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ABSTRACT

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POTENTIAL HEALTH HAZARDS OF VIDEO DISPLAY TERMINALS

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In response to a request from three California unions to evaluate potential health hazards from the use of video display terminals (VDT's) in information processing applications, the National Institute for Occupational Safety and Health (NIOSH) conducted a limited field investigation of three companies in the San Francisco-Oakland Bay Area. A preliminary walk-through survey was conducted in November 1979, followed by an additional four-phase, in-depth investigation in 1980, which used (1) radiation measurements; (2) industrial hygiene sampling; (3) a survey of health complaints and psychological mood states; and (4) ergonomics and human factors measurements. The radiation surveys indicated exposure well below current occupational exposure standards. Air samples showed no hazardous chemical exposures. A questionnaire survey indicated that a higher percentage of VDT operators reported more visual complaints at two of the three sites, more muscular complaints at one site, and more emotional complaints at all sites. Ergonomic evaluation indicated measured illumination levels at VDT workstations were generally acceptable, although problems of glare and physical dimensions of the workstations were sometimes noted. The report of this study provides detailed explanations of methodologies, tabulated results, general recommendations, and a 3-page reference list. Author/LMM)

DISCLAIMER

Mention of company names or products does not constitute endorsement by the National Institute for Occupational Safety and Health.

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FOREWORD

This report describes the findings of a field investigation carried out by the National Institute for Occupational Safety and Health (NIOSH). The investigation was conducted at three companies in the San Francisco-Oakland Bay Area at the request of three labor unions to determine the potential health hazards associated with the use of video display terminals.

Since this is a report of a limited field investigation, the conclusions and recommendations apply only to the facilities which were studied. Generalization of the findings and recommendations to other work situations must await further confirmation from additional laboratory and field research which is currently in progress.

ABSTRACT

In July 1979 NIOSH received a request from three unions in California to evaluate potential health hazards from the use of video display terminals (VDTs) in information processing applications. Numerous complaints had been voiced by employees using the terminals of a wide range of symptoms including headaches, general malaise, eyestrain and other visual and musculoskeletal problems. Three companies located in the San Francisco Bay area agreed to participate in this investigation.

In response to this request, a preliminary walk-through survey was conducted in November 1979. An in-depth investigation in January 1980 included four phases: 1) radiation measurements, 2) industrial hygiene sampling, 3) a survey of health complaints and psychological mood state, and 4) ergonomics and human factors measurements. Measurements of ionizing and nonionizing radiations were made on a random sample of 25 percent of the VDTs. Samples of workroom air were obtained and analyzed to determine exposure to selected airborne chemical contaminants. Health complaints and psychological mood state in VDT operators and a comparison group of nonoperators were evaluated using a multifaceted questionnaire. The ergonomics and human factors evaluation was conducted by examining several workplace and VDT characteristics.

The radiation surveys demonstrated that exposure to x-ray, radio-frequency, ultraviolet, and visible radiation was well below current occupational exposure standards, and, in many cases, below the detection capability of the survey instruments. The air samples showed that there were no hazardous chemical exposures. Specifically, workplace ambient levels of carbon monoxide, formaldehyde, hydrocarbons, acetic acid and ozone were all well below current occupational exposure limits.

The questionnaire survey indicated that a higher percentage of VDT operators reported more visual complaints at two of the three sites, more muscular complaints at one site, and more emotional complaints at all sites. Differences in the demographic make-up of the groups could have influenced these results, but were not evaluated due to small numbers of survey respondents in certain categories.

The ergonomic evaluation of the VDT workstations indicated that the measured illumination levels were generally acceptable; however, glare was a problem at a number of workstations. Some problems were noted with the physical dimensions of the workstations, including excessive keyboard height and VDT screen height.

Based upon the findings from this survey, general recommendations concerning work/rest regimens, testing of operators' visual functions, and ergonomic factors are provided in this report.

CONTENTS

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INTRODUCTION

In July 1979, the National Institute for Occupational Safety and Health (NIOSH) received a request from three labor unions in California to "conduct an in-depth study that can answer the variety of questions raised by users of video display terminals." The companies that participated in this investigation are identified only as Site 1, 2, or 3 in this report. All of the companies are located in the San Francisco Bay area.

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 protocol for the in-depth investigation 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--The video display terminal (VDT) is an electronic device that can emit one or more types of electromagnetic radiation. Both ionizing (X-ray) and nonionizing (ultraviolet, visible and radiofrequency) radiation measurements were made on a sample size of approximately 25 percent of the VDTs at each facility. At least one terminal of every model from each manufacturer was surveyed at each facility.

2. Industrial Hygiene--Samples of workroom air were obtained and analyzed to determine the concentration of selected airborne chemical contaminants. 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 dimensions, 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 general recommendations.

METHODOLOGY

Radiation

The proper conduct of a radiation survey requires a basic understanding of the radiation source and its characteristics. The VDT used in word processing applications is very similar in operation to a black and white television set. It contains a source of electrons and a phosphor-coated screen within a specially designed picture tube (cathode ray tube). The cathode, or electron gun, releases a narrow beam of electrons that is accelerated by high voltage to the anode or phosphorescent screen. The beam scans the screen horizontally and vertically at fixed, predetermined rates. The interaction of the electron with the phosphor changes the electron's kinetic energy into light. The viewed image is produced by modulating the number of electrons in the electron beam in response to an incoming electrical signal.

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 radio-frequency (RF) radiation. Performing a complete radiation survey requires several instruments in order to measure the different radiation types that can be emitted by the VDT.

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 nanometers (nm). The instrument reads out in watts per centimeter squared (W/cm^2). The minimum detectable level is 5×10^{-8} W/cm^2 and the accuracy is about ±20 percent. All measurements with this 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) of 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 meter (m) from the tube face. The minimum luminance that can be read is 0.5 fL and the overall accuracy is taken as ±10 percent. Environmental illuminance was measured with a Photo Research Lite-Mate/Spot-Mate Photometer in units of lux. The minimum illuminance that can be detected is 1 lux with an accuracy of ±10 percent.

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). 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 decibel (dB) and -3.5 dB corresponding to +41 percent and -55 percent. 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 percent and -50 percent. All measurements were done by slowly scanning every accessible surface of the terminal generally within 5 centimeters (cm). The Model 8644 probe can be used in the frequency range of 10 to 3000 megahertz (MHz) and the Model 8635 probe from 10 to 300 MHz. 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 hertz (Hz) to 525 MHz but it responds 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 et al., 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 the 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. Many 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 milliroentgen 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 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 cathode ray tube. Exposure rates as low as 0.05 mR/hr can be measured and the overall accuracy is about ±15 percent.

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 present from the few emission sources present.

General hydrocarbon levels were measured with an HNU Model 101 Photoionization Analyzer equipped with an 11.7 electron volt (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. 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 percent and ±25 percent, respectively. Air sampling was conducted at locations judged to have the highest levels of air contaminants.

Health Complaints and Psychological Status

The purpose of this phase of the investigation was to determine health risk to VDT operators based on self-reported complaints and measures of psychological status. A questionnaire survey was used to collect information about job stressors, stress level, working conditions, disease state, health complaints and current psychological state. Information about job stress level and specific stressors was obtained from scales developed by Caplan et al. (1975) and Insel and Moos (1974) for comparing stress over a number of different occupations. Questions about working conditions, disease states and health complaints were taken from prior NIOSH studies (Smith et al., 1979). In addition, special questions were developed primarily for the evaluation of video display operations (Dodson et al., 1979). Psychological mood state was evaluated using the Profile of Mood States (McNair et al., 1971). By mutual agreement of the union and management, only information concerning health complaints and current psychological state is included in this report. The other information will be included in a separate report that does not identify specific information with an individual workplace.

Prior to conducting the questionnaire survey, agreement was obtained from the employers to survey all available VDT operators and all available comparison nonoperators. In one case, only a sample of VDT operators and nonoperators was made available for surveying on the day of the survey by decision of the management. For this worksite, a sample of one-fifth of the VDT operators and an equal number of nonoperators were surveyed. Since this investigation was a health risk evaluation rather than a controlled field study, traditional sampling strategies and survey distribution methods were not employed. Questionnaires were distributed to VDT operators and nonoperators either individually or in small groups during working hours at their regular work areas. All participants were referred to the instructions contained in the questionnaire and asked to fill out the questionnaire at home. Questions about the purpose of the study were briefly addressed. The questionnaires were either collected at the worksite on the day after distribution or returned in a postage-paid envelope which was provided with all questionnaires. A total of 508 VDT operators and 415 nonoperators were given questionnaires.

Because this was a health risk evaluation and not a controlled field study, a number of essential requirements for the use of inferential statistics could not be met. Therefore, the statistical evaluation consists solely of comparisons between the operators and nonoperators in the percentages that reported particular health complaints or disease states. For the purpose of making judgements about the seriousness of a particular health complaint, any complaint that was reported by fifty percent of the operators and/or nonoperators was considered a potential health problem. For comparisons between operators and nonoperators any health complaint or disease state showing a twenty percentage point disparity between the groups was considered to demonstrate a significant difference.

Additionally, mean responses for operators and nonoperators on psychological mood scales are reported along with judgements on the differences between the groups.

Ergonomic Evaluation

The ergonomic evaluation involved three types of data collection: measurement of illumination and luminance levels, measurement of the physical dimensions of the workstation, and direct observation of workstation features which were of special interest. The workstation design features noted included adjustability of screen contrast and brightness, legibility of the display, adjustability of the operator's chair, adjustability of the keyboard and screen position, and design features such as desk characteristics. The VDTs involved in the evaluation were chosen so as to provide a sample representing the range of unit types and operating conditions existing at the worksite. All measurements were made with the VDT and any related equipment in its normal operating condition.

Luminance measures were made with a Photo Research Spectra Mini-Spot Photometer from an angle approximating the viewing angle of the operator. The same instrument was used in conjunction with an RS-1 Reflectance Standard (a square approaching unitary reflectance) to obtain illuminance measures. Luminance was measured in footlamberts, and the values obtained were converted to candles/meter squared (cd/m^2) afterwards. Illumination levels were measured in footcandles and converted to lux. Luminance levels of potential glare sources (i.e., high luminance regions within the operator's field of vision) were measured with the photometer from the operator's seated position. Reflected glare was not measured at all sites because such measurements were considered impractical for this survey. Measurements at sites 1 and 2 were taken between 10:00 a.m. and 7:30 p.m. on overcast days; thus none of the workstations adjacent to windows were observed under high glare conditions with reference to sunlight. Measurements at site 3 were taken between 12:30 p.m. and 7:30 p.m. on a sunny day; thus some but not all of the workstations adjacent to windows were observed under high glare conditions with reference to sunlight.

Physical dimensions of the workstation were obtained using a carpenters level and a tape measure. These included the height from the floor to the chair seat pan, keyboard and screen center, and the distance from the home row of the keyboard to the center of the screen. These data were used along with data from the literature on median body dimensions for males and females in the USA (Dreyfus, 1967; McCormick, 1964; Van Cott and Kincaid, 1963) to compute viewing distance and angle measurements.

Photographs were made of a number of workstations to serve as a record of workstation layout and operator working posture, and from these photographs judgements were made regarding the nature of operator posture. The postural data serve only to define problem areas, not causes, since it is not possible to determine with complete certainty from the photographs the reasons for observed awkward postures.

Indoor ambient temperatures and relative humidity were measured with a psychrometer.

RESULTS AND DISCUSSION
(Site 1)

Radiation

About 25 percent (18 of 71) of the VDTs in use at site 1 were surveyed. The results of the measurements are shown in Table 1. X-ray measurements were not distinguishable from background levels. Eleven terminals emitted from 0.06 to 0.60 $\mu W/cm^2$ ($1 \mu W/cm^2 = 10^{-6} W/cm^2$) in the near UV region. The visible radiation levels ranged from 3 to 40 fL. High readings were obtained when the electric ($2 \times 10^6 V^2/m^2$) and magnetic ($0.5 A^2/m^2$) field strengths from several Ontel terminals 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.

Comparisons of the maximum measured radiation levels with the current U.S. occupational exposure guidelines and standards are shown in Table 2. The x-ray, near UV and visible radiation levels are far below current standards 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 well below the current Occupational Safety and Health Administration (OSHA) standard. Based on these data, NIOSH concluded that VDTs at this site do not present a radiation hazard to the employee working at or near the terminals.

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, i.e., 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.

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 (Letter from E. Aslan, Narda Microwave Corporation, to D. Conover, NIOSH, dated April 14, 1980). Both phenomena 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 (Ruggera, 1980).

Table 1. Range of electromagnetic radiation measurements

Manufacturer	Model number	Number units measured	X-ray radiation (mR/hr)	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
All Models		18	ND	ND-.6	2-40	ND	ND

* 1 fL = 0.29 candles per meter squared
**ND = Not detectable

Table 2. Comparison of maximum measured radiation levels with currently accepted standards

Radiation region	Maximum level	Occupational standard	Reference
X-Ray	ND*	2.5 mR/hr	USDOL, 1980a
Ultraviolet (near)	0.60 $\mu W/cm^2$	1000 $\mu W/cm^2$	NIOSH, 1972
Visible	40 fL	2920 fL	ACGIH, 1979
Radiofrequency			
Electric field	ND	40,000 V^2/m^2**	USDOL, 1980b
Magnetic field	ND	0.25 A^2/m^2**	USDOL, I980b

* ND = Not detectable

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

Using a calibrated Hewlett-Packard Spectrum Analyzer, BRH obtained spectral data for both the electric and magnetic fields in the frequency range from 10 kilohertz (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. BRH concluded from the data that 95 percent of the RF radiation emitted by the terminal is in the range of 10 to 125 kHz. The BRH report states that the primary radiation source is through the CRT face. At 5 cm, the electric field strength was in the range of 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 concluded that the high electric and magnetic field readings resulted from this capacitive coupling phenomenon and are not due to RF radiation frequencies above 10 MHz. The flyback transformer can emit RF 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.

After considering the maximum measured radiation levels, the current exposure standards and the present knowledge of the biological effects of radiation, NIOSH concluded that VDTs do not emit radiation levels that present a hazard to exposed employees. However, where there is a significant probability of inadvertent contact with a high voltage source (flyback transformer), the high voltage source should be shielded to prevent such contact.

The flyback transformer is a common component found in all TV sets including VDTs. Some countries require shielding of this transformer but the U.S. does not. The shield is required to protect workers from inadvertent contact with a high voltage source and not because of 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 follow-up survey at Site 2. 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 readings with the Narda instrument. The shields were then replaced and repeat measurement showed that the readings with both probes were zero. Shields for this device are available from the Ontel Corporation and can be readily installed by service personnel.

