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investigation of radiation emissions from video display terminals

INVESTIGATION OF RADIATION EMISSIONS FROM VIDEO DISPLAY TERMINALS

Environmental Health Directorate
Health Protection Branch

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PREFACE

This review is intended to provide the informed reader with a summary of the radiation surveys previously performed and to assess the biological impact of any possible radiation emitted by VDTs.

Compilation of this review was largely undertaken by Dr. W.M. Zuk, Dr. M.A. Stuchly, Mr. P. Dvorak and Dr. Y. Deslauriers of the Radiation Protection Bureau.

TABLE OF CONTENTS

	Page
INTRODUCTION	1
1. **What is a Video Display Terminal?**	1
2. **How does a Video Display Terminal Work?**	1
3. **What are the Potential Sources of Radiation from VDTs?**	1
3.1 The Cathode Ray Tube (CRT)	2
3.2 The Horizontal Deflection System	2
4. **Review of Studies on Radiation Emissions from VDTs**	3
4.1 Outside Canada	3
4.2 In Canada	13
5. **Responsibilities of the Department of National Health and Welfare**	15
5.1 Occupational Health and Safety	15
5.2 Radiation Emitting Devices Regulations for Video Display Terminals	15
6. **R.P.B. Study of VDTs**	18
6.1 Introduction	18
6.2 X-ray Emission Measurements	18
6.3 Non-ionizing Radiation Measurements	18
SUMMARY	21
APPENDIX I - X-RAY MEASUREMENT TECHNIQUE	23
APPENDIX II - RADIOFREQUENCY AND EXTREMELY LOW-FREQUENCY EMISSIONS FROM VDTs	26
APPENDIX III - X-RADIATION EMISSION TEST DATA FOR VDTs AND VIDEO MONITORS	34
APPENDIX IV - VIDEO DISPLAY TERMINALS TESTED IN WHOLE BODY COUNTER	38
REFERENCES	40
ADDITIONAL BIBLIOGRAPHY	41

LIST OF TABLES

		Page
1	- Results of 1977 NIOSH Survey of VDTs	4
2	- Summary of Wolbarsht et al., Data for Integrated RMS Electric and Magnetic Field Intensities at 25 cm from the CRT Face	6
3	- Summary of NRPB Measurements on VDTs	8
4	- Summary of Microwave and RF Emission Measurements carried out by Electrical Research Association Technology Limited	9
5	- Summary of 1980 NIOSH Radiation Measurements	11
6	- Comparison of NIOSH 1980 Results with Accepted U.S. Standards	12
7a)	- BRH Results on X-Ray Emission and Comparison with U.S. Standards	14
b)	- List of Units Emitting Detectable X-Ray Levels at 5 cm from the Screen	14
8	- BRH Results on Non-Ionizing Radiation Emission and Comparison with U.S. Standards or Recommended Maximum Levels	15
9	- Summary of Data on X-Ray Emission from VDTs Canadian Institutions Excluding the R.P.B.	16
10	- Summary of X-Ray Emission Measurements	18
11	- RF Emissions from VDTs	19
12	- ELF Emissions (The Magnetic Field Intensity) from VDTs and other Devices	20
A1	- RF Emissions From VDTs	29
A2	- The Magnetic Field Intensity at ELF in A/m; Video Display Terminals	32
A3	- The Magnetic Field Intensity of ELF in A/m; Various Devices	33

FIGURE

1	- Electromagnetic Spectrum	27

Note on X-Radiation Units

To minimize the probability of numerical errors, all X-radiation data are reported in units in which they were measured and/or published. The relations between the units used in this report and the corresponding SI units are given below.

Exposure: 1 roentgen (R) = 2.58×10^{-4} coulomb per kilogram (C/kg)

Absorbed Dose: 1 rad (r) = 0.01 gray (Gy)

Dose Equivalent: 1 rem = 0.01 sievert (Sv)

INTRODUCTION

The technological advances in information handling brought about by microprocessors have resulted in the widespread use of word processors and video information systems in offices, in the communications field, in education and, with the advent of "personal computers," in our homes. An integral feature of almost all of these devices is the video display terminal (VDT).

The proliferation of VDTs has given rise to questions about possible adverse health effects associated with their use. In particular, considerable concern has been voiced by the media and labour organizations about the possibility of VDTs posing a radiation hazard to the operators of these devices.

This report is intended to address these concerns by presenting and discussing the results of radiation emission measurements carried out on VDTs by the Radiation Protection Bureau. While the report is not intended to be an exhaustive review of all of the world literature on the subject, the more important studies performed on VDTs are summarized and reviewed. Attention is drawn to recent information which has not yet become generally available.

1. What is a Video Display Terminal?

A video display terminal is essentially a television monitor that displays information received from a computer system or word processor rather than from a television broadcast signal. It is an integral part of the electronic data handling system making up a word processor. Together with a keyboard, the VDT constitutes the interactive element between the operator and the microprocessor. In some home computers, the TV set is used as the display terminal.

2. How does a Video Display Terminal Work?

The basic principle of operation of a VDT is similar to that of a television set. The VDT contains a large evacuated glass tube, called a cathode ray tube (CRT), which includes a source of electrons at one end (the cathode) and a fluorescent coating on the inside of the viewing face. Electrons released from the cathode are accelerated by a high voltage (typically in the range of 10 000 to 25 000 volts) and are projected onto the fluorescent material. This material emits visible light when it is struck by the fast-moving electrons. The cathode ray tube also includes various electrodes for focussing the electron beam and for scanning the beam across the fluorescent screen. Electronic circuitry in the VDT modulates the electron beam to produce the intended images on the screen.

3. What are the Potential Sources of Radiation from VDTs?

The potential sources of radiation from VDTs are the cathode ray tube (for X-rays, visible light, IR and UV radiations), the horizontal deflection system circuitry (for RF), and transformers and coils (for ELF).

3.1 The Cathode Ray Tube (CRT)

X-rays are produced whenever fast moving electrons are slowed down or stopped rapidly in a material. Such conditions arise inside the CRT of a VDT.

As pointed out in Section 2, the inside surface of the viewing face of the CRT is coated with a fluorescent material. When the electrons emitted from the cathode strike this material visible light is emitted. Ideally, the fluorescent screen should convert all of the energy of the incident electrons into visible light. In practice, however, some of the electrons lose energy by causing X-rays to be emitted instead.

Because of the relatively low operating voltages of VDTs the X-rays produced inside the CRT are of low energy and are not very penetrating. These X-rays are absorbed by the glass of the CRT and do not penetrate to the outside. In fact, the thickness of glass used in the CRT has much higher X-ray shielding properties than required for the voltages at which VDTs operate and is capable of absorbing X-rays of energies considerably higher than those produced in the CRT. The results of X-ray measurements confirm this statement.

Other types of electromagnetic radiations may also be generated inside the CRT. Depending on the type of fluorescent material used, ultraviolet and infrared radiations may be produced at the fluorescent screen by the bombarding electrons. As in the case of the X-rays, these radiations are essentially completely absorbed by the glass of the CRT. As will be seen later in this report, where UV radiation has been detected at the viewing screen of VDTs, the measured levels have been thousands of times lower than the level permitted for continuous occupational exposure.

In the case of visible light emitted by the CRT, measurements show that the levels are very low - some 200 times lower than the light level outdoors on a cloudy day and more than 1000 times lower than the level permitted for continuous viewing of laser radiation.

3.2 The Horizontal Deflection System

The source of RF in a VDT is the horizontal deflection system, which causes the electron beam in the CRT to move across the fluorescent screen, and its associated high-voltage circuit, the so-called "fly-back" transformer. The high-voltage circuit generates the high voltage necessary to accelerate the electrons emitted at the cathode to the high speeds necessary for visible light to be produced when they strike the fluorescent screen. These voltages are typically in the range of 10 000 to 25 000 volts, depending on the model of VDT.

To produce the electron beam deflection and scanning action required in the VDT, the horizontal output is pulsed on and off very rapidly - some 15 000 to 25 000 times per second (15 to 25 kHz), depending on the model of VDT. This rapid oscillation of the voltage gives rise

to RF fields in the vicinity of the fly-back transformer and its associated circuitry. The RF is produced at the fundamental frequency of the deflection system and at harmonic frequencies of up to about 150 kHz.

In instances where RF radiation from VDTs has been found, it has been near the surface of the VDT and the levels were found to decrease very rapidly with distance from the surface. At 20 to 30 centimetres away the RF was either nondetectable or, at worst, measured levels were significantly below the levels that can cause biological effect and below the most stringent exposure standard anywhere in the world.

