Communications Research Centre

REVIEW OF HEALTH AND SAFETY ASPECTS OF VIDEO DISPLAY TERMINALS

by

W.C. TREURNIET

CRC TECHNICAL NOTE NO. 712-E

Department of Communications | Ministère des Communications

OTTAWA, FEBRUARY 1982

COMMUNICATIONS RESEARCH CENTRE

DEPARTMENT OF COMMUNICATIONS

CANADA

REVIEW OF HEALTH AND SAFETY ASPECTS OF VIDEO DISPLAY TERMINALS

by

W.C. Treurniet

(Informatics Applications Management Branch)

CRC TECHNICAL NOTE NO. 712-E

February 1982

OTTAWA

TABLE OF CONTENTS

ABSTRACT 1

1. INTRODUCTION 1

2. FATIGUE 2
   2.1 Visual Fatigue 2
      2.1.1 Reflections 2
      2.1.2 Contrast Glare 3
      2.1.3 Display Quality 3
      2.1.4 Ophthalmological Deficiencies 4
   2.2 Skeletal Muscle Fatigue 5

3. ENVIRONMENTAL CONDITIONS 6

4. JOB CHARACTERISTICS 7

5. ELECTROMAGNETIC EMISSIONS 8

6. CONCLUSIONS 9

7. REFERENCES 9

APPENDIX A — **Annotated Bibliography** 13
   A1. Visual Effects 13
   A2. Postural Effects 28
   A3. Job Characteristics 30
   A4. Radiation 31

REVIEW OF HEALTH AND SAFETY ASPECTS OF VIDEO DISPLAY TERMINALS

by

W.C. Treurniet

ABSTRACT

The paper reviews the factors that contribute to worker complaints when video display terminals are introduced into the workplace. Survey data from field experiments indicate that a number of ergonomic factors and job characteristics can contribute to reports of discomfort from VDT users. Specifically, reports of visual discomfort are related to improper ambient lighting (which can cause bothersome reflections and contrast glare), poor display quality, and ophthalmological deficiencies. Reports of muscle pain and fatigue are related to poor workstation design such as improper heights of chair, keyboard, and display screen, and absence of source document holder, and no support for the forearms and wrists. The literature suggests further that the frequency of such complaints is influenced by the worker's attitude regarding the job. A negative attitude arising from performing a meaningless, routine task, or from having no opportunities for career advancement, will result in more complaints due to ergonomic shortcomings.

The review also considers the issue of electromagnetic emissions from television displays. Recent surveys show that modern VDTs do not emit detectable radiation.

1. INTRODUCTION

Video display terminals (VDTs) are rapidly becoming the dominant interface between humans and modern information processing equipment in various environments. The spreading use has created concern about potentially harmful effects on the operator. Most dramatic were claims that the VDTs emitted electromagnetic radiation capable of producing undesirable biological changes. The resultant focussing of scientific attention on the VDT in the workplace, identified various ergonomic requirements that were often not met.

Inadequate VDT and workplace design was considered responsible for a number of operator complaints related to the use of VDTs. Shortcomings in functioning of the visual system were also identified as possible causes of complaints. Finally, psychological effects of task structure has recently prompted examination of the relation between job design and worker acceptance of VDTs. Evaluation of potentially negative effects of VDT usage in the context of the total working environment renders the task much more complex than when considering only the VDT and the operator.

This review examines current knowledge about the effects of VDT usage on the health and safety of the operator. The issue will be considered from the following perspectives: (1) visual and skeletal muscle fatigue due to inadequate VDT and workplace design, (2) environment and job characteristics, and (3) electromagnetic emissions. Much of the subjective data has been obtained from field studies which notoriously suffer from lack of adequate experimental control. For example, the control group may not have performed exactly the same job as the experimental group, or the percentage of survey questionnaires returned was so low that any differences between experimental conditions may be easily attributed to biased sampling. In spite of the methodological problems, it was possible to extract from the literature a consensus about the sources of problems associated with introduction of VDTs into the workplace. An annotated bibliography of relevant papers is attached as Appendix A.

2. FATIGUE

Complaints from VDT operators are usually divided into two categories. One category describes effects of visual fatigue, and the other describes effects of skeletal muscle fatigue. Visual fatigue results from various qualities of the display and its surroundings such as brightness and contrast. Skeletal muscle fatigue is accelerated by improper posture or support resulting from poor workplace design. This section expands upon these two kinds of fatigue.

2.1 VISUAL FATIGUE

The symptoms of visual fatigue experienced by VDT operators are described in the literature. Examples are irritation, discomfort, or watering of the eyes, dull headaches, loss of visual acuity, blurred or double images, and difficulty in keeping eyes open (*Ostberg, 1975; Bedwell, 1978; Elias et al., 1980; Smith, 1979*). Field studies of VDT workplaces have attributed responsibility for these complaints to some characteristics of the operator, of the display and of the environment. Specifically, reflections, contrast glare, poor image quality, and a number of ophthalmological deficiencies are the major factors blamed for visual fatigue.

2.1.1 Reflections

Reflections from the VDT screen and the keys on some keyboards are either diffuse reflections or specular reflections. Diffuse reflections originate from an indirect light source and can reduce display contrast by raising the background luminance of the display. This is not a serious problem as long as the background luminance does not exceed approximately 20 cd/m^2. The operator can usually increase the brightness of the display to achieve the recommended figure to ground contrast of 10:1 (*Cakir et al., 1980*). Specular reflections, however, have more serious consequences. These occur when the screen acts as a mirror to reflect images of the immediate environment which could contain direct light sources or other objects. Specular reflections can interfere in at least two ways with viewing the display contents. The added luminance due to the reflected image may cause discomfort due to glare when the source is of sufficient brightness. A more serious problem is the division of attention imposed by the reflection. Mental workload is increased when the operator must distinguish which elements of the visual array are or are not to be ignored. Further, since the focal planes of the displayed and reflected information lie at different distances from the eyes, either one or the other is perceived as a double image. Attempts to correct the double image defocusses the alternate image. Thus, there is a tendency for the accommodation position to oscillate between the two planes (*Cakir, 1980*).

Daylight from windows is the main source of reflections on VDT screens. Positioning the screen so that it is perpendicular to the plane of the window minimizes the reflection. The literature also recommends that screens be positioned perpendicular to flourescent lighting on the ceiling. Screen filters are also recommended to reduce reflections. However, these should be selected with caution. Some cause drastic reductions in screen luminance, and may even result in additional reflections from the filter surface. Keys on keyboards should have a matt finish to minimize discomfort from that source.

2.1.2 Contrast Glare

Contrast glare is another characteristic of the display and its environment that can contribute to operator complaints (*Ostberg, 1975; Stewart, 1979*). If a VDT operator is facing a bright window or is in a brightly lit room, pupillary size will vary drastically as the field of view moves from the bright areas to the relatively darker area of the screen surface. These sudden demands on the iridomotor system are correlated with feelings of discomfort. An apparent solution is to lower the light level in the room so that it corresponds more closely to the brightness of the screen. However, in many task environments, the VDT operator must also read paper documents for which sufficient light is required. A room light level of about 300 lux has been recommended as a compromise for the conflicting requirements (*Cakir et al., 1980*).

2.1.3 Display Quality

The quality of the displayed information influences the amount of effort an operator must expend to read the display. Display quality is multi-dimensional and various characteristics need to be considered. Dot matrix characters should be at least 5x7, and 7x9 is usually the preferred minimum for good legibility. Character heights should be at least 3 or 4 mm, and the angle subtended should be 15 to 20 min of arc. Character widths should be about .7 or .8 of the height. The dot size should be sufficiently large to create the impression of a continuous stroke. Recommendations for spacing between characters on a row vary from a space that is just discernible to one-half of a character height. The space between rows of characters is generally recommended to be about 100 to 150 percent of the character height. Characters should have a contrast of 10:1 relative to the background luminance of the screen (e.g., *Cakir et al., 1980*).

Although most VDTs currently display bright characters on a dark background (positive contrast), recent work indicates that dark characters on a bright background (negative contrast) results in better operator performance. Further, observers almost unanimously preferred negative contrast over positive contrast (*Radl, 1980; Bauer and Cavonius, 1980*). However, to avoid the presence of flicker on the display with negative contrast, the refresh rate needs to be in the range of 70 to 100 Hz. A display with negative contrast has a higher luminance than one with positive contrast. Thus, contrast sensitivity of the eye is improved, the resulting reduced pupil size gives improved depth of field, and the speed at which accommodation can change is increased (*Bauer and Cavonius, 1980*). The increased depth of field may be especially important to older operators who have lost much of their ability to accommodate.

The best colour for a monochrome display has also been the subject of some research. Green is often recommended because the visual system appears most sensitive to that colour (*Stewart, 1979*). However, in a study that compared the effect of green and yellow characters on task performance and a number of visual parameters including acuity and colour adaptation, yellow appeared more desirable than green (*Haider et al., 1980*).

Another study compared relative performance and preference with green, yellow-green, two hues of yellow, two hues of orange, and white. Again, the yellow hues gave better performance than green and were also more preferred. Poorest performance and the lowest preference scores were obtained with the orange hues (*Radl, 1980*).

2.1.4 Ophthalmological Deficiencies

It has been stated that as high as 30 percent of the population has uncorrected or inadequately corrected vision (*Cakir et al., 1980; Stewart, 1979*). These people are most likely to suffer from eyestrain even when using a well designed display and environment. Common defects are presbyopia, cataracts, oculo-motor imbalance, and convergence insufficiency.

Presbyopia, which becomes more prevalent with age, is the progressive reduction in the ability of the lens to accommodate over a wide range. This condition is a handicap when the screen and source documents lie at different distances from the eyes. Therefore, it is often recommended that the screen and source documents be placed at similar distances from the eye to reduce accommodation fatigue and to help the presbyopic operator (*Stewart, 1979*).

Convergence insufficiency is a defect in binocular vision characterized by blurring or double vision. These symptoms are a result of inaccurate merging of the input to each eye to form a binocular image. The symptoms can be diagnosed as a refractive error and mistakenly treated with corrective lenses rather than orthoptic exercises. Approximately 10 percent of ophthalmology patients may have this condition (*Mahto, 1972*).

Eye motion is controlled by six muscles. To achieve a given movement, at least two muscles must act cooperatively, one with increasing tension and the other with decreasing tension. Oculo-motor imbalance occurs when poor cooperation among the muscles results in unnecessary muscle tension. The abnormal tension can result in pain and fatigue (*Ostberg, 1975*).

Cataracts are cloudy spots in the lens of the eye. When the spots become large enough, partial or complete blindness can result. Although the frequency of identification of cataracts increases with age, the occurrence of cataracts in relatively young people between the ages of 35 and 45 has been reported to be about four percent (*Marshall, 1981*).

