7.3 Display screen equipment

P. Schäfer, Ludwigsburg
H. Siekmann, Sankt Augustin

The display screen equipment (DSE) used at computer workstations largely falls into one of two categories. The first is liquid crystal display (LCD) equipment, often called "thin film transistor" (TFT) or "flat" screens. The second is cathode ray tube (CRT) equipment though these products only account for a fraction of new purchases today.

Although DSE work in itself does not expose workers to adverse conditions, it can lead to health problems. The causes include tasks requiring high levels of concentration, prolonged, tiring tasks, eyesight problems, poor lighting, glare and non-ergonomic workstation design. These can provoke symptoms such as fatigue, eye problems, headache, muscle tension, back problems, etc. (see the relevant sections of this report). To prevent these symptoms, DSE workstations must conform to health requirements, as set out in the Bildschirmarbeitsverordnung (Ordinance on Display Screen Work) [1]. DGUV Information 215-410, formerly BGI 650, "Bildschirm- und Büroarbeitsplätze – Leitfaden für die Gestaltung" (Display screen and office workstations – A guide to workstation arrangement)[2] gives specific guidance on how to implement the ordinance.

7.3.1 Radiation emission from display screen equipment

Depending on the type of DSE, electric and magnetic fields are generated within the equipment, as are various types of radiation. As Chapter 10 of these recommendations explains in detail, both CRT and LCD screens only cause very low emissions of electric, magnetic and electromagnetic fields. The amounts of other types of radiation emitted (see below) are also small. There is therefore no reason to be concerned about radiation emissions from DSE posing a risk to health. This is true of all DSE workstation scenarios, including multiple-monitor set-ups within one room, monitors installed at opposite workstations and pregnant women performing DSE tasks.

In contrast to LCD display screen equipment, CRT equipment is often subject to interference from electromagnetic fields, e.g. from the building's power distribution system. This can lead to flickering and changes in brightness and colour. CRT screens are particularly prone to this problem because even low-strength magnetic fields cause interference in them. For instance, a magnetic flux density of approximately 0.4 µT (caused, for example, by a passing electrically powered train) is sufficient to cause interference in sensitive equipment.

When electromagnetic fields have an impact on CRT equipment in the workplace, employees are often concerned that the fields might be harmful to humans too. However, such concerns are unfounded since interference can be caused even when the field strength is far lower than the threshold values specified for human protection.

Unlike with LCD screens, electrostatic field strengths of up to 7,000 V/m can occur at a distance of 30 cm from the surface of a CRT screen [3]. More modern CRT screens generate lower field strengths. The DGUV regulation 16, formerly BGV B11, "Elektromagnetische Felder" (Electromagnetic fields) [4] stipulates that the electrical field strength in static fields must not exceed 20,000 V/m. This value is complied with when working at CRT monitors. Charge can cause dust particles to be drawn in from the air if it is not directed away, as is the case with modern equipment.

Ionising radiation

Extensive research by the Physikalisch-Technische Bundesanstalt (PTB; Germany's national metrology institute) and measurements performed by the Karlsruhe Nuclear Research Centre (now part of the Karlsruhe Institute of Technology; KIT) show that exposure to ionising radiation at CRT screens is usually around two orders of magnitude lower than the level of natural radiation to which all humans are constantly exposed [3; 5]. This research also measured the radiation behind the monitors – an especially important aspect when several people work in one office and are consequently very close to the back of the monitor opposite them. Even in these cases, however, the additional exposure caused by X-rays emitted from the DSE was far below the level of natural radiation exposure.

Owing to the imaging technology they use, LCD screens do not generate any ionising radiation.

Optical radiation

Optical radiation is subdivided into ultraviolet radiation (UV), visible radiation (light) and infrared radiation (IR).The radiation in the visible spectrum is the desired form since screens' display functions use visible light.

All three types of radiation mentioned above are generated inside CRT equipment when the electron beam from the tube hits the fluorescent layer. IR radiation is also produced as a result of heat build-up in the tube's cathode.