Industrial Hygiene

In VDT areas, the general hydrocarbon levels ranged from 3.0 to 4.4 ppm, as shown in Table 3. Several areas had photo-reproduction equipment. Although this equipment did not significantly affect the general hydrocarbon levels, the peak levels near some terminals were as high as 10.5 ppm. Carbon monoxide levels ranged from 1.0 to 3.0 ppm (mostly from smoking) (see Table 3). Carbon monoxide has a recommended NIOSH Standard of 35 ppm (NIOSH, 1973). In the

Table 3. Chemical exposure data

Location/ VDT Number	Exposure	Conc (ppm)	Time
Hotel Room	Hydrocarbon (HC)*	2.0-2.4	0800
Conference Room	HC	3.5	1025
City Room (Sports)/42	"	4.4	1030
" "/56	"	3.5	1129
" "/56	Carbon Monoxide (CO)**	3.0	1147
" "/16	HC	3.4	1151
City Room (News/Copy Desk)/29	"	3.6	1209
City Room (City Rewrite)/27	"	3.4	1210
City Room (Versatec Paper Level)/45	"	30.0	1215
City Room (Versatec in Op)/45†	"	11.0	1217
City Room (UII Paper Level)/2	"	10.5	2220
City Room (UII in Op)/2†	"	3.6	1222
City Room (City Rewrite)/15	"	3.2	1225
Features (Versatec Paper Level)/37	"	12.0	1230
Features/51	"	3.2	1234
Features/51	CO	1.0	1240
Circulation/J6201	HC	3.2	1246
"	CO	2.0	1250
"	HC	3.2	1258
Composing/4	HC	3.8	1417
Composing/2	HC	3.2	1418
Composing/TV	HC	3.0	1419
"	Acetic Acid**	ND††	1420
"	Formaldehyde**	ND	1425
Composing/30	HC	4.8	1615
Conference Room	HC	3.2	1642

* General hydrocarbon levels were measured with a direct reading instrument (HNU) which was calibrated with methanol. This instrument is nonspecific, but if the hydrocarbon vapors being detected were pure methanol the concentrations would have to be reduced by about a factor of 0.25.

**Measurements were made with colorimetric tubes accurate to about ±25 percent.

† Reproduction equipment is operated very intermittently.

††ND = Not detectable

composing area, acetic acid and formaldehyde were measured (see Table 3) since photographic darkrooms were observed in this area. Neither of these chemicals was present in detectable quantities.

Because the direct reading instrument that is used to measure hydrocarbon levels is nonspecific, measurements were also taken in the hotel and in a conference room in order to make comparisons with measurements taken at VDT units. The control measurements at the hotel room ranged from 2.0 to 2.4 ppm and those in the conference room ranged from 3.2 to 3.5 ppm. The levels in the VDT areas and the conference room were not significantly different from those measured in the hotel room. Based on the measurements made, there is no indication that VDT operators at the above locations experience any hazardous chemical exposure.

Health Complaints and Psychological Status

Nature of Respondents: Questionnaires were given to 103 VDT operators and 93 nonoperators and responses were received from 49 VDT operators and 21 nonoperators for a response rate of 48 percent for the operators and 23 percent for the nonoperators. The data for 7 VDT operators were not used in the statistical analyses because (1) they worked less than 30 hours per week, or (2) an operator worked an average of less than two hours per day on the VDT, or (3) a VDT operator had less than two months of service on their VDT job.

The data for 5 nonoperators were not used in the analyses because (1) they worked less than 30 hours per week, or (2) their job requirements were much different than the other nonoperators and therefore were not comparable.

Demographic Characteristics: The respondent sample used for statistical evaluation was comprised of 42 VDT operators (33 males and 9 females) and 16 nonoperators (3 males and and 13 females). In terms of ethnic background of the VDT operators and nonoperators, whites made up the majority of respondents in each group (88 percent and 58 percent respectively); however, the nonoperators (NVDT) had a much higher percentage of Asian or Pacific Islanders (VDT = 2 percent, NVDT = 17 percent) and Hispanics (VDT = 5 percent, NVDT = 17 percent) than the operators. The mean age for the operators and nonoperators was the same (VDT = 44 years, NVDT = 44 years), but the educational level was higher for the VDT operators than for the nonoperators (VDT = 50 percent with at least a bachelors degree, NVDT = 8 percent with at least a bachelors degree). In terms of marital status 75 percent of the VDT operators were married, 14 percent single and 10 percent separated, widowed, or divorced; 55 percent of the nonoperators were married, none were single and 45 percent were separated, widowed, or divorced.

Health Complaints: There were 59 separate health complaints examined and for 17 of these fifty percent or more of the VDT operators and/or nonoperators reported an occurrence in the past year. Of the six visual complaints examined by the questionnaire, 4 had at least 50 percent of operators reporting an occurrence; for the muscular complaints, 2 out of 14 examined had at least fifty percent of the nonoperators reporting an occurrence; for the psychological complaints, 6 out of 10 had at least fifty percent of the operators and nonoperators reporting an occurrence; for the gastrointestinal complaints, 3 out of 11 had at least fifty percent of the operators reporting an occurrence; for the three cardiovascular complaints, none had fifty percent or more reporting an occurrence; and for the other complaints, 2 out of 15 had at least fifty percent of the operators and nonoperators reporting an occurrence.

Table 4 lists the percentages of VDT operators and nonoperators reporting a specific health complaint. The health complaints reported by a significantly higher percentage of VDT operators than nonoperators were primarily for emotional problems including anxiety, depression, irritability, tension, and gastrointestinal problems including gas pains, acid indigestion, and tight feeling in the stomach. In addition, operators also reported a significantly higher percentage of pain or stiffness in arms or legs, swollen or painful muscles and joints, and eye strain or sore eyes. The nonoperators reported significantly higher levels of back pain and fever or chills.

There were no health complaints showing a high rate of recurrence that demonstrated differences between VDT operators and nonoperators.

Disease States: Table 5 shows the percentage of operators and nonoperators reporting a specific disease state. As can be seen, only one disease state, arthritis or rheumatism, showed a significant difference between operators and nonoperators, with nonoperators reporting a higher level.

Mood State: Table 6 lists the mean values for the six dimensions of mood state reported by VDT operators and nonoperators and indicates that operators reported higher levels of anxiety, depression, anger and confusion.

Discussion of Findings from the Survey: There are some qualifications and cautions that must be raised in considering the nature and significance of the findings of the questionnaire survey. First, during the time that the survey was being conducted very difficult labor negotiations were under way and health and safety issues dealing with VDTs were a component of that bargaining. This may have produced a more emphatic response by VDT operators concerning health problems.

Second, the questionnaire survey was not carried out in accordance with strict survey research procedures in terms of subject sampling requirements, subject selection and randomization. However, the purpose was not to develop a statistical representation of the study group, but to define whether a health risk was associated with VDT use. As such, the results can indicate something about health risk but are limited in their general applicability.

Third, due to the small number of repondents, it was not possible to evaluate the impact of the various demographic variables on the health complaints, disease states or mood states even though there were marked differences between the VDT operators and nonoperators for some of the demographic variables.

With these limitations in mind, the results indicate that the VDT operators experienced a number of health complaints, particularly related to emotional and gastrointestinal problems, more so than the nonoperators. These findings demonstrate a greater level of emotional distress for the VDT operators which could have potential long term health consequences. However, it is quite likely that the emotional distress shown by the VDT operators is more related to the type of work activity than the use of VDTs.

Table 4. Percentage of VDT operators versus nonoperators reporting a health complaint

Health complaint	VDT operators	Non-operators
a. Shortness of breath or trouble breathing..................	26	25
b. Frequent colds or sore throats.........................	56	56
c. Persistent cough and spitting up sputum......................	33	38
d. Coughing up blood..............	--	--
e. Fever, chills, and aching all over......................	28	50
f. Hay fever or sinus trouble......	56	63
g. Wheezing in your chest..........	21	6
h. Respiratory infections..........	17	0
i. Jaundice, yellow eyes or skin..........................	--	--
j. Skin rash, itching skin, allergic skin reactions.........	44	25
k. Swollen or painful muscles or joints...............	30	6
l. Back pain......................	33	63
m. Pain or stiffness in your arms or legs...................	40	13
n. Pain or stiffness in your neck or shoulders...............	47	63
o. Changes in your ability to see colors..................	14	0
p. Tearing or itching of eyes......	51	44
q. Persistent numbness or tingling in any part of the body........................	24	19
r. Burning eyes....................	58	40
s. Occasions of easy irritability..	76	43
t. Difficulty sleeping............	67	56
u. Periods of depression..........	64	25
v. Ringing or buzzing in ears......	23	13
w. Headaches.....................	64	63
x. Fainting spells or dizziness....	14	6
y. Nervous or shaking inside.......	44	25
z. Times when you feel sweaty or trembly..............	33	25

Health complaint	VDT operators	Non-operators
aa. Increased urination............	39	25
bb. Painful urination..............	10	0
cc. Bloody urine...................	2	0
dd. Alarming pain or pressure in your chest...................	20	6
ee. Pain down your arms............	14	6
ff. "Racing" or pounding heart......	36	13
gg. Leg cramps.....................	36	44
hh. Times of severe fatigue or exhaustion..................	52	50
ii. Acid indigestion, heartburn, or acid stomach................	57	25
jj. Diarrhea for more than a few days.....................	12	6
kk. Gas or gas pains................	51	25
ll. Nausea or vomiting..............	14	6
mm. Blood in your bowel movement....	7	0
nn. Constipation....................	21	25
oo. Tight feeling in stomach........	35	6
pp. Bloated or full feeling.........	54	37
qq. Feeling of pressure in the neck......................	27	13
rr. Hemorrhoids or piles............	34	38
ss. Periods of extreme anxiety......	54	19
tt. Trouble digesting food..........	15	6
uu. Blurred vision..................	45	31
vv. Dryness in the mouth............	27	19
ww. Stomach pains...................	31	19
xx. Belching........................	46	38
yy. High levels of tension..........	58	31
zz. Difficulty with feet and legs when standing for long periods..	45	38
aaa. Shoulder soreness..............	43	38
bbb. Loss of feeling in the fingers or wrists......................	17	0
ccc. Neck pain that radiates into shoulder, arm or hand...........	19	6
ddd. Cramps in hands and fingers relieved only when not working..	17	13
eee. Loss of strength in arms or hands..........................	10	6
fff. Eyestrain or sore eyes..........	67	38
ggg. Stiff or sore wrists...........	7	0

Table 5. Percentage of VDT operators and nonoperators reporting a diagnosis of a disease state by their physician within the previous 5 years

Disease states	VDT operators	Nonoperators
Diabetes	4	0
Cancer	5	0
Hernia or Rupture	5	6
Tuberculosis	2	0
Asthma	5	0
High Blood Pressure	19	18
Heart Disease	12	0
Arthritis or Rheumatism	7	31
Epilepsy (Convulsions or Fits)	2	0
Glaucoma of the Eyes	5	0
Paralysis, Tremor, or Shaking	9	0
Kidney or Bladder Trouble	14	6
Lung or Breathing Problems	7	0
Stroke	2	0
Anemia	2	0
Gall Bladder, Liver	2	6
Thyroid Trouble or Goiter	5	0
Insomnia	9	6
Gastritis	9	0
Colitis	5	0
Stomach Ulcer	2	0
Cataracts	2	0
Mental or Psychological Problems	2	0

Table 6. Mean scale values for psychological mood states

Mood state	Scale means VDT operators	Non-operators
Anxiety	8.5	5.9
Depression	8.7	5.8
Anger	8.7	5.4
Vigor	16.9	16.3
Fatigue	6.0	6.2
Confusion	5.6	3.5

Ergonomics

The ergonomic evaluation of the VDT operations concentrated upon three aspects of the work environment: illumination, display legibility, and workstation design. Although these aspects will be treated separately in this report, they are interdependent, (e.g., illumination level and workstation design can affect display legibility); and all are strongly interactive with job task demands. For many of the factors reviewed in this evaluation, a range of recommended requirements are more appropriate, rather than one fixed numerical value because of differences in job task characteristics. Therefore, the development of one set of guidelines with universal application is not possible since the nature of the task being performed must be taken into account when selecting ergonomic approaches to solving VDT problems. It is recommended that a human factors professional be consulted during the design of future large scale installations.

Temperature and Humidity

Indoor ambient temperatures were in the 21-24°C range, and relative humidity ranged between 60 and 80 percent. Because temperatures and humidities in most indoor environments vary significantly with outdoor weather conditions, it is not possible to determine how representative these measures are of either seasonal or year round conditions.

Illumination

Proper illumination is essential so that both VDT screen and hard copy can be read without undue visual discomfort or fatigue. Visual discomfort and fatigue can also occur if the eye is exposed to large contrast variations, too much light, unclear display characters, or tube flicker. A wide variety of recommendations exist for lighting levels in VDT operations. The American National Standards Institute (ANSI, 1973) recommends minimum illumination levels of between 750 lux and 1600 lux for a general office environment, depending on the quality of the hard copy used and the type of tasks performed. Other recommendations, specifically for VDT offices, range between 200 lux and 1076 lux (Rupp, 1979).

The majority of the workstations had illumination levels between 500 and 700 lux; however, levels as low as 460 lux and as high as 1200 lux were measured (see Table 7). Certain areas were adjacent to windows which had the potential to create excessive illumination levels in periods of bright sunlight. Many of these windows were not equipped with curtains or blinds.

Table 7. Illumination levels at workstations

Illumination level (Lux)	Number of workstations
0 - 299	0
300 - 500	1
501 - 700	5
701 - 1000	0
Over 1000	1

It is very difficult to make recommendations about illumination levels if visual tasks requiring different illumination occur in the same work area. Relatively low illumination levels (300-500 lux) appear to be appropriate for VDT use, with higher levels (1000-1600 lux) being indicated for other visual tasks, particularly those which require the reading of poor quality hard copy. Consistent with the evidence in the literature, we recommend that the illumination levels be maintained between 500 and 700 lux in VDT areas, with care exercised that hard copy used by the operators have sufficiently high print/background contrast (at least 5:1) to allow for comfortable reading at these levels. This recommendation is essentially a compromise between the requirements for VDT work and the requirements for hard copy tasks; thus levels from 300 to 1200 lux may be appropriate where task demands dictate, particularly if illumination can be individually controlled by the operator. If illumination levels greater than 700 lux are necessary, use of individual workstation illumination is preferable to increasing the ambient illumination level of a total work area; but care should be exercised that the individual workstation luminaires do not become glare sources.

Horizontal illuminance on the screen should be kept low to minimize reflected glare. If lighting levels are increased over 700 lux for high demand visual tasks, particular care should be taken to eliminate glare on the VDT screen. A determination should be made as to whether any illuminance levels over 700 lux are in fact necessary to allow for task demands or employee comfort. Windows should be shielded by curtains, shades, or blinds, particularly during bright sunlight to prevent excess illuminance and reflected glare. Illumination levels were generally acceptable, although the need for existing illumination levels should be determined in those areas with levels greater than 700 lux.

Another area of concern with respect to visual discomfort or fatigue deals with contrasts between materials being read and other background sources of high luminance in the work environment. Excessive contrasts within the operator's field of vision can lead to difficulty in reading the display, and to visual fatigue due to the repeated need for light/dark adaptation. The range of individual station maximum simple luminance ratios were between 1:2 and 1:60 (see Table 8).

