PUBLICLY AVAILABLE SPECIFICATION

# IEC PAS 61747-5-3

Pre-Standard

First edition
2007-05

**Liquid crystal display devices –**

**Part 5-3:**
**Liquid crystal display devices –**
**Glass strength and reliability measurement method**



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# LIQUID CRYSTAL DISPLAY DEVICES –

## Part 5-3: Liquid crystal display devices – Glass strength and reliability measurement method

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IEC-PAS 61747-5-3 has been processed by IEC technical committee 110: Flat panel display devices.

The text of this PAS is based on the following document: This PAS was approved for publication by the P-members of the committee concerned as indicated in the following document:

| Draft PAS | Report on voting |
|---|---|
| 110/85/NP | 110/103/RVN |

Following publication of this PAS, which is a pre-standard publication, the technical committee or subcommittee concerned will transform it into an International Standard.

This PAS shall remain valid for an initial maximum period of three years starting from 2007-05. The validity may be extended for a single three-year period, following which it shall be revised to become another type of normative document or shall be withdrawn.

# INTRODUCTION

This PAS is devoted to the mechanical reliability of liquid crystal display (LCD) devices. This PAS is restricted to transmissive or reflective LCD modules using either segment, passive or active matrix and achromatic or colour-type LCDs that are equipped with their own integrated source of illumination or without their own source of illumination. Analysis and testing are performed on LCD module component glass as well as finished on LCD modules. Statistics of the mechanical strength of the modules are determined, allowing a prediction of module failure probability at a given stress level, or, for a given probability of failure, the maximum recommended safe loading stress for the module.

# LIQUID CRYSTAL DISPLAY DEVICES –

## Part 5-3: Liquid crystal display devices – Glass strength and reliability measurement method

## 1 Scope and object

This PAS applies to commercially available liquid crystal displays (LCDs). This PAS applies to all LCD types, including transmissive, reflective or transflective LCD modules using either segment, passive or active matrix and achromatic or colour-type LCDs that are equipped with their own integrated source of illumination or without their own source of illumination.

The object of this PAS is to establish uniform requirements for accurate and reliable measurements of the following LCD parameters, as defined herein:

a) quasistatic strength;

b) quasistatic fatigue.

The methods described in this PAS apply to all sizes, small and large, of LCDs.

Methods for measuring the fatigue constant are described in this PAS and are taken from the referenced literature [13-20]. The primary results are formulae for estimated allowable stress for the specified lifetime or estimated failure rate for the specified stress level. By way of an example, limited data for strength and fatigue behaviour of LCD glass are included in an informative annex to this PAS. Similarly, limited data for the static strength of LCD modules is also included and compared with that of parent glass.

## 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 61747-5, *Liquid crystal display devices – Part 5: Environmental, endurance and mechanical test methods*

## 3 Terms and definitions

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

**3.1**
**strength**
stress at which a sample fails for a given loading condition

**3.2**
**LCD surface strength**
biaxial strength wherein surface flaws with different orientations are subjected to uniform tension during measurement [1-4]

**3.3**
**LCD edge strength**
uniaxial strength wherein edge flaws are subjected to tension during measurement [5-8]

**3.4**
**LCD (mechanical) reliability**
Reliability expressed as either an estimated allowable stress which the LCDs can sustain for a specified period of time or as an estimated failure rate at a specified stress level. For quantifying the reliability of LCDs, both approaches use the power law for slow crack growth and require the knowledge of the fatigue constant for the parent glass employed in the LCD displays [9-12]

**3.5**
**parent glass**
sheet glass used as raw material for manufacturing of LCD panels and modules

## 4 Abbreviated terms

For the purposes of this document, the following abbreviations apply.

| | |
|---|---|
| FC | filled cell |
| FEA | finite element analysis |
| FPD | flat panel display |
| LCD | liquid crystal display |
| MC | mirror constant |
| MR | mirror radius |
| ROR | ring on ring |
| SCSC | stress corrosion susceptibility constant |
| VBT | vertical bend test |

## 5 Apparatus

The parameters in the following figures are used in the stress formulae of Clause 8. The dimensions are:

a) load (force): Newtons (N);
b) dimensions: millimeters (mm);
c) stress: MegaPascals (MPa).

