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# SELECT RESEARCH REPORTS ON HEALTH ISSUES IN VIDEO DISPLAY TERMINAL OPERATIONS

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Public Health Service
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Prefatory Note

This document is a collection of three reports dealing with an evaluation of select health issues associated with video display terminal (VDT) operations at three facilities in San Francisco. These three reports are pre-publications of articles slated to appear in the August 1981 issue of the Human Factors journal.

The current interest in this subject matter has dictated an accelerated need to provide the information contained in these reports. This document is for purposes of meeting this need.

The final VDT report will not be available until fall 1981. To receive a copy, please provide a self-addressed mailing label to:

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# AN INVESTIGATION OF HEALTH COMPLAINTS AND JOB STRESS IN VIDEO DISPLAY OPERATIONS

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## ABSTRACT

This paper describes one aspect of a field investigation into a potential health risk posed by video display terminal (VDT) work. In this part of the investigation, a questionnaire survey dealing with working conditions, job stress factors, health complaints and psychological mood state was filled-out by approximately 250 VDT operators and 150 non-operator control subjects at 5 participating work sites. The results of the survey indicated that clerical VDT operators reported higher levels of job stress and health complaints, but little difference in psychological mood state than both professionals who used VDT's and the control subjects. The job stressors showing the greatest impact on the clerical operators dealt with workload, workpace, lack of control over job activities, boredom and concerns about career development. The health complaints that showed the greatest differences between the groups dealt with visual, musculoskeletal and emotional health problems. The results indicate that job content factors and VDT use contribute to the problems observed in the VDT operators in an interactive way.

## INTRODUCTION

This paper describes one aspect of a field investigation of video display terminal (VDT) operations which was conducted by the National Institute for Occupational Safety and Health (NIOSH). This effort was undertaken by NIOSH at the request of a consortium of unions which sought an evaluation of the impact of video display work on employee health. The paper will deal with one phase of this investigation, namely, an examination of worker stress and health complaints as reported by respondents to a questionnaire survey.

Most of the research dealing with the health impact of VDT's has been conducted in Europe. A review of the various studies and evaluations of VDTs indicates much interest in ergonomic factors, particularly those that might contribute to visual problems of operators. This is likely due to the high frequency of VDT operator visual complaints which are generally reported (Grandjean, 1979). Lesser attention has been directed at psychological job stress in these operations, and how such stress relates to worker health complaints. In one study, Gunnarsson and Ostberg (1977) queried VDT operators about stressful elements of their jobs. In a department where operators had little control over their job tasks, 72 percent complained of monotony, while in a department where the job afforded some variety and control, only 10 percent felt the work was monotonous. In terms of work-pace, about 1/3 of all the operators felt that the pace was too fast, while 1/3 felt that the pace was too slow. When asked if their job was stressful, 64 percent said yes. In the group with little control of job task, 72 percent indicated that they would prefer a different job assignment. The results of this study are difficult to interpret since there wasn't an adequate control group, and therefore it is not possible to determine whether it was VDT use per se or other factors which were responsible for the operator complaints.

Grandjean (1979) cited a study by Cakir, Reuter, von Schmude and Armbruster (1978) which found that feelings of stress as expressed by a group of VDT operators did not differ in magnitude from other worker groups previously examined in other studies. However, VDT users displayed some loss in motivation and gave lower estimates of performance level.

In 1979, Cakir, Hart, and Stewart reported a series of studies aimed at defining the psychological and physical consequences of VDT work situations. In one study, VDT operators under a piece-rate pay system were compared to a group of hourly-paid operators. The results indicated differences between the groups in sociability, frame-of-mind, state of stress, fatigue, and inner security; with the piece-rate operators scoring poorer in all categories. Both groups showed significantly higher levels of stress and sleepiness and lower levels of well-being, positive frame-of-mind, self-confidence, social awareness, socialibility, and willingness to undertake further activity after work than before.

A second study in this series, involving more than 1,000 VDT operators, examined the relationship between self-reported monotony and fatigue. The results indicated that 20 to 30 percent of typists engaged in data input work with VDT's and 10 percent of other categories of clerical workers complained of monotony. On the other hand, for VDT operators who previously did clerical work, 60 percent complained of monotony even though their present jobs were similar to their previous clerical jobs in task requirements. The study showed that the jobs reporting the highest levels of monotony also reported the highest levels of fatigue.

Over the past few years, complaints about video display terminals have been steadily increasing in the United States. Early efforts of NIOSH in this area dealt with evaluating the possible health risks of VDTs regarding ionizing and non-ionizing radiation emissions. Some attention was also given to human factor concerns, but it remained for the current investigation to offer the first comprehensive evaluation of the problem in the United States. Specifically, this effort included: (1) radiation measurements on a sample of VDTs, (2) an ergonomic analysis emphasizing illumination/glare problems, work station design, and operator postural requirements, (3) an evaluation of job stress and strain reported by operators, and (4) a compilation of health complaints reported by operators. This paper will deal with the findings on job stress and strain and health complaints.

## METHODS

A specially prepared questionnaire was used to gather information about job demands, job stressors, job stress level, psychological mood, health complaints and working conditions for VDT operators and control groups at each of the five workplaces included in this investigation. Various measures of job demands and job stress were contained in the questionnaire. These included scales developed to compare stress in various jobs (Caplan et al, 1975), standardized job stress scales (Insel and Moos, 1974), and selected questions on sources of job stress developed specifically for this investigation. The frequency of health complaints experienced in the last one year period was recorded for each of 59 separate health problems using a four point scale ranging from never to constantly. The presence of a diagnosed disease state within the previous five years for each of 23 diseases was also recorded by participants. Psychological mood state was evaluated using a standardized psychological test (Profile of Mood States, McNair, Lorr and Droppleman, 1971).

Included in the questionnaire form was a cover letter that explained the purpose of the investigation and gave instructions for filling out and returning the survey form. Table 1 lists the various subject areas that were examined by the questionnaire. (Insert Table 1)

Workplaces: The investigation was carried out at five workplaces, four newspapers or related operations and one insurance company. The VDT operators at these workplaces engaged in various jobs including data entry and retrieval, word processing, writing, editing and telephone sales. The control subjects at these workplaces were engaged in data entry and retrieval, word processing, and telephone sales, but did not use VDT equipment in carrying-out their work activities. For example, the control subjects doing word processing tasks were using standard electric typewriters, while those doing data retrieval tasks were using card index equipment.

Distribution and Collection of Questionnaires: Since the parties requesting the investigation served as the target group for study, traditional sampling strategies and distribution methods were not employed. Table 2 shows the number of questionnaires distributed, the number returned and the response rate.

Distribution and collection of the questionnaire forms was designed to minimize disruption of ongoing work activities and differed for each workplace. Generally, an announcement explaining the investigation was made to each department at a workplace by their supervisor on the morning of the investigation. Later, NIOSH researchers explained the investigation and distributed forms. Wherever possible, the NIOSH investigators met with the employees in small groups in which the purpose of the survey was explained, employee questions answered, and the questionnaire forms were distributed. At some sites there were no facilities for centrally gathering employees to explain and distribute the questionnaire forms. In these cases, forms were handed out to each employee individually with a short explanation. Each was referred to the instructions in the cover letter of the form. The forms were taken home and filled-out. The NIOSH investigators were on-site the next day to collect completed forms and answer questions. A postage-paid envelope was provided with all forms for those employees completing the questionnaire but not wishing to return them to work. (Insert Table 2)

Statistical Analyses: The data from the five workplaces were pooled to achieve an adequate sample size for statistical evaluation. The fact that all 5 worksites had similar video environments and were located in the same geographic (city) area offered further rationale for this combining procedure. Data from all survey respondents were used in the statistical analyses except where missing values precluded inclusion. The respondents to the questionnaire survey were put into three groups based on their work activities. These were: (1) professionals using VDT's, (2) clerical and office workers using VDT's and (3) non-VDT users who acted as control subjects. The professionals who used VDT's were mainly reporters, editors, copy editors and printers. These jobs afforded a great deal of self-control over work activities which provided variety and challenge. These operators were not tied to their VDT for any set time period and could set their own workpace within deadline limits. The clerical VDT operators were data entry clerks, data retrieval clerks, classified advertising clerks, circulation and distribution clerks and telephone inquiry clerks. These jobs were highly regimented with little operator control over work activity. The operators were tied to their workstations for fixed time periods except for formalized work/rest breaks and had little control over their workpace. The non-VDT users were in identical jobs to the clerical VDT operators except that they didn't use the VDT in performing their job tasks. Their working conditions were almost identical to the clerical VDT operators.

