The Health Hazards of Computers
A Guide to Worrying Intelligently
Edited by Art Kleiner

This amalgamation of information, conjecture, experiment, and reporting is the end of a 12-month odyssey. It started last June, when we were planning the "Computers as Poison" issue (Fall '84 WER).

"We really should have something on the health hazards of video-display terminals (VDTs)," I said to Kevin and Stewart. "After all, it's a major uncertainty. You sit with your nose squeezed against the beast for hours every day; you hear vague reports of cataracts and birth defects; you hear, on the other hand, industry groups saying there's nothing wrong with the machines... Whom should you believe?"

A tip from Mike Castleman of Medical Self-Care Magazine led me to the Center for Investigative Reporting in San Francisco. A reporter there named Diana Hembree had already been investigating VDT radiation health hazards for several months, with a particular interest in its effects on women workers — most VDT terminal grunt workers, such as airline reservation clerks and data-entry operators, are women. At my request, she assembled a group of investigators to look into potential radiation hazards from personal computers. Their original article arrived in time for the Computers as Poison issue, but because it reported on a situation that was simultaneously controversial, extremely technical, and inconclusive, we didn't feel comfortable printing the article without scientific review.

Thus we held it and sent it to two dozen physicists, radiologists, biophysicists, and doctors — all people with a preestablished interest in this topic. Diana's original theme wasn't particularly incendiarly; it basically said, "There seems to be cause for concern, but nothing conclusive; more research is needed." We got back a dozen replies, some complimentary and others criticizing us for everything from hysterical sensationalism to underplaying the danger. Some of those replies led to further interviews that supplemented Diana's already exhaustive research.

Meanwhile, discussion on the EIES computer network began turning up comment from other people who had investigated the issue.

Ultimately, I edited Diana's article, plus some of the replies and other comments, into these 14 pages. We've broken it down by possible health hazard — non-ionizing radiation, glare, X-rays, noise, posture — and added a list of nagging questions and an analysis of potential remedies. It may not be conclusive, but I feel it will give you a complete picture of your choices as is possible now. And it's more newsworthy than it was last June, because several things have happened since then:

First, the academic/scientific establishment, which seemed firmly opposed last year to the idea that VDTs could be
Pulsed electromagnetic radiation is the information channel of the universe. Electricity, broadcast waves, telecommunications, X-rays, microwaves, and visible light — all travel as waves or pulses of energy, moving at the speed of light.

This chart of the electromagnetic spectrum shows the overall range of electromagnetic frequencies. In order to fit the spectrum into a reasonable space, the horizontal scale is logarithmic — each marker represents a frequency ten times greater than the marker to its left.

illustrations by Don Ryan

producing harmful electromagnetic radiation, is admitting more doubt this year. This is partly due to some recent experiments on the biological effects of low-frequency radiation, reported herein.

Second, thanks largely to the persistence of labor unions concerned about VDT workers, there are some beginning attempts to measure low-frequency radiation from specific computer terminals and cross-check those measurements against observed biological effects. The pioneer in this is a doctor named Hari Sharma at the University of Waterloo in Ontario, who is — to our knowledge — the only doctor so far to do the obvious: to investigate a particular complaint of health problems among VDT workers and test the machines they work on for low-frequency radiation. His results are the first to suggest that different computer brands will produce radiation with different biological effects.

Third, two of the scientists who responded to Diana's article — a physicist named Elizabeth Rauscher and her partner, an electronics engineer named William Von Bise — have begun to take on the daunting task of measuring radiation from various brands of personal computers and comparing them to each other. In February, they spent a day at Whole Earth's offices, measuring five different brands of computer under a variety of conditions. Though their research is far from conclusive — Whole Earth offices, for instance, bear no resemblance to a laboratory — they came up with some intriguing preliminary interpretations.

Finally, a variety of radiation, glare, and static-electricity filtering shields have proliferated in the last year, designed to filter out a variety of different types of radiation. We asked Mike Skaar, who evaluates and sells screen filters professionally, to help us get a sense of what's available and how they compare to each other.

Unfortunately, some of the screen-filter companies are now using scare-tactic salesmanship that seems as suspect as the protests by computer manufacturers that the terminals are completely safe. "I got a call last week from a PR woman in Chicago," Time magazine computer editor Philip Elmer-Dewitt told us this spring, "pushing a company that sold glare-and-radiation-proof screens to stick on the front of your terminal. To buttress her pitch, she cited a Chicago Trib article that 'linked' time at a terminal with 'increased risk of miscarriage.' She's not only yelling fire in the maternity ward, she's probably covering up the wrong end of the CRT tube. Pinning this down once and for all would do an invaluable service to everyone. Why is it so hard to get to the facts?"

Because, Phil, the research is disparate, inconclusive, and contradictory. Many of the researchers have vested interests of one sort or another. Herewith, our best shot at cutting through the murk — with hopefully not too much oversimplification. The authors and interviewees wrote this material independently of each other; the responsibility for editing it all together is mine.
LOUIS JAFFE (proprietor of Chariot computer network, member of the Society for Information Display):

Take any ordinary AM radio, turn up the volume, and hold the antenna near your computer. The noise emissions it picks up from the computer are usually loud enough to drown out local broadcast stations.