The designs of the oscillator circuits used in VDTs and the nature of their operation preclude the emission of microwaves (electromagnetic radiation of frequencies between 300 megahertz and 300 gigahertz) and none have been detected from VDTs.

4. Review of Studies on Radiation Emissions from VDTs

A number of studies on VDTs have been carried out worldwide in response to concerns about possible hazardous radiation emissions. These studies included measurements for both ionizing radiation (X-rays) and non-ionizing radiation and covered virtually every make and model of VDT. The published results of the most significant studies are reviewed in this section.

4.1 Outside Canada

In 1977 the United States National Institute of Occupational Safety and Health (NIOSH) published the results of a 1975 study of three types of VDTs used in a major newspaper facility. A total of twenty-three units were measured for emission of X-rays and for UV, IR, visible and RF radiations. The results of this survey are summarized in Table 1.

The highest level of ultraviolet radiation detected by NIOSH was 500 000 times lower than the occupational exposure limit. The measured luminance of light in the visible region of the electromagnetic spectrum was 140 times below the safe exposure limit. No infrared or radiofrequency radiation could be detected. The X-ray emission measurements showed no levels above instrumental background, which fluctuated between 0.16 and 0.7 mR/h. (The gross X-ray level readings ranged from 0.12 to 0.85 mR/h). The one unit which showed a momentary reading of 0.85 mR/h was found, on rechecking to read 0.20 mR/h. The momentary high reading was attributed to background fluctuation and the overall conclusion was that there was no measurable x-radiation.

In the 1977 NIOSH report[1], reference is made to a 1977 survey of 67 VDTs, in the same newspaper facility, by a major insurance company. The maximum instrument reading was 0.2 mR/h and, since the background ranged from 0.1 to 0.3 mR/h, the conclusion was that no measurable x-radiation was being emitted by the VDTs surveyed.

Table 1 - Results of 1977 NIOSH Survey of VDTs

Type of Radiation	Maximum Measured Level	U.S. Occupational Exposure Standard
Ultraviolet	2×10^{-9} W/m^2	1×10^{-3} W/m^2
Visible	21 fL	2.92×10^{3} fL
Infrared	Not detectable	10^{-2} W/m^2
RF (E-field)	Not detectable	2×10^{2} V/m
RF (H-field)	Not detectable	5×10^{-1} A/m
X-ray	0.85 mR/h*	2.5 mR/h**

Note:

W/m^2	refers to watts per metre squared
fL	refers to luminance in foot-lamberts
V/m	refers to volts per metre
A/m	refers to amperes per metre
mR/h	refers to milliroentgens per hour
E-field	refers to the electric field
H-field	refers to the magnetic field

* Includes background level and was subsequently determined to be incorrect.

** Based on an annual exposure limit of 5000 mR divided by 2000 working hours per year.

The overall conclusion reached by NIOSH was that the VDTs surveyed did not appear capable of producing radiation at levels which would be an occupational hazard.

In 1979 Weiss and Petersen(2) of the Bell Telephone Laboratories published the results of their study of electromagnetic radiation emitted from 11 units of 8 models of VDTs used by the Bell System. Their study included measurements for RF and microwaves (over the frequency range 10 kHz to 18 GHz), X-rays and UV, IR and visible light (over a band of wavelengths from 350 to 600 nanometers).

As in the case of the 1977 NIOSH study, no ionizing radiation could be detected above the ambient background level. RF radiation was detected between 1.5 kHz and 1.4 GHz; however, the maximum level found was more than 100 times lower than the most restrictive safety standard in the world (that of Czechoslovakia). Radiation in the ultraviolet region of the spectrum was also detected; however, the measured values were at least 10 000 times below occupational exposure limits. On the basis of these results Weiss and Petersen concluded that "there is no experimental or epidemiological evidence presently available to indicate that these levels of radiation could have any detrimental effects on the health of personnel using video computer terminals such as those examined in this study."

Wolbarsht et al.[3] carried out precise measurements on one model of VDT, an IBM Model 3277, for RF in the frequency range 10 kHz to 10 GHz, for UV, IR, and visible light over the wavelength range 0.2 to 10 micrometres, and for X-rays in the energy range 5 to 40 keV. The significant difference between this study and previous ones was that the measurements were made in the laboratory, with detection sensitivities greater than those possible under field conditions. Furthermore, measurements were also made with an overvoltage fault induced in the VDT to maximize the potential for radiation emissions.

Using a NaI(Tl) scintillation detector, Wolbarsht et al. set an upper limit on possible X-ray emissions of 3×10^{-6} R/h. There was no significant difference in results between measurements made under normal and fault conditions of operation.

In the RF and microwave regions, both electric and magnetic field measurements were made on the VDT, and were compared to similar measurements on a colour and a black and white television receiver. The results of these measurements are summarized in Tables 2(a) and 2(b). The USA (ANSI) and the USSR standards are given in these tables for comparison purposes. A comparison of these results with the appropriate standards showed large safety margins for this model of VDT.

The emission levels measurements by Wolbarsht et al. in the UV, visible and IR gave similar results of those of NIOSH; measured levels were several orders of magnitude below established occupational safety limits. For example, in the 200-320 nm (ultraviolet) region, the measured irradiance of 1.25×10^{-10} W/cm^2 was 800 times below safety limit; in the 320-400 nm (near-ultraviolet) region the measured irradiance was 10^7 times below safety limits; the measured visible luminance was 273 times below the occupational exposure limit; in the 400-700 nm (visible light) region, the measured irradiance was over 7000 times below the safety limit; and in the 0.7-4.1 μm (IR) region, the measured irradiance of 2.0×10^{-5} W/cm^2 was 500 times below the safety standard.

On the basis of these results, Wolbarsht et al. concluded that there was no radiation hazard associated with this model of VDT and that other environmental factors were more important in evaluating the effects of VDTs for long-term use.

Vetter[4] reported on X-ray emission measurements carried out on two models of VDTs at the International Atomic Energy Agency in Vienna. The measurements were made with a ZnS scintillation crystal, a Ge(Li) X-ray detector and with CaF_2 thermoluminescence dosimeters. In both cases no X-rays were detectable above normal background levels, which were found to be 8 μR/h at the IAEA establishment.

Table 2 - Summary of Wolbarsht et al., Data for Integrated RMS Electric and Magnetic Field Intensities at 25 cm from the CRT Face

(a) Electric Field

Frequency Range	VDT (IBM 3277)	Colour TV (Sony)	Black & White TV (Motorola)
	(V/m)	(V/m)	(V/m)
1 kHz - 10 MHz	2.25×10^{-1}	7.5	11.1
10 MHz - 10 GHz	5.23×10^{-3}	2.41×10^{-3}	5.6×10^{-4}
	Plane Wave Equivalent Power Densities		
	(mW/cm^2)	(mW/cm^2)	(mW/cm^2)
1 kHz - 10 MHz	1.34×10^{-5}	1.49×10^{-2}	3.27×10^{-2}
10 MHz - 10 GHz	7.26×10^{-9}	1.54×10^{-9}	8.35×10^{-11}

ANSI and USSR Standards for RF and Microwaves (Electric Field)

	ANSI Standards	
	(V/m)	(mW/cm^2)
1 kHz - 10 MHz	none	none
10 MHz - 10 GHz	193	10

	USSR Standards	
	(V/m)	(mW/cm^2)
60 kHz - 3 MHz	50	6.63×10^{-1}
3 MHz - 30 MHz	20	1.1×10^{-1}
30 MHz - 50 MHz	10	3.0×10^{-2}
50 MHz - 300 MHz	5	1.0×10^{-2}
300 MHz - 300 GHz		1.0×10^{-2}

(b) Magnetic Field

Frequency Range	VDT (IBM 3277)	Colour TV (Sony)	Black & White TV (Motorola)
	(A/m)	(A/m)	(A/m)
1 kHz - 10 MHz	8.96×10^{-4}	3.59×10^{-2}	2.73×10^{-2}
10 MHz - 100 MHz	1.89×10^{-6}	2.61×10^{-7}	(below noise)
	Plane Wave Equivalent Power Densities		
	(mW/cm^2)	(mW/cm^2)	(mW/cm^2)
1 kHz - 10 MHz	3.03×10^{-5}	4.86×10^{-2}	2.81×10^{-2}
10 MHz - 100 MHz	1.35×10^{-10}	2.57×10^{-12}	(below noise)

ANSI and USSR Standards for RF and Microwaves (Magnetic Field)

Frequency Range	ANSI		USSR	
	(A/m)	(mW/cm^2)	(A/m)	(mW/cm^2)
1 kHz - 10 MHz	none	none	5.0	9.43×10^2
10 MHz - 100 MHz	0.5	10	0.3	3.39

In Britain, the National Radiological Protection Board and Electrical Research Association Technology Limited carried out a study of VDTs for the U.K. Health and Safety Executive. More than two hundred different types of VDTs were surveyed under normal operating conditions and the measurements covered various regions of the electromagnetic spectrum. The results of these measurements, reported by Cox[5], are summarized in Tables 3 and 4.

