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Edition 1.0 2015-01

INTERNATIONAL STANDARD

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

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

CDV	Report on voting
110/570/CDV	110/610A/RVC

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.

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 publication will remain unchanged until the stability date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

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- withdrawn,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

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

INTRODUCTION

Mobile electronic devices have become increasingly sophisticated and often include 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 standard 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.

LIQUID CRYSTAL DISPLAY DEVICES –

Part 40-4: Mechanical testing of display cover glass for mobile devices – Biaxial flexural strength (ring-on-ring)

1 Scope

This part of IEC 61747-40 is a mechanical performance testing procedure for cover glass used in electronic flat panel displays in mobile devices. This standard is focused on the measurement of as-received surface fracture load via biaxial flexure generated by ring-on-ring.

2 Normative references

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

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

IEC 61649:2008, *Weibull analysis*

3 Terms, definitions and abbreviations

3.1 Terms and definitions

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

3.1.1
specimen
individual piece of glass to be tested to failure

3.1.2
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

3.1.3
sample size
number of specimens in a sample

3.1.4
nominal value
value about which a tolerance range is specified

3.2 Abbreviations

PTFE polytetrafluoroethylene

4 General

This test measures surface fracture load by forcing a ring through a specimen that is supported by another, larger ring. The two rings shall be parallel and concentric and the applied force shall be perpendicular to the surface formed by the top of the support ring. The loads at fracture are measured. These loads are not normalized to strength using factors such as specimen dimensions and material properties because significant non-linearities may exist which render the classical formulas inaccurate.

The test is applied to a sample of several specimens. The sample statistics of the fracture load values are defined in Clause 7. The statistical values to be reported or specified are given in Clauses 8 and 9.

The specimens to be tested are typically 50 mm to 60 mm in width and 50 to 110 mm in length, with thickness ranging from 0,55 mm to 2,0 mm. The specimen is placed on the support ring so it is centered on the ring. Before the specimen is placed on the support ring, the surface that will contact the load ring is covered with a layer of polymeric adhesive tape to preserve the fracture surface and reduce the scattering of glass fragments upon breakage. The support ring is also covered with PTFE film to minimize contact damage and friction.

The general requirements of the apparatus are given in Clause 5. Apparatus dimensions can be affected by specimen dimensions. These relationships are outlined in 5.4.

Testing procedures are given in Clause 6.

It is assumed that all measurements are performed by personnel skilled in the general art of mechanical property measurements. Furthermore, it should 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 61747-40-1. Specimens shall be stored in such an environment for at least four hours before testing.

5.2 Testing frame

The testing frame provides the aspects needed for the controlled vertical movement of some mechanical elements relative to a test fixture surface. It also includes a load cell to indicate the applied force of these mechanical elements against other mechanical elements that are attached to the test surface and detectors to indicate displacement from the start of motion. A controller is also required to coordinate the necessary motions. These may be driven by external commands or by load cell responses. Examples of motion directives include:

- Jog up or down.
- Slow manual up or down until the stop button is pushed.
- Return to a preset start of test.
- Traverse downward at a fixed rate until fracture is detected, then stop.
- Emergency stop.

In addition to providing motion control and measurement of load, the controller shall, at minimum, report the fracture load, allow the setting of the cross head traverse rate, and display the load as a function of time and/or deflection from the start of the test. Other features can include:

- Collection, organization, storage, and reporting of information entered for the sample, its specimens, failure load data, and statistical analysis results.

The main structural elements of the testing frame shall be made of steel with dimensions large enough so compliance is essentially zero with respect to the maximum force that will be applied. This maximum force depends on the specimens being tested, but should generally be less than 10 kN. These elements include:

