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Edition 1.0 2018-02

INTERNATIONAL STANDARD

colour inside

Liquid crystal display devices –
Part 40-5: Mechanical testing of display cover glass for mobile devices – Strength against dynamic impact by a sharp object with the specimen rigidly supported

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The text of this International Standard is based on the following documents:

FDIS	Report on voting
110/936/FDIS	110/958/RVD

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

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

A list of all parts in the IEC 61747 series, published under the general title *Liquid crystal display devices*, can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under "http://webstore.iec.ch" in the data related to the specific document. At this date, the document will be

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- withdrawn,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

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INTRODUCTION

Mobile electronic devices have become increasingly sophisticated and often incorporate displays for the purposes of user interface and viewing. Such displays commonly incorporate a transparent cover glass, which aids in protecting the display against the introduction of damage through routine device transport and use, as well as occasional or accidental misuse.

The purpose of this document is to provide mechanical testing procedures for cover glasses utilized in such applications. Such glasses can be strengthened, for example via an ion-exchange process, which acts to increase mechanical strength through the introduction of a surface compressive layer.

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LIQUID CRYSTAL DISPLAY DEVICES –

Part 40-5: Mechanical testing of display cover glass for mobile devices – Strength against dynamic impact by a sharp object with the specimen rigidly supported

1 Scope

This part of IEC 61747 is a mechanical performance testing procedure for cover glass used in electronic displays in mobile devices. This document focuses on the measurement of surface impact energy required to fracture a specimen due to the collision of sharp particles onto the surface of a cover glass. This is achieved by dropping a ball on a sheet of coated abrasives placed on the cover glass, which is rigidly supported. The failure mode is associated with damage introduction via sharp contact. Crack propagation is enhanced by central tension in the case of strengthened glass. This failure mode represents one of several field failure modes observed in mobile devices.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 61649:2008, *Weibull analysis*

IEC 61747-40-1, *Liquid crystal display devices – Part 40-1: Mechanical testing of display cover glass for mobile devices – Guidelines*

ISO 6344-1, *Coated abrasives – Grain size analysis – Part 1: Grain size distribution test*

ISO 8512-2, *Surface plates – Part 2: Granite*

JIS R6111, *Artificial abrasives*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

3.1
specimen
individual piece of glass to be tested for failure

3.2
sample
group of specimens sharing a common pedigree (such as manufacturing process and period of production), for which failure statistics can be generated and reported

3.3
sample size
number of specimens in a sample

3.4
nominal value
value about which a tolerance range is specified

3.5
coated abrasives
abrasive tool including abrasive grain which adheres to a flexible substrate, such as paper or fabric, with a bonding agent

3.6
rigidly supported
specimen-supporting condition in which one of the surfaces is in contact with a flat, minimally-compliant surface without adhesives

4 General

This test simulates the fracture of a cover glass on its surface when rigidly supported. Typically, surface fracture is caused by the dynamic contact with a sharp object, and central tension enhances the crack propagation. In this document, coated abrasives are employed to replicate ordinary ground surface and the impact is introduced by dropping a steel ball.

This test is statistical in nature. A ball is dropped onto each of a number of specimens in a sample. The energy required to break each specimen is recorded. Statistics that might be specified are calculated and reported. The energy required to break a given specimen is determined by starting with a minimum drop height and then increasing the drop height by a fixed increment for drops that do not result in breakage.

The typical energy required to break specimens will depend on the thickness of the specimen and the internal stress distribution. Sample breakage values should only be compared when the thickness of the samples is the same.

The specimens to be tested are typically larger than 40 mm x 40 mm with a thickness ranging from 0,55 mm to 2,0 mm. The combination of ball mass and drop height yields the breakage energy. The apparatus allows for drops of up to 50 cm. A ball mass of 4 g can be adequate for specimens with a thickness ranging from 0,55 mm to 1,0 mm. Thicker or stronger specimens can require a larger ball for a 100 % breakage from a drop height of 50 cm.

Clause 5 describes the apparatus. Clause 6 describes the procedures for both the sample as a whole as well as for an individual specimen. Clause 7 describes the calculations.

It is assumed that all measurements are performed by personnel skilled in the general art of mechanical property measurements. Furthermore, it shall be assured that all equipment is suitably calibrated as is known to skilled personnel and that records of the calibration data and traceability are kept.

