Review
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The role of the ophthalmologist in forensic medical judgement for videoterminalists

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Abstract

This work describes what are the regulations in the field of safety and prevention in the workplace, with particular regard to the legal medical aspects of the doctor in charge of Occupational Medicine in correlation with ergophthalmological examinations.

The main subjects of this treatment are the employees videoterminalists. The first part of this work aims to analyze the compliance, as well as laws and legislative decrees governing the obligations and duties of the employer to its employees, regarding the compliance of workplaces and equipment with the instrument that are routinely used by employees videoterminalists.

The discussion continues by focusing on the specific aspects of the ergophthalmological examination. It also describes the different phases of the eye examination, starting from the identification of the employee and then to the collection of anamnestic data, which are an integratedpart of the medical-legal act and are also a useful tool for the final diagnosis.

The discussion of the various phases of the ergophthalmological examination concludes with a description of indirect ophthalmoscopy with its crucial points, which are important points in any ophthalmological examination.

Given the considerable diffusion and the great amount of technological innovations in the field of display screens, we conclude the discussion with a historical overview of the display screens that have been habitually used by employees in their workplace, describing the mechanism that underlie their operation through some hints of Physics. ***Clin Ter 2022; 173 (2):187-194 doi: 10.7417/CT.2022.2415***

Key words: *Ergophthalmology, Forensic medical ophthalmology, Videoterminalists*

Today more than in the past video terminals have profundly influenced our working routines, as well as the way we learn what we study and in particular how we relate to each other in our daily lives. With constant updates and new discoveries, video terminals have become a powerful tool and for some types of work computers are definitely inpispensable. New technologies have changed our lifestyles and improved our quality of life, but the continued use of these new technologies has pathophysiological effects on our health.

The pathophysiological effects on employees are directly associated with the characteristics of the working environment in which they work. In addition to the peculiarities of the work tasks carried out by the employees, the tools used, software and working time characteristic of the several types of employment are also taken into account. The occupational health physician dealing with ergophthalmology must necessarily examine the above elements, and assess both compliance and suitability in the specifics of each case. The delicate task of the occupational health physician is to assess the suitability of workplaces, equipment and any risks related to the work task carried out by employees.

The verification of fitness for work is subject to and governed by the indications of Legislative Decree 626/94, in fact, the elements that require an accurate assessment are provided for and regulated by the legislative provision in article 52 of Legislative Decree 626/94. This article makes it clear that it is the employer who personally examines the employee's workstations and assesses possible risk factors for employee's eyes health. In addition, it is always the employer who must ensure that his employees have workstations suited to their work activities and health needs, reducing possible issues due to incorrect working postures that induce physical and mental fatigue of the employee. Finally, the ergonomic and environmental hygiene conditions of the employee's workplace are taken into account.

The Decree of the Ministry of Labour of 10/02/2000 regulates the guidelines to be observed for the professional use of video terminals, and contains indications concerning both the work environments where staff will habitually carry out their duties, and the furnishings for the office or other specific workstation. The aim is to avoid or significantly reduce visual problems and mental fatigue disorders. These indications are ascribable and referable to minimum requirements.

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Italian legislation on video terminals

According to Legislative Decree 81/08 – Consolidation Act on Health and Safety at Work amended by Legislative Decree 106/09 – the employee who habitually carries out his or her work duties while working at a VDT incurs a number of plausible risks, it is therefore necessary, as well as obligatory, to verify and assess the risks together with the prompt implementation of the actions that are aimed at protecting the health and safety of the employees. Work carried out regularly in front of a VDT is considered to be a risky activity for the health and safety of workers (1,4,7). As specified and defined in Legislative Decree 81/08, which recalls what was already proposed in Legislative Decree 626/94 and Law 422/00, which observes and implements European Directives on various issues relating to safety at work. Article 173 of the Consolidation Act on Health and Safety at Work defines VDT as alphanumeric or graphic screens regardless of the type of display used. In general, this definitions agrees with that provided in Legislative Decree 626/94. The work equipment that is complete with video terminals are all those that have the aforementioned type of screen.