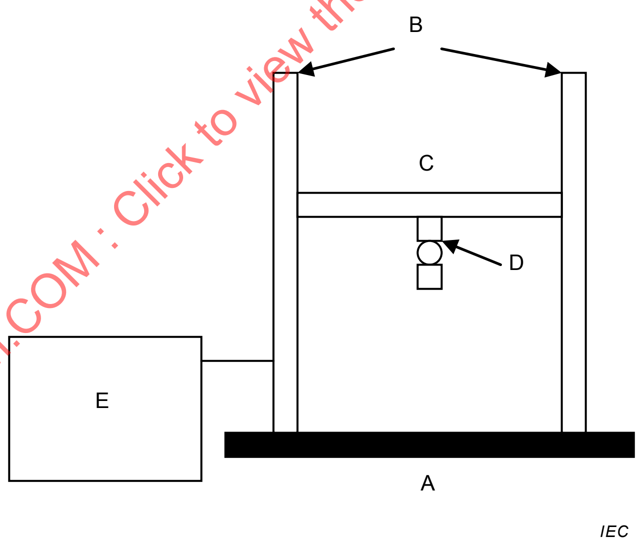
- the testing surface,
- vertical support columns,
- a cross head,
- motion tractors within the support columns,
- load cell assembly and attachment mechanisms.

The minimum and maximum rates of motion shall encompass the range of 0,001 mm/min and 1 000 mm/min.

The controller shall sample the load cell and displacement detectors at a minimum rate of 10 kHz.

The load cell shall be calibrated against a known weight, force gauge or load cell and be linear to within 1 % over the maximum applied force. The load cell shall be capable of being reset to zero after the attachment of mechanical elements to it before apparatus setup is complete. It shall also include an attaching mechanism.

Figure 1 illustrates some of the elements of the testing frame.



Key

A Testing surface

B Support columns

C Cross head (moves up and down)

D Load cell assembly

E Controller

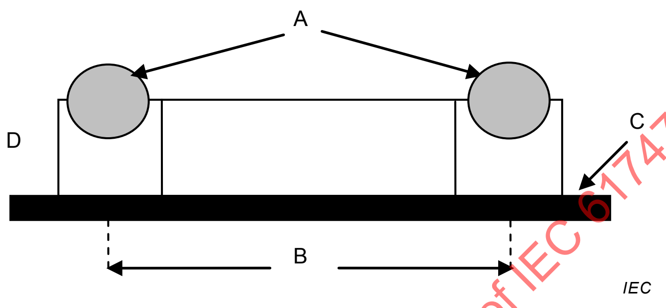
Figure 1 – Testing frame

5.3 Test fixture and setup

Subclause 5.3 outlines the generic test fixture elements and setup procedure. Subclause 5.4 identifies the requirements of the dimensional characteristics, which can depend on specimen characteristics.

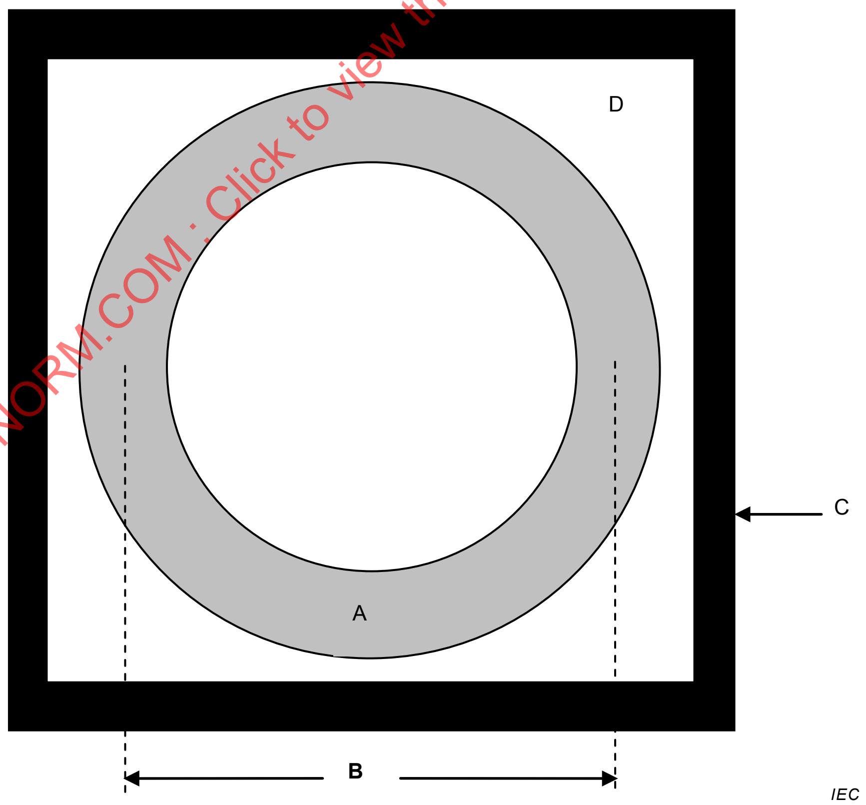
The primary test fixture elements are the support assembly and the load assembly. These are illustrated in from Figure 2 to Figure 5. Other test fixture elements include:

