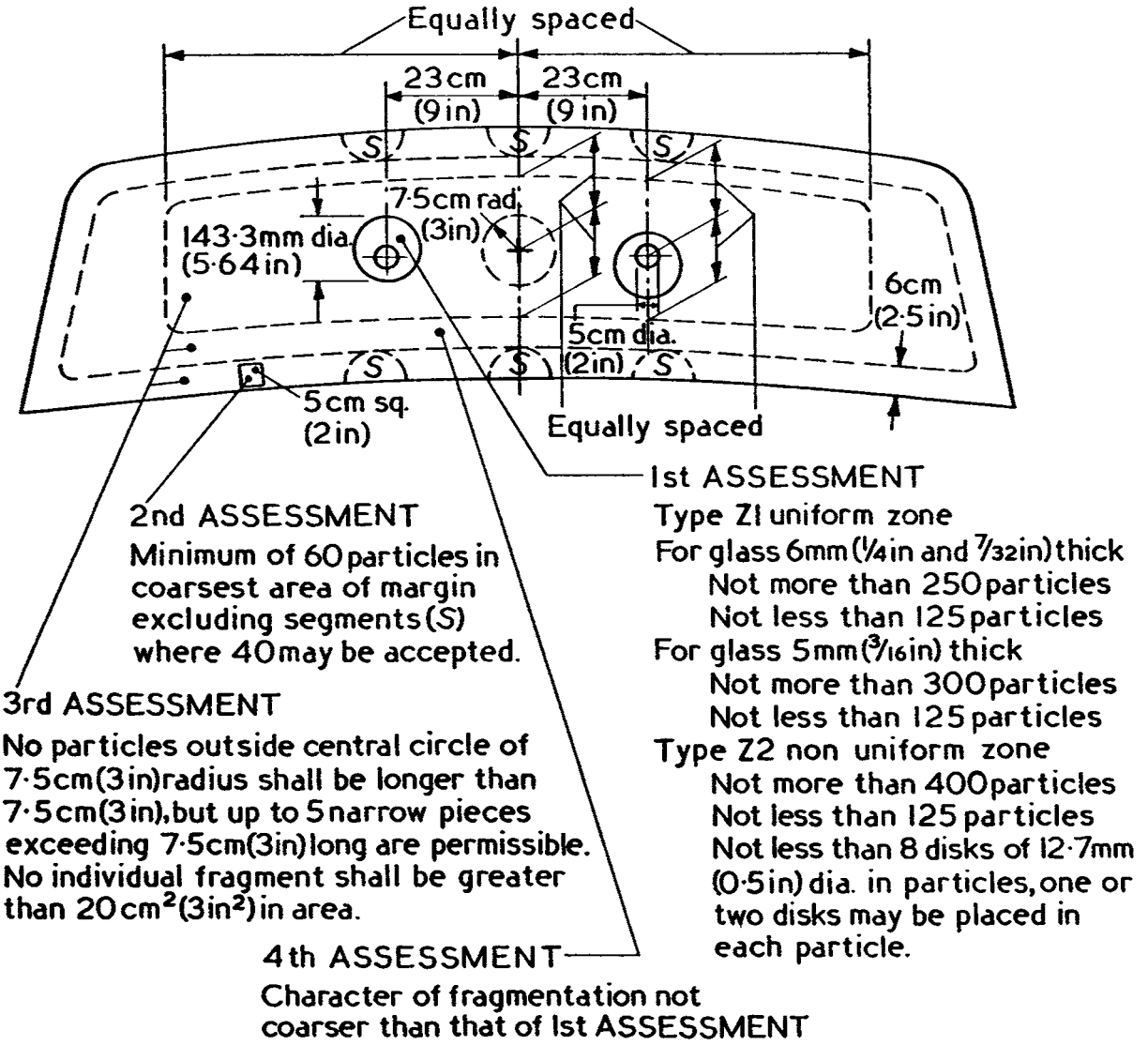


A. Glass with uniform heat treatment (see **2.6.4.1**)

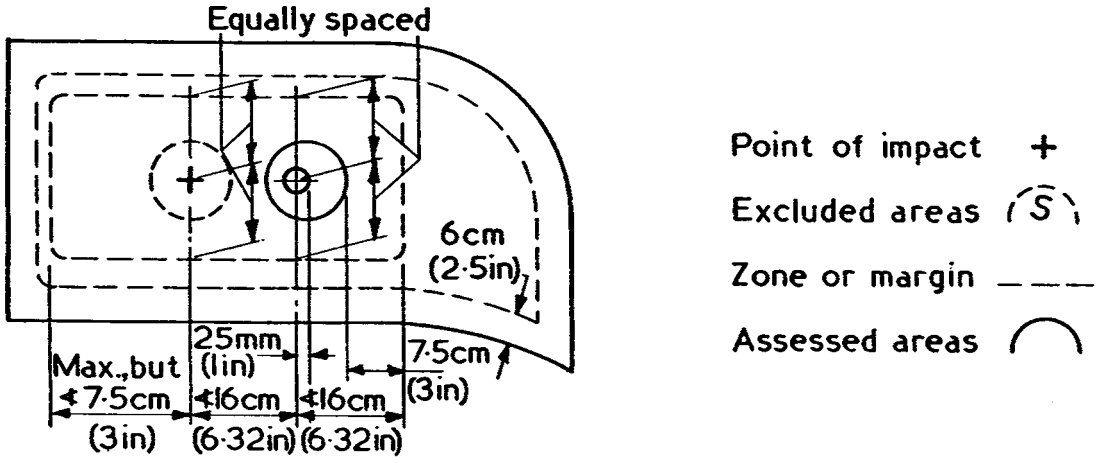


B. Glass with Type Z small uniform zone (see **2.6.4.2**)

Figure 3 — Particle count and size determinations (see also Table 4) *(continued)*



C. Windscreens with wide zone of modified heat treatment (see **2.6.4.3**)



D. Half-windscreen with wide zone of modified heat treatment (see **2.6.4.4**) **assessment 1 to 4 as above**

Figure 3 — Particle count and size determinations (see also Table 4) *(concluded)*