Table 8. Work area maximum luminance ratio

Ratio	Number of workstations
1:0 - 1:10	0
1:11 - 1:20	4
1:21 - 1:30	1
Over 1:30	2

Maximum luminance ratios within the operator's field of vision of between 1:3 and 1:10 have been recommended with the narrower range being preferred by Cakir et al., (1979). We recommend that area luminance ratios should be brought within the 1:10 range. This can be done by keeping illumination levels within the recommended range (see previous section), and avoiding the use of high reflectance surfaces in the work area. However the exclusive use of dark colors to cut down reflectivity may have a negative emotional impact on employees.

Another problem concerns direct/discomfort glare. Discomfort glare* sources were visible at 5 of the 7 workstations surveyed, particularly when the operator would shift his/her direction of viewing (see Table 9). The glare sources included windows and light fixtures with luminance levels of up to 1700 cd/m^2. It should be noted that in offices with windows both illumination and glare levels can be affected by the weather and the time of day; thus, although severe window glare was not noted during the site visit, a potential glare problem exists in any office with at least one window exposed to direct or reflected sunlight.

*Discomfort glare is likely to produce a subjective feeling of discomfort in individuals without a significant short range decrease in performance, while disability glare interferes with the ability to distinguish visual objects within the field of view and hence causes significant decreases in performance.

Table 9. Number of workstations where glare sources are visible

Glare level (cd/m^2)	Number of workstations
0 - 750	3
751 - 1500	3
1501 - 2250	1
Over 2250	0

Most discomfort glare can be eliminated by (1) the use of shades, curtains or blinds on all windows exposed to direct or reflected sunlight, (2) the use of recessed light fixtures with baffles or special covers to direct light downward, and (3) proper positioning of VDTs with respect to glare sources.

Display Legibility

It has been shown that there is a relationship between display legibility and visual fatigue (Gould, 1963). Two major components of legibility were examined in this evaluation: image quality and reflected glare. The first component of display legibility is image quality, which was judged by the researchers conducting the ergonomic evaluation. No visually detectable jitter or flickering was observed on any of the screens examined nor was any detectable flicker reported by operators when questioned; however, the perceptibility of flickers varies with illumination, screen luminance, whether foveal or peripheral vision is used and operator sensitivity characteristics. In a few cases, slight blurring of characters was observed at the screen edges. It is possible that such blurring could produce continuous refocusing by the operator and hence visual fatigue (Cakir et al., 1979). However, it was judged that the character blurring observed was not sufficiently pronounced to interfere with the operator's ability to readily distinguish characters. The displays all used a minimum 5 x 7 dot matrix to form characters approximately 3.0 mm in height. This character size corresponds to a recommended minimum 5 x 7 dot matrix and range of recommended height of 2.6 to 4.2 mm (Rupp, 1979). No characters of unusual design, which would pose additional reading problems, were observed by the investigators; however, some VDT units were equipped with a "boldface" text feature, which some operators found difficult to distinguish from the standard text. Some VDTs had brightness and contrast controls accessible to the operator. Composing tasks may pose special problems due to the requirement for multiple character sets.

Reflected glare also can have a serious impact upon display legibility. This phenomenon results from the reflection of light from luminance sources such as overhead lights in the VDT screen. Reflected glare may be either specular or diffuse; that is, the reflections may be perceived by the operator as image(s) (e.g. light fixtures, walls etc.) or as bright spot(s) on the screen. Because of the curvature of the screen, reflections from high luminance surfaces in the work area behind the operator may be visible on the screen. Such reflected glare decreases the effective image/background contrast in portions of the screen. In extreme cases, it may "wash out" the image entirely; high levels of reflected glare can approximate the luminance of characters on a display at the low end of the acceptable character luminance range (45-160 cd/m^2) (Cakir et al., 1979). Excessive reflected glare can increase visual fatigue and can contribute to poor operator posture as operators change position in an attempt to read characters obscured by glare.

At this site, reflected glare generally consisted of reflections of light fixtures and windows. The maximum reflected luminance levels on the VDT screens ranged from 3 to 14 cd/m^2. Some units had anti-glare coatings apparently provided by the manufacturer. A number of operators had stacked books or papers so that they shaded the screen in an apparent attempt to reduce reflected glare.

The following are general approaches for reducing reflected glare:

1. Drapes, shades, and/or blinds over windows should be closed, especially during direct sunlight conditions.

2. The terminals should be properly positioned with respect to windows and overhead lighting, so that glare sources are not directly in front of the operators, nor are they reflected in the VDT screen.

3. Screen hoods may be installed to completely or partially shield the screen from reflections.

4. Anti-glare filters may be installed on the VDT screen.

5. Direct lighting fixtures may need to be recessed; and baffles may be used to cover light fixtures to prevent the luminaires from acting as a glare source, or special covers on light fixtures may be used to direct the light downward rather than allowing the light to diffuse.

6. Properly installed indirect lighting systems will limit the luminaires' potential as glare sources, although some reflected glare may still be present.

Attempts at positioning the VDT to reduce glare problems from overhead lights may have only limited success in most large offices because of the sheer number of such lights. However, it can be used effectively to reduce glare from windows. Hoods are often not completely effective in reducing reflected glare, particularly when a large number of high luminance surfaces are located behind the operator. The characteristics and effectiveness of different types of glare filters vary widely, and some screen filters may have detrimental effects on image quality or contrast and care should be used in their selection. In many cases a combination of the above approaches is needed to eliminate reflected glare and these should be chosen based on the particular nature of the glare sources in the work environment.

In summary, the available literature supports the recommendation that drapes, shades or blinds be used to reduce reflections from windows, and that illumination levels be kept in the 500 to 700 lux range wherever possible to limit the reflected glare from work surfaces. Additional treatment for the reduction of reflected glare may still be necessary, however, in which case the approaches discussed above should be considered.

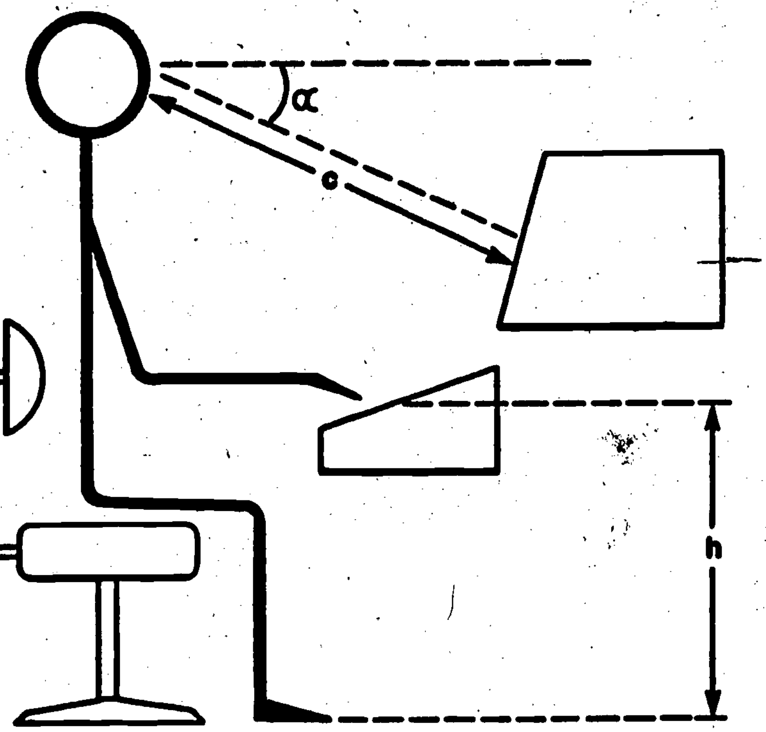
Workstation Design

Four factors related to workstation design were examined. These were keyboard height, viewing distance, viewing angle, and chair features. The method of measuring the first three factors is diagrammed in Figure I.

Excessive keyboard height can lead to musculoskeletal fatigue due to the static loading imposed on the operator by the need to keep hands in an elevated position. One European recommendation for the height of the home row keys in a fixed height workstation is 720-750 mm (28 1/4 - 29 1/2 in.)(Cakir et al., 1979). The U.S. Military Standard 1472B (1974) specifies a working surface height of 740-790 mm (29 1/4 - 31 in.), which is approximately the customary keyboard height range for typing in most offices in this country. Rebiffe (1969) has recommended that the angle between the upper and lower arms be between 80° and 120° and that the angle of the wrist be no greater than ±10°. This would require that the keyboard be approximately elbow height, which varies from 605 mm for 5th percentile females to 820 mm for 95th percentile males (Van Cott and Kincaid, 1963). In any event, sufficient clearance must be allowed for the operator's legs (645 mm for 95th percentile males) (Van Cott and Kincaid, 1963). Thus either a fairly wide range of adjustability or some compromises between leg clearance and keyboard height are necessary.

Three basic types of workstations were observed: (1) units in which the VDT screen and keyboard sat on a typewriter stand or other piece of furniture adjacent to an office desk, with home row heights of 775-820 mm. (Although these units had screen and keyboard in separate housings, the operators apparently did not adjust keyboard position in relation to the screen); (2) units in which separate screen and keyboard housings sat on desks with home row heights in the neighborhood of 810 mm; and (3) units in which one-piece VDTs sat on special VDT stands with home row height in the neighborhood of 760 mm (see Table 10).

Incorrect viewing distance and angle can impose the necessity for awkward postures when viewing the display. Proper viewing distance is also important in minimizing visual system fatigue. In addition, viewing distance should not be so great that the characters subtend less than the minimum arc required for reading. A viewing distance of 450-500 mm (17 3/4 - 19 3/4 in.) with a maximum of 700 mm (27 1/2 in.) has been recommended by Cakir et al., (1979). A variety of recommendations exist regarding screen viewing angle (Cakir et al., 1979; Dreyfus, 1967; International Business Machines Corp., 1979). Generally these recommendations place the center of the VDT screen at a position between 10° and 20° below the horizontal plane at the operator's eye height. Cakir et al., (1979) make the additional recommendation that the top of the screen be below



α -- viewing angle, from horizontal

c -- viewing distance

h -- height of keyboard home row

Figure 1. Critical workstation dimensions

eye height, while Grandjean (1980) recommends that the top line of the display be 10-15° below the horizontal, with no portion of the screen at an angle greater than 40° below the horizontal.

Table 10. Keyboard height (floor to home row)

Keyboard heights (mm)	Number of workstations
0 - 720	0
721 - 750	0
751 - 790	5
Over 790	2

The estimated viewing distance and viewing angles for male and female operators of median dimensions are summarized in Table 11. Many of the viewing angles were higher than recommended, especially for male operators of greater than median dimensions. Viewing distances were all in the acceptable range (450 to 700 mm).

Table 11. Hypothetical viewing angle and distance at workstations for median males and females

Sex	Viewing angle (degrees)	Number of workstations	Viewing distance (mm)	Number of workstations
Males	0 - 9	0	0 - 449	0
	10 - 20	1	450 - 500	0
	21 - 30	2	501 - 700	6
	Over 30	4	Over 700	1
Females	0 - 9	1	0 - 449	0
	10 - 20	0	450 - 500	4
	21 - 30	3	501 - 700	3
	Over 30	3	Over 700	0

Where feasible, workstations should be modified so that the keyboard and screen heights are appropriate for the operators. We recommend that where possible, any replacement furniture purchased be designed to allow both keyboard and screen to be within the preferred ranges and adjustable for the preference of each operator and that adjustments be made where possible to allow correct positioning of keyboard and screen on the existing furniture. Home row height should be between 720 and 790 mm, preferably adjustable. Workstations should allow sufficient leg clearance for all operators. Consistent with the need for firmly planted feet, footrests should be provided for any operators needing them.

Screen height and position should be adjusted to suit the individual operator. Screen center should normally be 10-20° below the horizontal plane through the operator's eyes, with the top line of the screen below eye level. The viewing distance should normally be between 450-500 mm, and adjustable by the operator without adoption of unusual postures. Viewing distances greater or less than 450-500 mm are acceptable if necessary to accommodate individual operator comfort. It should be noted that these workstation dimensions may pose special visual problems for operators wearing bifocals or those wearing reading glasses ground for reading at 330 mm, and special provisions may be required for these operators.

Most workstations observed were not equipped with copy holders; but consideration should be given to supplying them. The preferred position for the copy holders is near the VDT screen in order to minimize both repeated changes in accommodation and visual search. It is best to allow the operator some flexibility in positioning a copy holder, however, so that it can be placed in the position which the operator finds most comfortable.

Operator chairs should be adjustable in height and have backrests. Backrests should be adjustable to the lumbar region (mid-back) to provide adequate support. If a full backrest is provided, only the lumbar region of the back should contact the backrest during normal sitting (Kroemer and Robinette, 1969) as freedom of motion of the arms and shoulders is required for typing. There were a few cases in which operators were seated on straight-backed chairs without any adjustment for height. Except for these cases, the chairs provided were typical of the secretarial/clerical chairs generally found in offices.

The available literature supports the recommendation that operators should have chairs with adjustable seat height, and an adjustable backrest to provide support to the lower back. It has been recommended by Hunting, Laeubli and Grandjean (1980) that workstations should have a place for operators to rest their wrists and forearms while keying. This could be accomplished by providing chairs with armrests. However, if armrests are supplied, they should be supplied only to those operators desiring them and/or be removable. Moreover, they should be designed so as not to interfere with keyboard operation and to allow the operator to position the chair properly in relation to the keyboard. Another alternative is to arrange for a ledge at the bottom of the keyboard on which the operators can place their wrists.

Preferred operator posture is for the operator to be seated erect, with the thoracic region of the spine convex, the lumbar region concave, the thighs horizontal and the feet flat on the floor or footrest (Cakir et al., 1979). Weight transfer to the seat should be primarily through the buttocks, not through the thighs. The angle between upper arm and forearm should be 80-120°. The operator should have sufficient freedom of movement to adjust his/her posture to relieve fatigue.

RESULTS AND DISCUSSION
(Site 2)

Radiation

Slightly over 25 percent (51 of 194) of the VDTs in use at site 2 were surveyed. The results of the measurements are shown in Table 12. X-ray measurements were not distinguishable from background levels. Five terminals emitted from 0.03 to 0.65 $\mu W/cm^2$ ($1\ \mu W/cm^2 = 10^{-6}\ W/cm^2$) in the near UV region. The visible radiation levels ranged from 2 to 30 fL. High readings were obtained when the electric ($2 \times 10^6\ V^2/m^2$) and magnetic ($0.5\ A^2/m^2$) field strengths from several Ontel terminals and one Systems Integrated (SII) 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 12 show that no measurable levels of RF radiation were present.

Comparisons of the maximum measured radiation levels with the current U.S. occupational exposure guidelines and standards are shown in Table 13. The x-ray, near UV, and visible radiation levels are far below current standards 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 well below the current Occupational Safety and Health Administration (OSHA) standard. Based on these data, NIOSH concluded that the VDTs at this site do not present a radiation hazard to the employee working at or near the terminals.

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, i.e., 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 SII 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 (Letter from E. Aslan, Narda Microwave Corporation, to D. Conover, NIOSH, dated April 14, 1980). Both phenomena 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 (Ruggera, 1980).

Table 12. Range of electromagnetic radiation measurements.