Article 172 of the Consolidation Act on Health and Safety at Work makes it clarifies what the possible exceptions may be in relation to the driving positions of vehicles, transport systems and also computer system that will be intended primarily for use by the public. This category also includes: calculators along with cash registers and all those machines or measuring equipment that are, however, equipped with a small screen for displaying data (2, 3, 6).

According to article 173 of the Consolidation Act on Health and Safety at Work video screen employees are all workers who habitually and systematically use a video screen to perform work tasks assigned by the employer. Working hours for videoterminals include a total of at least twenty hours a week with mandatory breaks of at least fifteen minutes every two working hours.

It is important to remember that the systematic use of the VDT involves an activity that must necessary be constant, and therefore not attributable to occasional use for short working hours. This statement modifies what was established by the previous legislative decree 626/94, which considered the continuous use of VDT_S to be at least four hours per day, and therefore the organisation of work according to how many continuous hours the worker occupies in front of the VDT is no longer decisive (5, 9, 10).

Art. 174, c. 1 is referred to as a specific provision for the analysis of special risks to eyesight and eyes to which workers may be exposed in the normal course of their work. The employer, moreover, according to art. 28 is obliged to carry out an assessment of the risks present at the beginning of the work activity. This also includes checking the work environment together with the furniture to avoid problems related to posture and mental fatigue, but also examining and taking appropriate measures for the ergonomic and hygienic conditions of the work environment: these measures are found in art. 174, c.2. The employer, therefore, has an obligation to enforce the safety measures indicated, and would be punishable if these are not complied with, or if they do not meet the minimum requirements in the workplace and the working environment in general (8, 11, 12).

As early as the 1980_S, it became necessary to regulate the use of VDT_S in some way, and it was already assumed and predicated that the use of VDT_S would lead to postural problems of varying degrees. In addition, both the visual and mental demands of the job would change substantially. Before Legislative Decree 626/94 VDT_S were among the machines that had special characteristics and functions, and previously the work activity of VDT workers was governed and regulated by the indications contained in DPR n. 547 of April 1955 (Regulations for the prevention of accidents at work) and DPR n. 303 03/19/1956 (General regulations for occupational hygiene). The following circulars of the Ministry of Labour have been issues to define the working conditions of video terminal workers:

- Ministry of Labour Circular Letter, 06/05/1985, no. 98 defining the working conditions for videoterminal workers,
- Ministry of Labour Circular Letter, 12/11/1986, giving indications on eye tests,
- Ministry of Labour Circular Letter, 04/19/1987, issuing indications for radiation control.

The Ministry of Labour Circular, 09/01/1987, no. 98 defines in general terms the rules for the application of the laws governing accident prevention, as well as the rules on hygiene in the workplace. Subsequently we have other circulars that regulating the work activity for video terminal workers:

- Ministry of Labour Circular Letter, 05/09/1988 on "Video terminal work and institutional activities of Local Health Units",
- Ministry of Public Administration Circular Letter, 02/22/1991, no. 71991 describing the guidelines for the use of video terminals in public administrations,
- Ministry of the Interior Circular Letter, 09/23/1993, no. 850 on "Health checks for video terminal workers"

Council Directive 90/270/EEC, published on 06/21/1990 in the Official Journal of the European Community no. 156, aims to supplement and better define the "Minimum safety and health requirements for work with display screen equipment".

This Directive is important because it provides definitions of: display screen, display screen workstation and VDT_S workers. The same Directive, in its annexes, contains specific and detailed safety requirements concerning workplace equipment, the general working environment and the computer-human interface. These requirements have been transcribed into the legislation transposing the Directive, updated with technical progress and an understanding of the risks (13, 15, 17).

