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TECHNICAL REPORT

colour inside

Display lighting unit – Part 1-4: Glass light guide plate

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Part 1-4: Glass light guide plate

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CONTENTS

FOREWORD 4
1 Scope 6
2 Normative references 6
3 Terms, definitions and abbreviated terms 6
3.1 Terms and definitions 6
3.2 Abbreviated terms 6
4 Overview 7
4.1 General 7
4.2 Light guide plate technologies and its typical materials 7
4.3 Advantages of and issues with GLGP 8
5 Optical characteristics 9
5.1 Factors affecting optical characteristics of GLGP 9
5.2 Optical absorption of the glass materials for LGP 9
5.3 Optical absorption and scattering loss caused by the dot pattern 11
5.4 Incident loss 11
5.5 Effect of the reflection tapes 12
5.6 Discussions for possible future standardization 12
5.6.1 Applicability of existing standards 12
5.6.2 Mechanical structure and interface 13
5.6.3 Hotspot influence caused by LED light source 13
5.6.4 Non uniformity around edge 13
5.6.5 Optical absorption of glass materials for LGP 13
6 Mechanical and environmental characteristics 13
6.1 General 13
6.2 Rigidity 14
6.3 Thermal expansion and heat resistance/noninflammability 15
6.4 Humidity absorption 17
6.5 Impact resistance 18
6.6 Discussions for possible future standardization 19
7 Additional functions and possible future standardization 19
7.1 General 19
7.2 Local dimming for HDR TV 19
7.3 Curved GLGP for curved LCD 20
7.4 Quantum dot coating and quantum dot coated film LCD 21
7.5 Frontlight 21
7.6 Transparent LCD 21
7.7 Combination with PDLC 22
Bibliography 23

Figure 1 – Structure of edge-lit BLU and LGP 7
Figure 2 – Light propagation in LGP 8
Figure 3 – Examples of internal transmittance spectra at 50 cm in optical path length 10
Figure 4 – Chromaticity gradient against the distance from incident edge 10
Figure 5 – Variation of the relative BLU luminance against the thickness of the GLGP 12
Figure 6 – Weight /thickness dependence of the rigidity of PMMA and glass for LGPs 15

Figure 7 – Schematics of the simulation setup for the deformation calculation of the LGP by pulling up one corner and fixing the other three corners 15
Figure 8 – Horizontal bowing of polymeric LGPs under elevated temperature 16
Figure 9 – Simulated temperature distribution of (a) GLGP and (b) PMMA LGP 17
Figure 10 – Simulated thermal deformation of (a) GLGP and (b) PMMA LGP due to LED lighting 17
Figure 11 – Increase in the horizontal length of LGP with temperature change for a 65” diagonal LGP 18
Figure 12 – Example of curved LCD using a curved GLGP.. 20
Figure 13 – Example of transparent LCD 21
Figure 14 – Example of transparent LCD with GLGP including PDLC 22

Table 1 – Comparison between polymers and glasses for LGP 8
Table 2 – Physical properties of commercial glass for LGP and PMMA 14
Table 3 – Comparison of thickness, weight, and calculated deformation between GLGP, PMMA LGP, and PMMA combined with steel plate 15
Table 4 – Comparison of GLGP and polymer LGP in confined structure under humid condition 18
Table 5 – Impact resistance with different machining 19

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DISPLAY LIGHTING UNIT –

Part 1-4: Glass light guide plate

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IEC TR 62595-1-4, which is a Technical Report, has been prepared by IEC technical committee 110: Electronic displays.

The text of this Technical Report is based on the following documents:

Enquiry draft	Report on voting
110/1174/DTR	110/1200/RVDTR

Full information on the voting for the approval of this technical report 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 62595 series, published under the general title *Display lighting unit*, 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

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DISPLAY LIGHTING UNIT –

Part 1-4: Glass light guide plate

1 Scope

This part of IEC 62595, which is a Technical Report, provides general information for judging the necessity of future standardization of glass light guide plates for display lighting units, which include backlight units for transmissive displays such as LCDs, and frontlight units for reflective displays.

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 62595-1-2:2016, *Display lighting unit – Part 1-2: Terminology and letter symbols*

3 Terms, definitions and abbreviated terms

For the purposes of this document, the following terms and definitions given in IEC 62595-1-2 and the following 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 Terms and definitions

3.1.1
glass light guide plate
GLGP
light guide plate whose optically transparent medium is made of glass material

Note 1 to entry: See IEC 62595-1-2:2016, 3.3.1. A GLGP includes optical elements for light guide plates, such as diffusion patterns, in addition to a glass sheet for light guide plates.

3.2 Abbreviated terms

BLU	backlight unit
CTE	coefficient of thermal expansion
DLU	display lighting unit
FLU	front lighting unit
FPC	flexible printed circuits
GLGP	glass light guide plate
HDR	high dynamic range
LC	liquid crystal

LCD	liquid crystal display
LED	light emitting diode
LGP	light guide plate
MCPCB	metal core printed circuit board
MS	methyl-methacrylate styrene copolymer
PDLC	polymer dispersed liquid crystal
PMMA	polymethyl methacrylate
S/N	signal/noise ratio

4 Overview

4.1 General

Glass light guide plate (GLGP) enables distinctive display product features such as thinner, lighter, larger and narrower bezel design with several additional considerations of material properties and stabilities compared to conventional polymer light guide plate. This document intends to investigate display product features enabled by GLGP and to identify possible future standardization.

4.2 Light guide plate technologies and its typical materials

An LGP is a component of an edge-lit backlight unit (BLU) as shown in Figure 1 and in IEC 62595-1-2:2016, Annex A. This edge-lit BLU has been widely used for thin LCDs. In the BLU, the light emitted from LEDs positioned in close proximity to the edges of the LGP is optically coupled into the LGP to illuminate an LC device. Figure 2 shows the schematics of the cross-section view of the LGP. The light from the LEDs propagates in the LGP by means of total internal reflection, and the patterned reflection dots at the surface disrupt the total internal reflection to couple out light, resulting in uniform light output for surface illumination.