It has been suggested that viewing a VDT screen may be eased even for people with no refractive errors by fitting them with lenses that permit the wearer to focus at infinity while viewing the screen. Although this may combat myopic spasms that can occur following much near viewing, there is also some indication that conflict with the convergence subsystem may result. Accommodation and convergence are interdependent, and when the need for accommodation is removed, the still present need for convergence may cause eye strain (*Hartridge, 1919*). Perhaps lenses could be combined with prisms to remove the need for both accommodation and convergence at a predefined viewing distance. The assumption of one viewing distance is probably not valid for most work environments, however.

A need to improve the near point without decreasing the far point of accommodation is met for a number of people by prescribing bifocals. However, bifocals designed to facilitate reading from a paper source may require adoption of tiring postures when used to read from the VDT screen (*Stewart, 1979*). Therefore, optometrists need to prescribe bifocals suitable for the task of viewing VDT screens (*Bedwell, 1978*).

It is clear that existing defects of the visual system enhance the likelihood of fatigue from viewing a VDT. It is not as clear whether prolonged viewing causes permanent visual defects. Continuous near viewing is held by some to encourage the development of myopia. For example, Young (1981) found intraocular pressure to increase in monkeys as power of accommodation increased. He suggested that the increased pressure maintained for long periods was responsible for the lengthening of the eye to produce permanent myopia. However, Taylor (1981) maintained that there is no evidence from epidemiological studies that near work results in long-term changes in myopia. Ostberg (1980, 1981) found that intense VDT viewing induced a temporary presbyopia by causing the near point of accommodation to move farther away. Haider et al., (1980) found effects of VDT viewing on acuity and colour perception, but these effects were also temporary. Thus, it appears that prolonged VDT viewing temporarily affects the functioning of the eyes. However, there is no evidence that permanent changes occur.

2.2 Skeletal Muscle Fatigue

Nelson and Ladan (1976) showed that clerical office workers experience systematic variations in subjective fatigue over the course of a day or week. Fatigue was relatively high and constant during the morning hours, but decreased monotonically during the afternoon. Further, fatigue was relatively high on

Mondays and Fridays but low during the intervening days. Motivational and cognitive factors as well as muscle fatigue were suggested as explanations of these variations.

Corlett and Manenica (1980) investigated the use of reported pain and discomfort to measure the effect of sustained postures. Discomfort was found to be a function of maximum endurance time. That is, the amount of reported discomfort at a given time was proportional to the percentage of the total endurance time already experienced. Further, a 3/4 hour rest pause had a relatively small ameliorating effect on the amount of reported pain, and had no effect on the rate of increase of discomfort. The study concludes that maintenance of body postures for most of the working day will result in considerable pain.

These two studies suggest a priori that VDT operators will experience bodily discomfort if they work continuously for relatively long periods of time. It is not surprising, therefore, that field studies report the development of pain in particular areas of the body in keyboard operators (*Hunting, Laubli, and Grandjean, 1980; Elias et al., 1980; Hunting, Grandjean, and Maeda, 1980*). Although all keyboard operators reported more pain than clerical workers who did not use keyboards, the frequency of reported pain was much higher in data entry terminal operators than in conversational terminal operators and typists. Data entry terminal operators sit for longer periods of time in a constrained posture that encourages the development of pain in the neck, shoulders, and right arm and hand. Adequate back support, a forearm or wrist support, and a source document holder would help reduce muscle fatigue.

Anthropometric data are available to design a proper workstation. Because people vary in size, furniture should be easily adjustable (*Stewart, 1979*). The VDT screen and keyboard should be separately adjustable to accommodate operators of different sizes and different task requirements. The feet should be flat on the floor, the forearms approximately horizontal when the fingers are on the home row of the keyboard, and the line of sight should be about 20 to 40 degrees below the horizontal. It is also recommended that the paper source, keyboard and screen should all be the same distance from the eyes. Variations in posture during the work period are necessary to reduce the buildup of fatigue, and adjustable workstation components make this possible.

3. ENVIRONMENTAL CONDITIONS

VDT workstations are a new addition to the office environment, and can contribute to office noise. Noise from cooling fans on some models can be an irritant. Some workstations include hard copy printers that each create as much as 75 dB(A) of noise. This exceeds the 55 to 65 dB(A) levels considered desirable for office areas (*Stewart, 1979*).

VDTs generate heat that needs to be dissipated to avoid discomfort. Humidity control is useful to prevent eye irritation and feelings of itchiness due to excessive dryness of the air (*Stewart, 1979*). Excessive heat can contribute to development of hemmorhoids, especially if a worker is exposed to the heat of nearby machines.

Prolonged work on a VDT requires much visual accommodation at near distances. Therefore, the office environment needs to be designed so that the eyes can be rested by viewing a patterned space at a distance. The space may include a window view, an interesting office landscape that may include plants, or wall murals (*Stewart, 1979*).

4. JOB CHARACTERISTICS

Fatigue arises from physical exertion, and it can be exacerbated by negative cognitive and motivational aspects of the job. Because of the multidimensional nature of the job environment, it is difficult to be precise about the social and personal factors that facilitate fatigue.

Smith et al. (1980) found that workers in an environment where career growth was of concern, tended to be more anxious and irritable than workers in another environment where such was not the case. It was felt that inadequacies in job design contributed to frequency of health complaints from the VDU operators.

Elias et al., (1980) found that significantly more data acquisition operators than dialogue operators were dissatisfied with their job, and had more psychological, psychosomatic and visual strain symptoms. The data acquisition job was more restrictive, required less learning, and consisted of shorter work cycles than the more interactive job.

These studies show that one cannot refer to VDT operators as a homogeneous group. The managerial environment as well as the type of job being performed with the VDT influence the effects on the operator. Bertinuson (1981) ranks tasks performed with VDTs on a dimension loosely labelled low level to high level. Presumably, the dimension refers to the amount of control the operator has over pacing the work, and the amount of creativity involved in the job. Examples of jobs that fall along this dimension are as follows: data entry, data acquisition, interactive dialogue, word processing, programming, text composing, graphic design, and scientist. The first three types of jobs limit the operator to predefined formats, while the rest use the VDT as a tool with which to be creative. Because of the predefined formats in the first three classes of jobs, employers can use the computer to monitor employee productivity. This is often perceived as threatening by the operator. There is also a tendency to break jobs into smaller units and make them more routine, perhaps to reduce training time, or perhaps because computer programs tend to be inflexible. Gregory (1981) suggested that the data entry job may be improved by integrating more skills into the job, by giving operators more control over the pace of work and the way it is done, by more on-the-job training and opportunities for advancement, by increasing rest breaks, and by increasing pay or decreasing the length of the work week. Sauter (1981) noted that, although intelligent software can be used in a negative way by monitoring employee productivity, it can also help the operator by guiding cognitive processes and reducing cognitive load. Guion (1981) suggested that the complexity of the task should be matched to the capabilities of the person. Some people, who may not wish to perform challenging tasks, may prefer the monotony provided by data entry.

Rest pauses can help to reduce visual strain from working with a VDT (*Haider et al., 1980*). However, the optimum ratio of work and rest periods probably depends on the task (*Ostberg, 1975*). It has been suggested that a 15 minute rest be permitted for every hour worked, or a half hour rest for every two hours worked. Others suggest that an employee's work be organized so that two hours work at a VDT is followed by two hours spent doing other work that does not require visual accommodation at near distances. These options are available to a manager interested in safeguarding the health and happiness of his or her employees and in improving productivity.

5. ELECTROMAGNETIC EMISSIONS

The potential danger of radiation from VDTs has been a cause for concern by individuals, labour unions, governments, and industry. In response to this concern, a number of investigations have examined the levels of emission of ionizing and non-ionizing radiation from representative samples of VDTs and colour televisions (e.g., *Moss et al., 1977; Buckler, 1980; Wang, 1975; Murray et al., 1981*). The most recent studies show that modern VDTs do not emit detectable levels of radiation at any frequency. Recent publicity suggested that microwaves from VDTs were responsible for cataracts in the eyes of two New York Times newspaper employees and that x-radiation from VDTs at the Toronto Star was responsible for four cases of fetal deformity. However, tests of the VDTs, in both cases, showed no evidence of any radiation (*Marshall, 1981*).

Government authorities in Canada and the United States hold that modern VDTs and television displays do not produce detectable levels of ionizing radiation (*Letourneau, 1981; Marshall, 1981*). The National Institute for Occupational Safety and Health (NIOSH) in the United States claims a sensitivity of five times background radiation levels (*Murray et al., 1981*). Health and Welfare, Canada, is able to measure x-radiation levels that are one-thousandth of background levels (*Letourneau, 1981*). Zuk (personal communication) further indicated that manufacturers are requested by Health and Welfare to remove televisions from the marketplace in Canada if any x-radiation is detected during routine testing. This policy is justifiable because minimal expense is required with current technology to ensure that television tubes do not emit detectable x-rays.

A recent additional concern is the effect of a static electric field on the VDT operator. Ostberg (1981) noted that about 100 VDT operators in Scandinavian countries have suffered facial rashes. He hypothesizes that harmful ionized particles in particular environments are attracted to the face because of an electric field gradient of approximately 2000 volts between the face and the VDT screen. This voltage gradient would also influence the movement of ionized air molecules. There exists a controversial literature regarding the beneficial effect of negatively charged air ions on body chemistry and mood states (reviewed in *Soyka and Edmonds, 1977*). The negative potential at the operator would tend to repel negative air ions, and might cause discomfort such as migraine headaches, irritability, and depression. The effect of static electric fields at the VDT workstation requires further investigation.

6. CONCLUSIONS

Much of the field research measuring subjective responses to questions related to VDTs is flawed methodologically. Some flaws are the result of poor planning, while some are beyond the control of the researcher. Guion (1981) mentions five requirements for survey work that are often violated. These are (a) competent sampling, (b) competent job analysis, (c) competent measurements of variables of interest as well as ensuring their reliability and validity, (d) competent control (sampling or statistical), and (e) competent data analysis.

In spite of the difficulties encountered by researchers, the literature gives a definite sense that workplaces and jobs are not always designed with proper consideration for the welfare of the worker. Ergonomic requirements are not always met, causing workers to suffer visual strain and bodily discomfort. The psychological environment can be negative due to labour-management conflicts, career uncertainty, and managerial insensitivity. Ergonomic inadequacies by themselves are often tolerated by highly motivated workers. However, these same workers will turn into complainers when motivation and self-esteem drop because of poor job design. A good work environment appears to be one where both the physical and psychological needs of the employees are seriously addressed by those in control.

This report also examines the issue of operator safety with regard to emission of electromagnetic radiation from televisions. Modern televisions do not emit detectable levels of radiation at any frequency. There is, therefore, no danger from electromagnetic emissions.