The standard atmospheric conditions given in IEC 61747-5, 1.4.3, shall apply, except that the relative humidity shall be in excess of 95 % (vapour) unless otherwise specifically agreed between the customer and the supplier.

### 5.1 Method A: Quasistatic biaxial strength

The quasistatic biaxial strength of parent glass is measured in the ring-on-ring (ROR) fixture shown in Figure 1. The dimensions of load and support rings are selected so as to minimize large deflection and the associated membrane stress, especially for ultra-thin glass, although the effect of such non-linearities on strength can be quantified using finite element analysis (FEA) [21-24]. All ring surfaces in contact with the test specimens should be rounded off, with radii of 2× to 3× the thickness of the glass specimen. In general, certain trade-offs are necessary in designing the test specimen and the ROR fixture because the key object is to measure the quasistatic strength of as large a test area as possible without introducing large non-linearities. Alternatively, a large sample quantity is required to obtain the strength distribution representative of full-size module. Since the strength of glass surface is primarily dictated by the quality of that surface, i.e., surface defects, it is imperative to measure the biaxial strength of those surfaces that have been exposed to handling and processing damage during the fabrication of LCD devices. Such data are then a good representation of LCD module strength.

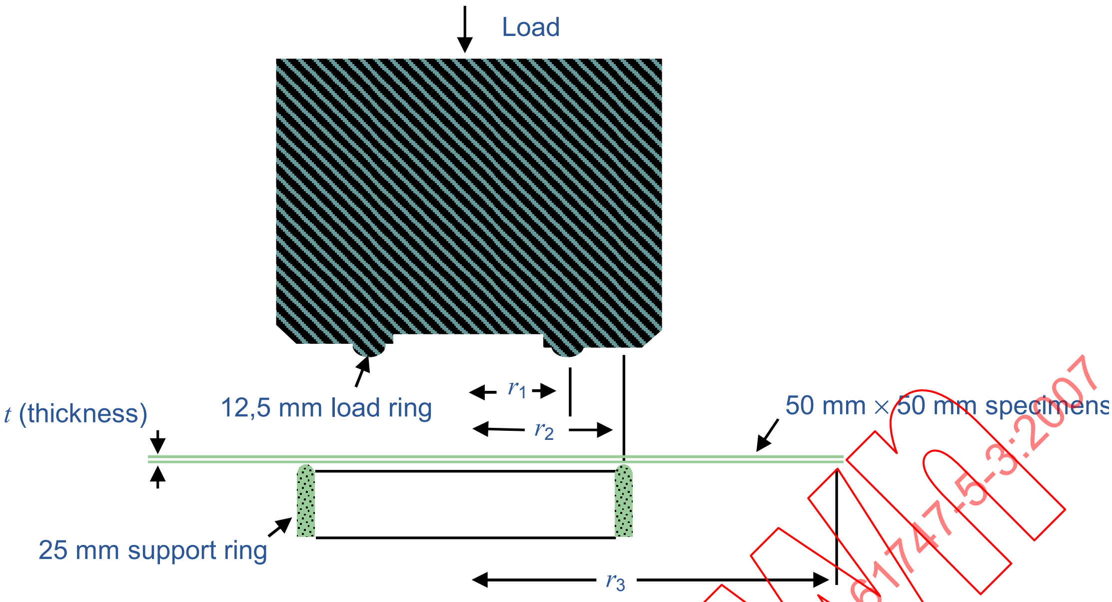


**Figure 1 – Schematic of ROR test fixture for measuring biaxial strength of parent glass**

For square specimens, the specimen radius, $r_3$, is the average of the inscribed and circumscribed circles.

