OCCUPATIONAL SAFETY 70 AND HEALTH SERIES

VISUAL DISPLAY UNITS: RADIATION PROTECTION GUIDANCE

Prepared by the International Non-Ionizing Radiation Committee of the International Radiation Protection Association in collaboration with the International Labour Organization

INTERNATIONAL LABOUR OFFICE, GENEVA

The International Programme for the Improvement of Working Conditions and Environment (PIACT) was launched by the International Labour Organisation in 1976 at the request of the International Labour Conference and after extensive consultations with member States. PIACT is designed to promote or support action by member States to set and attain definite objectives aiming at "making work more human". The Programme is thus concerned with improving the quality of working life in all its aspects: for example, the prevention of occupational accidents and diseases, a wider application of the principles of ergonomics, the arrangement of working time, the improvement of the content and organisation of work and of conditions of work in general, a greater concern for the human element in the transfer of technology. To achieve these aims, PIACT makes use of and co-ordinates the traditional means of ILO action, including:

- the preparation and revision of international labour standards;
- operational activities, including the dispatch of multidisciplinary teams to assist member States on request;
- tripartite meetings between representatives of governments, employers and workers, including industrial committees to study the problems facing major industries, regional meetings and meetings of experts;
- action-oriented studies and research; and
- clearing-house activities, especially through the International Occupational Safety and Health Information Centre (CIS) and the Clearing-house for the Dissemination of Information on Conditions of Work.

This publication is the outcome of a PIACT project.

Visual display units:
Radiation protection guidance

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Preface

This publication is one of a series of practical guides on occupational hazards arising from non-ionizing radiation (NIR), carried out in collaboration with the International Non-Ionizing Radiation Committee (INIRC)[1] of the International Radiation Protection Association (IRPA) as part of the ILO International Programme for the Improvement of Working Conditions and Environment (PIACT).

The purpose of this book is to provide information, basic reference materials and guidance regarding the safety of visual display units (VDUs) with respect to radiation emissions. It is intended for the use of competent authorities, employers and workers, and in general of all persons in charge of occupational safety and health. The following topics are covered: characteristics, measurement and levels of radiation emissions from VDUs; assessment of exposure and laboratory studies; health effects and human studies; prevention and control measures; and quality control and maintenance.

The manuscript was prepared by an IRPA/INIRC working group, chaired by Professor B. Knave, which included Dr. M. Repacholi, Dr. J. Stolwijk and Dr. M. Stuchly from the INIRC, and Dr. U. Bergqvist from the National Institute of Occupational Health of Sweden. Following comments received from INIRC members, it was reviewed in detail during the annual meeting of the IRPA/INIRC in Rome, May 1991, in cooperation with Dr. G.H. Coppée representing the International Labour Office.

This book is the result of a joint ILO/IRPA-INIRC activity and is published by the ILO on behalf of the two organizations. The ILO wishes to thank the International Non-Ionizing Radiation Committee of the IRPA, and in particular Professor B. Knave and his working group for their contribution and cooperation in the preparation of this practical guide on radiation protection aspects of VDUs in the workplace.

[1] Since May 1992 the INIRC of the IRPA has become an independent scientific body called the International Commission on Non-Ionizing Radiation Protection (ICNIRP) and has responsibility for NIR protection in the same way as the International Commission on Radiological Protection (ICRP) has for ionizing radiation. (ICNIRP Secretariat: c/o Dipl.-Ing. R. Matthes, Bundesamt für Strahlenschutz, Institut für Strahlenhygiene, Ingoldstädter Landstrasse 1, D-85764 Oberschleissheim, Germany. Tel.: 49 89 31603237; Fax: 49 89 31603111.)

Contents

Summary

The visual display unit (VDU) has become a major element in the modern work environment as an interface between operator and computer. The discussion as to whether work at VDUs can affect human health has been centred on different types of effect such as eye changes or discomfort, musculoskeletal problems, adverse reproductive outcomes, skin disorders and stress reactions.

Ergonomic and organizational concerns pertaining to eye discomfort, stress reactions or pain in the neck or the wrists and other musculoskeletal disorders, motivate a number of preventive or remedial actions. Such actions should be directed towards the VDU entity, the workplace, the work environment, the design of the work task and work organization. A large number of national and international provisions, studies, documents and recommendations have been published.[1]

A number of careful studies have measured the electromagnetic radiation or fields from different types of VDUs. Until recently most screens have been based on the cathode ray tube (CRT) technique. Liquid crystal (LCD), plasma and electroluminance (ELD) displays are more recent advantageous alternatives because of low weight (easy to carry around) and lower electromagnetic fields. Their disadvantages are poor visual ergonomics (low contrast and small usable viewing angles) and long change-over times. However, LCD screens have, during the last years, reached a more acceptable stage of development. This guide focuses on radiation issues of CRT-based VDUs, which may be summarized as follows:

X-ray radiation: This is produced within the CRT. The glass material of the tube, however, effectively prevents any leakage of X-ray radiation outside the tube. Thus, X-ray emission from VDUs is not detectable.

Ultraviolet radiation (UVR): UVA (long wavelength UVR) radiation can be detected from certain VDUs. The levels are, however, insignificant compared to present IRPA/INIRC general population and occupational standards, and also insignificant compared to emission from other sources (e.g. sunlight through windows).

Light: Visible radiation is emitted and is necessary in order to perform the intended function of the VDU – to provide a visual display. Luminance levels are

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[1] Among the documents published at the international level, the following could be mentioned:

WHO: *Visual display terminals and workers' health*, WHO Offset Publication No. 99 (Geneva, 1987). This document contains a comprehensive review of the various health problems confronting VDU workers. The review is current up to 1986-87.

idem: *Update on visual display terminals and workers' health*, WHO/OCH/90.3 (Geneva, 1990). The summary statements and the recommendations in the 1987 document are here updated.

EEC: Council Directive on the minimum safety and health requirements for work with display screen equipment. *Official Journal of the European Communities*, L156/14, 1990 (Luxembourg). This document contains the minimum requirements of European Community members, applicable from 31 Dec. 1992.

ILO: *Working with visual display units*, Occupational Safety and Health Series No. 69 (Geneva, 1989).

adjustable to the comfort of the operators and are far below current exposure limits.

Infrared radiation (IR): IR is emitted from all bodies. Since all surfaces of the VDU are at room temperature or slightly above, IR can be detected, although at levels far below any limits of concern for health.

Low-frequency electromagnetic fields: In the radiofrequency (very low frequency, VLF) range and extremely low frequency (ELF) field range, electric and magnetic fields can be measured. The dominant sources are the power supply (at 50/60 Hz) and the horizontal and vertical sweep generators (at frequencies of 15-35 kHz and 50-80 Hz, respectively). These fields do not represent any risk factor when compared with current IRPA/INIRC general population or occupational guidelines. Epidemiological studies have generally failed to show an association between the use of VDUs emitting those fields and various health problems that have been suggested as due to those fields. Attempts to relate health hazards to explicitly measured fields emanating from VDUs have also been unsuccessful.

Electrostatic fields, air ions: Electrostatic fields at VDU workplaces have been suggested as a possible cause of skin disorders. The magnitudes of electrostatic fields are greater in the environment of VDU operators than for office workers without VDU work. This may, in turn, cause changes in light air ion concentrations. No correlations between electrostatic fields from the VDUs or air ions at operator positions and skin problems have, however, been found.

Ultrasound: Airborne ultrasonic (acoustic) radiation is produced in CRTs as a result of mechanical vibrations generated in the core of the flyback transformer (responsible for the horizontal sweep of 15-35 kHz). The sound pressure levels found are considerably below existing general public and occupational limits of exposure levels. Some individuals may detect this or a subharmonic in the higher noise frequency region as an annoying factor.

Health effects which have been suggested as caused by exposure to electromagnetic radiation or fields include adverse pregnancy outcome, skin disorders and cataracts of the eyes. Comparison of the occurrence of cataracts and of adverse pregnancy outcomes among VDU operators to those of the reference group have failed to show an excess occurrence due to VDU work. In some countries, a number of VDU operators have experienced skin complaints. The relationship of these to specific factors of VDU work is not known.

Based on current biomedical knowledge, it can be concluded that there are no health hazards associated with radiation or fields from VDUs. Thus there is no scientific basis to justify shielding or radiation monitoring, nor eye examinations to search for ocular pathology due to radiations in VDU operators. However, since a large number of people are involved in VDU work, it is important that further knowledge is gained on certain areas where our knowledge must be regarded as incomplete:

(a) further investigations should be undertaken to determine the possibility that skin complaints may be related to VDU work;

(b) the possibility of interactions between low-frequency magnetic fields and biological systems requires – in general – further work. Consideration should be given to magnetic fields in various situations, and should not be restricted to VDU work situations.

1

Scope and purpose

The visual display unit (VDU) has, in a very short period of time, emerged from comparative obscurity in scientific laboratories to become an integral and indispensable part of normal working life for millions of people in workplaces. As the technological revolution continues, the use of computers with screen-based output units or VDUs grows at an ever-increasing rate. Worldwide, millions of VDUs are now in use, receiving and processing information on television-like screens or monitors.

When one considers the revolutionary change in work practice thrust upon so many people at such speed by the precipitate introduction of digital computer technology, it is not surprising that concerns have been raised. At the onset, these were centred on observed problems such as eye fatigue and on perceived or expected changes in working life. Later, towards the end of the 1970s, concerns about radiation surfaced, largely owing to the use of television technology in the manufacture of VDUs and the discussion on X-ray emission from television screens that had persisted since the 1950s. Spurred by concerns about health effects and possible harmful radiation, VDU operators have voiced their concerns through the media and their unions. These concerns have arisen from case reports of cataracts, miscarriages, birth defects, premature births, newborn deaths and skin rashes. Other concerns centre on non-radiation issues: eye strain and irritation, repetitive strain injury to hands and arms, blurred vision, and neck and shoulder aches.

Many operators are women, often of child-bearing age, and particular concerns have been expressed about possible effects on pregnancy from emissions of low-level radiation or from some other unknown factors. Controversy has arisen because of reports from over 20 work sites around the world claiming an unusually high number of pregnancy problems among VDU operators. These have been termed "problem pregnancy clusters".

In response to all these problems and concerns, working guidelines or legislation have been adopted in several countries requiring a number of actions such as radiofrequency (RF) shielding of VDUs, non-VDU work during pregnancy, employer-provided eye examinations, regular work breaks, screen image quality assurance and ergonomic demands at the workplace. It should be recognized that well-documented problems based on ergonomic and work organization conditions have motivated many of these actions.

The scope of this book is to address all concerns related to emissions of radiations from VDUs. It provides in particular:

- a description of the types of VDU used in the workplace;
- a summary of the radiations and fields emitted from CRT-based VDUs identifying the source(s) generating these emissions, characterizing the wavelength or frequency and strength of emission;

- an overview of measurement techniques used to determine exposure levels to VDU operators;
- a comparison between radiation and field emissions from VDUs and generally accepted international standards limiting human exposure to these emissions;
- a brief review of the pertinent laboratory studies conducted on experimental animals to determine the biological effects of the radiations and fields;
- details of studies conducted on various groups of workers, including VDU operators;
- a health risk assessment of exposure to radiations and fields from VDUs, including the scientific basis for the development of human exposure limits;
- details on the issue of VDU maintenance, its effect on radiation emissions, and the need for testing radiation emissions during the useful life of VDUs;
- information on control measures concerning the working environment and working conditions, including an assessment of the need for health surveillance of VDU operators in the workplace;
- a statement on radiation emissions and possible health consequences issued by the IRPA/INIRC is appended for use in information that can be provided to VDU operators;
- common questions with answers about VDU concerns of operators.