7. REFERENCES

Anderson, G.E., Tell, R.A. and Youmans, H.D. *Spectral Transmission and Attenuation of X-Radiation by Glasses and Resins used in Color Television Picture Tubes.* IEEE Trans. on Broadcast and Television Receivers, Vol. BTR-16 (2): 82-88, 1970.

Bauer, D. and Cavonius, C.R. *Improving the Legibility of Visual Display Units through Contrast Reversal* in Ergonomic Aspects of Visual Display Terminals, E. Grandjean and E. Vigliani, (Eds.), London: Taylor and Francis, 1980.

Bedwell, C.H. Assessment of Eye Strain and Difficulty in Viewing Visual Display Units. Proc. of the Ergonomics Society Conference on *Eyestrain and VDUs*, Loughborough Univ. of Technology, December, 1978.

Bertinuson, J. Panel participant at the Symposium on Video Display Terminals and Vision of Workers, Washington, D.C., 1981.

Braestrup, C.B. and Mooney, R.T. *X-Ray Emission from Television Sets.* Science, 130:1071-1074, 1959.

Buckler, G. *VDT Radiation Levels not Harmful, Tests Show.* Computing Canada, p. 4, November 25, 1980.

Cakir, A.E. *Human Factors of VDU Design.* In P.A. Kolers, M.E. Wrolstad, and H. Bouma (Eds.), Processing of Visible Language 2, New York: Plenum Press, 1980.

Cakir, A., Hart, D.J., and Stewart, T.F.M. *Visual Display Terminals*, Toronto: John Wiley & Sons, 1980.

Charlton, M.H. and Hoefer, P.F.A. *Television and Epilepsy.* Archives of Neurology, 1964, 11:239-247.

Corlett, E.N. and Manenica, I. *The Effects and Measurement of Working Postures.* Applied Ergonomics, 1980, 11:7-16.

Eleccion, M. *X-Radiation from Colour Television Receivers.* IEEE Spectrum, pp. 95-104, July, 1968.

Elias, R., Cail, F., Tisserand, M., and Christmann, H. *Investigations in Operators Working with CRT Display Terminals: Relationships between Task Content and Psychophysiological Alterations* in Ergonomic Aspects of Visual Display Terminals, E. Grandjean and E. Vigliani, (Eds.), London: Taylor and Francis, 1980.

Gregory, J. Panel participant at the Symposium on Video Display Terminals and Vision of Workers, Washington, D.C., 1981.

Guion, R. Panel participant at the Symposium on Video Display Terminals and Vision of Workers, Washington, D.C., 1981.

Haider, M., Kundi, M., and Weibenbock, M. *Worker Strain Related to VDUs with Differently Coloured Characters* in Ergonomic Aspects of Visual Display Terminals, E. Grandjean and E. Vigliani, (Eds.), London: Taylor and Francis, 1980.

Hartridge, H. *Physiological Eye-Strain.* Proc. of the Physiological Society, May, 1919.

Harvey, T.S. *Experiments with White Rats, Bush Beans, and Tradescantia Plants in the Vicinity of Television Receivers.* IEEE Trans. Broadcast and Television Receivers, Vol. BTR-13: 51-63, July, 1967.

Health and Welfare, Canada. *The Television Set and X-Radiation.* Dispatch No. 31 (Revised), Educational Services, Health Protection Branch, Summer, 1978.

Hopkinson, R.G. *Glare Discomfort and Pupil Diameter.* J. Opt. Soc. Am., 1956, 46:649-656.

Hunting, W., Laubli, T. and Grandjean, E. *Constrained Postures of VDU Operators* in Ergonomic Aspects of Visual Display Terminals, E. Grandjean and E. Vigliani, (Eds.), London: Taylor and Francis, 1980.

Hunting, W., Grandjean, E., and Maeda, K. *Constrained Postures in Accounting Machine Operators.* Applied Ergonomics, 1980, 11:145-149.

Kelly, R.B. *The Effect of Direction of Contrast on TV Legibility under Varying Ambient Illumination.* Reviewed in Legibility of Alphanumeric Characters and Other Symbols, D.Y. Cornog and F.C. Rose, National Bureau of Standards Misc. 262-2, 1967.

Laubli, T., Hunting, W., and Grandjean, E. *Visual Impairments in VDU Operators Related to Environmental Conditions* in Ergonomic Aspects of Visual Display Terminals, E. Grandjean and E. Vigliani (Eds.), London: Taylor and Francis, 1980.

Letourneau, E.G. *Are Video Display Terminals Safe?* Canadian Medical Association Journal, 1981, 125:534.

Mahto, R.S. *Eye Strain from Convergence Insufficiency.* British Medical Journal, 1972, 2:564-565.

Marshall, E. *FDA Sees no Radiation Risk in VDT Screens.* Science, 212:1120-1121, 1981.

Moss, C.E., Murray, W.E., Parr, W.H., Messite, J., and Karches, G.J. *A Report on Electromagnetic Radiation Surveys of Video Display Terminals.* National Institute for Occupational Safety and Health, Report No. NIOSH 78-129, December, 1977.

Murray, W.E., Moss, C.E., Parr, W.H., and Cox, C. *A Radiation and Industrial Hygiene Survey of Video Display Terminal Operations.* Human Factors, 1981, 23:413-420.

Nelson, T.M. and Ladan, C.J. *Patterns and Correlates of Fatigue among Office Workers.* J. Occup. Psychol., 1976, 49:65-74.

NYCOSH, *New Technology: Danger and Opportunity for Workers.* New York Committee for Occupational Safety and Health, 1980.

Ostberg, O. *CRTs Pose Health Problems for Operators*, Int. J. Occup. Health and Safety, 44(6):24-26, 1975.

Ostberg, O. *Accommodation and Visual Fatigue in Display Work* in Ergonomic Aspects of Visual Display Terminals, E. Grandjean and E. Vigliani, (Eds.), London: Taylor and Francis, 1980.

Ostberg, O. Panel participant at the Symposium on Video Display Terminals and Vision of Workers, Washington, D.C., 1981.

Radl, G.W. *Experimental Investigation for Optimal Presentation Mode and Colours of Symbols on the CRT-Screen* in Ergonomic Aspects of Visual Display Terminals, E. Grandjean and E. Vigliani, (Eds.), London: Taylor and Francis, 1980.

Sauter, S. Panel participants at the Symposium on Video Display Terminals and Vision of Workers, Washington, D.C., 1981.

Smith, M.J., Stammerjohn, L.W., Cohen, B.G.F., and Lalich, N.R. *Job Stress in Video Display Operations* in Ergonomic Aspects of Visual Display Terminals, E. Grandjean and E. Vigliani, (Eds.), London:Taylor and Francis, 1980.

Smith, W.J. *A Review of Literature Relating to Visual Fatigue*. Proc. of the Human Factors Society, 23rd Annual Meeting, Boston, Mass., pp. 362-366, 1979.

Soyka, F. and Edmonds, A. *The Ion Effect*, Toronto: Lester and Orpen, 1977.

Sperling, G. *Flicker in Computer-Generated Visual Displays: Selecting a CRO Phosphor and other Problems*. Behav. Res. Meth. & Instrum., 1971, 3:151-153.

Stewart, T.F.M. *Eyestrain and Visual Display Units: A Review*. Displays, 1:25-32, April, 1979.

Taylor, H. Panel participants at the Symposium on Video Display Terminals and Vision of Workers, Washington, D.C., 1981.

Young, F. Panel participant at the Symposium on Video Display Terminals and Vision of Workers, Washington, D.C., 1981.

Wang, Y-S. *Measurement of Ionizing Radiation from Color Television Receivers by Thermoluminescent Dosimeters*. Health Physics, 28(1):78-80, 1975.

APPENDIX A

Annotated Bibliography

This appendix contains an annotated bibliography of literature relevant to the issue of health and safety aspects of visual display terminals. Papers were included when they were judged to make a significant contribution to knowledge. Original sources and comprehensive reviews fulfilled this criterion. Brief reviews in newspapers and trade journals were not considered useful.

A1. VISUAL EFFECTS

Bauer, D. and Cavonius, C.R. *Improving the Legibility of Visual Display Units through Contrast Reversal* in Ergonomic Aspects of Visual Display Terminals, E. Grandjean and E. Vigliani, (Eds.), London: Taylor and Francis, 1980.

The study examined the effect of direction of contrast on performance measures and preference. Typically, VDT displays present bright letters on a dark background. Reversing the direction of contrast has several advantages. The increased display luminance enhances contrast sensitivity of the eyes. Further, the higher adaptation level encourages more rapid accommodation, and the smaller pupil diameter improves depth of field and reduces optical distortions. The increased depth of field is particularly important for older viewers who may have lost much of their ability to accommodate.

The disadvantage of reversed contrast is the increased perceptibility of flicker due to the higher screen luminance. Eight observers were allowed to increase the refresh rate of a VDU until flicker just disappeared. The screen was a P4 (white) phosphor operating at a luminance of 200 cd/m^2, without pattern. Flicker disappeared in peripheral vision when the refresh rate was raised to 90 Hz. To ensure the complete absence of flicker, a refresh rate of 100 Hz was used in subsequent experiments. Display luminance was set at 80 cd/m^2 to match the luminance of typical documents on a desk when room illumination was 550 lux.

The first experiment required recognition of a four-letter nonsense word displayed on the VDU. The positive contrast condition was defined as conventional light letters refreshed at 50 Hz on a low, 4 cd/m^2 background, and the negative contrast condition was dark letters on an 80 cd/m^2 background refreshed at 100 Hz. The negative contrast condition resulted in 26 percent fewer errors than the conventional positive contrast condition.

A second experiment required the detection of spelling discrepancies of nonsense words on the VDU screen compared to similar words typed on paper. Again, the negative contrast condition resulted in 23 percent fewer errors in performance than the positive contrast condition. Additionally, performance with negative contrast was about eight percent faster.

Of the 13 men and 10 women who participated in one or both of the experiments, all but one preferred the display with negative contrast. Comments were that it was easier to read and more comfortable to use. Positive contrast was described as requiring more effort and being more tiring.

Bedwell, C.H. *Assessment of Eye Strain and Difficulty in Viewing Visual Display Units.* Proc. of the Ergonomics Society Conference on Eyestrain and VDUs, Loughborough Univ. of Technology, December, 1978.