These three groups were compared over various measures of job stress, health complaints and psychological status. The job stress and psychological status measures were examined using Analysis of Variance (General Linear Model Procedures for Unequal Cells) (SAS, 1979) to compare the mean levels, while health complaints measures were examined by Chi-Square analysis to compare the percentages reporting a complaint. Duncan Range tests were used to determine the particular means that differed when a Analysis of Variance indicated a significant difference.

To evaluate the similarity of make-up of the VDT operator groups and control subjects, demographic variables such as age, sex, ethnic background, education level, and marital status were compared. The percentage of persons in various categories were evaluated using Chi Square analysis. When significant differences were observed for a particular demographic variable, a two way

Analysis of Variance was used, with the total number of health complaints serving as the dependent variable, to determine if there was an interaction such that the demographic variable influenced any of the groups differently than the others. If a positive interaction was found, further analysis of the data was undertaken to isolate the influence of the interacting variable.

## RESULTS

Demographics: Table 2 shows the number of respondents to the questionnaire survey and indicates that the VDT operators had a 50 percent response rate while the control subjects had a 38 percent response rate. Table 3 shows the distribution of respondents by age, sex, and ethnic status. Evaluations of the demographic variables for the professionals using VDT's, the clerical VDT operators and the control subjects indicated significant differences in the percentages of respondents in the various categories for age, sex, ethnic background, level of schooling, marital status, years with current employer, and years at current job. Two-way Analysis of Variance tests indicated that there were no significant interactions for any of these demographic features using total health complaints as the dependent variable and therefore it was assumed that they did not differentially affect the study groups.

(Insert Table 3)

General Sources of Stress: Table 4 shows the percentages of VDT operators and control subjects reporting the occurrence of eight sources of life stress and personal problems on a frequent basis. As can be seen, significantly more clerical VDT operators reported job stress and health problems than professionals using VDT's or control subjects, while both clerical VDT operators and professionals using VDT's reported career problems more often than control subjects. (Insert Table 4)

Job Stress: Table 5 shows the response means for VDT operators and control subjects for the ten dimensions of the Work Environment Scale (Insel and Moos, 1974). The VDT operators and control subjects reported mean values for nine of the ten dimensions that were divergent from established normative values in an elevated stress direction. The only dimension that did not show an elevated stress level above normative values was for supervisory control, however, this was true only for the professionals using VDTs. These observations concerning the higher than normative levels of stress for all three groups were not based on statistical tests but solely on examination of the mean values and judgements about their differences. (Insert Table 5)

Using Analysis of Variance methods and subsequent Duncan range tests for comparing the three groups, the clerical VDT operators reported significantly less peer cohesion and job autonomy with more work pressure and greater control by their supervisor than professionals using VDT's or control subjects. The clerical VDT operators also reported less involvement and staff support than the professionals using VDT's. The professionals who used VDT's reported greater autonomy and less control by their supervisor than the control subjects. For all of the significant stress factors there was a similar pattern of response in that the clerical VDT operators reported the highest levels of stress, followed by the control subjects, and then the professionals using VDTs who showed the lowest levels of stress.

Table 6 shows the response means for the VDT operators and control subjects for nine job demands dimensions developed by The Institute for Social Research (ISR) (Quinn & Shepard, 1974; Caplan et al, 1975). As can be seen, the clerical VDT operators reported higher workload, more boredom, greater workload dissatisfaction, greater job future ambiguity and lower self esteem than either the professionals using VDT's or the control subjects. The clerical VDT operators also reported more role ambiguity than the professionals using VDT's. The professionals using VDT's reported less boredom than the control subjects. The same general pattern of stress response observed for the Work Environment Scale was also seen for the ISR stress dimensions, with the clerical VDT operators showing the highest stress levels followed by the control subjects and the professional VDT operators. (Insert Table 6)

Table 7 shows the specific job factors (stressors) for which the clerical VDT operators reported more problems than both the professionals using VDT's and the control subjects. These job factors fall into four general categories including problems with workload, workpace, boring job tasks, and lack of career development. (Insert Table 7)

Psychological Mood Disturbances: Table 8 shows the mean value for each of the six scales of the Profile of Mood States (McNair & Droppleman, 1971) for the VDT operators and control subjects. Only the fatigue scale showed a significant difference between the three groups with the clerical VDT operators reporting more fatigue than either the professionals using VDT's or the control subjects. (Insert Table 8)

Health Complaints: Table 9a lists the health complaints for which there were significant differences between the clerical VDT operators and the control subjects. Twenty-six of the fifty-nine health complaints examined were significantly higher for the clerical VDT operators. These health complaints fell into three general areas of health problems: (1) visual, (2) musculoskeletal and (3) emotional. (Insert Table 9a)

Table 9b lists the health complaints for which there were significant differences between the professionals using VDT's and the control subjects. There were six health complaints showing a significant difference, with the professionals using VDT's reporting higher levels for three (burning eyes, eye strain and irritability) and the control subjects reporting higher levels for three (fainting, pain down arm and colds). Of special interest is the fact that there were more health complaints (thirty-three) for which there were significant differences between the clerical VDT operators and the professionals using VDT's than between the clerical VDT operators and the control subjects. In all cases the clerical VDT operators had more complaints than the professionals using VDT's, which were essentially visual, musculoskeletal or emotional in nature. (Insert Table 9b)

## DISCUSSION

This evaluation has limited generalizability since the study sites were known sources of union complaints of health problems rather than simply drawn through a random selection process. Moreover, participants were not selected randomly but were volunteers, and difficult labor negotiations were underway at the time of the data collection. Its purpose was to determine through the use of a questionnaire survey if there was a potential health risk from using VDTs at the workplaces investigated. The current investigation utilized a number of experimental controls such as comparison groups of workers in the same facilities, and ordered distribution and collection of questionnaires to ensure standardized procedure wherever possible to provide the "clearest" data for making determinations of health risk and increasing the overall usefulness of the data.

The results of the study indicate that all worker groups evaluated including the control subjects reported high levels of psychosocial job stress when compared to worker groups examined using similar measures in previous studies (Insel and Moos, 1974; Caplan et al, 1975). One explanation for this heightened stress level for both the VDT operators and control subjects is that it may have been due to organizational factors such as strained employee/management relations. While this factor was not measured in the survey, strained relations produced by difficult labor negotiations could have accounted for the increased stress. The control subjects in particular had work circumstances that could have increased their overall job stress level. At one site many of the control subjects were aware that they might lose their job by the end of the year due to a business slowdown, and that those who would be retained would become VDT operators. Also, at the other four sites, the control subjects knew they would be converting to VDTs within months. Such factors most likely contributed to an elevation in stress for the control subjects. This elevation may account for the lack of extensive differences in stress level and health complaints between the control subjects and the professionals using VDTs, however, other factors described later may also have contributed to this result.

The major finding of this investigation is that working with VDTs is associated with high levels of job stress and certain types of health complaints in a selective manner. Clerical VDT operators showed much higher levels of visual, musculoskeletal, and emotional health complaints, as well as higher job stress levels, than both control subjects and professionals using VDTs. However, there were very few differences between control subjects and professional VDT operators. One interpretation of this result is that the VDT use tended to have a greater effect on those aspects of the job that were stress producing such as the conditions that were inherent in the clerical job activities, with little effect on the less stressful job activities such as those in the professional work. This conclusion cannot be definitely made since the investigation did not contain a professional group not using VDTs that could be compared to the professional VDT operators. However, the results do suggest that there is a relationship between job activities and VDT use that bring about job stress and health complaints, and that the problem does not lie solely with VDT use.

Yet part of the impact on the clerical VDT operators most likely was a function of VDT use since the VDT imposes physical stressors that other office machines or hand work do not. These include the visual load of screen viewing and the additional postural requirements for viewing and keying. The higher level of visual and musculoskeletal complaints reported by the VDT operators, particularly the clerical operators, would tend to verify that the physical aspects of VDT use does adversely affect the operators. However, there was not a strong relationship between the amount of time spent working at the VDT and the resultant health complaints, since there was only a slight positive correlation (Pearson $r = .19$, $p$ $.01$) between the number of hours working on the VDT and the total number of health complaints. While this correlation is statistically significant, the overall relationship is not great. Therefore, it seems likely that there must be other factors beyond the physical presence of the VDT that contribute to the health complaints and stress level of the clerical operators. One such factor may be job content.

When the job features of the various groups are examined we see that the clerical VDT operators held jobs involving rigid work procedures with high production standards, constant pressure for performance, very little operator control over job tasks, and little identification with and satisfaction from the end-product of their work activity. In contrast to the clerical VDT operators, the professionals using VDTs held jobs that allowed for flexibility, control over job tasks, utilization of their education and a great deal of satisfaction and pride in their end-product. While both jobs had tight deadline requirements, the professional operators had a great deal of control over how these would be met. In their case, the VDT was a tool that could be used for enhancing their end-product, while for the clerical VDT operators, the VDT was part of a new technology that took more and more meaning out of their work. It's not surprising that the professionals using VDTs did not report levels of job stress as high as the clerical VDT operators. In fact, when the significant stress findings are examined, a pattern appears in which the professionals using VDTs reported the lowest stress levels while the clerical VDT operators reported the highest stress levels with the control subjects in the middle. This suggests that the use of the VDT is not the only factor contributing to operator stress levels and health complaints, but that job content also makes a contribution.