Table 3 - Summary of NRPB Measurements on VDTs

Electromagnetic Radiation Type	Quantity Measured	Maximum Emission Measured
X-rays	dose equivalent rate	< 10 µrem/h*
UV	irradiance	
240 - 336 nm		0
336 - 440 nm		0.124 W/m^2
Visible	irradiance	
400 - 700 nm		2.5 W/m^2
IR	irradiance	
700 - 1050 nm		0.05 W/m^2
10 µm - 3 mm		4 W/m^2
Microwave & RF		
18 GHZ - 300 MHz	power density	5 W/m^2
3 GHz - 10 MHz	power density	1000 W/m^2**
220 MHz - 10 kHz	electric field intensity	> 300 V/m***

* This means that X-ray exposure rate, if any, is below the detection threshold of the meter used, Victoreen 440 RF/C; 10 µrem/h is approximately the level of dose equivalent rate due to natural radiation background.

** Subsequent measurements did not confirm this result, the instrument used was found a subject of interference by fields at lower frequencies, i.e., those produced by the fly-back transformer.

*** At the surface of the unit.

Table 4 - Summary of Microwave and RF Emission Measurements carried out by Electrical Research Association Technology Limited

Microwave and RF Frequency Range	Maximum Measured Electric Field Intensity (V/m) at the Surface
300 GHz - 30 GHz	not measured
30 GHz - 1 GHz	not measured
1 GHz - 300 MHz	0.01
300 MHz - 30 MHz	0.18
30 MHz - 10 MHz	0.12
10 MHz - 3 MHz	0.5
3 MHz - 300 kHz	16
300 kHz - 150 kHz	600
150 kHz - 10 kHz	1800

No X-ray emissions exceeding the level of natural background of ionizing radiation (approximately 10 µrem/h) were found. This is about fifty times less than the level that would correspond to the maximum permitted emission level of 0.5 mR/h at 5 cm for household products in Britain. No UV radiation was detected at wavelengths below 336 nm. In the 336-440 nm range the maximum detected UV emission was 124 nW/m^2, which is about 100 times below the permitted continuous occupational exposure level in this region. In the visible light region (400-700 nm) the maximum emission measured was 2.5 W/m^2, which is 25 times below the permitted limit. In the near infrared region (700-1050 nm) the maximum emission measured (50 mW/m^2) was 100 times below acceptable levels and no far infrared radiation (10 µm-3 mm) was detectable.

Similar results were obtained for RF and microwave radiation. No microwaves were detected and in the worst case the maximum RF level detected was 10 times lower than the appropriate exposure limit.

Cox stressed that the measured values were far in excess of those to which the operator would be exposed since the measurements were made at the surface of the VDTs and with brightness and contrast controls adjusted to maximum settings. Furthermore, the measured RF fields were highly localized and dropped by a factor of at least 1000 at the position where the operator would normally be. The conclusion drawn by Cox from these results was that the very low levels detected did not pose a radiation hazard to operators in either the long or the short term.

In 1980, Terrana et al.,[6] of the Institute of Occupational Health of the University of Milan, measured 85 VDTs for X-ray emissions. Again, no X-ray emissions above background levels were detected.

In 1981, NIOSH published[7] the results of an in-depth study of VDTs, which encompassed radiation, industrial hygiene, health complaints and ergonomics. The study involved two newspaper offices and an insurance company and was carried out in response to a request from three unions. The radiation measurements were for both ionizing (X-rays) and non-ionizing (UV, visible and RF) radiation and involved a sample size of at least 25% of the VDTs at each of the facilities. (A total of 136 VDTs were tested.) The results of the NIOSH measurements and comparisons of these results are given in Tables 5 and 6, respectively.

In summarizing these results, the authors of the NIOSH report stated: "The radiation surveys demonstrated that exposure to X-ray, radiofrequency, ultraviolet, and visible radiation was well below current occupational exposure standards, and, in many cases, below the detection capability of the survey instruments". Furthermore, in view of the nonexistent or very low radiation levels, NIOSH concluded that routine radiation surveys of VDTs are not warranted.

In 1981, the U.S. Bureau of Radiological Health published an extensive report[8] on their study aimed at determining the levels of radiation emitted by VDTs. This report presents in detail the results of measurement of X-ray emission from 125 VDTs, and of non-ionizing radiation (including ultrasound in addition to electromagnetic radiations) on 34 of these units. The measurements were performed under controlled laboratory conditions, and the study analyzed very thoroughly potential sources of radiations, both in normal operation and in fault conditions.

The testing of VDTs for x-radiation emission was performed under the same test conditions (Phase III) as specified by the U.S. federal performance standard for television receivers. Specifically, the product was tested with line voltages adjusted up to 130 V(AC), and the user and service controls adjusted as necessary in combination with the worst-case component or circuit fault in order to maximize the X-ray emission. Phase III compliance testing is done under conditions of degradation which still allow the display of viewable intelligence on the CRT screen. In the case of VDTs cited in this report, the screen was entirely filled with characters. The tested units were supplied from the manufacturer's stock.

The procedure for detecting ionizing radiation consisted of scanning all surfaces of the VDT with a Geiger-Müller (GM) survey meter to determine x-radiation emission. The actual measurement of any detected x-radiation was made using an ionization chamber instrument at a distance of 5 cm from the surface of the set. The instrument used for that measurement, Victoreen 440 RF/C, averages x-radiation over an area of 10 square centimetres.

Table 5 - Summary of 1980 NIOSH Radiation Measurements

Manufacturer	Model Number	Number of Units Measured	X-ray Radiation (mR/h)	Ultraviolet Radiation ($\mu W/cm^2$)	Visible Radiation (fL)*	Radio-frequency Radiation	
						Electric field (V^2/m^2)	Magnetic field (A^2/m^2)
Harris	2200	3	ND**	ND	3	ND	ND
IBM	3278	3	ND	.06-.13	2-4	ND	ND
Ontel	OP-1	4	ND	ND-.6	9-25	ND	ND
	OP-1/16	6	ND	ND-.3	5-40	ND	ND
	OP-1/S11	2	ND	.3-.4	20	ND	ND
Delta Data	5000	5	ND	ND	2-5	ND	ND
IBM	3278	3	ND	ND	2	ND	ND
Systems Integrated	ET960	20	ND	ND	4-18	ND	ND
Ontel	OP-1/16	5	ND	ND-0.1	2-30	ND	ND
	OP-1/64	1	ND	0.65	30	ND	ND
	OP-1/S11	8	ND	ND-0.1	3-20	ND	ND
Courier	TC30C1	37	ND	ND	1-5	ND	ND
Courier	110071-001	8	ND	ND	2-4	ND	ND
Courier	110117-001	4	ND	ND	1-2	ND	ND
Courier	110127-001	1	ND	ND	1	ND	ND
Courier	11270	17	ND	ND-0.10	1-6	ND	ND
All Models		136	ND	ND-0.65	2-40	ND	ND

* 1 fL = 0.29 candle/m^2

** ND = not detectable

Table 6 - **Comparison of NIOSH 1980 Results with Accepted U.S. Standards**

Radiation Region	Maximum Level	Occupational Standard
x-ray	ND*	2.5 mR/h
UV (near)	0.65 $\mu W/cm^2$	1 000 mW/cm^2
Visible	40 fL	2 920 fL
RF:		
- Electric Field	ND	40 000 V^2/m^2**
- Magnetic Field	ND	0.25 A^2/m^2**

* ND = not detectable

** Far field equivalent of 10 mW/cm^2

In each case, the high-voltage portion of VDT was also investigated and analyzed. The high voltage of CRT is of primary concern because it determines the energy of the x-radiation and, consequently, whether the radiation can escape from the glass envelope of the CRT. Some of the tested models contain high voltage hold-down or limiting circuits to prevent abnormal rise of high voltage applied to the CRT. In most cases the high voltage could be maximized by disrupting the regulation (constant output voltage) either in the low-voltage power supply or in the high-voltage power supply itself. In some cases maximum high voltage was obtained by disrupting the hold-down circuit. In every case a single failure was introduced to ensure that maximum high voltage was obtained for the failure condition. The CRT beam current was optimized, as necessary, to yield maximum x-radiation, by adjustment of the brightness, contrast, or beam limiter controls.

