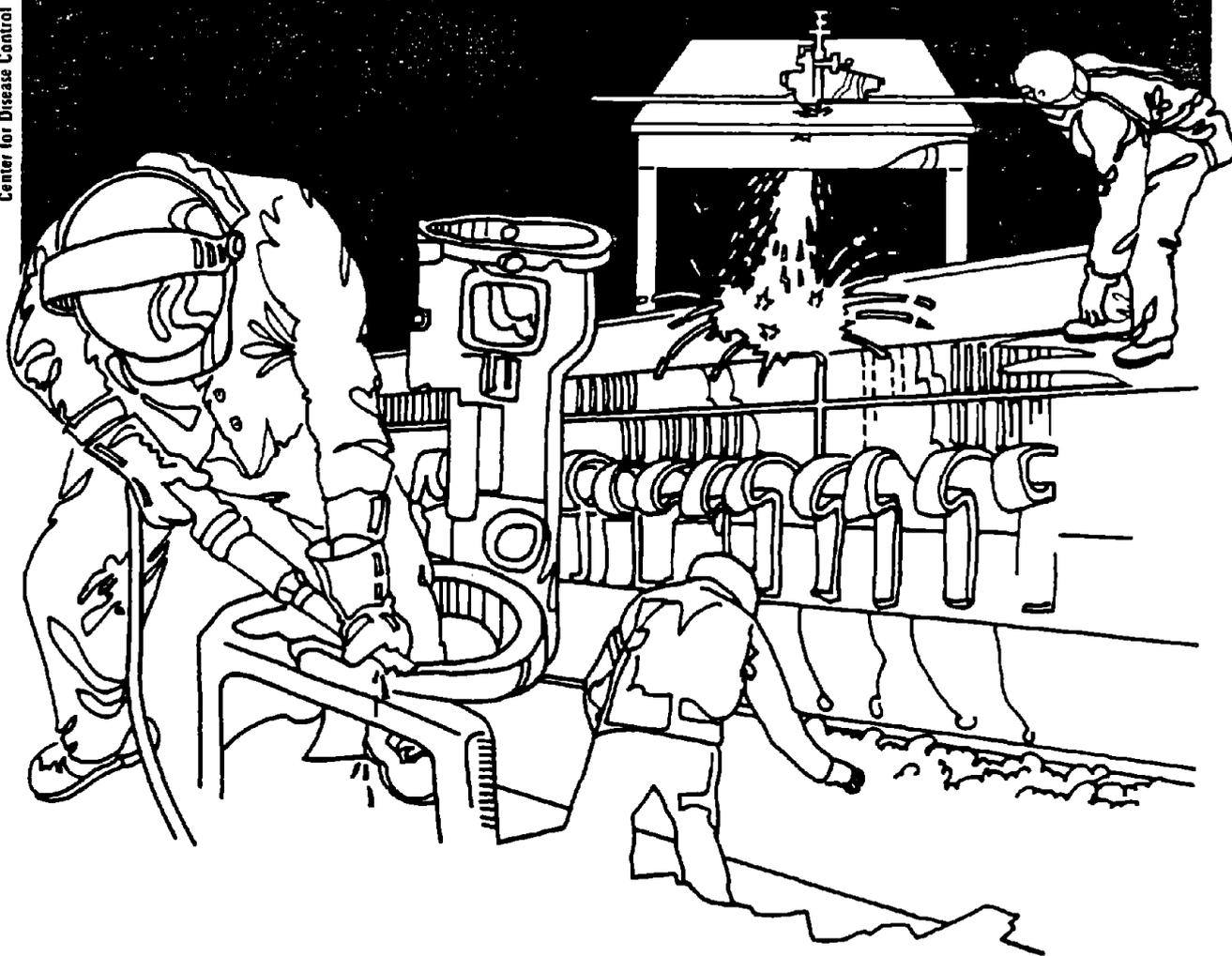


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U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES • Public Health Service  
Center for Disease Control • National Institute for Occupational Safety and Health

# NIOSH



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SAN FRANCISCO, CALIFORNIA

## Technical Assistance Report

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16. Abstract (Limit 200 words)