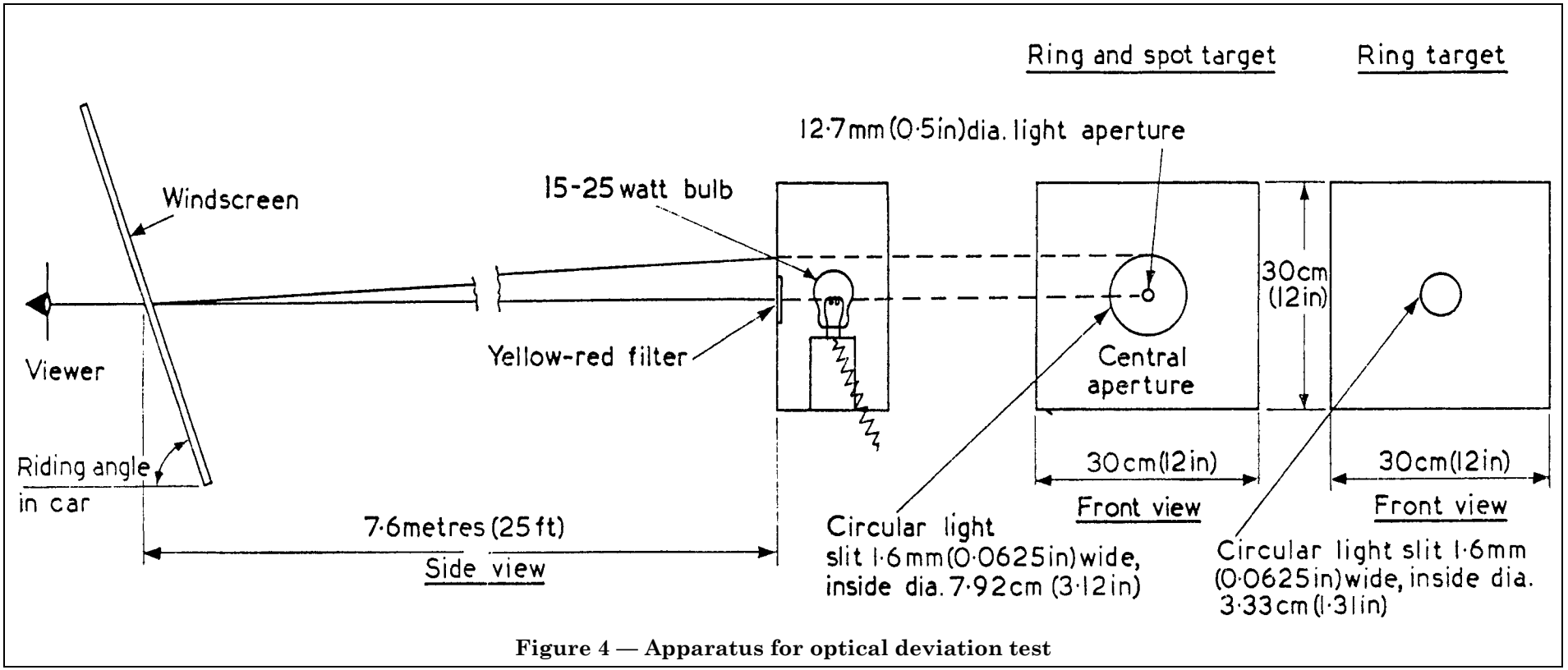


Figure 4 — Apparatus for optical deviation test

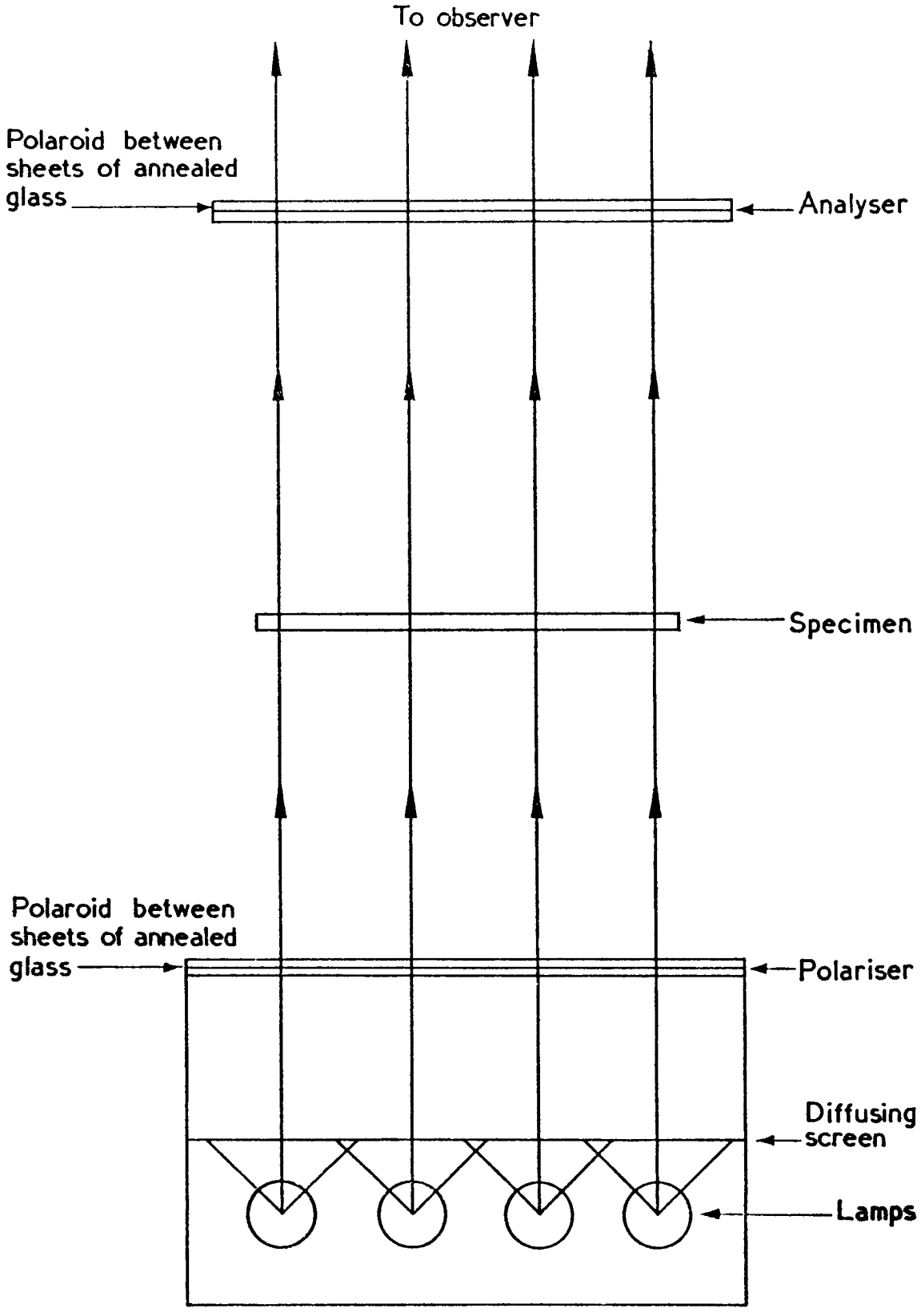