Thirty-four VDTs were tested as described above. None of these units emitted x-radiation above 0.5 mR/h at 5 cm; no detectable level of radiation was found for 33 units, while one unit emitted 0.42 mR/h at 5 cm from the screen surface.

In addition, x-radiation emission data for 91 previously tested VDTs have been included and re-analyzed, in order that the ionizing radiation characteristics can be explored in depth for both monochrome and color VDTs. Of these 91 VDTs previously tested under Phase III conditions, between 1975 and 1978, 8 units representing 3 basic models emitted x-radiation above the limit. Some were recalled by the manufacturer for modification in order to comply with the standard; other manufacturers were not permitted to introduce those particular products into the U.S. market. One model emitted x-radiation for only a few minutes before the VDT failed completely; its components were overstressed and the VDT became inoperative. The manufacturer of that model was also notified of the Bureau's evaluation and that model

is no longer manufactured. There seems to be little correlation between the operating high voltage and the presence or absence of X-ray emission, but most of the units emitting X-rays show a larger than average increase of high voltage in the fault condition. Exactly one half of the units emitting X-rays were monochrome and half were color VDTs. None of the models emitting detectable levels of radiation has been found in Canada.

The authors summarize their results as follows:

"In general, emission levels from the terminals tested, both under normal operating and worst-case conditions, fall within the standards and guidelines currently in effect for each type of radiation. A few of the tested units emitted x-radiation in excess of that allowed under the television receiver standard, and these models have been corrected or withdrawn from the market. Thus video display terminals should not pose a radiation risk to those who operate them."

A summary of the results is given in Tables 7 and 8.

4.2 In Canada

Besides the surveys and tests performed by the Radiation Protection Branch in the field and in its low-background facility, data and studies by several other Canadian institutions, both governmental and nongovernmental, were available at the time of writing this report. Practically all dealt with a possibility of X-ray emission by VDTs, some of them treated the other forms of radiation that could conceivably be emitted by VDTs, and in several studies possible health hazards connected with VDT operations were discussed.

The results for X-ray emission are given in Table 9.

The only survey that presents consistently non-zero X-ray leakage levels is the one undertaken by Bell Canada. The results of this survey were not confirmed by any other groups. Several units that supposedly emitted the highest levels of x-radiation were retested by Radiation Protection Branch, both in the field and in the low-background facility. None of them showed any detectable X-ray emission.

No correlation has been observed between VDT control settings (brightness, contrast, filling of screen) and X-ray meter readings in any of the surveys.

Investigations of emissions of non-ionizing radiation at radio and microwave frequencies were reported by two provinces. The Alberta Workers Health, Safety and Compensation checked 130 VDTs (51 different models from 28 suppliers). The measurements were performed in frequency range 0.9 - 10 GHz, with the minimum detectable level of 0.01 mW/cm^2. None of the 130 VDTs tested emitted levels above the detection threshold. The Saskatchewan Department of Labour investigated 10 VDTs (four models) in the frequency range 10 kHz - 220 MHz. The highest electric field intensity of 250 V/m was found 10 cm from the surface at the side of one unit.

Table 7(a) - BRH Results on X-Ray Emission and Comparison with U.S. Standards

No. of Models		Maximum Emission (mR/h @ 5 cm)	U.S. Exposure or Emission Standard Level (mR/h)
Tested	Non-Compliant		
125	8	2.0	2.5 (Occupational Exposure) 0.5 (Emission at 5 cm)

None of these non-compliant models is available on the market; two more models had a detectable emission level below 0.5 mR/h limit.

Table 7(b) - List of Units Emitting Detectable X-Ray Levels at 5 cm from the Screen

Manufacturer	Model	Test Date	Fault kV	Fault mA	mR/h
Ball Brothers	TU-8C,B&W	21 JUN 78	22.0	200	0.72
Ball Brothers	THC17C,B&W	09 OCT 75	23.4	200	0.4 *
Ball Brothers	TU-8C,B&W	30 JUN 78	22.1	210	0.96
Ball Brothers	TU-8C,B&W	07 JUL 78	23.7	160	0.66
Conrac	5512/C12,COL.	13 AUG 75	29.5	720	1.6
Conrac	5522/C12,COL.	12 AUG 75	32.9	200	0.65
Conrac	5522/C12,COL.	12 AUG 75	30.5	400	1.15
Elston	DM20-12A0,B&W	26 SEP 79	25.5	300	0.42*
Ikegami	TM10,COL.	15 JUN 76	30.0	660	2.0
Ikegami	TM10,COL.	12 JUL 76	30.3	590	1.2

* Not above the U.S. federal limit

B&W stands for monochrome, COL. stands for colour VDTs.

Table 8 - BRH Results on Non-Ionizing Radiation Emission and Comparison with U.S. Standards or Recommended Maximum Levels

Radiation Type	Maximum Level Measured	Maximum Standard or Recommended Level
RF Electric Field Strength (15-125 kHz)	64 V/m	no standard
RF Magnetic Field Strength (15-125 kHz)	0.69 A/m	no standard
Ultrasound	68 dB at 40 kHz	75 dB
Near Ultraviolet	5×10^{-6} W/cm^{2}sr	1×10^{-3} W/cm^{2}sr
Radiance (visible and infrared)	$<1 \times 10^{-3}$ W/cm^{2}sr	2×10^{-2} W/cm^{2}sr

The highest level 10 cm from the screen was 7 V/m, and for most terminals the field intensity was 2 V/m at any location 10 cm from the external surface.

5. Responsibilities of the Department of National Health and Welfare

5.1 Occupational Health and Safety

The Radiation Protection Bureau is responsible for promoting and facilitating the safe use of radiation emitting devices by workers under federal jurisdictions. This includes all employees of Public Service departments and agencies and of organizations that are subject to the Canada Labour Code. Any device that emits or is potentially capable of emitting radiation must conform to installation and use standards that are acceptable to or prescribed by the Radiation Protection Bureau. To ensure conformity to these standards the Bureau systematically conducts radiation protection surveys of such equipment in facilities under federal jurisdiction.

Statutory authority for these activities is provided for by the Canada Dangerous Substances Regulations, issued under Part IV of the Canada Labour Code, and the Safety Standard Respecting Dangerous Substances in the Public Service of Canada, issued by Treasury Board.

5.2 Radiation Emitting Devices Regulations for Video Display Terminals

The Radiation Emitting Devices Act, passed by the Canadian federal government in 1970, provides statutory authority for regulating the safety of radiation emitting devices sold in Canada. The Radiation Emitting Devices Act applies to all devices capable of emitting electromagnetic radiation of frequencies greater than 10 MHz or ultrasonic waves having frequencies greater than 10 kHz.

Table 9 - Summary of Data on X-Ray Emission from VDTs Canadian Institutions Excluding the R.P.B.

Institution	Test Equipment	No. of Units	VDT Setting	Minimum Distance	X-Ray Levels Detected
Bell Canada	Victoreen 440 Victoreen 440 RF/C	925	Full screen, maximum brightness	Not stated*	0.00 to 0.23** mR/h
University of Western Ontario	Victoreen 444	35	Normal operation and full screen maximum contrast and brightness	Less than 5 cm	Not distinguishable from background
Ontario Hydro	TLD	18	Not stated	Detector in contact with screen	Max. 0.01 mR/h above background
	Not stated	1	"Crash test"	Not stated*	Less than 0.316 mR/h
Manitoba Cancer Treatment and Research Foundation	Victoreen Thyac III G.M. Survey Meter	50	Not stated	1 cm	Not distinguishable from background
Alberta Workers' Health Safety and Compensation	Berthold LB 1200 G.M. Instrument	130	Not stated	Detector face in contact with screen	Not distinguishable from background
Saskatchewan Labour	Victoreen 444	>250	Full screen, maximum brightness	Not stated*	Not distinguishable from background
Ministère des affaires sociales, Québec	TLD	2	Maximum brightness	Detector in contact with screen	Not distinguishable from background
Ontario Ministry of Labour	Victoreen 440 RF/C Thyac 3	>350	Full screen, maximum brightness	Typically 5 cm	<0.05 mR/h
British Columbia Ministry of Health	Victoreen 440 RF Dental film	>200	Full screen, maximum brightness	Detector in contact with screen	<0.1 mR/h
Nova Scotia Dept. of Health	Berthold *** LB 1200/LB 6513	58	Normal operation	5 cm	<0.025 mR/h
New Brunswick Dept. of Health	Eberline E-140/HP260	32	Full screen, maximum brightness	Detector in contact with screen	Not distinguishable from background

* The regulatory leakage exposure rate measurements are normally taken at 5 cm from the screen.

