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REDLINE VERSION

INTERNATIONAL STANDARD

colour inside

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

IEC 61747-40-1:2019-04 RLV(en)

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

LIQUID CRYSTAL DISPLAY DEVICES –

Part 40-1: Mechanical testing of display cover glass for mobile devices – Guidelines

FOREWORD

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This redline version of the official IEC Standard allows the user to identify the changes made to the previous edition. A vertical bar appears in the margin wherever a change has been made. Additions are in green text, deletions are in strikethrough red text.

International Standard IEC 61747-40-1 has been prepared by IEC technical committee 110: Electronic displays.

This second edition cancels and replaces the first edition published in 2013. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

a) withdrawal of test methods unsuitable for mobile display cover,
b) revision of test methods based on newly developed market relevance,
c) addition of test method for abraded strength,
d) addition of explanations about the relevance between the test methods and the fracture mode, and
e) revision of terms and definitions.

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

CDV	Report on voting
110/1040/CDV	110/1093/RVC

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.

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.

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

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- withdrawn,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.

IMPORTANT – The “colour inside” logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this publication using a colour printer.

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 guidelines for cover glasses ~~utilized~~ used in such applications. Such glasses ~~may or may not~~ can be strengthened or not, for example via an ion-exchange process, which acts to increase mechanical strength through the introduction of a surface compressive layer.

It is assumed that all measurements – described in detail in individual test method standards – are performed by personnel skilled in the general art of mechanical property measurements. Furthermore, it ~~should be assured~~ is recommended that all equipment is suitably calibrated as is known to skilled personnel and that records of the calibration data and traceability are kept.

LIQUID CRYSTAL DISPLAY DEVICES –

Part 40-1: Mechanical testing of display cover glass for mobile devices – Guidelines

1 Scope

This part of IEC 61747 ~~is a~~ provides mechanical performance testing guidelines for cover glass used in electronic flat panel displays in mobile devices. This document focuses on key mechanical testing performance parameters and covers mainly strength and damage resistance attributes. The test methods ~~will~~ focus on the cover glass level testing only.

NOTE The glass used for cover glasses for electronic mobile devices can be chemically strengthened by an ion-exchange process. This ion exchange process increases the mechanical strength of the glass.

2 Normative references

There are no normative references in this document.

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
abraded
subjected to a defined process which introduces mechanical abrasive damage to a portion of the specimen to be placed under tension during subsequent flexural strength testing

EXAMPLE Biaxial flexure via ring-on-ring.

3.2
as-received
representative of standard sample preparation and handling practices, and therefore free of intentional mechanical damage such as abrasion, scratching, or indentation

Note 1 to entry: The strength of glass is not an intrinsic material property, and like other brittle elastic materials, is highly dependent upon the surface flaw population. The term "as-received" is meant to represent the surface condition upon specimen receipt and ~~should be~~ is distinguished from a condition where damage has been intentionally introduced prior to testing.

3.3
central tension
CT
tensile stress generated within the interior of a glass article which serves to counteract (i.e., force balance) compressive stress acting at or near the article surface

~~Note 1 to entry: This note applies to the French language only.~~

3.4
chemically strengthened
subjected to a molten salt bath containing alkali ions typically larger than those residing in the glass, resulting in the generation of residual compressive stress (3.5) and central tension (3.3)

3.5
compressive stress
CS
maximum residual stress in compression measured near the glass surface

~~Note 1 to entry: This note applies to the French language only.~~

3.6
cover glass
~~cover lens~~
glass that typically protects an optical component such as a display from damage

3.7
damage resistance
ability to resist certain potential damage-inducing events such as abrasion~~, indentation or scratching~~

~~**2.8**~~
~~**depth of layer**~~
~~**DOL**~~
~~distance from the surface of a strengthened glass to the depth of zero stress or the depth of transition from compressive to tensile stress~~

~~Note 1 to entry: The ability to approximate this depth is dependent upon the measurement methodology chosen.~~

~~Note 2 to entry: This note applies to the French language only.~~

3.8
edge strength
measured stress at failure in the case where failure is known to have originated from a specimen edge

3.9
mobile device
electronic device that includes a battery and is designed to be carried about by consumers

3.10
retained surface strength
~~**abraded surface strength**~~
measured stress (or measured load or impact energy when stress cannot be measured) at failure in the case where failure is known to have originated from a specimen surface which has experienced a ~~prescribed~~ specified abrasion or mechanical damage event

3.11
strength
stress, load, or impact energy at which a specimen fails for a given loading condition

3.12
thermally strengthened
subjected to fast cooling of the glass exterior relative to the glass interior, resulting in the generation of residual compressive stress (3.5) and central tension (3.3)

4 Mechanical performance testing guidelines

4.1 General

The appropriate attribute(s) and test method(s) shall be selected based on the detail specification or depending on the purpose of the evaluation.