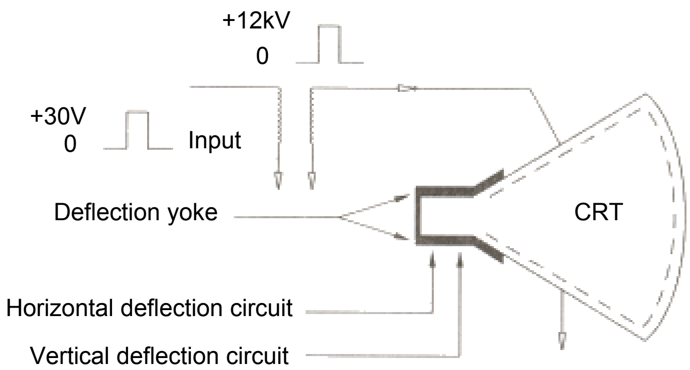
The purpose of this guide is to provide an analysis of the data from surveys and measurements of radiation emissions from VDUs, relate this to existing data on scientific biological effects and reach a conclusion regarding the safety of VDUs with respect to radiation emissions. The book is intended for the use of the competent authorities, employers and workers and their organizations, occupational safety and health specialists and VDU operators.

2

The principles of VDU construction

A VDU is essentially a television-type monitor that displays information received from a computer system or word processor rather than from a signal broadcast for television. Together with a keyboard, the VDU constitutes the interactive element between the operator and the computer system. The VDU could be linked to a main computer, as with a terminal, or the physical entity comprising the VDU could also include the computer system, as with a personal computer (PC).

Figure 1. The major components of the monitor in a conventional VDU



Source: Tell, 1990.

As shown in figure 1, the basic principle of operation of most VDUs in use is similar to that of television sets. They contain a large evacuated glass tube, called a cathode ray tube (CRT), which includes a source of electrons (the cathode) and a phosphor coating on the inside of the viewing face of the screen. Electrons released from the cathode are accelerated by a high voltage (typically in the range of 10-25 kV) towards a second electrode called the anode. They pass through a hole in the anode on to the phosphor material. This material emits visible light when struck by the fast-moving electrons. The direction and thus the impact point of the electrons on the phosphor are controlled by magnetic fields produced by deflecting coils mounted near the back of the tube. In this manner the electron beam is swept horizontally and vertically across the viewing face – the whole face normally being covered in about 1/70th of a second. By modulating the intensity of the electron beam in each position, the resulting pattern of light and dark points can be generated into a picture. The electronic circuitry used to control these processes gives rise both to radiofrequency (RF) fields and to electric and magnetic fields of lower frequencies.

More recently, solid state circuitry in conjunction with liquid crystal, gas plasma or similar display technologies has been used to replace cathode ray tubes, so far however to a rather limited extent. These displays generally produce lower field levels than CRT units since they do not use electron beams, and thus do not require the magnetic coil system. Non-CRT units will not be discussed further in this guide.

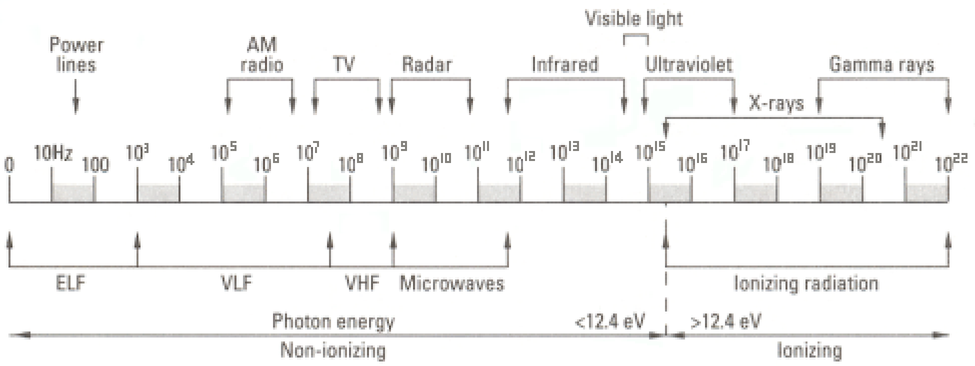
3

Types, sources, measurements and levels of electromagnetic fields from VDUs

Radiations and fields emitted from the VDU include optical radiations: ultraviolet radiation (UVR), visible and infrared (IR) radiation. Inside the CRT, soft X-rays are produced but the glass prevents any emission of X-rays from VDUs. Electric and magnetic fields are emitted in three different frequency regions: radiofrequency (RF) fields from the electronic circuitry and signal traffic, very low frequency (VLF) fields from the horizontal deflection coil circuitry, and extremely low frequency (ELF) fields from the main power supply, transformers and the vertical deflection coils. In addition, acoustic or ultrasound radiation may be produced by disk drives and the horizontal deflection system, primarily the transformer of some VDUs.

Figure 2 shows the electromagnetic spectrum, with the frequency and location in the spectrum of each radiation and field, and the typical applications. Ultrasound is an acoustic radiation, not an electromagnetic radiation, and so does not form part of this spectrum.

Figure 2. The electromagnetic spectrum of radiations and fields



The WHO, in conjunction with the IRPA, has published a series of environmental health criteria documents on non-ionizing radiations. These documents incorporate a review of the biological effects literature and an assessment of the potential health hazards posed by exposure to each radiation. The non-ionizing radiations covered are ultraviolet radiation (UNEP/WHO/IRPA, 1979), ultrasound (UNEP/WHO/IRPA, 1982a), lasers and optical radiation (UNEP/WHO/IRPA, 1982b), extremely low frequency electric fields (0-300 Hz) (UNEP/WHO/IRPA, 1984), magnetic fields (UNEP/WHO/IRPA, 1987) and electromagnetic fields (>300 [Hz-300] GHz) (UNEP/WHO/IRPA, 1993). The WHO Regional Office for Europe has also completed a detailed review of the scientific literature on the biological effects of non-ionizing radiations (WHO, 1989). These documents constitute a database for evaluation of radiation emissions of VDUs, and will be referred to where appropriate.

3.1 Ionizing (X-ray) radiation

3.1.1 Description

X-rays are a form of electromagnetic radiation with extremely high frequencies and very short wavelengths, i. e. with sufficiently high energies to enable ionizing processes (formation of ions by breaking molecules or removing electrons from matter). They form part of the ionizing portion of the electromagnetic spectrum. X-rays are produced within the VDU when the electrons are rapidly decelerated as they strike the phosphor at the front of the monitor screen. Because of the relatively low operating voltages of VDUs, X-rays produced within VDUs are much less energetic than, for example, X-rays used for medical purposes. The thickness of glass used in all monitor screens has higher X-ray shielding properties than is required for the energy level of X-rays produced by VDUs. This glass is capable of absorbing X-rays of energies considerably higher than those produced in the CRT. Thus, under all VDU operating conditions, these soft (weak) X-rays are absorbed by the glass screen of the monitor and do not penetrate the glass.

3.1.2 Measurements

X-ray emissions can be measured with a Geiger-Müller (GM) survey meter or a scintillation counter. The basic requirements are the ability to measure extremely low energy (a few kiloelectronvolts) X-rays and to have sufficient sensitivity. The meter must not be susceptible to electromagnetic interference (EMI), otherwise false readings due to electromagnetic fields around VDUs could appear.

3.1.3 Levels encountered

Numerous radiation measurements both in field and laboratory conditions have been conducted worldwide in attempts to detect ionizing (X-ray) radiation emissions from VDUs. Basically, these attempts have failed, in that no detectable emissions beyond the "natural" or "instrumental" backgrounds could be detected (Cox, 1984; Moss et al., 1977; Weiss and Petersen, 1979; Phillips, 1981; Terrana et al., 1982; Wolbarsht et al., 1980; Paulsson et al., 1984; Murray et al., 1981; Health and Welfare Canada, 1983; Pomroy and Noel, 1984; Joyner et al., 1984; Bureau of Radiological Health, 1981).

Emissions of X-rays from VDUs are so weak that they cannot penetrate the front glass screen and so cannot be detected against the normally encountered background levels of ionizing radiation. In order to quantify precisely these low emissions, sophisticated measurement equipment must be used and the measurements conducted inside a shielded locality (low background/whole-body counter) where the radiation background levels are very low. Such measurements provide no indications that VDUs emit X-rays. In one survey, the Bureau of Radiological Health (1981) of the United States Department for Health and Human Services, Food and Drug Administration, made measurements under controlled laboratory conditions of X-ray emissions from 125 VDUs. Measurements were performed during normal operation and under failure mode conditions where key components in the circuitry were deliberately failed to produce the theoretically maximum radiation emission. Of the 34 VDUs tested, and of 91 units previously tested and subsequently re-analysed, no detectable level of X-rays was found for 117 units, while eight units emitted levels around or above 0.5 mR/h at 5 cm from the screen surface. All these latter models were either withdrawn or refused entry into the market. Since these tests on early VDUs (up to 1978), none have been found to emit X-rays.

3.1.4 Evaluation in terms of standards and requirements

As the large number of tests cited above show, no VDU unit under normal operating procedures was found to emit X-rays. It can therefore be considered established that the soft X-rays produced within VDUs are absorbed within the screen, so that no X-ray exposure due to the VDU affects the operator. Although a few units were, prior to 1978, shown to emit levels above 0.5 mR/h under artificially induced conditions ("worst case"), such faulty units appear no longer to be found. Thus, VDU units can be stated to conform to standards in terms of X-ray emission.

3.2 Optical radiation

Ultraviolet radiation (UVR), visible radiation and infrared radiation (IR) are collectively referred to as optical radiation. The distinction between ultraviolet radiation and light, for example, is basically determined not by any qualitatively different physical properties, but by the fact that radiation of only certain wavelengths penetrates to the retina of the human eye and so is capable of producing the physiological reaction of vision; thus light is physiologically distinct from UVR.

3.2.1 Ultraviolet radiation

UVR of wavelengths longer than about 335 nm (i.e. UVA radiation) is emitted at low levels from some VDU screen phosphors, essentially dependent on the emission characteristics ("colour") of the phosphor. The UVR emission is greatly attenuated by the thick glass screen of the display tube because glass is an excellent absorber of UVR; this effectively precludes emission of shorter wavelength UV radiation.

3.2.2 Light

Light (wavelength 400-760 nm) is the useful and essential component of emission from a VDU. The type of phosphor used in the VDU screen determines the colour of the activated part of the display on a monochrome monitor, for example, white, green or amber, with the non-activated part usually being dark grey or black. Multicolour monitors use a special phosphor material and an electron gun to produce colour images, basically by activating three different phosphors in points very close to each other. The colour is then determined by the relative intensities/luminances of these three activated points. The brightness level of the display is adjustable for operator comfort. The levels of light emitted by the CRT are low when compared with the some 200 times higher light level outdoors on a cloudy day.

The emission of visible light is the useful visual component of the VDU unit. As such, it has a necessary biological effect in that we perceive this light. The perception of light may, however, be related to unwanted physiological reactions in terms of fatigue or eye strain due to characteristics of the light such as glare or flicker. These conditions and effects are legitimate concerns from the standpoint of vision ergonomics, but their existence should not be confused with the radiation issues discussed here.

3.2.3 Infrared radiation

IR (wavelength 760 mn-1 mm) is commonly referred to as heat, emitted from any warm object. Since VDUs contain a high-voltage power supply and various electronic circuits, heat is generated whenever the system is on and current flows. Much of this heat is carried away by movement of surrounding air, and only very low levels of IR are radiated. The warm air may cause unwanted increases in room temperature – an ergonomic consideration.