** A jump of about 0.1 mR/h coinciding with the change from 440 to 440 RF/C meter can be observed in the tables of results; the background varies by a factor of 2 to 4 with time and location of the site.

*** Not RF shielded.

A significant aspect of the Act is that it provides authority for promulgating regulations on the design, construction and functioning of devices and their components "for the purpose of protecting persons against personal injury, impairment of health or death from radiation." According to the Act, no person can import or sell in Canada any radiation emitting device of a class for which standards have been prescribed unless the device and its components comply with the applicable standards. It is the responsibility of the manufacturer or distributor to ensure that the device conforms to the requirements of the regulations.

Regulations for television receivers, video monitors and video display systems have been in effect since 1972. These regulations incorporate limits on maximum radiation emission as well as specific labelling requirements for purposes of identifying the source of manufacture of the products.

The VDT operators are not radiation workers, and therefore the maximum permissible levels of X-ray emission from the VDTs are set at the levels allowed for TV sets in Canada, U.S., U.K., etc., i.e., at 0.5 mR/h. This limit ensures that for a person watching the screen, whether it be a TV or a VDT, for 40 hours a week, 50 weeks a year, (i.e., 2000 hours) the X-ray exposure received from the unit does not result in the whole body dose equivalent approaching the 500 mrem per year limit applicable to the population at large.

For a unit emitting the maximum permitted level of x-radiation, the total exposure at 5 cm from the screen would be 1R during a 2000 hours worked per year. The VDT screen is viewed typically from some 40 cm distance. Since this distance is comparable with the dimensions of radiation source (screen), and the absorption in the screen would cause the angular distribution of intensity to be strongly peaked in the direction of operator, the radiation would decrease much more slowly than with the inverse square of distance. It is a conservative estimate that at 40 cm the intensity would be somewhat less than one half of its value at 5 cm.

This X-ray exposure would be limited to a small part of the body. The dose delivered by soft X-rays decreases very rapidly with the depth and, therefore, the tissues and organs lying deeper than a few centimetres would be practically completely shielded by the overlying tissue. For these reasons, the actual whole body dose equivalent would be a few mrem per year.

The average whole body dose equivalent due to ionizing radiation from environmental and internal sources on this continent varies from some 100 mrem/year to about 250 mrem/year. The whole body dose equivalent that could conceivably result from exposure to X-ray emission from a marginally acceptable TV or VDT is then much less than the naturally occurring fluctuations in the environmental radiation to which each of us is exposed. It has to be emphasized, though, that in reality the TV sets and VDTs that are on the market do not emit measurable levels of radiation.

Responsibility for enforcing compliance with the regulations resides with the Radiation Protection Bureau. The Bureau conducts a comprehensive compliance program which includes sampling and testing of devices at points of import or distribution, testing at its laboratories and evaluation of detailed technical submissions.

6. VDT Studies Carried Out by the Radiation Protection Bureau

6.1 Introduction

The possibility of X-ray emission by equipment using the Cathode Ray Tube (CRT) to display information, such as TV receivers, oscilloscopes, radar displays, or video display terminals, has been studied by the Radiation Protection Bureau since early 1970s. A number of tests were done during the preparatory stages for promulgation of the Radiation Emitting Devices Regulations for Television Receivers (these regulations are also applicable to video display monitors and terminals). After these Regulations had been promulgated on June 1, 1972 the video display terminals were tested regularly as described in Appendices I and II. The results of these tests are summarized in Tables 10-12. All models tested by June 1, 1982 are listed in Appendices III and IV.

6.2 Table 10 - Summary of X-ray Emission Measurements

Test Type	No. of Models	No. of Units	Max. Emission (mR/h)	Distance (cm)	Note
Regulatory	122	227	not detectable	5	Appendix I.A, III
Low Background	49	52	not detectable	10	Appendix I.B, IV

The regulatory measurements were done with a Victoreen 440 RF/C meter which can measure X-ray levels lower than 0.1 mR/h, while the low background measurements were performed in the Whole Body Counter using instruments capable of low-energy X-ray detection down to one millionth of one milliroentgen per hour (see Appendix I.B).

6.3 Non-ionizing Radiation Measurements

The radiofrequency (RF) emissions were measured in the frequency range 10 kHz -220 MHz with the minimum detectable level of 1 V/m. A total of 86 VDTs (57 different models from 25 suppliers) were tested. The results are summarized in Table 11, and more detailed information is given in Appendix II.

The extremely low frequency (ELF) emissions were evaluated in the frequency range 5 - 500 Hz with the minimum detectable level of about 0.001 to 0.01 A/m (depending on the frequency). The results for three VDTs, a few common electrical devices and different ambient conditions are summarized in Table 12.

Table 11 - RF Emissions from VDTs

Field Intensities	Operator Exposure(1) (Number of Models)	Keyboard Maximum(2) (Number of Models)	Localized Maximum(2) (Number of Models)
Below 1 V/m	37	33	5
1 - 5 V/m	20	20	5
5 - 10 V/m	-	4	1
10 - 60 V/m	-	-	21
60 - 200 V/m	-	-	10
Above 200 V/m	-	-	15

1. Measured 30 cm from the screen.

2. Measured as close as possible to the surface.

Table 12 - ELF Emissions (The Magnetic Field Intensity) from VDTs and other Devices

Description	Field Intensity (A/m)
Laboratory, fluorescent lights	0.188
Office, fluorescent lights	0.064
Residence, kitchen, fluorescent lights	0.103
Residence, kitchen, lights off	0.088
VDT, Sony CUM 115, 30 cm from screen	0.213
VDT, H-P 2640B, 30 cm from screen	0.097
VDT, Perkin Elmer 500, 30 cm from screen	0.217
IBM typewriter, Model 72, keyboard	0.127
IBM typewriter, Model 72, back	1.64
Baseboard heater	3.965
Hair dryer, GE-CD100A	0.236
Hand mixer, GE-M7A	9.295

SUMMARY

Radiation emissions from VDTs are either nonexistent or are so low that no standard in the world would classify these emissions as hazardous.

The major points emphasized in this document are summarized below:

1. A large number of reputable scientific surveys on radiation emissions from VDTs have been carried out all over the world. Collectively these surveys have encompassed virtually every make and model of VDT and have included emission measurements for X-ray, microwave, radiofrequency, extremely low frequency, ultraviolet, infrared and visible radiations.

2. VDTs have no components that can generate microwave radiation and none has ever been detected.

3. Some low frequency (up to 150 kilohertz) radiofrequency radiation has been detected very close to the surface of some VDTs. However, the levels fall off so rapidly with distance that at the position of the operator they are either nondetectable or significantly lower than the most restrictive standard in the world.

4. The human body is highly reflective to radiofrequency radiation of frequencies below 200 kilohertz and only a minimal amount of the radiation is absorbed by the human body.

5. Measurements of VDTs for X-ray emissions have repeatedly shown none detectable above natural background levels.

6. The Radiation Protection Bureau has carried out X-ray measurements on over 250 VDTs, comprising 150 different models. No x-radiation above background was detected.

7. To assess the validity of claims that VDTs might be emitting X-rays below the background level, 48 different models were measured in the R.P.B. low-level counting facility. This facility can detect low energy X-rays at emission levels 500 000 times lower than the mandatory standard for VDTs (0.5 mR/h). No X-ray emission was detected.

8. Visible light is produced in a VDT and is necessary for it to function. However, the level is very low -- some 200 times lower than the light level outdoors on a cloudy day and about 100 times lower than occupational exposure limits.

9. Ultraviolet and infrared radiations have either been nondetectable or some 10 000 times below occupational radiation exposure limits.

10. Extremely low-frequency emissions are of very low intensity, comparable to the intensities of emissions from other common electrical and electronic devices.

There is no reason for any person, male or female, young or old, pregnant or not, to be concerned about radiation health effects from VDTs.

X-RAY MEASUREMENT TECHNIQUE

A. Regulatory Compliance Tests

Video Display Terminals are classified as television receivers and fall under the same regulations established under the Federal Radiation Emitting Devices Act. These regulations are applicable at the point of importation or manufacture and stipulate standards of design, construction and functioning. X-ray emission is limited to a maximum of 0.5 mR/h at 5 cm from any accessible surface even if failure or malfunction of one or more components occurs.

The X-rays Section of the Radiation Protection Bureau conducts a compliance program which includes field surveys, laboratory testing and review of technical reports supplied by the manufacturer.