The standard environment for testing shall be as follows:

– temperature: 23 °C ± 3 °C
– relative humidity: 50 % ± 5 %

unless otherwise specified in the detail specification. These standard requirements are established to control fatigue effects when performing mechanical testing on glass. If environmental conditions differ from the standard environment, the conditions shall be reported with the test data.

4.2 Mechanical testing guidelines for display cover glass for mobile devices

~~The mechanical attributes and measurement methods are given in Table 1.~~

~~Table 1 – Mechanical attributes and measurement methods~~

~~Category~~	~~Attributes~~	~~Unit~~	~~Test method~~
~~Strength (as-received)~~	~~Edge strength~~	~~MPa~~	~~Uniaxial flexural strength (4-point bend)~~
~~Strength (as-received)~~	~~Surface strength~~	~~N~~	~~Biaxial flexural strength (ring-on-ring)~~
~~Impact resistance~~	~~Surface energy-to-failure~~	~~Joules~~	~~Biaxial flexural energy-to-failure (ball drop)~~
~~Surface damage resistance~~	~~Scratch performance~~	~~gF~~ ~~N~~	~~Scratch lateral crack visibility/retained strength~~
~~Surface damage resistance~~	~~Retained surface strength~~	~~N~~	~~Abraded biaxial flexural strength (ring-on-ring)~~
~~Surface damage resistance~~	~~Resistance to indentation cracking~~	~~gF~~ ~~N~~	~~Visual median radial crack resistance/retained strength~~

A comprehensive list of all cover glass test methods and failure mechanisms is given in Table 1.

Table 1 – Comprehensive list of cover glass testing methods

Failure location	Failure mechanism	Subject (typical)	Attribute	Test methods	Units	Corresponding document
Edge	Overstress of edge flaws	As-received glass	Edge strength	Uniaxial flexure strength (four-point bend)	MPa	IEC 61747-40-2
Surface	Overstress from blunt impact	As-received glass	Surface impact resistance	Biaxial flexure energy-to-failure (ball drop)	J	IEC 61747-40-3
Surface	Overstress of surface flaws	As-received glass	Surface strength	Biaxial flexure stress (ring-on-ring)	N	IEC 61747-40-4
Surface	Sharp contact damage introduction propagated by central tension under rigid support condition	As-received glass	Resistance against surface sharp contact damage and propagation under rigid support condition	Sharp contact impact under rigid support condition (ball drop on coated abrasives)	J	IEC 61747-40-5
Surface	Sharp contact damage in combination with or followed immediately by flexural stress	Abraded glass	Retained strength	Abraded biaxial flexural strength (abraded ring-on-ring)	N	IEC 61747-40-6

In case the samples to be tested are that of strengthened glass – for example, via chemical or thermal means – the results of mechanical testing will depend on the degree of strengthening. This degree of strengthening may be characterized by attributes such as compressive stress, depth of layer, or other attributes. While these are to be stated ~~with any~~ in the test reports, the measurement methods for these parameters are outside the scope of this ~~guideline~~ document.

Strengthened glass~~es~~ may result in non-linearities (such as in load to stress conversion) due to high deformations and the formation of membrane stresses, which shall be taken into consideration during data analysis and reporting.

Table 2 summarizes the comprehensive list of test methods for cover glasses described in Table 1. Test methods described in IEC 61747-40 (all parts) can be classified according to the types of external load applied and pre-conditioning. In Table 2, “n/a” means that a test method does not exist for the condition because the failure mechanism is not well understood, the failure mechanism is not common, the failure mechanism has not been observed for cover glasses, or the pre-condition is not relevant to the failure mechanism being tested.