3.2.4 Measurements of optical radiation

Instruments measuring optical radiation can be either broadband, covering a considerable part of the optical radiation range, or able to operate over a very narrow and selective wavelength region. The latter (spectroradiometers) can thus be used to scan the entire region of light, for example, and thus produce a spectrum. The quantity used to characterize exposure for "each" wavelength is spectral irradiance with units of $W/(m^2.nm)$, normally presented in a curve across the region in question. Emission is expressed in units of $W/(m^2.sr.nm)$, which corresponds to the exposure in a standard cone with a 1 sr solid angle. Thus, emission is distance independent, in contrast to exposure which decreases with distance.

When summarizing the emission across a wider part of the spectrum by a broadband instrument, an important issue arises in that different wavelengths have very different biological properties. For example, vision is most efficiently produced (under bright conditions) by light of 555 nm, while light of other wavelengths is less effective. Thus a summary of all wavelengths should take this into account. This is done by incorporating a filter in the instrument, which reduces less efficient wavelengths by an appropriate amount prior to recording, or by using a spectroradiometer (as described above) and determining the level by computing the resultant outcome according to the relevant spectral weighting scheme.

For UVR, different spectral weighting schemes exist, based on UVR between 270 nm and 300 nm as being the most biologically efficient wavelengths for producing various ocular and skin reactions. The quantity "irradiance" is a measure of exposure rates in a (specified) region with units of W/m^2. The biologically weighted radiant exposure of equivalent dose, for a specified time, has units of J/m^2 effective.

When considering optical radiation, a number of constraints have to be made in the measuring situation, depending generally on the purpose of measurement. For radiation protection purposes, emission measurements of optical radiation should be performed with the VDU brightness adjusted to its maximum. If the VDU is capable of presenting a positive polarity image (i.e. dark characters on a bright background), then a uniform bright background should be arranged. If the VDU is strictly to be used for negative polarity (i.e. bright characters on a dark background), the (dark) screen should be completely filled with (bright) character M; measurements should then be conducted at a specified distance and with background light eliminated.

Other considerations are necessary when measuring the optical radiation from an ergonomic standpoint. The ISO Standard IS 9241 Part 3 (ISO, 1990) gives instructions on how such measurements are to be conducted in order to comply with the requirements of the standards. The voluntary test requirements of the Swedish Board for Technical Accreditation (MPR, 1990a) also include detailed instructions on photometric measurements of light from VDUs.

3.2.5 UVR levels

A number of authors have measured the UVR from VDUs. Generally, emissions were not detected at wavelengths shorter than some 340 nm, thereby excluding the UVB and UVC regions. In the UVA region, however, exposure levels varied considerably between investigations, from non-detectable or, in one instance, a detected level of 0.1 μW/m², to some 0.001 W/m² (Cox, 1984; Moss et al., 1977; Weiss and Petersen, 1979; Murray et al., 1981; Bureau of Radiological Health, 1981; Health and Welfare Canada, 1983; Joyner et al., 1984; Paulsson et al., 1984; Wolbarsht et al., 1980; Phillips, 1981). Both differences in measurement practices and differences in VDU phosphor types would be responsible for the variation. Generally, these data were expressed in terms of exposure; thus variations in measuring distances become important.

Field-type UVR exposure measurements of VDU and non-VDU workstations have been carried out, for example, by Knave et al. (1985b). They found that ambient exposures for VDU workers in Stockholm latitudes were about 0.04 W/m², and for non-VDU workers 0.13 W/m². They attributed the higher levels for non-VDU workers to actions taken due to the presence of VDUs, such as decreasing the ambient room illumination or drawing blinds across windows.

3.2.6 Light levels

The levels of measured emission or exposure from VDUs vary with settings and, for exposure of the eye, this depends also on the part of the eye which is considered. However, photometric emission is normally less than 100 cd/m² and radiometrically less than 10 W/(m².sr) (Cox, 1984; Moss et al., 1977; Murray et al., 1981; Bureau of Radiological Health, 1981; Health and Welfare Canada, 1983).

The momentary levels of the peak emission at the time when the electron beam impacts a point on the phosphor may, for "fast phosphors", be higher than 10,000 cd/m² but, due to the very short duration of those phosphor pulses, this would correspond to an average emission of the order of 50 cd/m² (Nylén and Bergqvist, 1986).

Generally, light emissions from VDUs are more of an ergonomic than a radiological problem. The problem is more often that the light levels are too low, especially compared with those used to read manuscripts (Knave et al., 1985b). There have, however, been instances where bright light settings have caused discomfort, for example, for individuals with light sensitivity.

3.2.7 IR levels

Emissions of IR were measured around over 200 different models of VDU (Cox, 1984). In the near infrared region (760-1,050 nm) the maximum emission measured was 50 mW/m², but no far infrared radiation was detectable. Others have produced similarly low readings (Moss et al., 1977; Weiss and Petersen, 1979; Bureau of Radiological Health, 1981; Health and Welfare Canada, 1983).

3.2.8 Evaluation in terms of standards and requirements

As the levels of UVR, light and IR emitted from VDUs are very low, no acute effects occur and consideration of radiation is only necessary for delayed or late effects from low-level chronic exposure to each of the optical radiations. Emissions of optical radiations are considerably lower than various general public or occupational standards, or compared with other sources such as sunlight or many artificial light sources. Although these standards are set primarily from consideration of acute effects, the very low levels encountered from VDUs when evaluated in terms of these standards, combined with the fact that VDU emissions are small compared with those associated with other sources in offices, are sufficient to disregard these emissions as a health hazard.

From an ergonomic viewpoint, both light and heat emission from VDU equipment may be of concern only in terms of fatigue and some other physiological effects. One primary concern is that while the minimum attainable luminance level of VDUs should be 35 cd/m², with higher levels of some 100 cd/m² often being preferred (ISO, 1990), such levels are not obtainable by all existing VDUs.

3.3 Radiofrequency fields

3.3.1 Microwaves

Microwaves are a subset of the radiofrequency range and comprise a part of the electromagnetic spectrum with wavelengths between 1 mm and 1 m, corresponding to frequencies of 300 GHz to 300 MHz. Thus, this region is adjacent to but with longer wavelengths than the infrared radiation region. Microwaves are not deliberately produced, but may be emitted at extremely low levels from VDUs as part of an "electronic noise" from various signal traffic processes (see further discussion below).

3.3.2 Radiofrequency fields between 300 MHz and 300 kHz

Fields with frequencies of 300 MHz to 300 kHz are used commonly for broadcast and television signals. VDUs and their associated computers, like other electronic equipment, operate on and generate RF signals. One source of such fields is the signals which are modulated at some 3 to 30 MHz in order to produce variations of luminance between subsequent spots on the screen. These fields contain information about the characters on the screen, and detection of such fields from a distance makes it possible to determine this information. Thus, these fields are usually kept at very low levels to avoid the possibility of "espionage".

In addition to the basic modulation frequency, harmonics may appear owing to the non-sinusoidal variation of these fields over time. It is conceivable that part of this harmonic spectrum may extend into the lower part of the microwave spectrum.

3.3.3 Measurements

In principle, the term "radiation" is restricted to propagating electromagnetic phenomena that can be described as an orthogonal combination of the electric and magnetic field components. Only one of these components needs to be measured and the other can be determined from a simple relationship between them. The exposure or power density is normally described as the product of these two components and is in units of W/m^2. The requirement for such a description is that the distance from the source to the observer is sufficiently large. For coherent sources this corresponds to the distance being greater than λ or $2a^2/\lambda$ – whichever is the greater – where a is the dimension of the source, and λ is the wavelength (IRPA, 1991). If this requirement is not met, the electric and the magnetic fields must be separately described, since there is no longer any simple relationship between them. In this case the measuring unit is volt per meter (V/m) for the electric field, and ampere per meter (A/m) for the magnetic field. The magnetic field can also be expressed as the magnetic flux density in tesla (T) or in gauss (G). In air, the relationships between these units are:

$$1\ \text{G} = 10^{-4}\ \text{T}$$

$$1\ \text{A/m} \approx 1.3 \times 10^{-6}\ \text{T}$$

Because of the operator's proximity to the source of RF emissions from VDUs, these fields are best described in terms of electric and magnetic fields. In other situations further from the source, RF fields may be adequately described as radiation.

Because of RF field perturbations (particularly in the case of electric fields) and direct coupling of the meter to the elements producing the fields, measurements at distances close to the VDU surface (closer than about 0.15 m) are frequently in error and should not be relied upon. A more reasonable distance for measurements is 0.5 m.

Some instruments give indications of the total magnetic field independent of its direction. However, others respond only to one direction of the field. In order to obtain the total field, the meter's sensor has to be placed in three mutually perpendicular directions (x-, y– and z-) and the readings added using the following formula:

$$A_t = [\, A_x^2 + A_y^2 + A_z^2 \,]^{1/2}$$

where A_t is the total magnetic field strength (A/m) or the magnetic flux density (T), A_x is the component in the x-direction, and so on.

These general considerations for field measurements apply also to fields of lower frequencies described below.

3.3.3.1 Microwave levels

Generally, microwave emissions from VDUs have not been detected (Cox, 1984; Phillips, 1981). In one survey, Weiss and Petersen (1979) reported low readings at 1.4 GHz, but attributed these to the computer and not to the display terminal. As suggested above, microwave harmonics of the high radiofrequency signal traffic could conceivably be found around VDUs.

3.3.3.2 Radiofrequency field levels

Emissions of electric and magnetic fields in these frequency regions are detected, with levels found at operator distances in the order of 1 mV/m and some tenths of mA/m (Cox, 1984; Weiss and Petersen, 1979; Bureau of Radiological Health, 1981; Moss et al., 1977; Terrana et al., 1982; Wolbarsht et al., 1980).

3.3.4 Evaluation in terms of standards and requirements

Detailed analyses of scientific reports on exposure of animals to microwaves and radiofrequency fields have been conducted by UNEP/WHO/IRPA (1993), WHO (1989) and IRPA (1988a). All of these reports concluded that, in the microwave region, there is a threshold exposure of some 1-4 W/kg specific absorption rate of energy required to produce any adverse effect in laboratory animals. Such rates are orders of magnitude higher than those due to VDU exposure. Furthermore, the calculated energy deposition from typical fields around VDUs is totally insignificant compared to metabolic heat (Stuchly et al., 1983).

Microwaves are not deliberately emitted from VDUs and the levels of RF fields found are several orders of magnitude below existing standards around the world.

3.4 Very low and extremely low frequency fields

3.4.1 Description

Very low frequency fields of frequencies of some 15-50 kHz are found around CRT-based VDUs. The source and the primary frequency is due to the horizontal deflection system, i.e. the line frequency. Harmonics of up to ten times this line frequency can usually be found (Paulsson et al., 1984). The electric fields are often centred around the flyback transformer, while the magnetic fields are more oriented towards the deflection coils. Extremely low frequency fields are also found. A VDU-specific source is the vertical deflection system, i.e. the image frequency. In television sets, this frequency is usually 50 (or 60) Hz. Modern VDUs, especially those with positive polarity, often use somewhat higher frequencies (of about 70 to 80 Hz) to avoid flicker problems. In addition, VDUs also contain sources of 50 or 60 Hz fields, due to the power source.

