A Radiation and Industrial Hygiene Survey of Video Display Terminal Operations

William E. Murray, C. Eugene Moss, Wordie H. Parr and Clinton Cox

Human Factors: The Journal of the Human Factors and Ergonomics Society 1981 23: 413

DOI: 10.1177/001872088102300404

HUMAN FACTORS, 1981, 23(4), 413—420

A Radiation and Industrial Hygiene Survey of Video Display Terminal Operations

WILLIAM E. MURRAY[1], C. EUGENE MOSS *and* WORDIE H. PARR, *Division of Biomedical and Behavioral Science, and* CLINTON COX, *Division of Surveillance, Hazard Evaluations, and Field Studies, National Institute for Occupational Safety and Health, Cincinnati, Ohio*

Radiation surveys were performed on 136 terminals of some 530 in use at three different sites. Researchers measured both ionizing and nonionizing radiation. In the industrial hygiene survey, samples of workroom air were analyzed to determine worker exposure to selected airborne chemical contaminants. The results of these tests demonstrated that the VDT operators included in this investigation were not exposed to hazardous levels of radiation or chemical agents.

INTRODUCTION

The possibility of health hazards, particularly radiation effects, has caused considerable concern among operators of video display terminals (VDTs). Specific questions concerning eyestrain, cataracts, cancer, reproductive disorders, general malaise, and other symptoms are often mentioned. This study was requested in July, 1979, by three labor unions. It incorporates data from three different companies.

A NIOSH team conducted a walk-through survey at each location in November, 1979. The team met with management and labor representatives, toured each facility, described the study protocol, and talked with selected employees. A full report on the walk-through survey was sent to each party by NIOSH in December, 1979. The in-depth study followed in January, 1980, in the four phases discussed below:

(1) Radiation—Since the video display terminal (VDT) can emit one or more types of electromagnetic radiation, both ionizing (X-ray) and nonionizing (ultraviolet, visible, and radio-frequency), radiation measurements were made on a sample of 136 of the 530 VDTs at the three facilities. At least one terminal of every make and model was surveyed at each facility.

(2) Industrial Hygiene—Samples of workroom air were analyzed to determine the concentration of selected airborne chemical contaminants within the VDT areas. These data were used to determine if sources such as photographic darkrooms, photocopiers, and other photo-reproduction equipment produced airborne chemical exposures.

(3) Health Complaints—Office work conditions were evaluated using a multifaceted questionnaire. This survey instrument included questions concerning the employee's health and lifestyle as well as many aspects of the work environment. Employee participation in the questionnaire survey was voluntary.

(4) Ergonomics—Several variables, including workplace dimension, seating, lighting, temperature, and humidity, were evaluated.

The remainder of this report includes a detailed explanation of the methodologies employed, a discussion of the results and the conclusions for the radiation and industrial hygiene phases of the investigation. The

[1] Requests for reprints should be sent to William E. Murray, Division of Biomedical and Behavioral Science, National Institute for Occupational Safety and Health, 4676 Columbia Parkway, (C-27), Cincinnati, OH 45226.

health complaints and ergonomics phases are discussed elsewhere in this publication.

METHODOLOGY

Radiation

The proper conduct of a radiation survey requires a basic understanding of the radiation source and its characteristics. The VDT can produce several types of electromagnetic radiation, depending upon its operating characteristics. Low energy X-rays can be generated by the cathode ray tube (CRT) and electronic damper circuits. Depending on the phosphor used, ultraviolet (UV), visible, and infrared (IR) radiation can be emitted from the screen face. Certain electronic components and circuits can produce radiofrequency (RF) radiation. Performing a complete radiation survey requires several instruments in order to measure the different radiation types that can be emitted.

An International Light Model IL730A Actinic Radiometer with probe PT171C (filter and diffuser attached) was used to measure the irradiance in the near UV wavelength range of 320 to 400 nm. The instrument reads out in watts per centimeter squared (W/cm^2). The minimum sensitivity is 5×10^{-8} W/cm^2, and the accuracy is $\pm 20\%$. All measurements with the instrument were made at contact with the VDT screen face.

A Photo Research Spectra Mini-Spot Photometer was used to measure the luminance (visible radiation) on the VDT screen. The value obtained with this instrument in footlamberts (fL) represents the apparent brightness observed by the operator, regardless of distance from the screen. Readings were taken at a distance of approximately 1 m from the tube face. The minimum luminance that can be read is 0.5 fL, and the overall accuracy is $\pm 10\%$. The values measured are also presented in units of candelas per meter squared (cd/m^2).