- Clamps used to fasten the support assembly to the test frame testing surface.
- Machined installation gage to align the support and load assemblies.
- Micrometer with flat anvil faces and resolution of 0,002 mm or better.



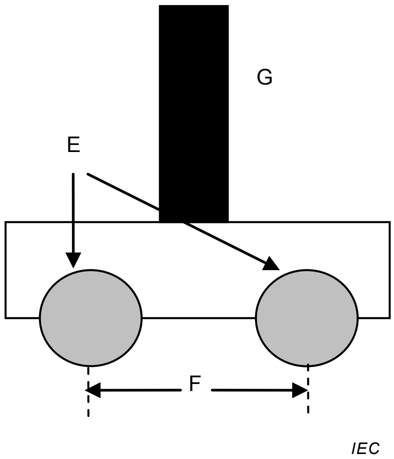
NOTE The key to the letters is provided in Figure 5.

Figure 2 – Support assembly (side view, cross-section)



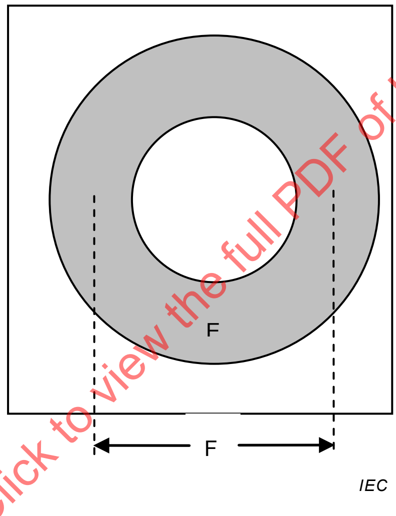
NOTE The key to the letters is provided in Figure 5.

Figure 3 – Support assembly (top view)



NOTE The key to the letters is provided in Figure 5.

Figure 4 – Load assembly (side view, cross-section)



Key

A Support ring

B Support ring diameter, d_S

C Support assembly attachment surface

D Support assembly body

E Load ring

F Load ring diameter, d_L

G Compression bar

Figure 5 – Load assembly (bottom view)

Setup steps include:

a) Attach the load assembly to the test frame load cell assembly at the compression bar.

b) Reset to zero on the load cell.

c) Roughly center the support assembly below the load assembly.

d) Place the installation gage onto the support ring so the bottom groove contains the ring.

e) Slowly, lower the cross head and adjust the support assembly until the load ring is contained in the installation gage top groove.

f) Clamp the support assembly onto the test frame testing surface.

g) Raise the cross head until the separation of the load and support rings is suitable for loading a specimen and set the start point.

The installation gage bar is a machined metal block with top and bottom grooves corresponding to the loading ring and support ring respectively. It is used to assure parallel and concentric alignment of the two assemblies.

When assembled, the rings shall be parallel to 0,05 mm per 25 mm in length and concentric to within 0,25 mm.

5.4 Test fixture dimensions

The test fixture dimensions are driven by the specimen dimensions: length, l, width, w, and thickness, h.

The height of the support assembly body shall be sufficient to accommodate the maximum specimen deflection.

The support ring diameter, d_S, and load ring diameter, d_L, are set in terms of the nominal specimen length, l_{nom}, as in equations (1) and (2).

$$d_S \leq \frac{4}{5} l_{nom} \tag{1}$$

$$d_L = \frac{1}{2} d_S \tag{2}$$

The support ring diameter is critical to obtaining comparable testing results because it can affect the Weibull scaling parameter (see Clause 7). Unless otherwise specified, the support ring diameter is 25,4 mm.