3.4.2 Measurements

The characteristics of both the electric and the magnetic fields are distinctly non-sinusoidal in the very low frequency region, the magnetic field basically having a "sawtooth" appearance, while the electric field is better described as "spiked". (It should be noted that this description is actually a time domain alternative to the spectral domain analysis performed when describing the fields in terms of basic frequencies and harmonics.) In the extremely low frequency region, a similar description applies in principle. However, these latter fields are mixed with other fields of different appearances, making the final appearance somewhat less distinct.

A controversy has existed as to the appropriate parameter by which to measure (at least) the magnetic fields. Alternatives being used are the magnetic field (or flux density) in A/m (or T), or the time derivative of the field (in mT/s). Furthermore, both peak-to-peak and root-mean-square (rms) characterizations have been utilized. Lately, the emphasis has centred on rms field strengths/flux densities.

Standards for measuring electric and magnetic fields in office environments have been drafted in Sweden (SEK, 1989), including both electric and magnetic fields in the very low and extremely low frequency regions. Basically, alternating fields (electric and magnetic) are measured in the frequency domain – on the premise that the measurement system should be adaptable also to sources other than VDUs.

3.4.3 VLF and ELF field levels

Emission levels of electric and magnetic fields have been measured by a number of investigators. For example, at frequencies between 15 kHz and 125 kHz, electric fields of up to 64 V/m and magnetic fields up to 0.69 A/m have been measured at 5 cm distance from VDUs by the Bureau of Radiological Health (1981). These emission levels decreased to 2.4 V/m and 0.04 A/m, respectively, when measured at a distance of 30 cm.

Exposure levels at operator distances found around VDUs have been increasingly monitored. In general, the very low frequency fields found around VDUs are by and large due to the VDU, while the exposure levels of extremely low frequency fields are more often due to a number of sources, including but not necessarily dominated by the VDU. Although a large number of measurements have recently been made, few have hitherto been published.

One example of exposure levels of VDU workstations was presented in a recent epidemiological study on pregnancy and VDU work (Schnorr et al., 1991):

- very low frequency electric field: about 3-4 V/m;
- extremely low frequency electric field: about 2 V/m;
- a very low frequency magnetic field: between some 25 and 130 nT;
- extremely low frequency magnetic field: about 400 nT.

These levels are in reasonable agreement with exposure or emission levels found in other studies (Bureau of Radiological Health, 1981; Cox, 1984; Paulsson et al., 1984; Terrana et al., 1982; Weiss and Petersen, 1979; Hietanen and Jokela, 1990), although a more common finding is that of lower VLF than ELF electric fields. This may, in field exposure measurements, be due for example to the presence of other electrical appliances in the vicinity of the VDU which often cause the dominant electric and magnetic ELF field exposures at VDU workstations.

3.4.4 Evaluation in terms of standards and requirements

Studies on experimental animals exposed to time-varying ELF electric and magnetic fields have been reviewed by UNEP/WHO/IRPA (1984, 1987), WHO (1989) and IRPA (1990). It was concluded that the results of laboratory studies could be grouped according to the current density induced. These were as follows:

- Between 1 and 10 mA/m² minor biological effects were reported.
- Between 10 and 100 mA/m² there are well-established effects, including visual and nervous system effects.
- Between 100 and 1,000 mA/m² stimulation of excitable tissue is observed and there are possible health hazards.
- Above 1,000 mA/m² extra systoles and ventricular fibrillation can occur (acute health hazards).

It was noted that the current density normally occurring in the body is up to 10 mA/m². Only minor non-hazardous effects occur up to 10 mA/m², and current densities greater than 100 mA/m² need to be induced for adverse health effects to occur. To induce an average current density of 10 mA/m², humans would need to be exposed to an electric field of 25-50 kV/m or a magnetic field of 5mT.

Consequently, IRPA (1990) published limits of exposure to 50/60 Hz electric and magnetic fields. For a full day's occupational exposure, these limits are: electric field strength ≤ 10 kV/m; and magnetic field strength ≤ 0.5 mT. Emissions of ELF from VDUs are incapable of causing exposure at these levels. Currently, concern exists about the possibility of various effects due to exposure levels considerably below those causing these induced current densities. No standards have, however, been developed taking such possible effects into account since they have not been verified and thus could not be evaluated in terms of health risks.

In the VLF frequency region, few standards exist. In an adjacent frequency region (100 kHz-1 MHz), guidelines do exist (IRPA, 1988a), limiting the electric field strength to 614 V/m and the magnetic field strength (at 100 kHz) to 16 A/m. Extrapolated to VDU frequencies, this would correspond to some 83 μT.

The European Community's Directive concerning minimum requirements for VDUs contains the following requirement: "All radiation with the exception of the visible part of the spectrum shall be reduced to negligible levels from the point of view of the protection of workers' safety and health" (EEC, 1990, Annex, 2(f)).

Exposures due to ELF emission from VDUs are frequently low compared with other sources in the office, and often insignificant compared with those encountered in numerous other occupations. Concerning VLF emissions from VDUs, few such comparisons are possible, since there are fewer other emission sources in similar work situations.

Recently, the Swedish Board for Technical Accreditation (MPR, 1990b) issued voluntary technical guidelines to restrict emission of VLF and ELF from VDUs. These emission guidelines were, however, not based on health or other biological aspects. Adherence to these voluntary limits would ensure, for VLF fields, that fields were as low as was technically attainable and, for ELF fields, that VDUs would not significantly contribute to exposure levels in offices. For magnetic fields, the following field levels at 50 cm around the VDU were given: ≤ 250 nT (5 Hz-2 kHz) and ≤ 25 nT (2 kHz-400 kHz). For electric fields, the levels were: ≤ 25 V/m (5 Hz-2 kHz) and ≤ 2.5 V/m (2 kHz-400 kHz).

3.5 Electrostatic fields

3.5.1 Description

Static electric fields (of zero frequency) occur generally when the surface of objects collect an electric charge that is not immediately carried to ground or discharged. Static electric fields around VDUs originate owing to the acceleration potential inside the VDU, and a secondary potential being caused by this on the glass surface. As such, these levels are very dependent on the surface conditions in terms of conductance, which in turn are influenced, for example, by the relative humidity of the room. Subsequent to a static charge build-up on this surface after the VDU is switched on, some reduction in field strength is often found, ostensibly due to the collection of counter ions (ions of opposite charge) and charged dust particles on the glass material.

A second common source of static electric fields in the VDU work situation is that due to the operator. This is frequently noticeable in conditions of low relative humidity, for example, below some 20-30 per cent. The total electrostatic field is then due to both these sources.

3.5.2 Measurements

Measurements of electrostatic fields from VDUs have been described (MPR, 1990a). By using a standardized situation, the equivalent surface potential of the screen can be calculated. Thus, measurements of VDU emissions are increasingly reported not as field strengths, but as the equivalent potential (V).

3.5.3 Levels

Determination of the electrostatic field or equivalent surface potential is dependent on ambient conditions and conditions of the screen surface – thus the reproducibility of measurements is rather low under non-controlled conditions. Nevertheless, reported emission measurements range from zero to some few kV positive (equivalent surface potential) (Cato Olsen, 1981; Harvey, 1984; Paulsson et al., 1984; Knave et al., 1985b). The situations may, under certain unfavourable conditions, cause exposure levels of up to some 15 kV/m. Such levels are then caused by a combination of VDU and operator charge (Knave et al., 1985b).

3.5.4 Evaluation in terms of standards and requirements

Limits for electrostatic fields of some 20-60 kV/m were issued in the USSR.[1] Thus, exposure situations, also in extreme situations, are lower. However, these levels are intimately related to low relative humidity. If the European Community's minimum directives (EEC, 1990) of "an adequate level of humidity shall be established and maintained" are met (where "an adequate level of humidity" is interpreted as at least 30 per cent), such electrostatic field exposure levels would not occur.

In the voluntary emission guidelines from the Swedish Board for Technical Accreditation (MPR, 1990a, 1990b), the electrostatic field is measured at a distance of 10 cm from the VDU screen and the result expressed as equivalent surface potential, i.e. the potential on a conductive surface which creates a field of the same strength as the VDU screen. Technically, an equivalent potential of ≤ 500 V (±) should be attainable. Note again that these emission guidelines are not related to any health, or other biological, effects.

3.6 Ultrasound

Ultrasound emissions (waves with acoustic frequencies above 16 kHz) and noise may be produced by mechanical vibrations associated with the electron beam scanning control circuits – primarily the iron core of the transformer. Another sound source is the hard disk drive of the personal computer (PC). Some VDUs or PCs may produce acoustic emission levels which are annoying in the same way that the hiss from an air-conditioning system or the hum from some lighting fixtures may be irritating. Conventional sound-deadening techniques can alleviate these problems. In order to characterize these sound/ultrasound emissions, measurements should be performed for each of the 1/3 octave bands from 6.3 kHz to 40 kHz. The units are dBA.

Following a review of airborne ultrasound made by UNEP/WHO/IRPA (1982a), it was concluded that the use of experimental animals to test for biological effects has serious drawbacks because, compared with human beings, they have a greater hearing acuity, wider audible frequency range, and a greater surface-area-to-mass ratio combined with a lower total body mass. Hence, extrapolation of data from airborne ultrasound studies with animals to humans cannot seriously be considered except in the most general concepts.

No adverse physiological or auditory effects appear to occur in humans exposed to ultrasound at sound pressure levels up to about 120 dB. At 140 dB, mild heating may be felt in the skin clefts. Subjective or symptomatic complaints such as nausea, vomiting, fatigue, headache, and unpleasant sensations of fullness or pressure in the ears have been reported by persons exposed in the industrial environment. It is difficult to state that the observed effects were due to airborne ultrasound and not audible noise, because many sources of exposure contain acoustic frequencies in both the audible and ultrasonic ranges (UNEP/WHO/IRPA, 1982a).

[1] The names of the countries used in this book are consistent with the dates of the relevant texts and standards cited.

Levels of ultrasound in the 16-20 kHz frequency bands up to 61 dB and in higher frequency bands (25-40 kHz) up to 68 dB have been measured in a few VDUs (Bureau of Radiological Health, 1981). These levels are well below that which has been reported to cause adverse effects. The IRPA guidelines (1984) limit continuous occupational exposure around 20 kHz to 75 dB, and to 110 dB for frequency bands of 25-100 kHz.

3.7 Summary

In summary, VDUs emit non-ionizing radiations (NIR) such as visible light, together with very low levels of ultraviolet or infrared radiation. VDUs are not a source of X-rays nor of microwave radiation. In addition, low levels of radiofrequency, very low and extremely low electric and magnetic fields are normally found around VDUs. Depending on, for example, the humidity, electrostatic fields are also found. Noise and low-level ultrasound can also be found around VDUs or auxiliary equipment. Table 1 (overleaf) summarizes the levels of non-ionizing radiation measured around VDUs and compares these with the IRPA exposure limits.

Table 1. IRPA/INIRC general public (GP) and occupational (Occ) non-ionizing radiation (NIR) limits[1] versus levels of NIR measured from VDUs

Non-ionizing radiation (NIR)	IRPA/INIRC limits		Levels at VDUs (CRT)	References[2]
	GP	Occ		
ELF	E:5 kV/m	E:10 kV/m	E:2 V/m	Schnorr et al. (1991)
50-60 Hz	B:0.1 mT	B:0.5 mT	B:0.4 μT	
VLF[3]	E:82 W/n	E:614 W/n	E:4 W/n	Schnorr et al. (1991)
3-30 kHz	B:2.3 μT	B:83 μT	B:0.1 μT	
Microwaves	2-10 W/m²	10-50 W/m²	Undetected	Cox (1984)
IR[3]	100 W/m²	100 W/m²	< 10 W/m²	Cox (1984)
UVA	10^4 J/m², 8 h	10^4 J/m², 8 h	300 J/m², 8 h	Paulsson et al. (1984)
UVB and C	1 mW/m²	1 mW/m²	Undetected	Cox (1984)
Airborne ultrasound	100 dB	110 dB	68 dB	Bureau of Radiological Health (1981)
Electrostatic fields	–	–	Up to 15 kV/m	Knave et al. (1985b)

[1] The IRPA/INIRC limits referred to in this table have been, in some cases, simplified so as to provide a comparative example for VDUs. These values are not to be applied generally and may be frequency dependent. The appropriate IRPA/INIRC guidelines are referred to for more details on the exposure limits.