The review considers various factors that are thought to contribute to eye strain while viewing VDUs. Symptoms of prolonged viewing may consist of headaches or eyes hurting, as well as a pulling feeling across the forehead or around the eyes, facial and ocular muscular stress, tired eyes, blinking or twitching of the lids, difficulty in keeping the eyes open, a feeling of drowsiness, and watering or red eyes. Viewing under stressed conditions may be accompanied by postural tension and discomfort at the back of the head and down the neck and back, as well as nausea if convergence of the eyes is being maintained with difficulty. There may also be increased sensitivity to light. Discomfort can be aggravated by adverse environmental aspects such as excessive job pressure, background noise, excessive heat, and lack of visual task change or rest. Even when optical conditions are adequate, there may still be misreading of characters along or down lines due to visual anomalies such as confusion, blurring, or doubling of characters. These effects are more likely to occur upon quick transfer of gaze, especially where binocular coordination is less used and stable.

Viewing distance should be within the outer limits of a common reading distance (40 to 50 cm). This will avoid excessive demands on convergence, and is within the range for stable binocular control. If visual task areas are in unaccustomed locations, stable dynamic binocular alignment may be difficult and binocular image confusion and errors such as double vision may occur. In general, difficulty of convergence is greater at or above the horizontal than below since we habitually look down when we read. The visual task areas include the VDU keyboard, paper documents containing data to be processed, as well as the VDU screen. Segments of bifocals worn by operators must be of sufficient width to view all viewing areas without excessive head movement.

Cakir, A.E. *Human Factors of VDU Design.* In P.A. Kolers, M.E. Wrolstad, and H. Bouma (Eds.), Processing of Visible Language 2, New York: Plenum Press, 1980.

The paper reports on a field study covering more than 1000 subjects in 30 sites. In general, the study found that visual strain is one of the most significant problems in working with VDTs. However, it cannot be measured objectively. Visual strain is highly correlated with optical properties of CRT displays as well as paper documents and keyboards. In particular, backaches, neckaches, and headaches increased with increased duration of working with VDTs ($r = .59$), text on paper documents was harder to read than on VDTs, and black keyboards were related to a higher incidence of eye irritation and general fatigue than grey keyboards.

Recommendations for a bright environment:

- display background should have minimum luminance of 10 cd/m^2.
- optimum contrast between display and background is 8:1 to 10:1. Therefore, character luminance should be about 80 to 100 cd/m^2.
- minimum character size should be 18 minarc at 50 cm. Character size should be at least 3 mm.
- reflections should be minimized without diffusing character images (as some filtering techniques do).
- flicker or jitter should be avoided.
- keytops should be light in colour with a matt finish (about 40 to 60 percent reflection).
- function keys should be colour coded to reduce search time.
- a daylight room should be illuminated by at least 300 lux of artificial light.

Reflections were found to be a major source of distraction and discomfort. Reflections reduce brightness contrast of the display. Contrast reduction can be decreased by repositioning the display, or by use of some types of screen filters. Fine-grained anti-reflection coatings or a high-quality etched screen surface are most preferred of the filters available. Micromesh filters effectively reduce reflection but also reduce the luminance of the display.

Reflected images obscure the display. This occurs in at least two ways. First, patterns in the reflection interfere with the patterns projected by the display. Second, the reflections lie in a different focal plane from the display contents, resulting in accommodation difficulty. Accommodation oscillates between the display contents and the reflected image. In general, this type of disturbance can be minimized by ensuring that light sources are unstructured and no brighter than necessary to read paper documents. Reflections can be a source of glare which can be an irritant in itself.

Cakir, A., Hart, D.J., and Stewart, T.F.M. *Visual Display Terminals*, Toronto: John Wiley & Sons, 1980.

The book is subtitled A Manual Covering Ergonomics, Workplace Design, Health and Safety, Task Organization. Each of these subjects are comprehensively discussed as the authors view the current knowledge related to the proper use of VDTs.

Chapter 1 describes the operation of a VDT, including the CRT, the keyboard, radiation emissions, and how the VDT is a component of a larger system. Chapter 2 discusses light, vision, and the optical characteristics of visual displays. Chapter 3 discusses the ergonomic requirements for VDTs including legibility requirements, image stability, and keyboard design. Chapter 4 discusses the ergonomic requirements for VDT workplaces including anthropomorphic aspects of the workplace, and the optimum working environment. Chapter 5 is concerned with the health, safety and organisational aspects of working with VDTs. Factors contributing to postural and visual discomfort are discussed, as well as psychological aspects of the work. The latter include studies of mental work load, alienation, fatigue and monotony, job satisfaction, workload and time pressure, and the need for rest pauses. Appendices include an ergonomic checklist for VDTs and VDT workplaces, and a discussion of eye tests for VDT operators.

The book appears invaluable for anyone seriously interested in optimizing the VDT user's working environment. An extensive bibliography is provided for anyone wishing to see original sources of the information in the book.

Charlton, M.H. and Hoefer, P.F.A. *Television and Epilepsy.* Archives of Neurology, 1964, 11:239-247.

The paper describes nine case studies of epileptic seizures in the United States apparently precipitated by watching television. These cases are in addition to three in the United States and at least 55 in Europe that were already reported.

1. A 14 year old boy complained of a headache and dizziness while watching television, and then lost consciousness. Some weeks later, the same thing happened while changing channels on the television. Photic stimulation during a medical examination yielded a photoconvulsive response between 7 and 50 flashes/sec. There was also a response to sudden bright light at rates above fusion frequency.

2. A 10 year old boy suffered a 30 min period of confusion while watching television before breakfast. Under similar circumstances some weeks later, he experienced a seizure. Photic stimulation during a medical examination showed a photoconvulsive response between 10 and 18 flashes/sec. The patient suffered two more convulsions subsequently while watching television before breakfast.

3. A female patient suffered two grand mal seizures while watching television at ages of 13 and 14. A photoconvulsive response was noted from 12 to 20 flashes/sec.

4. A six year old boy experienced seizure-like behaviour while watching television. Two years later, he experienced a second attack while watching television before breakfast. The resting EEG showed paroxysmal discharges, and photic stimulation above 10 flashes/sec produced a convulsive response. At 14 flashes/sec, the patient lost consciousness.

5. A female patient suffered headache, nausea, and vomiting between the ages of 9 and 11, always while watching television. She blamed especially one channel on the family television which was stated to "function poorly". The EEG showed a pattern of discharges indicative of petit mal which were precipitable by photic stimulation at frequencies above 10 flashes/sec. A response was also produced by irregular flicker at a relatively high frequency.

6. A 10 year old boy suffered two attacks, both while watching television. The EEG showed activity consistent with a convulsive disorder. However, photic stimulation produced no change in the background EEG.

7. A 10 year old boy suffered two epileptic attacks, both while watching television. At age 11, he had three more attacks not related to viewing television. At age 13, a neurological examination showed that photic stimulation produced a photoconvulsive response at from 10 to 20 flashes/sec.

8. A nine year old girl suffered a convulsion while adjusting a television set in England. Five days later, another seizure was experienced while she was turning on the television set. A year later, there was another attack while watching television, and at age 12, two more seizures occurred while watching television. At age 14, she was given a neurological examination. The resting EEG showed spontaneous seizure patterns, and a convulsive response above 10 flashes/sec.

9. An eight year old girl had two seizures within one month, both while watching television. Questioning revealed no indication that the set had functioned abnormally. The resting EEG was markedly abnormal, but photic stimulation showed no response.

The author notes that the majority of reported cases of epilepsy associated with television viewing fall within the pediatric age group (i.e., six to 14 years). This implies that this age group may be particularly sensitive to photic stimulation. In two cases, seizures occurred before breakfast, suggesting that hypoglycemia may be an aggravating factor.

Seizures were occasionally elicited during a loss of vertical synchronization or while the channel was being changed. Loss of vertical hold results in rhythmical photic stimulation. However, irregular flashes or a single flash were shown to be capable of eliciting a convulsive response. It was thought that the 25 or 30 Hz refresh rate of the video interlaced fields may, in some cases, be epileptogenic. Patients were told not to watch faulty televisions, to stay at a good distance from the screen, and to have someone else adjust the channels.

Haider, M., Kundi, M., and Weibenbock, M. *Worker Strain Related to VDUs with Differently Coloured Characters* in Ergonomic Aspects of Visual Display Terminals, E. Grandjean and E Vigliani, (Eds.), London: Taylor and Francis, 1980.

The study examined the effect of different colour displays on various measures obtained from 13 female VDT operators ranging in age from 21 to 41. Nine female office workers ranging in age from 23 to 45 served as controls. Green and yellow were the colours tested. Although not specifically stated, it is assumed that these colours were the colour of text displayed on a dark background. Dependent measures reported were "subjective state", visual acuity, colour-contingent after-effects, organization of perception, and activation reflected by heart rate. Performance on several tasks conducted over a three-hour period was also measured. Tasks consisted of text comparison from screen to screen, copying alphabetic character groups from copy (paper) to screen, copying alphabetic character groups from screen to screen, translating Swahili words from copy to screen, search and calculation from screen to screen, and finally, text comparison from copy to screen.

Performance improved over the three hours for both groups. However, performance with the yellow characters was lower at the beginning and higher at the end than with the green characters. This interaction was thought to be due to a relative lack of experience with yellow characters. After the novelty effect was over, subjects performed better with yellow characters.

Changes in visual acuity were measured during and up to 15 mins. following the work period. The yellow characters produced a smaller reduction in acuity than the green characters. Evidence was also presented that a rest pause after the first hour prevents a further loss of acuity after the second hour. However, a four hour work period with rest pauses resulted in considerable loss of acuity. These data support the need for shorter work periods as well as for periods with breaks.

Measurement of colour-contingent after-effects using an anomaloscope showed a smaller effect from using yellow rather than green characters. After work, the measured values tended to return to baseline, but even after 15 mins. the baseline values were not completely restored.

Effects of colour on visual organization was inferred from the magnitude of the Muller-Lyer illusion after the work period. Immediately after the work period, the illusion was strongest for those who read yellow characters. However, the illusion returned to baseline more quickly than for those who read green characters. This interaction may also be related to the difference in experience with the two colours.

Subjective ratings showed that VDT operators were significantly more tired and sleepy than office worker controls after the three hour work period. However, there was no significant difference between work with green and yellow displays.

The authors conclude that yellow characters should be recommended in the future for use with VDTs. However, both colours are satisfactory from a psychophysiological point of view.

Hartridge, H. *Physiological Eye-Strain.* Proc. of the Physiological Society, May, 1919.

The author notes that eye-strain is often considered to be due to excessive use of accommodation in cases of hyper-metropia (long sight). This explanation is difficult to apply to eye-strain in myopic persons. Fatigue of the ciliary muscles cannot explain the experienced discomfort. The author also notes that there is a close association between the control of convergence and accommodation in the visual system. He hypothesizes that eye-strain arises when demands are placed on either accommodation or convergence alone, and that the visual system is most comfortable when accommodation and convergence occur together.