A Narda Model 25540 meter and two probes were used to measure RF radiation. The Model 8644 probe was used to measure the electric field strength in volts squared per meter squared (V^2/m^2), and the Model 8635 probe measured the magnetic field strength in amperes squared per meter squared (A^2/m^2). The minimum detectable limit for the electric field probe is 2000 V^2/m^2 with an accuracy of +1.5 dB and −3.5 dB corresponding to +41% and −55% respectively. For the magnetic field probe, the minimum detectable limit is 0.1 A^2/m^2 with an accuracy of ± 3.0 dB corresponding to +100% and −50%. The Model 8644 probe can be used in the frequency range of 10 to 3000 MHz, and the Model 8635 probe from 10 to 300 MHz. All measurements were made by slowly scanning every accessible surface of the terminal as close to the surface as possible, generally within 5 cm. To determine the frequency of any RF radiation emanating from the terminal, a Hewlett-Packard Model 5303B/5300B Frequency Counter with a Singer Model 90799 loop antenna was used. This counter responds to frequencies in the range from 0 Hz to 525 MHz, but it responds only to the most intense signal.

Two instruments were used in the X-ray survey. A Stoms meter was employed first to detect any X-ray beams generated by the terminal (Rechen, Schneider, and Stoms, 1968). Every accessible surface of the VDT was slowly scanned as close to the surface as possible. This instrument is very sensitive and specifically designed to locate small, low-energy [down to 12 to 13 kiloelectron volts (keV)] X-ray beams. It was designed by the Food and Drug Administration's Bureau of Radiological Health (BRH) for use in enforcing its television receiver performance standard. This meter is very energy dependent, but it is used only to detect, and not to measure, X-rays. The device uses four Victoreen Model 1B85 Geiger-Mueller tubes as the detectors and is calibrated electronically with a Tektronix Model 7603 Oscilloscope and a pulse generator. At least three background readings were taken in each area or room where VDTs were located; typical readings were in the 50 to 200 counts per minute (cpm) range. A reading of 3000 to 4000 cpm is roughly equivalent to an exposure rate of 0.5 milliroentgens per hour (mR/hr), which is the BRH emission standard for television receivers. A Victoreen Model 440 RF/C was available to measure X-ray emissions accurately in case any had been detected with the Stoms meter. The 440 RF/C is specifically designed to measure X-ray emissions from TV receivers and is shielded against electromagnetic (RF) interference. It responds adequately to photon energies from 6 to 42 keV. The maximum X-ray energy from these terminals is approximately 15 to 20 keV, depending on the operating voltage of the CRT. Exposure rates as low as 0.05 mR/hr can be measured, and the overall accuracy is ±15%.

Radiation measurements were performed on a sample size of approximately 25% of the VDTs at each company. Of the 530 VDTs, 136 units from six manufacturers were selected to be surveyed. The largest portion of the sample (90%) were terminals from three manufacturers—Courier, Systems Integrated, and Ontel. Several models of the Courier and Ontel terminals were included. The remainder of the sample was comprised of units from Delta Data, Harris, and IBM.

In performing the survey, each company was divided into smaller sections such as departments or divisions. This was done primarily for the convenience of the research team and also because it seemed to minimize disruption of the employees' work routines. The number of terminals in each area was determined, and a 25% sample selected arbitrarily by the team. When possible, terminals were selected that were in use by employees. At least one unit of every make and model was included in the sample. All requests to survey a specific terminal were honored.

Industrial Hygiene

Walk-through surveys of VDT areas indicated that there were few sources of airborne chemical contaminants. The occupational sources that researchers identified were photographic darkrooms, photocopiers, and other photo-reproduction equipment. The one general source of indoor air pollution that researchers observed was smoking.

Because hydrocarbons are the primary chemical used in operating the various occupational sources, general hydrocarbon concentrations were measured in order to determine the air quality level. The selection of the other chemicals to be measured was based on the specific source (e.g., carbon monoxide from smoking, acetic acid and formaldehyde from photographic processing). Although the above chemicals are not the only ones present, they are indicative of the general airborne contaminant levels generated by the few emission sources located within the VDT areas.

General hydrocarbon levels were measured with an HNU Model 101 Photoionization Analyzer equipped with an 11.7 eV lamp calibrated for direct reading in parts per million (ppm) (vol/vol) of methanol. The photoionization analyzer is a nonspecific instrument and cannot be used to identify or measure individual hydrocarbons within a mixture of hydrocarbons. Therefore, the measured levels should only be used to estimate the magnitude of hydrocarbon concentrations; these values are only representative of the actual levels present. For example, if the vapor detected was pure methanol, the concentration would have to be reduced by a factor of 0.25. Carbon monoxide, acetic acid, formaldehyde, and ozone levels were measured with appropriate Drager colorimetric tubes using a Drager Model 31 hand-operated bellows pump. The photoionization analyzer and colorimetric tube measurements are accurate to about ±5% and ±25% respectively. Air sampling was conducted at locations that were judged to have the highest levels of air contaminants.