An industrial hygiene survey was conducted at the Oakland Tribune (SIC-2711), Oakland, California, in November 1979 and January 1980. The evaluation was requested by representatives of newspaper union locals out of concern for potential health hazards associated with the use of video display terminals (VDT). Measurements were made of X-irradiation, radiofrequency, ultraviolet, and visible radiation at the terminals. Air samples were analyzed for carbon-monoxide (630080), formaldehyde (50000), hydrocarbons, and acetic-acid (64197). Self administered medical questionnaires were given to 103 VDT operators and 93 comparisons. An ergonomic evaluation of the VDT work stations was conducted. All radiation levels and chemical concentrations were below relevant federal standards. Only 49 VDT operators and 21 comparisons returned the questionnaires. VDT operators reported a higher percentage of gastrointestinal and emotional health complaints than comparisons. The ergonomic evaluation showed that illumination of the VDT work stations was generally acceptable, although glare was occasionally a problem. Other problems included excessive keyboard and VDT screen height. The authors conclude that the significance of the differences in health complaints between the VDT operators and comparisons cannot be assessed due to the small number of questionnaire responses.

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POTENTIAL HEALTH HAZARDS OF VIDEO DISPLAY TERMINALS  
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## ABSTRACT

In July 1979 NIOSH received a request from the San Francisco-Oakland Newspaper Guild (Local # 52) and the Bay Area Typographical Union (Local # 21) to evaluate potential health hazards from the use of video display terminals (VDTs) in information processing applications at the Oakland Tribune. 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.

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 4) psychological mood state, 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 non-operators 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, and acetic acid were all well below current occupational exposure limits.

The questionnaire survey indicated that a higher percentage of VDT operators reported gastrointestinal and emotional health complaints than non-operators. However, these findings may have been due to differences in the demographic makeup of the two groups. The effect of these differences on health complaints could not be determined due to the small number of survey respondents.

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.

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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 requesting locals included the San Francisco-Oakland Newspaper Guild Local No. 52, the Office and Professional Employees Union Local No. 3, and the Bay Area Typographical Union Local No. 21. The companies that agreed to participate in this investigation were the Oakland Tribune, the San Francisco Newspaper Agency (including the San Francisco Chronicle and Examiner) and Blue Shield of California. All of the companies are located in the San Francisco Bay area. This report concerns only the investigation at the Oakland Tribune; separate reports have been prepared for the other companies.

A NIOSH team conducted a walk-through survey at each location in November 1979. The team met with management and labor representatives, toured each facility, described the 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 investigation 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 PTL71C (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  $5 \times 10^{-8} W/cm^2$  and the accuracy is about  $\pm 20$  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  $\pm 10$  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  $\pm 10$  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  $\pm 3.0$  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 milliroentgens per hour (mR/hr) which is the BRH emission standard for television receivers. A Victoreen Model 440 RF/C was available to measure x-ray emissions accurately in case any had been detected with the Stoms meter. The 440 RF/C is specifically designed to measure x-ray emissions from TV receivers and is shielded against electromagnetic 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 non-specific 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 and formaldehyde 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 are 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 Oakland Tribune to survey all available VDT operators and all available comparison non-operators. 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 non-operators 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 returned in a postage-paid envelope which was provided with all questionnaires. A total of 103 VDT operators and 93 non-operators 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 non-operators 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 non-operators was considered a potential health problem. For comparisons between operators and non-operators 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 non-operators 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 ( $\text{cd/m}^2$ ) 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 because such measurements were considered impractical for this survey. Measurements were taken between 10:00 a.m. and 7:30 p.m. on an overcast day; thus none of the workstations adjacent to with 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

### Radiation

At the Oakland Tribune, about 25 percent (18 of 71) of the VDTs in use 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  $\mu\text{W}/\text{cm}^2$  ( $1 \mu\text{W}/\text{cm}^2 = 10^{-6} \text{ W}/\text{cm}^2$ ) in the near UV region. The visible radiation levels ranged from 3 to 40 fL. High readings were obtained when the electric ( $2 \times 10^6 \text{ V}^2/\text{m}^2$ ) and magnetic ( $0.5 \text{ A}^2/\text{m}^2$ ) 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 the Oakland Tribune 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

Table 1. Range of electromagnetic radiation measurements

| Manufacturer | Model number | Number units measured | X-ray radiation (mR/hr) | Ultraviolet radiation ( $\mu\text{W}/\text{cm}^2$ ) | Visible radiation (fL)* | Radio-frequency radiation Electric field ( $\text{V}^2/\text{m}^2$ ) | Magnetic field ( $\text{A}^2/\text{m}^2$ ) |
|--------------|--------------|-----------------------|-------------------------|---|-------------------------|--|--|
| 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 $\mu\text{W}/\text{cm}^2$ | 1000 $\mu\text{W}/\text{cm}^2$    | NIOSH, 1972  |
| Visible            | 40 fL                          | 2920 fL                           | ACGIH, 1979  |
| Radiofrequency     |                                |                                   |              |
| Electric field     | ND                             | 40,000 $\text{V}^2/\text{m}^2$ ** | USDOL, 1980b |
| Magnetic field     | ND                             | 0.25 $\text{A}^2/\text{m}^2$ **   | USDOL, 1980b |

\* ND = Not detectable

\*\*Far field equivalent of 10  $\text{mW}/\text{cm}^2$

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).