This hypothesis is supported by the observation that eye-strain develops quickly when reading is done with special lenses that have a focal length equivalent to the reading distance. With these lenses, no accommodation is required but convergence of the eyes must still occur to avoid a double image.

Hopkinson, R.G. *Glare Discomfort and Pupil Diameter*. J. Opt. Soc. Am., 1956, 46:649-656.

The study examined the relationship between pupil diameter and sensation of discomfort that results from a bright light source in the field of view. Although pupil diameter is influenced by incident light levels, there was not a clear relationship between pupil diameter and magnitude of glare sensation. It was observed that a very bright source will cause an irregular cyclic variation in pupil diameter which has a period of a few seconds. This variation is itself not unusual as it occurs when an observer fixates normally in the absence of glare. The author speculates that discomfort arises when conflicting signals attempt to adjust pupil size to match first the glare source, then the background. The author also cites a private communication with H.C. Weston who suggested that the pupil variation may be an emotional response to pain. Pain causes the pupil to dilate. Dilation increases the light admitted from the glare source. The increased light input signals the pupil to constrict. Oscillation of pupil diameter could result as the effects of pain and sensory input continue to produce conflicting actions.

Kelly, R.B. *The Effect of Direction of Contrast on TV Legibility under Varying Ambient Illumination*. Reviewed in Legibility of Alphanumeric Characters and Other Symbols, D.Y. Cornog and F.C. Rose, National Bureau of Standards Misc. 262-2, 1967.

The effect of ambient illumination on television legibility was studied. Twelve subjects viewed for 15 sec each, 20 white-on-black or black-on-white characters on a closed circuit, 675 line television. Characters were 1/8 inch high and spanned five scan lines. Performance decreased as ambient illumination increased. It was concluded that white characters are suitable for low (.026 foot-candles) ambient illumination, while black characters are most suitable under high (more than 186 foot-candles) ambient conditions.

Laubli, T., Hunting, W., and Grandjean, E. *Visual Impairments in VDU Operators Related to Environmental Conditions* in Ergonomic Aspects of Visual Display Terminals, E. Grandjean and E. Vigliani (Eds.), London: Taylor and Francis, 1980.

The causes of eye impairments were studied in four groups of office workers. The groups consisted of users of data entry terminals, users of conversational terminals, users of office typewriters, and those who performed traditional office work. The latter performed the same task as the users of conversational terminals, but in a phase before the introduction of VDUs.

Data was collected using a survey inquiring about physical impairments in various parts of the body, about drug consumption, and about working conditions. A medical examination of upper extremities and vision was also conducted.

A variable called the Uniformity Figure (UF) was defined to describe an aspect of raster displays. The periodic refresh results in approximately sinusoidal variations in the intensity of a picture element (pixel). Further, there is a baseline intensity influenced by the background luminance below which the sinusoid does not go. If the base height is "a" and the amplitude of the sinusoid is "b", UF = a/b. The UF, therefore, is a measure of luminance oscillation. The UF of characters was measured by focusing the optic system of the photometer on a completely illuminated field of about 1 mm^2. The UF of the screen was measured by focusing on the whole screen. The refresh rate was 50 Hz, and both green and white phosphors were used.

The UF was measured under lighting conditions selected by the operator. The UF of single characters was significantly higher for data entry terminals than for conversational terminals. This finding may be related to the fact that conversational terminal operators raised the contrast of the display in order to improve reading conditions. The data entry operators mainly viewed the source document rather than the VDU screen.

Analysis of the survey data showed that the incidence of visual impairments was high in the two VDU groups and among the typists, but moderate in the traditional office workers. The impairments appeared related to eye fatigue or irritation and to impaired accommodation. Impairments frequently persisted following work periods and interfered with television viewing and reading during leisure time. Frequency of reported eye impairments was positively correlated with measured display contrast and high luminance oscillation (i.e., low UF). Contrast was generally above the recommended level. Degree of reported annoyance was positively correlated with measured intensity of reflections, but there was no relation between reported eye impairments and reflections.

A high luminance oscillation (i.e., a low UF) was related to complaints of eye irritations but seemed independent of complaints of impaired accommodation. A low UF was also strongly related to a decrease in measured visual acuity. Contrast variations showed no effect on visual acuity. Incidentally, the authors note that perceptibility of flickering characters is not significantly dependent on the oscillation level defined by the UF. They conclude that the degree of flicker and the degree of luminance oscillation are both important criteria to evaluate a terminal display.

Mahto, R.S. *Eye Strain from Convergence Insufficiency.* British Medical Journal, 1972, 2:564-565.

The paper maintains that a common cause of eye strain and headache is convergence insufficiency. Out of a population of 310 patients, 34 had varying degrees of this problem. Of these 34 people, 70.5 percent were women and 29.4 percent were men. Convergence insufficiency is often mistaken for refractive error, and corrective glasses are usually prescribed instead of orthoptic exercises. Patients should be advised to seek ophthalmological treatment if ocular symptoms persist following treatment for refractive error.

New Technology: Danger and Opportunity for Workers. New York Committee for Occupational Safety and Health, 1980.

This paper reviews the problems associated with use of VDTs in the office environment, and discusses measures that can be taken to reduce negative effects of VDT use. Common complaints voiced by VDT operators are (s) soreness, redness, stinging, itching, irritation, and general discomfort of the eyes, (b) pains in the neck and back, (c) dull headaches, (d) loss of visual acuity (seeing blurred or double images and fuzzy, coloured fringes), (e) dizziness and nausea, (f) problems with eyeglasses and contact lenses. These health problems are often caused by a combination of poor machine design and maintenance, incorrect office layout and lighting, and too few rest pauses.

One cause of eye strain may be fatigue of the muscles of the eye. These include the oculomotor muscles, the iris muscles, and the ciliary muscles. The ciliary muscles are responsible for compressing the lens for focussing at close range. Extended viewing at close range is thought to be very tiring to these muscles. Rest pauses are recommended during which the operator should view at greater distances. Two hours is thought to be the maximum time that should be spent doing continuous screen work. This kind of administrative control of a health hazard might require a fifteen minute break every hour or a half hour every two hours, or workers may alternate so that one hour is spent working with the VDT and the next hour is spent doing another kind of work involving viewing at greater distances.

Eye strain can arise from glare on the VDT screen from window light, shiny work surfaces, keyboards, and too bright artificial lighting. Neck and back pains may also be caused by glare as operators contort body position to minimize interference from glare. Glare can be reduced by equipping VDTs with non-reflective screens. Other measures that can be taken to prevent glare are: (a) installation of blinds or awnings on nearby windows, (b) relocation of machines or lighting fixtures, (c) installation of properly designed indirect lighting, (d) reduction of general lighting without interfering with reading from paper documents, and (e) installation of dimmers so that operators can control the level of overhead lighting.

Another cause of eye strain is contrast glare arising from a background that is much brighter than the VDT screen. Because the pupils adjust to the total light entering the eye, the screen images become difficult to see. Again, back and neck pains can result from uncomfortable postures adopted to block the brighter light source. The problem can be minimized by reducing the brightness of the background by shading windows or changing the colour of walls. Brightness controls on the VDT should always be accessible so that contrast glare can be somewhat under the control of the operator.

Flicker arising from the way the image is refreshed can also be an irritant. Reducing the brightness of the display will decrease the possibility of flicker. Again, the need for a brightness control is apparent.

Poor design of screen size and colour can result in less than optimum readability. It is better to have a relatively large screen, a viewing distance in excess of two feet, and character heights of at least 3/16 of an inch. A detachable keyboard allows viewing distance to be adjusted by the operator. It is recommended that screen colour be dark green and that characters be light green or yellow. However, the question of which colour combination is optimum is very much a research issue.

Defects in display quality that develop during use of the machine (e.g., blurring) need to be corrected by adequate maintenance.

Designers of corrective lenses must take into account that the wearer works on a VDT, since special lenses may be required. Bifocal wearers need to be especially careful that postural problems do not arise during viewing.

Muscle fatigue results from maintenance of a fixed posture for a long time. However, some positions are less fatiguing than others. The most comfortable viewing position is with the eyes looking slightly downward. Since people vary in size, screen height and angle should be adjustable by the operator. A detachable keyboard is also recommended to permit independent adjustment of keyboard and display.

Sitting for long periods under poor conditions may cause other health problems such as back pains, varicose veins, and hemmorhoids. The latter problem is more likely when seating is exposed to the heat of nearby machines. Any condition of employment that increases stress, such as a feeling of lack of control, can compound the stressful effect of poor workplace design.

Employees are advised to encourage the employer to respond to demands for safety and health on the job by:

1. using union pressure to provide adequate rest breaks, eye exams at employer's expense, specific improvements of the work environment, and union participation in equipment purchasing decisions.

2. providing training sessions for all employees as well as educational materials on occupational safety and health.

3. keeping records of problems with individual machines and of operator complaints.

The paper closes by considering the possibility of hazards from radiation emitted by VDTs. Although limited tests have been done by government and industry, the results have been challenged since some radiation frequencies were not tested, and most machines were not tested at all. It is argued that manufacturing defects or poor maintenance could cause higher levels of radiation to be emitted, and that there is no known safe level of exposure.

Ostberg, O. *CRTs Pose Health Problems for Operators*, Int. J. Occup. Health and Safety 44(6):24-26, 1975.

Literature related to ergonomics of the office environment is reviewed. Problems in work place design can give rise to fatigue. Fatigue can be expressed by specific symptoms or can have a more general effect on the whole body and mind. There are large individual differences in the conditions that can lead to fatigue.

The likelihood of fatigue is increased by postural defects. Incorrect posture arises from badly designed office furniture as well as task demands. For example, visual tasks are often not at the same location as the work surfaces of the hands. Bad posture can arise if the visual task forces unnatural positioning of the body.

Fatigue can arise from continued processing of information even when no physical effort is involved. This is particularly so when there is a lack of rest pauses. VDU operators often pause while waiting for a response from the computer. However, because the pause duration is unpredictable, the pauses are actually stressors. Although good work organization and efficient rest pauses are important for reducing fatigue, no recommendations are offered regarding the optimal ratio of work and rest periods.

Discomfort due to fatigue is more likely to be observed when there is decreased job involvement. Such alienation arises easily when the work is computerized because of insufficient efforts to avoid the creation of highly specialized and routinized tasks.

Visual fatigue symptoms described by VDU operators as well as others, fall into four categories. Ocular symptoms include uncomfortable, heavy, burning sensations around the eyes. Visual symptoms are forms of disturbed vision such as double vision and colour fringes around objects, as well as difficulty in fixating objects. Systemic symptoms, the most common, are pains in the head, neck and arms. Finally, behavioural symptoms are actions taken by individuals to make the visual task easier or to avoid distractions such as glare.