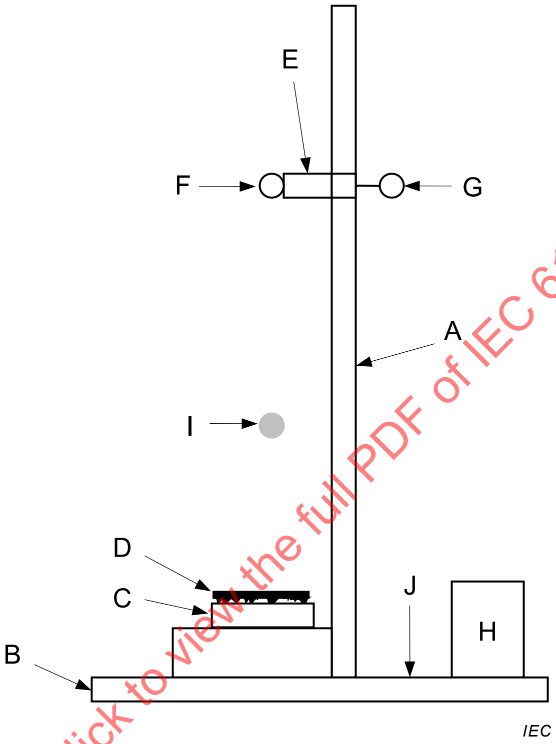
5 Apparatus

5.1 Testing environment and pre-conditioning

The standard testing environment is specified in IEC 61747-40-1. Specimens shall be stored in such an environment for at least 4 h before testing.

5.2 Apparatus overview

Figure 1 shows the overview of the apparatus.



A Height adjustment beam
B Base (granite)
C Specimen
D Coated abrasives
E Armature
F Ball release mechanism
G Height adjustment clamp
H Ball release controller
I Ball (while dropping)
J Base

Figure 1 – Apparatus overview

5.3 Height adjustment beam

This beam shall be long enough to allow drops from a maximum height of at least 50 cm. It is perpendicular to the testing surface. It shall be marked with distances from the test surface in increments of 1 cm. The test surface is the top surface of the coated abrasives when it is set on the specimen. Drop distance is the distance from the test surface to the bottom of the ball when it is attached to the ball release mechanism.

5.4 Base (granite)

This base shall be made of granite, and shall be rigid and fully supported to ensure minimal energy absorption by the structure. Absorption of energy by the base can lead to a variation in the energy applied to the specimen. The dimension of the granite base shall be at least 200 mm (W) x 100 mm (D) x 50 mm (H). Top surface quality shall be grade 0 or 1 as specified in ISO 8512-2.

5.5 Coated abrasives

The abrasive particle of the coated abrasives shall be made of alumina or silicon carbide (SiC) abrasives as specified in JIS R6111 and the particle size shall be P30 as stipulated in ISO 6344-1. Flatness of the coated abrasives should be such that the abrasive grit is in contact with the surface equally over the full length. The dimensions of the sheet of coated abrasives shall be larger than the fluctuation of the contact point. The position of the specimen shall be moved 3 mm from the previous testing point after each drop and replaced with a new sheet after every 10 drops.

5.6 Armature

This connects the ball release mechanism to the height adjustment beam. It shall be perpendicular to the height adjustment beam.

5.7 Ball release mechanism

The ball release stabilization mechanism shall be used. Either electromagnetic, vacuum-assisted or precise ball position stabilization system is recommended. This ensures free gravitational acceleration of the ball upon release.

Tethering or the use of a guide tube are not acceptable means of ball release and/or guidance.

5.8 Height adjustment clamp

This holds the armature at a height that is indicated by the height adjustment beam while a ball is set and dropped from that height. The clamp is released following the ball drop to allow movement to a different height.

5.9 Ball release controller

The controller is an electronic switch with two states:

a) load and hold ball;

b) release ball.

5.10 Ball

The ball used for testing shall be produced from a steel alloy with Rockwell hardness of C60 to C67, and shall possess a reflective surface finish. The diameter tolerance shall be no greater than ±0,05 mm from the nominal value, and the deviation from sphericity shall be no greater than 0,025 mm. Ball mass shall be within ±2,0 % of the specified value, and the actual (measured) mass shall be used for all energy calculations.

5.11 Base

The base used to support the height adjustment beam shall be stable enough so as not to introduce unnecessary movements during testing.