Table 2 – Matrix of cover glass test methods and glass condition

Strength evaluation / Pre-conditioning	(Quasi) Static		Dynamic	
	Uniaxial bend	Biaxial bend	Biaxial bend	Concentrated load
	Four-point bend	Ring-on-ring	Ball drop	Contact with coated abrasives
None (pristine or as-received)	IEC 61747-40-2	IEC 61747-40-4	IEC 61747-40-3	IEC 61747-40-5
Grit particle abrasion	n/a	IEC 61747-40-6	n/a	n/a

5 Brief overview of mechanical test methods

5.1 Edge strength

Uniaxial flexural strength (four-point bend):

A uniaxial flexural test via a four-point bend methodology has been selected as the best representative test for edge strength. This is related to the observations of failures occurring from edge flaws rather than surface flaws in the specimen.

The test method can be used to evaluate cover glass edge failures caused by uniaxial stress to edge flaws, for example.

5.2 Surface impact resistance (energy-to-failure)

Biaxial flexural energy-to-failure (ball drop):

A biaxial flexural test via a ball drop provides an indirect measurement of surface strength by applying a biaxial stress to the glass surface upon ball impact. Measurement of the impact energy is used to approximate equivalent performances for different ball sizes, weights and drop heights.

The test method can be used to assess cover glass surface failures caused by biaxial stress to pre-existing surface damage (e.g. damage caused to the surface during the fabrication process), for example.

5.3 Surface strength

Biaxial flexural strength (ring-on-ring):

A biaxial flexural test via a ring-on-ring methodology is designed to test surface strength. ~~A note of caution:~~ It is important to be aware that when the specimen deflects more than 1/2 of its thickness, the load-to-stress relationship is no longer linear, and non-linear effects shall be taken into account to properly convert load to stress.

The test method can be used to assess cover glass surface failures caused by biaxial stress to pre-existing surface damage, for example.

~~Scratch performance~~

~~Scratch lateral crack visibility/retained strength~~

~~Lateral cracks are cracks originating from the sub-surface of the glass (not from the surface) which initially extend nearly parallel to the surface. These cracks may ultimately propagate to intersect the surface of the glass resulting in visible chipping. The test is performed in a step-~~

~~load manner utilizing sliding indentation with, for example, a Knoop or Vickers diamond tip. Retained strength after sliding indentation may be measured via biaxial flexure (ring-on-ring) with the indentation site oriented in tension.~~

5.4 Resistance against sharp contact surface damage and propagation under rigid support (energy-to-failure)

Sharp contact impact resistance under rigid support condition (ball crop on coated abrasives):

Ball drop methodology with rigid support is employed to indirectly measure surface strength during sharp particle impact. This is achieved by dropping a ball onto a glass specimen with a sheet of coated abrasives placed on top of the glass. The test is focused on glass surface flaw generation and propagation by central tension when the glass is rigidly supported.

The test method can be used to assess cover glass surface failures caused by sharp contact damage penetration into the central tension region.

5.5 Retained surface strength

Abraded biaxial flexural strength (ring-on-ring):

An abraded biaxial flexural test (via ring-on-ring) can be an effective measure of the retained surface strength of a test specimen. ~~Development of an abrasion method for standardization is currently under evaluation.~~ The surface of the specimen is abraded by grit particle abrasion using a pre-determined apparatus and abrasives.

Grit particle abrasion is employed as the method to introduce damage to the glass surface. As mentioned in 5.3, deflections during loading of more than 1/2 of the glass thickness can lead to non-linearity of the load-to-stress relationship.

The test method can be used to assess cover glass surface failures caused by sharp contact damage accompanied by, or simultaneous with, bending.

~~Resistance to indentation cracking~~

~~Visual median/radial crack resistance/retained strength~~

~~Median/radial cracks extend from the corners of the indent impression and are oriented perpendicular to the surface so that they have the greatest strength-limiting effect in bending. The test is performed in a step-load manner with, for example, a Vickers diamond tip until the cracks form. Retained strength after indentation may be measured via biaxial flexure (ring-on-ring) with the indentation site oriented in tension.~~

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~~IEC 61747-5:1998, *Liquid crystal and solid-state display devices – Part 5: Environmental, endurance and mechanical test methods*~~

IEC 61747-5-3~~:2009~~, *Liquid crystal display devices – Part 5-3: Environmental, endurance and mechanical test methods – Glass strength and reliability*