Manufacturer	Model number	Number units measured	X-ray radiation (mR/hr)	Ultraviolet radiation ($\mu W/cm^2$)	Visible radiation (fL)*	Radio-frequency radiation: Electric field (V^2/m^2)	Radio-frequency radiation: Magnetic field (A^2/m^2)
Delta Data	5000	5	ND**	ND	2-5	ND	ND
IBM	3278	3	ND	ND	2	ND	ND
Systems Integrated	ET960	29	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
All Models		51	ND	ND-0.65	2-30	ND	ND

* 1fL = 0.29 candle per meter squared

** ND = Not detectable

Table 13. Comparison of maximum measured radiation levels with currently accepted standards.

Radiation region	Maximum level	Occupational standard	Reference
X-Ray	ND*	2.5 mR/hr	USDOL, 1980a
Ultraviolet (near)	0.65 $\mu W/cm^2$	1000 $\mu W/cm^2$	NIOSH, 1972
Visible	30 fL	2920 fL	ACGIH, 1979
Radiofrequency			
Electric field	ND	40,000 V^2/m^2**	USDOL, 1980b
Magnetic field	ND	0.25 A^2/m^2**	USDOL, 1980b

* ND = Not detectable

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

Using a calibrated Hewlett-Packard Spectrum Analyzer, BRH obtained spectral data for both the electric and magnetic fields in the frequency range from 10 kilohertz (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. BRH concluded from the data that 95 percent of the RF radiation emitted by the terminal is in the range of 10 to 125 kHz. The BRH report states that the primary radiation source is through the CRT face. At 5 cm, the electric field strength was in the range of 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 concluded that the high electric and magnetic field readings resulted from this capacitive coupling phenomenon and are not due to RF radiation frequencies above 10 MHz. The flyback transformer can emit RF 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.

After considering the maximum measured radiation levels, the current exposure standards and the present knowledge of the biological effects of radiation, NIOSH concluded that VDTs do not emit radiation levels that present a hazard to exposed employees. However, where there is a significant probability of inadvertent contact with a high voltage source (flyback transformer), the high voltage source should be shielded to prevent such contact.

The flyback transformer is a common component found in all TV sets including VDTs. Some countries require shielding of this transformer but the U.S. does not. The shield is required to protect workers from inadvertent contact with a high voltage source and not because of 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 this site. 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 readings with the Narda instrument. The shields were then replaced and repeat measurement showed that the readings with both probes were zero. Shields for this device are available from the Ontel Corporation and can be readily installed by service personnel.

Industrial Hygiene

The general hydrocarbon levels were from 1.4 to 2.1 ppm (see Table 14). Some areas had reproduction equipment that was evaluated at other locations with VDTs and was determined to have no significant effect on general hydrocarbon levels. Carbon monoxide levels were not detectable to 2.0 ppm. 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 VDT. Ozone has an OSHA standard of 0.1 ppm (USDOL, 1980c). Although the VDT seemed to be operating properly, it was concluded that electrical arcing inside the cabinet was the probable cause and the unit was immediately removed from service for repair.

Table 14. Chemical exposure data

Location/ VDT Number	Exposure	Conc (ppm)	Time
Hotel Room	Hydrocarbon (HC)*	2.0-2.4	0800
Features/35	HC	1.4	1015
Features/35	Carbon Monoxide (CO)**	ND††	1039
Features/85	CO	ND	1125
Features/85	HC	1.6	1130
Editorial (News)/127	CO	2.0	1150
Editorial (News)/127	HC	1.6	1151
Editorial (City)/in 107 chassis†	Ozone (O_3)†	0.09	1158
Editorial (City)/in 77 chassis	O_3	ND	1200
Editorial (News/128	HC	1.4	1230
Editorial (Sports)/14	HC	1.4	1246
Editorial (City)/31	HC	1.4	1300
Editorial (City)/99	CO	1.0	1549
Editorial (City)/99	HC	2.1	1549
Editorial (Scene)/15	HC	2.0	1600
Editorial (Sports)/11	HC	1.9	1610
Editorial (News)/64	HC	1.9	1620
Circulation/3	HC	2.0	1810
Circulation/3	CO	1.0	1813
Classified/122	HC	2.0	1830
Classified/122	CO	1.0	1835
Composing/3	HC	2.0	1845
Composing/3	CO	ND†	1900

* General hydrocarbon levels were measured with a direct reading instrument (HNU) which was calibrated with methanol. This instrument is nonspecific but if the hydrocarbon vapors being detected were pure methanol, the concentrations would have to be reduced by about a factor of 0.25.

** Measurements were made with colorimetric tubes accurate to about ±25 percent.

† VDT # 107 was the only unit that seemed to be emitting ozone, probably arcing inside.

†† ND - Not detectable

Because the direct reading instrument that is used to measure hydrocarbon levels is nonspecific, measurements were also taken in the hotel in order to make comparisons with measurements taken at VDT units. The control measurements at the hotel room ranged from 2.0 to 2.4 ppm. The levels in the areas with VDTs were actually lower than those measured in the hotel room (probably as a result of heavy city traffic). Based on the measurements made, there is no indication that VDT operators at the above locations experience any hazardous chemical exposure.

Health Complaints and Psychological Status

Response Rate: Questionnaires were given to 303 VDT operators and 212 nonoperators and responses were received from 131 VDT operators and 94 nonoperators for a response rate of 43 percent for the operators and 44 percent for the nonoperators. The data for 26 operators and 32 nonoperators were not used in the analysis because: (1) the participant worked less than 30 hours per week, or (2) the job category of the participant had less than five workers and therefore would not allow for statistical comparison by job type, or (3) a VDT operator worked an average of less than two hours per day on the VDT, or (4) a VDT operator had less than two months of service on their VDT job.

Demographic Characteristics: The respondent sample used for the statistical evaluation was comprised of 105 VDT operators (65 males and 40 females) and 62 nonoperators (23 males and 39 females). In terms of the ethnic background of the VDT operators and nonoperators, whites made up the majority of respondents in each group (91 percent and 79 percent respectively). The mean age for the operators and nonoperators (NVDT) was similar (VDT = 42 years, NVDT = 43 years); however, the VDT operators were more highly educated (VDT = 65 percent with at least a bachelors degree, NVDT = 30 percent with at least a bachelors degree). In terms of marital status, 55 percent of the VDT operators were married, 30 percent were single and 15 percent were separated, widowed or divorced; 36 percent of the nonoperators were married, 34 percent were single and 30 percent were separated, widowed or divorced.

Health Complaints: There were 59 separate health complaints examined and for 16 of these fifty percent or more of the VDT operators and/or nonoperators reported an occurrence in the past year. These complaints can be broken into categories of health problems such as muscular, visual, psychological, gastrointestinal, cardiovascular and others. Of the six visual complaints examined by the questionnaire, 4 had at least fifty percent of the operators and nonoperators reporting an occurrence; for the muscular complaints, 2 of 14 examined had at least fifty percent of the operators and nonoperators reporting an occurrence; for the psychological complaints, 5 of 10 had at least fifty percent of the operators and nonoperators reporting an occurrence; for the gastrointestinal complaints, 3 of 11 had at least fifty percent of the operators or nonoperators reporting an occurrrence; for the three cardiovascular complaints, none had fifty percent or more reporting an occurrence; and for the other complaints, 2 of 15 had at least fifty percent of the operators and nonoperators reporting an occurrence.

Table 15 shows the percentage of VDT operators and nonoperators reporting a specific health complaint. There were three health complaints that the VDT operators reported significantly more often than the nonoperators. These were eyestrain (VDT = 84 percent, NVDT = 64 percent), burning eyes (VDT = 67 percent, NVDT = 47 percent) and sore shoulder (VDT = 49 percent, NVDT = 29

Table 15. Percentage of VDT operators versus nonoperators reporting a health complaint

Health complaint	VDT operators	Non-operators
a. Shortness of breath or trouble breathing	32	39
b. Frequent colds or sore throats	50	61
c. Persistent cough and spitting up sputum	32	27
d. Coughing up blood	1	0
e. Fever, chills, and aching all over	41	42
f. Hay fever or sinus trouble	51	39
g. Wheezing in your chest	25	19
h. Respiratory infections	22	17
i. Jaundice, yellow eyes or skin	2	5
j. Skin rash, itching skin, allergic skin reactions	32	29
k. Swollen or painful muscles and joints	34	25
l. Back pain	64	48
m. Pain or stiffness in your arms or legs	39	42
n. Pain or stiffness in your neck or shoulders	61	49
o. Changes in your ability to see colors	8	5
p. Tearing or itching of eyes	51	39
q. Persistent numbness or tingling in any part of your body	17	19
r. Burning eyes	67	47
s. Occasions of easy irritability	75	60
t. Difficulty sleeping	51	53
u. Periods of depression	65	61
v. Ringing or buzzing in ears	31	22
w. Headaches	64	67
x. Fainting spells or dizziness	8	15
y. Nervous or shaking inside	23	34
z. Times when you feel sweaty or trembly	32	27

Health complaint	VDT operators	Non-operators
aa. Increased urination	33	34
bb. Painful urination	8	7
cc. Bloody urine	1	2
dd. Alarming pain or pressure in your chest	12	14
ee. Pain down your arms	9	19
ff. "Racing" or pounding heart	31	28
gg. Leg cramps	38	39
hh. Times of severe fatigue or exhaustion	54	56
ii. Acid indigestion, heartburn, or acid stomach	49	61
jj. Diarrhea for more than a few days	12	19
kk. Gas or gas pains	44	58
ll. Nausea or vomiting	18	29
mm. Blood in your bowel movement	3	2
nn. Constipation	31	29
oo. Tight feeling in stomach	33	35
pp. Bloated or full feeling	44	55
qq. Feeling of pressure in the neck	39	32
rr. Hemorrhoids or piles	29	15
ss. Periods of extreme anxiety	42	36
tt. Trouble digesting food	21	22
uu. Blurred vision	40	27
vv. Dryness in the mouth	27	24
ww. Stomach pains	26	33
xx. Belching	36	41
yy. High levels of tension	64	60
zz. Difficulty with feet and legs when standing for long periods	29	32
aaa. Shoulder soreness	49	29
bbb. Loss of feeling in fingers and wrists	8	9
ccc. Neck pain that radiates into shoulder, arm or hand	27	19
ddd. Cramps in hands and fingers relieved only when not working	10	3
eee. Loss of strength in arms or hands	9	12
fff. Eyestrain or sore eyes	84	64
ggg. Stiff or sore wrists	10	2

percent). There was one health complaint that was reported as having frequent recurrences significantly more often by VDT operators; this was eyestrain or sore eyes (see Table 16).

Disease States: Table 17 shows the percentages of VDT operators and nonoperators reporting a specific disease diagnosis or being treated for a particular disease in the previous five-year period for 23 select diseases. None of the disease states displayed a significant difference between operators and nonoperators. However, of interest is the high percentage of VDT operators reporting mental or psychological problems (16 percent of the VDT operators reported such conditions).

Psychological Mood States: Table 18 lists the mean values for VDT operator and nonoperators for the six dimensions of psychological mood evaluated. Anxiety, depression, anger, fatigue, and confusion were all higher for the VDT operators.

Discussion of the Findings from the Survey: There are some qualifications and cautions that must be raised in considering the nature and significance of the findings of the questionnaire survey. First, during the time the survey was being conducted, very difficult labor negotiations were under way and health and safety issues concerning video display terminal work were a component of that bargaining. This may have produced a more emphatic response by VDT operators concerning health problems.

Second, ethnic status appears to have had an effect on the frequency of health complaints such that nonwhite VDT operators reported more health complaints than white VDT operators, while nonwhite nonoperators reported less health complaints than white nonoperators. This inflated the difference in reporting of health complaints between VDT operators and nonoperators. This effect cannot be clearly substantiated, however, due to the small number of nonwhite participants in this evaluation. It is a factor that needs further examination.

Third, the questionnaire survey was not carried out in accordance with a strict survey research procedure in terms of subject sampling requirements, subject selection and randomization. However, the purpose was not to develop a statistical representation of the study group, but to define whether a health risk was associated with VDT use. As such, the results can indicate something about health risk at this site but are limited in their general applicability.

Keeping these limitations in mind, the results demonstrated that a high percentage of VDT operators and nonoperators experienced a number of health complaints, particularly related to visual, muscular and emotional difficulties. The results showed that the VDT operators reported higher levels for a limited number of visual complaints (2 out of 6). This demonstrates a potential problem area but does not conclusively indicate a serious problem. On the other hand, the VDT operators reported higher mean responses for five of the six mood states examined which indicates a greater level of emotional distress. This is a significant finding and most likely is more related to the type of work activity of the VDT operators than their use of the VDT.

Table 16. Percentage of VDT operators versus nonoperators reporting a health complaint as occurring frequently or constantly

	Health complaints	VDT operators	Non-operators
a.	Shortness of breath or trouble breathing	1	8
b.	Frequent colds or sore throats	8	5
c.	Persistent cough and spitting up sputum	5	3
d.	Coughing up blood	0	0
e.	Fever, chills, and aching all over	2	0
f.	Hay fever or sinus trouble	16	17
g.	Wheezing in your chest	1	0
h.	Respiratory infections	2	2
i.	Jaundice, yellow eyes or skin	0	2
j.	Skin rash, itching skin, allergic skin reactions	7	3
k.	Swollen or painful muscles and joints	8	3
l.	Back pain	13	8
m.	Pain or stiffness in your arms or legs	8	5
n.	Pain or stiffness in your neck or shoulders	20	13
o.	Changes in your ability to see colors	0	0
p.	Tearing or itching of eyes	17	6
q.	Persistent numbness or tingling in any part of your body	2	3
r.	Burning eyes	24	10
s.	Occasions of easy irritability	22	11
t.	Difficulty sleeping	9	6
u.	Periods of depression	11	5
v.	Ringing or buzzing in ears	8	6
w.	Headaches	14	10
x.	Fainting spells or dizziness	1	0
y.	Nervous or shaking inside	5	5
z.	Times when you feel sweaty or trembly	5	4

Health complaints	VDT operators	Non-operators
aa. Increased urination	4	5
bb. Painful urination	2	0
cc. Bloody urine	0	0
dd. Alarming pain or pressure in your chest	0	2
ee. Pain down your arms	2	2
ff. "Racing" or pounding heart	2	3
gg. Leg cramps	6	5
hh. Times of severe fatigue or exhaustion	10	10
ii. Acid indigestion, heartburn, or acid stomach	10	14
jj. Diarrhea for more than a few days	2	3
kk. Gas or gas pains	8	8
ll. Nausea or vomiting	1	3
mm. Blood in your bowel movement	0	0
nn. Constipation	2	0
oo. Tight feeling in stomach	7	5
pp. Bloated or full feeling	7	5
qq. Feeling of pressure in the neck	11	6
rr. Hemorrhoids or piles	4	2
ss. Periods of extreme anxiety	8	6
tt. Trouble digesting food	0	6
uu. Blurred vision	11	5
vv. Dryness in the mouth	5	5
ww. Stomach pains	2	6
xx. Belching	6	5
yy. High levels of tension	17	13
zz. Difficulty with feet and legs when standing for long periods	8	5
aaa. Shoulder soreness	8	10
bbb. Loss of feeling in the fingers and wrists	2	0
ccc. Neck pain that radiates into shoulder, arm or hand	4	2
ddd. Cramps in hands and fingers relieved only when not working	3	0
eee. Loss of strength in arms or hands	1	2
fff. Eyestrain or sore eyes	32	8
ggg. Stiff or sore wrists	1	0

Table 17. Percentage of VDT operators and nonoperators reporting diagnosis or treatment of a disease state by their physician within the previous 5 years

Disease states	VDT operators	Nonoperators
Diabetes	2	3
Cancer	2	4
Hernia or Rupture	1	3
Tuberculosis	0	0
Asthma	4	4
High Blood Pressure	15	17
Heart Disease	2	5
Arthritis or Rheumatism	9	17
Epilepsy (Convulsions or Fits)	0	2
Glaucoma of the Eyes	0	2
Paralysis, Tremor, or Shaking	1	2
Kidney or Bladder Trouble	7	7
Lung or Breathing Problems	8	10
Stroke	0	2
Anemia	3	5
Gall Bladder, Liver	0	5
Thyroid Trouble or Goiter	4	9
Insomnia	4	7
Gastritis	10	17
Colitis	5	5
Stomach Ulcer	5	9
Cataracts	1	3
Mental or Psychological Problems	16	7

Table 18. Mean scale values for psychological mood states

	Scale Means	
Anxiety	9.7	6.9
Depression	9.6	6.2
Anger	9.3	5.8
Vigor	17.2	18.2
Fatigue	7.5	5.2
Confusion	6.1	4.0

Ergonomics

The ergonomic evaluation of the VDT operations concentrated upon three aspects of the work environment: illumination, display legibility, and workstation design. Although these aspects will be treated separately in this report, they are interdependent, (e.g., illumination level and workstation design can affect display legibility); and all are strongly interactive with job task demands. For many of the factors reviewed in this evaluation, a range of recommended requirements are more appropriate rather than one fixed numerical value because of differences in job task characteristics. Therefore, the development of one set of guidelines with universal applications is not possible since the nature of the task being performed must be taken into account when selecting ergonomic approaches to solving VDT problems. It is recommended that a human factors professional be consulted during the design of future large scale installations.