Eye defects such as refractive disorders and cataracts interfere with the visual task. Inadequate accommodation power can interfere with the ability to view objects much separated in depth. Oculo-motor imbalance (phoria) is thought to be a common source of fatigue.

Fatigue arises from inappropriate lighting conditions that result in glare and reflections. Specification of the best lighting conditions must consider the particular visual task.

Characteristics of the object to be viewed can lead to fatigue. The size of the object, and the contrast (brightness and colour) between the object and its background, must satisfy certain requirements. Viewing distance can influence the ability to view objects at different depths. Blurring of objects contributes to visual fatigue as does flicker and relatively slow variations in average brightness that require adaptation. Viewing comfort is enhanced when the eyes are directed downward at an angle of 20 degrees.

Since general fatigue facilitates visual fatigue, the type of work is important. Systemic fatigue arises from a monotonous job as well as from the stress of not understanding or accepting the peculiarities of the computer system. Fatigue from a data entry task can arise because the task is both boring and demanding. A man-computer dialogue can generate fatigue when the interaction is hostile to the operator in terms of logic, syntax, format, and response times.

Another more specific cause of visual fatigue is contrast glare when the eyes adapt to a relatively bright background luminance and not to the screen luminance. The requirement for sufficient light to read paper documents conflicts with the requirement for low ambient illumination in order to read a CRT display.

Flicker is another visual irritant when viewing CRT displays. It is estimated that at least 40 percent of clerical workers find 60 Hz CRT flicker uncomfortable. Cost considerations inhibit manufacturers from making VDUs with higher, invisible refresh rates.

Radl, G.W. *Experimental Investigation for Optimal Presentation Mode and Colours of Symbols on the CRT-Screen* in Ergonomic Aspects of Visual Display Terminals, E. Grandjean and E. Vigliani, (Eds.), London: Taylor and Francis, 1980.

The first study examined ways to improve readability of a VDU screen placed in a poor optical environment containing glare sources such as windows or bright walls. Contrast glare was reduced by surrounding the screen with black frames of varying widths. The effects of the frames were evaluated with both a performance measure and a visual comfort rating scale. Performance improved as frame width increased up to a point beyond which performance decreased. It was hypothesized that too wide a frame caused a too low adaptation level of the eye. A further improvement was found using a frame with a brightness gradient from black at the VDU screen to white at the outside. A frame was recommended for applications where contrast glare cannot be avoided.

The second study determined the best colour for displaying symbols on the dark background of the VDU screen. Criteria were a performance measure and preference ratings. Colours were green, white, three hues of yellow, and two hues of orange. The results showed lowest performance with two of the orange hues, and these were also least preferred of all the colours.

The third study attempted to evaluate the effect of various colour combinations on a performance measure. However, the results are unclear since there was no indication in the report that luminance was controlled.

The fourth study evaluated the relative effects of positive and negative contrast on a performance measure and ratings of visual comfort. Positive contrast refers to light letters on a dark display, and negative contrast refers to dark letters on a light display. Flicker was reduced by refreshing the display at a rate of 66 Hz. Room illumination was 500 lux. Performance was significantly better with negative contrast, and visual comfort was also significantly higher. Negative contrast was also recommended because there is minimal adaptation required when the eye moves from the screen to a paper source, because discomfort glare is reduced, and because screen reflections are less perceptible.

Rohmert, W. and Lucyak, H. *Ergonomics in the Design and Evaluation of a System for Postal Video Letter Coding.* Applied Egonomics, 1978: 9:85-95.

The study examined various alternatives for improving workplace design for a new "video-letter-coding" system to be implemented by the German Central Post Office. Of interest here is an experiment on display design that manipulated five variables. The variables were large vs small CRT displays, positive vs negative contrast, one vs two displays, horizontal vs vertical positioning of the two displays, and room brightness. Size of display, positioning of the displays, and direction of contrast had no effect on performance. Small displays, however, appeared to flicker less than the larger displays. Two displays produced a significant increase in performance over one display. This occurred because the next postal address displayed on the second CRT could be considered while keying the response to the current address. Ambient illumination above 500 lux appeared to reduce performance and produce eye irritations. A level of 100 lux was proposed as a compromise.

Smith, W.J. *A Review of Literature Relating to Visual Fatigue.* Proc. of the Human Factors Society, 23rd Annual Meeting, Boston, Mass., pp. 362-366, 1979.

The review was stimulated by concerns that long term viewing of video displays at close focal distances may contribute to visual fatigue. The discussion is limited to relevant aspects of the accommodation and pupillary systems.

Fatigue is generally defined as "weariness from exertion or the temporary loss of power to respond induced in a sensory receptor or motor end organ by continued stimulation". Three types of fatigue are identified. Acute fatigue arises from brief but tiring work activity primarily affecting the muscles, and is relieved by rest. Chronic fatigue involves cumulative physiological effects, and may not always be relieved by rest. Task induced fatigue arises from working at a particular task for a long time. It may be relieved quickly by changing tasks.

Four different methods have been developed to assess fatigue: (1) subjective assessments, (2) examination of work output for degradation over time, (3) measurement of neurosensory correlates, and (4) measurement of physiological correlates. The latter two methods currently appear to be most often applied. Reaction time and performance errors are two criteria used to evaluate neurosensory fatigue. Physiological fatigue is evaluated with such variables as heart rate, muscle tonus, pupillary response time to light, binocular fusion, and visual accommodation time, to near and far points.

Symptoms of visual fatigue include inability to maintain focus and fixation, blurred vision, double vision, bloodshot eyes, inflamed eyelids, watering eyes, a tense or heavy sensation in the eyes, a burning sensation in the eyes, and frequent blinking.

Review of the literature provided some support for a number of measures of visual fatigue. Measurement of changes in near and far points suggested that either or both change to decrease the range of accommodation. Alternation of near and far accommodation was reported to increase the time to accommodate. Four hours of reading was found to reduce visual acuity. Fatigue was related to a constriction in pupil size, and a constantly changing pupil size was thought to induce fatigue. Because people with a congenitally absent iris did not experience photophobia, the iridomotor system was further linked to ocular discomfort.

The author concludes from the review that visual acuity and physiological responses, such as pupil size and regularity, are likely correlates of visual stress. However, these relationships need to be confirmed by adequately controlled experiments.

Sperling, G. *Flicker in Computer-Generated Visual Displays: Selecting a CRO Phosphor and other Problems.* Behav. Res. Meth. & Instrum., 1971, 3:151-153.

The author discusses why flicker appears on a cathode-ray oscilloscope (CRO). The appearance of flicker is minimized or eliminated by either refreshing the image at a sufficiently high rate or by choosing a phosphor with a sufficiently long time constant. A model is presented that represents the visual system's response to flicker as a series of RC stages. The CRO phosphor is represented as an additional RC stage. Therefore, increasing the refresh rate is much more effective in reducing apparent flicker than increasing the phosphor time constant. Further, the time constant of the phosphor must not be so long as to cause smearing of imagery in motion.

The critical flicker fusion frequency for a particular individual is influenced by a number of factors including the luminance, size, and chromaticity of the flickering field, and the retinal region being stimulated. In general, the critical frequency lies somewhere between 40 and 70 Hz.

Stewart, T.F.M. *Eyestrain and Visual Display Units: A Review.* Displays, 1:25-32, April 1979.

Many theories exist regarding the origin of visual fatigue. The most satisfactory is one which integrates other conflicting theories. This theory holds that "visual fatigue may be the sensation that results from the system responding to feedback that the image is not clear". If the image is degraded, continued attempts will be made to produce a satisfactory percept. The paper discusses five factors that cause or aggravate visual fatigue: visual aspects, posture, general environment, work design, and individual characteristics.

Visual Factors:

Poor image quality can lead to visual fatigue. Parameters that affect quality include character size and shape, intercharacter spacing, stability, resolution, luminance, contrast, and chromaticity.

The optimum character height is 20 minutes of arc, and the width should be 70-80 percent of the height. Space between characters should be 20-50 percent of the height.

The shape of characters on an interlaced display may be enhanced by filling in a dot in one field of the frame where two dots, each in both fields, meet diagonally. However, because each field is refreshed at half the line frequency, dots on only one field will "jitter" or "shimmer". In fact, flicker at that frequency has been known to induce epileptic seizures in susceptible people. The perception of flicker is affected by various display characteristics such as colour, size and brightness of the image. Further, power supply instabilities may cause the whole screen image to waver in slow rhythmic waves.

Because the human eye is most sensitive to the yellow/green part of the spectrum, a green phosphor is often recommended as being restful. However, this position has no empirical support. For monochrome displays, luminance contrast is more important than colour.

Reflections on the surface of the VDU are a major problem for the user because they are distracting. Contrast between characters and screen background is reduced, resulting in a reduction in legibility of text. Because the reflected images differ slightly from the displayed characters in viewing distance, the eyes will attempt to focus on either one image or another. Focussing effort is increased. Shielding and appropriate repositioning of the screen can reduce glare, and various types of filters can be obtained to reduce reflections.

Contrast glare arising from too bright an environment around the VDU increases viewing problems. Because VDU operators look frequently but briefly at the VDU screen, insufficient adaptation occurs and probably inadequate accommodation. Contrast glare can be reduced by selecting a compromise room light level which is bright enough for paperwork but does not significantly reduce screen contrast. A light level between 300 and 500 lux is recommended. The luminance ratios of VDU, desk and room should not exceed 1:3:10.

Difficulties can also arise from light reflections from shiny key tops. Keys should have a matt surface and be a neutral colour.

Posture:

People will adopt postures which will improve matters in the short term but cause them increased strain and fatigue in the longer term. Poor positioning of the screen and keyboard force uncomfortable postures. The optimum height of a keyboard is such that the forearms are approximately horizontal. The optimum height for the screen is such that the line of sight of the operator is about 30-40 degrees below the horizontal. Since operators vary in size, the equipment should be designed so that these components can be adjusted independently. Another item which causes problems is the lack of an appropriate surface to place documents. Lecturn type document holders can reduce the contortions resulting from reading from paper laying on a horizontal disk surface. Ideally, the paper source, keyboard and screen should all be the same distance from the eyes.

Even an ideal posture is tiring if maintained for a long period. Adjustability of the equipment components allows the operator to make slight variations in posture.

General Environment:

Visual relief areas should be present to allow the operator to rest the eyes by viewing a patterned space at a distance. The space could be a bright corner, or plants, or a window view.

Adequate air conditioning is required to remove the heat generated by VDUs. Humidity control is needed to prevent drying of the secretions on the surface of the eyes, and to prevent irritation and feelings of itchiness or fatigue.

Noise from printers associated with many VDUs often exceed the 55 to 65 dB(A) levels recommended for office areas, and can be quite distracting and objectionable. Some people with sensitive hearing are bothered by the high frequency tone emitted by high voltage video circuitry.