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  $4.9 \times 10^{-5} A^2/m^2$  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 the San Francisco Chronicle. 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 Composing, 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 non-specific, measurements were also taken in the hotel and in a conference room at the newspaper 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.

Table 3. Chemical exposure data

| Location/<br>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<br>Desk)/29       | "                      | 3.6        | 1209 |
| City Room (City<br>Rewrite)/27         | "                      | 3.4        | 1210 |
| City Room (Versatec<br>Paper Level)/45 | "                      | 30.0       | 1215 |
| City Room (Versatec<br>in Op)/45+      | "                      | 11.0       | 1217 |
| City Room (UII Paper<br>Level)/2       | "                      | 10.5       | 2220 |
| City Room (UII in Op)/2+               | "                      | 3.6        | 1222 |
| City Room (City Rewrite)/15            | "                      | 3.2        | 1225 |
| Features (Versatec<br>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 non-specific 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

## Health Complaints and Psychological Status

Nature of Respondents: Questionnaires were received from 49 VDT operators and 21 non-operators for a response rate of 48 percent for the operators and 23 percent for the non-operators. 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 non-operators 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 non-operators 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 non-operators (3 males and 13 females). In terms of ethnic background of the VDT operators and non-operators, Whites made-up the majority of respondents in each group (88 percent and 58 percent respectively); however, the non-operators (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 non-operators was the same (VDT = 44 years, NVDT = 44 years), but the educational level was higher for the VDT operators than for the non-operators (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 non-operators 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 non-operators 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 of 14 examined had at least fifty percent of the non-operators reporting an occurrence; for the psychological complaints, 6 of 10 had at least fifty percent of the operators and non-operators reporting an occurrence; for the gastrointestinal complaints, 3 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 of 15 had least fifty percent of the operators and non-operators reporting an occurrence.

Table 4 lists the percentages of VDT operators and non-operators reporting a specific health complaint. The health complaints reported by a significantly higher percentage of VDT operators than non-operators 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 eyestrain or sore eyes. The non-operators 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 non-operators.

Disease States: Table 5 shows the percentage of operators and non-operators reporting a specific disease state. As can be seen, only one disease state,

Table 4. Percentage of VDT operators versus non-operators 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<br>Operators | Non-<br>Operators |
|---|------------------|-------------------|
| aa. Increased urination.....  | 39               | 25                |
| bb. Painful urination.....  | 10               | 0                 |
| cc. Bloody urine.....   | 2                | 0                 |
| dd. Alarming pain or pressure<br>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<br>or exhaustion.....                     | 52               | 50                |
| ii. Acid indigestion, heartburn,<br>or acid stomach.....              | 57               | 25                |
| jj. Diarrhea for more than<br>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. Bloating or full feeling.....                                     | 54               | 37                |
| qq. Feeling of pressure in<br>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<br>when standing for long periods.. | 45               | 38                |
| aaa. Shoulder soreness.....   | 43               | 38                |
| bbb. Loss of feeling in the fingers<br>or wrists.....                 | 17               | 0                 |
| ccc. Neck pain that radiates into<br>shoulder, arm or hand.....       | 19               | 6                 |
| ddd. Cramps in hands and fingers<br>relieved only when not working..  | 17               | 13                |
| eee. Loss of strength in arms or<br>hands.....                        | 10               | 6                 |
| fff. Eyestrain or sore eyes.....                                      | 67               | 38                |
| ggg. Stiff or sore wrists.....  | 7                | 0                 |

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

| Disease States                   | VDT Operators | Non-Operators |
|----------------------------------|---------------|---------------|
| 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             |

arthritis or rheumatism, showed a significant difference between operators and non-operators, with non-operators reporting a higher level.

Mood State: Table 6 lists the mean values for the six dimensions of mood state reported by VDT operators and non-operators 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 underway 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 respondents, 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 non-operators 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

Table 6. Mean scale for psychological mood states'

| POMS Measures | Scale Means |         |
|---------------|-------------|---------|
|               | VDT         | Control |
| 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     |

gastrointestinal problems, more so than the non-operators. 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.