Temperature and Humidity

Indoor ambient temperatures were in the 23-25° C range, and relative humidities were between 40 and 50 percent. Because temperatures and humidities in most indoor environments vary significantly with outdoor weather conditions, it is not possible to determine how representative these measures are of either seasonal or year-round conditions.

Illumination

Proper illumination is essential so that both VDT screen and hard copy can be read without undue visual discomfort or fatigue. Visual discomfort and fatigue can also occur if the eye is exposed to large contrast variations, too much light, unclear display characters, or tube flicker. A wide variety of recommendations exist for lighting levels in VDT operations. The American National Standards Institute (ANSI, 1973) recommends minimum illumination levels of between 750 lux and 1600 lux for a general office environment, depending on the quality of the hard copy used and the type of tasks performed. Other recommendations, specifically for VDT offices, range between 200 lux and 1076 lux (Rupp, 1979).

The majority of the workstations had illumination levels between 500 and 700 lux; however levels as low as 430 lux and as high as 1200 lux were measured (see Table 19). Certain areas were adjacent to windows which had the potential to create excessive illumination levels in periods of bright sunlight. These windows were equipped with glare (tinted) filters which reduced the transmitted light when the windows were closed, but they were not equipped with curtains or blinds.

It is very difficult to make recommendations about illumination levels if visual tasks requiring different illumination occur in the same work area. Relatively low illumination levels (300-500 lux) appear to be appropriate for VDT use, with higher levels (1000-1600 lux) being indicated for other visual tasks, particularly those which require the reading of poor quality hard copy. Consistent with the evidence in the literature, we recommend that the illumination levels be maintained between 500 and 700 lux in VDT areas, with care exercised that hard copy used by the operators have sufficiently high print/background contrast (at least 5:1) to allow for comfortable reading at these levels. This recommendation is essentially a compromise between the requirements for VDT work and the requirements for hard copy tasks; thus, levels from 300 to 1200 lux may be appropriate where task demands dictate, particularly if illumination can be individually controlled by the operator. If illumination levels greater than 700 lux are necessary, use of individual workstation illumination is preferable to increasing the ambient illumination level of a total work area; but care should be exercised that the individual workstation luminaires do not become glare sources.

Table 19. Illumination levels at workstations

Illumination level (lux)	Number of workstations
0 - 299	0
300 - 500	3
501 - 700	16
701 - 1000	2
over - 1000	2

Horizontal illuminance on the screen should be kept low to minimize reflected glare. If lighting levels are increased over 700 lux for high demand visual tasks, particular care should be taken to eliminate glare on the VDT screen. A determination should be made as to whether any illuminance levels over 700 lux are in fact necessary to allow for task demands or employee comfort. Windows should be shielded by curtains, shades, or blinds, particularly during bright sunlight to prevent excessive luminance and reflected glare. Illumination levels were generally acceptable, although the need for existing illumination levels should be determined in those areas with levels greater than 700 lux.

Another area of concern with respect to visual discomfort or fatigue deals with contrasts between materials being read and other background sources of high luminance in the work environment. Excessive contrasts within the operator's field of vision can lead to difficulty in reading the display, and to visual fatigue due to the repeated need for light/dark adaptation. The range of individual station maximum simple luminance ratios were between 1:2 and 1:40 (see Table 20).

Maximum luminance ratios within the operator's field of vision of between 1:3 and 1:10 have been recommended with the narrower range being preferred by Cakir et al. (1979). We recommend that area luminance ratios should be brought within the 1:10 range. This can be done by keeping illumination levels within the recommended range (see previous section), and avoiding the use of high reflectance surfaces in the work area. However, the exclusive use of dark colors to cut down reflectivity may have a negative emotional impact on employees.

Table 20. Work area maximum luminance ratios

Ratio	Number of workstations
1:0 - 1:10	10
1:11 - 1:20	6
1:21 - 1:30	1
over - 1:30	3

Another problem concerns direct discomfort glare*. Discomfort glare sources were visible at 20 of the 24 workstations surveyed, particularly when the operator would shift his/her direction of viewing. The glare sources included windows and light fixtures with luminance levels of up to 2100 cd/m^2. It should be noted that in offices with windows both illumination and glare levels can be affected by the weather and the time of day; thus, although severe window glare was not noted during the site visit, a potential glare problem exists in any office with at least one window exposed to direct or reflected sunlight, particularly with the windows open for ventilation, since opening the windows limits the effectiveness of the window filters in use at this site.

Most discomfort glare can be eliminated by (1) the use of shades, curtains or blinds on all windows exposed to direct or reflected sunlight, (2) the use of recessed light fixtures with baffles or special covers to direct light downward, and (3) proper positioning of VDT's with respect to glare sources.

Display Legibility

It has been shown that there is a relationship between display legibility and visual fatigue (Gould, 1968). Two major components of legibility were examined in this evaluation: image quality and reflected glare. The first component of

*Discomfort glare is likely to produce a subjective feeling of discomfort in individuals without a significant short range decrease in performance, while disability glare interferes with the ability to distinguish visual objects within the field of view and hence causes significant decreases in performance.

display legibility is image quality, which was judged by the researchers conducting the ergonomic evaluation. No visually detectable jitter or flickering was observed on any of the screens examined nor was any detectable flicker reported by operators when questioned; however, the perceptibility of flickers varies with illumination, screen luminance, whether foveal or peripheral vision is used, and operator sensitivity characteristics. In a few cases, slight blurring of characters was observed at the screen edges. It is possible that such blurring could produce continuous refocusing by the operator and hence visual fatigue (Cakir et al., 1979). However, it was judged that the character blurring observed was not sufficiently pronounced to interfere with the operator's ability to readily distinguish characters. The displays all used a minimum 5 x 7 dot matrix to form characters approximately 3.0 mm in height. This character size corresponds to a recommended minimum 5 x 7 dot matrix and range of recommended height of 2.6 to 4.2 mm (Rupp, 1979). No characters of unusual design, which would pose additional reading problems, were observed by the investigators; however, some VDT units were equipped with a "boldface" text feature, which some operators found difficult to distinguish from the standard text. Some VDTs had brightness and contrast controls accessible to the operator, others did not. Composing tasks may pose special problems due to the requirement for multiple character sets.

Reflected glare also can have a serious impact upon display legibility. This phenomenon results from the reflection of light from luminance sources such as overhead lights in the VDT screen. Reflected glare may be either specular or diffuse; that is, the reflections may be perceived by the operator as image(s) (e.g., light fixtures, walls etc.) or as bright spot(s) on the screen. Because of the curvature of the screen, reflections from high luminance surfaces in much of the work area behind the operator may be visible on the screen. Such reflected glare decreases the effective image/background contrast in portions of the screen. In extreme cases, it may "wash out" the image entirely; high levels of reflected glare can approximate the luminance of characters on a display at the low end of the acceptable character luminance range (45-160 cd/m^2) (Cakir et al., 1979). Excessive reflected glare can increase visual fatigue and can contribute to poor operator posture as operators change position in an attempt to read characters obscured by glare.

Reflected glare generally consisted of reflections of light fixtures and windows. The maximum reflected luminance levels on the VDT screens ranged from 1 to 58 cd/m^2, and the investigators as well as operators who were questioned had difficulty reading certain screens which had high reflected glare levels. Of the 24 screens evaluated, six (25 percent) had reflected glare levels which could make it difficult to read characters on parts of the screen (see Table 21). Some units had anti-glare coatings apparently provided by the manufacturers, others had etched glass screens, and some had been fitted with grid type glare filters. A number of operators had constructed makeshift hoods for their VDT's from newspaper or cardboard, or had simply stacked books or papers so that they shaded the screen in an attempt to reduce reflected glare. One work area had desks with white tops which aggravated the glare problem.

Table 21. Number of workstations from which glare sources are visible

Glare level (cd/m^2)	Number of workstations
0 - 750	2
751 - 1500	16
1501 - 2250	2
over - 2250	0

The following are general approaches for reducing reflected glare:

1. Drapes, shades, and/or blinds over windows should be closed, especially during direct sunlight conditions.

2. The terminals should be properly positioned with respect to windows and overhead lighting, so that glare sources are not directly in front of the operators, nor reflected in the VDT screen.

3. Screen hoods may be installed to completely or partially shield the screen from reflections.

4. Anti-glare filters may be installed on the VDT screen.

5. Direct lighting fixtures may need to be recessed; and baffles may be used to cover light fixtures to prevent the luminaires from acting as a glare orurce, so special covers on light fixtures may be used to direct the light downward rather than allowing the light to diffuse.

6. Properly installed indirect lighting systems will limit the luminaires' potential as glare sources, although some reflected glare may still be present.

Attempts at positioning the VDT to reduce glare problems from overhead lights may have only limited success in most large offices because of the sheer number of such lights. However, it can be used effectively to reduce glare from windows. Hoods are often not completely effective in reducing reflected glare, particularly when a large number of high luminance surfaces are located behind the operator. The characteristics and effectiveness of different types of glare filters vary widely. Some screen filters may have detrimental effects on image quality or contrast and caution should be used in their selection. In many cases a combination of the above approaches is needed to eliminate reflected glare and these should be chosen based on the particular nature of the glare sources in the work environment.

In summary, the available literature supports the recommendation that drapes, shades or blinds be used to reduce reflections from windows, and that illumination levels be kept in the 500 to 700 lux range wherever possible to limit the reflected glare from work surfaces. Additional treatment for the reduction of reflected glare may still be necessary, however, in which case the approaches discussed above should be considered.

Workstation Design

Four factors related to workstation design were examined. These were keyboard height, viewing distance, viewing angle, and chair features. (The method of measuring the first three factors was shown in Figure 1).

Excessive keyboard height can lead to musculoskeletal fatigue due to the static loading imposed on the operator by the need to keep hands in an elevated position. One European recommendation for the height of the home row keys in a fixed height work station is 720-750 mm (28 1/4 - 29 1/2 in.)(Cakir et al., 1979). The U.S. Military Standard 1472B (1974) specifies a working surface height of 740-790 mm (29 1/4 - 31 in.), which is approximately the customary keyboard height range for typing in most offices in this country. Rebiffe (1969) has recommended that the angle between the upper and lower arms be between 80° and 120° and that the angle of the wrist be no greater than $\pm 10°$. This would require that the keyboard be approximately at or below elbow height, which varies from 605 mm for 5th percentile females to 820 mm for 95th percentile males (Van Cott and Kincaid, 1963). In any event, sufficient clearance must be allowed for the operator's legs (645 mm for 95th percentile males) (Van Cott and Kincaid, 1963). Thus either a fairly wide range of adjustability or some compromises between leg clearance and keyboard height are necessary.

Five basic types of workstations were observed at this site: (1) specifically designed workstations which had an inset area for placement of the keyboard (which was movable in relation to the VDT screen) and home row heights between 760 and 775 mm; (2) units in which the one-piece VDT screen and keyboard sat on a typewriter stand of an office desk, with home row heights of 720-840 mm; (3) units in which one-piece VDTs sat on a typewriter stand between two desks with home row heights of 810-815 mm; (4) units in which separate screen and keyboard housings sat on desks with home row heights of 720-740 mm; and (5) units in which one-piece VDTs sat on special VDT stands with home row heights of 775-810 mm (see Table 22).

Table 22. Keyboard height (floor to home row)

Keyboard height (mm)	Number of workstations
0 - 720	0
721 - 750	3
751 - 790	12
over - 790	11

Incorrect viewing distance and angle can impose the necessity for awkward postures when viewing the display. Proper viewing distance is also important in minimizing visual system fatigue. In addition, viewing distance should not be so great that the characters subtend less than the minimum arc required for reading. A viewing distance of 450-500 mm (17 3/4 - 19 3/4 in.) with a maximum of 700 mm (27 1/2 in.) has been recommended by Cakir et al. (1979). A variety of recommendations exist regarding screen viewing angle (Cakir et al., 1979; Dreyfus, 1967; International Business Machines Corp., 1979). Generally these recommendations place the center of the VDT screen at a position between 10° and 20° below the horizontal plane at the operator's eye height. Cakir et al. (1979) make the additional recommendation that the top of the screen be below eye height, while Grandjean (1980) recommends that the top line of the display be 10-15° below the horizontal, with no portion of the screen at an angle greater than 40° below the horizontal.

The estimated viewing distance and viewing angles for male and female operators of median dimensions are summarized in Table 23. Many of the viewing angles were higher than recommended, especially for male operators of greater than median dimensions. Viewing distances were all in the acceptable range (450 to 700 mm).

Where feasible, workstations should be modified so that the keyboard and screen heights are appropriate for the operators. We recommend that where possible, any replacement furniture purchased be designed to allow both keyboard and screen to be within the preferred ranges and adjustable for the preference of each operator and that adjustments be made where possible to allow correct positioning of keyboard and screen on the existing furniture. Home row height should be between 720 and 790 mm, preferably adjustable. Workstations should allow sufficient leg clearance for all operators. Consistent with the need for firmly planted feet, footrests should be provided for any operators needing them.