Field surveys are conducted at the premises of users, manufacturers, importers and vendors of VDTs. The radiation survey meter used to measure X-ray emission is a Victoreen 440 RF/C. This instrument is shielded against stray radiofrequency fields. It is an ionization chamber device designed to detect X-rays of the energies that might be emitted by VDTs. The VDT is powered at the normal line voltage (110-120 VAC) and critical electronic components are not made to fail or malfunction. Measurements are made with the screen filled with characters. The controls are first set to provide normal brightness and contrast, and then adjusted to the maximum brightness and contrast. This covers both the conditions of normal operation and of maximum probability of X-ray emission.

In laboratory testing, the manufacturer is asked to submit a representative sample to the Radiation Protection Bureau. The survey meter used is again the Victoreen 440 RF/C. The line voltage is adjusted to a maximum of 127 VAC and the operator and service controls are adjusted to produce the CRT current and voltage designed to maximize any X-ray emissions. In addition, electronic components that can affect X-ray emission are altered in such a way as to increase the likelihood of these emissions. One restriction of this failure mode testing is that the malfunction induced must not prevent the VDT from displaying a useful image that fills at least 60% of the screen.

Manufacturers of VDTs marketed in Canada are requested to provide the Radiation Protection Bureau with technical reports on their products.

These reports require detailed information on the design and functioning of the VDT, as well as on the shielding and the design of special circuits to reduce the possibility of X-ray emission. The manufacturer outlines his quality control procedures, sampling methods and corrective action program for substandard products. A description of the radiation tests performed

by the manufacturer, the test instruments used, their frequency and methods of calibration and the results of the tests are also included in the report. Should such a report be incomplete or raise doubts about compliance with the regulations, the manufacturer may then be asked to send a representative sample to the Radiation Protection Bureau for testing.

B. The Use of the R.P.B. Whole Body Counter for Low-Level Radiation Measurement on VDTs

The R.P.B. whole body counter is designed to measure very small quantities of radioactivity in the human body. The radiation detectors are housed in a chamber large enough to contain a human subject, and the chamber walls are thick enough (20 cm steel plus 0.6 cm lead) to reduce the natural background by a factor of about 1000, when the whole spectrum is considered. The facility is described in detail in the IAEA Directory of Whole Body Monitors(9).

The facility is engaged mainly in occupational health work, namely in measuring the very small amounts of uranium, radioiodine and thorium that are taken into the body by some workers in industry, universities and hospitals. The facility has participated in an international intercalibration study for plutonium in the lung, and is the National Reference Center for the calibration of other whole body counting facilities in Canada.

The low-energy emissions from many of the radioactive materials under investigation in the facility such as ^{125}I, and natural uranium, are in the same energy region as the emission that could be theoretically produced by a VDT, that is from about 10 keV to 25 keV.

The detectors used in the facility are extremely sensitive, more sensitive by a number of orders of magnitude than the GM (GEIGER-MUELLER) tube, or the ionization chamber which are the detection elements in most survey instruments.

The extreme sensitivity, coupled with the massive shielding, means that extremely low levels of radioactivity can be detected. The radiation fields associated with these small quantities are also extremely low. As an example, the facility can detect about 100 pCi* of ^{241}Am, an isotope that gives off an X-ray emission at 17 keV. The calibration of VDT tests was done with a ^{241}Am source certified to within ±5%. The radiation field associated with 100 pCi of ^{241}Am when its only 17 keV emission is considered, is less than 10^{-9} R/h. The normal background radiation field, to which we are all exposed, arises mainly from cosmic rays and natural radioactivity in soil and rocks. The size of this radiation field varies considerably with location and altitude but extensive surveys have shown that in average cosmic rays contribute about 28 mrad/yr and terrestrial radioactivity about 44 mrad/yr(10). The sum of these dose rates is equivalent to about 8×10^{-6} R/h.

*100 pCi = 100 picocuries = 3.7 becquerels (Bq)

Thus by measuring VDTs in the whole body counter, dose rates in the order of 1/1000 the natural background rate would be detectable.

Measurements made up to the present time, on over 50 different units, have shown no difference in count-rate whether the unit was on, with the screen full of characters, or switched off.

RADIOFREQUENCY AND EXTREMELY LOW-FREQUENCY EMISSIONS FROM VDTs

Radiofrequency (RF) radiation occupies a part of the electromagnetic spectrum in the non-ionizing range at frequencies between about 10 kHz and 300 MHz. Microwave radiation occupies frequencies between 300 MHz and 300 GHz. Extremely low frequencies (ELF) are usually defined as frequencies below 500 Hz (Figure 1).

The source of RF in the VDT is the horizontal deflection system for the electron beam and the associated high voltage circuit (so called fly-back transformer). An investigation at the Bureau of Radiological Health[3] has shown that the emissions of RF from the VDT contain the fundamental frequency of the deflection system, which is usually between 15 and 25 kHz, and up to 6 harmonics of significant intensities, i.e., frequencies up to 6 x 25 kHz = 150 kHz can be present.

At the Radiation Protection Bureau a survey has been performed to determine the levels of RF radiation around various models of VDTs. Only emissions at frequencies between 15 and 150 kHz have been found. A total of 86 units have been surveyed. These units included 57 different models manufactured by 25 firms. For all the units the intensity of the RF field at the operator's position (30 cm from the screen) was below 5 V/m (the equivalent power density about 7 $\mu W/cm^2$). Actually only 24% (21 units) had fields equal or greater than 1 V/m. Similarly, at the keyboard only 30 units (35%) had fields greater than 1 V/m. The maximum intensity of RF radiation at the keyboard was 7 V/m (for 2 units), and only 14 units had RF levels at the keyboard above 5 V/m, but below 7 V/m.

A total of 30 units (35%) had localized RF fields of a field intensity greater than 60 V/m (equivalent power density of 1 mW/cm^2). These fields were localized at various sites on the surface of the VDT, in some cases on the screen, on the top, on the side. In each case the intensity of these fields decreased rapidly with distance from the surface.

It was also observed that the RF fields at kilohertz frequencies of an intensity greater than 60 V/m interfered with some models (but not all) of radiofrequency and microwave survey meters operating above 10 MHz. The interference manifested itself by the meter's needle going off the scale, particularly in the close proximity of the electronic circuitry emitting the low frequency (kilohertz) RF radiation. The manufacturers of the meters acknowledged the observed interference problem.

The exposure limits as recommended by the Canadian federal government do not cover frequencies below 10 MHz. The limit for the general public at frequencies above 10 MHz is

60 V/m (equivalent power density 1 mW/cm^2). The emissions from the VDT at frequencies above 10 MHz are undetectably low, as there are no sources of radiation at these frequencies within the VDT.

It is a well established fact that a human body absorbs less RF radiation as its frequency decreases below 10 MHz. Therefore, if the exposure limit for RF at 10 MHz were applied to frequencies in the kilohertz range, an additional rather large safety factor would be included. The maximum exposure to the operator as determined by our survey (5 V/m) is more than 10 times less than the limit of 60 V/m, and the maximum exposure to the operator's hands is also well within that limit.

Complete measurement data is given in Table A1. Where no number is given that means the reading was below the detectability limit of 1 V/m.

The emissions from VDTs in the ELF range (5-500 Hz) were analyzed by monitoring the frequency spectra and measuring the intensity of the magnetic field at each frequency of the emissions. A Hewlett-Packard Spectrum Analyzer with a small calibrated loop antenna was used. The results for three VDTs are given in Table A2 and for a few other devices in Table A3. The emissions from VDTs occur at the power frequency of 60 Hz and its harmonics. The intensities are very low, comparable to ambient levels and the intensities of the emissions from other devices.

On the basis of the available scientific data the ELF emissions from VDTs are extremely unlikely to be of any health implications. This is because the intensities of the magnetic field are extremely low, well below the intensities that have been shown to produce biological effects.