Ergophthalmological examination

The employee must necessarily be indentified through valid identity document by the ophthalmologist. This verification is important because it constitutes a legal medical act. Before the specialist in ergophthalmology examines the employee, an interview with the patient is necessary to gather anamnestic information that is useful to the examiner in deciding on the different examination modalities, as well as prescribing higher level examinations if deemed necessary. In addition to being a legal medical act, the anamnesis is an important diagnostic tool by which the clinician is informed about the patient's general state of health, medical history and any surgery performed. The anamnesis is a crucial step in the ergophthalmological examination, which gathers information about the employee's work activity, such as: how many hours spends in front of the VDT, what kind of work and tasks performs, the employee's needs in performing a certain kind of work at the VDT.

After the anamnesis, eye convergence and conjugate movements are observed, and the cover test is performed to reveal any fories. The examination continues with an objective examination of the subject's anterior segment using the slit lamp. The objective examination in question is aimed at detecting the presence of any conjunctival inflammation or edema, which may be present when the employee spends several hours of the day in front of VDT. It is therefore very useful to examine the tear film, which may be compromised in patients with dry eye. In addition to assessing conjunctival or corneal inflammation, any inflammation of the structures of the anterior segment of the eye should also be investigated (13, 14, 16).

The objective examination proceeds by checking the trasparency of the dioptric media, first of the cornea and then of the crystalline lens, both of which must be avascular. Any corneal neovascularisation should always raise the suspiction of hypoxic distress. The depth of the anterior chamber is exmined and the angle of the chamber is estimated, and the reactivity of the pupil together the physiological eccentricity and morphology of the pupil are observed. The crystalline lens is then examined to assess its trasparency or the presence of probable sclerosis, which may be initial or advanced. If signs of cataracts are observed in either direct illumination or backlighting, by a coaxial light beam, these should be better studied by varying the slit lamp objective lens to have a optimal magnification for studying: location, depth, extent and morphology. Observation of perilimbal sclera is also important for the assessment of possible degenerative lesions such as pinguecula and pterygium, which could, depending on their extent, impair visual acuity. In order to better appreciate the scleral surface in its superior, inferior, lateral and medial extension, the subject should be asked to look in the direction opposite to the one being examined. The skin adnexa of the orbit as a whole are also assessed.

Applanation tonometry is routinely performed using a slit lamp to detect ophthalmotone, even if no signs or symptoms of endocular hypertension are found on physical examination. An intraocular pressure higher than 20mmHg will require a correction by defect through pachymetry, and if the pachymetric correction will result in ocular hypertone, will have to be evaluated before the visual acuity and after the posterior pole, espacially the excavation of the optic disc. The clinician will decide if it will be appropriate to prescribe further higher level tests for a more accurate control.

After the objective examination of the anterior segment, the examination continues with a distance and near visual acuity test, preceded by autorefractometry to assess the general refractive condition of both eyes. The Ishihara test may be performed to establish the presence of any dyschromatopsias. Finally, if there are no contraindications from the objective examination in the induction of mydriasis, mydriatic eye drops are instilled in order to obtain optimal, or at least convenient, pupil dilation for fundus oculi examination (18).

The ocular fundus examination is generally performed at the end of the eye examination and involves the analysis of the posterior segment, which includes the following structures: the vitreous body, central retina with he emergence of the optic nerve and the peripheral retina. For a complete assessment of the posterior pole and extramacular retina, as well as the peripheral retina, it is important to consider the mail landmarks.

The observation of the optic papilla and the foveal depression (recognisable by the marked pigmentation) are crucial for the distinction of the boundaries of the posterior pole, as well as of the central retina. The measurement of papillary diameters can be estimated to quantify the extent of any lesions, or the ophthalmologist can use a ruler mounted on an additional lens used with the slit lamp to objectively (standardised manner) measure the ophthalmoscopic findings. The detection of the areas in which the short ciliary nerves can be observed is of fundamental importance for orientation regarding the border of the equatorial retina. The two horizontal stripes that appear differently pigmented on ophthalmoscopic examination correspond to the course of the long ciliary nerves together with the course of the long ciliary vessels. The two bands, which have a curvilinear course in correspondence with the vertical meridians, can be appreciated due to the low pigmentation and would represent, according to C. Schepens, the closing point of the optic vesicle (19). (Fig. 1)

These landmarks and the structures that distinguish them are also important in describing the location and extent of any lesions.

