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Mechanical safety of cathode ray tubes

Sécurité mécanique des tubes cathodiques

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

MECHANICAL SAFETY OF CATHODE RAY TUBES

FOREWORD

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International Standard IEC 61965 has been prepared by IEC technical committee 39: Electronic tubes.

This second edition cancels and replaces the first edition published in 2000. This second edition constitutes a technical revision.

The main change with respect to the previous edition is the inclusion of the requirements for cathode ray tubes with film attached to the face plate.

The text of this standard is based on the following documents:

FDIS	Report on voting
39/264/FDIS	39/265/RVD

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

The committee has decided that the contents of this publication will remain unchanged until 2005. At this date, the publication will be

- reconfirmed;
- withdrawn;
- replaced by a revised edition, or
- amended.

INTRODUCTION

This International Standard sets forth test methods and limits for cathode ray tubes (CRTs). Originally, the only IEC standard for the mechanical safety of CRTs had been contained within Clause 18 of the equipment standard IEC 60065. Whereas that standard had been accepted and used by many countries, many others were not able to implement its requirements because of differing local needs. IEC 61965 was therefore published in 2000 with the aim of providing the basis for wider acceptance and use and reflecting the current IEC policy of producing separate component standards to which equipment standards can refer.

This 2nd edition covers the requirements for the CRTs with film attached to the faceplate as part of the safety implosion protection system.

Many years of experience had been built up in the use of both the IEC 60065 test and the other commonly used national alternatives. During the development of IEC 61965, extensive test programmes and ballistic and statistical calculations were carried out to verify that the requirements of the standard give protection for users of CRTs when the tubes are mounted in the equipment for which they are intended. This was also done to ensure that IEC 61965 maintains the stringent requirements of both IEC 60065 and the alternative tests in common use. These tests and calculations also confirmed

a) the acceptability of one standard ball for the mechanical strength test, and

b) the need for the implosion test where it is not always possible to induce rapid devacuation using the ball impact test.

As the impact tests in this standard are overstress tests, only the effect of rapid devacuation is evaluated and not subsequent relaxation of mechanical stresses in the CRT from the implosion protection system.

MECHANICAL SAFETY OF CATHODE RAY TUBES

1 Scope

This International Standard is applicable to cathode ray tubes and cathode ray tube assemblies (hereinafter referred to as CRTs) which are intended for use as components in apparatus and which have integral protection with respect to the effects of implosion.

These requirements apply to CRTs intended for use in apparatus including electrical and electronic measuring and testing equipment, information technology equipment, medical equipment, telephone equipment, television equipment and other similar electronic apparatus.

This standard is intended to apply only to those CRTs in which the face of the CRT forms part of the enclosure for the apparatus. The test methods do not apply to CRTs which are protected by separate safety screens.

A CRT covered by this standard is intended to be installed in an enclosure designed both to protect the rear of the CRT against mechanical or other damage under normal conditions of operation and to protect the user against particles expelled in a backwards direction from the CRT face in the event of implosion.

This standard contains requirements for CRTs of 76 mm diagonal and larger that incorporate implosion protection systems providing protection against the hazards of particles expelled forwards beyond the face. There is no intended protection against particles expelled in other directions.

Compliance is tested by subjecting CRTs to the test procedures and criteria, which are given in Clauses 8 (large CRTs), 9 (small CRTs) and 10 (CRTs with protective film) of this standard. The definitions of large and small CRTs are given in Clause 3.

NOTE This set of requirements replaces the current requirements for the mechanical safety of cathode ray tubes (CRTs) as described in IEC 60065 (Clause 18), which will be modified accordingly.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60065:2001, *Audio, video and similar electronic apparatus – Safety requirements*

IEC 60068-1:1988, *Environmental testing – Part 1: General and guidance*
Amendment 1 (1992)

IEC 60216-1:2001, *Electrical insulating materials – Properties of thermal endurance – Part 1: Ageing procedures and evaluation of test results*

ISO 527-1:1993, *Plastics – Determination of tensile properties – Part 1: General principles*

ISO 527-3:1995, *Plastics – Determination of tensile properties – Part 3: Test conditions for films and sheets*

ISO 8510-1:1990, *Adhesives – Peel test for a flexible-bonded-to-rigid test specimen assembly – Part 1: 90 degree peel*

3 Definitions

For the purposes of this document the following definitions apply.

3.1
bonded frame
system employing a preformed metal frame that covers the periphery of the CRT rim area. The space or void between the CRT rim and the metal frame is filled with resin or equivalent

3.2
CRT diagonal
nominal diagonal of the glass envelope at its maximum dimension (for example, mould-match line) excluding any hardware

3.3
CRT envelope
structure consisting of a face or faceplate, funnel and neck assembly

3.4
devacuation
equalization of the pressure in a CRT relative to the ambient pressure

3.5
fracture
one or more cracks in the faceplate or funnel causing a rapid or slow devacuation of the CRT envelope

3.6
glass particle
piece of glass that exceeds 0,025 g in weight

3.7
implosion
devacuation due to the rapid and sudden inward collapse of a CRT envelope, usually accompanied by a loud report

3.8
laminated CRT
system that provides a separate external safety panel bonded to the face of the CRT

3.9
prestressed banded CRT
system that employs a metal tension band (located over the CRT rim area) that is tightened by thermal shrinking, or other means, to a tensile load. The system may also include a metal rim band located between the tension band and the CRT rim. The tension band or the rim band or both may have an interlayer of tape, resin or the equivalent placed between the mating parts

3.10
prestressed banded CRTs with protective film
system employing a prestressed banded construction (see 3.9) that also includes a layer of film adhered to the CRT face as an integral component of the protection system

3.11
shaling
condition where the glassware splits into thin layers

3.12
test cabinet
enclosure, which is used to accommodate the CRT during tests

3.13
useful phosphor screen
a) colour CRT: the visible phosphored area of the CRT as viewed from the front

b) monochrome CRT: specified maximum useful phosphored area of the CRT

3.14
large CRT
CRT with diagonal dimension exceeding 160 mm

3.15
small CRT
rectangular CRT with a minor face dimension of at least 50 mm, a minimum diagonal dimension of 76 mm and a maximum diagonal dimension of 160 mm; a round CRT of a minimum diameter of 76 mm and a maximum diameter of 160 mm

3.16
common quality management system
quality management system described in documentation which is identical with systems used in two or more plants and under one central control and management

4 General requirements

4.1 Corrosion protection

If corrosion of a metal part will contribute to a failure to meet the requirements of this standard, then the part shall be adequately protected against corrosion.

4.2 Mechanical damage

To improve repeatability and reproducibility of test results, it should be verified that samples submitted for test have no external visible scratching on the surface of the faceplates.

4.3 Handling

Safety precautions should be addressed when handling test samples prior to and after testing.

4.4 Film-coated CRTs

In the case of CRTs with film, which is not an integral part of the implosion protection system, the product must be tested without film in accordance with Tables 1 and 2 and 6 to 9.

5 Environmental conditioning

5.1 Standard atmospheric conditions for testing

Unless otherwise specified, all tests and measurements shall be made under standard atmospheric conditions for testing as given in 5.3 of IEC 60068-1:

– temperature: 15 °C to 35 °C;
– relative humidity: 25 % to 75 %;
– air pressure: 86 kPa to 106 kPa

5.2 Preconditioning

Before CRTs are subjected to thermal conditioning or to testing they will be allowed to stabilize at standard atmospheric conditions for testing (see 5.1) for a minimum period of 16 h.

5.3 Thermal conditioning

Details of thermal conditioning are given in Tables 1 to 9. After thermal conditioning has been completed, the CRTs will be allowed to stabilize at standard atmospheric conditions for testing (see 5.1) for a minimum period of 24 h.

6 Sampling

6.1 Sampling plans

Details are given in Tables 1 to 9.

6.2 Sample numbers

The numbers of CRTs and the test programmes for prestressed banded CRTs are given in Tables 1, 2, 3 and 4, for bonded frame CRTs in Tables 6 and 7 and for laminated CRTs in Tables 8 and 9.

NOTE 1 Additionally, the number of samples for film-adhesion testing are given in Table 5.

NOTE 2 In addition to the quantities specified in the tables, additional samples should be made available for use in case of retest to satisfy the intent of the requirement.

6.3 Compliance

All CRTs in a test group shall comply with the test requirements for that group, except that, if only one CRT from all the test groups does not comply with the requirements, acceptability may be determined by subjecting a second test group to the set of tests during which unacceptable results occurred. The construction is acceptable if all CRTs in the second test group comply with the requirements.

7 Test preparation and set-up

7.1 Scratch patterns

As the form and depth of the scratch patterns may affect the force which is needed to obtain implosion or devacuation of the CRT, it is recommended that the scratches be made using a diamond- or carbide-tipped stylus, a glasscutter with a wheel of hardened steel or other similar tools.

7.2 Barriers

Barriers as specified in the test procedures, each made of 10 mm to 20 mm thick material, $250_{-3}^{\ 0}$ mm high and (2,00 ± 0,01) m long, shall be placed on the floor in front of the test cabinet at the specified locations, measured horizontally from the vertical plane of the centre of the front surface of the CRT to the near surface of the barrier closest to the tube face. The tolerance on the position of the barrier shall be ±10 mm, unless otherwise stated. The barriers may be less than 2 m long provided that they extend to the walls of the test room (see Figures 2 and 5). A non-skid surface such as a blanket or rug may be placed on the floor.

NOTE A particle travelling past the plane of the front surface of the barrier shall be considered to have passed the barrier.

7.3 Mounting

The CRT shall be mounted in a test cabinet of rigid construction and of suitable dimensions that does not permit a gap or opening wider than 6 mm around the CRT (see Figure 1). The mounting of the CRT in front of, or behind, the front panel of the test cabinet shall be in accordance with the CRT manufacturer's specifications or intended application. When mounting specifications are not available, the preferred mounting method shall be behind the front panel unless design features do not allow this condition.

A hole of suitable area shall be provided at the top of the cabinet to allow access to the funnel. This hole shall be covered during the impact test.

An opening having an area of not less than one-quarter of the area of the face of the CRT or 0,02 m^2, whichever is the smaller, shall also be provided in the bottom or rear of the cabinet for air intake in the event of an implosion.

The cabinet shall be firmly supported so as to prevent movement during the test.

7.4 Mounting position

The centre of the CRT shall be (1,00 ± 0,05) m above the floor.

8 Testing of large CRTs

8.1 Mechanical strength (ball impact test)

8.1.1 Test procedure

A solid smooth steel ball of (40 ± 1) mm diameter and mass of (260 ± 15) g, including the hook, and a minimum C scale Rockwell hardness of 60, shall be suspended by suitable means such as a fine wire or chain with a mass not exceeding 10 % of the mass of the ball and the hook. It shall be allowed to fall freely as a pendulum from a calculated height and strike the face of the CRT with an energy of (5,5 ± 0,1) J. The CRT shall be placed so that the face is vertical and in the same vertical plane as the point of support of the pendulum. A single impact shall be applied to any point on the CRT face at a distance of 40 mm or greater from the edge of the useful phosphor screen.

NOTE The test laboratory should consider all their test set-up uncertainties to ensure this 40 mm minimum position of the point of impact.

The barrier shall be placed 1,5 m from the plane of the centre of the face of the CRT (see Figure 2).

8.1.2 Glass throw criteria

A CRT is in compliance if the expulsion of glass within 5 s of the initial impact meets the following requirements:

a) there shall be no glass particle (a single piece of glass having a mass greater than 0,025 g) past the 1,5 m barrier;

b) the total mass of all pieces of glass past the 1,5 m barrier shall not exceed 0,1 g.

8.2 Implosion test (missile)

8.2.1 Test procedure

The face of the CRT at the top and bottom shall be scratched (3 ± 1) mm from the screen or phosphor edge into the viewing area. The scratches shall be horizontal lines (100 ± 5) mm long.

The impact object shall be a steel missile (see example in Figure 3) with a mass of (2,3 ± 0,1) kg, a minimum C scale Rockwell hardness of 60 and having one end rounded on a radius of (25 ± 0,5) mm.

The CRT shall be subjected to a single impact, intending to cause rapid devacuation using the minimum energy within the range. The impact object shall be swung through an arc of a pendulum to obtain an impact of not less than 7,0 J and not more than 14,0 J to cause rapid devacuation of the samples in the test group.

The impact area shall be the area bounded by two concentric circles where the radius of one circle is one-sixth of the height of the useful phosphor screen and the second circle radius is one-half of the height of the useful phosphor screen less 50 mm (see Figure 4). In Figure 4, if R_2 is less than R_1 then the impact shall be applied to the circle specified in R_1.

NOTE Previous testing experience on a particular CRT design (obtained from the CRT manufacturer or the test laboratory) should be considered when selecting the energy level within the range and the impact location.

The impact object travel shall be restricted so that the rounded end of the missile penetrates the CRT face equal to, or less than, 25 mm (see Figure 5).

Barriers shall be placed 1,0 m and 1,5 m from the vertical plane of the centre of the face of the CRT (see Figure 5).

If no CRTs devacuate as a result of this test then the alternative implosion test (missile) described in 8.2.3 shall be carried out.

8.2.2 Glass throw criteria

A CRT is in compliance if the expulsion of glass within 5 s of the initial impact meets the following requirements:

a) there shall be no single piece of glass having a mass greater than 15 g between the 1,0 m and 1,5 m barriers;

b) the total mass of all pieces of glass between the 1,0 m and 1,5 m barriers shall not exceed 45 g;

c) there shall be no single piece of glass having a mass greater than 1,5 g beyond the 1,5 m barrier.

8.2.3 Alternative implosion test (missile)

This alternative test shall be used as an additional test when the test in 8.2.1 has devacuated no CRTs, or may be used as an alternative to the test in 8.2.1 when it can be shown that the 8.2.1 test is unlikely to devacuate at least one CRT of the sample group.

8.2.3.1 Test procedure

As in 8.2.1, except that the impact object will be a steel missile (see example in Figure 11) with a mass of (1,4 ± 0,1) kg, a minimum C scale Rockwell hardness of 60 and one end rounded on a radius of (15 ± 0,5) mm.