Work Design:

When a user's work is meaningful and under personal control, minor inadequacies in work place design are likely to have minimal consequences. Consultations with users on workplace and work design are helpful in improving attitudes and reducing complaints.

Rest pauses should be planned to reduce fatigue and eye strain. Computerized tasks should be arranged to permit continued pride in one's work. Training and user support should be adequate to avoid additional stress and fatigue.

Individual Characteristics:

The occurrence of eyestrain also depends on some personal factors such as general health, general fatigue, smoking and drinking habits. Also, the quality of vision is known to deteriorate with age. However, older workers may have less trouble with reading from a VDU than from paper documents where viewing distance is usually shorter. VDU work seems to make people more aware of defects in their vision. As many as 30 percent of the population may have uncorrected or inadequately corrected visual defects.

Operators who wear glasses with a strong correction, may have quite a small depth of field. It is especially important for these people that keyboard, screen and paper source are all at the same viewing distance. Bifocal glasses can be a problem if they are designed for non-VDU use since the VDU is usually placed at a distance farther from that adopted for reading text on paper. Bifocals also encourage the adoption of unnatural postures when the screen position is not easily adjustable.

A2. POSTURAL EFFECTS

Corlett, E.N. and Manenica, I. *The Effects and Measurement of Working Postures.* Applied Ergonomics, 1980, 11:7-16.

The use of reported pain as an indicator of postural defects in the workplace was reviewed. Poor posture has been shown to lead either to a medium term effect (pain extending beyond the work period) or to a long term effect (bodily distortion). Short term effects tend to go unrecognized but have a major influence on performance.

In a series of experiments, a discomfort score was obtained by asking workers to identify, in decreasing order of pain level, which body parts were experiencing pain. A general comfort question was also asked. General discomfort appeared to be experienced when more than one part of the body was in moderate to high pain.

Pain was found to grow with working time. Further, a 3/4 hour pause for lunch was found to contribute a relatively small recovery, and the rate of increase of discomfort was approximately the same after as before the break. Pain intensity was found to be a linear function of the percentage of maximum endurance time. That is, when workload caused maximum endurance time to vary, pain level was proportional to the percentage of the total endurance time. The authors conclude that one cannot expect body postures to be maintained for significant proportions of the working day, without inducing considerable pain.

Hunting, W., Laubli, T. and Grandjean, E. *Constrained Postures of VDU Operators* in Ergonomic Aspects of Visual Display Terminals, E. Grandjean and E. Vigliani, (Eds.), London: Taylor and Francis, 1980.

The paper reports the results of a study of office keyboard operators and office workers who did no typing. Physical impairments and workplace design were evaluated. Physical impairments were assessed by a questionnaire, workplace dimensions were measured, and medical examinations of muscles and joints were made.

The questionnaire showed that about 10-15 percent of data entry terminal operators reported "almost daily" pains in the neck, shoulders, and right arm and hand. About half as many conversational terminal operators and typists reported pain in those areas, and almost none of the non-typists surveyed reported pain.

This pattern was repeated by medical findings regarding painful pressure points in the area of the shoulders, and pains in the neck and forearm muscles.

These results were taken as evidence that constrained postures may produce persistent injuries in muscles and tendons. Measurements of workplace dimensions indicated that one source of the problems might have been excessive heights of desk and keyboard levels above the floor. In fact, it was found that excessively high keyboard heights were related to a decreased incidence of physical complaints. This unexpected relationship was thought to have occurred for two reasons. First, when the source documents were laying on a relatively high desk, the postures of the head and trunk were improved, reducing the incidence of impairments. Second, operators using high keyboards tended to rest forearms and hands more often. The authors recommended the lower keyboard heights but with an adequate adjustable support for source documents. Provision should also be made for hand and forearm support especially when the task is characterized by frequent waiting times.

Hunting, W., Grandjean, E., and Maeda, K. *Constrained Postures in Accounting Machine Operators.* Applied Ergonomics, 1980, 11:145-149.

The effects of constrained postures on the frequency of physical complaints was investigated in a group of 119 female accounting machine operators. A control group of 57 shopgirls in a department store was also studied. The machine operator's task was to turn coupons on a table with the left hand, and to enter numerical data from the coupons on a keyboard. The average daily work on the accounting machine was five to six hours. Keying speed varied from 8000 to 12000 strokes/hour. The shopgirls spent their average day walking 58 min, standing 5 hr 25 min, and bending down 62 min.

Symptoms such as stiffness, tiredness, pains and cramps were assessed for each part of the body on a 3-point ordinal scale. There were no differences between the groups with respect to reported impairments in the trunk. However, the machine operators reported a significantly higher frequency of impairments in hands and arms than the shopgirls. Of these impairments, significantly more were reported on the right than on the left side. The shopgirls reported significantly more frequent and intense impairments in the legs than the machine operators. Of the questions related to general health, significantly more of the machine operators than the shopgirls reported "eyestrain" and "painful eyes".

The complaints of the machine operators were related to poor work place design such as improper orientation of the keyboard, improper height of the keyboard and source of documents, and the absence of a support for the right hand or forearm.

Nelson, T.M. and Ladan, C.J. *Patterns and Correlates of Fatigue among Office Workers.* J. Occup. Psychol., 1976, 49:65-74.

It is noted that individual characteristics manifested as tiredness and boredom may be related to job satisfaction, and that patterns of fatigue should be considered in planning rest pauses. The paper reports the results of a study using the Feeling Tone Checklist, developed by Pearson and Byars (1957), to measure variations in fatigue over the work day and the work week.

Subjects were 89 clerical staff, 28 of whom worked on a ten-hour-per-day four-day week, where the day not worked was rotated weekly. The rest worked an eight-hour five day week.

Feeling tone varied in a U-shaped function over the week, with Monday and Friday being the highest points. Tuesday was the lowest point. Averages within days showed that feeling tone was relatively high and constant during the morning hours, but dropped precipitously during the afternoon hours. No significant differences were found between the four and five work day groups. The author warns that the results are subject to variation by individual differences, but these data were not reported.

Because morning levels of feeling tone were high and declined only slightly, fatigue might be alleviated by alterations of afternoon schedules. Fatigue did not appear to be cumulative in relation to rest days since both the four and five day groups reported similar patterns. Therefore, the results appear due to motivational or cognitive factors. This hypothesis is further supported by the observation that employees who were employed longest felt best at days end. The authors suggest that the symptoms of fatigue may be similar to those resulting from perceptual deprivation.

A3. JOB CHARACTERISTICS

Elias, R., Cail, F., Tisserand, M., and Christmann, H. *Investigations in Operators Working with CRT Display Terminals: Relationships between Task Content and Psychophysiological Alterations* in Ergonomic Aspects of Visual Display Terminals, E. Grandjean and E. Vigliani, (Eds.), London: Taylor and Francis, 1980.

Health complaints were obtained via a questionnaire from two groups of women VDU operators. One group carried on a dialogue with a computer in the context of a publishing house and a pharmaceutical distribution company. The other group performed off-line data-acquisition in banking centres. With the aid of an eye movement recorder, data acquisition was characterized as a fragmented task with a higher frequency of sweeps between the visual display and documents than the dialogue task. It also was more restrictive, required less necessary learning, and consisted of shorter work cycles.

The questionnaire indicated that significantly more of data acquisition operators than dialogue operators were dissatisfied with their job. Further, significantly more of the data acquisition group reported psychosomatic disorders such as swellings, constipation, palpitations, and chest pains, nervous disturbances such as anxiety, irritability, and depression, and troubled sleep. Significantly more of the data acquisition group also reported visual strain symptoms such as a prickling sensation, blurred vision, discomfort glare, visual acuity weakness, and headaches. Pains also were reported significantly more often by the data acquisition group in the area of the neck, right shoulder, upper back, and lower back.

Smith, M.J., Stammerjohn, L.W., Cohen, B.G.F., and Lalich, N.R. *Job Stress in Video Display Operations* in Ergonomic Aspects of Visual Display Terminals, E. Grandjean and E. Vigliani, (Eds.), London: Taylor and Francis, 1980.

The paper reports on the results of a NIOSH survey of VDU operators at three sites in the United States that evaluated psychosocial stress and health complaints of the operators. Control groups were also included in the survey. Response rates tended to be quite low for both experimental and control groups at all three sites.

The survey results showed that all worker groups reported high levels of psychosocial stress. Also, the results indicated that job demands were responsible for a significant proportion of job stress and health complaints of VDU operators independent of their use of VDUs. Because VDU operators at one site showed more stress and health complaints than their controls and VDU operators at the other two sites, VDU use appears to interact with non-VDU related factors in this regard. The type of health complaints appeared also to have been influenced by job demand factors. At one location, typical health complaints from VDU operators were the expected visual and musculoskeletal variety. At the other two locations where job future and career growth were of greater concern, operators displayed more psychological problems such as anxiety and irritability.

The authors concluded that ergonomic solutions to inadequacies in workplace design must be supplemented with proper job design to maximize the protection of operator health.

A4. RADIATION

Anderson, G.E., Tell, R.A. and Youmans, H.D. *Spectral Transmission and Attenuation of X-Radiation by Glasses and Resins used in Color Television Picture Tubes.* IEEE Trans. on Broadcast and Television Receivers, Vol. BTR-16 (2): 82-88, 1970.

The paper reports on a study that determined the variables affecting X-ray protective properties of selected glasses and bonding resins used in the manufacture of television picture tubes. Results showed that the glass safety panel, normally bonded with resin to the face plate of the tube, reduced the photon rate by 75 percent. Measurements were made while displaying a green raster since others have found that X-ray production is most efficient for this phosphor. Tube voltage, which was 27.5 kv in this case, needs to be specified because the face plate becomes increasingly transparent as photon energy increases. Photon flux was reported to be maximal normal to the screen surface, and the flux density was found to be one-half the axial value at an angle of about 30 degrees on either side of the tube axis.

The attenuation coefficients of different glasses and resins were studied using an X-ray machine for which the emission spectra were matched to those of a picture tube. In general, it was found that the attenuation coefficient depended markedly on photon energy and thickness of the material. There were also large differences among the different materials tested.

Braestrup, C.B. and Mooney, R.T. *X-Ray Emission from Television Sets.* Science, 130:1071-1074, 1959.

The paper reports the results of studies to evaluate the gonad dose to the population of X-rays generated by television picture tubes. Authorities such as the International Commission of Radiological Protection, the National

Academy of Sciences, and the British Medical Research Council, agree "that the dose to the gonads should be kept as low as possible without sacrificing the many benefits associated with the use of radiation". Televisions are a potential source of non-useful X-rays. Because they are watched by a high percentage of the population, even small amounts of emitted radiation is of interest because of the possible impact on the gene pool.