Posterior pole: includes both the macula and the optic papilla, and is bounded by an imaginary circle passing externally to the optic disc and a papillary diameter away from it. The imaginary circle touches the temporal retinal vascular arcades,

Medium periphery: extends from the posterior pole to an imaginary circular line that touches the ampullae of the swirling veins at the rear,

Periphery proper: starts from the imaginary circular line that touches the ampullae of the swirling veins at the back, this circular line separates the middle periphery from the periphery proper. The periphery proper has as its anterior limit the anterior border of the vitreous base, which appears as a grey or slightly pigmented line, that Eisner called "the median white line" and corresponds to Daicker's posterior circular orbicular band; and it is located with good clinical approximation in the middle of the pars plana of the ciliary body, and it is easier to detect in aphakics subjects,

Equatorial region: straddles the equator of the eyeball. The equatorial region starts (posterior limit) from the imaginary circular line that touches the ampullae of the swirling veins posteriorly (the same circular line that marks the limit between the middle periphery and the periphery proper). The anterior limit of the equatorial region is constituted by an imaginary circular line that lies midway between the ora serrata and the equator,

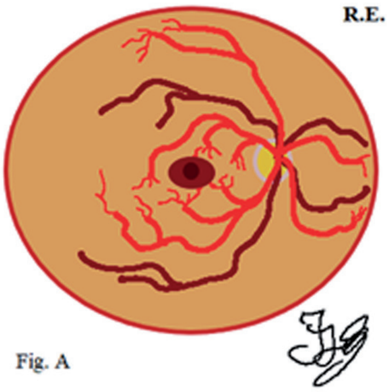

Fig. A

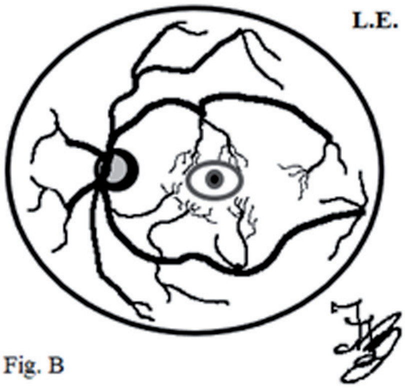

Fig. B

Fig. A: Normal retina.

Fig. B: Normal retina in black and white for best contrast.

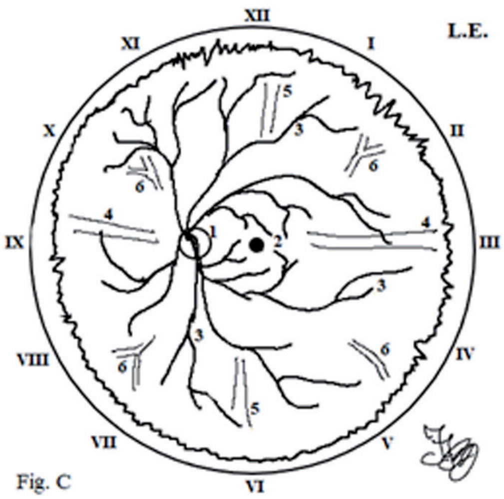

Fig. C

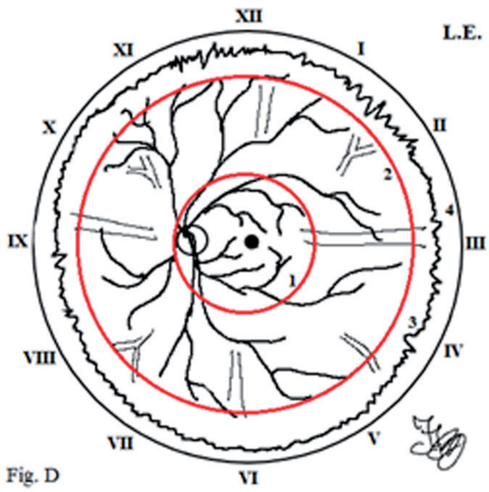

Fig. D

Fig. C: **1**) optic disc, **2**) macular region with foveal depression, **3**) retinal vessels, **4**) stripes with variable pigmentation corresponding to the course of the long ciliary vessels and nerves, **5**) low pigmented curvilinear bands along vertical meridians may represent the closure point of the optic vesicle, **6**) short ciliary nerves.