8.2.3.2 Glass throw criteria

As in 8.2.2. If no CRTs devacuate as a result of the test in 8.2.3.1, then the glass throw requirements of 8.2.2 are deemed to have been satisfied.

8.3 Implosion test (thermal shock)

8.3.1 Test procedure

The CRT shall be mounted in the test cabinet, which is described in 7.3 and 7.4. The barrier shall be placed at (150 ± 2) mm from the vertical plane of the centre of the face of the CRT. An area shall be scratched on the faceplate sidewall or face of the CRT using one of the patterns illustrated in Figure 6.

A thermal shock shall be applied using one of the following methods.

a) Liquid nitrogen

   The scratched area shall be cooled using liquid nitrogen until a fracture occurs. A dam of modelling clay or equivalent may be used to contain the liquid nitrogen.

b) Hot rod

   The end of an ordinary flint glass rod, of suitable diameter (for example, 10 mm) shall be heated until it is red hot and nearly fluid. The heated end of the rod shall be pressed firmly on the scratched area of the CRT. If devacuation of the CRT does not occur within 10 s then the rod shall be withdrawn and cold water poured slowly on the scratched area. If a devacuation cannot be induced by repeated applications of the hot rod then the test shall be carried out using liquid nitrogen (see 8.3.1a).

8.3.2 Glass throw criteria

A CRT is in compliance if, within 5 s of the initial fracture, no glass particle is expelled through the plane of the face beyond the 150 mm barrier.

8.4 High-energy impact test

CRTs, which have a laminated implosion protection system, shall be subjected to the following high-energy impact test.

8.4.1 Test procedure

A (25 ± 1) mm diameter steel pin (see Figure 9) shall be inserted through the hole at the top of the test cabinet and placed on the CRT envelope (3 ± 1) mm behind the seal of the faceplate and funnel. If the hardware extends back from the seal more than 3 mm so as to interfere with the placement of the pin, then the pin shall be placed as close as possible to the hardware without touching it. A weight (see Figure 10), having a mass of (4,5 ± 0,1) kg, shall be caused to fall from a height so as to impact the pin at the end of its fall.

The height of the test mass shall be adjusted to limit the amount of energy to the minimum required to produce fracturing of the glassware, but not less than 7 J.

If fracturing of the glass does not occur, the impact energy shall be increased in 7 J increments to a maximum of 63 J using a new test sample each time until all the CRTs in the test group have suffered rapid devacuation.

The impact energy shall not be so large as to cause the pin to punch a hole with little or no cracking or shaling of the glassware. If this condition does occur then a lower impact energy shall be selected so as to result in fracturing (7 J steps not necessary).

NOTE Previous testing experience on a particular CRT design (obtained from the CRT manufacturer or the test laboratory) should be considered when selecting the energy level within the range.

The implosion pin shall be restricted so that its travel on impact shall be a maximum of 6 mm. The pin travel restriction assembly shall be positioned so that its impact energy shall not be transferred to the test cabinet. Figures 8, 9 and 10 give examples of equipment that may be used.

Barriers shall be placed 1,0 m and 1,5 m from the plane of the centre of the face of the CRT.

8.4.2 Glass throw criteria

A CRT is in compliance if the expulsion of glass within 5 s of the initial impact meets the following requirements:

a) there shall be no single piece of glass having a mass greater than 15 g between the 1,0 m and 1,5 m barriers;

b) the total mass of all pieces of glass between the 1,0 m and 1,5 m barriers shall not exceed 45 g;

c) there shall be no single piece of glass having a mass greater than 1,5 g beyond the 1,5 m barrier.

9 Testing of small CRTs

9.1 Mechanical strength (ball impact test)

9.1.1 Test procedure

A solid smooth steel ball of (40 ± 1) mm diameter and mass of (260 ± 15) g, including the hook, and a minimum C scale Rockwell hardness of 60, shall be suspended by suitable means such as a fine wire or chain with a mass not exceeding 10 % of the mass of the ball and hook. It shall be allowed to fall freely as a pendulum from a calculated height and strike the face of the CRT with an energy of (2,0 ± 0,1) J. The CRT shall be placed so that the face is vertical and in the same vertical plane as the point of support of the pendulum. A single impact shall be applied to any point on the CRT face at a distance of 25 mm or greater from the edge of the useful screen.

NOTE The test laboratory should consider all their test set-up uncertainties to ensure this 25 mm minimum position of the point of impact.

The barrier shall be placed 0,6 m from the plane of the centre of the face of the CRT (see Figure 2).

9.1.2 Glass throw criteria

A CRT is in compliance if the expulsion of glass within 5 s of the initial impact meets the following requirements:

a) there shall be no glass particle (a single piece of glass having a mass greater than 0,025 g) past the 0,6 m barrier;

b) the total mass of all pieces of glass past the 0,6 m barrier shall not exceed 0,1 g.

9.2 Implosion test (high ball)

If implosion or rapid devacuation does not occur when the CRT is tested as specified in 9.1 then a CRT having other than a laminated implosion protection system shall be subjected to the following test.

9.2.1 Test procedure

The face of the CRT shall be scratched at the top and bottom edges (3 ± 1) mm from the screen phosphor edge into the viewing area. The length of the scratches shall be 45 % to 55 % of the longest dimension/width of the face of the CRT.

Using a (40 ± 1) mm diameter steel ball having a mass of (260 ± 15) g and a minimum C scale Rockwell hardness of 60, a CRT having other than a laminated implosion screen shall be subject to additional impact tests during which the impact energy shall be increased in 0,7 J increments until fracturing occurs. A new sample shall be used for each test until all CRTs in the test group have been tested, with implosion or rapid devacuation occurring.

Barriers shall be placed 0,6 m and 1,2 m from the plane of the centre of the face of the CRT (see Figure 2).

9.2.2 Glass throw criteria

A CRT is in compliance if the expulsion of glass within 5 s of the initial impact meets the following requirements:

a) there shall be no single piece of glass having a mass greater than 15 g between the 0,6 m and 1,2 m barriers;
b) the total mass of all pieces of glass between the 0,6 m and 1,2 m barriers shall not exceed 45 g;
c) there shall be no single piece of glass having a mass greater than 1,5 g beyond the 1,2 m barrier.

9.3 Implosion test (thermal shock)

9.3.1 Test procedure

As 8.3.1.

9.3.2 Glass throw criteria

As 8.3.2.

9.4 High-energy impact test

CRTs, which have a laminated implosion protection system, shall be subjected to the following high-energy impact test.

9.4.1 Test procedure

A (9,5 ± 0,5) mm diameter steel pin shall be inserted through the hole in the top of the test cabinet and placed directly on the envelope seal line. A weight (see Figure 10) having a mass of (0,45 ± 0,02) kg shall be caused to fall freely from a height so as to impact the pin at the end of its fall.

The height of the test mass shall be adjusted to limit the amount of energy to the minimum amount required to produce fracturing of the glassware, but not less than 2,7 J.

If fracturing of the glass does not occur, the impact energy shall be increased in 0,7 J increments, using a new test sample each time, until all CRTs in the test group have been tested with rapid devacuation.

The impact energy shall not be so large as to cause the pin to punch a hole with little or no cracking or shaling of the glassware. If this condition does occur then a lower impact energy shall be selected so as to result in fracturing (0,7 J steps not necessary).

NOTE Previous testing experience on a particular CRT design (obtained from the CRT manufacturer or the test laboratory) should be considered when selecting the energy level within the range.

The impact pin shall be restricted so that its travel on impact shall be a maximum of 6 mm. The pin travel restriction assembly shall be positioned so that impact energy shall not be transferred to the test cabinet. Figures 8, 9 and 10 give examples of equipment that may be used.

Barriers shall be placed 0,6 m and 1,2 m from the plane of the centre of the face of the CRT.

9.4.2 Glass throw criteria

A CRT is in compliance if the expulsion of glass within 5 s after the initial impact meets the following requirements:

a) there shall be no single piece of glass having a mass greater than 15 g between the 0,6 m and 1,2 m barriers;
b) the total mass of all pieces of glass between the 0,6 m and 1,2 m barriers shall not exceed 45 g;
c) there shall be no single piece of glass having a mass greater than 1,5 g beyond the 1,2 m barrier.

10 Testing of prestressed banded CRTs with protective film

10.1 General

For CRTs that employ a film layer on the CRT face that is an integral part of the implosion protection system, the tests described in Clauses 8 and 9 shall be applied in accordance with Tables 3 or 4. The film on all samples tested with the protective film attached shall first be scored as described in 10.2. Additionally, the tests of 10.3 and 10.4 are required in accordance with Table 5.

NOTE In the case of CRTs with film which is not an integral part of the implosion protection system, this clause does not apply and the product must be tested without film in accordance with Tables 1 and 2 and 6 to 9.

10.2 Film scoring pattern for CRTs with protective film

All samples subjected to the tests in Tables 3 and 4 with the protective film attached shall be scored along both diagonals of the face for a minimum of 80 % of the external glass dimension using one of the following methods, at the CRT manufacturer's option:

a) scoring shall be done with a tool and stylus as defined in Figure 7 and applied under the following conditions:
   – tool orientation with respect to glass surface: (90 ± 10)°;
   – force: (4 ± 2) N;
   – speed: 2 to 10 cm/s;
b) scoring shall be done with a sharp utility knife with a short blade to cut through the total thickness of the film, but avoiding damage to the glass.

10.3 Peel test

10.3.1 Sample preparation

Twenty samples of the film, bonded to glass sections, shall be prepared. The glass sections shall be 35 mm minimum wide and 150 mm minimum length. The attached film test samples shall be (25 ± 0,5) mm wide and 250 mm minimum length. Test samples shall be produced using representative manufacturing conditions.

10.3.1.1 Sample conditioning shall be in accordance with Table 5.

10.3.1.2 Additionally, all test samples are to be conditioned for at least 24 h at (25 ± 2) °C immediately prior to the peel test.

10.3.2 Test procedure

The tests are to be performed in accordance with ISO 8510-1. The film strip is to be pulled from the surface at an angle of 90° at a rate of (50 ± 5) mm/min. The average peel force for at least 100 mm detachment is to be recorded and the average peel force per cm of width is to be calculated.

10.3.3 Requirements

The average peel force, for each individual sample, shall be a minimum of 3,5 N per cm of width. The film shall withstand the specified force of 3,5 N without tearing.

10.4 Immersion test

10.4.1 Test procedure

Four samples of film bonded to glass sections, prepared as described in 10.3.1, shall be immersed each in one of the following aqueous solutions for 24 h:

1) (70 ± 5) V/V % denatured ethyl alcohol
2) (9 ± 1) W/W % aqueous ammonia solution
3) (5 ± 1) W/W % sodium hypochlorite
4) (70 ± 5) V/V % isopropyl alcohol.

NOTE All four solutions are to be used. Only one test section is to be subjected to each solution.

The test samples are to be removed from the test solutions, blotted dry and conditioned for 24 h at (25 ± 2) °C.

The samples are then to be subjected to the peel test described in 10.3.2.

10.4.2 Requirements

The average peel force, for each individual sample, shall be a minimum of 3,5 N per cm of width. The film shall withstand the specified force of 3,5 N without tearing.

11 Marking

Along with the CRT manufacturer's name, trade name or identifying code, and a type number, each CRT which meets the requirements of this standard shall be marked with the following statement, or wording with a similar meaning. The marking shall be of a permanent and legible type and in the appropriate language.

WARNING This cathode ray tube employs integral implosion protection. For continued safety it must be replaced with a cathode ray tube of the same or equivalent type number.

12 Application notes for pre-stressed banded CRTs with protective film

The CRT manufacturer shall provide application notes with the following statements or wording with a similar meaning, and in the appropriate language:

SAFETY NOTES

a) Manufacturers of products incorporating CRTs must ensure that the enclosure front bezel totally covers all edges of the protective film applied to the face of these CRTs.

b) The end-product manufacturer shall provide a warning statement in the user's instruction manual. This shall state:

   WARNING The CRT in this product employs a protective film on the face. This film must not be removed as it serves a safety function and removal will increase the risk of serious injury.

13 Normative requirements for the use of Tables 1 and 2 (prestressed banded CRTs)

Sampling and testing for new construction (sampling plan I), new construction with known tape or resin (sampling plan II), tension band only (sampling plan III) and alternative construction (sampling plan IV) will be used when any of the following new construction features or variations in construction apply. Unique constructions may require a special investigation.

13.1 Sampling plan I: New construction

Applicable to first-time testing for a CRT manufacturer or a change in construction of a previously tested CRT that employs any of the following nominal design changes.

13.1.1 Size

New CRT diagonal size range (see Table 10).

13.1.2 Deflection angle

New deflection angle range for a particular CRT size range (see Table 10).

13.1.3 Glassware shape

Glassware, in a particular CRT size and deflection angle range, having the following shape variations, is considered a new glassware shape:

a) front panel outside curvature: a change in height measurement from the Z point to the centre of the face panel of more than ±10 % from a previously tested CRT for a manufacturer;

b) aspect ratio: any change in the height-to-width ratio of the front panel from a previously tested CRT for a manufacturer;

c) glassware thickness: a change in glassware thickness of more than ±20 % at any point, other than the neck, from a previously tested CRT for a manufacturer;

d) corner radius: any change in external or internal panel corner radius (plan view) of more than ±10 %.

13.1.4 Glassware supplier

New glassware supplier not previously used by the CRT manufacturer. Subsidiaries of present glassware suppliers who use the same chemistry, mould designs, processes and quality control arrangements, under a common quality management system, are not considered to be new suppliers.

13.1.5 Resin

New resin in the prestressed banded system. A resin is considered new if it is of a different generic type, for example, epoxy, polyester or other material.

13.1.6 Tape

New tape employed in the tension band system. A tape is considered new if one or more of the following circumstances apply:

a) tape width – the tape width under the tension band is reduced by more than 20 %;
b) change in generic type of adhesive, for example, acrylic, silicone, natural rubber, etc;
c) adhesion – more than 20 % decrease in adhesion strength;
d) single-sided adhesive – tape that is changed from a double-sided adhesive to a single-sided adhesive;
e) any combination that differs from that used in previously tested CRTs;
f) change in backing generic type, for example, polyester cloth, etc.;
g) change in backing thickness of more than ±20 %.