The minor radius of the load and support rings (i.e., the radius of the ring surface in contact with the specimen under test) shall be greater than $h/2$.

5.5 Loading rate

The cross head traverse rate during testing shall be constant. The rate is set to 1,2 mm/min unless otherwise specified.

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 Crush hazard – Only one person may operate the testing frame

Operator injury may occur if more than one person operates the system. Before working in the hazard area between the upper and lower fixtures, ensure that other personnel cannot operate the computer system or other controls.

6.1.3 Crush hazard – Take care when installing or removing a specimen

Installation or removal of a specimen involves working inside the hazard area between the fixtures.

- Keep clear of the fixture at all times.
- Never enter the hazard area between the fixtures while the cross head is moving.

6.1.4 Hazard – Press the emergency stop button when an unsafe condition is observed

If an unsafe condition is observed, press the emergency stop button. Correct the unsafe condition before resuming testing.

6.1.5 Flying debris hazard – Ensure that specimens are installed correctly

Always install the specimens in the center of the fixtures in line with the load path. Incorrect specimen installation creates stresses which can damage the fixtures. The high energies involved can project broken parts some distance from the test area.

6.1.6 Hazard – Protect control cables from damage or disconnection

Protect all cables, particularly transducer cables, from damage. Damage to control and feedback cables can induce an open loop condition which may drive the cross head to the extremes of its motion.

6.2 Sample

The sample size is 30, excluding any specimens rejected for pre-existing damage. Values associated with edge failures are included in the sample, but the values are treated as late suspensions (see Clause 7). If there are more than 10 suspensions, the testing fails and a new sample shall be selected.

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

- Determine and record the following information:
  - sample identification,
  - sample specimen nominal dimensions: length, width, thickness,
  - requesting person.
- Determine whether existing test fixtures are compatible. If not, change them (Clause 5).
- Record the fixture dimensions or identification number.
- Set and record the cross head traverse rate.
- Determine and record whether width is to be measured on each specimen. If specimen width varies less then 5 % of average, the average width may be used for each specimen.
- Set the start-of-test height for the testing frame.
- Zero the micrometer. This is done by gently closing the anvils with no specimen present, and pressing the reset button.

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.

a) Determine and record the specimen identification number.

b) Inspect for any damage. If damaged, report this, but do not include in the testing.

c) If required (see 6.2), measure and record the width.

d) Measure and record the thickness to the nearest 0,001 mm. This measurement shall be done at a location on the specimen that is away from any edge and in a location that will not be stressed (the overhang area).

e) Cut a section of polymeric adhesive tape that can cover the specimen and place it sticky side up on the working surface.

f) Gently attach one edge of the specimen to one end of the tape.

g) Gently lower the rest of the specimen onto the rest of the tape.

h) Carefully trim the excess tape away from the specimen.

i) Return the test frame to the start-of-test position and place a piece of PTFE film on top of the support ring. The film shall be large enough to cover the entire support ring, and shall have a hole cut or punched in the center so that the specimen centers will remain unsupported. Next, place the specimen onto the PTFE-covered support ring with the polymeric adhesive tape side up.

NOTE The load ring will touch the polymeric adhesive tape.

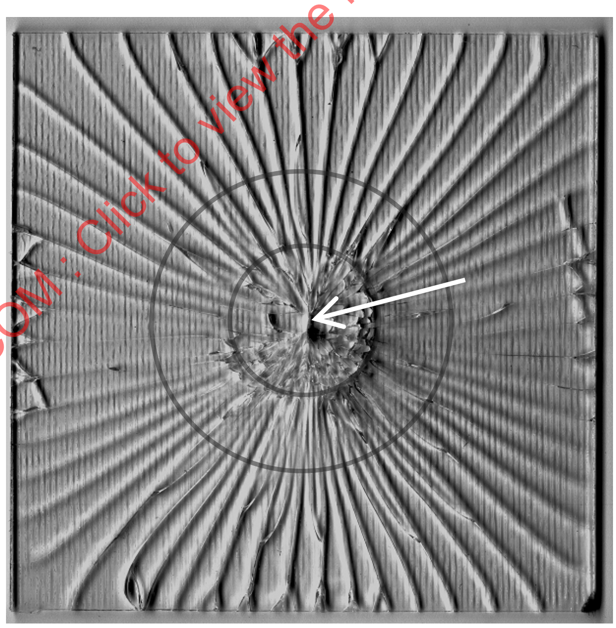
j) Start the test sequence.