Almost all of the UV radiation generated in CRT monitors is absorbed by the glass of the tube so the intensity measurable outside on the screen's surface is very low [6]. For instance, the maximum irradiance measured in the UV-A range is lower than 10 mW/m^2 [7]. The UV-B radiation values are three to six orders of magnitude below that. The UV-A exposure for an eight-hour work shift is less than 288 J/m^2, comparable with the eye exposure threshold values of 10,000 J/m^2 recommended by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) [8 to 10]. Consequently, UV radiation emission from CRT screens does not pose a risk for humans.

The intensity of the visible radiation emitted by CRT monitors in order to display information is considerably lower than the level that is potentially harmful to the eyes.

IR radiation emission from CRT display screen equipment is also negligible [6].The measured irradiance is 200 mW/m^2 [7] whilst the limit values recommended by the ICNIRP is 100,000 mW/m^2 [11]. Health risks from IR radiation emission are therefore unlikely too.

Besides the desired visible radiation, LCD screens emit UV and IR radiation. However, the UV and IR intensity is low and roughly equivalent to that of conventional fluorescent tubes. This means that LCD screens are not harmful to users either, be it through the visible radiation or UV and IR radiation emissions.

7.3.2 Display screen robustness to lighting

Display screens have optically transparent surfaces that reflect part of the light that falls on them. This reflection is either spectral (e.g. in the case of untreated screen surfaces) or diffuse (e.g. in the case of roughened screen surfaces).

Unwanted reflection is disadvantageous in DSE work because it reduces the contrast between the individual characters on the screen, making it more difficult to distinguish between them. Moreover, users have to concentrate harder in order to comprehend the information on the screen properly. The stronger the reflection, the more adverse the effect on the user, which is why screens should always have an anti-glare surface. It is therefore essential that buyers of display screen equipment ensure the equipment has good anti-glare properties. This is particularly true of notebooks, which are often used in lighting conditions that are less than ideal.

In the past, the reflective properties of display screens were divided into three reflectance classes, for positive and negative display, in accordance with DIN EN ISO 9241-7 [12] and DIN EN ISO 13406-2 [13]. The current standard, DIN EN ISO 9241-307 [14], no longer includes these reflectance classes. Instead, it specifies the test conditions under which display screen reflection should be measured (Table 11). Accordingly, today's Geprüfte Sicherheit (GS; tested safety) certificates include the following statements:

Light source with large aperture = 200 cd/m²

and

Light source with small aperture = 2,000 cd/m²,
equivalent to former reflectance class I

A display screen with these anti-glare properties can be used without hesitation in any office environment and is therefore unconditionally recommended.

Since screens' reflective properties depend on the display mode, there might be different figures given for positive and negative display. If not, the equipment either comes with positive or negative display only or it has the same reflective properties regardless of the display mode.

In addition to these anti-reflection measures, another step that can be taken is to display dark characters on a light background (positive display). This reduces the disruptive effect of any reflections that cannot be completely avoided as well as lessening the restrictions on the positioning of equipment within the work environment.

It should also be noted that colour difference, i.e. the difference between two colours, becomes more difficult to discern with increasing illumination of the screen from the ambient lighting. This is particularly true with screens that offer good anti-glare properties. The same applies to luminances and contrasts, though to a lesser degree. It is for these reasons that manufacturers now state the on-screen illuminance for which the product is suitable. Technical data sheets and GS certificates indicate the intended screen illuminance in lux. This parameter refers to the maximum permissible illuminance on the screen from the ambient lighting. The actual illuminance on a given screen can be measured at the workstation in question using a luxmeter (with the probe turned outwards).

To ensure that screens can display distinguishable colours even at workstations close to windows, it is recommended to use screens with a declared intended screen illuminance of at least 1,500 to 2,000 lux. Although reflective screens are not as sensitive to high illuminances, their higher reflectance makes them unsuitable for office environments (see above).

As filters added in front of screens often result in poorer display, they should only be used once all factors have been carefully considered. For instance, it should be possible to adjust the screen brightness to compensate for any reduction in brightness caused by attaching a filter.