13.2 Sampling plan II: New construction with known resin or tape

Applicable to first-time testing for a CRT manufacturer or a change in construction of a previously tested CRT that employs any of the following nominal design changes:

13.2.1 Tape and resin

A new CRT construction as defined in 13.1.1 to 13.1.4 with a tape or resin, which has been previously tested and found acceptable for a CRT manufacturer in the same or a larger CRT size.

13.3 Sampling plan III: Tension band and alternative tension band

Applicable to any of the following changes in tension band or hardware:

13.3.1 Tension band only

CRTs using this construction employ only a tension band. There is no material between the tension band and the CRT envelope. This sampling plan applies to new constructions as well as a construction change where tape or resin is deleted from the system.

13.3.2 Band-end securement

For tension band only construction, where there are significant changes in the band-end securement method, such as a change from spot weld to crimp type.

13.3.3 Band tension

A change in nominal band tension or minimum glassware recovery value of greater than –5 % to +15 % from a previously tested CRT, employing a particular size range, deflection angle range and glassware shape.

13.3.4 Band-tension system

Change in the band-tensioning system such as a change from machine tightened to shrink band, or others.

13.3.5 Hardware

Change in the hardware system such as addition or deletion of rim bands, reinforcing bars or other structural materials between the tension band and the CRT envelope.

13.3.6 Band width

Reduction of nominal tension bandwidth by more than 10 %.

13.3.7 Band material

Change in metallurgical composition.

13.3.8 Band position

Change in the nominal location of the band (forward or backward) by more than 3 mm from its original position as measured from the front of the band to the Z point on the panel.

13.3.9 Band-surface coating

Addition or change in the surface coating of the tension band when welding is the method of band-end securement. CRTs need not be tested if the tensile strength of the new welded band is equal to, or greater than, the original.

13.4 Sampling plan IV: Alternative construction

Applicable to any tension band construction such as tension band only, tension band with tape, rim band, etc. Alternative construction consists of variation in construction in any of the following.

13.4.1 Size

New size within a diagonal size range previously tested for the CRT manufacturer.

13.4.2 Deflection angle

New deflection angle within a range previously tested for a CRT manufacturer.

13.4.3 Glassware supplier

Glassware supplier previously used by the CRT manufacturer in another size range.

13.4.4 Glassware thickness

Glassware whose minimum thickness varies from the glassware originally tested by more than ±10 % and less than, or equal to, ±20 % at any point other than the neck, is considered an alternative construction.

13.4.5 Resin

Resin used in the prestressed banded system is considered an alternative construction if the tensile strength of the cured resin is less than 80 % of the original resin. Addition of tested resin to a CRT construction previously tested using a tension band only (without resin) will be accepted without testing.

13.4.6 Tape

Addition of tested tape to a CRT construction previously tested using a tension band only (without tape) will be accepted without testing.

14 Normative requirements for the use of Tables 3 and 4 (prestressed banded with protective film)

Sampling and testing for new construction (sampling plan I), new construction with known resin, tape, film or adhesive (sampling plan II), alternative tension band (sampling plan III) and alternative construction (sampling plan IV) will be used when any of the following new or variations in construction apply. Unique constructions may require a special investigation.

14.1 Sampling plan I: New construction

Applicable to first-time testing for a CRT manufacturer or a change in construction of a previously tested CRT that employs any of the following nominal design changes.

14.1.1 Size

New CRT diagonal measurement size range (see Table 10).

14.1.2 Deflection angle

New deflection angle range for a particular CRT size range (see Table 10).

14.1.3 Glassware shape

Glassware in a particular CRT size and deflection angle range, having the following shape variations, is considered a new glassware shape.

a) Front panel outside curvature – a change in height measurement from the Z point of the centre of the face panel of more than ±10 % from a previously tested CRT for a manufacturer;
b) aspect ratio – any change in the height-to-width ratio of the front panel from a previously tested CRT for a manufacturer;
c) glassware thickness – a change in glassware thickness of more than ±20 % at any point, other than the neck, from a previously tested CRT for a manufacturer;
d) corner radius – any change in external or internal panel corner radius (plan view) of more than ±10 %.

14.1.4 Glassware supplier

New glassware supplier not previously used by the CRT manufacturer. Subsidiaries of present glassware suppliers who use the same chemistry, mould designs, processes and quality control arrangements, under a common quality management system, are not considered to be new suppliers.

14.1.5 Resin

New resin in the pre-stressed banded system. A resin is considered new if it is a different generic type, for example, epoxy, polyester or other material.

14.1.6 Tape

New tape employed in the tension band system. A tape is considered new if

a) tape width – the tape width under the tension band is reduced by more than 20 %;
b) change in generic type of adhesive, for example, acrylic, silicone, natural rubber, etc.;
c) adhesion – more than 20 % decrease in adhesion strength;
d) single-sided adhesive – tape that is changed from a double-sided adhesive to a single-sided adhesive;
e) any combination that differs from that used in previously tested CRTs;
f) change in backing generic type, for example, polyester cloth, etc;
g) change in backing thickness of more than ±20 %.

14.1.7 Adhesive for protective film

New adhesive used with protective film. An adhesive is considered new if:

a) change in generic type of adhesive, for example, acrylic, silicone, natural rubber, etc.;
b) adhesion – more than 20 % decrease in adhesion strength.

14.1.8 Protective film

New film employed in the protection system. A film is considered new if:

a) change in film generic type, for example, polyester, etc.;
b) change in film thickness of more than ±15 %.

14.2 Sampling plan II: New construction with known resin, tape, film or adhesive

Applicable to first-time testing for a CRT manufacturer or a change in construction of a previously tested CRT that employs any of the following nominal design changes.

14.2.1 Tape and resin

A new CRT construction as defined in 14.1.1 to 14.1.4 with a tape or resin, which has been previously tested and found acceptable for a CRT manufacturer in the same or a larger CRT size.

14.2.2 Film and adhesive

A new CRT construction as defined in 14.1.1 to 14.1.4 with a film and adhesive combination which has been previously tested and found acceptable for a CRT manufacturer in the same or a larger CRT size.

14.3 Sampling plan III: Alternative tension band

Applicable to any of the following changes in tension band or hardware.

14.3.1 General

This sampling plan applies to construction changes in tension band or hardware as well as a construction change where tape or resin is deleted from the tension band system.

14.3.2 Band-end securement

A significant change in the band-end securement method, such as a change from spot weld to crimp type.

14.3.3 Band tension

A change in nominal band tension or minimum glassware recovery value of greater than -5 % to +15 % from a previously tested CRT, employing a particular size range, deflection angle range and glassware shape.

14.3.4 Band-tension system

Change in the band-tensioning system such as a change from machine tightened to shrink band, or others.

14.3.5 Hardware

Change in the hardware system such as addition or deletion of rim bands, reinforcing bars or other structural materials between the tension band and the CRT envelope.

14.3.6 Band width

Reduction of tension bandwidth by more than 10 %.

14.3.7 Band material

Change in metallurgical composition.

14.3.8 Band position

Change in the location of the band (forward or backward) by more than 3 mm from its original position as measured from the front of the band to the Z point on the panel.

14.3.9 Band surface coating

Addition or change in the surface coating of the tension band when welding is the method of band-end securement. CRTs need not be tested if the tensile strength of the new welded band is equal to, or greater than, the original.

14.4 Sampling plan IV: Alternative construction

Applicable to any tension band construction such as tension band only, tension band with tape, rim band, etc. Alternative construction consists of the variation in construction in any of the following:

14.4.1 Size

New size within a range previously tested for the CRT manufacturer.

14.4.2 Glassware supplier

Glassware supplier previously used by the CRT manufacturer in another size range.

14.4.3 Glassware thickness

Glassware whose minimum thickness varies from the glassware originally tested by more than ±10 % and less than, or equal to, ±20 % at any point other than the neck, is considered an alternative construction.

14.4.4 Resin

Resin used in the prestressed banded system is considered an alternative construction if the tensile strength of the cured resin is less than 80 % of the original resin. Addition of resin to a CRT construction previously tested using a tension band only (without resin) will be accepted without testing.

14.4.5 Tape

Addition of tape to a CRT construction previously tested using a tension band only (without tape) will be accepted without testing.

15 Alternative thermal conditioning for use with Tables 3 and 4 (prestressed banded with protective film)

This alternative high temperature thermal conditioning can be used where the requirements of 15.1 and 15.2 are satisfied. Samples of the CRT only, without the film, are conditioned at 150 °C for 48 h or other Arrhenius based time/temperature combinations as specified in footnote d of Tables 3 and 4. After removal from the conditioning chamber, the CRT samples are allowed to stabilize for at least 24 h at (25 ± 2) °C. The film is then to be affixed to the CRT face, using representative manufacturing conditions and stabilized at standard atmospheric conditions for at least 24 h, prior to impact and implosion testing as defined in Tables 3 and 4.

15.1 Additional peel force requirements where alternative thermal conditioning is to be performed

The five-sample average of the average peel force of the test pieces thermally conditioned according to 10.3.1.2 shall not be less than 90 % of the five-sample average of the average peel force of the as-received test pieces (10.3.1.1). In no case shall the average peel force for any single sample be less than 3,5 N per cm of width.

15.2 Tensile strength test where alternative thermal conditioning is to be performed

15.2.1 Sample preparation

Ten samples of the film shall be prepared according to the requirements of ISO 527-1 and ISO 527-3. Five of these samples in the as-received condition shall be set aside for test. The other five samples shall be thermally conditioned in accordance with 10.3.1.2.

15.2.2 Test procedure

Samples shall be tested in accordance with the test method of ISO 527-1 and ISO 527-3 The rate of separation of the grips of the testing machine shall be the same for both as-received samples and thermally conditioned samples.

The average of the tensile strength (σ_m) of the film shall be calculated for the as-received samples and, separately, for the thermally conditioned samples.

15.2.3 Requirements

The average tensile strength (σ_m) for the thermally conditioned samples shall not be less than 90 % of the average σ_m for the as-received samples.

16 Normative requirements for the use of Tables 6 and 7 (bonded frame CRTs)

Sampling and testing for new construction (sampling plan I) and alternative construction (sampling plan II) will be used when any of the following new construction features or variations in construction applies. Unique constructions may require a special investigation.

16.1 Sampling plan I: New construction

Applicable to first-time testing for a CRT manufacturer or change in construction of a previously tested CRT that employs any of the following nominal design variations:

16.1.1 Size

New CRT diagonal size range (see Table 10).

16.1.2 Deflection angle

New deflection angle range for a particular CRT size range (see Table 10).

16.1.3 Glassware shape

Glassware in a particular CRT size and deflection angle range having the following shape variations is considered a new glassware shape:

a) front panel curvature and corner radius – a change in height measurement from the Z point to the centre of the face panel of more than ±10 % from a previously tested CRT for a CRT manufacturer;
b) aspect ratio – any change in the nominal height-to-width ratio of the front panel from a previously tested CRT for a CRT manufacturer;
c) glassware thickness – a change in glassware thickness of more than ±20 % at any point, other than the neck, from a previously tested CRT for a CRT manufacturer.

16.1.4 Glassware supplier

New glassware supplier not previously used by the CRT manufacturer. Subsidiaries of present glassware suppliers who use the same chemistry, mould designs, processes and quality control arrangements, under a common quality management system, are not considered to be new suppliers.

16.1.5 Resin

New resin used in a CRT employing a particular size range, deflection angle range and glassware shape.

16.1.6 Resin thickness

A change in the resin thickness of more than ±25 %.

16.1.7 Frame thickness

A change in the thickness of the material used to form the frame of more than ±10 %.

16.2 Sampling plan II: Alternative construction

Consists of variation in construction in any of the following nominal design changes.

16.2.1 Size

New size within a diagonal size range previously tested for a CRT manufacturer.

16.2.2 Deflection angle

New deflection angle within a range previously tested for a CRT manufacturer.

16.2.3 Glassware supplier

Glassware supplier previously used by the CRT manufacturer in another size range.

16.2.4 Glassware thickness

Glassware whose thickness varies from the glassware originally tested by more than ±10 % and less than, or equal to, ±20 % at any point other than the neck, is considered an alternative construction.

16.2.5 Resin

New resin for a size within a size range previously tested for that particular resin.

16.2.6 Resin thickness

A change in resin thickness of more than ±10 % but less than, or equal to, ±25 %.

17 Normative requirements for the use of Tables 8 and 9 (laminated CRTs)

Sampling and testing for new construction (sampling plan I) and alternative construction (sampling plan II) will be used when any of the following new construction features or variations in construction applies. Unique constructions may require a special investigation.

17.1 Sampling plan I: New construction

Applicable to first-time testing for a CRT manufacturer or a change in construction of a previously tested CRT that employs any of the following nominal design variations.

17.1.1 Bonding material

New bonding material used or proportion of resin to hardener changed by more than ±20 %.

17.1.2 Bonding material thickness

A change in bonding material thickness of more than ±25 %.

17.1.3 Front panel thickness

A decrease in front panel glass thickness of more than 25 %.

17.2 Sampling plan II: Alternative construction

Applicable to a variation in construction in any of the following nominal design changes.

17.2.1 Bonding material

Bonding material previously tested for a CRT manufacturer but used in a different size range (see Table 10).

17.2.2 Bonding material thickness

A change in bonding material thickness of more than ±10 % and less than, or equal to, ±25 %.

17.2.3 Front panel thickness

A decrease in front panel glass thickness in the range of 10 % to 25 %.

Table 1 – Sampling and test programme for prestressed banded CRTs exceeding 160 mm diagonal

Sampling plan	CRT design[a]	Thermal conditioning				Impact and implosion test groups		
		Number of CRTs	Circulating air chamber			Number of CRTs to be tested as described in		
			Temp °C[b]	RH %	Time h	8.1 (ball)[c]	8.3 (thermal)	8.2 (missile)
						Group A	Group B	Group C
I	New construction	5	–	–	–	2	1	2
		4	150[d]	–	48[d]	2	1	1
		4	50	90 – 95	48	2	1	1
		4	[e]	–	[e]	2	1	1
II	New construction with previously tested tape or resin	12	–	–	–	6	2	4
III	Tension band only and alternative tension band	9	–	–	–	4	2	3
IV	Alternative construction	6	–	–	–	3	1	2

[a] See Clause 13 for details of the requirements regarding changes in design features.