k) Observe the load versus time or cross head position graph and other signs of testing progress for any abnormalities. If any are observed, this might be cause to suspend or omit the result.

l) Record the failure load.

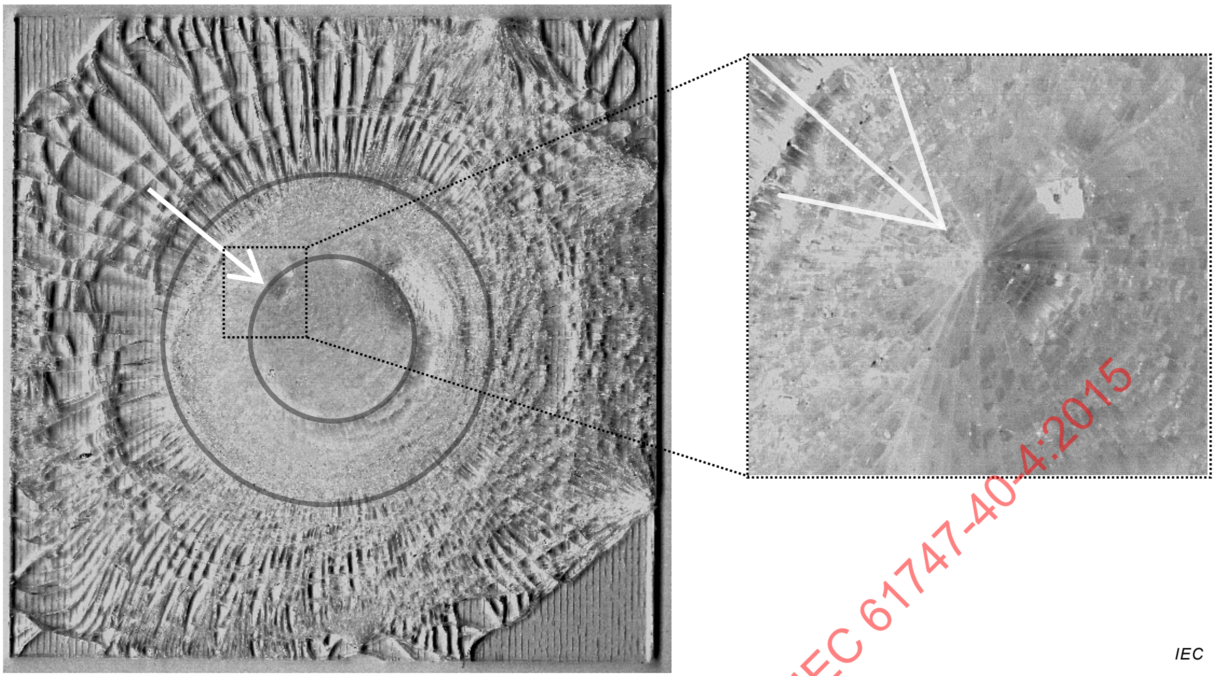
m) Inspect the fracture pattern to determine whether the break originated from the edge or surface, and if the latter, from which position. Surface failures originating from the bottom (tensile) surface inside or underneath the loading ring should not be suspended. Surface breaks originating from either the top or bottom surface outside of the load ring shall be treated as suspended data, as should all edge breaks. Figure 6 shows a surface break originating from inside of the load ring. Figure 7 illustrates a surface break originating from underneath the load ring. Figure 8 shows a break originating from the specimen edge.

n) Remove the broken glass and thoroughly clean the area for the next test.