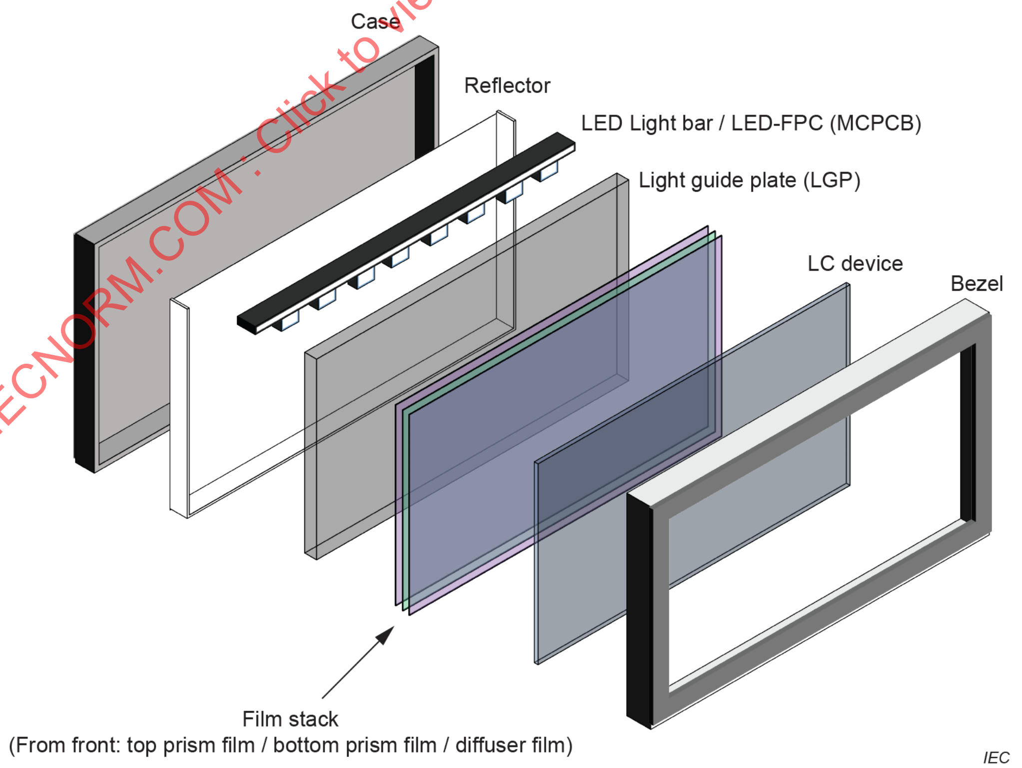


Figure 1 – Structure of edge-lit BLU and LGP

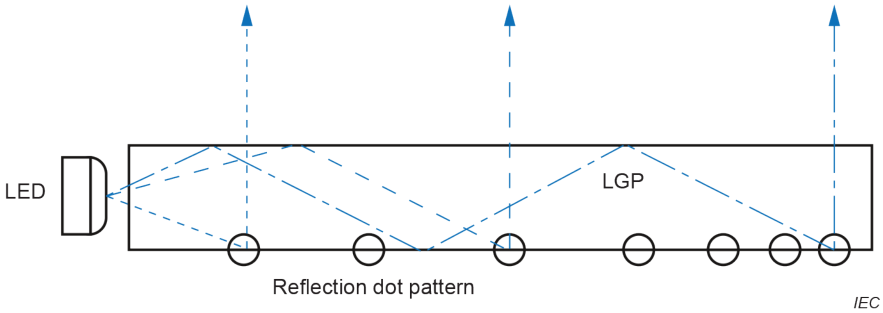


Figure 2 – Light propagation in an LGP

Generally, polymer materials, such as polymethyl methacrylate (PMMA) and methyl-methacrylate styrene copolymer (MS), have been applied for the LGP due to their excellent optical properties. However, the polymer LGP has apparent disadvantages: lower stiffness, deformation by humidity, higher thermal expansion, and lower chemical and thermal stability (see Table 1). Because of its lower stiffness, the polymer LGP is difficult to apply for extra-large size displays, that is, larger than 65 inches with ultra-thin design less than 5 mm. Easier deformation by humidity and thermal expansion result in the limitation of TV sets design to keep the optical clearance between LEDs and LGPs. In addition, the thermally unstable nature is not suitable for future high power LEDs that also generate more heat and introduce higher temperature; it potentially limits the brightness improvement of the BLU [10][1].

Table 1 – Comparison between polymers and glasses for LGP

	Polymer	Glass
Young's modulus (GPa)	Low (~5)	High (≈70)
Thermal conductivity (W/m/K)	Low (≈0,2)	High (≈1,1)
Thermal expansion ($\times 10^{-7}$ 1/K)	High (> 400)	Low (< 100)
Water/humidity absorption (vol %)	High (< 0,1)	None
Flammability	Yes	No

4.3 Advantages of and issues with GLGP

Glass materials have been gathering much attention these days as the candidates for novel LGP materials because they have better chemical durability, thermal stability, and mechanical properties in comparison with polymers. GLGPs have been already mass produced [1] to [3], and GLGP installed LCD TVs and monitors have been on the market [4], [5].

Although anticipation has increased, various major hurdles have to be overcome before GLGPs become popular. One is the facility asset: existing production lines, supply chains of BLUs are basically optimized to use polymer LGPs, and are not easy to convert to use GLGPs. Another big issue is the lack of appropriate information: most of the documentation related to the LGP was prepared with the use of polymers in mind, therefore the appropriate information is difficult to reach. Evaluation methods are also designed with the use of polymers in mind, hence some of these, such as optical properties, mechanical and environmental properties, seem inappropriate to the glass. If the correct recognition of the difference between these two materials is not sufficient, biased knowledge and experiences of the polymer LGP can prevent the adoption of the glass materials. In addition, the current structure explained in Figure 1 would be based on polymer LGPs, and for GLGPs a new structure might be applied according to the feature of the GLGP. The current standards for BLUs need to be checked considering whether they are based on only polymer LGPs or not.

———————

1 Numbers in square brackets refer to the Bibliography.

As an additional point of view, compared with polymer LGPs, GLGPs may be suitable not only for the BLUs mentioned above but also for other DLUs such as FLUs, transparent LCDs, and so on, which seems attractive for the future. According to this situation, this document summarizes the basic information of GLGPs and the desirable characters for GLGP application, in order to discuss the necessity of revising the current BLU standards [6] to [9] and proposing new standards.