[b] The tolerance of the oven temperature shall be ±2 °C.

[c] CRTs not visibly damaged in this test may also be subjected to the tests described in 8.2 and 8.3. If a CRT yields unacceptable results in either of these tests, the results shall be considered inconclusive and disregarded. A new CRT shall be tested in its place, as previous testing might have weakened the CRT.

[d] Other Arrhenius based time/temperature combinations (according to the principles of IEC 60216-1) may be used (for example, 140 °C for 96 h, 130 °C for 168 h, 120 °C for 336 h or 110 °C for 672 h).

[e] CRTs shall be thermally cycled between –40 °C and +70 °C at the rate of two cycles per day for a total of five cycles and held at each temperature extreme for 4 h.

Table 2 – Sampling and test programme for prestressed banded CRTs from 76 mm to 160 mm diagonal

Sampling plan	CRT design[a]	Thermal conditioning				Impact and implosion test groups		
		Number of CRTs[f]	Circulating air chamber			Number of CRTs to be tested as described in		
			Temp °C[b]	RH %	Time h	9.1 (ball)[c]	9.3 (thermal)	9.2 (high ball)[f]
						Group A	Group B	Group C
I	New construction	5	–	–	–	2	1	2
		4	150[d]	–	48[d]	2	1	1
		4	50	90 – 95	48	2	1	1
		4	[e]	–	[e]	2	1	1
II	New construction with previously tested tape or resin	12	–	–	–	6	2	4
III	Tension band only and alternative tension band	9	–	–	–	4	2	3
IV	Alternative construction	6	–	–	–	3	1	2

[a] See Clause 13 for details of the requirements regarding changes in design features.

[b] The tolerance of the oven temperature shall be ±2 °C.

[c] CRTs not visibly damaged in this test may also be subjected to the tests described in 9.2 and 9.3. If a CRT yields unacceptable results in either of these tests, the results shall be considered inconclusive and disregarded. A new CRT shall be tested in its place, as previous testing might have weakened the CRT.

[d] Other Arrhenius based time/temperature combinations (according to the principles of IEC 60216-1) may be used (for example, 140 °C for 96 h, 130 °C for 168 h, 120 °C for 336 h or 110 °C for 672 h).

[e] CRTs shall be thermally cycled between –40 °C and +70 °C at the rate of two cycles per day for a total of five cycles and held at each temperature extreme for 4 h.

[f] Test 9.2 is only applied if implosion or rapid devacuation does not occur in ball test 9.1.

Table 3 – Sampling and test programme for prestressed banded CRTs with protective film exceeding 160 mm diagonal

Sampling plan	CRT design[a]	Thermal conditioning				Impact and implosion test groups		
		Number of CRTs	Circulating air chamber			Number of CRTs to be tested as described in		
			Temp °C[b]	RH %	Time h	8.1 (ball)[c]	8.3 (thermal)	8.2 (missile)
						Group A	Group B	Group C
I	New construction	5[f]	---	---	---	2	1[g]	2[h]
		4[f & p]	150[d]	---	48[d]	2	1[g]	1[h]
		4[f]	50	90 – 95	48	2	1[g]	1[h]
		4[f]	[e]	---	[e]	2	1[g]	1[h]
		5[k]	---	---	---	4[m]	1[n]	---
II	New construction with previously tested tape or resin and film/ adhesive combination	12[f]	---	---	---	6	2[g]	4[h]
		4[k]	---	---	---	3[m]	1[n]	---
III	Alternative tension band	9[f]	---	---	---	4	2[g]	3[h]
		3[k]	---	---	---	2[m]	1[n]	---
IV	Alternative construction	6[f]	---	---	---	3	1[g]	2[h]
		3[k]	---	---	---	2[m]	1[n]	---

[a] See Clause 14 for details of the requirements regarding changes in design features.

[b] The tolerance of the oven temperature shall be ±2 °C.

[c] CRTs not visibly damaged in this test may also be subjected to the tests described in 8.2 and 8.3. If a CRT yields unacceptable results in either of these tests, the results shall be considered inconclusive and disregarded. A new CRT shall be tested in its place, as previous testing might have weakened the CRT.

[d] Other Arrhenius based time/temperature combinations (according to the principles of IEC 60216-1) may be used (for example, 140 °C for 96 h, 130 °C for 168 h, 120 °C for 336 h or 110 °C for 672 h).

[e] CRTs shall be thermally cycled between -40 °C and +70 °C at the rate of 2 cycles per day for a total of 5 cycles and held at each temperature extreme for 4 h.

[f] Film on all samples is scored as detailed in 10.2.

[g] The scratch patterns described in 8.3.1 shall be positioned on the faceplate sidewall.

[h] The film is to be cut in the prescribed scratch pattern of 8.2.1. The glass is then scratched through the same cuts in the film.

[k] Supplied by manufacturer without film.

[m] Glass throw criteria of 8.1.2 modified to “there shall be no glass particle having a mass greater than 10 g past the 1,5 m barrier”.

[n] Glass throw criteria of 8.3.2 modified to “there shall be no glass particle having a mass greater than 2 g past a 0,5 m barrier and no glass particle beyond a 2,0 m barrier” .

[p] See Clause 15 for alternative thermal conditioning.

Table 4 – Sampling and test programme for prestressed banded CRTs with protective film from 76 mm to 160 mm diagonal

Sampling plan	CRT design[a]	Thermal conditioning				Impact and implosion test groups		
		Number of CRTs	Circulating air chamber			Number of CRTs to be tested as described in		
			Temp °C[b]	RH %	Time h	9.1 (ball)[c]	9.3 (thermal)	9.2 (high ball)[j]
						Group A	Group B	Group C
I	New construction	5[f]	---	---	---	2	1[g]	2[h]
		4[f & p]	150[d]	---	48[d]	2	1[g]	1[h]
		4[f]	50	90 – 95	48	2	1[g]	1[h]
		4[f]	[e]	---	[e]	2	1[g]	1[h]
		5[k]	---	---	---	4[m]	1[n]	---
II	New construction with previously tested tape or resin and film/adhesive combination	12[f]	---	---	---	6	2[g]	4[h]
		4[k]	---	---	---	3[m]	1[n]	---
III	Alternative tension band	9[f]	---	---	---	4	2[g]	3[h]
		3[k]	---	---	---	2[m]	1[n]	---
IV	Alternative construction	6[f]	---	---	---	3	1[g]	2[h]
		3[k]	---	---	---	2[m]	1[n]	---

[a] See Clause 14 for details of the requirements regarding changes in design features.

[b] The tolerance of the oven temperature shall be ±2 °C.

[c] CRTs not visibly damaged in this test may also be subjected to the tests described in 9.2 and 9.3. If a CRT yields unacceptable results in either of these tests, the results shall be considered inconclusive and disregarded. A new CRT shall be tested in its place, as previous testing might have weakened the CRT.

[d] Other Arrhenius based time/temperature combinations (according to the principles of IEC 60216-1) may be used (for example, 140 °C for 96 h, 130 °C for 168 h, 120 °C for 336 h or 110 °C for 672 h).

[e] CRTs shall be thermally cycled between -40 °C and +70 °C at the rate of 2 cycles per day for a total of 5 cycles and held at each temperature extreme for 4 h.

[f] Film on all samples is scored as detailed in 10.2.

[g] The scratch patterns described in 9.3.1 (8.3.1) shall be positioned on the faceplate sidewall, or direct on face in a cut out window of minimal 20 mm × 20 mm.

[h] The film is to be cut in the prescribed scratch pattern of 9.2.1. The glass is then scratched through the same cuts in the film.

[j] Test 9.2 is only applied if implosion or rapid devacuation does not occur in ball test 9.1.

[k] Supplied by manufacturer without film.

[m] Glass throw criteria of 9.1.2 modified to “there shall be no glass particle having a mass greater than 10 g past the 1,5 m barrier”.

[n] Glass throw criteria of 9.3.2 (8.3.2) modified to “there shall be no glass particle having a mass greater than 2 g past a 0,5 m barrier and no glass particle beyond a 2.0 m barrier” .

[p] See Clause 15 for alternative thermal conditioning.

Table 5 – Sampling and test programme for adhesion of film used in CRTs with protective film (tested according to Tables 3 and 4)

Sampling plan	CRT design[a]	Thermal conditioning				Test groups	
		Number test samples	Preconditioning			Number of test samples to be tested as described in	
			Temp °C[b]	RH %	Time h	10.3 (peel test)	10.4 (immersion test)
I	New construction	5[c]	---	---	---	5	---
		5[c]	100[d]	---	168[d]	5	---
		5[c]	32	80 – 90	168	5	---
		5[c]	[e]	---	[e]	5	---
		4[f]	---	---	---	---	4

[a] See Clause 14 for details of the requirements regarding changes in design features.

[b] The tolerance of the oven temperature shall be ±2 °C.

[c] Test samples prepared according to 10.3.1.

[d] Other time/temperature combinations may be used, as follows: 90 °C for 336 h, 87 °C for 504 h or 82 °C for 1 440 h.

[e] Test samples shall be thermally cycled between (–40 ± 2) °C and (+70 ± 2) °C at the rate of 2 cycles per day for a total of 5 cycles and held at each temperature extreme for 4 h.

[f] Test samples prepared according to 10.4.1.

Table 6 – Sampling and test programme for bonded frame CRTs exceeding 160 mm diagonal

Sampling plan	CRT design[a]	Thermal conditioning				Impact and implosion test groups		
		Number of CRTs	Circulating air chamber			Number of CRTs to be tested as described in		
			Temp °C[b]	RH %	Time h	8.1 (ball)[c]	8.3 (thermal)	8.2 (missile)
						Group A	Group B	Group C
I	New construction	5	–	–	–	2	1	2
		4	150[d]	–	48[d]	2	1	1
		4	50	90 – 95	48	2	1	1
		4	[e]	–	[e]	2	1	1
II	Alternative construction	6	–	–	–	3	1	2

[a] See Clause 16 for details of the requirements regarding changes in design features.

[b] The tolerance of the oven temperature shall be ±2 °C.

[c] CRTs not visibly damaged in this test may also be subjected to the tests described in 8.2 and 8.3. If a CRT yields unacceptable results in either of these tests, the results shall be considered inconclusive and disregarded. A new CRT shall be tested in its place, as previous testing might have weakened the CRT.

[d] Other Arrhenius based time/temperature combinations (according to the principles of IEC 60216-1) may be used (for example, 140 °C for 96 h, 130 °C for 168 h, 120 °C for 336 h or 110 °C for 672 h).

[e] CRTs shall be thermally cycled between –40 °C and +70 °C at the rate of two cycles per day for a total of five cycles and held at each temperature extreme for 4 h.

Table 7 – Sampling and test programme for bonded frame CRTs from 76 mm to 160 mm diagonal

Sampling plan	CRT design[a]	Thermal conditioning				Impact and implosion test groups		
		Number of CRTs[f]	Circulating air chamber			Number of CRTs to be tested as described in		
			Temp °C[b]	RH %	Time h	9.1 (ball)[c]	9.3 (thermal)	9.2 (high ball)[f]
						Group A	Group B	Group C
I	New construction	5	–	–	–	2	1	2
		4	150[d]	–	48[d]	2	1	1
		4	50	90 – 95	48	2	1	1
		4	[e]	–	[e]	2	1	1
II	Alternative construction	6	–	–	–	3	1	2

[a] See Clause 16 for details of the requirements regarding changes in design features.

[b] The tolerance of the oven temperature shall be ±2 °C.

[c] CRTs not visibly damaged in this test may also be subjected to the tests described in 9.2 and 9.3. If a CRT yields unacceptable results in either of these tests, the results shall be considered inconclusive and disregarded. A new CRT shall be tested in its place, as previous testing might have weakened the CRT.

[d] Other Arrhenius based time/temperature combinations (according to the principles of IEC 60216-1) may be used (for example, 140 °C for 96 h, 130 °C for 168 h, 120 °C for 336 h or 110 °C for 672 h).

[e] CRTs shall be thermally cycled between –40 °C and +70 °C at the rate of two cycles per day for a total of five cycles and held at each temperature extreme for 4 h.

[f] Test 9.2 is only applied if implosion or rapid devacuation does not occur in ball test 9.1.

Table 8 – Sampling and test programme for laminated CRTs exceeding 160 mm diagonal

Sampling plan	CRT design[a]	Thermal conditioning			Impact and implosion test groups		
		Number of CRTs	Circulating air chamber		Number of CRTs to be tested as described in		
			Temp °C[b]	Time h	8.1 (ball)[c]	8.3 (thermal)	8.4 (high energy)
					Group A	Group B	Group C
I	New construction	5	–	–	2	1	2
		5	150[d]	48[d]	2	1	2
II	Alternative construction	5	–	–	2	1	2

[a] See Clause 17 for details of the requirements regarding changes in design features.

[b] The tolerance of the oven temperature shall be ±2 °C.

[c] CRTs not visibly damaged in this test may also be subjected to the tests described in 8.3 and 8.4. If a CRT yields unacceptable results in either of these tests, the results shall be considered inconclusive and disregarded. A new CRT shall be tested in its place, as previous testing might have weakened the CRT.

[d] Other Arrhenius based time/temperature combinations (according to the principles of IEC 60216-1) may be used (for example, 140 °C for 96 h, 130 °C for 168 h, 120 °C for 336 h or 110 °C for 672 h).

Table 9 – Sampling and test programme for laminated CRTs from 76 mm to 160 mm diagonal

Sampling plan	CRT design[a]	Thermal conditioning			Impact and implosion test groups		
		Number of CRTs	Circulating air chamber		Number of CRTs to be tested as described in		
			Temp °C[b]	Time h	9.1 (ball)[c]	9.3 (thermal)	9.4 (high energy)
					Group A	Group B	Group C
I	New construction	4	–	–	2	1	1
		4	150[d]	48[d]	2	1	1
II	Alternative construction	3	–	–	1	1	1

[a] See Clause 17 for details of the requirements regarding changes in design features.