As stated earlier, the group of control subjects had similar job tasks to the clerical VDT operators with the exception that they didn't use a VDT. Their job demands in terms of workload were about the same as the clerical VDT operators but they were able to set their workpace within each workday. On the other hand, the clerical VDT operators were monitored closely by the computer systems which provided up-to-the-minute performance reports on the rate of production and error levels to supervisors. This produced a feeling in the clerical VDT operators that they were being constantly "watched" by the computer and controlled by the supervisor.

The comparison of the working conditions for the various groups demonstrates that those working conditions that led to the stress problems reported by the clerical VDT operators are not entirely related to the VDT use, but are also related to the entire work system that goes along with using VDTs. In the case of the clerical VDT operators the computer system technology under which they worked was designed without regard to the "human" factor in the system. In essence, the design reflected the VDT and computer capabilities and performance functions which were then imposed on the operator. Basically, the use of the VDT was a secondary influence on the job task activities as compared to the influence of the total computer system and its requirements. This is a serious concern since the persons who design systems such as these, and thereby the work activities of VDT operators, are typically computer scientists and systems analysts who have no concept of the human element in such a work process. This leads to a dehumanization of the work activity that is similar to that produced by the introduction of assembly lines in manufacturing industries. In fact, such offices become "paper factories" with clerical assembly lines in which the work content is simplified to increase "thru-put" and capitalize on computer capabilities. This leads to jobs that produce boredom and job dissatisfaction. As such, the machinery becomes a source of misery rather than a helpful tool as it is for the professionals using the VDTs.

Such a work environment also brings about worker fears that further automation and computerization of their job may lead to job loss or downgrading to a lower level job. The high level of job future ambiguity and concerns about career development shown by the clerical VDT operators in this investigation demonstrates this concern. In addition, almost fifty percent of the clerical VDT operators reported that it would be likely that they would be replaced by a computer at sometime in the future.

Those stress factors that displayed significant differences between the clerical VDT operators and both the professionals using VDTs and the control subjects dealt mainly with the work content, workload and career concerns. The clerical VDT operators reported jobs that were dull and boring with a great deal of structure and control both in terms of the job task requirements and supervision. They felt that the workload was very heavy and that the workpace was too fast with little control over the pacing. This resulted in their low ratings of job involvement and job autonomy, with greater role ambiguity than the other groups. These workers were not sure what their jobs required of them and felt they had very little control over or input to job requirements. They saw themselves in a highly controlled work environment that demanded high productivity.

This work atmosphere led to very low peer cohesion and staff support ratings as well as concerns about their job future. Of course such feelings are not unusual with clerical jobs since these jobs have inherent aspects which make them repetitious and structured. However, the main difference with these clerical VDT workers is the unusual lack of control over the work process which was imposed by the computer system under which they worked. Also, this same work system provided much closer tracking of their performance than traditional "paper pushing" systems. It is possible that their concerns about workpace and workload were related more to how closely these factors were monitored than to the physical nature of the work. The inflexibility of this work system and the directive/corrective management style that it engenders seems to produce a feeling of loss of control over work activity and this feeling may be the root problem of such workers.

While the other two groups also reported higher stress levels than previous studies, neither was as high as the clerical VDT operators. In fact the professional VDT operators reported the highest levels of job involvement and autonomy with the lowest levels of work pressure and workload difficulties than the other groups, while showing the most peer cohesion, staff support and the least boredom, role ambiguity and job future ambiguity. This group also had the least number of health complaints. The evidence from the stress evaluation supports the idea that VDT use per se is not completely responsible for the type of stress problems, the overall stress level, or the health complaints observed. More likely, other factors such as job content and the work system are major contributers to the stress problems observed by the clerical operators.

There were a number of health complaints that were reported more frequently by the VDT operators than the control subjects. These can be grouped into visual, musculoskeletal (mainly muscular) and emotional problems. The clerical VDT operators had considerably more of these health complaints than either the professionals who used VDTs or the control subjects. In fact there were greater differences between the clerical VDT operators and the professional VDT users than between the clerical operators and control subjects. This may demonstrate a relationship between job stress level and level of health complaints. However, such a relationship would be difficult to verify based on the current investigation which lacks sufficient control groups.

While a good deal of job stress problems can be traced to the job content of the participants in this investigation, the type of health complaints voiced are indicative of problems of a different nature. Specifically those problems that deal with the design of the workstation and the surrounding environment. Both clerical VDT operators and the professional VDT operators reported significantly more vision problems than the control subjects. These vision problems encompassed complaints such as burning eyes, eye strain, blurred vision, irritated eyes and even reports of changes in ability to see colors. These data indicate that the use of the VDT increased acute vision problems as reflected by self reports of the operators. These problems could be related to workload, but as stated earlier, the correlation between hours worked and health complaints was quite small even though it was significant. They also could be related to environmental factors such as the work area illumination, screen glare, clarity of images on the VDT, viewing distance and a host of other aspects of the work environment. The environmental characteristics of the workplace were evaluated in this investigation and are reported in a separate paper (Stammerjohn et al, 1981). The essence of this evaluation was that there were environmental factors that were outside of established or agreed upon environmental limits that could have contributed to the health complaints observed, particularly the visual and musculoskeletal problems.

However, the large difference in health complaints between the clerical VDT operators and the professional VDT operators gives compelling evidence that the environmental factors were not the total influence on the reporting of health complaints. In fact, as shown in the environmental measures (Stammerjohn et al, 1981) the establishments comprised of predominantly professional workers had just as many environmental problems as those predominated by clerical workers, yet the professional VDT users did not report equally high levels of visual and musculoskeletal health complaints as the clerical VDT operators.

The basic conclusion that can be drawn from this investigation is that a number of interacting factors including job task related features (job content, task requirements, workload) and environmental factors (lighting, workstation design) contributed to the observed levels of job stress and health complaints. The work system imposed by the use of VDT's may also contribute to the observed health problems, although it was not possible to clearly make this determination based on the current investigation. Because of this, solutions for dealing with potential health problems posed by VDT's must encompass both job redesign and workplace redesign factors to deal with all the root causes of the problems. Additionally, the design of computerized office systems cannot be left solely to computer experts who are concerned mainly with the capabilities and needs of the machinery of the system, but must have significant input from human factors experts who can take account of the needs of the "people component" of the system.

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Table 1. Topic Areas Covered in Questionnaire

Job information, e.g., job titles, work tasks, type of equipment used, work schedule, work/rest breaks

Job satisfaction, e.g., satisfaction with workload, pace, job tasks

Job stress, e.g., work pace, workload, ambiguity, attention required, skill use

Job future, e.g., career growth, usefulness of skills, promotion possibilities, lay-off, replacement by machines

Work environment, e.g., noise, temperature, lighting, distractions

Social environment, e.g., capabilities, adequacy, problems

Demographic, e.g., age, sex, ethnic background, height, weight, marital status

Supervision, e.g., style interaction

VDT-specific areas, e.g., features, use, problems

Medication usage, e.g., type, manner

Health complaints, e.g., general health problems, visual complaints

Medical history, e.g., major diseases

Sleep patterns, e.g., amount, quality

Personal habits, e.g., alcohol usage, smoking, coffee, tea, soft drink consumption

Recent life events, e.g., Holmes-Rahe Scale

Mood states, e.g., anxiety-tension, depression-dejection, anger, vigor, fatigue, confusion.

Table 2. Questionnaire Distribution and Subject Response Rates

| Group | Number Surveyed | Number Responding | Percentage Responding |
|---|---|---|---|
| VDT Operators* | 508 | 254 | 50 |
| Clerical Control Group | 415 | 157 | 38 |

*Total VDT operators at all workplaces - 656.

Table 3. Number of Study Participants by Select Demographic Characteristics*

| | Professionals using VDTs | Clerical VDT operators | Control clerical group |
|---|---|---|---|
| White females | | | |
| age, years | | | |
| <25 | 1 | 5 | 9 |
| 26-45 | 27 | 12 | 14 |
| >45 | 6 | 6 | 19 |
| White males | | | |
| age, years | | | |
| <25 | 2 | 5 | 1 |
| 26-45 | 34 | 6 | 4 |
| >45 | 47 | 1 | 6 |
| Nonwhite females | | | |
| age, years | | | |
| <25 | 0 | 2 | 3 |
| 26-45 | 3 | 31 | 20 |
| >45 | 0 | 5 | 9 |
| Nonwhite males | | | |
| age, years | | | |
| <25 | 0 | 1 | 0 |
| 26-45 | 4 | 5 | 7 |
| >45 | 1 | 3 | 1 |

*Includes only respondents who reported their ethnic background, sex and age.