Screen height and position should be adjusted to suit the individual operator. Screen center should normally be 10-20° below the horizontal plane through the

Table 23. Hypothetical viewing angle and distance at workstations for median males and females

Sex	Viewing angle (degrees)	Number of workstations	Viewing distance (mm)	Number of workstations
Males	0 - 9	0	0 - 449	0
	10 - 20	2	450 - 500	0
	21 - 30	11	501 - 700	19
	over - 30	6	over - 700	0
Females	0 - 9	1	0 - 449	0
	10 - 20	8	450 - 500	0
	21 - 30	8	501 - 700	19
	over - 30	2	over - 700	0

operator's eyes, with the top line of the screen below eye level. The viewing distance should normally be between 450-500 mm, and adjustable by the operator without adoption of unusual postures. Viewing distances greater or less than 450-500 mm are acceptable if necessary to accommodate individual operator comfort. It should be noted that these workstation dimensions may pose special visual problems for operators wearing bifocals or those wearing reading glasses ground for reading at 330 mm; special provisions may be required for these operators.

Workstations observed at Site 2 were not equipped with copy holders; but consideration should be given to supplying them. The preferred position for the copy holders is near the VDT screen in order to minimize both repeated changes in accommodation and visual search. It is best to allow the operator some flexibility in positioning a copy holder, however, so that it can be placed in the position which the operator finds most comfortable.

Operator chairs should be adjustable in height and have backrests. Backrests should be adjustable to the lumbar region (mid-back) to provide adequate support. If a full backrest is provided, only the lumbar region of the back should contact the backrest during normal sitting (Kroemer and Robinette, 1969) as freedom of motion of the arms and shoulders is required for typing. There were a few cases in which operators were seated on straight-backed chairs without any adjustment for height. Except for these cases, the chairs provided were typical of the secretarial/clerical chairs generally found in offices.

The available literature supports the recommendation that operators should have chairs with adjustable seat height, adjustable lumbar support height, and an adjustable backrest to provide support to the lower back. It has been recommended by Hunting, Laeubli and Grandjean (1980) that workstations should have a place for operators to rest their wrists and forearms while keying. This could be accomplished by providing chairs with armrests. However, if armrests are supplied, they should be supplied only to those operators desiring them and/or be removable. Moreover, they should be designed so as not to interfere with keyboard operation and to allow the operator to position the chair properly in relation to the keyboard. Another alternative is to arrange for a ledge at the bottom of the keyboard on which the operators can place his/her wrists.

Preferred operator posture is for the operator to be seated erect, with the thoracic region of the spine convex, the lumbar region concave, the thighs horizontal and the feet flat on the floor or footrest (Cakir et al., 1979). Weight transfer to the seat should be primarily through the buttocks, not through the thighs. The angle between upper arm and forearm should be 80-120°. The operator should have sufficient freedom of movement to adjust his/her posture to relieve fatigue.

RESULTS AND DISCUSSION
(Site 3)

Radiation

At Site 3, slightly over 25 percent (67 of 265) of the VDTs in use were surveyed. The results of the measurements are shown in Table 24. X-ray and RF measurements were not distinguishable from background levels. One terminal emitted 0.10 $\mu W/cm^2$ (1 $\mu W/cm^2 = 10^{-6}$ W/cm^2) in the near UV region. The visible radiation levels ranged from 1 to 6 fL.

Comparisons of the maximum measured radiation levels with the current U.S. occupational exposure guidelines and standards are shown in Table 25. It is readily apparent that the radiation levels are far below current standards and, in most cases, were not detectable. After considering the maximum measured radiation levels, the current exposure standards and the present knowledge of the biological effects of radiation, NIOSH concluded that the VDTs at this site do not emit radiation levels that present a hazard to the employee working at or near the terminals.

Industrial Hygiene

In VDT areas, the general hydrocarbon levels were in the range from 1.4 to 2.0 ppm, as shown in Table 26. Some areas had photo-reproduction equipment that had been evaluated at other locations with VDTs and had been determined to have no significant effect on general hydrocarbon levels. Carbon monoxide levels ranged from not detectable to 3.0 ppm (mostly from smoking) (see Table 26). Carbon monoxide has a recommended NIOSH standard of 35 ppm (NIOSH, 1973).

Because the direct reading instrument that is used to measure hydrocarbon levels is nonspecific, measurements were also taken in the hotel in order to make comparisons with measurements taken at VDT units. The control measurements at the hotel room ranged from 2.0 to 2.4 ppm. The levels in the areas with VDTs were actually lower than those measured in the hotel room (probably as a result of heavy city traffic). Based on the measurements made, there is no indication that VDT operators at the above location experience any hazardous chemical exposure.

Health Complaints and Psychological Status

Response Rate: Questionnaires were given to 102 VDT operators and 110 nonoperators and responses were received from 77 VDT operators and 40 nonoperators for a response rate of 75 percent for the operators and 36 percent for the nonoperators. The data for 5 VDT operators were not used in the statistical analysis because these operators worked less than 30 hours per week. The data for 5 nonoperators also were not used because they worked less than 30 hours per week, or due to their incidental use of VDTs in their job activities.

Table 24. Range of electromagnetic radiation measurements

Manufacturer	Model number	Number units measured	X-ray radiation (mR/hr)	Ultraviolet radiation ($\mu W/cm^2$)	Visible radiation (fL)*	Radio-frequency radiation: Electric field (V^2/m^2)	Radio-frequency radiation: Magnetic field (A^2/m^2)
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		67	ND	ND-0.10	1-6	ND	ND

* 1 fL = 0.29 candle per meter squared

** ND = Not detectable

Table 25. Comparison of maximum measured radiation levels with currently accepted standards

Radiation region	Maximum level	Occupational standard	Reference
X-Ray	ND*	2.5 mR/hr	USDOL, 1980a
Ultraviolet (near)	0.1 $\mu W/cm^2$	1000 $\mu W/cm^2$	NIOSH, 1972
Visible	6 fL	2920 fL	ACGIH, 1979
Radiofrequency			
Electric field	ND	40,000 V^2/m^2**	USDOL, 1980b
Magnetic field	ND	0.25 A^2/m^2**	USDOL, 1980b

* ND = Not detectable

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

Table 26. Chemical exposure data

Location/ VDT number	Exposure	Conc (ppm)	Time
Hotel Room	Hydrocarbon (HC)*	2.0-2.4	0800
Direct Data Entry (1st)/751	Carbon Monoxide (CO)**	ND†	1215
DDE (1st)/924	CO	3.0	1230
DDE (1st)/751	HC	1.8	1235
DDE (1st)/734	HC	1.6	1250
DDE (1st)/744	HC	1.7	1305
Audit/Edit/ Suspense/1220	HC	2.0	1340
Audit/Edit/ Suspense/801	HC	2.0	1400
Audit/Edit/ Suspense/801	CO	ND	1405
Audit/Edit/ Suspense/965	HC	1.9	1425
Beneficiary Service/ 1161	CO	ND	1515
Beneficiary Service/ 1146	HC	1.6	1525
Beneficiary Service/ 1161	HC	1.6	1530
DDE (2nd)/1309	HC	1.6	1700
DDE (2nd)/54	HC	1.4	1710
DDE (2nd)/469	CO	ND	1745
DDE (2nd)/469	HC	1.6	1750
ADS/6	HC	1.6	1810
Telephone Unit/1313	HC	1.6	1830
CDDE/776	HC	1.8	1855
PCP/33	CO	ND	1900
PCP/33	HC	1.7	1905

* General hydrocarbon levels were measured with a direct reading instrument (HNU) which was calibrated with methanol. This instrument is nonspecific but if the hydrocarbon vapors being detected were pure methanol, the concentrations would have to be reduced by about a factor of 0.25.

**Measurements were made with colorimetric tubes accurate to about ±25 percent.

† ND = Not detectable

Demographic Characteristics: The respondent sample used for the statistical evaluations was comprised of 72 VDT operators (13 males, 53 females, 6 no reported sex) and 35 nonoperators (8 males, 24 females, 3 no reported sex). The ethnic background of the VDT operators and the nonoperators was similar, with the largest category in each group being Asian or Pacific Islanders (38 and 45 percent respectively), next largest, whites (34 percent and 32 percent respectively) and all other ethnic backgrounds (28 percent and 32 percent respectively). The mean age for the VDT operators was 34 years and for nonoperators it was 38 years. The reported education levels were almost identical with the typical operator and non-operator reporting some college training. The marital status for the operators (59 percent married, 33 percent single, and 8 percent divorced, widowed or separated) and the nonoperators (55 percent married, 30 percent single, and 15 percent divorced, widowed, or separated) was similar.

Health Complaints: There were 59 separate health complaints examined, and for 35 of these, fifty percent or more of the VDT operators and/or the nonoperators reported an occurrence in the past year. These complaints can be broken into categories of health problems such as muscular, visual, psychological, gastrointestinal, cardiovascular and others. Of the 6 visual complaints examined by the questionnaire, 5 had at least fifty percent of the operators reporting an occurrence; for the muscular complaints, 12 out of 14 had at least fifty percent of the operators reporting an occurrence; for the psychological complaints, 7 out of 10 had at least fifty percent of the operators reporting an occurrence; for gastrointestinal complaints, 4 out of 11 had at least fifty percent of the operators or nonoperators reporting an occurrence; for the 3 cardiovascular complaints, none had fifty percent or greater reporting an occurrence; and for the other complaints, 7 out of 15 had at least fifty percent of the operators or nonoperators reporting an occurrence.

Table 27 lists the percentages of VDT operators and nonoperators reporting a specific health complaint, while Table 28 lists the percentage of operators and nonoperators reporting recurrences of specific health complaints. A number of health complaints showed significantly more operators reporting a problem and having more frequent recurrences of that problem than nonoperators. These included burning eyes, blurred vision, eyestrain or sore eyes, back pain, pain or stiffness in arms or legs, pain or stiffness in neck or shoulders, neck pain that radiates into shoulders/arms/hands, shoulder soreness, cramps in hands and fingers relieved only when not working, and times of extreme fatigue or exhaustion.

There were six health complaints reported by a significantly greater percentage of operators but which did not have recurrences. These were skin rash/itchy skin/allergic skin reactions, changes in ability to see colors, persistent numbness or tingling in any part of the body, loss of strength in arms or hands, stiff or sore wrists, and feeling nervous or shaking inside.

There were four health complaints that had similar percentages of operators and nonoperators reporting the complaint, but which had a significantly greater percentage of operators reporting recurrences of the problem. These were irritability, high levels of tension, headaches, and feeling of pressure in the neck.

Table 27. Percentage of VDT operators versus nonoperators reporting a health complaint

Health complaint	VDT operators	Non-operators
a. Shortness of breath or trouble breathing......................	39	50
b. Frequent colds or sore throats..	70	65
c. Persistent cough and spitting up sputum.........................	42	26
d. Coughing up blood..............	0	3
e. Fever, chills, and aching all over..............................	54	33
f. Hay fever or sinus trouble......	54	39
g. Wheezing in your chest..........	21	15
h. Respiratory infections..........	27	21
i. Jaundice, yellow eyes or skin...	3	6
j. Skin rash, itching skin, allergic skin reactions.........	62	38
k. Swollen or painful muscles or joints..........................	55	44
l. Back pain.......................	88	66
m. Pain or stiffness in your arms or legs........................	71	48
n. Pain or stiffness in your neck or shoulders...................	90	63
o. Changes in your ability to see colors........................	46	21
p. Tearing or itching of eyes......	79	62
q. Persistent numbness or tingling in any part of your body........	53	30
r. Burning eyes....................	77	44
s. Occasions of easy irritability..	82	71
t. Difficulty sleeping.............	56	53
u. Periods of depression...........	69	76
v. Ringing or buzzing in ears......	38	36
w. Headaches.......................	89	80
x. Fainting spells or dizziness....	41	27
y. Nervous or shaking inside.......	54	30
z. Times when you feel sweaty or trembly........................	43	38
aa. Increased urination.............	47	50
bb. Painful urination...............	12	9
cc. Bloody urine....................	2	6
dd. Alarming pain or pressure in your chest.....................	30	21

Health complaint	VDT operators	Non-operators
ee. Pain down your arms	46	32
ff. "Racing" or pounding heart	47	30
gg. Leg cramps	59	59
hh. Times of severe fatigue or exhaustion	83	59
ii. Acid indigestion, heartburn, or acid stomach	61	61
jj. Diarrhea for more than a few days	27	24
kk. Gas or gas pains	65	59
ll. Nausea or vomiting	30	29
mm. Blood in your bowel movement	6	12
nn. Constipation	45	50
oo. Tight feeling in stomach	43	48
pp. Bloated or full feeling	49	44
qq. Feeling of pressure in the neck.	64	45
rr. Hemorrhoids or piles	23	41
ss. Periods of extreme anxiety	61	52
tt. Trouble digesting food	39	29
uu. Blurred vision	78	47
vv. Dryness in the mouth	44	34
ww. Stomach pains	63	44
xx. Belching	45	36
yy. High levels of tension	69	63
zz. Difficulty with feet and legs when standing for long periods	54	44
aaa. Shoulder soreness	76	52
bbb. Loss of feeling in the fingers or wrists	39	24
ccc. Neck pain that radiates into shoulder, arm or hand	63	30
ddd. Cramps in hands and fingers relieved only when not working	58	35
eee. Loss of strength in arms or hands	43	19
fff. Eyestrain or sore eyes	93	55
ggg. Stiff or sore wrists	58	21

Table 28. Percentage of VDT operators versus nonoperators reporting a health complaint, as occurring frequently or constantly

Health complaint	VDT operators	Non-operators
a. Shortness of breath or trouble breathing	13	3
b. Frequent colds or sore throats	23	9
c. Persistent cough and spitting up sputum	6	9
d. Coughing up blood	0	0
e. Fever, chills, and aching all over	7	0
f. Hay fever or sinus trouble	21	9
g. Wheezing in your chest	4	3
h. Respiratory infections	3	0
i. Jaundice, yellow eyes or skin	0	0
j. Skin rash, itching skin, allergic skin reactions	17	6
k. Swollen or painful muscles and joints	28	13
l. Back pain	49	22
m. Pain or stiffness in your arms or legs	32	12
n. Pain or stiffness in your neck or shoulders	45	16
o. Changes in your ability to see colors	14	3
p. Tearing or itching of eyes	41	24
q. Persistent numbness or tingling in any part of your body	16	6
r. Burning eyes	37	16
s. Occasions of easy irritability	32	9
t. Difficulty sleeping	24	13
u. Periods of depression	26	9
v. Ringing or buzzing in ears	9	3
w. Headaches	37	13
x. Fainting spells or dizziness	10	0
y. Nervous or shaking inside	17	7
z. Times when you feel sweaty or trembly	12	16
aa. Increased urination	7	12
bb. Painful urination	1	0
cc. Bloody urine	0	0
dd. Alarming pain or pressure in your chest	9	3

Health complaint	VDT operators	Non-operators
ee. Pain down your arms.............	19	6
ff. "Racing" or pounding heart......	5	0
gg. Leg cramps......................	22	9
hh. Times of severe fatigue or exhaustion......................	36	12
ii. Acid indigestion, heartburn, or acid stomach...................	18	21
jj. Diarrhea for more than a few days...........................	3	0
kk. Gas or gas pains................	18	9
ll. Nausea or vomiting..............	1	0
mm. Blood in your bowel movement....	0	0
nn. Constipation....................	9	15
oo. Tight feeling in stomach........	9	6
pp. Bloated or full feeling........	14	6
qq. Feeling of pressure in the neck.	42	12
rr. Hemorrhoids or piles............	5	6
ss. Periods of extreme anxiety......	23	12
tt. Trouble digesting food..........	11	3
uu. Blurred vision..................	43	13
vv. Dryness in the mouth............	14	6
ww. Stomach pains...................	16	9
xx. Belching........................	8	6
yy. High levels of tension..........	39	13
zz. Difficulty with feet and legs when standing for long periods..	20	6
aaa. Shoulder soreness...............	42	18
bbb. Loss of feeling in the fingers or wrists........................	18	6
ccc. Neck pain that radiates into shoulder, arm or hand...........	37	9
ddd. Cramps in hands and fingers relieved only when not working..	28	3
eee. Loss of strength in arms or hands..........................	20	3
fff. Eyestrain or sore eyes..........	52	18
ggg. Stiff or sore wrists............	18	3

Disease States: Of the twenty-three disease states examined, there were none for which there was a significant difference between the VDT operators and the nonoperators. See Table 29 for the percentage of operators and nonoperators reporting a disease condition.