6 Procedure

6.1 Safety

6.1.1 Hazard – Broken glass

Wear safety glasses with side panels at all times. Wear gloves when handling broken glass.

6.1.2 Hazard – Compression due to moving ball

As previously noted, ball drop and rebound energies can be substantial and ball travel can be erratic. Care should be taken to ensure that all operators, assistants and persons in the area are alert and wearing appropriate personal protective equipment.

6.2 Sample

The sample size is 30, excluding any specimens rejected for pre-existing damage. Specimens that fail from their edge, and those that do not fail at the maximum dropping height are also treated as late suspensions (see 7.2). If there are more than 10 suspensions, the testing fails and test conditions such as ball weight should be reviewed. Instead of a 4 g ball, using a ball of 11,6 g (14 mm in diameter) is recommended. If maximum breakage height is less than 5 cm, test conditions should also be reviewed. In such case, a lighter ball should be used. Instead of a 4 g ball, a 2 g ball (8 mm in diameter) is recommended.

Upon receipt of a new sample, the following steps shall be taken:

1) Determine and record the following information:
   – sample identification;
   – sample specimen's nominal dimensions: length, width, thickness;
   – requesting person.
2) Determine whether existing test fixtures are compatible. If not, change them.
3) Record the fixture dimensions or identification number.
4) Determine whether a height adjustment factor is needed. This could be due to testing specimens with a different thickness than the thickness used to design the height adjustment beam or due to a different specimen holder than that used in the design.
5) Thoroughly clean the testing area.

6.3 Individual specimen

Complete the following steps on each specimen of the sample. The working surfaces should be clean and free of anything that can induce damage. Application of the polymeric adhesive tape is intended to preserve the fracture surface and to reduce the scattering of glass fragments upon breakage:

a) Determine and record the specimen identification number.
b) Check the surface of each specimen before the test by visual inspection. If damaged, report this, but do not include in the testing.
c) Cut a section of polymeric adhesive tape that can cover the specimen and place it sticky side up on the working surface. Drawing a grid (typically 3 mm spacing) on the tape surface is useful as a marker of a specimen shift after each dropping.
d) Gently attach one edge of the specimen to one end of the tape.
e) Gently lower the rest of the specimen onto the rest of the tape.
f) Carefully trim the excess tape away from the specimen.
g) Place the specimen onto the base of granite with the polymeric adhesive tape side facing downward. Set the armature for a 1 cm ball drop.

h) Repeat the following for each drop:
   1) load the ball;
   2) drop the ball;
   3) wait 10 s after the drop.

i) Remove the coated abrasives from the specimen and check to see whether there is breakage in the specimen. Check carefully because breakage can be faint in this test.

j) If no breakage, check that the sample remains correctly positioned, replace the coated abrasives on the specimen, move the specimen 3 mm from the previous testing point, move the armature up 1 cm and repeat steps a) to d).

k) At this point, breakage has occurred or the maximum height has been reached without breakage. Record the height and judge whether there is a need to review the test conditions. If the height is too low or the height is at maximum without breakage, review the test conditions. If the maximum breaking height for all the specimens is less than 5 cm or the height is 50 cm without breakage, review the test conditions. In the former case, use of a lighter ball, or in the latter case, use of heavier ball is recommended.

l) Regain possession of the ball and thoroughly clean the area.

6.4 Complete the report

The calculations will normally be done by computer:

– enter the sample identification and dimensions;
– complete the breaking energy calculations of 7.1;
– complete the Weibull analysis of 7.2;
– print the report.

7 Calculations

7.1 Breaking energy

The breaking energy, E, in units of joules, is given as Formula (1).

$$E = \frac{m}{1000} g \frac{(h+c)}{100} \tag{1}$$

where:

m is the ball mass (g)

h is the armature height (cm)

c is a correction factor for specimen nominal thickness variation (cm)

g is the gravitational acceleration factor = 9,81 m/s^2

7.2 Statistical calculations

The Weibull analysis document, IEC 61649, shall be used to calculate the following parameters:

– Weibull scale parameter, η (J)
– Weibull shape parameter, β
– the 10 percentile fracture energy, B_{10} (J)

The maximum likelihood estimate (MLE) method of calculation shall be used for the Weibull parameters. See IEC 61649:2008, 9.6. The following formulae are adapted from Equations (17) and (18) in IEC 61649:2008 in order to accommodate suspensions as variable censoring.