IEC 61747-40 (all parts), *Liquid crystal display devices*

IEC 61747-40-2, *Liquid crystal display devices – Part 40-2: Mechanical testing of display cover glass for mobile devices – Uni-axial flexural strength (4-point bend)*

IEC 61747-40-3, *Liquid crystal display devices – Part 40-3: Mechanical testing of display cover glass for mobile devices – Biaxial flexural energy to failure (ball drop)*

IEC 61747-40-4, *Liquid crystal display devices – Part 40-4: Mechanical testing of display cover glass for mobile devices – Biaxial flexural strength (ring-on-ring)*

IEC 61747-40-5, *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*

IEC 61747-40-6, *Liquid crystal display devices – Part 40-6: Mechanical testing of display cover glass for mobile devices –Retained biaxial flexural strength (abraded ring-on-ring)"*

~~ASTM C 158 – 02, *"Standard Test Methods for Strength of Glass by Flexure (Determination of Modulus of Rupture)"*~~

~~ASTM C 1499 – 05, *"Standard Test Method for Monotonic Equibiaxial Flexural Strength of Advanced Ceramics at Ambient Temperature"*~~

~~Morris, D.J., Myers, S.B., Cook, R.F., *"Indentation crack initiation in ion-exchanged aluminosilicate glass"*, Journal of Materials Science 39 (2004), pp. 2399-2410~~

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A bilingual version of this publication may be issued at a later date.

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LIQUID CRYSTAL DISPLAY DEVICES –

Part 40-1: Mechanical testing of display cover glass for mobile devices – Guidelines

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3.1
abraded
subjected to a defined process which introduces mechanical abrasive damage to a portion of the specimen to be placed under tension during subsequent flexural strength testing

EXAMPLE Biaxial flexure via ring-on-ring.

3.2
as-received
representative of standard sample preparation and handling practices, and therefore free of intentional mechanical damage such as abrasion, scratching, or indentation

Note 1 to entry: The strength of glass is not an intrinsic material property, and like other brittle elastic materials, is highly dependent upon the surface flaw population. The term “as-received” is meant to represent the surface condition upon specimen receipt and is distinguished from a condition where damage has been intentionally introduced prior to testing.

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central tension
CT
tensile stress generated within the interior of a glass article which serves to counteract (i.e., force balance) compressive stress acting at or near the article surface

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chemically strengthened
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compressive stress
CS
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edge strength
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mobile device
electronic device that includes a battery and is designed to be carried about by consumers

3.10
retained surface strength
measured stress (or measured load or impact energy when stress cannot be measured) at failure in the case where failure is known to have originated from a specimen surface which has experienced a specified abrasion or mechanical damage event

3.11
strength
stress, load, or impact energy at which a specimen fails for a given loading condition

3.12
thermally strengthened
subjected to fast cooling of the glass exterior relative to the glass interior, resulting in the generation of residual compressive stress (3.5) and central tension (3.3)

4 Mechanical performance testing guidelines

4.1 General

The appropriate attribute(s) and test method(s) shall be selected based on the detail specification or depending on the purpose of the evaluation.

The standard environment for testing shall be as follows:

– temperature: 23 °C ± 3 °C
– relative humidity: 50 % ± 5 %

unless otherwise specified in the detail specification. These standard requirements are established to control fatigue effects when performing mechanical testing on glass. If environmental conditions differ from the standard environment, the conditions shall be reported with the test data.

4.2 Mechanical testing guidelines for display cover glass for mobile devices

A comprehensive list of all cover glass test methods and failure mechanisms is given in Table 1.

Table 1 – Comprehensive list of cover glass testing methods

Failure location	Failure mechanism	Subject (typical)	Attribute	Test methods	Units	Corresponding document
Edge	Overstress of edge flaws	As-received glass	Edge strength	Uniaxial flexure strength (four-point bend)	MPa	IEC 61747-40-2
Surface	Overstress from blunt impact	As-received glass	Surface impact resistance	Biaxial flexure energy-to-failure (ball drop)	J	IEC 61747-40-3
Surface	Overstress of surface flaws	As-received glass	Surface strength	Biaxial flexure stress (ring-on-ring)	N	IEC 61747-40-4
Surface	Sharp contact damage introduction propagated by central tension under rigid support condition	As-received glass	Resistance against surface sharp contact damage and propagation under rigid support condition	Sharp contact impact under rigid support condition (ball drop on coated abrasives)	J	IEC 61747-40-5
Surface	Sharp contact damage in combination with or followed immediately by flexural stress	Abraded glass	Retained strength	Abraded biaxial flexural strength (abraded ring-on-ring)	N	IEC 61747-40-6