Psychological Mood State: Table 30 lists the mean values for operators and non-operators for the six dimensions of psychological mood state evaluated. Only the fatigue scale showed a higher mean for the VDT operators than for the nonoperators worthy of noting.

Discussion of the Findings from the Survey: There are some qualifications and cautions that must be raised in considering the nature and significance of the findings of the questionnaire survey. Specifically, during the time that the questionnaire survey data were collected, very difficult labor negotiations were under way and health and safety issues relating to VDTs were a component of that bargaining. Hence, this could have sensitized respondents to certain health complaints which could have been further reinforced by a letter sent to all VDT operators by the local union stewards on the day prior to the survey. While urging participation in the survey, this letter also stated that a prior evaluation of the workplace by the NIOSH investigative team had indicated a likelihood of visual problems for VDT operators.

Secondly, the questionnaire survey was not carried out in accordance with a strict survey research procedure in terms of subject sampling requirements, subject selection and randomization. However, the purpose was not to develop a representative study group, but to define whether a health risk was associated with VDT use. As such, the questionnaire results can indicate something about health risk at this site, but are limited in their general applicability.

Keeping these limitations in mind, the results demonstrated that a large percentage of both the VDT operators and non-oprators experienced a number of health complaints, particularly related to visual, muscular and emotional difficulties. The results also showed that a significantly greater percentage of VDT operators expressed these health complaints than nonoperators. The visual, muscular and emotional health complaints reported were of a varied nature indicating a general influence of the work activity as opposed to a focal problem area.

Ergonomics

The ergonomic evaluation of the VDT operations concentrated upon three aspects of the work environment: illumination, display legibility, and workstation design. Although these aspects will be treated separately in this report, they are interdependent, (e.g., illumination level and workstation design can affect display legibility); and all are strongly interactive with job task demands. For many of the factors reviewed in this evaluation, a range of recommended requirements are more appropriate rather than one fixed numerical value because of differences in job task characteristics. Therefore, the development of one set of guidelines with universal applications is not possible since the nature of the task being performed must be taken into account when selecting ergonomic approaches to solving VDT problems. It is recommended that a human factors professional be consulted during the design of future large scale installations.

Table 29. Percentage of VDT operators and nonoperators reporting diagnosis or treatment of a disease state by their physician within the previous 5 years

Disease state	VDT operators	Nonoperators
Diabetes........................	2	0
Cancer..........................	3	0
Hernia or Rupture...............	3	3
Tuberculosis....................	3	0
Asthma..........................	4	6
High Blood Pressure.............	16	27
Heart Disease...................	3	9
Arthritis or Rheumatism.........	10	15
Epilepsy (Convulsions or Fits)..	1	3
Glaucoma of the Eyes............	3	3
Paralysis, Tremor, or Shaking...	6	3
Kidney or Bladder Trouble.......	15	18
Lung or Breathing Problems......	16	6
Stroke..........................	1	0
Anemia..........................	13	9
Gall Bladder, Liver.............	3	6
Thyroid Trouble or Goiter.......	10	0
Insomnia........................	3	9
Gastritis.......................	24	21
Colitis.........................	1	0
Stomach Ulcer...................	10	6
Cataracts.......................	1	0
Mental or Psychological Problems.....................	5	12

Table 30. Mean scale values for psychological mood states

Mood state	Scale means VDT Operators	Non-Operators
Anxiety	11.1	10.4
Depression	10.1	11.3
Anger	7.9	9.6
Vigor	14.8	17.2
Fatigue	9.8	5.9
Confusion	6.7	6.4

Temperature and Humidity

Indoor ambient temperatures were in the 22-24°C range, and relative humidities ranged around 35 percent. Because temperatures and humidities in most indoor environments vary significantly with outdoor weather conditions, it is not possible to determine how representative these measures are of either seasonal or year-round conditions.

Illumination

Proper illumination is essential so that both VDT screen and hard copy can be read without undue visual discomfort or fatigue. Visual discomfort and fatigue can also occur if the eye is exposed to large contrast variations, too much light, unclear display characters, or tube flicker. A wide variety of recommendations exist for lighting levels in VDT operations. The American National Standards Institute (ANSI, 1973) recommends minimum illumination levels of between 750 lux and 1600 lux for a general office environment, depending on the quality of the hard copy used and the type of tasks performed. Other recommendations, specifically for VDT offices, range between 200 lux and 1076 lux (Rupp, 1979).

The majority of the workstations had illumination levels between 500 and 700 lux; however levels as low as 300 lux and as high as 1200 lux were measured (see Table 31). According to management, the employees were allowed to determine whether the overhead lights in their area would be on or off, giving them some group control over illumination levels. Certain areas were adjacent to windows which had the potential to create excessive illumination levels in periods of bright sunlight; however, these windows were equipped with curtains which if properly utilized should eliminate excessive illumination from the windows.

Table 31. Illumination levels at workstations

Illumination level (lux)	Number of workstations
0 - 299	0
300 - 500	2
501 - 700	18
701 - 1000	0
over 1000	2

It is very difficult to make recommendations about illumination levels if visual tasks requiring different illumination occur in the same work area. Relatively low illumination levels (300-500 lux) appear to be appropriate for VDT use, with higher levels (1000-1600 lux) being indicated for other visual tasks, particularly those which require the reading of poor quality hard copy. Consistent with the evidence in the literature, we recommend that the illumination levels be maintained between 500 and 700 lux in VDT areas, with care exercised that hard copy used by the operators have sufficiently high print/background contrast (at least 5:1) to allow for comfortable reading at these levels. This recommendation is essentially a compromise between the requirements for VDT work and the requirements for hard copy tasks; thus; levels from 300 to 1200 lux may be appropriate where task demands dictate, particularly if illumination can be individually controlled by the operator. If illumination levels greater than 700 lux are necessary, use of individual workstation illumination is preferable to increasing the ambient illumination level of a total work area; but care should be exercised that the individual workstation luminaires do not become glare sources.

Horizontal illuminance on the screen should be kept low to minimize reflected glare. If lighting levels are increased over 700 lux for high demand visual tasks, particular care should be taken to eliminate glare on the VDT screen. Windows should be shielded by curtains, shades, or blinds, particularly during bright sunlight to prevent excessive luminance and reflected glare. Illumination levels were generally acceptable, except in some areas adjacent to windows with open curtains where they were too high.

Another area of concern with respect to visual discomfort or fatigue deals with contrasts between materials being read and other background sources of high luminance in the work environment. Excessive contrasts within the operator's field of vision can lead to difficulty in reading the display, and to visual fatigue due to the repeated need for light/dark adapation. The range of individual station maximum simple luminance ratios were between 1:8 and 1:50 (See Table 32).

Table 32. Work area maximum luminance ratio at workstations

Ratio	Number of workstations
1:0 - 1:10	2
1:11 - 1:20	12
1:21 - 1:30	5
over 1:30	3

Maximum luminance ratios within the operator's field of vision of between 1:3 and 1:10 have been recommended with the narrower range being preferred by Cakir et al. (1979). We recommend that area luminance ratios should be brought within the 1:10 range. This can be done by keeping illumination levels within the recommended range (see previous section), and avoiding the use of high reflectance surfaces in the work area. However, the exclusive use of dark colors to cut down reflectivity may have a negative emotional impact on employees.

Another problem concerns direct discomfort glare. Discomfort glare* sources were visible at 21 of the 22 workstations surveyed, particularly when the operator would shift his/her direction of viewing. The glare sources included windows and light fixtures with luminance levels of up to 2350 cd/m^2 (See Table 33). All windows observed were equipped with curtains; however, in many cases these curtains were left open. It should be noted that in offices with windows both illumination and glare levels can be affected by the weather and the time of day; thus, although severe glare was noted in only one office, a potential glare problem exists in any office with at least one window exposed to direct or reflected sunlight.

*Discomfort glare is likely to produce a subjective feeling of discomfort in individuals without a significant short range decrease in performance, while disability glare interferes with the ability to distinguish visual objects within the field of view and hence causes significant decreases in performance.

Table 33. Number of workstations from which glare sources are visible

Glare level (cd/m^2)	Number of workstations
0 - 750	4
751 - 1500	13
1500 - 2250	2
over 2250	3

Most discomfort glare can be eliminated by (1) the use of shades, curtains or blinds on all windows exposed to direct or reflected sunlight, (2) the use of recessed light fixtures with baffles or special covers to direct light downward, and (3) proper positioning of VDTs with respect to glare sources.

Display Legibility

It has been shown that there is a relationship between display legibility and visual fatigue (Gould, 1968). Two major components of legibility were examined in this evaluation: image quality and reflected glare. The first component of display legibility is image quality, which was judged by the researchers conducting the ergonomic evaluation. No visually detectable jittering or flicker was observed on any of the screens examined nor was any detectable flicker reported by operators when questioned; however, the perceptibility of flicker varies with illumination, screen luminance, whether foveal or peripheral vision is used, and operator sensitivity characteristics. In a few cases, slight blurring of characters was observed at the screen edges. It is possible that such blurring could produce continuous refocusing by the operator and hence visual fatigue (Cakir et al., 1979). However, it was judged that the character blurring observed was not sufficiently pronounced to interfere with the operator's ability to readily distinguish characters. The displays all used a minimum 5 x 7 dot matrix to form characters approximately 3.0 mm in height. This character size corresponds to a recommended minimum 5 x 7 dot matrix and range of recommended height of 2.6 to 4.2 mm (Rupp, 1979). No characters of unusual design, which would pose additional reading problems, were observed by the investigators. The VDTs had brightness and contrast controls accessible to the operator.

Reflected glare also can have serious impact upon display legibility. This phenomenon results from the reflection of light from luminance sources such as overhead lights in the VDT screen. Reflected glare may be either specular or diffuse; that is, the reflections may be perceived by the operator as an image(s) (e.g., light fixtures, walls, etc.) or as a bright spot(s) on the screen. Because of the curvature of the screen, reflections from high luminance surfaces in much of the work area behind the operator may be visible on the screen. Such reflected glare decreases the effective image/background contrast in portions of the screen. In extreme cases, it may "wash out" the image entirely; high levels of reflected glare can approximate the luminance of characters on a display at the low end of the acceptable character luminance range (45-160 cd/m^2) (Cakir et al., 1979). Excessive reflected glare can increase visual fatigue and can contribute to poor operator posture as operators change position in an attempt to read characters obscured by glare.

Reflected glare was present despite the fact that the screens had an etched glass surface to reduce specular reflections; this reflected glare generally consisted of reflections from windows and overhead lights. The maximum reflected luminance levels on the VDT screens ranged from 9 to 50 cd/m^2, and the investigators and operators who were questioned had difficulty reading certain screens which had high reflected glare levels. Of the 22 screens evaluated, three (approximately 14 percent) had reflected glare levels which could make it difficult to read characters on parts of the screen.

The following are general approaches for reducing reflected glare:

1. Drapes, shades, and/or blinds over windows should be closed, especially during direct sunlight conditions.

2. The terminals should be properly positioned with respect to windows and overhead lighting so that glare sources are not directly in front of the operators, nor reflected in the VDT screen.

3. Screen hoods may be installed to completely or partially shield the screen from reflections.

4. Anti-glare filters may be installed on the VDT screen.

5. Direct lighting fixtures may need to be recessed; and baffles may be used to cover light fixtures to prevent the luminaires from acting as a glare source, or special covers on light fixtures may be used to direct the light downward rather than allowing the light to diffuse.

6. Properly installed indirect lighting systems will limit the luminaires' potential as glare sources, although some reflected glare may still be present.

Attempts at positioning the VDT to reduce glare problems from overhead lights may have only limited success in large offices because of the sheer number of such lights. However, it can be used effectively to reduce glare from windows. Hoods are often not completely effective in reducing reflected glare, particularly when a large number of high luminance surfaces are located behind the operator. The characteristics and effectiveness of different types of glare filters vary widely, and some screen filters have detrimental effects on image quality or contrast and caution should be used in their selection. In many cases a combination of the above approaches is needed to eliminate reflected glare and these should be chosen based on the particular nature of the glare sources in the work environment.

In summary, the available literature supports the recommendation that drapes, shades or blinds be used to reduce reflections from windows, and that illumination levels be kept in the 500 to 700 lux range wherever possible to limit the reflected glare from work surfaces. Additional treatment for the reduction of reflected glare may still be necessary, however, in which case the approaches discussed above should be considered.

Workstation Design

Four factors related to workstation design were examined. These were keyboard height, viewing distance, viewing angle, and chair features. (The method of measuring the first three factors was shown in Figure 1).

Excessive keyboard height can lead to musculoskeletal fatigue due to the static loading imposed on the operator by the need to keep hands in an elevated position. One European recommendation for the height of the home row keys in a fixed height workstation is 720-750 mm (28 1/4 - 29 1/2 in.)(Cakir et al., 1979). The U.S. Military Standard 1472B (1974) specifies a working surface height of 740-790 mm (29 1/4 - 31 in.), which is approximately the customary keyboard height range for typing in most offices in this country. Rebiffe (1969) has recommended that the angle between the upper and lower arms be between 80° and 120° and that the angle of the wrist be no greater than ±10°. This would require that the keyboard be at approximately at or below elbow height, which varies from 605 mm for 5th percentile females to 820 mm for 95th percentile males (Van Cott and Kincaid, 1963). In any event, sufficient clearance must be allowed for the operator's legs (645 mm for 95th percentile males) (Van Cott and Kincaid, 1963). Thus either a fairly wide range of adjustability or some compromises between leg clearance and keyboard height are necessary.

Three types of workstations were observed at this site: (1) specifically designed workstations which had an inset area for placement of the keyboard and home row heights between 760 and 775 mm; (2) units in which the VDT screen and keyboard sat on a standard desk, with home row heights of 820-830 mm; and (3) telephone units in which the VDT screen and keyboard sat on a revolving platform somewhat above desktop height and between two desks. The last arrangement raised the keyboard height to between 840 and 870 mm (see Table 34).