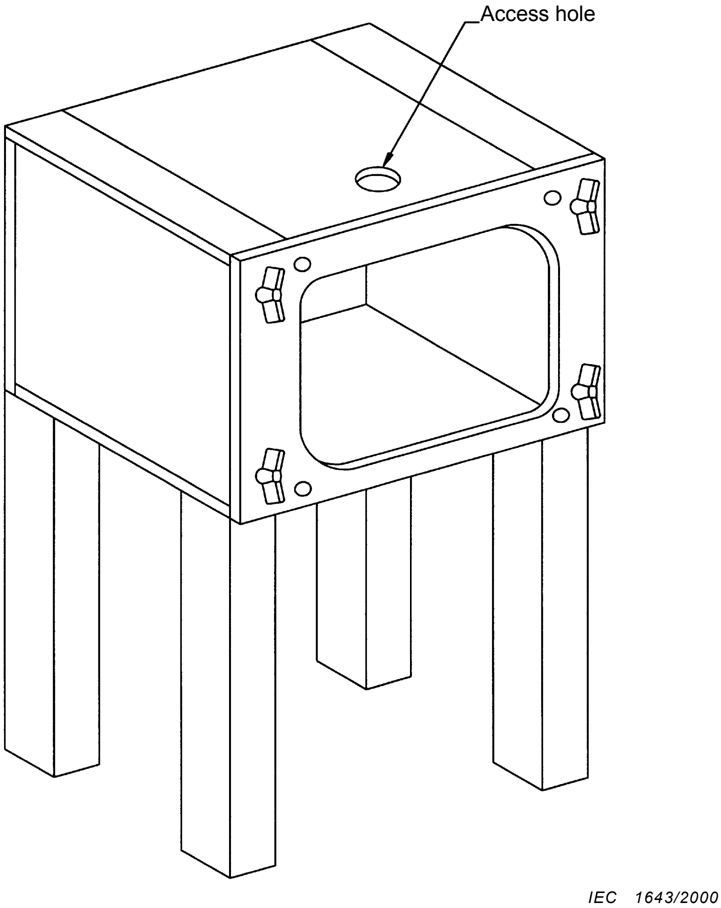
[b] The tolerance of the oven temperature shall be ±2 °C.

[c] CRTs not visibly damaged in this test may also be subjected to the tests described in 9.3 and 9.4. If a CRT yields unacceptable results in either of these tests, the results shall be considered inconclusive and disregarded. A new CRT shall be tested in its place, as previous testing might have weakened the CRT.

[d] Other Arrhenius based time/temperature combinations (according to the principles of IEC 60216-1) may be used (for example, 140 °C for 96 h, 130 °C for 168 h, 120 °C for 336 h or 110 °C for 672 h).

Table 10 – CRT size and deflection angle ranges

CRT diagonal size range mm		Diagonal deflection angle degrees	
Laminated construction	**Prestressed banded and bonded frame construction**	**Laminated construction**	**Prestressed banded and bonded frame construction**
76 – 160	76 – 160	40 – up	40 – 69
161 – 320	161 – 255		70 – 99
321 – 520	256 – 350		100 – 112
521 – 690	351 – 460		113 – up
691 – 850	461 – 540		
	541 – 640		
	641 – 740		
	741 – 890		
	891 – 1 200		



NOTE 1 A cabinet is typically 20 mm thick and made of plywood or metal of similar strength. The front panel should be made of plywood, typically 20 mm thick.

NOTE 2 An opening having an area of not less than one-quarter of the area of the face of the CRT or 0,02 m^2, whichever is the smaller, should be provided in the bottom or rear of the cabinet for air intake in the event of an implosion.

Figure 1 – Example of a test cabinet

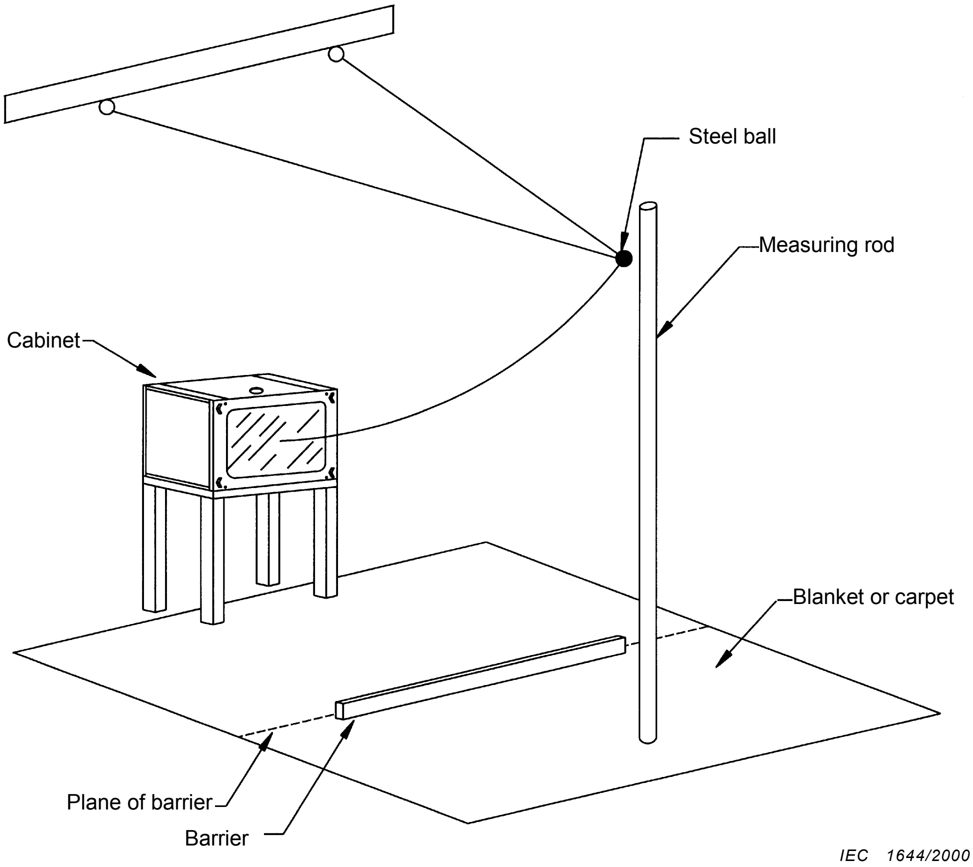
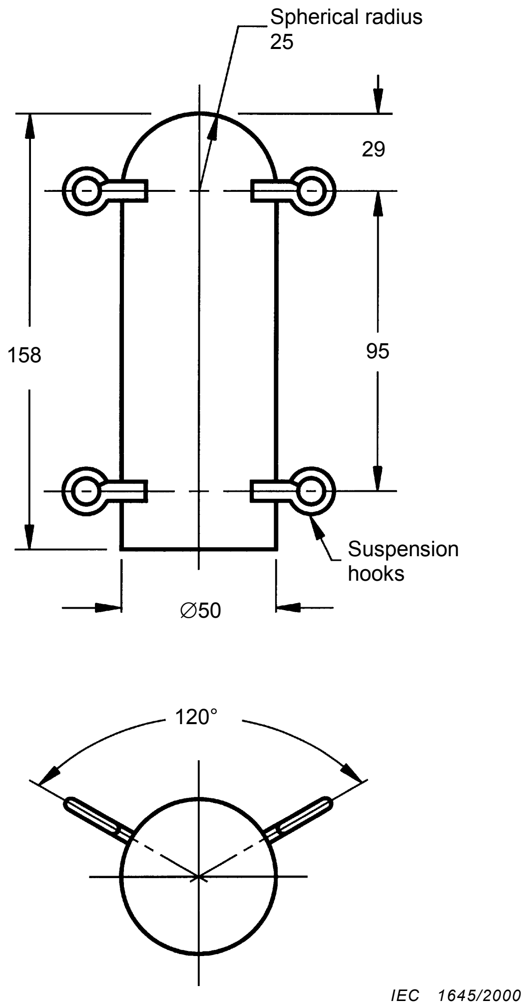
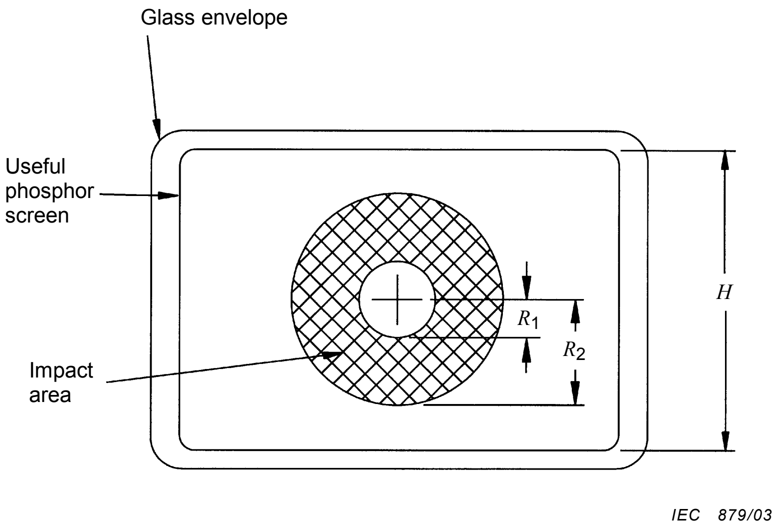


Figure 2 – Example of a ball impact test



NOTE All linear dimensions are in millimetres.

Figure 3 – Example of a 2,3 kg steel missile



Key

H height of the useful phosphor screen

R_1 H/6

R_2 H/2 – 50 mm

Figure 4 – Missile impact area on a typical CRT

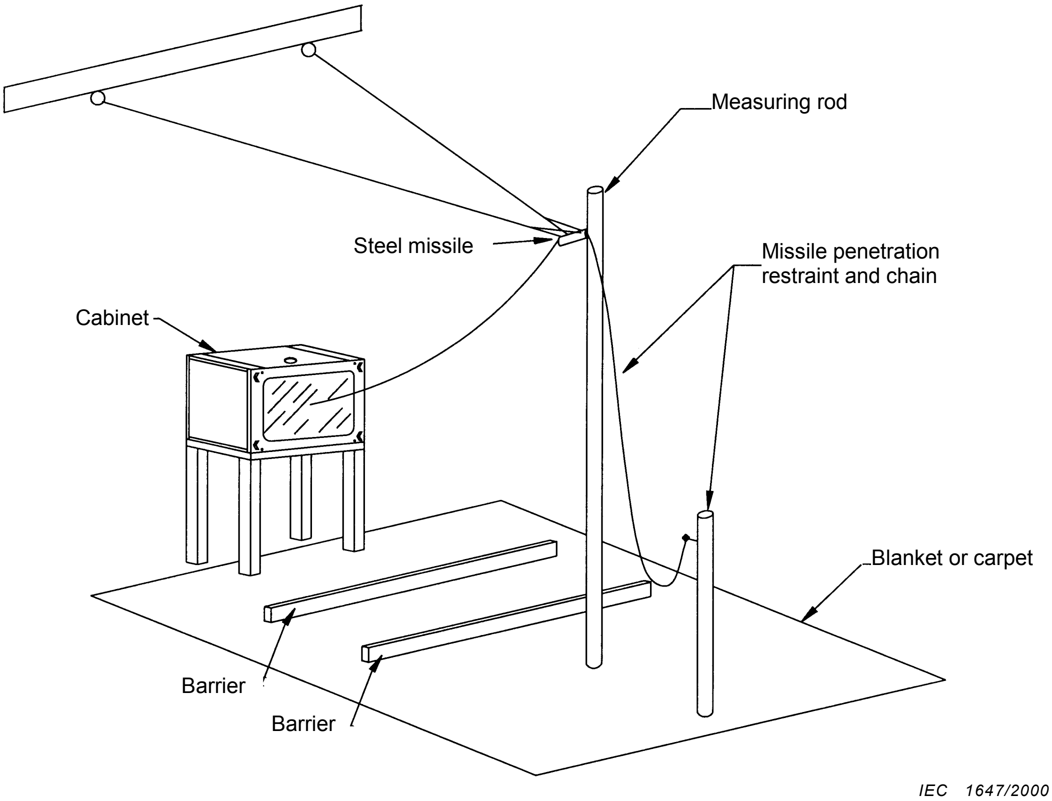
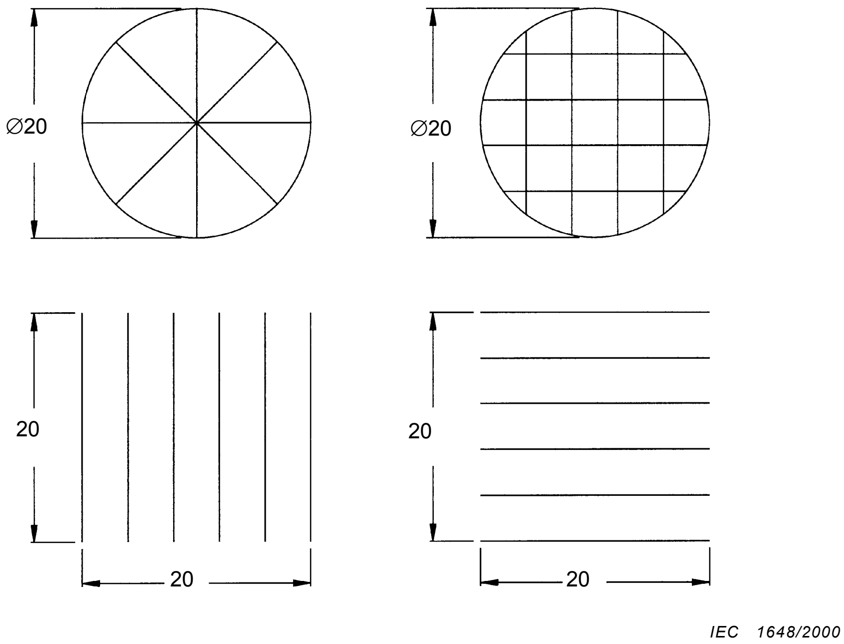
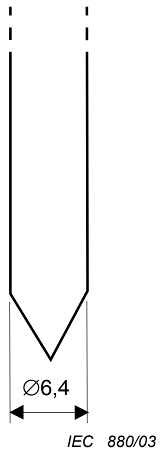