In case the samples to be tested are that of strengthened glass – for example, via chemical or thermal means – the results of mechanical testing will depend on the degree of strengthening. This degree of strengthening may be characterized by attributes such as compressive stress, depth of layer, or other attributes. While these are to be stated in the test reports, the measurement methods for these parameters are outside the scope of this document.

Strengthened glass may result in non-linearities (such as in load to stress conversion) due to high deformations and the formation of membrane stresses, which shall be taken into consideration during data analysis and reporting.

Table 2 summarizes the comprehensive list of test methods for cover glasses described in Table 1. Test methods described in IEC 61747-40 (all parts) can be classified according to the types of external load applied and pre-conditioning. In Table 2, “n/a” means that a test method does not exist for the condition because the failure mechanism is not well understood, the failure mechanism is not common, the failure mechanism has not been observed for cover glasses, or the pre-condition is not relevant to the failure mechanism being tested.

Table 2 – Matrix of cover glass test methods and glass condition

Strength evaluation / Pre-conditioning	(Quasi) Static		Dynamic	
	Uniaxial bend	Biaxial bend	Biaxial bend	Concentrated load
	Four-point bend	Ring-on-ring	Ball drop	Contact with coated abrasives
None (pristine or as-received)	IEC 61747-40-2	IEC 61747-40-4	IEC 61747-40-3	IEC 61747-40-5
Grit particle abrasion	n/a	IEC 61747-40-6	n/a	n/a

5 Brief overview of mechanical test methods

5.1 Edge strength

Uniaxial flexural strength (four-point bend):

A uniaxial flexural test via a four-point bend methodology has been selected as the best representative test for edge strength. This is related to the observations of failures occurring from edge flaws rather than surface flaws in the specimen.

The test method can be used to evaluate cover glass edge failures caused by uniaxial stress to edge flaws, for example.

5.2 Surface impact resistance (energy-to-failure)

Biaxial flexural energy-to-failure (ball drop):

A biaxial flexural test via a ball drop provides an indirect measurement of surface strength by applying a biaxial stress to the glass surface upon ball impact. Measurement of the impact energy is used to approximate equivalent performances for different ball sizes, weights and drop heights.

The test method can be used to assess cover glass surface failures caused by biaxial stress to pre-existing surface damage (e.g. damage caused to the surface during the fabrication process), for example.

5.3 Surface strength

Biaxial flexural strength (ring-on-ring):

A biaxial flexural test via a ring-on-ring methodology is designed to test surface strength. It is important to be aware that when the specimen deflects more than 1/2 of its thickness, the load-to-stress relationship is no longer linear, and non-linear effects shall be taken into account to properly convert load to stress.

The test method can be used to assess cover glass surface failures caused by biaxial stress to pre-existing surface damage, for example.

5.4 Resistance against sharp contact surface damage and propagation under rigid support (energy-to-failure)

Sharp contact impact resistance under rigid support condition (ball crop on coated abrasives):

Ball drop methodology with rigid support is employed to indirectly measure surface strength during sharp particle impact. This is achieved by dropping a ball onto a glass specimen with a sheet of coated abrasives placed on top of the glass. The test is focused on glass surface flaw generation and propagation by central tension when the glass is rigidly supported.

The test method can be used to assess cover glass surface failures caused by sharp contact damage penetration into the central tension region.

5.5 Retained surface strength

Abraded biaxial flexural strength (ring-on-ring):

An abraded biaxial flexural test (via ring-on-ring) can be an effective measure of the retained surface strength of a test specimen. The surface of the specimen is abraded by grit particle abrasion using a pre-determined apparatus and abrasives.

Grit particle abrasion is employed as the method to introduce damage to the glass surface. As mentioned in 5.3, deflections during loading of more than 1/2 of the glass thickness can lead to non-linearity of the load-to-stress relationship.

The test method can be used to assess cover glass surface failures caused by sharp contact damage accompanied by, or simultaneous with, bending.

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