Table 4. Percentage of VDT Operator and Control Subjects Reporting Frequent Sources of Life Stress and Personal Problems

| | Job** | Career* | Finances | Other People | Health* | Time Pressures | Unknown | Family |
|---|---|---|---|---|---|---|---|---|
| Professional VDT | 37 | 30 | 26 | 26 | 3 | 41 | 9 | 18 |
| Clerical VDT | 48 | 34 | 31 | 17 | 14 | 37 | 16 | 16 |
| Control | 29 | 15 | 26 | 14 | 5 | 31 | 10 | 16 |

*sign. at .01 level using a Chi Square test for homogeneity
**sign. at .05 level

Table 5. Mean Responses for VDT Operators and Controls for WES[1] Stress Scales

| | STRESS SCALES | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Involvement** | Peer Cohesion* | Staff** Support | Autonomy* | Task Orientation | Work* Pressure | Clarity | Control* (By Sup.) | Innovation | Physical Comfort |
| Prof. VDT (PV) | 1.50 | 2.09 | 1.85 | 2.32 | 1.82 | 2.25 | 1.35 | 1.41 | 1.24 | 1.27 |
| Clerical VDT (CV) | 1.04 | 1.33 | 1.38 | 1.14 | 2.02 | 3.38 | 1.17 | 3.04 | 1.18 | 1.28 |
| Control (C) | 1.25 | 1.88 | 1.56 | 1.75 | 1.81 | 2.43 | 1.55 | 2.65 | 0.94 | 1.13 |
| Duncan Range Results | PV>CV | PV&C>CV | PV>CV | PV>C>CV | | CV>PV&C | PV>C>PV | | | |
| WES Norms[1] | 2.80 | 2.73 | 2.94 | 2.69 | 2.51 | 1.77 | 2.33 | 2.32 | 2.40 | 2.04 |

*sign. at .01 level using an Analysis of Variance
**sign. at .05 level

[1] Work Environment Scale (Insel and Moos, 1974) Form S.

Table 6. Mean Responses for VDT Operators and Controls for Job Demands[1] Stress Scales

| | Workload* Dissatisfaction | Boredom* | Role** Ambiguity | Quantitative Workload-Q.* | Quantitative Workload-E. | Lack of Self-Esteem* | Role Conflict | Workload Variance | Job Future Ambiguity* |
|---|---|---|---|---|---|---|---|---|---|
| Professional VDT (PV) | 2.21 | 2.09 | 1.55 | 3.55 | 3.38 | 9.96 | 1.82 | 2.74 | 3.04 |
| Clerical VDT (CV) | 3.17 | 3.36 | 1.79 | 4.04 | 3.55 | 12.41 | 1.71 | 3.02 | 3.50 |
| Control (C) | 2.43 | 2.63 | 1.73 | 3.61 | 3.60 | 9.73 | 1.92 | 2.87 | 3.10 |
| Duncan Range Results | CV>PV&C | CV>C>PV | CV>PV | CV>PV&C | | CV>PV&C | | | CV>PV&C |
| Jod Demands and Worker Health Study Median Scores[1] | 2.13 | 1.83 | 2.06 | -- | 3.51 | -- | 1.75 | 2.81 | 2.70 |

*sign. at .01 level using an Analysis of Variance
**sing. at .05 level

[1]Scales taken from Job Demands and Worker Health (Capland et al, 1975).

Table 7. Percentage of VDT Operators and Controls Reporting Frequent Levels of Particular Stressors Showing Significant Differences[1]

| Stressors | Clerical VDT | Professional VDT | Control |
|---|---|---|---|
| Interesting work | 24 | 76 | 53 |
| Bored with work | 48 | 15 | 23 |
| Work is dull | 42 | 13 | 27 |
| Increased concentration required | 45 | 26 | 34 |
| Able to chose own work | 4 | 28 | 18 |
| Dislike workload | 45 | 15 | 21 |
| Unhappy with workload | 36 | 17 | 21 |
| Have to work too hard | 76 | 53 | 61 |
| Behind in work by at least one week | 27 | 10 | 8 |
| Heavy workload | 82 | 70 | 73 |
| Dissatisfied with workpace | 41 | 17 | 18 |
| Have to work too fast | 82 | 65 | 65 |
| Can et own workpace | 41 | 61 | 73 |
| Certain in career future | 14 | 37 | 44 |
| Promotion opportunities | 13 | 37 | 31 |
| Worry about reprimands | 24 | 3 | 8 |

[1]Significant at the 95 percent confidence level or greater using a Chi Square test for homogeneity.

Table 8. Mean Scale Values for Mood States for VDT Operators and Control Subjects

| | MOOD STATES | | | | | |
|---|---|---|---|---|---|---|
| | Anxiety | Depression | Anger | Vigor | Fatigue* | Confusion |
| Professional VDT | 9.7 | 9.6 | 9.4 | 16.6 | 7.2 | 6.2 |
| Clerical VDT | 10.2 | 9.7 | 8.0 | 16.0 | 9.0 | 6.2 |
| Controls | 7.9 | 7.6 | 7.2 | 17.2 | 5.9 | 4.4 |
| Duncan Range Results | | | | | CV>PV&C | |

*Sign at .01 level using an Analysis of Variance test.

Table 9a. Percentage of Clerical VDT Operators and Control Subjects with Selected Health Complaints Showing a Significant[1] Effect

| | PERCENTAGE | |
|---|---|---|
| Health Complaints | Clerical VDT | Control Subjects |
| Skin rash | 57 | 31 |
| Irritability | 80 | 63 |
| Fainting | 36 | 17 |
| Nervous | 50 | 31 |
| Fatigue | 74 | 57 |
| Pain down arm | 37 | 20 |
| Stomach pains | 51 | 35 |
| Change in color perception | 40 | 9 |
| Irritated eyes | 74 | 47 |
| Burning eyes | 80 | 44 |
| Blurred vision | 71 | 35 |
| Eye strain | 91 | 60 |
| Swollen muscles and joints | 50 | 25 |
| Back pain | 78 | 56 |
| Painful or stiff arms or legs | 62 | 35 |
| Painful or stiff neck or shoulders | 81 | 55 |
| Numbness | 47 | 18 |
| Neck Pressure | 57 | 34 |
| Difficulty with feet from standing long periods | 49 | 35 |
| Sore shoulder | 70 | 38 |
| Loss of feeling in wrists or fingers | 33 | 11 |
| Neck pain into shoulder | 56 | 19 |
| Hand cramps | 49 | 16 |
| Loss of strength in arms or hands | 36 | 14 |
| Stiff or sore wrists | 47 | 7 |

[1]At 95 percent level of confidence or greater using a Chi Square test for homogeneity.

Table 9b. Percentage of Professionals Using VDT's and Control Subjects with Selected Health Complaints Showing a Significant[1] Effect

| | PERCENTAGE | |
|---|---|---|
| Health Complaints | Professional VDT | Control Subjects |
| Burning eyes | 60 | 44 |
| Eye Strain | 78 | 60 |
| Irritability | 76 | 63 |
| Fainting | 8 | 17 |
| Pain down arm | 11 | 20 |
| Colds and sore throat | 49 | 63 |

[1]At 95 percent level of confidence or greater using a Chi Square test for homogeneity.

# EVALUATION OF WORK STATION DESIGN FACTORS IN VDT OPERATIONS

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## ABSTRACT

An on-site evaluation was conducted at five establishments using VDTs, to examine the current practices with respect to VDT workstation design, and to compare these to recommendations obtained from the literature. Measurements were made of such critical design factors as keyboard height, screen height, workstation illumination and glare. A questionnaire was used to measure the degree to which the operators perceived certain workstation design problems as bothersome.

Illumination levels were generally in the 500-700 lux range, and the questionnaire data confirmed that these levels were acceptable to most employees. A number of design problems were found in the VDT workstations, including excessive keyboard heights and screen positioning which would require excessive inclination of the head and neck for screen viewing. A majority of the operators surveyed found a number of factors to be bothersome, including to screen readability, reflected glare, screen brightness and flicker to be bothersome. A number of the dissatisfaction parameters were found to be related to levels of health complaints.