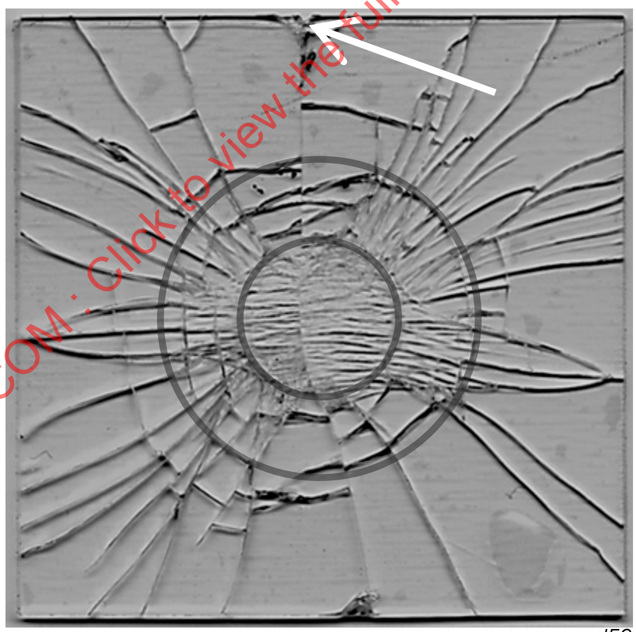
NOTE The load and support ring positions during testing are approximated by the dark circles, while the arrow tip represents the failure origin location.

Figure 6 – Surface fracture originating from inside the load ring



NOTE The load and support ring positions during testing are approximated by the dark circles, while the arrow tip represents the failure origin location.

Figure 7 – Surface fracture originating from underneath the load ring



NOTE The load and support ring positions during testing are approximated by the dark circles, while the arrow tip represents the failure origin location.

Figure 8 – Edge fracture originating from outside the load ring

6.4 Complete the report

The report shall include, at a minimum, the information found in 8.1. Individual customers may require additional information.

Depending on the capabilities of the testing frame controller, preparation of the report may require the statistical analysis items in Clause 7 to be calculated, stored, and printed on another computer.

7 Calculations

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

- Weibull scale parameter, η (N).
- Weibull shape parameter, β.
- The 10th percentile fracture load, B_{10} (N).

The maximum likelihood estimate (MLE) method of calculation shall be used for the Weibull parameters. See 9.6 of IEC 61649:2008. The following equations are adapted from equations (17) and (18) of IEC 61649:2008 in order to accommodate suspensions as variable censoring. This is justified by considering an edge break. If the edge flaw had not been present, the largest surface flaw would have failed at a larger load than the fracture load of the edge flaw. In a sense, the testing of the surface flaw was terminated before fracture.

Following the notation of IEC 61649, let t_i represent valid fracture load 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 equation (3).

$$\frac{\sum_{i=1}^{r} t_i^{\beta} \ln t_i + \sum_{j=1}^{s} T_j^{\beta} \ln T_j}{\sum_{i=1}^{r} t_i^{\beta} + \sum_{j=1}^{s} T_j^{\beta}} - \frac{1}{\beta} - \frac{1}{r} \sum_{i=1}^{r} \ln t_i = 0 \tag{3}$$

Given this value for the shape parameter, the scale parameter is given as equation (4).

$$\eta = \left[\frac{1}{r} \left(\sum_{i=1}^{r} t_i^{\beta} + \sum_{j=1}^{s} T_j^{\beta} \right) \right]^{1/\beta} \tag{4}$$

The point estimate of the 10th percentile, B_{10}, is calculated using 9.8 of IEC 61649:2008 and equation (20) of IEC 61649:2008. Equation (20) is repeated here as equation (5) for convenience. In Clause 9, this parameter is recommended to be specified for performance standards. It combines the scale and shape parameters to single, meaningful, metric.

$$B_{10} = \eta[-\ln(0,9)]^{1/\beta} \tag{5}$$

In addition to the calculation of statistical parameters, a Weibull plot is required (see 8.2). See 7.2.3 of IEC 61649:2008 for instructions on how to produce such a plot. An example Weibull plot is shown in Figure 8.