5 Optical characteristics

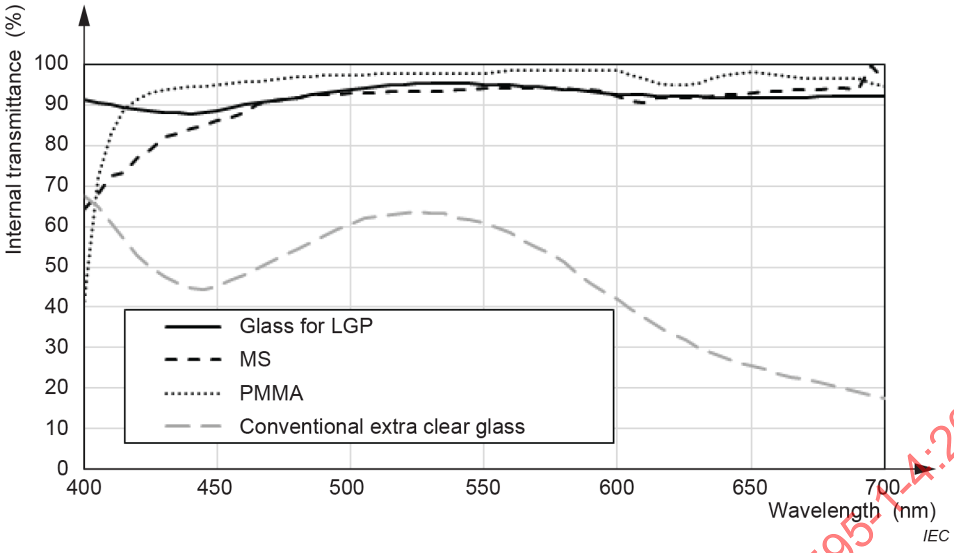
5.1 Factors affecting optical characteristics of GLGPs

The main function of the GLGP is the light propagation from the incident edge to the output surface, and both the radiant or luminous flux and chromaticity are expected to become uniform in the whole output surface. Applying the reflection tapes around one or three side (non-incident) surfaces of the GLGP can increase the luminance and uniformity. Uniformity of the illuminant power and chromaticity depend on the optical absorption, scattering loss during the propagation, and loss of the LED coupling at the incident edge.

1) Optical absorption: the absorption of the glass material itself is the major factor to determine the optical performance of the GLGP.
2) Scattering loss: the GLGP generally uses ink-based light extraction. It uses scattering as its mechanism to control light. This scattering by the reflection dot pattern has spectral and spatial dispersion, thus it also causes the similar effect of optical absorption. This effect is not unique to GLGP, but the GLGP is expected to use a thinner thickness compared to polymer LGPs, such as less than 3 mm in thickness, so the light hits the ink more often than on a thicker LGP, and it amplifies the ink's deleterious effects.
3) Loss of the LED coupling: from the viewpoint of GLGPs, the loss at the LED coupling is affected by the distance between the LED and the LGP and the edge surface condition of the GLGP such as edge straightness, edge surface waviness, incident area width, chamfering shape and roughness.

5.2 Optical absorption of the glass materials for LGPs

The optical path length of the LGP in LCD TVs is longer than several tens of centimetres, whereas that in general usage is several millimetres at the most. Therefore, lower optical absorption, that is, higher internal transmittance, is mandatory for the glass for LGPs. These distinguishing characteristics are reported in the references [10] and [11]. Figure 3 shows examples of internal transmittance spectra of the commercial glass for LGPs. The spectra of MS, PMMA and conventional extra clear glass for solar cells are shown as a reference. Note that the optical path length of the spectra in Figure 3 is 50 cm, in contrast with the length of the normal spectra which is 1 cm at the most. As shown in Figure 3, the glass for LGPs showed significantly higher internal transmittance than conventional glasses; the internal transmittance of the glass for LGPs is higher than 80 % even if the optical path length is as long as 50 cm.



NOTE The solid, dashed, dotted, long-dashed lines represent the commercial glass for LGP, MS, PMMA, and conventional extra clear glass for solar cell, respectively.

Figure 3 – Examples of internal transmittance spectra at 50 cm in the optical path length

In addition, the spectral shape of the glass for LGPs in the visible wavelength region is flatter, that is, there is less wavelength dispersion than the conventional glasses. It is important to suppress the chromaticity change of GLGPs.

Figure 4 shows an example of the chromaticity gradient against the distance from the incident edge by using the conventional glass as LGP. dx and dy in Figure 4 represent the chromaticity difference between the measured position and the incident edge which is calculated from the difference of x and y at the measured points and at incident edge, respectively, where x and y are the chromaticity parameters derived from tristimulus values which are defined in ISO/CIE 11664-1 [30]. The variation of dx and dy as shown in Figure 4 indicates the occurrence of the colour shift. The large spectral dispersion of the transmittance easily causes the colour gradation.