### 5.2 Method B: Quasistatic edge strength (parent glass)

The quasistatic strength of the edges of parent glass is measured in the VBT fixture shown in Figure 2. The dimensions of the glass specimen and the test fixture are so chosen as to minimize buckling of the top edge which is in compression during the test because the load is applied from the top. As in the case of surface strength, it is equally imperative that the edges of glass specimens should have been exposed to handling and processing damage during the fabrication of LCD devices. In addition, the glass specimen should be large enough to represent the full-size module.

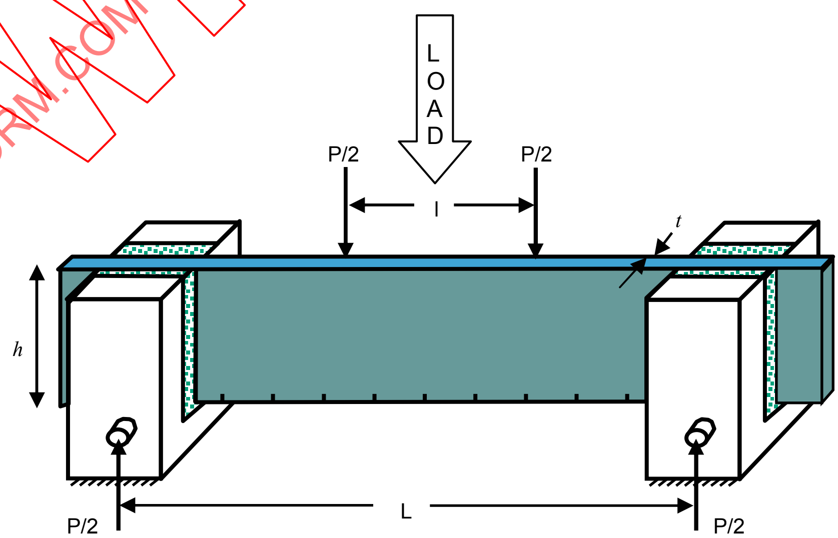


**Figure 2 – Vertical bend test fixture for measuring the edge strength of parent glass**

## 5.3 Method C: Quasistatic strength (module)

The quasistatic strength of the full-size module is measured by supporting it on the mounting points and loading it at the centre, as shown in Figure 3. The loading point of the test fixture is rounded and may be padded to avoid inducing additional flaws on the glass surface. Several modules are tested in this manner to obtain a statistically significant strength distribution representative of surface damage induced by the handling, processing and fabrication of the LCD module. These data are also useful for estimating the module strength at orders of magnitude of lower failure probabilities. The same apparatus may also be used for loading the LCD module off centre and obtaining its strength at different locations.

Figure 3a

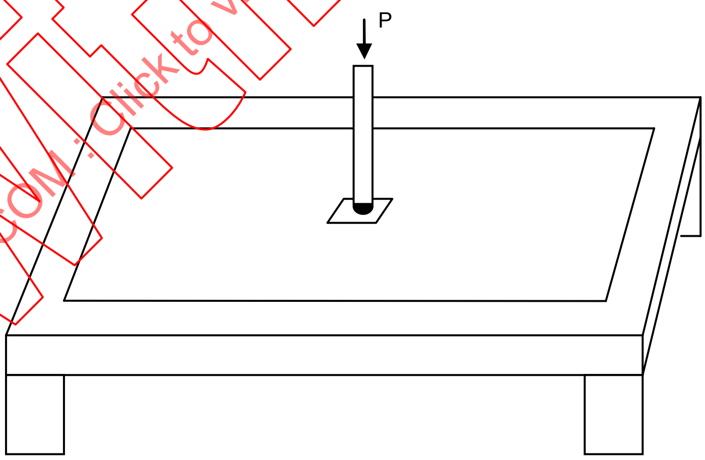


Figure 3b

**Figure 3 – Schematic of strength measurement for full-size LCD module**



## 5.4 Method D: Fatigue constant

The fatigue constant of parent glass is obtained by measuring its biaxial strength at four, or more, different stress rates, each successive rate being one order of magnitude lower, using the ROR fixture shown in Figure 1. A sample quantity of at least 25 specimens shall be used at each of the stress rates to obtain a reliable value of fatigue constant. The specimens used for this measurement should also have been exposed to handling and processing damage representative of the manufacturing of FC and LCD modules.