Table 11:
Reflectance classes as per DIN EN ISO 9241-307 and former reflectance classes as per DIN EN ISO 13406-2;
large AP = large aperture, small AP = small aperture

Reflectance classes as per DIN EN ISO 9241-307, Luminance from directed reflected light sources in cd/m²	Suitable environment	Former reflectance class as per DIN EN ISO 13406-2
$L_{large\ AP} = 200$ and $L_{small\ AP} = 2\,000$	Screens of this type can be used in any office environment.	I
$L_{large\ AP} = 200$ or $L_{small\ AP} = 2\,000$	In unfavourable lighting conditions or locations close to windows, unwanted reflections may appear on these screens.	II
$L_{large\ AP} = 200$ or $L_{small\ AP} = 2\,000$	The reflection on these screens is usually so disruptive that they are not suitable for office work in normal office environments.	III

7.3.3 References

[1] Verordnung über Sicherheit und Gesundheitsschutz bei der Arbeit an Bildschirmgeräten (Bildschirmarbeitsverordnung – BildscharbV) vom 4. Dezember 1996. BGBl. I (1996), p. 1843-1845; last revision BGBl. I (2008), p. 2768

[2] DGUV Information 215-410: Bildschirm- und Büroarbeitsplätze – Leitfaden für die Gestaltung (formerly BGI 650). Published by: Verwaltungs-Berufsgenossenschaft, Hamburg 2012

[3] Handbuch Nichtionisierende Strahlung. Published by: Berufsgenossenschaft der Feinmechanik und Elektrotechnik (BGFE), Cologne 1999 – Loose-leaf ed.

[4] DGUV Vorschrift 16: Elektromagnetische Felder (formerly BGV B 11) (06.01). Carl Heymanns, Cologne 2001

[5] *Lauterbach, U.*: Strahlenexposition durch Datensichtgeräte. In: PTB-Berichte – Serie Dosimetrie Nr. 10. Published by: Physikalisch Technische Bundesanstalt (PTB), Braunschweig 1984

[6] *Bittighofer, P. M.*: Strahlenemissionen aus Bildschirmgeräten. Arbeitsmed. Sozialmed. Präventionsmed. 23 (1988) No. 11, p. 269-274

[7] *Marriott, I. A.; Stuchly, M. A.*: Health aspects of work with visual display terminals. J. Occup. Med. 28 (1986) No. 9, p. 833-848

[8] International Commission on Non-Ionizing Radiation Protection: Guidelines on limits of exposure to ultraviolet radiation of wavelenghts between 180 nm and 400 nm (Incoherent Optical Radiation). Health Physics 49 (1985) No. 2, p. 331-340

[9] International Commission on Non-Ionizing Radiation Protection: Proposed Change to the IRPA 1985 Guidelines on Limits of Exposure to Ultraviolet Radiation. Health Physics 56 (1989) No. 6, p. 971-972

[10] International Commission on Non-Ionizing Radiation Protection: Guidelines on UV radiation exposure. Health Physics 71 (1996) No. 6, p. 978

[11] International Commission on Non-Ionizing Radiation Protection: Guidelines on Limits of Exposure to broadband incoherent optical radiation (0,38 to 3 µm). Health Physics 73 (1997) No. 3, p. 539-554

[12] DIN EN ISO 9241-7: Ergonomische Anforderungen für Bürotätigkeiten mit Bildschirmgeräten – Teil 7: Anforderungen an visuelle Anzeigen bezüglich Reflexionen (12.98). Beuth, Berlin 1998 (zurückgezogen)

[13] DIN EN ISO 13406-2: Ergonomische Anforderungen für Tätigkeiten an optischen Anzeigeeinheiten in Flachbauweise – Teil 2: Ergonomische Anforderungen an Flachbildschirme (12.03). Beuth, Berlin 2003 (zurückgezogen)

[14] DIN EN ISO 9241-307: Ergonomie der Mensch-System-Interaktion – Teil 307: Analyse- und Konformitätsverfahren für elektronische optische Anzeigen (06.09). Beuth, Berlin 2009