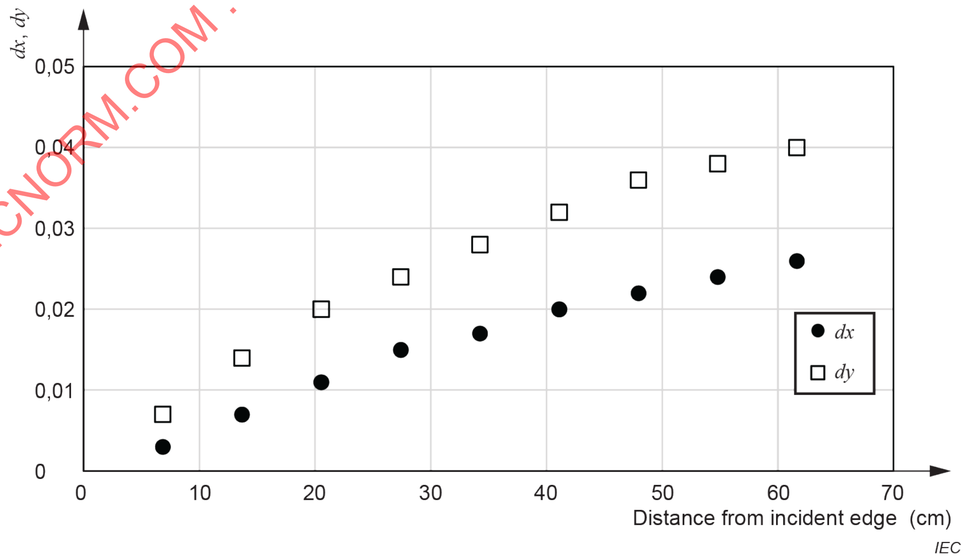


Figure 4 – Chromaticity gradient against the distance from the incident edge

For the evaluation of the optical absorption of the glass materials for LGPs, precise optical absorption data of the material for LGPs is mandatory information for designing the BLU. The optical path length of the GLGPs is several ten times longer than that for conventional usage, thus the accuracy needs to improve in comparison with the available data. The conventional evaluation is inappropriate because the optical path length is too short to gain enough S/N, and the effect of the surface scattering is not negligible. Therefore, the evaluation by using the sample of a longer optical path length is preferable. One example of the precise evaluation for the purpose is to use a spectral optical setup with a coherent light source, such as super continuum white light, to avoid losses caused by total internal reflections during propagation. By using the setup, a sample of about 50 cm in length can be measured. Another example is to use an available optical spectrophotometer with a combination of a well collimated light source and a special attachment to ensure the repeatability of the sample's precise position. A sample of 5 cm to 15 cm in length can be measured by using the setup. Both examples seem to show a good correlation with each other, if the measurement setup is done under the appropriate conditions. The detailed measurement conditions and possibility of future standardization may need to be discussed.

5.3 Optical absorption and scattering loss caused by the dot pattern

There are various techniques for dot patterning for polymer LGPs such as molding during sheet formation process, screen printing, inkjet printing, CO_2 laser patterning or imprinting. However, the dot pattern for GLGP is basically formed by dot printing techniques due to the limitation of the cost and optical performance. UV cured or IR cured inks are widely used, and using the inks with less colouring is important especially for GLGPs A GLGP is basically expected to have a thinner thickness compared to polymer LGPs, and in a thinner condition the light hits the ink more often than on a thicker LGP, amplifying the ink's deleterious effects.

The dot pattern can be formed by engraving the patterned pits at the surface of the glass. Mechanical holing, chemical etching and laser patterning techniques can be applied for this process. In these types, controlling the spatial and spectral dispersion of the scattering by controlling the pit's size and shape is the key to suppressing the optical degradation.

The influence of this degradation needs to be measured and evaluated.

5.4 Incident loss

The LED bar and LGP coupling straightness can affect the coupling alignment between LEDs and LGPs, and thus the coupling efficiency. In addition, the variation of the LED bar (peak to peak about 100 µm) and the waviness of the coupling edge surface of the LGP can change the gap between the LED and LGP, and thus the coupling efficiency. The surface roughness of the incident plane also likely affects the coupling efficiency between LEDs and LGPs. Although the loss is not unique to a GLGP and is likely also present in a plastic LGP, the difference caused by the brittleness of the glass material should be taken into account. The cutting and breaking method for the glass materials and the chamfering that prevents the edge from cracking are different from the plastic materials, and these techniques might affect the incident surface condition.

Surface roughness plays a non-intuitive role in the coupling efficiency between the LEDs and GLGP. Roughness is typically described in terms of the average height variation of a topographic measurement across the surface (e.g. R_a). However, the lateral correlations in the surface roughness can significantly alter the way light propagates through the surface. So far, there is no way to generalize the behaviour of surface quality on LGP performance. Detailed examination of which edge surface conditions dominantly affect light input efficiency, the appropriate definition of surface roughness for GLGP's incident plane, and the standardization of the incident loss measurement may need to be discussed.

The width of the incident area is important to ensure enough light coupling between LEDs and GLGPs. Figure 5 shows the measured variation of the relative BLU luminance against the LGP thickness [10]. A commercial edge-lit BLU of a 55” LCD TV was used for the measurement by replacing the original polymer LGP with GLGP. The optical alignment displacement caused by the thickness mismatch from the original LGP was adjusted by inserting the PET sheet between the reflection sheet and case. The distance between the GLGP and LED bar was 0,6 mm. Each plot in Figure 5 was the nine-point averaged data in the incident plane of the GLGP, and was measured by using a 2D luminance colorimeter. The angular light distribution of each GLGP was adjusted to be almost the same as the PMMA LGP. As shown in the figure, the luminance was found to vary with the thickness between 1,8 mm to 2,5 mm.

This will be related with the power consumption or efficiency of the DLU.

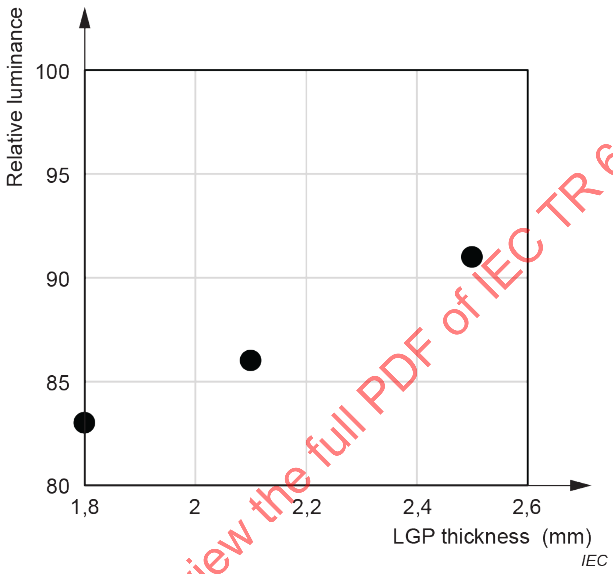


Figure 5 – Variation of the relative BLU luminance against the thickness of the GLGP

5.5 Effect of the reflection tapes

Applying the reflection tapes around one or three side (non-incident) surfaces of the GLGP can increase the luminance and uniformity.