Fig. D: **1**) imaginary circle delimiting the rear pole, **2**) immaginary circle corresponding to the equator, **3**) ora serrata, **4**) extreme limit of the ocular fundus passing through the posterior border of the ciliary processes.

Oral region: situated astride the ora serrata, has its posterior limit constituted by the imaginary circular line that lies halfway between the ora serrata and the equator (anterior limit of the equatorial region), while the anterior limit is constituted by the median white line known as the extreme limit of the retinal periphery, and which always corresponds to Daicker's posterior circular orbicular band,

Anterior ciliary portion of the pars plana: anterior to the median white line (Daicker's posterior circular orbicular band) is a region of pars plana that is not part of the extreme periphery of the ocular fundus and is called the anterior ciliary portion of the pars plana. The anterior portion of the pars plana differs from the posterior portion of the pars plana in that the latter is more granular due to variations in the pigment epithelium and the presence of zonular epiciliary fibres. Only the posterior portion of the pars plana is included in the region of the extreme periphery of the ocular fundus,

Median fibrillar tract: the boundary separating the two portions of the pars plana, and which would approximately be half of the pars plana, is actually marked by the median white line. On the median white line there are thickenings of vitreous structures constituting the median fibrillar tract.

Indirect ophthalmoscopy of the ocular fundus can be performed using the slit lamp or the Schepens binocular ophthalmoscope. For the examination of the central retina and posterior pole, slit lamp ophthalmoscopy is recommended for its excellent detail rendering. The possibility of varying the magnification of the slit lamp objective allows the accurate examination of the central retinal structures and the optic nerve. Additional slit lamp lenses that can be used to assess the posterior pole can be low magnification, such as the second generation 90D lens with a magnification of 0,76x (95° - 116° field of view) and the third generation with a magnification of 0,72x (103° - 124° field of view), which can be used in addition to posterior pole examination for a panretinal examination; then high magnification 1,30x (57° - 70° field of view) lenses can be used for macular and papillary details.

Fundus oculi examination performed with the Schepens indirect binocular ophthalmoscope makes use of supplementary lenses with a dioptric power ranging from 13D (5,50x and 36° - 43° field of view) to even 40D (1,67x and 69° - 90° field of view). Objective lenses with a dioptric power close to 28D 2,27x (53° - 69° field of view) are suitable for ophthalmoscopy in subjects with myopic pupils, while additional lenses with a dioptric power equal to or even lower than 20D are recommended in order to have a higher magnification of 3,13x (46° - 60° field of view) of the details of the retinal and papillary structures of the posterior pole, but with a reduced field of analysis compared to lenses with a higher dioptric power that offer a wide field of examination but with reduced magnification. We can also state that supplementary lenses with a dioptric power equal to or greater than 25D and 2,08661 inches of diameter (56° - 73° field of view) can be used for a general panretinal examination even in subjects with small pupils (20).

Types of display screens used over time

We conclude this discussion with a look at the different types of VDT_S, that have been used and are still currently in use. With the widespread use of video terminals and new technological achievements, display screens have evolved a great deal. Let's take a brief look at the display screens used by videoterminalists over time, up to today's most sophisticated ones.

CRT display screens

The CRT screen, or cathode ray tube screen, works by focusing an electron beam, with the help of electric and magnetic fields, on a screen fitted with molecules that become excited when hit by the accelerated electrons. The acceleration of the electrons is due to the large electromotive force (potential difference) applied between the anode and cathode. This type of system has a high sensitivity and it is possible to obtain large images with modest input signal voltages. In addition, the fidelity of the reproduction of the images generated allows phenomena to be recorded on the screen at high frequencies in the order of magnitude of 10^6. The cathode ray tube consists of a glass ampoule in which there is a very high vacuum so as not to further increase the heat generated by the accelerated electron beam and to keep their trajectory straight (at least initially).