## INTRODUCTION

In July of 1979 a consortium of unions (The Newspaper Guild, Communication Workers of America, Office and Professional Employees International Union and the Typographical Workers Union) requested that the National Institute for Occupational Safety and Health (NIOSH) examine the health hazard potential of working with video display terminals (VDTs). NIOSH undertook an evaluation of potential health problems for VDT operators at five workplaces. Included in this evaluation were (1) radiation measurements on a sample of VDTs, (2) industrial hygiene measurements of the VDT work areas, (3) a questionnaire survey of job stress and somatic (health) complaints of operators, and (4) examination of VDT workstation and work area environmental features. Smith et al. (1981) discuss job stress and health in VDT operators as compared to other workers doing similar jobs who do not use VDTs (see pages of this issue). This paper will present an evaluation of the working environment of the VDT operators along a number of dimensions related to physical stress, and will relate these results to worker satisfaction with the workstation on these same dimensions.

The evaluation of the workstation (the immediate area in which the operator works including all furniture and equipment routinely used by the operator) and its environment focused primarily on an examination of factors potentially related to visual and musculoskeletal problems, which have been shown by prior studies to be the health problems most often observed in VDT operators (Grandjean, 1979; Holler et al, 1975; Gunnarsson and Ostberg, 1977). This examination dealt with the ergonomic aspects of VDT use, an area which has not previously been extensively evaluated in the United States. Cakir and colleagues (Cakir et al, 1978; Cakir et al, 1979) have published one of the most comprehensive discussions of the human factors issues related to VDT work and have developed a checklist for the evaluation of VDT workplaces. Based on their findings, they have presented a number of recommendations for the design of both the VDT, the workstation and the surrounding work environment. In addition, some European countries (Sweden, Germany) have developed standards which specify both voluntary and mandatory design requirements for the VDTs and specify the environmental conditions under which VDTs may be operated. Since no comparable standards exist in the U.S., the NIOSH evaluation relied heavily on the European experience and on basic principles of human factors (McCormick, 1976; Poulton, 1972; Grandjean, 1971).

Proper illumination is essential so that both VDT screen and hard copy can be read without undue visual discomfort or fatigue. 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. Cakir et al (1979) recommend illumination levels between 300 and 500 lux for VDT workplaces, while Ostberg (1979) recommends levels as low as 200 lux with supplementary task illumination.

Glare as a factor in VDT operations, can be classified in two ways (1) disability glare vs. discomfort glare, and (2) direct glare vs. reflected glare. 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. Reflected glare (sometimes called veiling reflections) is characterized by VDT screen regions with high background luminance levels caused by the reflection of light from other sources.

Reflected glare from sources such as overhead lights can also have serious impact upon display legibility. Reflected glare may be either specular or diffuse. 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, such glare 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 $cd/m^2$) (see 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.

Another factor related to visual discomfort and fatigue is the contrast between materials being read (e.g., on the VDT screen) 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. 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).

In terms of workstation design a number of factors can influence worker comfort and health. Some of these are keyboard height, viewing distance, viewing angle, and chair features.

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. The Cakir et al (1979) recommendation for the height of the home row keys in a fixed height workstation is 720-750 mm. The U.S. Military Standard 1472B (DOD, 1974) specifies a working surface height of 740-790 mm, which approximates the customary keyboard height range for typing in most offices in the United States.

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 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). On the other hand, sufficient clearance must be allowed for the operators' legs (645 mm for 95th percentile males) (see Van Cott and Kincaid, 1963). Thus either a fairly wide range of adjustability or some compromises between leg clearance and keyboard height are necessary. Some authors recommend fairly high working surfaces (keyboards) used in conjunction with footrests.

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Proper viewing distance is important in minimizing visual system fatigue, and incorrect viewing distance and angle can lead to awkward operator postures. 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 with a maximum of 700 mm has been recommended by Cakir et al (1979). A variety of recommendations regarding screen viewing angle have been offered by Dreyfus (1967), Cakir et al, (1979) and IBM (1979). Generally these recommendations place the center of the VDT screen at a position between $10^{o}$ and $20^{o}$ below the horizontal plane at the operator's eye height. Cakir et al (1979) made 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 $10^{o}$-$15^{o}$ below the horizontal, with no portion of the screen at a angle of greater than $40^{o}$ below the horizontal.

## METHODS

The ergonomic evaluation was conducted on a sample of the VDT workstations at five worksites in the San Francisco Bay area. All workstations were randomly selected, with the exception that at least one sample representative of each equipment type and one sample representative of each major design alternative were chosen. The survey was adapted from a human factors checklist developed for use by NIOSH in a proposed evaluation of letter sorting machine operators in the U.S. Postal Service. The modified checklist sought information in a number of areas, such as workstation design, physical environment, and qualitative assessments of the task characteristics. The job design and equipment design portions of the checklist were, in general, limited to data which could be observed directly or elicited through informal interviews. Cakir et al (1979) have published a somewhat similar checklist.

The evaluation of workstation design involved three types of data collection: (1) measurement of illumination and luminance levels, (2) measurement of the physical dimensions of the workstation, and (3) direct observation of workstation features which were of special interest. The workstation design features noted included adjustability of screen contrast and brightness, quality of display, adjustability of the chair, adjustability of the keyboard and screen position, and design features such as desk characteristics. The workstations examined at each site provided a sample representing the range of VDT types and operating conditions existing at the worksite, and all measurements were made with any equipment adjustments left as they had been set by the operators or other site personnel. Not all measurements were taken at all workstations.

Luminance measures were made with a Photo Research Spectra Mini-Spot Photometer from the position of the operator. The same instrument was used in conjunction with an RS-1 Reflectance Standard to obtain illuminance measures. Luminance was measure in foot-Lamberts, and the values obtained were converted to candelas/square meter ($cd/m^2$) afterwards. The ratio of the VDT background to the highest luminance region of the operators general visual field was computed. Illumination levels were measured in foot-candles and converted to lux. Measurements were taken at various hours on both clear and overcast days, and a few areas were examined after dusk; thus some but not all areas 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 published by McCormick (1964), Dreyfus (1967), and 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.

A few measurement attempts were unsuccessful, most notably that of character luminance. The investigators were unable to get repeatable measures of character luminance with the equipment used in this field survey. A technique using different instrumentation is being developed for future field studies.

In addition to the workstation evaluations, a questionnaire was distributed to a sample of the employees at each worksite. The methodology used in the distribution and collection of the questionnaire is described in detail by Smith et al (1981) and will not be repeated here. However, it should be noted that, because the survey was anonymous, it was not possible to link questionnaire responses to specific design features. Two blocks of items from this questionnaire are particularly relevant to the human factors evaluation: (1) a 13 item employee rating of workstation design and (2) a 59 item checklist of somatic complaints. Two of the three groups examined by Smith et al, are of primary interest here, professional VDT operators and clerical VDT operators, with only a few comparisons being made with non-VD workers.

In the workstation design section, the respondent was asked to rate parameters affected by workstation design using a five point scale ranging from "no bother or problem" to "constantly bothersome." The parameters rated in this manner were screen brightness, character brightness, readability. screen angle, keyboard angle, screen height, keyboard height, distance to the screen, distance to the keyboard, screen glare, keyboard glare, noise from the VDT, and screen flicker. Summary statistics were computed by group (professional vs. clerical) for these items.

Another section of the questionnaire presented a list of 59 somatic complaints. The respondent was asked to rate the frequency of occurrence of each complaint during the last year on a four point scale ranging from "never" to "constantly," with corresponding scale values of 1 to 4. A subset of the 59 items were combined into four scales representing musculoskeletal complaints, visual function complaints, emotional complaints, and psychosomatic complaints. It was not possible to validate these scales due to the small sample size, rather reliance was placed on the content validity of the scales.

The response range on each of these scales was partitioned to form low, median, and high complaint groups, with each group having an approximately equal number of respondents. The responses to the questions on workstation design ranged over the five point scale with values from "no bother or problem" to "constantly bothersome". These responses divided into positive and negative responses, with a positive response being that the factor was at least occasionally bothersome. An analysis was conducted to identify relationships between the four scales and the 13 design factors using a Chi Square analysis.

## RESULTS

Workplaces: Five sites were examined. One was an insurance company in which all of the VDT operations examined were clerical in nature. These included data entry, data retrieval for claims review, and data editing. The other four establishments were newspaper operations, at which both professional VDT tasks such as entering and editing stories and compositing and clerical VDT tasks such as answering telephone inquiries regarding circulation and taking classified ads were carried out.

Illumination and Contrast: The majority of workstations at the sites examined had illumination levels between 500 and 700 lux; however, levels as low as 300 lux and as high as 1200 lux were observed (see Table 1). At one site, 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 at each site were adjacent to windows which had the potential to create excessive illumination levels in periods of bright sunlight. At one site, windows were equipped with curtains which if properly utilized would have eliminated excessive illumination from the windows; at a second site the windows were equipped with tinted filters which reduced transmitted daylight somewhat. The range of individual station maximum simple luminance ratios (the ratio between low and high luminance field at that workstation) at the sites visited were between 1:2 and 1:60.