RESULTS AND DISCUSSION

Radiation

Slightly over 25 % (136 of 530) of the VDTs were surveyed. The results of the measurements are shown in Table 1. X-ray measurements were not distinguishable from background levels. Emissions in the near UV ranged from not detectable to 6.5×10^{-7} W/cm^2. The visible radiation levels ranged from 1 to 40 fL (0.29 to 11.7 cd/m^2). High RF readings were obtained when the electric (2×10^6 V^2/m^2) and magnetic (0.5 A^2/m^2) field strengths from several Ontel terminals and one Systems Integrated terminal were measured. For reasons discussed below, these readings are considered to be anomalous and are not a result of the presence of an RF radiation field. Thus, the results in Table 1 show that no measurable levels of RF radiation were present.

Determining the source of the high electric and magnetic field strength readings required considerable investigation. The high RF readings noted from the Ontel terminals were observed in the same general position on the terminal, the left upper rear portion of the case. Ontel informed NIOSH that the flyback transformer, which generates the high voltage necessary to operate the CRT, is located near this position. For the Systems Integrated terminal, the high reading was noted on the right side of the VDT where the transformer is located.

When the detectors of the Narda probes for electric and magnetic field strength are brought close to this circuit, the flyback transformer and the Narda meter are capacitively coupled, resulting in a current flow (Kucia, 1972). This capacitive current flow in the Narda meter interferes with the electronic circuitry of the Narda instrument and can result in either an upscale or downscale reading (Aslan, 1980). In other words, the meter will register either a very high reading or a negative (below instrument zero) reading. Both effects were observed during the course of the survey and interfered with the capability of the instrument to quantitate RF radiation fields accurately. Because of this difficulty NIOSH requested BRH to carry out spectral measurements under laboratory conditions on a similar Ontel terminal. The purpose of these laboratory tests was to determine the intensity and frequency of any emitted RF radiation field.

Using a calibrated Hewlett-Packard Spectrum Analyzer, BRH obtained spectral data for both the electric and magnetic fields in the frequency range from 10 kHz to 100 MHz. Integrated measurements from 10 kHz to 200 MHz were made (for the electric field strength only) with an Instruments for Industry Model EFS-1. Researchers at BRH concluded from the data that 95% of the RF radiation emitted by the terminal is in the range of 10 to 125 kHz. The BRH report (Ruggera, 1980) states that the primary radiation source is through the CRT face. At 5 cm, the electric field ranged from 784 to 4096 V^2/m^2. This range of values dropped to 0.09 to 5.76 V^2/m^2 at 30 cm, which closely approximates the minimum viewing distance of the operator. The magnetic field strength was 0.49 A^2/m^2 at 5 cm, decreasing to 4.9×10^{-5} A^2/m^2 at 30 cm. No measurable RF radiation emissions above 500 kHz were found.

From the laboratory and field survey data, NIOSH determined that the high electric and magnetic field readings resulted from this capacitive coupling phenomenon and were not due to RF radiation frequencies above 10 MHz. The flyback transformer can emit RF

TABLE 1

Summary of Electromagnetic Radiation Measurements

Manufacturer	*Model Number*	*Number of Units Measured*	*Ionizing Radiation (mR/hr)*	*Ultraviolet Radiation (W/cm²)*
Courier	TC30C1 110071-001 110117-001 110127-001 112700	67	ND*	ND-1.0×10^{-7}
Delta Data	5000	5	ND	ND
Harris	2200	3	ND	ND
IBM	3278	6	ND	ND-1.3×10^{-7}
Systems Integrated	ET960	29	ND	ND
Ontel	OP-1 OP-1/64 OP-1/16 OP-1/S11	26	ND	ND-6.5×10^{-7}
All Models		136	ND	ND-6.5×10^{-7}

TABLE 1—*Continued*

Manufacturer	*Visible Radiation*		*Radio-Frequency Radiation*	
	(fL)	*(cd/m²)*	*Electric Field (V²/m²)*	*Magnetic Field (A²/m²)*
Courier	1-6	0.3-1.7	ND	ND
Delta Data	2-5	0.6-1.5	ND	ND
Harris	3	0.8	ND	ND
IBM	2-4	0.6-1.2	ND	ND
Systems Integrated	4-18	1.2-5.2	ND	ND
Ontel	2-40	0.6-11.6	ND	ND
All Models	1-40	0.3-11.6	ND	ND

* ND = Not detectable.

fields in the frequency range from 15 to 125 kHz, but there is no occupational exposure standard for this frequency range, and these frequencies have not been shown to cause biological injury.