Figure 5 — Diagram of typical polariscope

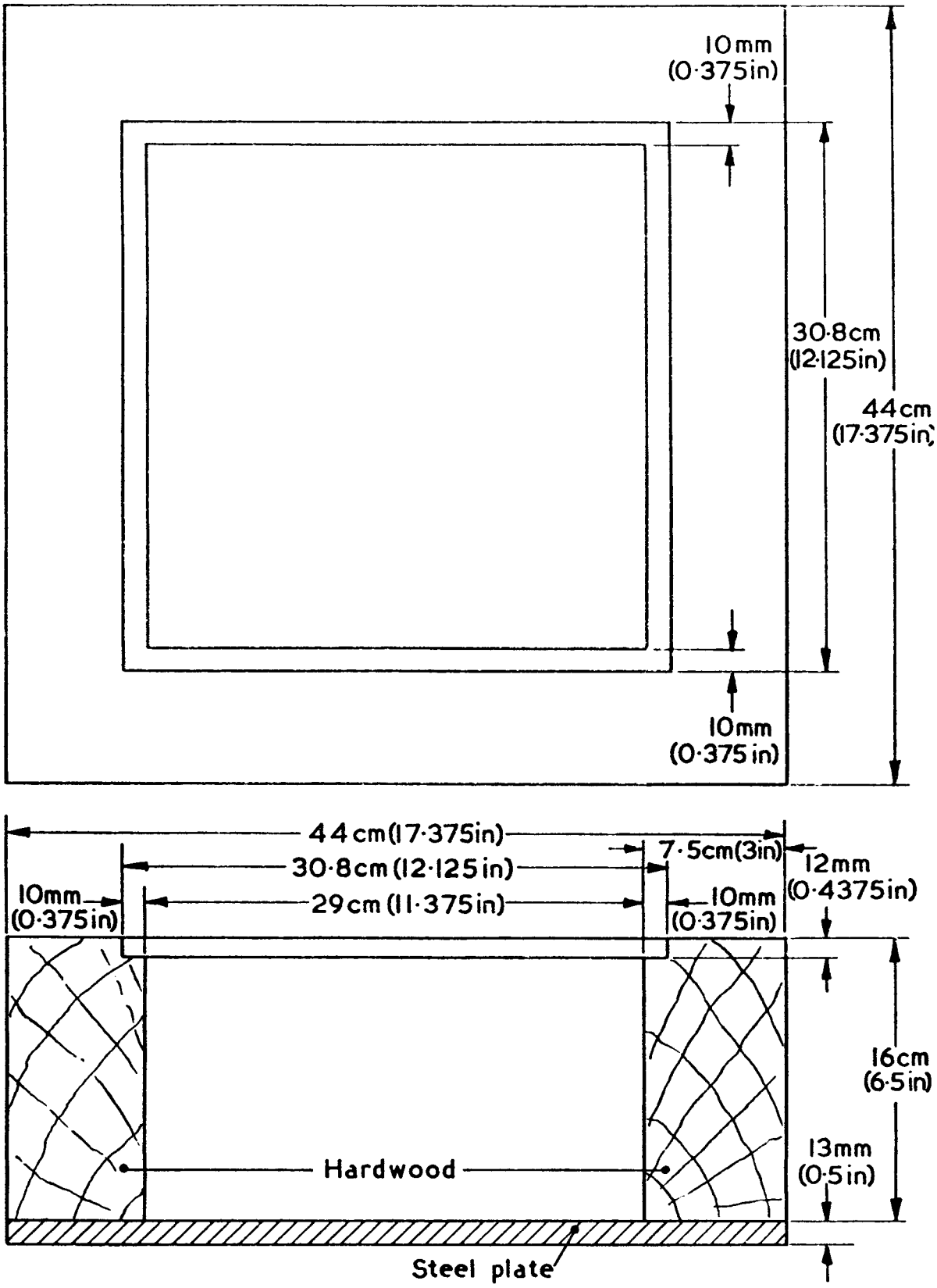


Figure 6 — Frame for fracture and adhesion test and impact test