## 6 Test sample

Samples shall be representative of normal processes. The sample sizes indicated below are minimal. Larger sample sizes will yield more accurate lifetime estimates.

### 6.1 Parent glass

A sample size of at least 50 specimens, each 50 mm × 50 mm, shall be used for measuring quasistatic biaxial strength (see 5.1) of parent glass. A similar sample size shall be used for characterizing abraded glass which simulates handling and processing damage.

The fatigue measurements are also carried out on 50 mm × 50 mm specimens prepared from abraded glass. A sample size of at least 25 specimens shall be used at each of the stress rates to obtain a fatigue constant value from regression analysis of strength versus stress rate data.

### 6.2 Full-size module

Full-size modules and filled cells can range from small to very large diagonal dimensions. In all cases, a minimum sample quantity of at least 25 filled cells or modules shall be used for measuring biaxial strength under static loading (see 5.3). Such data then help determine module strength at orders of magnitude of lower failure probabilities.

Similarly, a sample quantity of at least 25 filled cells shall be used for measuring the edge strength via the apparatus shown in Clause 5.

## 7 Procedure: Quasistatic loading

The loading rate or crosshead speed for measuring the strength of either parent glass, filled cell or full-size module is so chosen as to complete the measurement in 30 s to 45 s. The loading rate or crosshead speed shall be kept constant during this measurement.

## 8 Stress calculations

Stress calculations are used to normalize the load at failure to common stress units. This normalization takes into account differences in glass material, dimensions, and some design characteristics. For specimens of a common design and dimension, the failure load and pressure rate can be substituted for the failure stress and stress rate formulae of Clause 9. Poisson's ratio, $\nu$, is a material property that is normally available from the material supplier, but may be verified with material tests.

### 8.1 Quasistatic biaxial strength (parent glass)

The strength of 50 mm × 50 mm specimens of parent glass tested in the ROR fixture is calculated from equation (1) where $\sigma_{max}$ is the stress at failure, $P$ is the failure load, $t$ is the glass thickness, $\nu$ is the Poisson's ratio, $r_2$ is the radius of support ring, $r_1$ is the radius of the load ring and $r_3$ is the radius of the specimen.

$$\sigma_{max} = [3P/4\pi t^2]\bullet[2(1+\nu)\ln(r_2/r_1) + (1-\nu)(r_2/r_3)^2(1-r_1^2/r_2^2)] \qquad (1)$$

### 8.2 Quasistatic edge strength (parent glass)

The edge strength of parent glass specimens with height $h$, thickness $t$, load span $l$ and support span $L$ is calculated from failure load $P$ and equation (2).

$$\sigma_e = 3P(L\text{-}l)/(2th^2) \tag{2}$$

### 8.3 Quasistatic failure load (LCD module)

For this test, the failure load and the load rate are reported. While there are means to calculate the failure stress, this calculation is very complex and involves design characteristics. The failure-load values from this test may be substituted into the failure stress in the equations of Clause 9. Because failure-load values are not normalized to stress, the results are valid only for the size and design of the module tested.

## 9 Fatigue and reliability calculations

The strength distribution resulting from tests is made at rates considerably higher than those that are relevant to normal use. In addition, normal use will often reflect static load conditions in which the probability of failure at a given time is desired. To link the test loading conditions to the use conditions, the power-law theory of fatigue is used. For tests at rates cited in this PAS, the power-law fatigue relationship for a single flaw is:

$$\int_0^{t_F} \sigma^n(x)\,dx \approx BS^{n-2} \tag{4}$$

where

$\sigma(x)$ is the applied stress over time;

$t_F$ is the time of failure;

$S$ is the initial strength;

$n$ is the fatigue parameter;

$B$ is the strength preservation parameter.

The probability part of the relationship is based on the assumption that the initial strength values follow a Weibull distribution that is given by

$$1 - F = \exp\left[-\left(\frac{S}{S_0}\right)^{m}\right] \tag{5}$$

where

$F$ is the failure probability;

$S_0$ is the scaling parameter;

$m$ is the shape parameter.