The flyback transformer is a common component found in most TV sets and VDTs. Some countries require shielding of this transformer, but the United States does not. The shield is to protect workers from inadvertent contact with the high voltage source, not potential radiation exposure. However, the installation of a metallic shield will prevent the occurrence of erroneous readings such as those encountered in this investigation.

The effectiveness of the shield in preventing erroneous readings was demonstrated in a followup survey at one of the companies. NIOSH selected three Ontel terminals on which high electric and magnetic field strength readings were obtained during the initial survey. Shields had since been installed on these terminals. The terminals were surveyed with the Narda RF radiation instrument. With the shield removed, NIOSH again obtained high electric and magnetic

TABLE 2

Comparison of Maximum Measured Radiation Levels with Current Occupational Standards

Radiation Region	*Maximum Level*	*Occupational Standard*	*Reference*
Ionizing (X-Ray)	ND*	2.5 mR/hr	OSHA, 1980a
Near-Ultraviolet	6.5×10^{-7} W/cm²	1.0×10^{-3} W/cm²	NIOSH, 1972
Visible	40 fL (11.6 cd/m²)	2920 fL (1.0×10^{4} cd/m²)	ACGIH, 1979
Radiofrequency			
Electric Field	ND	40,000 V²/m²**	OSHA, 1980b
Magnetic Field	ND	0.25 A²/m²**	OSHA, 1980b

* ND = Not detectable.
** Far field equivalent of 10 mW/cm².

readings with the Narda instrument. The shields were then replaced, and repeat measurements showed zero readings with both probes.

Comparisons of the maximum measured radiation levels with the current United States occupational exposure guidelines and standards are shown in Table 2. The X-ray, near UV, and visible radiation levels are far below current standards, are far below the thresholds for producing biological injury, and, in most cases, were not detectable. The electric and magnetic field strengths are also considered to be below the detection limits of the Narda equipment and thus are below the current OSHA standard. Based on these data, the VDTs do not present a radiation hazard to the employee working at or near the terminals.

Much concern has been expressed regarding the possibility that the radiation emissions will increase if a terminal malfunctions. As far as can be determined, there are few measurement data available which address this issue. Under the BRH performance standard, the X-ray emission level from a television receiver may not exceed 0.5 mR/hr at 5 cm from any surface under specified test conditions. The following conditions are specified for X-ray measurements: (1) the receiver displays a usable picture, (2) the power source is operated up to maximum test voltage of the receiver, (3) all user and service controls are adjusted to maximize X-ray emissions, and (4) that component or circuit failure is induced which maximizes X-ray emissions (U. S. Dept. of Health and Human Services, 1980). Although not directly applicable to VDTs, this seems to imply that the radiation emissions would not increase significantly when a malfunction occurs.

Most electronic equipment is designed to operate within specified tolerances. Fluctuations beyond these tolerances may render the equipment inoperable or result in a breakdown of its components. As an electronic device, the VDT is subject to these tolerances, and, according to engineers familiar with their design and operation, a large excursion in these operating parameters would most likely render the terminal unusable. Therefore, malfunctions in VDT components would not result in significantly increased radiation emissions as compared to the current exposure standards. Cakir, Hart, and Stewart (1980) reached a similar conclusion regarding X-ray emissions and further concluded that aging of the terminal would lead to decreased X-ray emissions.

Industrial Hygiene

The results of the area air samples are pre-

TABLE 3

Summary of Airborne Chemical Exposure Levels for VDT Operators

Type of Sample	Number of Samples	Range (ppm)	Average (ppm)	OSHA Standard (ppm)
Hydrocarbon	42	1.4–4.8	2.4	—
Carbon Monoxide	16	<1.0*–3.0	<1.4	50**
Acetic Acid	1	—	<0.5	10
Formaldehyde	1	—	<0.1	3† 5 (ceiling) 10 (peak)

* All less than values express the lower detection limit.
** The NIOSH (1973) Recommended Standard is 35 ppm.
† The NIOSH (1978) Recommended Standard is 0.5 ppm for a 30-min sample.

sented in Table 3. General hydrocarbon levels were measured in VDT areas and also in nonoccupational areas (i.e., in the investigators' hotel room and one company conference room) for comparison purposes. The comparison levels ranged from 2.0 to 3.5 ppm as compared to 1.4 to 4.8 ppm in the VDT areas. Similar measurements were taken near operating photoreproduction equipment. These levels ranged from 30.0 ppm at the paper level to 11.0 ppm in the immediate vicinity of the machine. Because the equipment is operated intermittently, it apparently has no effect on the overall hydrocarbon level.