(Insert Table 1)

Glare: Potential discomfort glare sources existed at 46 of the 53 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$^2$. Although the windows at one site were equipped with curtains, in many cases these curtains were left open. It should be noted that in offices with windows both illumination and glare levels can be effected by the weather and the time of day; thus, although severe glare was noted in only one office, a potential glare problem existed in any of the offices with at least one window exposed to direct or reflected sunlight.

Reflected glare was present in most of the VDT screens surveyed; this reflected glare generally consisted of reflections from windows and overhead lights. At the insurance company, maximum and minimum luminance measures were taken of blank VDT screens to give a measure of reflected glare at that site. This data is given in Table 2. The maximum reflected luminance levels on the VDT screens ranged from 3 to 50 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 53 screens evaluated at all sites, nine, or approximately 17%, had reflected glare levels which could make reading characters on parts of the screen difficult.

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Techniques for limiting reflected glare were in use at many of the workstations examined. The majority of the VDT's had etched glass screens (to eliminate specular reflections) supplied by the manufacturer, while a few were equipped with film coatings also supplied by the manufacturer. Many employees at one of the sites had fashioned makeshift hoods from newspaper, cardboard and other materials. A few VDT's were equipped with honeycomb-type glare screens. The thin film coatings and honeycomb filters appeared to be successful in reducing reflections, but tended to smudge and collect dust, respectively. The makeshift hoods were somewhat effective, but many, particularly the deeper hoods, limited the operator's ability to adopt comfortable working postures. It is not possible from this limited data to make a global recommendation regarding methods to use in reducing reflected glare, especially as the specific nature of the job may have a impact.

(Insert Table 2)

Display Legibility: Image quality was judged by the researchers conducting this evaluation. No visually detectable jitter or flickering was observed on any of the screens examined nor was any flicker reported by a small sample of operators when questioned; however, the perceptibility of flicker varies with illumination, screen luminance, whether foveal or peripheral vision is used, and operator sensitivity. In a few cases, slight blurring of characters was observed at the screen edges. 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 character blocks 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. Many, but not all of the VDTs had brightness and contrast controls accessible to the operator.

Workstation Design: Several types of workstations were observed: (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; (3) units in which the VDT screen and keyboard sat on a revolving platform somewhat above desktop height and between two desks, giving keyboard heights from 840 to 870 mm; (4) units in which a VDT unit sat on a typewriter stand or shelf either at a workstation or between two workstations, giving keyboard heights from 720-840 mm; and (5) units at which the VDT sat on a special stand, giving a keyboard height of between 760 and 810 mm. In the first three groups, the VDT screen and keyboard were in separate housings, which would in principle allow the keyboard and screen to be positioned separately for the comfort of the operator. However, for the other two groups the VDT's did not allow separate positioning of the keyboard and screen, and in many cases, these units required excessive visual angle for tall operators. Keyboard heights are given in Table 3, and the estimated viewing distance and viewing angles for male and female operators of median dimensions at the sites visited are summarized in Table 4. Many of the viewing angles were larger than recommended especially for male operators of greater than median dimensions. However, as Table 4 shows, the viewing distances were all in the acceptable range (450 to 700 mm).

(Insert Tables 3 & 4)

A wide variety of operator chairs were present at these sites. However, most were standard typist chairs with, at minimum, adjustable seat pan height and back support. Some chairs had adjustments for seat pan angle and backrest tension, while a few were straight backed chairs with no adjustment features. The observed seat pan heights ranged between 420 mm and 510 mm, with a mean of 470 mm. Most of the chairs could be swivelled and moved on casters to enhance operator freedom of movement. Few chairs had any form of arm rest. All workstations examined had adequate knee room.

Questionnaire Findings: The questionnaire yielded some interesting data regarding the employees' perception of their workplace. In response to a group of questions concerning the office environment, most employees (63%) rated summer temperature and level of distraction (64%) as too high, while a slight majority were satisfied with the illumination and a slight plurality (41%) felt the winter temperature was too low; no significant differences were observed between VDT and non-VDT employees for these latter factors. Responses to a group of questions regarding lighting indicated that most employees were satisfied with the workstation (53%) and background (63%) illumination levels. A significantly larger proportion of the VDT operators (80%) than the non-operators (62%) reported glare from the workstation lighting, and more VDT operators (44% vs. 30%) reported shadows cast by background lighting. Of all employees responding, 38% reported their chairs were comfortable, while 32% reported them to be just adequate and 30% uncomfortable. However, 70% reported their chairs to be at correct height. The VDT and non-VDT groups did not differ significantly in their ratings of their chairs, either for comfort or correctness of height; however the clerical VDT workers found their chairs significantly less comfortable than did either the professional VDT workers or the non-VDT operators ($p<.01$, Chi-square).

Another group of questions dealt with how often VDT operators found various aspects of their workstations bothersome (Table 5). In order of prevalence (that is, the respondent finding the condition bothersome at least occasionally) the most frequent complaints were screen glare (85%), character brightness (70%), readability (69%), flicker (68%), and screen brightness (62%). The rest of the factors examined were reported as bothersome by fewer than half of the employees. (Insert Table 5)

Table 6 shows the relationship between the somatic complaint scales and employee dissatisfaction with workplace design parameters. For both professional and clerical VDT workers, a significant relationship existed between visual function complaints and the employee rating of the workplace design parameters, including glare, screen angle, noise from the VDT, and screen flicker. Data from the clerical VDT workers shows a relationship between the rating of the screen height and visual function complaints, while the data for the professional VDT workers shows a relationship between visual function complaints and the rating of screen brightness, letter brightness and readability. For the professional VDT operators several factors were shown to be related to musculoskeletal and mood complaints; but no significant relationships were found for psychosomatic complaints in either VDT group. (Insert Table 6)

## DISCUSSION

The purpose of this evaluation was to characterize the environmental and workstations design features of VDT operations to pinpoint potential sources of strain, and to be able to relate these factors in a general way to employee somatic complaints. Smith et al (1981) discuss the somatic complaints of VDT operators in more detail. In terms of characterizing the work environment, the human factors evaluation showed physical workstation design to be less than optimal in a number of respects. The keyboards observed were almost all placed higher than would be optimal for any but relatively tall operators, while in many cases the VDT screen heights were too low for a tall operator. In some cases, this was the result of placing the VDT units on standard office desk tops. In all of the workstations examined the minimum keyboard and screen heights were set by the design of the (non-adjustable) furniture, and in only a few cases had the keyboard been raised by the operator (e.g., by placing stacks of paper under the keyboard). For many work stations, the screen and keyboard were attached fixing the screen height in relation to the keyboard; however screen height had been raised for operator preference at some workstations at which the keyboard and screen were not attached. It is interesting to note that relatively few operators rated the keyboard or screen heights as bothersome, compared to other factors. It is worthy of note that these problems, particularly keyboard height are not unique to VDTs, and the operators interviewed indicated that they felt that these parameters were fixed and did not have any expectations that they could be changed.

Most of the VDT operators rated their chairs as at least adequate, and no significant differences in this rating were found between VDT and non-VDT groups. As no major differences were observed in the types of chairs used by the different groups, differences in task demands are one likely explanation for the differences between the ratings by the clerical VDT works and those by the other two groups. For instance, the VDT clerical jobs apparently offered less opportunity to get up and move around than did the jobs in the other two groups.

Measurements and observations at the worksites determined that the ambient illumination levels were generally within a range suitable for VDT use and most VDT operators and other employees reported the lighting levels as being acceptable. VDT operators were significantly more likely to report glare produced by the workstation lighting and shadows produced by the background lighting than were non VDT operators. In addition VDT operators reported more glare from background lighting and more shadows from workstation lighting than did other workers. Approximately 85% of the VDT operators reported that screen glare was bothersome at least occasionally. Thus, while ambient illumination levels were apparently generally satisfactory for both VDT and non - VDT tasks, VDT operators were less satisfied with other aspects of the workplace lighting than were other workers, presumably because of the special visual demands presented by the VDT task.

Most VDT operators found glare, screen and letter brightness, flicker, and readabiltiy bothersome. The reports of the VDT operators were verified by measurements of the glare, since reflected glare in the VDT screens was observed at every worksite. The dissatisfaction reported with character and screen brightness may also be related to reflected glare. While transmitted luminance levels of the screen were not accurately measurable with field equipment used in this study, the importance of this parameter is demonstrated by the level of reported VDT operator dissatisfaction with screen brightness. Procedures and instruments for making the required measurements are currently being developed to allow for further examination of this factor in detail in future studies.