Figure 5 – Example of a missile impact test



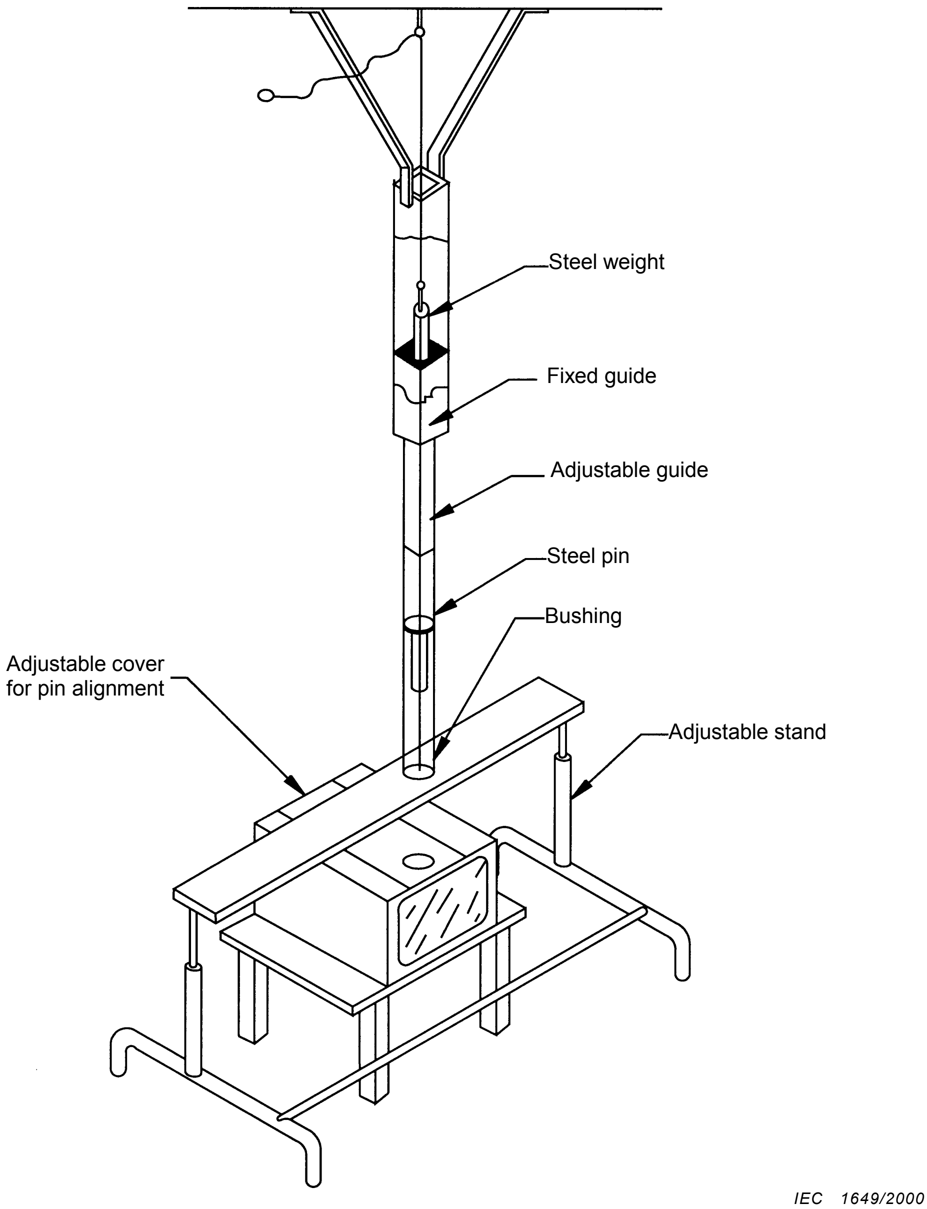
NOTE All linear dimensions are in millimetres.

Figure 6 – Options for scratch patterns for implosions by the thermal shock method



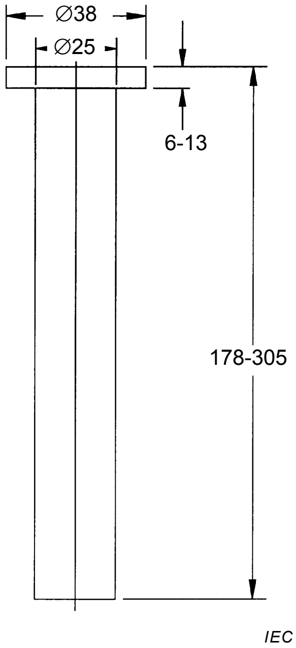
Steel drill rod, hardened to 60-62 on Rockwell C scale and with 60° conical tip and a tip radius of 0,03 mm ± 30 %

Figure 7 – Film scoring tool

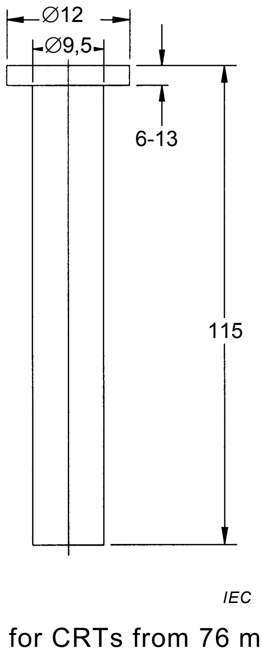


NOTE Adjust height of adjustable stand in such a way that, when the weight hits the pin, the amount of penetration of the pin into the CRT will be a maximum of 6 mm.

Figure 8 – Example of high-energy impact test set-up



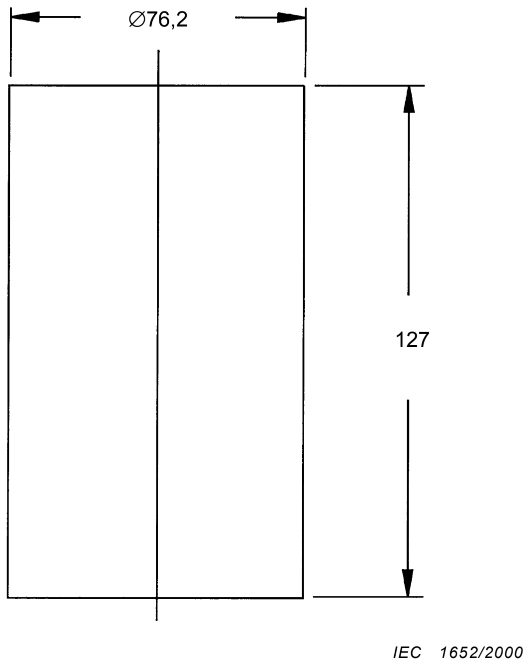
Example of steel pin for CRTs exceeding 160 mm face diagonal used in high-energy impact test



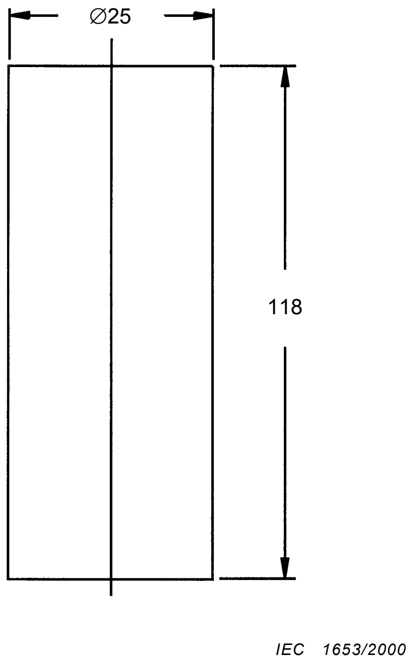
Example of steel pin for CRTs from 76 mm to 160 mm diagonal used in high-energy impact test

NOTE All linear dimensions are in millimetres.

Figure 9 – Steel pins used in high-energy impact test



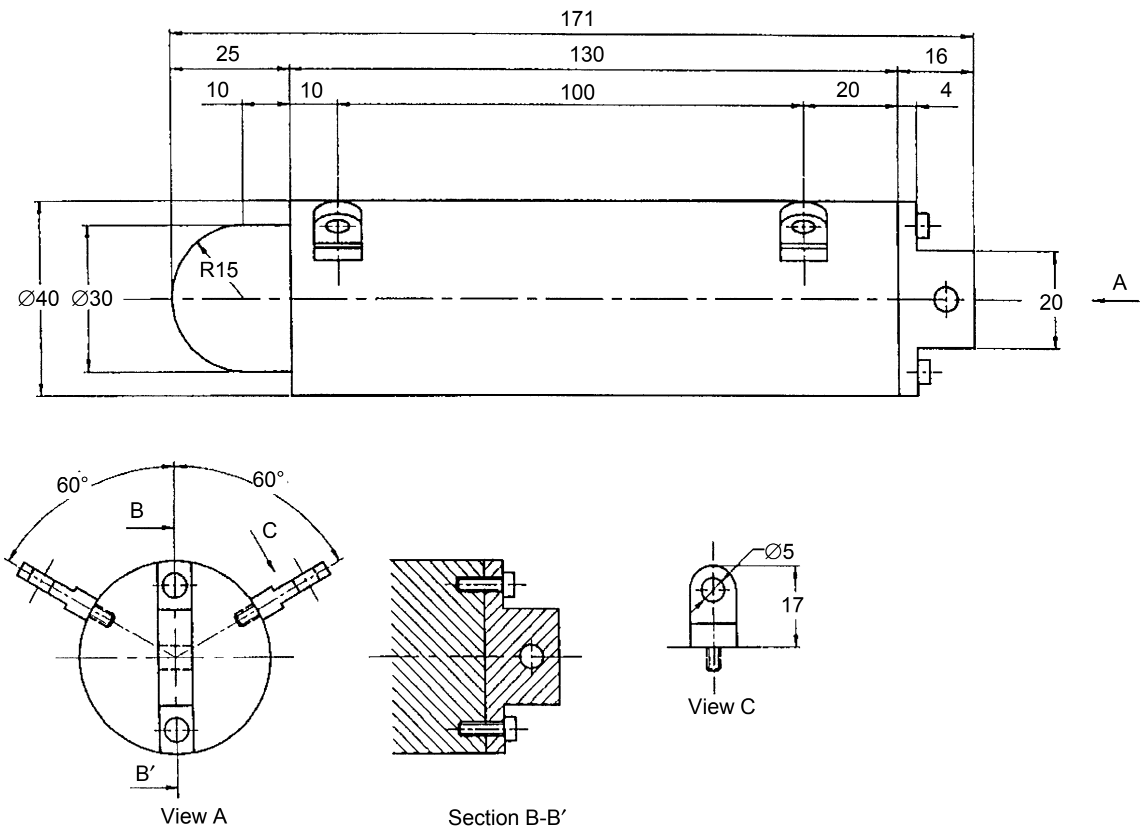
Example of 4,5 kg weight used in high-energy impact test
on CRTs exceeding 160 mm diagonal



Example of 0,45 kg weight used in high-energy impact test
on CRTs from 76 mm to 160 mm face diagonal

NOTE All linear dimensions are in millimetres.

Figure 10 – Weights used in high-energy impact test



IEC 1654/2000

NOTE 1 All linear dimensions are in millimetres.

NOTE 2 Weight: approx. 1,4 kg.

NOTE 3 Rockwell hardness: >60.

NOTE 4 Surface: chromium coating.

Figure 11 – Example of 1,4 kg steel missile

Annex A
(informative)

Background to the development of this standard

At its meeting in Eindhoven on 8-9 November 1994, IEC TC 39 noted that a confusing and costly situation had developed world wide concerning the certification of the mechanical strength of cathode ray tubes (CRTs). The current Clause 18 of IEC 60065 was still being used in most countries and had proved to be satisfactory to them. The binational standard UL 1418/CSA-C22.2 No. 228-92 was also being used for certification, mainly in the North American continent. The committee decided to propose a New Work Item 39/231/NP to develop a new standard which would ultimately replace the existing standards. After the voting stage it was clear that sufficient support existed and Working Group 2 was established comprising experts from Canada, Italy, Japan, Korea, the Netherlands, United Kingdom, United States of America and Germany.

IEC 60065 is an equipment standard under the responsibility of IEC TC 92. TC 39 undertook the task of creating a new standard intended to replace Clause 18 of IEC 60065, in line with the IEC policy that component requirements should be published in component standards, in the development of which due notice should be given to the component user requirements (Administrative Circular No. 71/1988).

At its first meeting, TC 39/WG 2 noted that, in fact, Clause 18 of IEC 60065 and the binational UL/CSA standard were the two documents which required harmonization. The two standards are similar in approach to testing. They both contain conditioning regimes and tests to prove the mechanical strength and the effects to the user of the implosion or rapid devacuation of the CRT. Both standards address only CRTs which have integral implosion protection systems.

Over 30 years' experience has been built up in the use of both standards. In that time, CRT technology has moved forward in the area of implosion protection systems and with the evolution of larger CRTs. Experience has also shown that certain areas of interpretation need to be addressed.

This standard contains the following main clauses:

- environmental conditioning instructions for use prior to testing;
- test methods and requirements which demonstrate that the CRT is mechanically strong enough to withstand impact damage which could be encountered in normal use so that the viewer is adequately protected against injury;
- test methods and requirements which demonstrate that, in the event of an implosion or rapid devacuation of the CRT, the implosion occurs in a controlled manner;
- detailed sampling tables which specify the numbers of CRTs to be tested to certify new designs and changes in design or construction;
- dedicated test methods and requirements for small CRTs (76 mm to 160 mm diagonal) and large CRTs (exceeding 160 mm diagonal).

During the development of the new standard, the TC 39/WG 2 members carried out extensive testing programmes and calculations to demonstrate that the proposed new test methods ensure protection for the users of the CRTs which are covered by the standard, and that the stringent requirements of either of the existing standards are not degraded. The conclusions of these findings are summarized as follows.