Incorrect viewing distance and angle can impose the necessity for awkward postures when viewing the display. Proper viewing distance is also important in minimizing visual system fatigue. In addition, viewing distance should not be so great that the characters subtend less than the minimum arc required for reading. A viewing distance of 450-500 mm (17 3/4 - 19 3/4 in.) with a maximum of 700 mm (27 1/2 in.) has been recommended by Cakir et al. (1979). A variety of recommendations exist regarding screen viewing angle (Cakir et al., 1979; Dreyfus, 1967; International Business Machine Corp., 1979). Generally these recommendations place the center of the VDT screen at a position between 10° and 20° below the horizontal plane at the operator's eye height. Cakir et al. (1979) make the additional recommendation that the top of the screen be below eye height, while Grandjean (1980) recommends that the top line of the display be 10-15° below the horizontal, with no portion of the screen at an angle of greater than 40° below the horizontal.

Table 34. Keyboard height (floor to home row)

Keyboard height (mm)	Number of workstations
0 - 720	0
721 - 750	0
751 - 790	6
over 790	14

The estimated viewing distance and viewing angles for male and female operators of median dimensions are summarized in Table 35. Many of the viewing angles were higher than recommended, especially for male operators of greater than median dimensions. Viewing distances were all in the acceptable range (450 to 700 mm).

Table 35. Hypothetical viewing angle and distance at workstations for median males and females

Sex	Viewing angle (degrees)	Number	Viewing distance (mm)	Number
Males	0 - 9	0	0 - 449	0
	10 - 20	5	450 - 500	0
	21 - 30	15	501 - 700	20
	over 30	0	over 700	0
Females	0 - 9	0	0 - 449	0
	10 - 20	17	450 - 500	0
	21 - 30	3	501 - 700	20
	over 30	0	over 700	0

Desk top workstations should be modified so that the keyboard and screen heights are appropriate for the operator. Telephone inquiry workstations should be modified so that the screen and keyboard are closer to the operator and the keyboard is at an appropriate height. We recommend that, where possible, replacement furniture be designed to allow both keyboard and screen to be within the preferred ranges and adjustable for the preference of each operator. Home row height should be between 720 and 790 mm, preferably adjustable. Workstations should allow sufficient leg clearance for all operators. Consistent with the need for firmly planted feet, footrests should be provided for any operators needing them.

Screen height and position should be adjusted to suit the individual operator. Screen center should normally be 10-20° below the horizontal plane through the operator's eyes, with the top line of the screen below eye level. The viewing distance should normally be between 450-500 mm, and adjustable by the operator without adoption of unusual postures. Viewing distances greater or less than 450-500 mm are acceptable if necessary to accommodate individual operator comfort. It should be noted that these workstation dimensions may pose special visual problems for operators wearing bifocals or those wearing reading glasses ground for reading at 330 mm; special provisions may be required for these operators.

Most workstations observed were equipped with copy holders which were positioned by the operator. The preferred position for the copy holders is near the VDT screen in order to minimize both repeated changes in accommodation and visual search. It is best to allow the operator some flexibility in positioning a copy holder, however, so that it can be placed in the position which the operator finds most comfortable.

Operator chairs should be adjustable in height and have backrests. Backrests should be adjustable to the lumbar region (mid-back) to provide adequate support. If a full backrest is provided, only the lumbar region of the back should contact the backrest during normal sitting (Kroemer and Robinette, 1969) as freedom of motion of the arms and shoulders is required for typing. There were a few cases in which operators were seated on straight-backed chairs without any adjustment for height. Except for these cases, the chairs provided were typical of the secretarial/clerical chairs generally found in offices.

The available literature supports the recommendation that operators should have chairs with adjustable seat height, and an adjustable backrest to provide support to the lower back. It has been recommended by Hunting, Laeubli and Grandjean (1980) that workstations should have a place for operators to rest their wrists and forearms while keying. This could be accomplished by providing chairs with armrests. However, if armrests are supplied, they should be supplied only to those operators desiring them and/or be removable. Moreover, they should be designed so as not to interfere with keyboard operation and to allow the operator to position the chair properly in relation to the keyboard. Another alternative is to arrange for a ledge at the bottom of the keyboard on which the operator can place his/her wrists.

Preferred operator posture is for the operator to be seated erect, with the thoracic region of the spine convex, the lumbar region concave, the thighs horizontal and the feet flat on the floor or footrest (Cakir et al., 1979).

Weight transfer to the seat should be primarily through the buttocks, not through the thighs. The angle between the upper arm and forearm should be 80-120°. The operator should have sufficient freedom of movement to adjust his/her posture to relieve fatigue.

Additional Comments Regarding Site 3

Little is known about the special demands imposed by the workstations utilizing both VDTs and microfilm units. It is hypothesized by some researchers that the repeated light/dark adaptation required by this set-up would lead to undue visual fatigue; however, the microfilm units could independently lead to visual fatigue since they had small character images which were often of poor quality. In addition, the large number of equipment items at these stations prevented positioning the VDT and other equipment optimally for correct operator posture. We recommend that the equipment at these workstations be carefully positioned for operator comfort and that efforts be made to improve the microfilm image quality. In addition, the effects on the visual system of varying gaze from the relatively bright microfilm unit to the darker VDT unit should be evaluated.

GENERAL RECOMMENDATIONS

Radiation Testing

Based on the radiation survey data from this investigation at the three sites and previous NIOSH investigations, it can be concluded that the VDT does not present a radiation hazard to the employees working at or near a terminal.

There is considerable technical difficulty in performing radiation surveys of VDTs since such surveys require considerable technical knowledge and skill in conducting the survey and interpreting the results. Considering this and the low radiation levels emitted by the VDTs examined to date, routine surveys of video display terminals are not warranted.

Workstation Design Features

It should be noted that the approaches to one aspect of the design may impact other aspects as well; thus careful consideration of the task demands and the total workstation is essential. As a matter of preference, it is recommended that the maximum possible flexibility be designed into the workstation so that it can be adapted to the individual operator. Specifically, it would be desirable for the chair to have adjustable seat pan height, backrest height and tension. Similarly, the keyboard height, and screen height and position should be independently adjustable. The operator should also be able to adjust screen brightness and contrast.

Bearing in mind that designing for adjustability of critical workstation parameters is the preferable method for assuring operator comfort, there are basic recommendations which can be used as guides to proper workstation design. These recommendations are generally levels or ranges which are acceptable for most operators; but, values outside these ranges may be necessary based on the needs of individual operators.

Consistent with evidence in the literature, one recommendation is that the workstation be designed so that viewing distance can be maintained between 450 and 500 mm with exceptions based on individual operator needs. Alternatively, Whycer (1978) suggests the location of the viewing distance be individualized such that 2/3 or less of the operator's range of accommodation be used. Further, it is recommended that viewing angle be in the range of 10-20°, with the top edge of the screen no higher than operator eye level and the bottom edge of screen no lower than 40° below eye level. Keyboard height should be between 740 and 790 mm (at home row). Where possible, provisions should be made for detachable keyboards and furniture which allows adjustment of various dimensions for individual operators.

Operator chairs should have adjustable heights and backrests. Backrest should adjust to the lumbar region (mid-back) to provide adequate support.

Illumination

The available literature suggests that lighting levels be set up at approximately 500-700 lux depending upon the visual demands of other tasks performed in the same work area.

Glare Control

Direct and reflected glare should be limited through one or more of the following methods:

1. Drapes, shades, and/or blinds over windows should be closed, especially during direct sunlight conditions.

2. The terminals should be properly positioned with respect to windows and overhead lighting.

3. Screen hoods may be installed.

4. Anti-glare filters may be installed on the VDT screen.

5. Direct lighting fixtures may need to be recessed; and baffles may be used to cover fluorescent fixtures to prevent the luminaires from acting as a glare source, or special covers on light fixtures may be used to direct the light downward rather than allowing the light to diffuse.

6. Properly installed indirect lighting systems will limit the luminaires' potential as glare sources, although some reflected glare may still be present.

Work-Rest Regimens

There are a number of factors to be considered when determining an appropriate work-rest regimen for VDT operators. These would include fatigue, visual effects and psychological impact. Fatigue of the major postural musculature as well as the manipulative muscles has been demonstrated in VDT operators. Hunting et al. (1980) showed that data-entry VDT operators reported significantly more muscular complaints than interactive VDT operators or secretarial/clerical workers using standard electric typewriters. This effect could have been due to the increased postural and keying demands of these VDT operators or visual requirements that induced improper posture. Smith et al. (1980) also found that VDT operators reported more muscular complaints than nonoperators. However, the nonoperators were not performing the same level of keying tasks as the VDT operators and therefore it is not certain if the effect was due to the keying requirements of the task or VDT characteristics.

There are two areas of interest regarding the vision of VDT operators and work-rest health determinations. The first concerns the visual system in terms of the muscles used in accommodation and convergence. Hollar et al. (1975), Haider et al. (1980) and Gunnarsson and Soderberg (1980) have demonstrated changes in visual function, presumably related to video display terminal viewing. These changes were all of a minor nature and transient but illustrate the potential for chronic effects given long term VDT use. The second concerns other visual symptoms observed in VDT operators that have been generally referred to as visual fatigue and/or eyestrain. These have included heavy eyes, burning eyes, itching eyes, tearing eyes, eyestrain, or eye soreness. These effects have been reported by large numbers of VDT operators (Hultgren & Knave, 1973 - 47 percent; Gunnarsson and Ostberg, 1977 - 76 percent; Cakir et al., 1978 - 68 percent to 85 percent; Laubli et al., 1980 - 65 percent; Dainoff et al., 1980 - 45 percent; Gunnarsson and Soderberg, 1980 - 62 percent; and Smith et al., 1980 - 67 percent to 93 percent). While these symptoms are difficult to relate to specific visual processes, they demonstrate that the visual system is under stress which is reflected by reports of visual strain. These symptoms refer mainly to acute conditions whose relationship to chronic visual problems is not clear and has to be established by further research. Yet the high percentage of operators reporting such acute visual complaints is evidence of a potential problem; and given the repeated use of the VDT over many years may produce a cumulative trauma. Therefore remedial action to reduce these acute complaints is in order.

Finally, high levels of psychological distress have been reported by VDT operators (Smith et al., 1980; Gunnarsson and Ostberg, 1977; and Cakir et al., 1978). In particular, jobs that require heavy work loads and time pressures seem to be most prone to psychological distress such as anxiety, depression, irritability, monotony, fatigue and lack of inner security.

Based on our concerns about potential chronic effects on the visual system and musculature and prolonged psychological distress, we recommend the following work-rest breaks for VDT operators:

1. A 15-minute work-rest break should be taken after two hours of continuous VDT work for operators under moderate visual demands and/or moderate work load.

2. A 15-minute work-rest break should be taken after one hour of continuous VDT work for operators under high visual demands, high workload and/or those engaged in repetitive work tasks.

The work-rest break schedule that has been recommended in this report is designed to minimize the visual and muscular problems of VDT operators. Haider et al. (1980) and Holler et al. (1975) found that a break of 15 minutes after two hours of VDT work was sufficient for recovery from temporary myopia for most individuals studied. However, the data from the current investigation suggest that a 15-minute break after two hours of VDT work may not be adequate for other problems such as asthenopia or for muscular problems. Therefore, for highly demanding VDT tasks a 15-minute break after one hour is suggested. While there is no research evidence that this work/rest schedule will be sufficient to deal with all of the reported problems, it is felt that this schedule should be tried before more disruptive schedules (such as the job rotation suggested by Holler et al., 1975) are implemented.

Visual Testing

The American Optometric Association (AOA)(1980) has conducted a review of rules promulgated by the States regarding standards for minimum optometric testing. They indicate that the following procedures are among those usually mandated as minimum optometric testing:

1. Complete case history (ocular, physical, occupational and other pertinent information).

2. Naked visual acuity/or visual acuity of each eye uncorrected and with best correction.

3. Detailed report of external findings (lids, cornea, sclera, etc.)

4. Ophthalmoscopic examination (media, fundus, blood vessels, disc).

5. Corneal curvature measurement (dioptric)/keratometer (ophthalmometer) readings.

6. Static retinoscopy/objective refraction of each eye.

7. Amplitude of convergence and accommodation.

8. Phoria and duction findings; horizontal and vertical, distance and near.

9. Subjective findings/subjective refraction of each eye for distance and near vision with phoropter or adequate trail case and trail frame.

10. Fusion and stereopsis.

11. Color vision.

12. Visual fields and/or tonometry.

In terms of pre-placement visual testing, Hirschfelder (1980) of the National Society for the Prevention of Blindness states:

"Although the majority of industrial jobs require more extensive test of eyesight, especially where machining, measuring, and assembling to very close tolerances are concerned, the following primary visual skills, at the very least, should be checked:

"Central visual acuity (sharpness of vision) at distance (ability to see test targets well at 20 feet).

"Central visual acuity (sharpness of vision) at near point (ability to see test targets well at 13 to 16 inches).

"Muscle balance and eye coordination (ability to keep eyes in balance, to prevent one eye from deviating vertically or horizontally; ability of eyes to relay images from various distances which brain can fuse without difficulty).

"Depth perception (ability of eyes to judge relationships of objects in space).

"Color discrimination (ability of eyes to judge colors correctly).

"Note: Employees or job candidates who wear corrective lenses, including those of the contact type, should be tested both with and without them."

Hirschfelder (1980) goes on to say "In all cases, however, the key purpose of testing is to measure individual visual skills in relation to individual seeing demands of specific jobs."

Based on evidence of acute vision problems in VDT operators (Haider et al., 1975, 1980; Gunnarsson et al., 1977, 1980; Laubli et al., 1980; Dainoff et al., 1980; and Smith et al., 1980), we feel that there is a need for mandatory vision testing for VDT operators. In addition, the high visual demands of VDT work tasks define a requirement for properly corrected vision for adequate performance and reduced visual strain. The suggested vision testing programs of the National Society for the Prevention of Blindness (Hirschfelder, 1980) and those reviewed by the AOA are a logical basis for vision testing requirements for VDT operators. The proposed visual testing program is primarily for the purpose of ensuring that operators have the appropriate corrected vision for performing their VDT work tasks. In some cases the job tasks will require a different correction factor than is needed for daily living activities such as reading the newspaper or driving a car. Determinations of the proper corrected vision have to be made with the viewing requirements of the job tasks in mind.

It is recommended that given the mounting anecdotal evidence of ophthalmologic complaints associated with VDT use and the paucity of research pertaining to the incidence, etiology, or pathophysiology of these events, that at the very least VDT workers should have a comprehensive pre-placement vision examination. Either the AOA or Hirschfelder's recommendations could serve as a basis for the exam. We also recommend that those individuals who become symptomatic even after the initial exam should receive appropriate medical care and that a general exam should be repeated periodically. The periodicity of these repeat exams should depend on the natural history of VDT ophthalmic pathology (information that is not yet available). Current NIOSH and other investigative research should clarify this issue.

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