Carbon monoxide levels ranged from less than 0.1 to 3.0 ppm (mostly from smoking) (see Table 3) compared to the recommended NIOSH Standard of 35 ppm (NIOSH, 1973) and the OSHA Standard of 50 ppm, (OSHA, 1980c). Acetic acid and formaldehyde were also measured (see Table 3), but these chemicals were not present in detectable quantities. The odor of ozone was noticed near one VDT; an ozone level of 0.09 ppm was measured inside the cabinet of the terminal. The odor was not noticed at any other terminal. OSHA has a standard of 0.1 ppm for ozone (OSHA, 1980c). Although the VDT seemed to be operating properly, it was concluded that electrical arcing inside the cabinet was the probable cause, and the terminal was removed from service for repair.

The hydrocarbon levels in the VDT area did not vary substantially from those in the nonoccupational areas. In fact, all chemical contaminant concentrations measured were far below any recommended guidelines or standards. Based on these measurements, there is no indication of any hazardous chemical exposures for the VDT operators who were included in this study.

CONCLUSIONS

Radiation

The radiation levels emitted by a video display terminal are very low compared to current occupational exposure standards. In many cases, the levels are below the detection capability of the survey instrumentation used. Based on the survey data, NIOSH concludes that the VDT does not present a radiation hazard to the employee working on or near a terminal.

There is considerable difficulty in performing surveys on VDTs and in interpreting the results of such measurements. Considering this and the very low radiation levels found in this study and other similar investigations, NIOSH concludes that routine surveys of video display terminals are not warranted.

Industrial Hygiene

Few sources of airborne chemical contamination were found. The measurements showed that the airborne levels of hydrocarbons, carbon monoxide, formaldehyde, and acetic acid were very low. Therefore, the employees are not exposed to hazardous levels of airborne contaminants.

REFERENCES

American Conference of Governmental Industrial Hygienists (ACGIH). *Threshold limit values for physical agents*, Cincinnati: Author, 1979, 90-92.

Aslan, E., Narda Microwave Corporation. Personal communication, March, 1980.

Cakir, A., Hart, D. J., and Stewart, T. F. M. *The VDT Manual.* Chichester, England: John Wiley and Sons, 1980.

Kucia, H. R. Accuracy limitation in measurements of HF field intensities for protection against radiation hazards. *IEEE Transactions on Instrumentation and Measurements*, 1972, *IM-21(4)*, 412-415.

National Institute for Occupational Safety and Health (NIOSH). Criteria for a recommended standard . . . Occupational exposure to ultraviolet radiation. Washington, DC: Author, Publication No. HSM73-110009 (NTIS: PB214268), 1972.

National Institute for Occupational Safety and Health (NIOSH). Criteria for a recommended standard . . . Occupational exposure to carbon monoxide. Washington, DC: Author, Publication No. 11000 (NTIS: PB8212629), 1973.

National Institute for Occupational Safety and Health (NIOSH). Criteria for a recommended standard . . . Occupational exposure to formaldehyde. Washington, DC: Author, Publication No. 77-126 (NTIS: PB273805), 1978.

Occupational Safety and Health Administration (OSHA). Code of Federal Regulations, Title 29, Chapter XVII, Part 1910.96, Ionizing radiation, 1980. (a)

Occupational Safety and Health Administration (OSHA). Code of Federal Regulations, Title 29, Chapter XVII, Part 1910.97, Nonionizing radiation, 1980. (b)

Occupational Safety and Health Administration (OSHA). Code of Federal Regulations, Title 29, Chapter XVII, Part 1910.93, Air contaminants, 1980. (c)

Rechen, H. J. L., Schneider, R. H., and Stoms, R. K. Calibration and energy dependence of the EPRL X-ray survey meter. Conference on Detection and Measurement of X-Radiation from Color Television Receivers, Washington, D.C., March 28-29, 1968.

Ruggera, P. S. Laboratory measurements of video display devices to determine the amplitude and frequency of their radiofrequency emissions. Rockville, MD, Bureau of Radiological Health, Unpublished Report, May, 1980.

U. S. Department of Health and Human Services (DHHS). Regulations for the administration and enforcement of the Radiation Control for Health and Safety Act of 1968. Washington, DC: Author, Publication No. (FDA) 80-8035, July, 1980.