The amount of X-rays emitted was found to vary greatly as a function of tube voltage. The author states that emission varies as the 20th power of tube potential. Thus, a stable tube voltage is a requirement if radiation measurements are to have any meaning.

The voltage on most home television sets ranges from 10 to 25 kv. The level of radiation emitted by a television tube depends on the distance of the measuring probe from the tube. Because of the large area of the source, there is no effect of distance within eight cm of the surface. Between eight and 100 cm, the rate of reduction is less than at distances over 100 cm where the decrease follows the inverse square law. The relative levels of radiation at given distances depend on raster size and tube potential.

Attenuation experiments indicated that the level of radiation was much reduced by a thin glass barrier. It was also noted that the amount of attenuation is greatly affected by tube voltage and the presence or absence in the glass of materials of high atomic number.

Depth dose estimates were made using a water phantom at a distance of 100 cm from the X-ray source operating at 25 kv and 20 ma. Measurements were made at a depth in the water of one and five cm, the average depths of the testes and ovaries, respectively. The depth dose at one cm was reported to be 75 percent, and at five cm, 10.8 percent, of the air exposure dose. The effect of tube voltage is evident from the finding that the depth dose at five cm was 0.01 percent for 15 kv and two percent for 20 kv. Thus, tube voltage has the most influence on the depth dose to the gonads. A variation of one kv can change the dose to the ovaries by a factor of six.

The population gonad dose from television is estimated based on an average of 1000 viewing hours per person per year. The radiation level is assumed to be the current maximum allowable level of .5 mR/hr measured at five cm from the screen. Values are computed for viewing distances of 100 and 200 cm. The estimated yearly gonad dose for females at 100 cm is 4.4 mrad, and the dose at 200 cm is 1.1 mrad. The estimated yearly dose for males at 100 cm is 30 mrad, and the dose at 200 cm is 7.5 mrad. These levels are compared to the average natural background radiation level of 100 mrad per year. The author concludes that the additional exposure obtained at "normal" viewing distances is acceptable.

Buckler, G. *VDT Radiation Levels not Harmful, Tests Show.* Computing Canada, p. 4, November 25, 1980.

This newspaper article reports on the results of a study of 86 VDTs at Metropolitan Life Insurance Co. in Ottawa and Toronto. The study, conducted by a private consulting firm, measured levels of X-ray and RF radiation. The highest measured RF level was 50 times lower than the government maximum permissible level. The maximum X-ray reading from a VDT was .05 mR/hr which is 10 times less than the maximum permissible level of .5 mR/hr. Momentary increases up to .75 mR/hr were thought to be due to background radiation sources since they were also observed while making background level readings. The average background X-radiation varied from .01 to .04 mR/hr.

Eleccion, M. *X-Radiation from Colour Television Receivers.* IEEE Spectrum, pp. 95-104, July 1968.

The paper summarizes the issues discussed at the Conference on Detection and Measurement of X-Radiation from Color Television Receivers held by the Public Health Service's National Center for Radiological Health (NCRH) in cooperation with the Electronics Industries Association (EIA).

The maximum safe level of X-radiation from televisions has been defined by the NCRH as .5 mR/hr averaged over an area of 10 cm^2 at any external location five cm from the surface of the television receiver cabinet under normal operating conditions. At a viewing distance of 2.3 meters, this level of radiation would be below the background radiation level of .01 to .02 mR/hr. Therefore, the author concludes that the safety standard recommended by NCRH is conservative.

An NCRH speaker at the conference concluded that X-radiation standards should be based on health-related criteria, and should emphasize the importance of a "virtual absence" of X-ray emission from any colour receiver surface.

It is noted that targets of high atomic weight yield larger amounts of X-rays, and that the greater the speed of the cathode electrons, the more penetrating, or harder, the resulting X-rays. A paper from Zenith Radio Corporation indicated that 80 percent of the electrons in the scanning beam are intercepted by the shadow mask in colour receivers, and the remaining 20 percent excite the phosphor screen. Thus, most of the X-radiation originates at the shadow mask. Different colour phosphors emit differing amounts of X-radiation with green emitting the highest level, blue the next highest, and red, the lowest. The latter differences probably arise because the phosphor atoms differ in atomic weights. The level of radiation was found to be sensitive to line voltage. A five volt increase in the line voltage can raise the level by a factor of two.

Another paper from NCRH concluded that, although acute effects of radiation from televisions is highly improbable, late effects from chronic exposure are of concern. Further, instrumentation needs to be developed to provide detailed information on narrow high-intensity beams.

A paper from the University of Chicago concluded that only a negligible radiation dose reaches the depths of most critical organs. Only the eyes and the testicles are sufficiently close to the surface to be at all at risk.

In conclusion, the record indicates to Mr. Eleccion that a properly operating television receiver emits a level of ionizing radiation that is too low to cause somatic injury. However, it is recognized that the question of possible long term effects has not been resolved, and that steps need to be taken to maintain radiation output at as low a level as possible.

Harvey, T.S. *Experiments with White Rats, Bush Beans, and Tradescantia Plants in the Vicinity of Television Receivers.* IEEE Trans. Broadcast and Television Receivers, Vol. BTR-13: 51-63, July, 1967.

The report describes experiments on possible biological effects of proximity to a television set due to X-ray exposure. Since typical colour television sets produce no more than .05 mR/hr, the emission of X-rays from colour television sets was considered negligible relative to background radiation levels.

The highest level used in the experiments was 1.5 mR/hr. The accumulated dose was as high as 240 times the average dose that would be received by a viewer exposed to the recommended maximum safe level for 1000 hrs from a viewing distance of one meter. The rats developed normally and produced normal offsprings. Histological analyses showed no abnormalities of the brain, gonads, spleen, and sternum. The plants also matured and reproduced normally.

Health and Welfare, Canada. *The Television Set and X-Radiation.* Dispatch No. 31 (Revised), Educational Services, Health Protection Branch, Summer, 1978.

The three page document briefly discusses the nature and effects of X-radiation, mentions some sources of X-radiation encountered in health services, industry, the home, and other areas such as airports, and discusses related standards for television receivers. The latter are primarily of interest here.

Black and white television sets operate at a much lower voltage than colour televisions, so are not a source of concern. A Canadian survey, conducted on TVs purchased during or before 1969, showed that about 11 percent of the sets tested emitted radiation above the accepted international standard of 0.5 mR/hr. The standard is thought to carry a high safety margin. The Radiation Emitting Devices Act requires that all new television receivers sold in Canada since 1975 must not exceed this standard even if failure or malfunction of one or more components occurs. The regulation is enforced by Health Protection Branch inspectors who regularly inspect the premises of Canadian plants that manufacture televisions, and samples of foreign-made receivers are routinely inspected in the Health Protection Branch laboratories.

Marshall, E. *FDA Sees no Radiation Risk in VDT Screens.* Science, 212:1120-1121, 1981.

The paper reports on testimony given by engineers and radiological specialists to the investigations subcommittee of the House Committee on Science and Technology (U.S.). The essence of the testimony was that there is no reason to think that video display terminals (VDTs) emit harmful radiation.

The possibility that microwave radiation from VDTs may be harmful was discussed. Such radiation has been found to produce cataracts in rabbits' eyes. When two New York Times VDT operators developed cataracts, the VDTs were suspected as the cause. However, measurements showed that VDTs produce no microwave radiation.

The director of the Bureau of Radiological Health at the Food and Drug Administration pointed out that four percent of the population between 35 and 45 suffers from natural cataracts. Since about seven million people in the U.S. regularly use VDTs, it should be within statistical norms for 280,000 of these users to have cataracts at an early age.

Moss, C.E., Murray, W.E., Parr, W.H., Messite, J., and Karches, G.J. *A Report on Electromagnetic Radiation Surveys of Video Display Terminals.* National Institute for Occupational Safety and Health, Report No. NIOSH 78-129, December, 1977.

Electromagnetic (EM) radiation was measured from several models and types of video display terminals (VDT). The EM spectrum was examined in the X-ray region, the visible region extending into the ultraviolet and infrared, and the radio frequency (RF) region. The microwave region was not examined. The ultraviolet radiation emitted by the VDTs was six orders of magnitude lower than the occupational exposure standard. Infrared and RF radiation was not detectable. X-ray emission from the VDTs was about one-third of the occupational exposure standard of 2.5 mR/hr. The report concludes that EM radiation from VDTs is considerably below current safety standards.

Murray, W.E., Moss, C.E., Parr, W.H., and Cox, C. *A Radiation and Industrial Hygiene Survey of Video Display Terminal Operations.* Human Factors, 1981, 23:413-420.

A survey was performed by NIOSH at the request of several labour unions representing three different companies. Electromagnetic radiation measurements were made on a sample of 136 of 530 VDTs, and samples of workroom air were analyzed to measure airborne levels of hydrocarbons, carbon monoxide, formaldehyde, and acetic acid. The study found no indication of hazards from either radiation or chemical contaminants. X-radiation exposure rates as low as .05 mR/hr could be measured with an overall accuracy of plus or minus 15 percent.

Wang, Y-S. *Measurement of Ionization Radiation from Color Television Receivers by Thermoluminescent Dosimeters.* Health Physics, 28(1):78-80, 1975.

The paper introduces a new thermoluminescent technique that is very sensitive to low doses of X-radiation. The technique was used to measure ionizing radiation emission from 28 randomly chosen colour television home receivers in Taiwan. Radiation levels varied from .001 to .255 mR/hr under normal working conditions. Data was presented for 12, 14, 16, 17, 18, 19, 20, and 25 inch picture tubes. On the average, radiation levels measured at the sides of the sets was about 27 percent of the levels measured at the front of the sets. The levels emitted at the front of the 20 and 25 inch sets was approximately double the level emitted at the front of sets 19 inch and smaller. Emission levels measured at the front of the 20 inch sets was approximately 17% of the levels measured inside the television set around the picture tube.

CRC DOCUMENT CONTROL DATA

1. ORIGINATOR: Department of Communications / Communications Research Centre

2. DOCUMENT NO: CRC Technical Note No. 712-E

3. DOCUMENT DATE: February 1982

4. DOCUMENT TITLE: Review of Health and Safety Aspects of Video Display Terminals

5. AUTHOR(s): W. C. Treurniet

6. KEYWORDS:
(1) Video
(2) Terminals
(3) Health

7. SUBJECT CATEGORY (FIELD & GROUP: COSATI)

05 Behavioral and Social Sciences

05 05 Human Factors Engineering

8. ABSTRACT:

As in Abstract (page 1)

9. CITATION:

DATE DUE
DATE DE RETOUR

LOWE-MARTIN No. 1137

Government of Canada
Gouvernement du Canada