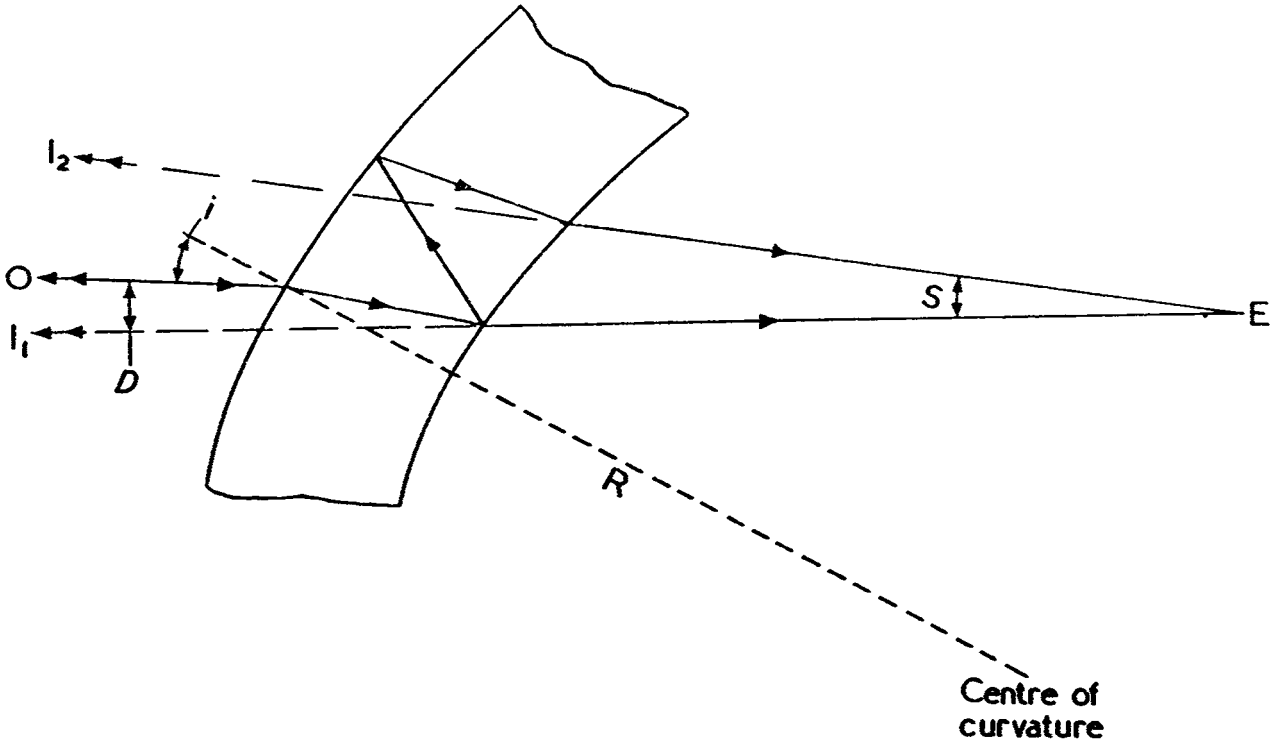


Figure 7 — Deviation and separation of images due to curvature

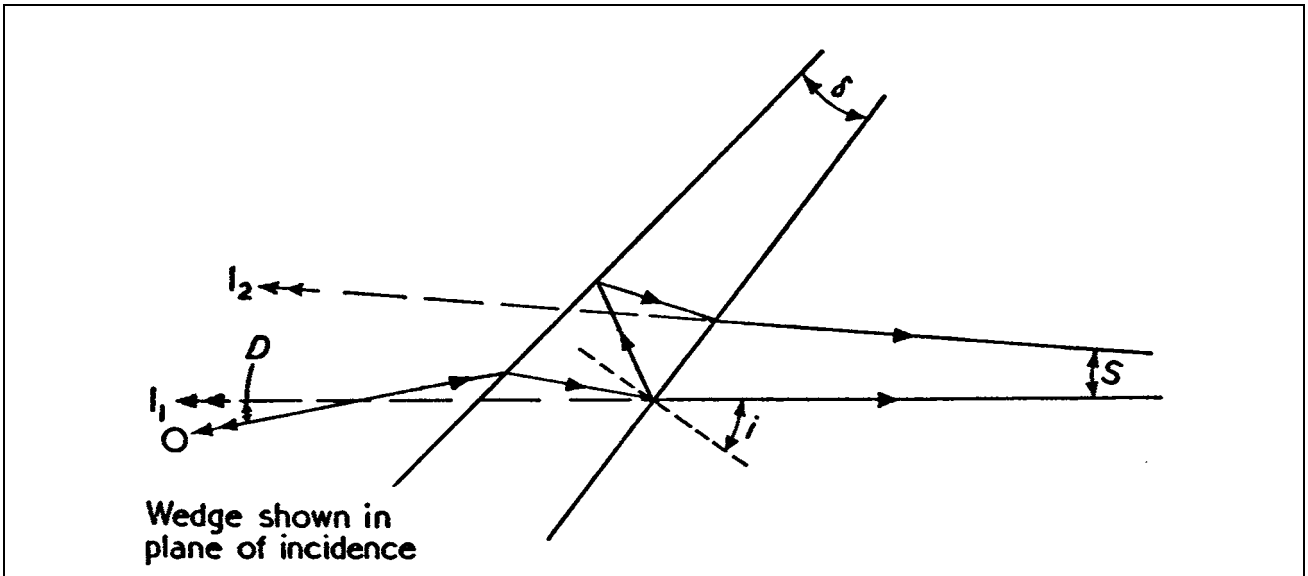