The questionnaire did not tap information regarding the specific nature of the brightness, flicker, and readability problems perceived by the operators; thus a number of different phenomena may have been contributed to the responses to these items. It is worthy of note that most of the VDTs had controls for adjustment of brightness, and thus the complaints regarding character brightness may have been connected with difficulty in adjusting the brightness to ambient lighting and glare conditions. Readability and flicker problems were also reported by the VDT operators as bothersome, however no objective measures of these parameters were taken, and subjective evaluations by the investigators did not indicate that a large problem was likely. Moreover, it must be emphasized that a variety of other factors play a role in the perception of flicker and in the readability of the display (Gould, 1968 and Grandjean, et al, 1977). In terms of display readability the subjective investigator assessment was concerned mostly with character style for which no standards exist (Snyder and Maddox, 1980), but the operators may have also been responding, in part, to the problem with glare and luminance mentioned above.

While at is not possible to infer causality, the data relating somatic complaints to workstation parameters suggest that in both VDT respondent groups a relationship exists between the worker rating of several workstation design parameters (glare, noise from the VDT, screen angle and flicker) and the prevalence of somatic complaints related to vision. Among the clerical VDT workers, the rating of VDT height was related visual function complaints; and among the professional workers, several parameters (screen glare, screen angle, and flicker) were related to several of the complaint scales. In all of these cases, high levels of somatic complaints appeared to be associated with higher levels of worker dissatisfaction with the parameter than were low levels of somatic complaints. A number of differences between the two groups, including sample size, differing task demands, differences in workstation design and equipment, and demographic differences may in part account for the varying findings.

## CONCLUSIONS

This evaluation was conducted at a limited number of worksites, which cannot be assumed to be representative of all VDT workplaces, and therefore it is not appropriate to generalize these results to other VDT operations. However, a number of conclusions appear to be warranted in regard to these sites: (1) glare, screen luminance and readability were bothersome to VDT operators and objective measures demonstrated glare to be a problem, (2) physical workstation design was generally less than optimal with respect to such parameters as keyboard height, screen position and chair design; but operators generally perceived these aspects as less bothersome than those not related to visual problems; (3) lighting was generally within the recommended ranges, and most VDT operators and other workers rated illumination levels as "about right." However, the VDT operators were significantly more likely than the others to rate the lighting as producing glare. These conditions can be related to operator health complaints particularly those concerning visual and musculoskeletal problems.

The factors considered in this investigation can thus be divided into several groups, based on the results of the worksite evaluations and the questionnaire. Measured illumination levels were generally within the recommended range, and most of the respondents rated the lighting levels as approximately correct. Screen glare was measured at only one site, with some measured levels appearing to be quite high; and in the questionnaire, 85% of the respondents reported at least occasional problems with glare, and this rating of glare was shown to be related to certain groups of somatic complaints. Screen brightness, readability, and flicker were not measured at the worksite because of methodological difficulties, but these were reported as bothersome by at least half of the operators and some significant relationships to somatic complaints were identified. Keyboard height and screen height (viewing angle) were found to frequently be non-optimal in worksite measurements, but they were rated as bothersome by less than half the respondents, while screen height was related to some measure of somatic complaints. Angle of the keyboard, screen distance from the operator, keyboard distance from the operator and glare off the keyboard were not identified as major problems during worksite evaluations, nor were they rated as bothersome by a majority of the operators. Screen angle and noise from the VDT were not measured, nor were they rated as bothersome by a majority of the operators, but they did show significant relationships to somatic complaints. Since screen angle can affect screen glare levels, it is suggested that this feature be measured in future studies.

Based on the results of this investigation, it is recommended that future human factors evaluations of VDT workplaces include measurements of:

(1) illumination levels;

(2) glare, particularly glare on the VDT screen;

(3) screen flicker, background and character brightness, and readability;

(4) workstation dimensions including keyboard and screen height, screen angle, knee room, and chair dimensions and characteristics;

(5) Noise and other environmental measures, with particular reference to noise from the VDT;

(6) analysis of the VDT and other tasks involved, and employee questionnaires, where necessary.

For some of the parameters listed above, such as flicker, adequate field measurement techniques are not readily available, and considerable ingenuity will be required in making these measurements. Further research aimed at determining the relationship of these parameters to performance and health effects is also necessary.

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Table 1 - Illumination levels at workstations

| Level (lux) | Number of workstations |
| --- | --- |
| 0 - 299 | 0 |
| 300 - 500 | 6 |
| 501 - 700 | 39 |
| 701 - 1000 | 2 |
| >1000 | 5 |

Note: Cakir et al (1979) recommend a range of 300-500 lux. Other recommendations, both higher and lower, exist.

Table 2 - Screen background luminances

| Luminance ratio | Number | Maximum background luminance (cd/m$^2$) | Number |
|---|---|---|---|
| <1:3 | 12 | <10 | 3 |
| 1:3 - 1:5 | 4 | 10 - 15 | 4 |
| 1:5 - 1:10 | 3 | 16 - 20 | 9 |
| >1:10 | 3 | 21 - 45 | 4 |
| | | >45 | 2 |

Table 3 - Keyboard height (floor to home-row)

| Keyboard height (mm) | Number of stations |
|---|---|
| 0 - 720 | 0 |
| 721 - 750 | 3 |
| 751 - 790 | 23 |
| >790 | 27 |

Note: Keyboard height ranges recommended in the literature are generally around 720-760 mm (Cakir et al, 1979). The U.S. Military Standard recommends a working surface height of 740-790 mm (Department of Defense, 1974).

Table 4 - Screen viewing angle and distance for male and female operators of median dimensions

| Sex | Viewing angle | Number | Viewing distance (mm) | Number |
|---|---|---|---|---|
| Males | 0 - 9° | 0 | 0 - 449 | 0 |
| | 10 - 20° | 8 | 450 - 500 | 0 |
| | 21 - 30° | 28 | 501 - 700 | 45 |
| | >30° | 10 | >700 | 1 |
| Females | 0 - 9° | 2 | 0 - 449 | 0 |
| | 10 - 20° | 25 | 450 - 500 | 4 |
| | 21 - 30° | 14 | 501 - 700 | 42 |
| | >30° | 5 | >700 | 0 |

Note: Recommendations in the literature generally range between 10° and 20° for viewing angle and 450-700 mm for viewing distance.

Table 5 - Percentage of VDT operators rating workplace design parameters as bothersome

| | Often bothersome | Occasionally bothersome | No bother or problem |
|---|---|---|---|
| Screen brightness | 18 | 43 | 38 |
| Character brightness | 23 | 47 | 30 |
| Readability | 28 | 41 | 31 |
| Angle of screen | 18 | 26 | 55 |
| Angle of keyboard | 14 | 25 | 61 |
| Screen height | 27 | 26 | 57 |
| Height of keyboard | 13 | 24 | 63 |
| Screen distance from operator | 13 | 22 | 65 |
| Keyboard distance from operator | 10 | 23 | 67 |
| Glare off screen | 45 | 39 | 15 |
| Glare off keyboard | 9 | 17 | 74 |
| Noise from VDT | 14 | 20 | 66 |
| Flicker | 26 | 41 | 32 |

Note: Rows do not sum to 100% due to rounding error.

Table 6. Percentage of VDT operators who rated workplace design features as bothersome vs. somatic complaint status[1]

| | Professional Employees (N=112) | | | Clerical Employees (N=80) | | |
|---|---|---|---|---|---|---|
| | Low complaints | Medium complaints | High complaints | Low complaints | Medium complaints | High complaints |
| Musculoskeletal complaints vs. | | | | | | |
| Screen angle | 26 | 41 | 56 | | | |
| Screen height | 26 | 35 | 59 | | | |
| Screen glare[2] | 34 | 56 | 63 | | | |
| Screen flicker | 50 | 64 | 84 | | | |
| Visual function complaints | | | | | | |
| Screen brightness | 38 | 57 | 80 | | | |
| Character brightness | 49 | 68 | 90 | | | |
| Readability | 51 | 75 | 84 | | | |
| Screen angle | 30 | 41 | 61 | 26 | 27 | 70 |
| Screen height | | | | 32 | 23 | 64 |
| Screen glare[2] | 27 | 42 | 87 | 17 | 42 | 55 |
| Noise from VDT | 14 | 21 | 45 | 26 | 43 | 61 |
| Screen flicker | 49 | 70 | 90 | 45 | 65 | 84 |
| Emotion/mood complaints | | | | | | |
| Screen brightness | 37 | 54 | 75 | | | |
| Screen angle | 23 | 51 | 50 | | | |
| Screen height | 23 | 51 | 55 | | | |
| Screen glare[2] | 30 | 63 | 50 | | | |
| Noise from VDT | 7 | 30 | 38 | | | |
| Screen flicker | 50 | 68 | 83 | | | |

[1]Significant at $p<.05$ or better by Chi Square test.
[2]Figures for screen glare represented the percentages of the operators who rate glare as at least "often bothersome" as opposed to "occasionally bothersome" or no bother.