[2] For further references, see text.

[3] Extrapolated from existing guidelines.

4

Assessment of exposure and laboratory studies

4.1 Optical radiations (UVR, light and IR)

Optical radiations are not very penetrating, and so the eye and the skin are the organs of concern. The main acute effects of high exposures are photokeratitis or thermal photochemical retinal injury for the eye and erythema or burns for the skin. Delayed effects include cataractogenesis and possible retinal degeneration for the eye, and accelerated ageing and cancer for the skin. The biological effects of all optical radiation can be divided into three major categories: thermal (including thermo-mechanical), photochemical, and direct electric field effects. Above threshold levels, the predominant mechanism depends on maximum exposure rates and total exposure, and on wavelength regimes. The thermal effects are characteristic of the IR region extending into the visible region. The photochemical effects are mainly characteristic of the ultraviolet region, but also occur in the visible region.

Since the levels of UV, light and IR emitted from VDUs are very low, it is only necessary to consider delayed or late effects from low-level chronic exposures from each of the optical radiations. A detailed summary of laboratory studies on experimental animals has been reviewed by UNEP/WHO/IRPA (1979) and WHO (1989). Brief details on their implications for humans are provided.

Some UV exposure is needed by the body for the production of vitamin D3 and for maintaining resistance to occasional intense UV exposures that can occur in the working and living environment. However, above certain exposure levels, detrimental effects such as premature skin ageing, development of actinic keratosis (abnormalities in skin growth) and skin cancer can result.

For the eye, some types of cataract seen predominantly in the elderly may be due to repeated exposure to UV over many years. UV levels up to about 0.05 W/m² in the wavelength region 335-400 mn are emitted from VDUs. This wavelength region (called UVA) has thresholds for effects which are of the order of 1,000 times higher than shorter wavelengths of UV. Further, in a number of situations, the eye is normally subjected to irradiances up to about 1 W/m², except when in the sun or exposed to similar bright light sources where the irradiances will be very much higher.

Studies of skin and ocular injury in the UVA (315-400 nm) provide sufficient data to identify injury thresholds for the unprotected eye and skin (IRPA, 1985; IRPA, 1989; WHO, 1989). Skin damage is principally thermal in nature, requiring very high irradiances except in photosensitive individuals. Photokeratitis and lenticular opacities have been produced in experimental animals only with acute exposure at high radiant exposures.

There are no indications that the low levels of UVA found in most indoor work environments present a hazard. Thus, the exposure limits for UVA are set well below most conceivable thermal or photochemical injury mechanisms.

The interaction of IR with biological tissues is mainly thermal. IR may augment the biological response to other agents. The major health hazards are thermal injury to the eye and skin, including corneal burns from long wavelength (far) IR, heat stress, and retinal and lenticular injury from short wavelength (near) IR (WHO, 1989). Thus if a person is unable to feel very warm from an IR source, no adverse biological effect is expected. Near IR emission from the surface of VDUs up to 50 mW/m² has been measured. Standards worldwide are currently set at 100 W/m².

4.2 RF fields

In the RF frequency range, thermal mechanisms of interaction with biological materials are well established and form the basis for the IRPA (1988a) guidelines, for example. Thus, above 10 MHz, guidelines are established based on the specific absorption rates (SAR). For lower frequencies, the possibility of non-thermal mechanisms should be considered, but their impacts are at present difficult to quantify. Therefore, the lower frequency limit of the IRPA guidelines is set at 100 kHz. In the range from 100 kHz to 10 MHz, the magnetic field limits are set to follow an inverse frequency dependence. The electric fields are more restricted, owing to risks of radiofrequency burns or shocks.

Movement of calcium ions across the membrane of brain tissue has been reported from exposure to RF fields at specific modulation frequencies and field amplitude. This effect occurs at modulation frequencies around 16 Hz, but no effect is reported from the unmodulated RF fields.

4.3 Low-frequency fields

The flyback transformer in the horizontal deflection system produces low-frequency fields at the fundamental frequency of the deflection system (15-25 kHz) and at harmonic frequencies of up to about 150 kHz.

Although the database is limited, there has not been any scientific evidence to indicate that the low-frequency fields produced by the flyback transformer could pose any health hazard.

Some laboratory experiments on cell cultures suggest that low-frequency electric or magnetic fields may influence cell function, including differentiation and gene expression (Beltrame et al., 1980; Chiabrera et al., 1979; Goodman and Henderson, 1986; Liboff et al., 1984; Marron et al., 1986; Takahashi et al., 1986). Few if any of these studies have, however, been successfully reproduced. These *in vitro* findings require further study so that the mechanisms underlying the effects can be understood and the potential to do harm (if any) properly assessed.

Delgado et al. (1982) incubated fertilized chicken eggs for 48 hours while exposing them to low-frequency magnetic fields of 10 Hz, 100 Hz and 1,000 Hz. Gross morphological and histological analysis of the exposed embryos suggested that the fields altered the development of the embryos. These effects occurred at all three frequencies tested, but were especially predominantly at 100 Hz. A later publication of work in

Delgado's laboratory, Ubeda et al. (1983), suggested that the waveform of the ELF magnetic field was an important factor in producing the altered chick embryo development. They found that the most powerful effects occurred using pulses with a rise time of 42 µsec. In a series of experiments by Juutilainen and co-workers (Juutilainen et al., 1987), indications of an effect of weak (> 1 A/m) 100 Hz magnetic fields on chick embryos were also obtained. An attempt to reproduce Delgado's results was made in six separate laboratories operating in four different countries (Berman et al., 1990). All used common design equipment but some variations occurred in the protocols; for example, one laboratory used a different strain of fertilized eggs of domestic chickens. Only two of the six laboratories reported a statistically significant higher number of structural anomalies in magnetic field exposed embryos than controls. The authors claimed an overall significance when the data of the six laboratories were pooled. However, this set of experiments indicated that more research was necessary, using tighter protocols, before one could determine if pulsed magnetic fields had an impact on developing embryos. Teratological experiments utilizing chicken embryos are considered very sensitive and not necessarily applicable to human health risk assessment.

Teratological studies using rats or mice and sawtooth magnetic fields – similar to those around VDUs – have been made, with varying results (Frölén and Svedenstål, 1988; Stuchly et al., 1988; Tribukait et al., 1987). Up till now the best controlled laboratory study (Wiley et al., 1992) – with a rigorous design and continuous reliance on quality measures – was carried out at the Faculty of Medicine, University of Toronto. The specific aim of this study was to determine whether exposure to 20 kHz sawtooth magnetic fields altered the frequency of undesirable pregnancy outcomes in CD-1 mice. The results did not support the hypothesis that VDU-like magnetic fields were adversely associated with reproductive fertility, toxicity, foetal viability or foetal malformations.

Effects on human amniotic cells of 50 Hz magnetic field exposures have been studied. In one study (Galt, 1990) a significant decrease in chromosome aberration frequency was found in exposed cells, in contrast to previously reported findings of increased aberration frequency (Nordensson et al., 1989). These contradictory results are confusing, because the Galt study was designed as a replicate of the Nordensson study.

4.4 Static electric fields and air ions

As described in section 3.5, a static electric field builds up on the front glass surface of the monitor owing to the acceleration potential inside the VDU. This static field will cause a collection of counter ions and charged dust particles near the glass surface. Hypothetically, the electrostatic field would also reduce the concentrations of light air ions at the operators' position. This section briefly describes possible effects in VDU operators that may be due to such variations in air ion concentrations.

Early studies on exposure of humans to the hot dry winds (*Sharav*) in Israel (Sulman, 1980) suggested that they gave rise to an increased serotonin level; it was suggested that this might be caused, for example, by an excess of positive ions due to these winds. Subjective effects were also reported from people exposed to a similar wind (*Foehn*) in Switzerland. These effects included headaches, dizziness, fatigue and anxiety as reported in a review by Jeffrey (1989). Conversely, beneficial effects have been reported in people exposed to negative ions (Hawkins and Barker, 1978; Baron et al., 1985).

When the literature on air ions was critically analysed (Johnson and Dodge, 1982; Jeffrey, 1989), it was found that reported effects of concentrations of negative ions, positive ions or both in excess of those encountered in clean outdoor air are so varied, so contradictory, and so poorly researched that no conclusions can be drawn about the biological effects of breathing such air. Discrepancies in the research include concern about the accuracy of air ion measurement, type of clothing worn by subjects, exposure description of subjects and other factors such as temperature and humidity. No complete replication of any study has occurred, making all conclusions suggestive at best.

VDU operators are exposed to only very low concentrations of air ions, which are much lower than from the hot dry winds. A few attemps have been made to measure the effects of VDUs, presumably of their electrostatic field, on light air ions (Knave et al., 1985b; Charry et al., 1986). While these studies are somewhat contradictory, reported magnitudes of changes are small compared to variations due to other factors such as ventilation. In conjunction with the general paucity of suggestive conclusions concerning health risks of air ions in general, it can be reasonably concluded that air ions from VDUs would not have any adverse health impact (WHO, 1987).

5

Health effects and human studies

In the late 1970s to early 1980s, it was suggested that three types of adverse health effects were caused by working with a VDU. These effects were cataracts, adverse pregnancy outcomes and skin rashes. The initial concerns were primarily focused on radiation such as X-rays or UVR. These were dismissed because of the very low or nonexistent exposure levels of these radiations. Attention then turned to various electric fields around the VDUs. Following some experimental studies as cited above, especially the results of Delgado et al. (1982), the focus of attention changed to primarily magnetic fields around VDUs. Lately, some recurrence of interest in electric fields has taken place, for example, in Swedish discussions on skin problems.

It should be emphasized, however, that the scientific discussion on the possibility of such adverse health effects of VDU work has by no means been limited to that of magnetic fields, nor indeed to that of radiation. Other types of factors present in VDU work have been, and are, of major interest for the discussion on the possibility of these effects. Central factors for this discussion are, in particular, stress, and indoor climatic factors.

The basic issue, however, is whether VDU work influences the occurrences of any adverse effects. This has been studied in a number of epidemiological studies, the results of which will be reviewed below.

5.1 Adverse pregnancy outcome

The question whether work at VDUs can affect the result of pregnancy outcome arose around 1979-80 with the observations of so-called "clusters of adverse pregnancy outcomes". These cluster observations consist of some groups of pregnant VDU-working women with unusually high occurrences of spontaneous abortion or birth of malformed children. These clusters can be explained on the basis that a number of groups of both increased and decreased occurrence should occur by chance alone, but only clusters of increased occurrence are likely to be (selectively) observed and reported (Bergqvist, 1984).