At one and is the cathode (which has a negative charge) which emits the electrons once it has been suitably heated to create a flow of electrons by thermionic emission. The generated electrons will then be accelerated by the anode, and acquiew a velocity that will allow them to have an increase in kinetic energy: $E_c = \frac{1}{2}mv^2$

The kinetic energy is that given to the electron of charge *e* by the anodic voltage equal to V_a where: and the velocity of the electron can be approximated as:

$$v^2 = \frac{2e}{m}V_a$$

Let us see in practice the calculation of the speed assumed by an electron accelerated by a d.o.p. of 100kV (typical for x-ray tubes): assume the change in kinetic energy of the electron is equal to the work of the electric field generated by the electron flow:

$$e\Delta V = \Delta K \cong K = (\gamma - 1)mc^2$$

where:

- *e*, represents the charge of the electron equal to: $-1{,}60\cdot10^{-19}$C,
- m, is considered as the rest mass of the electron equivalent to: $9{,}1\cdot10^{-31}$kg,
- γ, is the Lorentz factor:

$$\gamma = \frac{c}{\sqrt{c^2 - v^2}} = \frac{1}{\sqrt{1-\left(\frac{v}{c}\right)^2}} = \frac{1}{\sqrt{1-\beta^2}} \text{ where } \beta = \frac{v}{c}$$

and *v* is the speed of the reference system,

- c, is equivalent to the speed of light: 299792458m/s

If the initial kinetic energy of the electrons is assumed to be negligible, it will be seen that:

$$\gamma \equiv \frac{1}{\sqrt{1-\frac{v^2}{c^2}}} = 1 + \frac{e\Delta V}{mc^2}$$

$$1 - \frac{v^2}{c^2} = \left(1 + \frac{e\Delta V}{mc^2}\right)^{-2}$$

$$\frac{v}{c} = \sqrt{1 - \left(1 + \frac{e\Delta V}{mc^2}\right)^{-2}}$$

$$v = c\sqrt{1 - \left(1 + \frac{e\Delta V}{mc^2}\right)^{-2}}$$

Substituting for this, we obtain the speed assumed by the electron that has been accelerated by the potential difference of 100kV: 164331895,1m/s.

Once the velocity of the electron has been defined, it will pass through an electric field in order to be directed, and subsequently intercepted, at a point on the fluorescent screen. The electric field is created by a capacitor to which a known d.o.p. is applied. The electron is subjected to a transverse force which is a function of the intensity of the electric field between the capacitor armatures, so that the following relationship exists:

$$F = B \cdot e$$

However, the electron is stimulated by an acceleration caused by the d.o.p. applied to the cathode and anode:

$$a = \frac{F}{m} = B\frac{e}{m} = \frac{V_p}{d} \cdot \frac{e}{m}$$

It is clear that the electron is question, which has its own velocity, once placed in the electric field generated between the capacitor plates, is stimulated not only by the acceleration of the anode, but also by two movements:

– Longitudinal motion: uniform motion $S_l = vt$
– Transverse motion: uniformly accelerated motion

$$S_t = \frac{1}{2}at^2$$

Since the electron has to impinge on the fluorescent screen, it will have a well defined trajectory both from the capacitor armatures and from the magnetic coils that further serve to focus the electron beam. The calculation of the trajectory will be given by the relationship involving the quotients of time:

$$t = \frac{S_l}{v} \quad \text{e} \quad t^2 = \frac{S_l^2}{v^2}$$

If we substitute in the equation: $S_t = \frac{1}{2}at^2$

the value t^2 equal to $t^2 = \frac{S_l^2}{v^2}$

we will have that: $S_t = \frac{1}{2}a\frac{S_l^2}{v^2}$

and in view of the fact that the product K of the two ratios is almost constant, we will have that: $S_t = K \cdot S_l^2$

The trajectory of the electron, when it will cross the capacitor armature, will become parabolic. On leaving the capacitor armature the electron will continue towards a point on the screen in a straight line, and this “new” trajectory will subtend an angle θ with the horizontal line. The angle θ is important in defining static sensitivity as the tangent of the same angle: $A_s = tg\theta$

If we wanted to increase sensitivity, and have a greater transverse deviation of the electron flow (which is a function of the supply voltage of the capacitor armatures), for the same diverter voltage, decreasing the accelerating voltage is necessary; so that this phenomenon would result in a consequent decrease in focus and brightness.