NOTE Load and load rate are un-normalized stress values and may be substituted for stress values when the specimen materials, dimensions, and design are common.

### 9.1 Fatigue constant calculation

The fatigue constant results from testing multiple samples to failure at multiple loading rates. Let $c_j$ represent the median failure stress of the $j$th rate and let $\dot{c}_j$ represent the $j$th stress rate. When the log of these values is plotted, a line is seen. The slope of the line is $1/(n + 1)$. That is, fit the following linear regression for the parameters, $a$ and $b$,

$$\text{then} \quad n = 1/b - 1 \tag{6}$$

NOTE Alternative calculation methodologies can be found in ASTM C1368. However, in all cases, care should be exercised in the interpretation of bimodal distributions.

### 9.2 Weibull parameter calculation from dynamic failure stress data

The data for this calculation is usually obtained from an experiment at a single stress rate and uses the fatigue constant value derived from a different multiple stress rate experiment. The $N$ failure stress data values are sorted from minimum to maximum and indexed with $k$ (from 1 to $N$). For each, the effective strength, $Seff_k$ is calculated as:

$$\ln\left(Seff\right)_k = -\frac{1}{n-2}\ln\left[\dot{\sigma}(n+1)\right] + \frac{n+1}{n-2}\ln\left[\sigma_k\right] \tag{7}$$

The Weibull parameters are found by fitting the following linear regression:

$$\ln\left(-\ln\left(1-\frac{k-0{,}3}{N+0{,}4}\right)\right) = m\ln\left(Seff_k\right) - m\ln\left(Seff_0\right) \tag{8}$$

The slope of the regression yields $m$ and the intercept of the regression yields the composite parameter on the right.

### 9.3 Static fatigue failure probability calculation

This calculation uses the parameters already determined from 9.1 and 9.2. There are usually three ways to ask reliability questions:

a) At a given probability of failure and static load what is the time to failure?

b) At a given static load and time to failure, what is the probability of failure?

c) At a given probability of failure and lifetime, what could the applied load be?

All these questions are evaluated using a different formulation for effective strength:

$$\ln\left(Seff\right) = \frac{1}{n-2}\ln\left(\dot{\sigma}_a\right) + \frac{1}{n-2}\ln\left(t_F\right) \tag{9}$$

where

$\sigma_a$ is the applied load;

$t_F$ is the time to failure.

Any of the reliability equations can be evaluated rearranging the elements of the following equation.

$$\ln\left(-\ln\left(1-F\right)\right) + m\ln\left(Seff_0\right) = \frac{mn}{n-2}\ln\left(\dot{\sigma}_a\right) + \frac{m}{n-2}\ln\left(t_F\right) \tag{10}$$

## 10 Reporting requirements

The following parameters shall be reported with the test results.

a) Type of specimens.

b) Sample quantity.

c) Sample size.

d) Testing rates.

e) Testing conditions including relative humidity of samples.

# Annex A
(informative)

## Worked test example

Figure A.1 shows the Weibull distribution [29] of the biaxial strength of the parent glass with abraded surface representing handling and processing damage. Both 0,7 mm and 1,1 mm thick glasses show nearly identical strength distribution, i.e. the strength of the glass is dictated by surface flaws and not by its thickness. The strength data before and after abrasion are summarized in Table 1. Indeed, handling and processing damage can decrease the mean strength of the parent glass by 40 % to 50 %.