### 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 at the Oakland Tribune 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.

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

Table 7. Illumination levels at workstations

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

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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. At the Oakland Tribune, 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 at the Oakland Tribune 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 at the Oakland Tribune were between 1:2 and 1:60 (see Table 8).

Table 8. Work area maximum luminance ratio

| Ratio           | Number of workstations |
|-----------------|------------------------|
| 0.0:1 - 10.0:1  | 0                      |
| 10.1:1 - 20.0:1 | 5                      |
| 20.1:1 - 30.0:1 | 1                      |
| Over 30.0:1     | 1                      |

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 at the Oakland Tribune. 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<sup>2</sup>. 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.

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.

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\*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 from glare sources are visible

| Glare level<br>(cd/m <sup>2</sup> ) | Number of<br>workstations |
|-------------------------------------|---------------------------|
| 0 - 750                             | 2                         |
| 751 - 1500                          | 3                         |
| 1501 - 2250                         | 1                         |
| Over 2250                           | 0                         |

## 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 as well as 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 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<sup>2</sup>) (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 the Oakland Tribune, 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<sup>2</sup>. 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, 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.

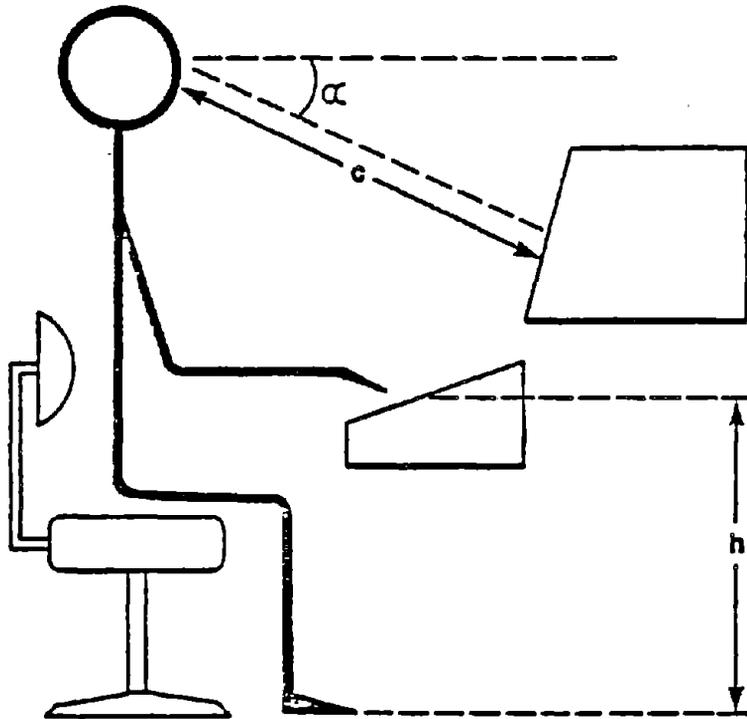
Attempts at positioning the VDT to reduce glare problems from overhead lights may have only limited success in most large offices because of the sheer number of such lights. However, it can be used effectively to reduce glare from windows. Hoods are often not completely effective in reducing reflected 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, 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 are diagrammed 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  $80^{\circ}$  and  $120^{\circ}$  and that the angle of the wrist be no greater than  $+10^{\circ}$ . 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



$\alpha$  -- viewing angle, from horizontal

$c$  -- viewing distance

$h$  -- height of keyboard home row

Figure 1. Critical workstation dimensions

adjustability or some compromises between leg clearance and keyboard height are necessary.

Three basic types of workstations were observed at the Oakland Tribune: (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.

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 at the Oakland Tribune are summarized in Table 10. 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 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.

Table 10. Keyboard height (floor to home row)

| Keyboard height<br>(mm) | Number of<br>workstations |
|-------------------------|---------------------------|
| 0 - 720                 | 0                         |
| 721 - 750               | 0                         |
| 751 - 790               | 5                         |
| Over 790                | 2                         |

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

| Sex     | Viewing Angle (degrées) | 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                      |

Most workstations observed at the Oakland Tribune 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 copy holders, 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. At the Oakland Tribune 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 removeable. 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 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.

## GENERAL RECOMMENDATIONS

### Radiation Testing

Based on the radiation survey data from this investigation at the Oakland Tribune 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, Whyser (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 of 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 non-operators. However, the non-operators 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; 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; 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 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 fifteen 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 trial case and trial 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; 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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