Alternative explanations of these clusters would involve causal factors due to VDU work. A number of such factors have been suggested during the past decade, the majority being, however, without substance. For example, the first suggested factor was X-rays, but due to the absence of X-ray emission in VDU work situations it cannot be considered for causality relationships in adverse pregnancy outcomes among VDU workers. At present, two possibilities are being examined: VLF magnetic fields and stress or worry (Bergqvist, 1990). The credibility of the first, as evidenced from experimental studies, has been discussed above in some detail. Stress and anxiety are ergonomic factors, not radiation related.

5.1.1 Epidemiological studies

A large number of epidemiological studies have been conducted in order to elucidate whether VDU work during pregnancy increases the risks of miscarriages or giving birth to a malformed child. In order to arrive at such conclusions, the typical procedure is to compare a group of women who worked with VDUs during pregnancy with another group of women who did not do so. A straight comparison of, for example, percentages of miscarriages between such groups is, however, seldom possible. Prior to any comparison, the impact of known factors for miscarriages such as maternal age, and so on, must be eliminated. Thus, an epidemiological study of adverse pregnancy outcomes is a long and rather complicated procedure, where a number of conditions must be fulfilled for a proper conclusion to be possible.

The issue of pregnancy and VDU work is or has been the subject of more than 20 such studies. Several have deficiencies or failed on certain conditions necessary for reliable results to be obtained (none of these studies showed any relationship between VDU work and adverse pregnancy outcomes). It should also be mentioned that other types of studies (e.g. surveys or extended cluster investigations) have been performed in Australia, Canada, Japan, Norway, Poland, the United Kingdom (two) and the United States (four), without evidence of a difference between VDU workers and referents.

Further discussion will be limited to those ten studies of sufficient size and quality to be able to detect any difference, should one exist. These studies are summarized in table 2. In most studies, there is no evidence of increased occurrence of spontaneous abortion (Bryant and Love, 1989; Butler and Brix, 1986; Ericson et al., 1985; Ericson and Källén, 1986; Nielsen and Brandt, 1990; Schnorr et al., 1991), of serious malformations (Ericson et al., 1985; Goldhaber et al., 1988; Kurppa et al., 1985; Brandt and Nielsen, 1990), nor of other researched endpoints such as foetal death around delivery, low birth weight and preterm delivery (Ericson et al., 1985; McDonald et al., 1988; Nielsen et al., 1989; Nurminen and Kurppa, 1988), or threatened abortion, placental weight and maternal blood pressure (Nurminen and Kurppa, 1988).

The Montreal study was designed around all women who reported to 11 Montreal hospitals during 1982-84 for childbirth or spontaneous abortion (McDonald et al., 1988). They were interviewed as to working conditions during their current pregnancies, as well as previous ones. Apart from an isolated increase in renal urinary defects, the study shows no evidence of increased malformation, but is not so clear as to spontaneous abortion – especially among previous abortions. The design of this study does, however, tend to exaggerate the odds ratio for VDU-exposed compared to non-exposed women in previous pregnancies (McDonald et al., 1988; Bergqvist, 1984). By stratification, this systematic error was eliminated, and then the apparent increase in odds among VDU-exposed women was absent (McDonald et al., 1988). A similar but smaller error is likely also as regards spontaneous abortion among current pregnancies.

In the Swedish case-control study (Ericson and Källén, 1986), crude odds ratios (odds ratio, OR, is the measure of relative risk in case-control studies) for malformation (and to some degree also for spontaneous abortion) among VDU operators were increased compared to non-VDU working women. The study did attempt to account also for other possible causes of adverse pregnancy outcomes – and when effects related to stress and smoking were eliminated, the above-noted increase in adverse pregnancy outcomes was no longer apparent.

Table 2. Epidemiological studies comparing occurrences of spontaneous abortion and malformation for women using VDUs during pregnancy with women who did not

Study/authors	Number of pregnancies	Spontaneous abortion	Serious malformation	Comments
Montreal (McDonald et al., 1988)	104 620	?	No[1]	See text
Finnish Register I (Kurppa et al., 1985)	2 950	–	No	
Swedish case-control (Ericson and Källén, 1986)	1 447	No[2]	?[2]	See text
National Insurance (Ericson et al., 1985)	4 347	No	No	
Michigan (Butler and Brix, 1986)	817	No	–	
Kaiser Permanente (Goldhaber et al., 1988)	1 583	Increase	No	See text
Finnish Register II (Nurminen and Kurppa, 1988)	1 475	–	–	Other endpoints; see text
Alberta (Bryant and Love, 1989)	980	No	–	
Århus (Brandt and Nielsen, 1990; Nielsen and Brandt, 1990)	6 541	No	No	
NIOSH (United States)	882	No	–	

Notes
"–" means not investigated. "**No**" refers to the inability of the study to establish any real difference between VDU working and referent women. "**?**" refers to studies where results can be interpreted in more than one way. "**Increase**" refers to studies where results indicate a difference between VDU working and referent women.

Source: Schnorr et al., 1991.

[1] Odds ratio for spontaneous abortion and renal urinary tract malformations increased in some comparisons. The total number of malformations was not increased.
[2] Overall, effects correlated with VDU work were eliminated when controlling for stress and smoking. Owing to small numbers, a separate analysis on malformation was not performed.

In another case-control study performed at three Kaiser Permanente clinics in northern California (Goldhaber et al., 1988), an increase was reported in spontaneous abortion among VDU operators compared with referents. However, this significant increase was due to a trend in one of the job categories (clerical workers), while another job category (managers, professionals) reported a decrease in relation to VDU work. This contrary information from two job categories has two ramifications: (a) the summary across job categories is not justified; and (b) it makes the interpretation of magnetic fields as a cause rather dubious, but does instead suggest job-specific factors as possible causal factors.

Schnorr et al. (1991) compared a cohort of female telephone operators who used VDUs at work with a cohort of operators who did not use them. Exposure was assessed by the number of hours per week according to company records and by measuring electric and magnetic fields (45-60 Hz and 15 kHz) at the VDU workstations and at the workstations without VDUs. Among 2,430 women interviewed there were 882 pregnancies (366 exposed, 516 controls) that met the criteria for inclusion in the study. No excess risk of spontaneous abortion among women who used VDUs during the first trimester of pregnancy (OR = 0.93, 95 per cent CL 0.63-1.38) was found. There was no risk associated with the use of VDUs when accounting for multiple pregnancies, early and late abortions, and all foetal losses. No dose-response relation was apparent when examining the number of hours at the VDU, or the measured electric and magnetic fields.

Recently, a Finnish study has reported an association between miscarriages and ELF magnetic fields measured around VDUs. There was no association between miscarriages and VLF fields. While these results are not sufficient to establish any causal relationships, they do suggest the need for a replication study (Lindbohm et al., 1992).

Several studies show increases in some specific malformations:

- hydrocephalus in the Århus study;
- renal malformation in the Montreal study; and
- cardiovascular defects in the Finnish Register I study.

A lower than expected number of specific malformations was also found, such as:

- central nervous system in the Århus and the Finnish Register I study;
- extremities malformation in the Århus study, etc.

However, the size of the studies precludes efficient determination of whether a specific abnormality is increased or not. That is to say, the confidence intervals associated with specific malformations are generally very wide – and random variation is able to produce quite varied results.

Thus, the majority of these epidemiological studies have failed to demonstrate an increased occurrence of spontaneous abortion and malformed children in relation to VDU use. Some studies, however, contain results that could be interpreted as an increased risk in relation to VDU work. It is, however, likely that methodological problems account for an observed increase in some of these, as was discussed above for the Montreal study. Recall bias (bias due to memory in answering a questionnaire, or an interview) is a possible contributor to the outcome of the Swedish case-control study, and the presence of recall bias in such circumstances was demonstrated in the Alberta study (Bryant and Love, 1989).

Other possible risk factors which have been suggested are various job conditions such as stress or ergonomic factors. In the Århus study (Brandt and Nielsen, 1990), there was a tendency towards higher risks for adverse pregnancy outcomes in VDU work with elevated stress levels, in contrast to VDU work with low stress levels – a tendency which is consistent in general with the findings of the Kaiser Permanente (Goldhaber et al., 1988) and the Swedish case-control study (Ericson and Källén, 1986). There was no indication of adverse pregnancy outcome risks being associated with ergonomic situations such as prolonged physical inactivity (Nielsen and Brandt, 1990).

5.1.2 Conclusion as to pregnancy effects

Experimental studies, while showing a diverse outcome, have as a whole failed to demonstrate an effect on reproductive processes in magnetic field situations resembling those around VDUs. Most epidemiological studies have failed to show a difference between women who worked at a VDU during pregnancy and those who did not, while those that do, suggest a difference related to work situations (possibly stress) rather than any physical emissions from the VDUs.

5.2 Ocular effects

Studies have been conducted to determine the possibility of cataract formation. This followed the diagnoses in 1980 by one physician (Zaret, 1984) of some cases of "radiation-induced cataracts" in people working with VDUs, although these diagnoses were criticized (National Research Council, 1983). Some earlier epidemiological studies investigated this possibility, without showing any such effects. Discussions centred on radiation (i.e. X-ray or UV radiation), which has been shown to be either absent or present only in insignificant amounts (WHO, 1987; Marriott and Stuchly, 1986). Recently, a large-scale study from Italy demonstrated more clearly the absence of any real difference in cataract occurrences between VDU and non-VDU workers (Bonomi and Bellucci, 1989). The generally accepted conclusion of no link between VDU work and cataract formation is further supported by the lack of any known cataractogenic factor around VDUs.

5.3 Effects on the skin

In recent years, several studies on the possibility of skin problems in relation to VDU work have been conducted, mostly in Sweden. Epidemiological studies have indicated an excess of some subjectively reported symptoms such as rashes or itching sensations in VDU operators, but have not been able to demonstrate consistently a similar increase in diagnosed skin disorders (Knave et al., 1985a; Lidén and Wahlberg, 1985; Svensson and Svensson, 1987; Lidén and Wahlberg, 1990) nor in pathological skin changes (Berg, 1989).

Early case reports suggested a relationship with electrostatic phenomena in the workplace (Wedberg, 1987). Later studies have indicated that the electrostatic charge on the operator may play a role (Knave et al., 1985b); however, the interpretation is rather uncertain since the findings could be caused by low humidity. No indications exist on a link between the electrostatic field from VDUs and skin problems, despite several studies in this area (Swanbäck and Bleeker, 1989; Knave et al., 1985b; Lidén and Wahlberg, 1990). A similar lack of indications has resulted from attempts to link the VLF magnetic field from VDUs with skin problems (Swanbäck and Bleeker, 1989; Sandström et al., 1989). The interpretation that these failures are indicative of a lack of any real relationship between these two fields and skin problems among VDU operators is further supported by the often unsuccessful attempts to alleviate skin problems in Sweden by introducing "low radiation VDUs". In a study of VDU operators in Singapore (Koh et al., 1989), the proportion of VDU operators experiencing dermatological complaints was slightly lower among those using CRT-based VDUs (11.2 per cent) than among those using VDUs based on plasma techniques (13.4 per cent). Thus, this study fails to indicate a higher proportion of complaints among individuals using a VDU technique which generally implies higher VLF magnetic field exposures.

A number of alternative hypotheses have been advanced to account for the increased occurrence of subjective skin symptoms among VDU operators. These are:

- a bias towards higher reporting tendencies of slight skin problems by VDU operators;
- exposure to known contact allergens;
- indoor climatic factors causing physiological responses of dilating blood vessels, such as a high room temperature;
- stress causing similar responses;
- expectation responses (Pavlovian);
- reactions secondary to ocular fatigue;
- exposure to other fields, especially electric fields, in the workplace.

The main emphasis among research and successful preventive work in Sweden is at present centred on indoor climatic factors (Wahlberg and Lidén, 1988), although attention is given to most of the above factors.