Following the notation of IEC 61649, let t_i represent valid fracture energy values, with i = 1 to r, and let T_j represent the suspended values, with j = 1 to s.

The shape parameter is the value of β that satisfies Formula (2).

$$\frac{\sum_{i=1}^{r} t_i^{\beta} \ln t_i + \sum_{j=1}^{s} T_j^{\beta} \ln T_j}{\sum_{i=1}^{r} t_i^{\beta} + \sum_{j=1}^{s} T_j^{\beta}} - \frac{1}{\beta} - \frac{1}{r} \sum_{i=1}^{r} \ln t_i = 0 \qquad (2)$$

Given this value for the shape parameter, the scale parameter is given as Formula (3).

$$\eta = \left[\frac{1}{r} \left(\sum_{i=1}^{r} t_i^{\beta} + \sum_{j=1}^{s} T_j^{\beta} \right) \right]^{1/\beta} \qquad (3)$$

The point estimate of the 10th percentile, B_{10}, is calculated using IEC 61649:2008, 9.8 and Equation (20), which is repeated here as Formula (4) for convenience.

$$B_{10} = \eta [-\ln(0,9)]^{1/\beta} \qquad (4)$$

In addition to the calculation of statistical parameters, a Weibull plot is required (see 8.2). See IEC 61649:2008, 7.2.3, for instructions on how to produce such a plot. A typical Weibull plot is shown in Figure 2.

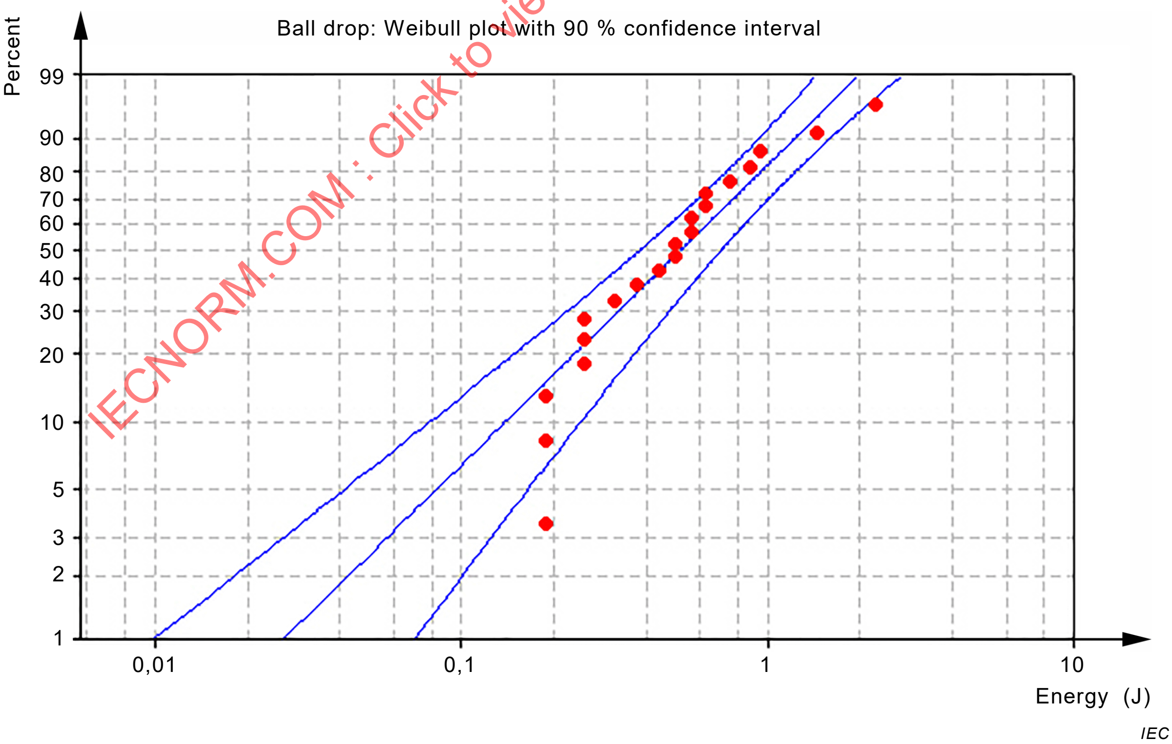


Figure 2 – Typical Weibull plot