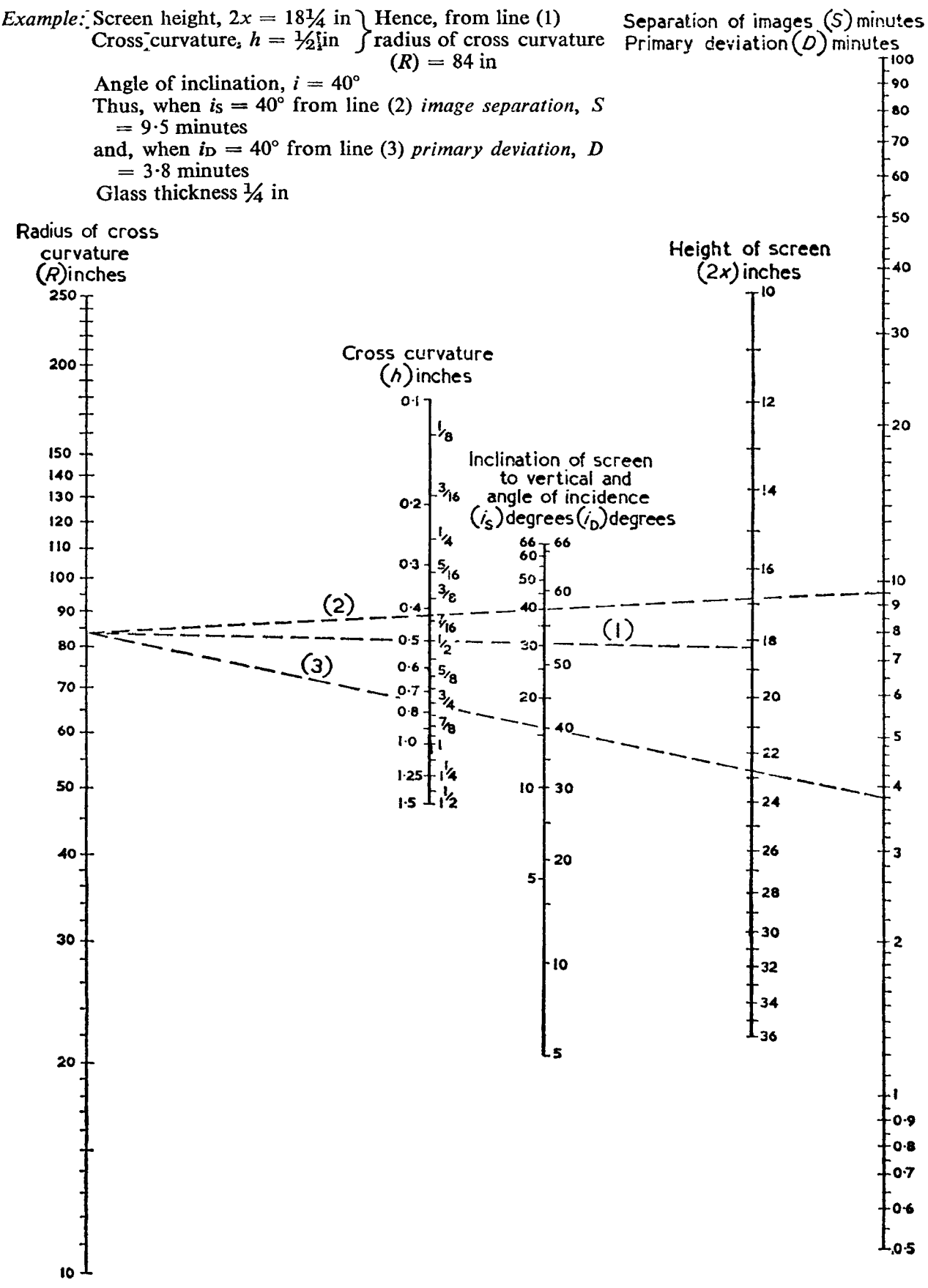


Figure 8 — Deviation and separation of images due to wedge



NOTE 1 minute of arc = 0.000 291 radians, or 1.047 inches at 100 yards.

Figure 9 — Relationship between optical characteristics of a curved windscreen

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