Apart from skin problems, a few individuals have also experienced other symptoms such as diffuse reactions of the nervous system, manifested as headaches, dizziness, and so on (Knave et al., 1989). The aetiology of these complaints remains open to debate and is at present being studied.

6

The organization of prevention and control measures

6.1 Risk assessment

VDUs have become a major element in the modern work environment as an interface between people and computers. The discussion as to whether work at VDUs can affect human health has been centred on different types of effect such as eye damage or discomfort, neck and shoulder discomfort, adverse reproductive outcomes, skin disorders and different stress reactions. Operators should be informed by their employers of the safety and health conditions which may involve risks of eye discomfort, ergonomic postural problems and workstation design. Daily work at VDU stations should be varied, and interrupted by breaks and interspersed with other types of work, thereby reducing the workload at the display screen.

6.1.1 Visual problems and ocular changes

A large number of studies show that VDU work is associated with an increase in the reported frequency of various types of eye discomfort, often described as "smarting" or a "gritty feeling". The mechanisms behind the eye discomfort are not fully understood, but the image quality of the VDU screens is generally inferior to that of black text on white paper. In addition, the screen image may also involve factors such as flicker that are not a part of paper presentation. Furthermore, several problematic conditions may be due to interactions between the screen and the illumination of the workplace, such as glare and reflections, or large differences in luminances between different visual task objects (screen, manuscripts).

Apart from the visual ergonomic issue of VDU work, the possibility of permanent damage due to VDU work or exposure has mainly been centred on the possibility of cataract formation due to such work; other changes such as development of myopia have also been considered. Epidemiological studies on cataract occurrence among VDU operators and other office groups have not found any evidence for increased cataract occurrence among VDU operators. Furthermore, the factors known or suspected to be cataractogenic are not present (at sufficient levels) around VDUs. There are no data suggesting that permanent myopia (nearsightedness) may develop, although some indications suggest that a short-term nearsightedness may occur briefly after work sessions.

Based on current knowledge, there are no health hazards associated with radiation or fields from VDUs. Thus there is no scientific basis to justify shielding VDU screens from any radiation emissions or to justify radiation monitoring or eye examinations to search for ocular pathology due to radiations in VDU operators.

6.1.2 Musculoskeletal problems and ergonomic design

The occurrence of musculoskeletal problems among VDU operators is high and indications exist that the frequency is increased in certain types of VDU work such as extensive data entry work. Such problems may occur in the neck/shoulder region, and in the hand/wrist region. An increased strain of the neck muscles has been reported also in objective measurements (electromyography). Adverse reading conditions as reported above may also be a cause of postural strain on the operator, resulting from a posture necessary for reading and keyboard operation which may lead to musculoskeletal discomfort. Other causes of postural strain may be due to the design of the workplace. One example is that of the reading area of the VDU being placed 10-20 degrees above the horizontal line from the operator's eye to the VDU, causing the line of sight and the head to be lifted up correspondingly. Stressful situations in a constrained posture will sometimes result in raised shoulders and unnatural use of arms and fingers, a frequent cause of neck, shoulder and upper limb disorders. The design and extensive use of various input devices are of obvious importance for hand/wrist conditions. Considerable attention has therefore been given to keyboard design; low-profile, detached keyboards are improvements that are being more widely used. More recently, other input devices such as a "mouse" have come into increasing use; these may, depending on the design of the workplace, be a cause of additional strain on wrist, arm and shoulder muscles.

As to permanent musculoskeletal injury, the situation is not fully known. Injuries such as tenosynovitis are known to result from long-term repetitive wrist movements; such conditions may conceivably also occur in long-term intensive operations on VDU keyboards. Whether the specific discomfort related to VDU work, such as neck or shoulder pain, may develop into permanent injury will depend on the organization of work and workload. Some case data suggest that it does not inevitably do so, although a final evaluation will need future studies. Careful attention to such conditions of discomfort is a prudent attitude. Finally, it should be emphasized that musculoskeletal problems in work associated with VDUs are preventable and that appropriate control measures should be introduced.

6.1.3 Skin problems

In several Scandinavian reports, an increased incidence of some common skin complaints (rashes, heat sensation, irritation, etc.) has been claimed to be associated with VDU work. The explicit factors involved have not yet been elucidated; however, the electrostatic charge on the operator (in conditions of low air humidity) has been suggested as a possible contributing factor. Such a charge will increase facial deposition of air contaminants (dust particles) on the operator; this may, in turn, cause a skin reaction, especially among sensitive individuals. Work stress has also been mentioned in this connection. In epidemiological studies, no excess of dermatological diseases or visible pathological skin reactions has been reported or detected.

6.1.4 Pregnancy outcome

During the past ten years much attention has been paid to the possibility of adverse pregnancy outcome being linked to VDU work. However, most epidemiological studies have failed to show a difference between women who worked and those who did not work at a VDU during pregnancy. Two recent epidemiological studies (Schnorr et al., 1991; Lindbohm et al., 1992) have measured VLF and ELF fields around VDUs. Both failed to find any relationship between spontaneous abortions and VLF fields, whereas the results varied as to ELF fields. Experimental studies, while showing a diverse outcome, have as a whole failed to demonstrate an effect on reproductive processes in magnetic field exposures characteristic of those around VDUs.

6.1.5 Work stress

Working conditions which might lead to stress reactions and stress-related diseases are common in many types of VDU work. Increased frequencies of stress-related symptoms have been found among many VDU operator groups, although the converse has also been found for other VDU groups. Some specific conditions occurring in the VDU situation that warrant concern are involuntary computer breaks, long waiting times and electronic monitoring or surveillance. In certain work situations (high workload, customer relations, incentive pay schemes) these conditions may cause unwanted and excessive stress reactions.

It is possible that stress reactions play a role in the development of eye discomfort and postural discomforts, as well as in the worsening of the above-mentioned skin complaints among operators. The possibility of a relationship between stress and miscarriage has received increased attention, both in general and in VDU work situations, but no definite statement as to this appears possible.

6.2 Quality control, maintenance and in-service testing

6.2.1 Quality control

Quality control in the manufacture of VDUs ensures that units function correctly. As stated previously, many VDUs have been tested, both in a normal and an abnormal mode of operation. No units have been found to exceed the widely accepted exposure limits at the nominal operator position of 30 cm from the screen. Therefore, no radiation quality control testing is necessary, in addition to that routinely performed by manufacturers to ensure that their units function correctly. However, if required, VDU manufacturers should be able to supply typical emission levels for electromagnetic radiations outside the visible range.

6.2.2 Installation and maintenance

Proximity to a number of VDUs is considered a possible way of enhancing exposure of workers to radiation emissions, particularly in the low-frequency field range. The magnitude of such emissions, however, has been found to decrease very rapidly with distance from the VDU. For example, if the operator distance from the screen of the VDU were doubled, the emissions would drop by a factor of between four and eight. Thus, operator exposure to fields from four to eight VDUs 60 cm away from an operator would be needed to double the emission levels to which an operator would be exposed if positioned 30 cm from his or her own screen. Being surrounded by four to eight VDUs all within 60 cm would not appear to be a realistic situation. Furthermore, the various fields being vectors, the sum of fields from several VDUs cannot be obtained by simply adding their numerical levels; the resultant field will at most attain this sum, and will generally be lower. (This is actually the basis for the use of compensation coils in "low radiation VDUs" to decrease the field emission from VDUs.) Regardless of these complications when trying to derive field exposures from emission data for various appliances, the levels would still be well below all relevant general public exposure standards. Appropriate workplace layout should normally ensure that VDU operators are no closer to any other VDU than they are to their own VDU.

Like other electronic equipment, VDUs sometimes break down and need to be repaired. While awaiting repair, VDUs should be switched off, not because of radiation emissions, but to avoid possible further damage. There are no components in a VDU which could malfunction and cause an unacceptable increase in emission levels while continuing to produce an acceptable display. Owing to the nature of the electronic circuits used in VDUs, they will only display clear and usable images if their voltages and currents are within design tolerances, so that any radiation emissions from repaired VDUs will be similar to those produced by new equipment.

6.2.3 In-service testing

Thousands of VDUs and model types have been tested worldwide for emissions of radiation. None of these VDUs has shown any radiation emission above recommended levels, and in all cases emissions are significantly lower than the accepted general public exposure standards. Thus it is unnecessary and wasteful to test VDUs for radiation emissions in service in the workplace.

If concern persists about the radiation emissions from new terminals, an effective way of ensuring that the VDU emissions conform to all appropriate standards is to incorporate the emission specifications into purchasing documentation for these units.

An example of a purchasing specification referring to radiation emission limits is given below. Clauses such as the following could be added to specifications used for purchasing VDUs:

(a) Test laboratory confirmation

The supplier, at the time of tendering, shall provide written confirmation from an approved test laboratory indicating that the VDU model complies in all respects with the radiation emission limits stated in the purchasing specifications. In addition, the exposure specifications from clause (c) below shall be complied with.

(b) Test conditions

If so tested, the VDU shall be operated as follows:

(i) external controls adjusted for maximum luminance;

(ii) at normal supply voltage;

(iii) for a VDU capable of presenting a positive polarity image (dark characters on a bright background), the screen should be bright (devoid of characters);

(iv) for a VDU only capable of presenting a negative polarity image (bright characters on a dark background), the screen should be filled with capital "M"s.

(c) Exposure to non-ionizing radiation

(i) The emission levels of ELF, VLF, RF and IR shall be such that appropriate national or international exposure standards (whichever are lower) are met at the operator's position at the VDU.

(ii) The UV irradiance in the wavelength range 315 to 400 nm shall not exceed 0.35 W/m² when measured 30 cm from the centre of, and perpendicular to, the screen. The measurement shall be performed for each colour generated by the VDU. The maximum UV emission shall be used to determine compliance. The measuring instrument shall have a known spectral response. Any response to visible radiation must be accounted for and the instrument reading adjusted accordingly.

(d) X-ray radiation

It has been established that no VDU monitors emit X-rays because of the thickness of the front glass screen on the monitor. However, for information, the standard for X-ray emission from television receivers (including domestic models) is that the emission does not exceed 0.5 mR per hour averaged over an area of 1,000 mm² measured at a distance of 5 cm from any surface of the picture tube.

6.2.4 VDU accessories

A number of commercial products are available that are claimed either to reduce the emission of electromagnetic radiation from VDUs or to protect (shield) the operator from the emissions. Typical of such devices are various forms of shield that attach to the VDU or are worn by the operator. Whereas the electrostatic charge on the VDU screen may be reduced using a grounded electrically conducting screen attached to the VDU (hence avoiding attracting dust), from the standpoint of the exposure of the operator the use of such screens provides little or no attenuation of magnetic field emissions. The wearing of smocks or other such "protective" garments is not recommended. The use of screens designed to reduce reflected light (glare) may be appropriate under certain conditions, when the glare problem could not be handled by adjustments to the workstation.

6.3 Control measures for the improvement of working conditions and the working environment

It is the employer's responsibility to establish and maintain a safe and healthy working environment which will facilitate optimal physical and mental health in relation to work. All workers should be informed of the health risks involved in their work and of the manner in which they can be prevented. Every worker should also receive training in use of the workstation before commencing this type of work and whenever the organization of the workstation is substantially modified.

The radiation protection guidance given in the preceding sections is to be seen within this general framework. The measures of prevention and protection which concern visual problems, musculoskeletal strain or stress and other health effects do not fall within the scope of this publication, which focuses on radiation issues. However, it is useful to recall the most usual control measures for the improvement of working conditions and the working environment.