5.6 Discussions for possible future standardization

5.6.1 Applicability of existing standards

For DLUs, there are currently four standards [6] to [9] related to measurement methods for BLU. They specify:

– power consumption,
– luminance,
– luminance uniformity,
– spectral power distribution,
– chromaticity,
– colour uniformity,
– angular luminance uniformity, and
– angular colour uniformity.

While these standards do not explicitly mention GLGP, the choice of an LGP material does not impact measurements, thus these standards all apply to GLGP. On the other hand, for considering the benefit of GLGP or clarifying the performance of a BLU, the following items (from 5.6.2 to 5.6.5) can be considered for future standardization.

5.6.2 Mechanical structure and interface

IEC TC 110 has discussed interfaces of DLU, i.e., electrical signal interface and mechanical interface. The mechanical interface tries to standardize the structure, size, and so on, shown in Figure 1. This structure is based on the polymer LGPs, and it can be discussed for a GLGP standardized structure. It seems to be helpful for increasing the applicability of GLGPs.

5.6.3 Hotspot influence caused by LED light source

IEC 62595-2-1 [7] specifies the examples of measurement points (25 points, 9 points and 5 points), and these points can be applied to BLUs with GLGPs too. However, as explained, the GLGP can position LEDs closer due to the low thermal expansion, the high heat resistance and the high thermal conductivity (see 6.3). This tends to cause luminance or chromaticity mura around the LED light source, and it is well-known as the “hotspot” effect. Therefore, in addition to the current measurement points, around the LED-mounted points, luminance/colour uniformity and its angular uniformity need to be measured.

5.6.4 Non uniformity around the edge

In the same manner as the hotspot influence, around the edge, luminance/colour uniformity and its angular uniformity might be measured, because this is important for slim edge LCDs.

5.6.5 Optical absorption of glass materials for LGPs

As mentioned in 5.2, precise optical absorption data of the material for LGPs is mandatory for designing the BLU, therefore the evaluation by using the sample of a longer optical path length in comparison to conventional measurement is preferable to meet the requirement of the accuracy. Such an evaluation technique requires certain measurement setup conditions to ensure data accuracy, thus the future standardization may be necessary to discuss. One possible solution is to use the reference sample to calibrate the measurement.

6 Mechanical and environmental characteristics

6.1 General

The physical properties of glass for LGPs and PMMAs are summarized in Table 2. The main motivation to use GLGPs instead of polymer LGPs is to exploit the mechanical and environmental advantage of the glass materials [11],[12].

The advantages of the glass materials are as follows:

- high rigidity (high Young's modulus),
- low thermal expansion,
- high heat resistance/noninflammability, and
- low humidity absorbance.

Table 2 – Physical properties of commercial glass for LGP and PMMA

Property	Glass for LGP	PMMA
Density (g/cm^3)	2,59	1,19
Refractive index	1,52	1,49
Coefficient of thermal expansion (x10^{-7} 1/K)	84	700
Softening point (°C)	740	
Young's modulus (GPa)	72	3
Poisson ratio	0,23	0,35
Thermal conductivity (W/m/K)	1,05	0,21
Specific heat (J/g/K)	0,76	1,4
Water absorption (%)	0	0,3

6.2 Rigidity

The rigidity of the substrate is proportional to (Young's modulus times the cube of thickness). As shown in Table 2, the modulus of glass is approximately 24 times larger than that of the PMMA. Therefore, the thickness of the GLGP can be roughly 0,35 (= $24^{-1/3}$) times thinner than the PMMA LGP while keeping the rigidity. Figure 6 shows the relation between weight/thickness and rigidity (given by Young's modulus times the cube of thickness) [11]. Circles and squares are the data for GLGPs and PMMA LGPs, respectively. The thickness is indicated next to each point in Figure 6. The GLGP has the same rigidity as the PMMA LGP with less thickness and light weight. For example, the flexural rigidity of a 0,7 mm thick GLGP is equivalent to a 2 mm thick polymer yet its weight is 69 % of the PMMA LGP.

If the thickness of a GLGP is the same as that of a conventional PMMA LGP, this high rigidity can realize a very thin and flat body TV design. Conventional large size edge-lit BLUs using PMMA LGPs need the support of the case which consists of the metal flame to keep the rigidity as shown in Figure 1. On the other hand, using GLGP can keep the rigidity without such bulky case, therefore a very thin and flat body design can be realized. Table 3 shows the comparison of the calculated deformation of the GLGP and PMMA LGP with the same thickness of 2,5 mm. The result of a 2,5 mm thick PMMA LGP with a 1,4 mm thick supporting steal plate is also shown in Table 3. Deformation was estimated by applying a load at one node of a 65"-size (1 440 mm x 810 mm) substrate when the other three nodes are fixed completely as shown in Figure 7 [12]. The deformation of the GLGP is less than 20 % that of the PMMA LGP. In addition, the deformation of the 2,5 mm thick PMMA LGP combined with the 1,4 mm thick steel plate is equivalent to that of the 2,5 mm thick GLGP; that is, using a GLGP can achieve a 1,4 mm slimmer thickness and 8 kg lighter weight than those of the combination of PMMA LGP and steel plate.