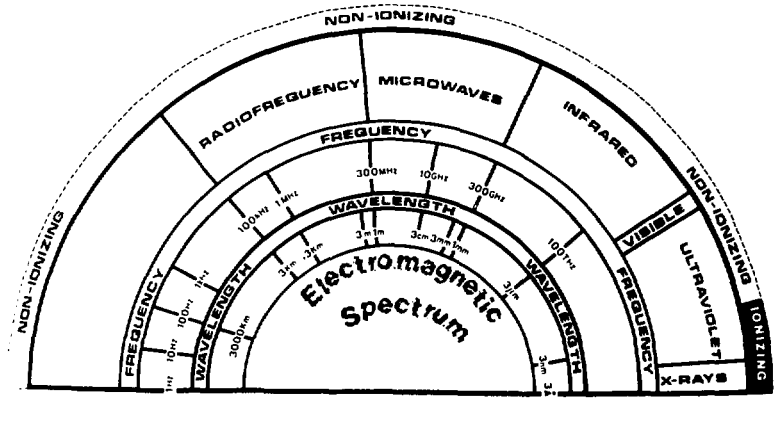

Figure 1. Electromagnetic Spectrum

Table A1 - RF Emissions from VDTs

Manufacturer	Model	Operator Exposure Maximum (V/m)	Keyboard Maximum (V/m)	Localized Field Maximum (V/m)
Conrac	Not stated			31.2
Cybernex	CT824-D10024		2	5
	CT824-D10024-DR1			2.2
	CT824-D10624-DR1			5
	LGR-1		1.2	28
	LGR-1/KH8024			2
	LGR-1/KH8024			3
	LTL-1/KC8024			4
	LTL-1/KC8024			4
	LTL-1/KC8024		4	100
	LGR-2			2
	LGR-2			8
	LGR-2		1.5	20
	LGR-2		1	15
	MDL-110			25
	XL-83		1.7	40
	XL-84		1	65
	XL-84		3	40
	Not stated		2	130
Data Media	1520			2.5
	1520			2.7
	1520			17
	1520			3
	1520			2.1
	3000			180
	3000			1.8
	3000			2
	3000			3
	3000	4		2.8
	Colorscan 10	2	3	>300 *
Digital Decascope	VT50-AB			5
	VT50-AR	1.3	1.2	250
	VT55-FE			3.5
Electrohome	G12-002 (Prototype)			37.4
	Telco-RM-NK			63.3
	V23-007			67.8

* > 300 means more than 300.

Hewlett-Packard	2640B	1.8	7	300
	2645A			12.7
	2645A			14.7
	2645A			12.7
	2645A			14.7
IBM	604			3.1
	3277			
	3277			
	3277			
	3277-02			
	3275-02	1.4	1	25
	3278	1.5		4
	3278-4			5
	3278-4			4
	3278-4			6
	3278-4		1	10
ITC Ikegami	PM-900 REV-E	1.4		300
Logicon	1020076-05-243		2	30
	1020076-05-266		2	86
Micom	M2002	1	2.5	270
	M2002	1.3	3	300
Ontel	OP1			11.1
Osborne	1			100
Perkin-Elmer	550			67
PSI	Bureaucrat	1.9		>310
	Bureaucrat	4.4	4.5	> 20
	Lobbyist	2.6	4.2	>368
Sony	CVM-115	2.3		>300
Sperry Univac	R2062	3.4		> 20
	R2950	3.5		>492
	3545-00	2.5		> 20
Sycor Inc.	1500-5	3.5		>374
	1500-5	2.7		> 20
Systematics General Corp.	T5177			
	T5177			
Tektronics	4010-1			
Telegram Communications Corp.	2277 MARK II			3.9

Teletype Corp.	40			
	40			
Televideo Inc.	950			300
Telex	278	1	1	260
	278		6	290
Volker Craig	VC303	2	4	130
	VC-414H			19
	VQ-414H		3	24
	VC-415-ARL		3	17
	VC-415-APL		3.5	23
	VC-415-APL	3	2	50
Wang	5536	2	7	>300
	5536		4.5	>300

Table A2 - The Magnetic Field Intensity at ELF in A/m; Video Display Terminals

Description	Frequency (Hz)							Total
	60	120	180	240	300	360	420	
Sony								
Model CUM-115 30 cm	0.085	0.042	0.027	0.02	0.016	0.013	0.01	0.213
in the front 50 cm	0.05	0.025	0.017	0.013	0.01	0.009	0.007	0.131
of the screen Power off	0.025	-	0.01	-	0.005	-	0.002	0.042
Hewlett-Packard								
Model 2640B 30 cm	0.046	0.012	0.016	0.007	0.007	0.004	0.005	0.097
in the front 50 cm	0.046	0.008	0.016	0.003	0.007	0.002	0.002	0.084
of the screen Power off	0.04	0.002	0.013	-	0.005	-	0.003	0.063
Perkin-Elmer								
Model 550 30 cm	0.07	0.04	0.047	0.02	0.016	0.013	0.011	0.217
in the front 50 cm	0.043	0.016	0.013	0.008	0.008	0.005	0.004	0.097
of the screen Power off	0.04	0.002	0.013	-	0.005	-	0.003	0.063
Perkin-Elmer								
Model 550 at back yoke	1.55	0.775	0.517	0.388	0.31	0.258	0.221	4.019

Table A3 - The Magnetic Field Intensity of ELF in A/m; Various Devices

Description	Frequency (Hz)								Total
	60	120	180	240	300	360	420	Other	
IBM typewriter Model 72									
Keyboard	0.047	0.007	0.016	0.003	0.009	0.001	0.004	0.04 (1)	0.127
Back	0.775	0.078	0.258	0.023	0.155	0.006	0.035	0.31 (1)	1.64
Pocket calculator transformer, TI-55	0.271	0.135	0.052	0.039	0.031	0.026	0.004	-	0.558
Baseboard heater	3.875	0.008	0.013	-	0.039	0.003	0.028	-	3.965
Hair dryer, GE CD100A	0.078	0.035	0.021	0.007	0.011	0.002	0.002	0.08 (2)	0.236
Hand mixer, GE-M7A	7.75	0.016	0.568	0.007	0.034	-	0.030	0.89 (3)	9.295
Electric kettle	0.70	0.002	0.013	0.001	0.005	-	0.002	-	0.723

1. Includes frequencies 30, 90, 150, 210 Hz etc.

2. 110, 230, 340, 350 Hz

3. 30, 160, 280, 390 Hz

X-RADIATION EMISSION TEST DATA FOR VDTs AND VIDEO MONITORS

Field Test Results

Manufacturer/Distributor	Model	No. Tested	Max. Emission (mR/h)
- (Airport Radar)	AASR-1	1	N/D*
AES Data	AES-100B-E	1	N/D
AES Data	AES Plus	1	N/D
AES Data	C-20	1	N/D
Bell Northern	Prototype Graphics Terminal	1	N/D
Bendix	Multispectral Analyser	1	N/D
Burroughs	TD-800	5	N/D
Chromatics	CG 1999	1	N/D
Chromatics	DV 1000	1	N/D
Chromatics	KV 1000	1	N/D
Commodore	PET 2001	1	N/D
Conrac	21359P-4	1	N/D
Conrac	CVA-23	2	N/D
Consolidated Computer	KEY EDIT 1000	6	N/D
Cromemco	3102	1	N/D
Control Data Canada	Vucom	1	N/D
Cybernex	MDL 110	1	N/D
Cybernex	LGR I	12	N/D
Cybernex	LGR II	1	N/D
Cybernex	LTL I	2	N/D
C.G.E.	CGE6810	2	N/D
Data Media	DT80/1	1	N/D
Datapoint	8200	2	N/D
Datapoint	6600	1	N/D
Datapoint	1800	1	N/D
Datapoint	3800	1	N/D
Delta Data Systems	E0A10B101	2	N/D
Delta Data Systems	P0A10M0-01	8	N/D

*N/D: non detectable

Digital Equipment of Canada	VT100-AA	1	N/D*
Digital Equipment of Canada	VT52-AE	3	N/D
Electrohome	CCTV	1	N/D
Electrohome	V10-420	1	N/D
Electrohome	V10-430	1	N/D
Electrohome	V05-301	2	N/D
Electrohome	V05-302	1	N/D
Electrohome	S02202	3	N/D
Electrohome	D02802	1	N/D
Electrohome	2250 NTSC	1	N/D
Electrohome	TELCO-KM-NK	1	N/D
Electrohome	G12-002	1	N/D
Electrohome	V23-007	1	N/D
General Terminal	GTC 400	1	N/D
Goodwood Data Systems	-	1	N/D
Goodwood Data Systems	VDM-14	2	N/D
Goodwood Data Systems	VDM-9	1	N/D
Goodwood Data Systems	10862	1	N/D
Goodwood Data Systems	10856	1	N/D
Hazeltine	Modular One	1	N/D
Heath (Zenith)	HE-Z89-48	1	N/D
Heath (Zenith)	GR-4000	1	N/D
Heath (Zenith)	D12	1	N/D
Hewlett-Packard	HP2621P	1	N/D
Hewlett-Packard	2645A	4	N/D
Hewlett-Packard	9845C	1	N/D
Hitachi	CUX-01	1	N/D
IBM	3277	4	N/D
IBM	2A Type 3279	1	N/D
IBM	3B Type 3279	1	N/D
IBM	50A	1	N/D
IBM	3276-32	1	N/D
Image Magnification	IMI-3000	1	N/D
Image Magnification	MI-1	1	N/D
Intergraph	Intergraph 3	1	N/D
Intelligent Systems	Intecolor 8031	1	N/D
Kratos	1930	1	N/D
Lanpar	LS400	1	N/D
Logicon	TPS600	2	N/D