Plasma display screens

The principle of operation is similar to that of the cathode ray tube screens described above, since the light emission is also based on the fluorescence of phosphors. The structure of this type of screen is made up of a matrix of cells between two sheets of glass, similar to that of LCD screens, which are in turn made up of tubes containing the fluorescent phosphors. The screen electrodes are positioned on the front glass, diaphanous and protected by a protective dielectric layer with a high secondary electron emission coefficient. The addressing electrodes are located on the glass plate to the rear of the matrix, which is also protected by a dielectric protective layer. The spatial arrangement of the electrodes follows that of a grid, with the screen electrodes having a horizontal orientation and the addressing electrodes having a vertical orientation.

The cells contain three sub-cells (themselves containing a mixture of Neon and Xenon atoms kept at low pressure) which are arranged orthogonally to the screen, covered with red, green and blue phosphors; the same phosphors also cover the dielectric at the rear of the cell. The front of the cell remains trasparent. An average d.o.p. of about 200V is applied to the intersecting electrodes in each cell, and as a result electrons are passed into the gaseous mixture contained in the sub-cell, which is ionised and becomes plasma. Ionised Xenon atoms emit ultraviolet light with λ equal to 147nm, while ionised Neon atoms produce an ionised secondary flow. The ultraviolet radiation impinges on the phosphorus atoms, which reach an excited state and, when they return to their previous energetic state, emit energy in the form of visible light (a phenomenon known as Stokes shift) in the wavelengths of the three primary colours: red, green and blue. Overall, the range of colours and shades perceived by the eye is similar to that produced by cathode ray tubes.

Liquid crystals display screens (LCD)

This screen is based on the optical properties of liquid crystals, which are contained between two glass plates fitted with electrodes for the application of electric fields. LCD_S operate in a similar way to plasma screens. Each electrode handles a small portion of the LCD panel, which can be likened to a single sub-pixel, the difference with plasma screens being that adjacent sub-pixels are not separated from each other. The liquid crystals allow the placement of two polarising filters with axes at right angles to each other, the light can be transmitted through the entire medium, and neglecting the percentage of light absorbed by the polarises, the screen is trasparent.

When the electric field is generated by energizing the screen electrodes, the molecules making up the liquid crystals are aligned parallel to the electric field lines, which results in a limitation of the rotation of the incoming light. If the liquid crystals are completely parallel with the lines of the generated electric field, the incident light is polarised orthogonally to the second polariser and will be blocked completely in its path; causing the pixel to appear unlit. The basis of image formation is the control of each individual sub-pixel, or the rotation of each individual liquid crystal. This allows the amount of light passing through the screen to be adjusted. The flaw in this mechanism in that if there are any faulty pixels, they will always appear illuminated; whereas LCD panels work in reverse, being trasparent when lit and dark when there is no d.o.p. applied to the electrodes.

LED display screens

Backlight screens are an advanced lighting technology compared to conventional LCD screens. The principle of operation assumes the existence of more than 2000 red, green and blue LED_S which, when activated in specific combinations, will produce a homogeneous light as the light passes through a diffusion plate. The light passing through the diffusion plate reaches the panel containing the liquid crystals, thus generating the final image.

There are different types of backlighting, we can have a side backlight with LED_S on the sides of the screen, or a carpet backlight which is more innovative that the previous one. The carpet backlighting portions and optimisation of each generated frame. The new OLED technology employs special organic materials for its operation, which release a great deal of brightness, thus saving energy compared to previous screens. The latest technology in the field of LED screens in the so called SED, which uses a much smaller emitter to illuminate the individual pixels, enabling the creation of very thin LCD panels with a very faithful rendering of images (21).

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