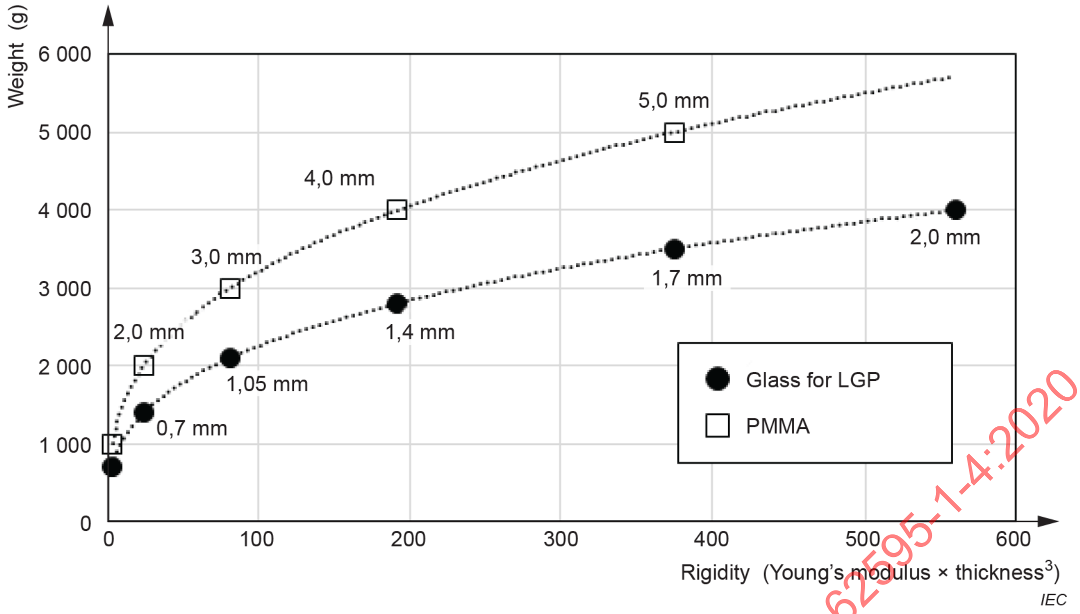


Figure 6 – Weight/thickness dependence of the rigidity of PMMA and glass for LGPs

Table 3 – Comparison of thickness, weight, and calculated deformation between GLGP, PMMA LGP, and PMMA combined with steel plate

	Total thickness (mm)	**Weight** (kg)	**50 N tension *Z* deformation** (mm)
GLGP	2,5	7,6	110
PMMA LGP	2,5	3,3	558
PMMA + steel	3,9 (2,5 + 1,4)	16,1	113
The size of each LGP is 65 inch (1 440 mm x 810 mm)			

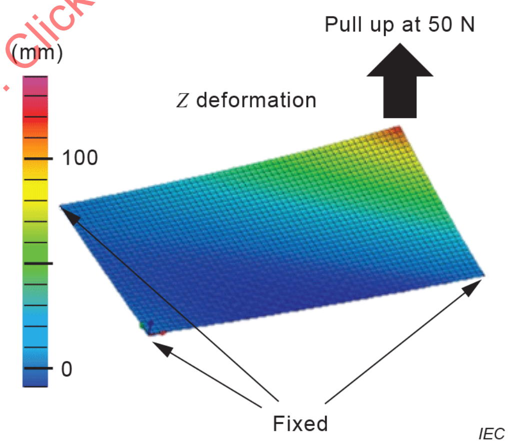


Figure 7 – Schematics of the simulation setup for the deformation calculation of the LGP by pulling up one corner and fixing the other three corners

6.3 Thermal expansion and heat resistance/noninflammability

As shown in Table 2, the CTE of glass is much lower than that of polymers, thus the deformation of a GLGP is almost negligible in comparison with polymer LGPs. Generally a conventional BLU structure needs to have extra space to accommodate LGP expansion according to the expected expansion. Instead of using polymer LGPs, GLGPs can omit a free space in a bezel, thus the narrower bezel design can be realized.

Figure 8 shows the change of the horizontal bowing of LGPs (PMMA and MS) against the temperature [11]. The flat portion corresponds to expansion within the free space in the bezel followed by an increase in the bowing amount. Such a warp causes brightness mura, or worse damages to the LCD panel placed in front of the LGP.

Noninflammability is one of the distinctive advantages of GLGPs compared to conventional polymer LGPs. Using GLGPs instead of polymer LGPs can reduce the risk of the spread of fire. This feature is very important for various applications, especially for large size displays, and for mobile displays, such as trains, buses, airplanes and cars.

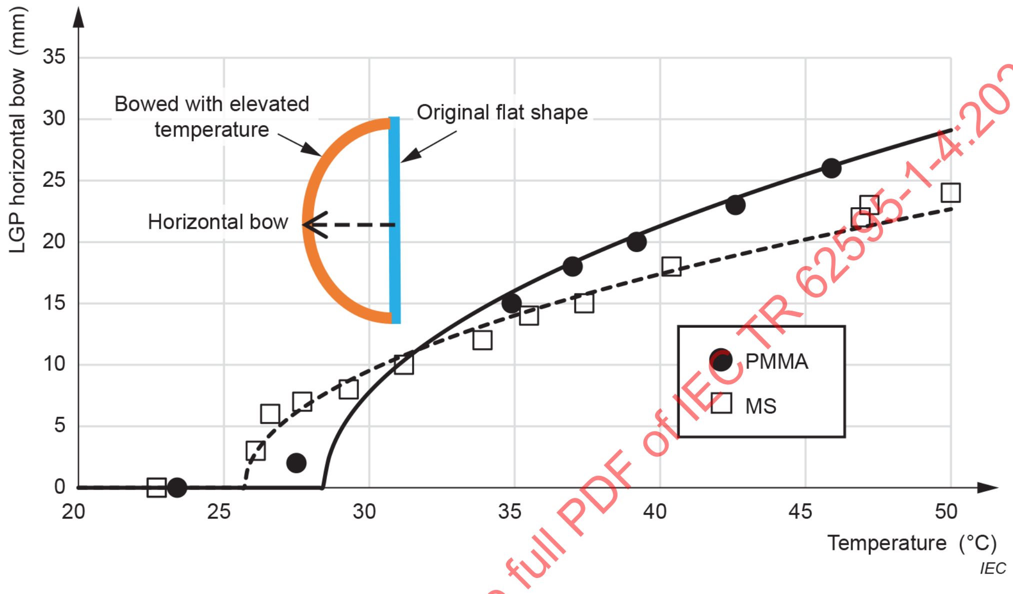
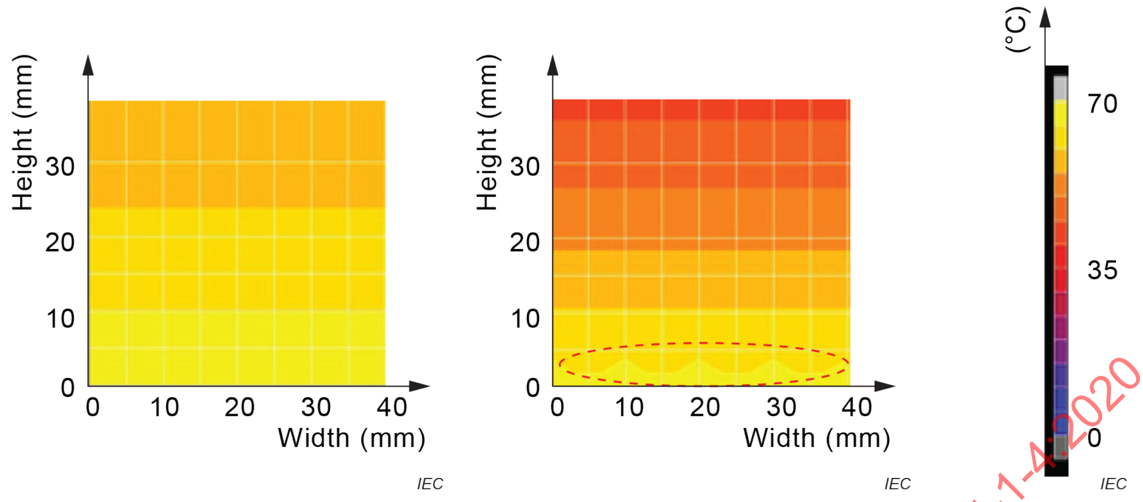