*N/D: non detectable

Micom	2000	2	N/D*
Micom	2001	1	N/D
Mitsubishi Electric	RH-5B	2	N/D
Motorola	-	3	N/D
Motorola	XM-227-1X	1	N/D
Motorola	XM-400-1Y	1	N/D
Motorola	VP6-S1	1	N/D
Motorola	VP4-S1	1	N/D
Motorola	KT232-4	1	N/D
Norango Computer Systems	-	1	N/D
Ontel	OP-1R	1	N/D
Panasonic	CT-110MC	1	N/D
Projection Systems	CV3	2	N/D
Raytheon	2652-500161	2	N/D
Raytheon	RYC 7308-01	1	N/D
Raytheon	Vucom 2	11	N/D
Raytheon	401-2A	1	N/D
Raytheon	402-2A	1	N/D
Raytheon	-	10	N/D
Radio Shack	TRS-80 Model 11	1	N/D
Radio Shack	TRS-80 Model 111	1	N/D
Radio Shack	TRS-80 Model 8201	1	N/D
Radio Shack	TRS-80 Cat. No. 26-1062	1	N/D
RCA	-	4	N/D
RCA	2588	2	N/D
Sanyo	DM5012CX	1	N/D
Sanyo	VM4092U	1	N/D
Sony	PVM-1211	1	N/D
Sony	-	8	N/D
Sony	KP7200	1	N/D
Spectral Data	700DR?B	1	N/D
Sperry Rand/Univac	CADE 1900	6	N/D
Sperry Rand/Univac	3534-00	3	N/D
Sycor	1500-5	2	N/D
TCTS	Vucom 1	3	N/D
TCTS	Vucom 11	8	N/D
TCTS	Vucom 111	1	N/D

*N/D: non detectable

Tektronix	4010S	1	N/D*
Tektronix	4013S	1	N/D
Tektronix	4013	1	N/D
Tektronix	4014	1	N/D
Tektronix	4016	1	N/D
Tektronix	4027	1	N/D
Tektronix	J1000	1	N/D
Teleram Communications	2277 Mark 11	1	N/D
Teletype	40	2	N/D
Televideo	TVA-912	1	N/D
Toshiba	-	1	N/D
Westinghouse	1600-S98-9005	1	N/D
Xerox	850	1	N/D
Monitors at Dorval Airport	-	7	N/D
Monitors at Mirabel Airport	S-70-2028-01	1	N/D
Monitors at Mirabel Airport	ARHL-1	1	N/D
Monitors at Mirabel Airport	-	2	N/D

*N/D: non detectable

VIDEO DISPLAY TERMINALS TESTED IN WHOLE BODY COUNTER

48 Models - 51 Units

Date	Serial No.	Manufacturer and Model
07/07/81	-------	Hewlett-Packard HP 2621 A/P
01/12/81	80062865	Cybernex MDL-100
02/12/81	7901354	Cybernex LGR-1
02/12/81	7901353	Cybernex LGR-1
03/12/81	7612002	Cybernex LGR-1/KH8024
04/12/81	51020170	Televideo Model 950
07/12/81	7801074	Cybernex Ltl-1 KC8024
09/12/81	701387	AES Data Ltd. Alphaplus 12
09/12/81	-------	*Sony Trintron KX 16HF-1
10/12/81	1061	Video Data Monitor VDM-14
14/12/81	-------	TSD Display Products N-DC-15
14/12/81	0003882	Radio Shack TRS-80 III Micro Computer
17/12/81	OIDS-DC Terminal	TES Data Screen Terminal: TEC Series 400 Data Screen Terminal
17/12/81	-------	Goodwood Data Systems Ltd. DVM-14 Series 1061, Motorola Terminal
11/01/82	2443	A.B. Dick Model 2205
25/01/82	090131	Sperry Univac UTS 20
01/02/82	1201818	Hazeltine Executive Model 80
01/02/82	81065409	Cybernex XL87F
01/02/82	927013121	Xerox Model X927
03/02/82	BLC-024-03677	Honeywell Ti BTRM 726A 001
10/02/82	AB 54318	Digital Model VT100-AA (Zentronics)
17/02/82	30675	*IBM Model 3B Type 3279
03/03/82	154274 Regent 30	ADDS-(CGE)- Applied Digital Data Sys.
03/03/82	9-504707	*Electrohome Model 13" COL GAMS MT
04/03/82	51057639	Datamex Televideo TV1-950
08/03/82	44670C-8	Datamex Colorscan-10
09/03/82	VE100647	MAI-Basic Four - Model 7270

*Colour Monitor

11/03/82	5019/992-1100	Comterm - 5278
	-0005-1402	------
22/03/82	004810	Anderson & Jacobson AJ-510
22/03/82	2021 7239B	Micom 2001 M2001-VDU (Philips)
24/03/82	24018-218	Volker Craig - VC 4404
26/03/82	ZVM-121	Apple II Monitor Zenith Data Systems
	A2S2-241326	Keyboard Apple II Model No. A2S1048
29/03/82	18073-7	Multi Port II CMQ
01/04/82	WF43689	VT100-AA Digital Equipment
05/04/82	2004784	Esprit (Hazeltine) - Ahearn & Soper
06/04/82	004265100A	Visual 100A - Ahearn & Soper
07/04/82	200001	AM Varityper 5404
08/04/82	927-016523	Xerox Model 820
08/04/82	1015	Comterm - 5279
14/04/82	9-504707	*Electrohome Model 13" COL GAMS MT
26/04/82	15417	*Intecolor Intelligent Sys. Corp. Datamex
27/04/82	008204001H(T)	Dy4 VGT-100H - Dy4 Systems Inc.
28/04/82	180358	Lanparscope XT-80 - Lanpar
29/04/82	40396022	*Electrohome 38-G12003-60 High Res.
03/05/82	7403	Decision Data Model 3751-11
04/05/82	A2225042	Lanparscope XT-100 - Lanpar
04/05/82	1928032	Lanparscope XT-51 - Lanpar
10/05/82	-------	TOPS - Bell Canada
11/05/82	LF 2382	Wang Word Processor - No. 5503
17/05/82	1885	CCI Model 625L - Bell Canada
17/05/82	70011	IBM 4978-2 - Bell Canada
01/06/82	P-5838	Microdata - Model 5420-00
02/06/82	D0524	Microdata - Model 8001/00-0452-XXX

*Colour Monitor

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82-EHD-91

ERRATA SHEET

"Investigation of radiation emissions from video display terminals"

Location	Is	Should Be
P.4, Table 1 second column	2×10^{-9} W/m^2 21 fL	2×10^{-5} W/m^2 21 fL (72 cd/m^2)
third column	1×10^{-3} W/m^2 2.92×10^{3} fL 10^{-2} W/m^2	10 W/m^2 2.92×10^{3} fL (1×10^{4} cd/m^2) 1×10^{2} W/m^2
add one line to the note list after Table 1, between W/m^2 and fL	-	cd/m^2 refers to candela per metre squared
P.8, Table 3 third column	2.5 W/m^2	0.8 W/m^2.sr
P.12, Table 6 second column	0.65 μW/cm^2 40 fL	6.5×10^{-3} W/m^2 40 fL (137 cd/m^2)
third column	1000 mW/cm^2 2920 fL	10 W/m^2 2920 fL (1×10^{4} cd/m^2)
P.15, Table 8 second column	5×10^{-6} W/cm^{2}sr $<1 \times 10^{-3}$ W/cm^{2}sr	5×10^{-2} W/m^2 <10 W/m^{2}sr
third column	1×10^{-3} W/cm^{2}sr 2×10^{-2} W/cm^{2}sr	10 W/m^2 2×10^{2} W/m^{2}sr
P.18, Table 10 first column	49	50
P.21, Item 7 line 2	48	50
P.38, line 2	48 Models - 51 Units	50 Models - 52 Units

ERRATA 82-EHD-91

TABLE A1

Manufacturer	Localized Field Maximum (V/m)	
	Is	Should Be
ITC Ikegami	300	>300
PSI Bureaucrat	>310	>300
Bureaucrat	>20	>300
Lobbyist	>368	>300
Sperry Univac R2062	>20	>300
R2950	>492	>300
3545-00	>20	>300
Sycor Inc. 1500-5	>374	>300
1500-5	>20	>300
Televideo Inc. 950	300	>300