A.1 Mechanical strength test

a) The ball impact test attempts to simulate the situation where the CRT can be struck by any likely domestic object. The shape and energy of such objects will vary enormously and the choice of a single device size and energy for this test is in order to ensure standardization i.e., an easily reproducible and repeatable test with the minimum of variability.

b) The 40 mm/5,5 J ball test was selected as it was already in use in IEC 60065 and was optional in the binational standard. Testing showed it to be generally equivalent to the use of the 51 mm/7 J ball when combined with the use of a single barrier at 1,5 m.

c) From ballistic and statistical calculations the kinetic energy of a 0,025 g particle (the maximum size permitted by this standard) is of the order of 1×10^{-4} J and the maximum particle speed is around 4 m/s (9 m.p.h.). This energy level is negligible with respect to its ability to cause flesh damage as human skin exhibits visco-elastic properties (people performing normal activities frequently encounter airborne particles of greater mass and higher velocity than this).

A.2 Implosion test

Due to the introduction of larger CRTs having thicker faceplates and to the use of laminated screens, it is not possible, in some cases, to induce rapid devacuation using the ball impact test. In order to evaluate the effectiveness of the implosion protection system, a test with a larger impact object (missile or high-energy) is used to induce rapid devacuation.

A.3 Small CRTs (76 mm to 160 mm diagonal)

Research has shown that small CRTs may require implosion protection systems. Scaled-down tests have been developed for these sizes.

A.4 Evaluation time

As the impact tests in this standard are overstress tests, evaluation of test results includes only the effect of rapid devacuation and not subsequent relaxation of mechanical stresses in the CRT from the implosion protection system. Five seconds is deemed satisfactory to evaluate the result of rapid devacuation and exclude results of stress relaxation.

Annex B
(informative)

Velocity and potential force of glass particles expelled from a CRT subjected to a ball impact – Ballistic and statistical calculations

B.1 Introduction

An assignment was given to determine the potential force of glass particles passing over the test set-up barriers after being expelled from a tested CRT subjected to a ball impact test. The test set-up barriers are placed at a distance of 0,9 m in the UL/CSA standard and 1,5 m in this standard. The equivalent instantaneous force of a glass particle with a specified mass of 25 mg at a given distance then needs to be determined. This can then also be compared to IEC 60065, Clause 18, in which a particle of 10 g is allowed to reach the barrier at 1,5 m.

A glass particle will be expelled at a vertical height of 1,0 m and would have the minimum velocity to pass over a 0,25 m barrier placed at 0,9 m in one solution and at 1,5 m in the other (Figure B.1). If possible, air resistance should be factored into the equation. In addition, any available information on medical studies determining the force required to lacerate human skin is to be acquired.

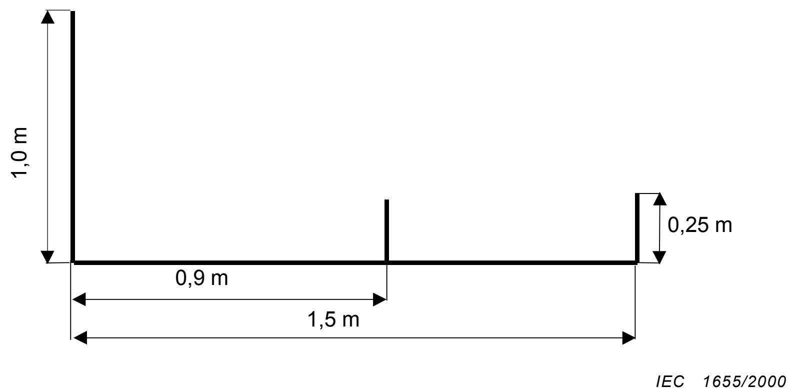


Figure B.1 – Height of the barriers and distances from the CRT face

The objective of this annex is to investigate the velocity and potential force of glass particles expelled from an imploding CRT. In this annex, the analysis of a glass particle with, and without, air friction influences is described. Finally conclusions are drawn.

B.2 Analysis without friction

B.2.1 Introduction

After a glass particle is expelled from the CRT screen, the primary forces acting on the particle are the gravitational force and the air friction. In this clause the trajectory of a glass particle is determined as it is expelled from a CRT screen with a certain velocity and angle. First, the analysis without air-friction influences is described because this enables the equations of motion to be solved analytically. Furthermore, due to the shape of the particles, the air resistance is probably very small. The trajectory of the glass particle then has a parabolic shape. This is shown in Figure B.2.

In the UL/CSA test set-up a barrier with a height h is placed at a distance l_2 from the screen. In the IEC test set-up, the barrier is placed at a distance l_1. The values for the set-up parameters are given in Table B.1. The implosion protection system of CRTs assures that glass particles with a mass of 25 mg will not exceed the respective distances.

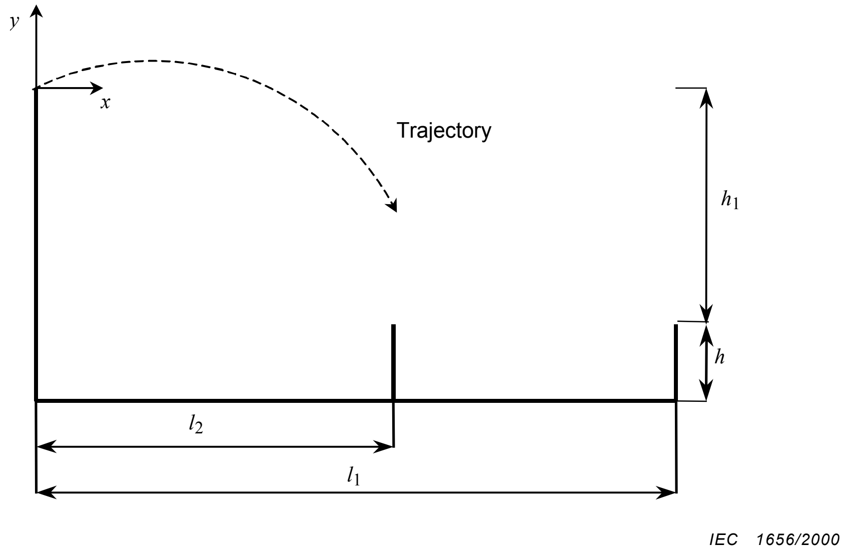


Figure B.2 – Example of the parabolic trajectory of a glass particle and the definition of the distances

Table B.1 – Values of the distances

Distances	**Values** m
h	0,25
h_1	0,75
l_1	1,5
l_2	0,9

B.2.2 Equations of motion

Figure B.3 shows the definition of a glass particle that is propelled from the CRT with an initial velocity v_0 under an angle β. The only force acting on the particle is the gravitational force. Newton's law can then be used to determine the force equilibrium in x- and y-direction:

$$ma_x = 0$$

$$ma_y = 0$$

where

m is the mass of the glass particle in kg;

a_x is the acceleration of the particle in x-direction in m/s^2;

a_y is the acceleration of the particle in y-direction in m/s^2;

g is the gravitational acceleration of 9,81 m/s^2.

These relations can be integrated twice with the initial conditions as shown in Figure B.3. This results in the following displacement equations:

$$x = v_0 \cos \beta \times t$$

$$y = v_0 \sin \beta \times t - \frac{1}{2} g t^2$$

where

x is the displacement in x-direction;

y is the displacement in y-direction;

v_0 is the initial velocity;

β is the initial angle at which the particle is expelled;

t is the time.

NOTE The time derivative of the displacement is the velocity and the time derivative of the velocity is the acceleration.

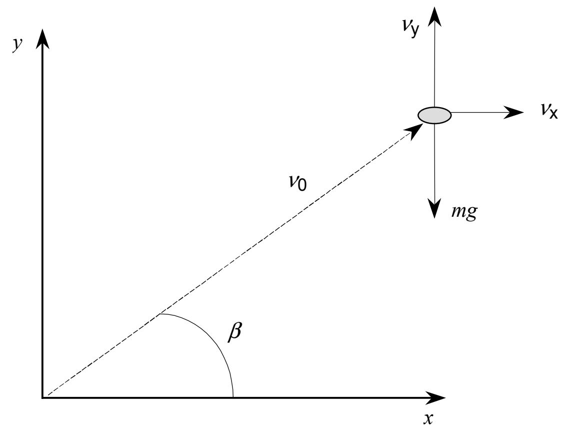


Figure B.3 – Definition of the initial angle and initial velocity and the forces acting on a particle

B.2.3 Minimum velocity to reach a prescribed distance

The unknowns in the equations of motion are the initial velocity v_0 and the time t. The initial angle β needs to be prescribed. Therefore, the required initial velocity depends on the value for β. The known values are $x = l_1$ or l_2 and $y = h$ (Table B.2 and Figure B.1).

There are two equations with two unknowns. To solve the equations a relation for t can be determined from the first equation and substituted in the second equation:

$$x = v_0 \cos\beta \times t \rightarrow t = \frac{x}{v_0 \cos\beta}$$

$$y = v_0 \sin \beta \times \frac{x}{v_0 \cos \beta} - \frac{1}{2} g \left(\frac{x}{v_0 \cos \beta} \right)^2$$

This can be rewritten to obtain the following relation:

$$v_0 = \sqrt{\frac{gx^2}{2x \sin \beta \cos \beta - 2y \cos^2 \beta}}$$

Figure B.4 shows the initial velocity that is required to pass over the barriers at $x = l_1$ (solid line) or $x = l_2$ (dashed line) as a function of the initial angle β. The curves can be interpreted as follows:

- if the initial angle β is 0°, then glass particles with a velocity higher than 3,8 m/s will pass over both barriers;
- if the initial angle β is 0°, then glass particles with a velocity lower than 2,3 m/s will remain within the barrier of 0,9 m;
- if the initial angle β is 0°, then glass particles with a velocity higher than 2,3 m/s and lower than 3,8 m/s will fall outside the barrier at 0,9 m and inside the barrier of 1,5 m.

It can be seen that the function has an upper and a lower boundary. The barriers can not be passed for any value of the initial velocity if the values for β are beyond these limits.

The limit to the velocity is defined by the boundary values of β. The velocity goes to infinity if the denominator in the root equation has a value of zero. This happens when

$$\beta = \tan^{-1}\left(\frac{y}{x}\right)$$

Table B.2 shows the upper and lower boundary values of the initial angle.

Table B.2 – Upper and lower boundary values of the initial angle

Barrier	β_{low}	β_{up}
l_1	–26,7°	90°
l_2	–39,8°	90°

An upper boundary β_{up} is reached when the angle is so great that an infinite value for the velocity is needed to reach a distance of l_1.

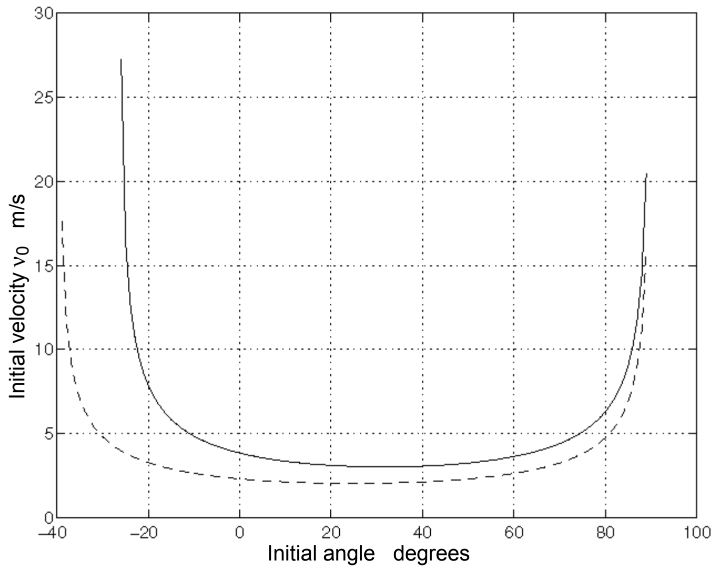


Figure B.4 – Initial velocity required to pass over barriers at $x = l_1$ (solid line) or $x = l_2$ (dashed line) as a function of the initial angle β

Figure B.5 gives an example of different trajectories of glass particles for an initial velocity of 4 m/s and different initial angles ranging from –25° to 50°. The y-displacement of –0,75 m corresponds to the top of the barriers. It can be seen that for an initial angle of –25° the glass particles fall inside the first barrier, while for angles larger than 0° the glass particles all fall outside the barriers.

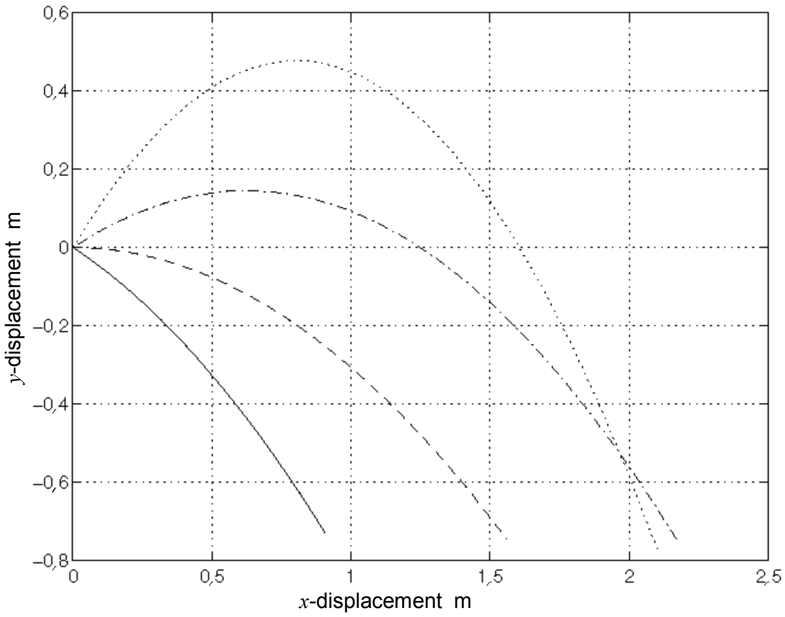


Figure B.5 – Trajectories for a glass particle for different initial angles and an initial velocity of 4 m/s

(β = –25° until t = 0,25 s (solid line); β = 0° until t = 0,39 s (dashed line); β = 25° until t = 0,6 s (dashed-dotted line); β = 50° until t = 0,82 s (dotted line))

B.2.4 Comparison of kinetic energies

A comparison is given below for the kinetic energy of particles expelled from CRTs which meet the different standards.