6.3.1 Lighting and vision

The quality of the character generation and of the screen is of significance for the extent of visual strain that has been observed to occur from VDU use. Both direct and indirect glare should be avoided by suitable positioning of the VDU and other means. A number of other recommendations were made such that the screen should be placed lower than the eye height and concerning the eye-screen distance, which should be adjusted individually but should not be too short.

It is essential that vision is properly corrected as prescribed by a competent person – and that the prescription has taken into account each individual's distance between the VDU and the eyes, the angle between the horizontal plane and the line between the eyes and the most common task area on the screen. Workers carrying out VDU work should be entitled to an appropriate vision test. A consultation of an eye specialist should be made available when necessary. If special eyeglasses are needed for work on VDUs, they should be provided to the worker as appropriate to his or her duties. The rationale behind the vision test and the prescription of special eyeglasses for VDU work is primarily the appearance of presbyopia with age and the difficulties which may then appear during VDU work, unless glasses adjusted for the specific work situation are used.

The level and the design of the lighting should be adapted to the nature of the task being performed and to the VDU display image. Modern VDUs with positive polarity (dark text on a bright background) are generally preferred since they place fewer restrictions on the ambient lighting and thus permit brighter workplaces. Such VDUs must, however, have a sufficiently fast refresh rate and/or have a sufficiently slow phosphor type that flicker is not perceived by the user. The lighting level should be less than 500 lux (vertical component) in order to avoid contrast reduction on the screen. For VDUs with negative polarity (bright text on a dark background), the lighting level should be restricted to less than 200 lux (vertical component). Another restriction of importance is that the luminance ratio between sequentially viewed visual task objects (e.g. documents: screen) is less than 10:1. This restriction is readily obtainable for positive polarity (bright) VDUs, but may be problematic for many negative polarity (dark) VDUs. It is generally recommended that the lighting be adjustable so that the operator can adapt it to his or her personal needs.

6.3.2 Work posture and workplace

Good work posture helps prevent' musculoskeletal pains and disorders. There is no single "ideal" position for extended periods. Whenever possible, frequent changes of position are recommended. The keyboard must be separate from the screen so that the workstation can be individualized.

The workstation must be properly planned. The working height and the avoidance of continued work in a constrained posture are particularly important. The table must be specially designed and adapted to the type of work involved. Features of a good seat include appropriate seat height adjusted to the user, comfortable sitting surface without undue pressure under the thighs and an adjustable backrest that supports the low back. The space under the desk should be free so as to permit movement of the legs and change of position.

Special attention should also be given to the ambient environment including noise, temperature and humidity. Typical recommendations would be a room temperature which would range from 19° to 23° centigrade, a humidity of 40-50 per cent and noise levels of 40-50 dB(A) for intellectual work, 60 dB(A) in offices in general and 65-70 dB(A) where verbal or telephone communications are needed (ILO, 1989).

6.3.3 Organization of the work

The best way of reducing any possible negative effect of VDU work on workers' health is to limit total time spent by each individual on working directly and intensively with the VDU screen. The work should preferably be split into several shorter periods rather than a single longer period on the screen. A mixture of VDU work and non-VDU work is recommended. As regards the daily working time with VDUs, various limitations have been proposed: for example, the International Federation of Commercial, Clerical, Professional and Technical Employees (FIET) has recommended a maximum working time with VDUs of no more than one half of the working day.

Short breaks are also necessary; for example, in the case of intensive work with a VDU screen a rest pause of 15 minutes for every work period of one and a half hours is typically suggested. The optimal length of pauses will be related to the nature of the task. The effectiveness of the pause will also be a function of when it is taken. In general, rest pauses should be planned so that they are taken prior to the onset of noticeable fatigue. Short, frequent pauses appear to be more effective than fewer, long pauses. Worker-controlled rest pauses may be more efficacious than rigid, supervisor or process-controlled pauses. Rest pauses should occupy between 5 and 10 per cent of the working time (ILO, 1989).

Monotonous work adds to occupational stress and its prevention needs good organization of work. Varying the tasks and the manner of work may be pursued by cooperation with the staff. Consultation and participation of workers and their representatives is a very important feature in improving the working environment and working conditions.

The technical design of VDU work makes electronic monitoring of work tasks possible. Examples of such monitoring have appeared, for example, in the recording of keystrokes for incentive pay schemes, or the recording of customers handled by a bank clerk. It must be emphasized that the use of such electronic monitoring is in general contrary to a good working environment.

Appendices

Appendix 1: Alleged radiation risks from visual display units

A statement by the international Non-Ionizing Radiation Committee of the International Radiation Protection Association (IRPA, 1988b)

Visual display units (VDUs) have become a major element in the modem work environment as an interface between man and computer. The discussion as to whether work at VDUs can affect human health has been centred on different types of effects, such as eye damage or discomfort, neck and shoulder discomfort, different stress reactions, skin disorders and adverse reproductive outcomes. In this context, much concern has been expressed in the media in relation to the possibility of radiation hazards due to VDUs based on cathode ray tubes (CRTs). This aspect will be covered in the present document, while the reader is referred to other texts for a discussion on the influence of various ergonomic factors on health (see, e.g., WHO, 1987).

A number of careful scientific studies have been focused on the measurement of electromagnetic radiation or fields due to VDUs, while some limited attention has also been given to acoustic radiation: several publications also address the topic of health risk assessment.

(1) Soft X-radiation is produced within the CRT. The glass material of the tube, however, effectively prevents any leakage of X-radiation outside of the tube during operation. Thus, X-radiation from VDUs is not detectable with normal measuring instruments.

(2) Ultraviolet radiation in the near region (UV-A) can be detected from certain VDUs. The levels are, however, insignificant compared with present occupational standards (10 W/m²) (IRPA, 1985) and also insignificant compared with emission from other sources (e.g. sunlight through windows). In one investigation, VDU operators were found to be exposed to lower levels of UVA than those not working with VDUs, attributable to the fact that the former often draw the window curtains.

(3) Visible radiation can be measured and is necessary in order to perform the intended function of the CRT – to provide a visual display. Luminance levels recorded are far below current exposure limits, this precluding (according to present knowledge) the possibility of pathological injury due to excessive exposure. There are ergonomic considerations of light emission from the display, such as flicker, contrast glare or readability. These are, however, not considered in this context.

(4) Infrared (IR) radiation is emitted from all warm bodies, and since all surfaces of the VDU are at room temperature or slightly above, IR radiation can be detected, although at levels far below any levels of concern for potential hazards.

(5) In the extremely low frequency and the radiofrequency regions, electric and magnetic fields have been detected. The dominant sources are the power supply and the vertical and horizontal sweep arrangements (at frequencies of some 50-80 Hz and 15-35 kHz, respectively). Compared to fields in many industrial or household situations, the fields around VDUs do not correspond to high-exposure situations. These fields do not appear to represent any risk factor when evaluated by comparison with current standards, guidelines and recommendations for occupational exposure.

(6) In some countries, a number of VDU operators have experienced skin disorders. The relationship of these to VDU work is not known. Electrostatic fields at VDU workplaces

have been suggested as a possible cause of skin disorders. Research conducted hitherto has indicated that the electrostatic charge of the operator might be a relevant factor. A relationship between electrostatic fields and skin disorders must, however, still be regarded as hypothetical.

(7) Airborne ultrasonic (acoustical) radiation is produced in VDUs as a result of mechanical vibrations generated in the core of the flyback transformer (responsible for the horizontal sweep of some 15-35 kHz). The sound pressure levels found are considerably below existing exposure limits (75 dB) (IRPA, 1984). Some sensitive individuals may detect this sound or a subharmonic as an annoying factor.

Effects which have been suggested as caused by exposure to electromagnetic radiation or fields include adverse pregnancy outcome or cataracts. Comparison of the occurrence of cataracts or of adverse pregnancy outcome among VDU operators with those of controls have failed to show an excess occurrence due to VDU work.

In conclusion, and based on current biomedical knowledge, there are no health hazards associated with radiation or fields from VDUs. Thus, there is no scientific basis to justify shielding or radiation monitoring of VDUs.

However, since a large number of people are involved in VDU work, it is important that further knowledge is attained on certain areas where our knowledge must be regarded as incomplete. These areas include: (a) further investigations into the possibility that skin disorders may be related to VDU work, and if so, the factor(s) involved; and (b) the possibility of interactions between low-frequency magnetic fields and biological systems. Consideration should be given to magnetic fields in various situations and should not be restricted to VDU work situations.

Measures should be taken to ensure that VDU workplaces are ergonomically well designed. This includes aspects of the VDU, the workstation and the work environment, as well as work organization. Visual screening examination is also valuable in ensuring that the operator has adequate visual acuity and that any corrective glasses are suitable for use at the VDU working distance.

Appendix 2: Some questions and answers

Do VDUs emit radiation?

Yes. VDUs emit radiation, particularly visible light which allows the characters on the screen to be seen. Weak electromagnetic fields and very low levels of other radiation, not visible to the human eye, can be detected by sensitive instruments. Similar emissions are produced by television receivers.

Can radiation from VDUs be harmful to health?

The levels of most radiations and electromagnetic fields emitted from VDUs are much less than those from natural sources, such as the sun or even the human body, and all are well below levels considered harmful by expert bodies such as the International Radiation Protection Association and the World Health Organization. Radiation emissions from VDUs are not considered to be harmful to health.

Are any protective devices needed against radiation from VDUs?

Fear of possible radiation effects has sometimes caused VDU operators to consider protective devices such as special aprons or radiation shields. These are of no value, because they are designed either to shield radiographers from X-rays, which VDUs do not emit, or to minimize low-level electromagnetic fields which are not regarded as hazardous in any case.

How should the workplace be organized if several VDUs are located together?

The weak electromagnetic fields produced by television receivers and VDUs extend in all directions, but their intensity decreases very quickly with distance from the source. A workplace should be organized to ensure that VDU operators are no closer to any other VDUs than they are to their own.

Does radiation increase as a VDU ages or is repaired?

There are no components in a VDU which could fail and cause an increase in emission levels while continuing to produce a clear usable image. Because of the nature of their electronic circuits, VDUs will show acceptable displays only if their currents and voltages are within design tolerances, and so an older or repaired VDU will not emit radiation significantly different from a new one of the same model.

Is there any benefit from testing VDUs for radiation emission while they are in service in the workplace?

No. When VDUs first became common, many workers were worried about the new technology. In-service testing in some workplaces may have allayed some worker concerns about radiation from VDUs, but since there is no increase in radiation emissions from VDUs as they age or are repaired, continued in-service testing is unnecessary.

Could radiation from a VDU harm an unborn child?

Given that the levels of radiation from VDUs are much lower than recommended limits, and that these limits themselves incorporate significant safety factors, there is no evidence to suggest that any harm to an unborn child would result from exposure to the radiation emissions from a VDU. Much research has already been done, and more is under way, to resolve this question. The weight of evidence so far indicates strongly that the answer is "no".

How do other types of display screens compare with VDUs?

Flat screen displays, such as the liquid-crystal or gas-plasma displays used in some laptop computers, produce even smaller amounts of radiation than those which use television-type tubes. It may be sensible to use the new types for special purposes, such as to increase portability or battery life, but concern about radiation emissions should not be a factor in their choice.

Can you reduce the strength of the static and low-frequency electric fields?

It has been shown that these electric fields are very low and have no effect on health. However, if it is found necessary to reduce the glare from the monitor it is possible to use a low-cost plastic screen which has a conductive coating. If the coating is grounded, the electric fields will be reduced to extremely low levels.

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