Figure 8 – Horizontal bowing of polymeric LGPs under elevated temperature

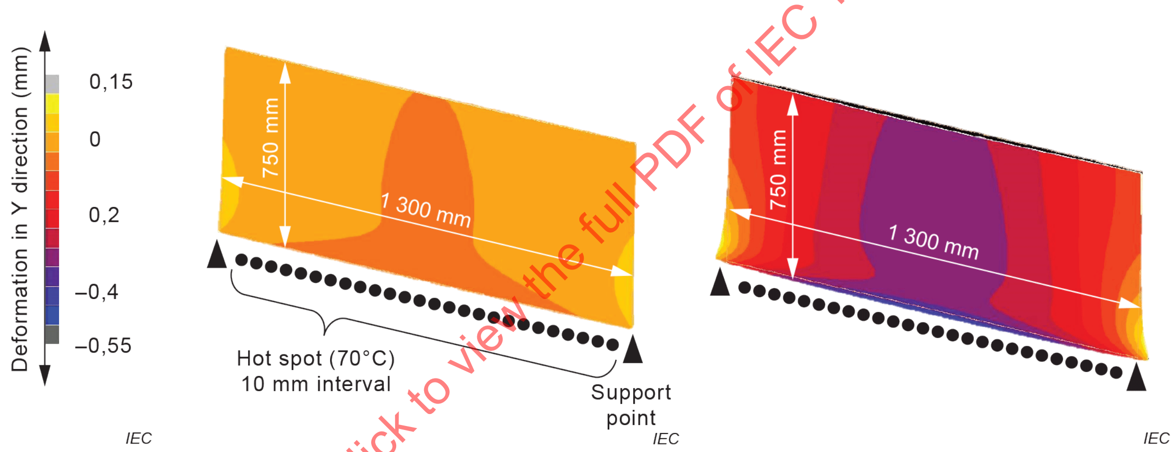
In addition, the low heat resistance and thermal conductivity of polymers versus glass limits the proximity between the LGP edge and the LED. A larger LGP-LED gap leads to a lower coupling efficiency, and thus requires more LEDs to maintain the screen brightness. On the other hand, the superior dimensional stability and heat resistance of GLGPs allow a smaller gap and tighter tolerance between the LGPs and LEDs, giving higher coupling efficiency than polymers.

The temperature distribution and the deformation under some conditions of LED lighting are shown in Figure 9 and Figure 10, respectively [12]. As shown in Figure 9, temperature distribution in a PMMA near the incident plane of a LED indicated by the red dot circle is bigger than that of glass for an LGP. The reason for temperature distribution is low thermal conductivity and high coefficient of thermal expansion of PMMA. This leads to waviness of the incident plane of the LED and brightness distribution of the BLU. As shown in Figure 10, the maximum deformation of glass for an LGP is five times smaller than that for PMMA.



a) GLGP b) PMMA LGP

Figure 9 – Simulated temperature distribution of (a) GLGP and (b) PMMA LGP



a) GLGP deformation = 0,08 mm b) PMMA LGP deformation = 0,45 mm

Figure 10 – Simulated thermal deformation of (a) GLGP and (b) PMMA LGP due to LED lighting

6.4 Humidity absorption

As shown in Table 2, the humidity swell of glass for an LGP is much lower than that for polymers. Figure 11 shows the increase in the length with temperature change and humidity [11]. The base length is 1 440 mm, equal to the horizontal direction length of a 65” diagonal LGP. Due to the low CTE (as mentioned in 6.3) and absence of the swell, glass shows only 6 % to 7 % of the length changes of MS and PMMA. This characteristic gives the GLGP an advantage in terms of applying for narrower bezel design LCD displays.

Table 4 shows a comparison of the GLGPs and polymer LGPs in a confined condition to realize a narrower bezel design LCD display. The GLGP’s almost negligible deformation owing to the nearly zero water absorption does not lead to out of plane warping even if under the humidity condition, whereas the polymer LGP shows the warping as shown in Figure 11. Such a warp causes brightness mura, or worse damages to the LCD panel placed in front of the LGP. Using GLGPs instead of polymer LGPs can prevent such trouble.