# A RADIATION AND INDUSTRIAL HYGIENE SURVEY OF VIDEO DISPLAY TERMINAL OPERATIONS

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In July 1979, the National Institute for Occupational Safety and Health (NIOSH) received a request from three labor unions in California to examine the potential health hazards of using video display terminals (VDTs) in information processing applications. Three companies located in the San Francisco metropolitan area agreed to participate in the study.

As part of this investigation, radiation surveys were performed on a sample that included 25 percent of the terminals in use. Researchers measured both ionizing and nonionizing radiation. In the industrial hygiene survey, samples of workroom air were analyzed to determine worker exposure to selected airborne chemical contaminants. The results of these tests demonstrated that the VDT operators included in this investigation were not exposed to hazardous levels of radiation or chemical agents.

## INTRODUCTION

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 (concerning potential health hazards) raised by users of video display terminals." Specific questions had been raised concerning eyestrain, cataracts, cancer, reproductive disorders, headaches, general malaise, sore muscles and other visual and musculoskeletal symptoms. The companies that agreed to participate in this investigation 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 study protocol and talked with selected employees. A full report on the walk-through survey was sent to each party by NIOSH in December 1979. The in-depth study followed in January 1980 in the four phases discussed below:

1. Radiation--Since the video display terminal (VDT) can emit one or more types of electromagnetic radiation, both ionizing (X-ray) and nonionizing (ultraviolet, visible and radio-frequency) radiation measurements were made on a sample size of approximately 25 percent of the VDTs at each facility. At least one terminal of every make and model was surveyed at each facility.

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

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

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

The remainder of this report includes a detailed explanation of the methodologies employed, a discussion of the results and the conclusions for the Radiation and Industrial Hygiene phases of the investigation. The Health Complaints and Ergonomics phases are discussed elsewhere in this publication.

METHODOLOGY

Radiation

The proper conduct of a radiation survey requires a basic understanding of the radiation source and its characteristics. The VDT can produce several types of electromagnetic radiation, depending upon its operating characteristics. Low energy X-rays can be generated by the cathode ray tube (CRT) and electronic damper circuits. Depending on the phosphor used, ultraviolet (UV), visible, and infrared (IR) radiation can be emitted from the screen face. Certain electronic components and circuits can produce 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 sensitivity is $5 \times 10^{-8}$ $W/cm^2$ and the accuracy is about $\pm 20$ percent. All measurements with 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 about $\pm 10$ percent. The values measured are also presented in units of candelas per meter squared ($cd/m^2$).

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

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

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

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

Industrial Hygiene

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

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

General hydrocarbon levels were measured with an HNU Model 101 Photoionization Analyzer equipped with an 11.7 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. For example, if the vapor detected was pure methanol, the concentration would have to be reduced by a factor of 0.25. Carbon monoxide, acetic acid, formaldehyde and ozone levels were measured with appropriate Drager colorimetric tubes using a Drager Model 31 hand-operated bellows pump. The photoionization analyzer and colorimetric tube measurements are accurate to about $\pm 5$ percent and $\pm 25$ percent, respectively. Air sampling was conducted at locations that were judged to have the highest levels of air contaminants.

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RESULTS AND DISCUSSION

Radiation

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

SEE TABLE 1

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

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

Using a calibrated Hewlett-Packard Spectrum Analyzer, BRH obtained spectral data for both the electric and magnetic fields in the frequency range from 10 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. Researchers at 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 (Ruggera, 1980) states that the primary radiation source is through the CRT face. At 5 cm, the electric field ranged from 784 to 4096 $V^2/m^2$. This range of values dropped to 0.09 to 5.76 $V^2/m^2$ at 30 cm which closely approximates the minimum viewing distance of the operator. The magnetic field strength was 0.49 $A^2/m^2$ at 5 cm decreasing to $4.9 \times 10^{-5}$ $A^2/m^2$ at 30 cm. No measurable RF radiation emissions above 500 kHz were found.

From the laboratory and field survey data, NIOSH determined that the high electric and magnetic field readings resulted from this capacitive coupling phenomenon and were not due to RF radiation frequencies above 10 MHz. The flyback transformer can emit RF fields in the frequency range from 15 to 125 kHz but there is no occupational exposure standard for this frequency range and these frequencies have not been shown to cause biological injury.

The flyback transformer is a common component found in most TV sets and VDTs. Some countries require shielding of this transformer but the U.S. does not. The shield protects workers from inadvertent contact with the 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 one of the companies. NIOSH selected three Ontel terminals on which high electric and magnetic field strength readings were obtained during the initial survey. Shields had since been installed on these terminals. The terminals were surveyed with the Narda RF radiation instrument. With the shield removed, NIOSH again obtained high electric and magnetic readings with the Narda instrument. The shields were then replaced and repeat measurements showed zero readings with both probes.

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

SEE TABLE 2

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

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

## Industrial Hygiene

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

SEE TABLE 3

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

The hydrocarbon levels in the VDT area did not vary substantially from those in the non-occupational areas. In fact, all chemical contaminant concentrations measured were far below any recommended guidelines or standards. Based on these measurements, there is no indication of any hazardous chemical exposures for the VDT operators who were included in this study. Although not directly applicable, this seems to imply that the radiation emissions would not increase significantly when a malfunction occurs.

## CONCLUSIONS

### Radiation

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

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

### Industrial Hygiene

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

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Department of Health and Human Services (DHHS). Regulations for the Administration and Enforcement of the Radiation Control for Health and Safety Act of 1968. Publication No. (FDA) 80-8035, 1980.

Table 1. Summary of electromagnetic radiation measurements

| Manufacturer | Model number | Number units measured | Ionizing radiation (mR/hr) | Ultraviolet radiation ($W/cm^2$) | Visible radiation (fL) | Visible radiation ($cd/m^2$) | Radio-frequency radiation: Electric field $(V/m)^2$ | Radio-frequency radiation: Magnetic field $(A/m)^2$ |
|---|---|---|---|---|---|---|---|---|
| Courier | TC30C1<br>110071-001<br>110117-001<br>110127-001<br>112700 | 67 | ND* | ND-1.0 x $10^{-7}$ | 1-6 | 0.3-1.7 | ND | ND |
| Delta Data | 5000 | 5 | ND | ND | 2-5 | 0.6-1.5 | ND | ND |
| Harris | 2200 | 3 | ND | ND | 3 | 0.8 | ND | ND |
| IBM | 3278 | 6 | ND | ND-1.3 x $10^{-7}$ | 2-4 | 0.6-1.2 | ND | ND |
| Systems Integrated | ET960 | 29 | ND | ND | 4-18 | 1.2-5.2 | ND | ND |
| Ontel | OP-1<br>OP-1/64<br>OP-1/16<br>OP-1/S11 | 26 | ND | ND-6.5 x $10^{-7}$ | 2-40 | 0.6-11.6 | ND | ND |
| All Models | | 136 | ND | ND-6.5 x $10^{-7}$ | 1-40 | 0.3-11.6 | ND | ND |

*ND = Not detectable

Table 2. Comparison of maximum measured radiation levels with current occupational standards

| Radiation region | Maximum level | Occupational standard | Reference |
|---|---|---|---|
| Ionizing (X-Ray) | ND* | 2.5 mR/hr | OSHA, 1980a |
| Near-Ultraviolet | $6.5 \times 10^{-7}$ W/cm$^2$ | $1.0 \times 10^{-3}$ W/cm$^2$ | NIOSH, 1972 |
| Visible | 40 fL (11.6 cd/m$^2$) | 2920 fL ($1.0 \times 10^4$ cd/m$^2$) | ACGIH, 1979 |
| Radiofrequency | | | |
| Electric Field | ND | 40,000 V$^2$/m$^2$** | OSHA, 1980b |
| Magnetic Field | ND | 0.25 A$^2$/m$^2$** | OSHA, 1980b |

* ND = Not detectable

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

Table 3. Summary of airborne chemical exposure levels for VDT operators

| Type of sample | Number of samples | Range (ppm) | Average (ppm) | OSHA Standard (ppm) |
| --- | --- | --- | --- | --- |
| Hydrocarbon | 42 | 1.4 - 4.8 | 2.4 | - |
| Carbon Monoxide | 16 | <1.0*- 3.0 | <1.4 | 50** |
| Acetic Acid | 1 | - | 0.5 | 10 |
| Formaldehyde | 1 | - | 0.1 | 3†<br>5 (ceiling)<br>10 (peak) |

* All less than values express the lower detection limit.

** The NIOSH (1973) Recommended Standard is 35 ppm.

† The NIOSH (1978) Recommended Standard is 0.5 ppm for a 30 minute sample.

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