The kinetic energy U_{kin} of the particle that hits the viewer is defined as

$$U_{kin} = \frac{1}{2} m v^2$$

in which v is the current velocity.

A rationale proposal is given below for $\beta = 0$ assumption.

In a ball impact test, glass particles may be thrown from the CRT into the room.

The characteristics of these particles, in terms of mass (m), initial velocity (v_0) and initial angle (β) depend on the mechanical strength of the CRT under evaluation (breakage configuration), the ball diameter (40 mm or 50 mm) and the impact energy applied for the test (5,5 J or 7,0 J).

Concerning the statistical distributions of the parameters v_0 and β, the following considerations can be made (due to the impact test methodology):

1) v_0 is independent from β
   (no preferential β for highest velocities)
2) β distribution is symmetrical with respect to $\beta = 0$ and its probability is decreasing for increasing (β) values.

A direct consequence of these characteristics is that the glass particle with the highest initial velocity v_0 (as for all the others) will most probably have an initial angle close to zero ($\beta = 0$).

In other terms, if a particle has passed over a barrier due to a combination of a large initial angle (β) and a high initial velocity (v_0), then it is highly probable that other particles originated by the same impact would be projected further away, due to the same initial velocity (v_0) and a smaller initial angle (β).

All this considered, the analysis of the different glass throw criteria assuming $\beta = 0$ offers results that should represent very closely the real maximum kinetic energy levels involved in a ball impact test.

From B.2.3 and Figure B.4 we know that the velocity of the glass particles to pass over the barriers set at 0,9 m and 1,5 m is about 2,3 m/s and 3,8 m/s respectively.

The kinetic energy of particles emitted from the tubes can be calculated with the above-mentioned formulas and depends on mass, speed and height. In the case of glass particles of 0,025 g, the initial kinetic energy needed to pass over a 0,9 m barrier is $0,66 \times 10^{-4}$ J and that needed for a 1,5 m barrier is $1,80 \times 10^{-4}$ J. The ratio between these two different scenarios of the latent kinetic energy in particles differs by a factor of 2,7 at a height of 1 m $0,66 \times 10^{-4}$ J versus $1,80 \times 10^{-4}$ J and a factor 1,3 on floor level $[(0,66 \times 10^{-4})$ J + $(2,45 \times 10^{-4})]$ J versus $[(1,80 \times 10^{-4})$ J + $(2,45 \times 10^{-4})]$ J. The figure of $(2,45 \times 10^{-4})$ J is the potential energy transferred into kinetic energy due to the vertical drop of the particle over a height of 1 m.

The existing IEC 60065 test permits particles of up to 10 g in weight to pass over a barrier at 1,5 m. In this case, the maximum energy of these particles could be around 0,7 J.

B.3 Analysis with friction

B.3.1 Introduction

In this clause, the analysis of the previous clause will be repeated with the incorporation of friction effects. The friction effects are caused by the air that has to be displaced during the trajectory. The friction effects result in an additional non-linear term in the equations of motion. The equations can then no longer be solved analytically.

B.3.2 Equations of motion

Figure B.6 shows the definition of a glass particle that is propelled from the CRT with an initial velocity v under an angle α. The forces acting on the particle are the gravitational force and the friction. The direction of the friction is always negative to the trajectory of the particle. Newton's law can then be used to determine the force equilibrium in x- and y-direction:

$$ma_{\mathrm{x}} = -F_{\mathrm{w}} \cos\alpha$$

$$ma_{\mathrm{y}} = -mg - F_{\mathrm{w}} \sin\alpha$$

where

m is the mass of the glass particle in kg;

a_{x} is the acceleration of the particle in x-direction in m/s^2;

a_{y} is the acceleration of the particle in y-direction in m/s^2;

F_{w} is the frictional force;

α is the initial angle under at which the particle is propelled;

g is the gravitational acceleration of 9,81 m/s^2.

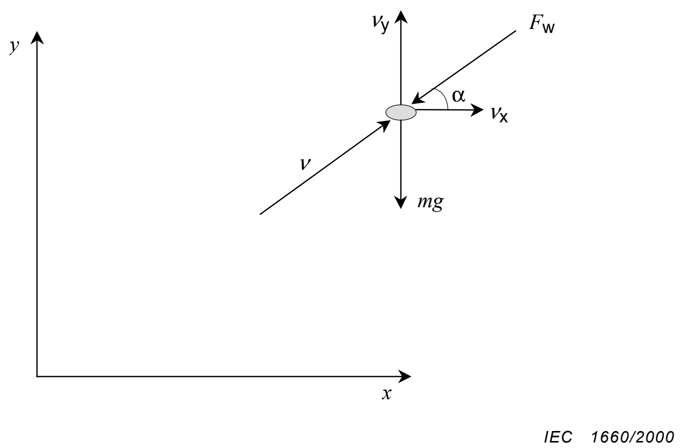


Figure B.6 – Definition of the forces acting on a particle

The frictional force is defined as

$$F_W = \frac{1}{2} \times C_W \times A \times \rho_A \times v^2$$

where

C_W is the resistance coefficient;

A is the cross-sectional area of the particle perpendicular to the trajectory;

ρ_A is the density of the medium;

v is the absolute value of the velocity (Figure B.6).

It must be noted that the friction force is not constant due to the dependence on the current velocity of the particle. The medium is considered to be air which has a density of approximately 1,2 kg/m^3 at sea-level.

The C_W value depends on the Reynolds number. The Reynolds number for a circular sphere is defined as

$$\text{RE} = \frac{\rho_A \times v \times D}{\mu}$$

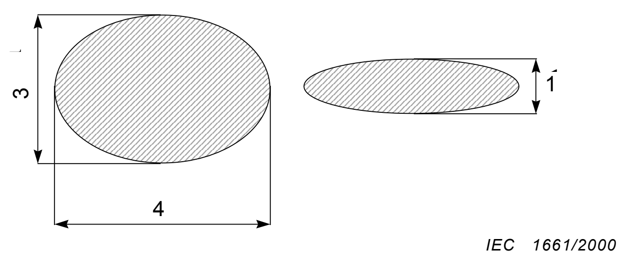
where

D is the diameter of the particle;

μ is the viscosity of the medium.

The Reynolds number can now be calculated. For this purpose, a particle is chosen with a diameter of 1×10^{-3} m, and a velocity of 5 m/s which moves through air with a viscosity of approximately $1{,}8 \times 10^{-5}$ kgm/s. This results in a Reynolds number of approximately 330. Typical C_W value versus Reynolds number curves then give a C_W of 0,44. It must be noted that the C_W value is approximately constant for Reynolds numbers in the region of 100 to 20 000. The rough approximations for the values of the velocity and diameter which are used to determine the Reynolds number are therefore justified.

It is the requirement of the present UL/CSA standard that the maximum mass of the particles that fall outside the barriers is 25×10^{-6} kg (25 mg). Measurements of a typical particle are shown in Figure B.7. A particle with these dimensions has an approximate mass of 25×10^{-6} kg when the density of screen glass is 2 730 kg/m^3. The cross-sectional area of a typical glass particle is then approximately 3×10^{-6} m^2.



Dimensions in millimetres

Figure B.7 – Measurements of a typical glass particle

The frictional force equation

$$F_w = \frac{1}{2} \times C_w \times A \times \rho_A \times v^2$$

can then be written as

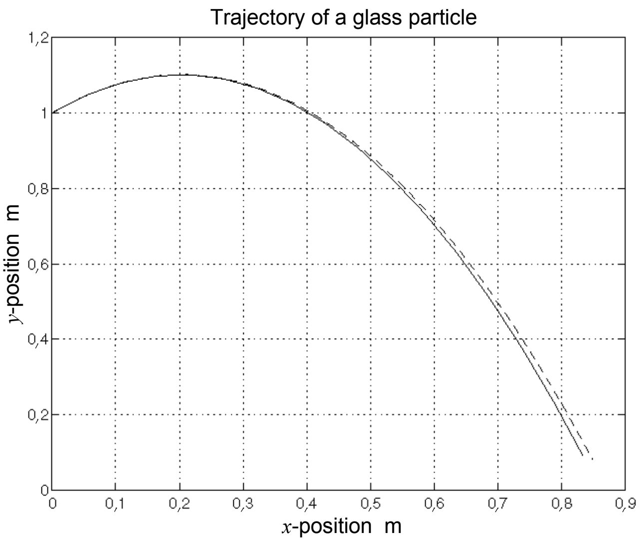
$$F_w = \frac{1}{2} \times 0{,}44 \times 3 \times 10^{-6} \times 1{,}2 \times v^2 = 7{,}9 \times 10^{-7} \times v^2$$

A typical value of the friction force for a velocity of approximately 4 m/s is then $1{,}25 \times 10^{-5}$ N. This can be compared to the gravitational force of $2{,}45 \times 10^{-4}$ N. It can then be seen that the friction is much smaller than the gravitational force. The influence of the friction does become quadratically larger for increasing velocities.

B.3.3 Minimum velocity to reach a prescribed distance

In order to determine the relation between the x-displacement, y-displacement and the initial velocity and angle, the force equilibrium equations have to be solved numerically. This is due to the non-linear terms and the dependence of the angle on the velocity. The equations can be solved with MATLAB.

From the numerical simulations it followed that the influence of the friction for the current velocities is very small. Figure B.8 shows the trajectory of a glass particle with an initial velocity of 2 m/s and an initial angle of 45° without friction (solid line) and with friction. It can be seen that if friction is included the particle has a deceleration in x- and y-direction but this is very small.



IEC 882/03

Figure B.8 – Trajectory of a glass particle with an initial velocity of 2 m/s and an initial angle of 45° without friction (dashed line) and with friction (solid line)

B.3.4 Influence of the cross-sectional area

The influence of the cross-sectional area has also been investigated. The cross-sectional area has a linear influence on the friction. An increase of the cross-sectional area will result in a larger friction and a larger deceleration of the particle. Figure B.9 shows the different trajectories of a glass particle with an initial velocity of 2 m/s and an initial angle of 45° for different values of the cross-sectional area. The cross-sectional area has been increased from 3×10^{-6} m^2 to 9×10^{-6} m^2. It can be seen that the increase of the cross-sectional area does not have such a large influence on the total displacement.

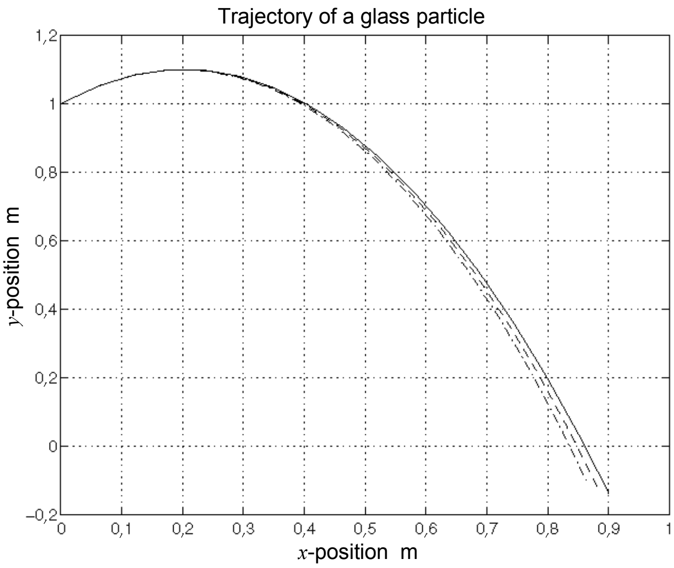


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Figure B.9 – Trajectories of a glass particle with an initial velocity of 2 m/s and an initial angle of 45° for different values of the cross-sectional area

(solid line = 3×10^{-6} m^2, dashed line = 6×10^{-6} m^2, dashed-dotted line = 9×10^{-6} m^2)

B.4 Potential threat

In this clause the potential threat of expelled glass particles will be discussed. In this annex, threat is defined as the danger of glass particles lacerating human skin.

B.4.1 Considerations of glass-to-skin impact

Human skin shows visco-elastic properties. This implies that the skin behaves elastically (the force acting on the skin causes a displacement of the skin, the relation is linear) but is also rate-dependent. A visco-elastic material appears stiffer when compressed at a higher velocity than a lower velocity. Furthermore, it can also be expected that different races show differences in skin material properties.

Glass particles can impact the skin with a certain velocity and energy. The kinetic energy in combination with the shape of a particle is the most important factor which determines threat. An object with a large energy which has a blunt shape will not easily penetrate the skin; the skin will deform elastically but will not tear. If the object has a sharp edge this can cause laceration of the skin. However, if the energy of the particle is too small, the skin will only deform elastically and the particle will "bounce off". The skin will then not be lacerated.

B.5 Conclusions

The following conclusions can be drawn.

- The path or trajectory of a glass particle depends on the initial velocity and direction. The gravitational force causes the particle to follow a parabolic path.
- Friction has only a marginal influence on the velocity and trajectory of a glass particle. This is due to the sharp-edged shape and low initial velocities.

- Particles can only pass over the barriers at 0,9 m or 1,5 m if the initial velocity is combined with an initial angle between –26,7° and +90° for 1,5 m barriers or –39,8° and +90° for 0,9 m barriers.
- The maximum kinetic energy of particles emitted from tubes which meet the requirements, as laid down in this standard and the UL/CSA standard, is of the order of $1,0 \times 10^{-4}$ J. The difference between particle energies needed to pass over barriers set at 0,9 m and 1,5 m is of a factor between 2,7 and 1,3 depending viewing height (1,0 m or at floor height).
- The potential threat of expelled particles in the form of skin lacerations is determined by the kinetic energy (includes mass and velocity) and shape of the particle.
- The energies mentioned above are negligible with respect to their ability to cause flesh damage, as human skin exhibits visco-elastic properties. The maximum particle speed is around 4 m/s (which equates to <10 mph) and cyclists, runners, etc. frequently encounter flying objects, dirt, grit particles greater than 0,025 g when travelling at higher speeds than this.
- The IEC 60065 test permits particles of up to 10 g in weight to pass a barrier at 1,5 m. In this case the maximum energy of these particles could be around 0,7 J.

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