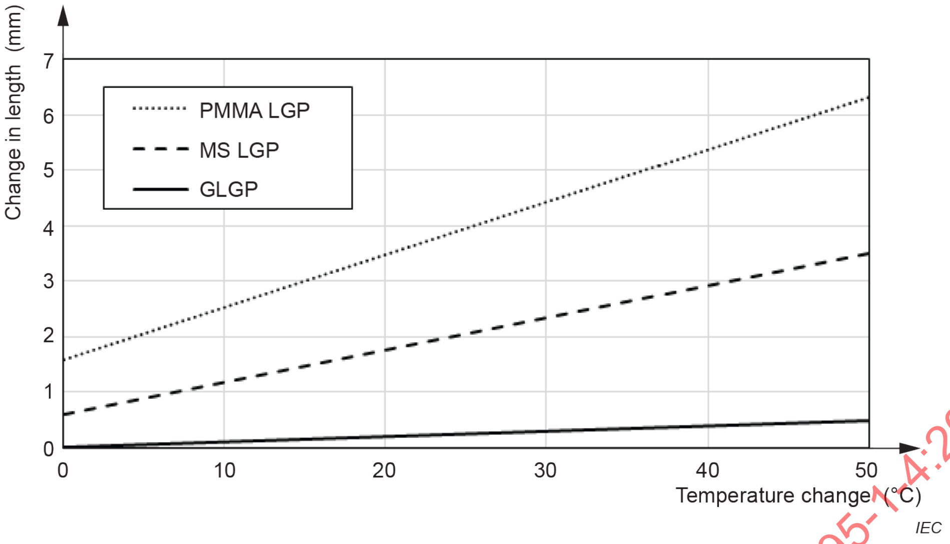
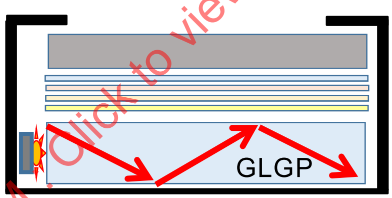
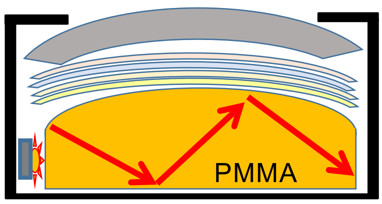


Figure 11 – Increase in the horizontal length of LGP with temperature change for a 65” diagonal LGP

Table 4 – Comparison of GLGP and polymer LGP in confined structure under humid condition

	GLGP	**PMMA LGP**
Water absorption rate (ISO 62 [29])	0,00 %	0,30 %
Deformation (RT, 60 % RH)	-	About 0,12 % [14]
Schematic images after deformation		

6.5 Impact resistance

One of the motivations for using a GLGP instead of polymer LGP is to realize a simpler BLU module design which uses the GLGP as a structural body to keep the module's entire rigidity without using supporting materials such as a bulky case and metal frames. The entire LCD module using a GLGP should follow the standard of mechanical test methods for LCD devices [15]. Another possibility for using a GLGP instead of polymer LGP is the component of FLU. In such case, both published standards for FLU ((IEC 62595-2-3) [9] and (IEC 61747-10-1) [15]) can be helpful.

Polishing, chamfering, and chemical strengthening are prominent ways to improve the impact resistance. Machining techniques without deteriorating the optical properties are necessary. Table 5 shows a summary of impact resistance with different machining.

Table 5 – Impact resistance with different machining

Glass LGP	**Strength** (MPa)
Only cutting	84,3
Polishing without chamfering	125,3
Polishing with chamfering	142,0
Polishing with chamfering and strengthening	233,7

6.6 Discussions for possible future standardization

There is no standard for these mechanical and environmental items for DLUs, because generally these tests are applied to LC panels, as LCD modules. For LCD modules, there are two standards [15], [16], and if necessary, these standards can be applied.

As explained, a DLU with GLGP has some benefits, but basically test conditions should be based on display applications. In some applications requiring high endurance performance, the polymer LGP sometimes causes special mura. In order to check it, new evaluation methods will be necessary.

7 Additional functions and possible future standardization

7.1 General

As explained, for the edge-lit BLUs, GLGP is considered a good solution; also, the GLGP is expected to realize many additional functions. In Clause 7, the candidates for these additional functions and possible future standardization are discussed.

7.2 Local dimming for HDR TV

The TV or PC markets are currently focusing on HDR technologies, which provide enhanced experiences, such as much brighter highlights due to high peak luminance [17], and improved details in dark areas. For LCDs, a dynamic backlight using local dimming is suitable, and it can improve the motion image quality of LCDs and also reduce the power consumption. In addition, boosting increases the block luminance to highlight an area with the saved power by local dimming.

GLGP is also suitable for dynamic backlight, and a GLGP with a built-in prism structure has been developed [18] in order to collimate the light from LEDs. In this development, by keeping the excellent properties of the GLGP, such as higher stiffness, higher stability, and higher durability, the local dimming function can be added to the BLU.

A holey-patterned GLGP with micro LEDs and patterned reflector has been developed [19]. This might be classified into a direct-lit BLU when focused on the LED arrangement, but the light from LEDs propagates into the GLGP. Compared with direct-lit BLUs, the thickness can be reduced.

For dynamic BLUs, the published standard (IEC 62595-2-1) [7] specifies measurement methods of block-wise BLUs as follows:

– light spread function using a single block white pattern,
– optical noise using a single block black pattern,
– optical signal-to-noise ratio in a block-wise BLU, and
– block-by-block uniformity.

These methods can be applied to the dynamic BLU with a GLGP.

For the LCD with a dynamic BLU, the following items are specified by IEC 61747-30-4 [20]:

- luminance and uniformity,
- chromaticity and uniformity,
- windows size dependence of luminance and chromaticity,
- contrast,
- flicker, and
- judder.

When these items are considered, in the next revision of IEC 62595-2-1 [7], the following key points can be discussed:

a) more details of block-by-block uniformity (i.e., how to characterise the uniformity),
b) mura caused by the block-wise structure, and
c) flicker (i.e., caused by PWM driving).

7.3 Curved GLGP for curved LCD

The GLGP is suitably applied to curved displays, and ultra-slim curved TVs with GLGP have been developed [21]. Thanks to the larger Young's modulus, the spring back is reduced, and the curvature sustaining and reliability are improved even with a curvature of 3 000 mm and a thickness of only 3,9 mm with a 55 inch diagonal size (see Figure 12).

IEC

Figure 12 – Example of curved LCD using a curved GLGP

The basic optical characteristics for the curved displays with a vantage point are specified in IEC TS 62715-5-2 [22] as follows:

– vantage-point luminance variation by viewing angles,
– vantage-point contrast ratio variation by viewing angles,
– vantage-point chromaticity variation of white colour by viewing angles,
– vantage-point colour gamut area variation by viewing angles,
– vantage-point chromaticity variation of primary colours by viewing angles,
– luminance uniformity and its uniformity variation by viewing angles,
– chromaticity uniformity and its uniformity variation by viewing angles, and
– viewing angle of half-luminance.

For curved displays without vantage points, such as a convex display, there are some explanations in IEC 62715-5-1 [23].