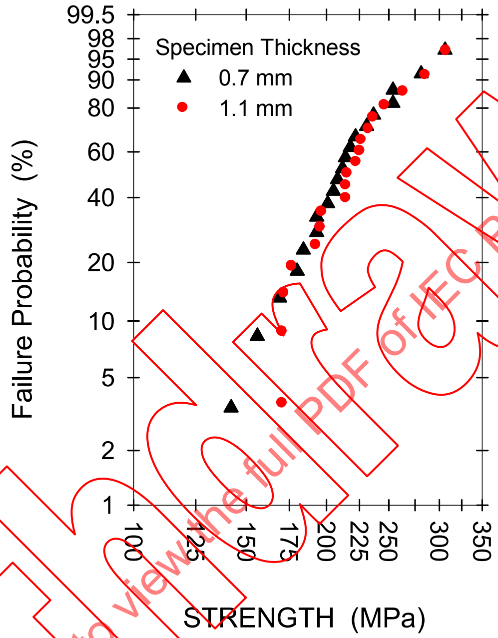


**Figure A.1 – Weibull plot of biaxial strength of abraded glass with different thicknesses**

**Table A.1 – Strength data before and after abrasion**

| **Thickness** mm | $N$ | $\sigma_{mean}$ MPa | $m$ | $S_0$ MPa |
|---|---|---|---|---|
| "As-received" | | | | |
| 0,7 | 30 | 367 | 3,9 | 404 |
| 1,1 | 50 | 417 | 3,7 | 460 |
| "Abraded" | | | | |
| 0,7 | 20 | 213 | 6,4 | 228 |
| 1,1 | 19 | 220 | 7,3 | 233 |

The strength value can also be estimated by measuring the mirror radius, $R_m$, of the specimen's fracture surface, as shown in Figures A.1 and A.2, and using equation (A.1).

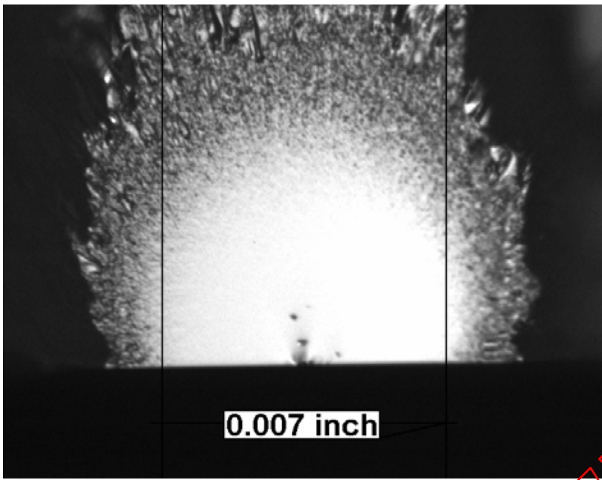


**Figure A.2 – Fracture surface of parent glass with 0,089 mm mirror radius**

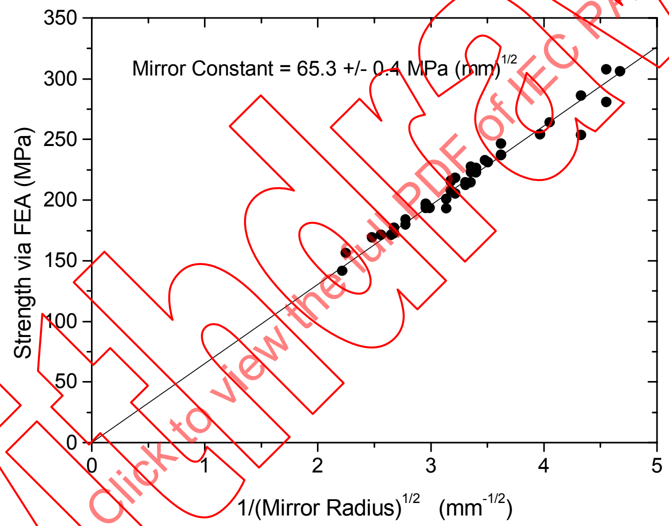


**Figure A.3 – Plot of calculated strength versus 1/square root of mirror radius**

$$\sigma_f = A/\sqrt{R_m}\ , \quad A = 65{,}3\ \text{MP}a\sqrt{m} \qquad \text{(A.1)}$$

The biaxial strength data for 17” modules employing 0,7 mm glass are plotted as Weibull distribution in Figure A.3. A bimodal distribution is obtained indicating two different families of flaws introduced during fabrication of the modules. Table A.2 summarizes the strength data and Weibull parameters.