Tune the radio to different frequencies and move it close to different components of the computer. Also make the computer do various things: disk accesses, typing, various screen displays, print-outs. You will find that the screen, keyboard, system unit, disk drive, and printer all make an amazing chorus of chirps, roars, clicks, and whines. Admittedly, you can’t use this to measure the particular frequencies the computer produces — but it handyly proves there is energy humming around outside a computer or terminal.

DIANA HEMBREE and KERRY NELSON (Center for Investigative Reporting): Virtually all personal computers use video-display terminals (VDTs) to display their text and graphics. These terminals, like TV sets, include a plastic or metal case enclosing a cathode ray tube (CRT), which uses high-voltage currents to fire an electron beam at the video screen. The high-speed electron beam, and the electronic components that gather power for it or aim it, generate a range of electromagnetic fields — including weak X-rays, ultraviolet radiation, infrared light, and radiation of many other frequencies. Although most radiation is absorbed by shielding built into the computer case or the glass screen, scattered reports of cataracts and problem pregnancy “clusters” stirred concern about possible radiation hazards from computer terminals beginning in 1977.

In 1977 two young New York Times copy editors using VDTs developed early stages of cataracts — an eye disease that usually affects the elderly. Dr. Milton Zaret, a Scarsdale ophthalmologist who since 1959 has published controversial findings on the effects of microwaves on the human eye, said that the cataracts were caused by exposure to radiation.1 Government investigators subsequently ruled out VDT emissions as a possible cause; but soon afterwards, early cataract symptoms turned up among several employees at the Baltimore Sun. Here again National Institute of Occupational Safety and Health (NIOSH) investigators found “no significant association” between VDT use and premature cataracts. However, NIOSH concluded that “the issue of VDT-associated cataracts is NOT resolved by our study.”2

The controversy over VDTs and radiation grew more heated during the next five years, as office workers reported separate “clusters” of miscarriages and birth defects at 15 VDT worksites in the U.S., Canada, and Europe. Government investigators at four of these places have excluded VDTs as a possible culprit, and federal health agencies in the U.S. have dismissed the clusters as statistical flukes. However, many VDT operators, reporting eyestrain, blurred vision, headaches, dizziness, back pain, irritability, and stress, are still worried about possible radiation hazards. Experts often trace these effects to assembly-line work pace and to poor VDT or work-station design, but a small but increasingly active group of medical researchers have said that the radiation hazard question is far from answered.

Among this group is Arthur Frank, chair of the Department of Preventive Medicine and Environmental Health at the University of Kentucky at Lexington. Dr. Frank, a well-known researcher on VDTs and human health, finds “a great paucity of scientific information on the possible health effects” of VDTs, now used by an estimated 15 million Americans. Unconvinced that studies of VDTs have given radiation a clean bill of health, Dr. Frank describes the VDT emissions issue as “unsettled.”

Not so, says government agencies in the United States and Canada, agencies which often have done their own VDT testing. The U.S. Food and Drug Administration, the American Academy of Ophthalmology, and a blue-ribbon panel of the National Academy of Sciences are among the groups that have evaluated and dismissed the idea of radiation hazards from terminals. Any radiation given off, they argue, falls well within federal guidelines and is too small an amount to pose a threat to health.

“There is absolutely no danger with radiation emissions from VDTs, even for pregnant women,” says William Murray, a radiation specialist for the National Institute of Occupational Safety and Health. Some industry officials have taken things a step further by deriding fears about radiation as irrational. Protecting workers from VDT radiation “is like protecting them from light bulbs,” says Charlotte Le Gates of the Computer and Business Equipment Manufacturers Association (CBEMA) told one reporter. “It’s like employees saying, ‘the office is filled with cosmic rays and you have to fight them with balloons.’”3 CBEMA has recently begun a multimillion-dollar media campaign, with TV spots and question-and-answer columns in newspapers, to convince computer users that VDT-emitted radiation is not hazardous.
The electromagnetic spectrum

DIANA HEMBREE and KERRY NELSON: In the past few years, a growing number of scientists have tentatively linked low-frequency electromagnetic (EM) radiation to profound biological and genetic changes in test animals.

Scientists have found that electromagnetic fields — regions actively dominated by electromagnetic radiation — may affect organisms at certain specific frequencies, or “power windows,” while even slightly lower or higher frequencies have no effect at all. For this reason and others, it is risky to assume that effects found at one frequency will be produced by others as well.

It is also important to note that this research on the biological effects of electromagnetic radiation has not focused on VDT radiation — and that no studies anywhere have conclusively linked radiation from VDTs to health problems. However, as the chart below shows, computer and computer terminal users are exposed to some low-frequency electromagnetic fields similar to those linked to biological effects. These similarities suggest that the question of VDT safety is still open. Unlike X-rays, low-frequency radiation is non-ionizing; it does not alter the atomic or molecular structure of substances through which it passes. Because ionizing radiation has been linked more obviously to health problems, much less is known about non-ionizing radiation. For decades, many physicists have argued that non-ionizing radiation could not affect the human body unless the electric field it created was intense enough to produce heat or an electric shock. But last summer a leading engineering journal declared that “a growing mass of evidence has virtually ended that debate: electromagnetic fields too weak to heat an organism could still affect it.”

“The [recent] scientific literature on weak-field effects is massive,” said Eric Lerner, a contributing editor to the Institute of Electrical and Electronics Engineers (IEEE) Spectrum. Lerner said that “evidence of the effects of EM fields on the nervous system and the immune systems of animals was already well established by the end of the ’70s, while evidence of EM effects on the genetic material in cell nuclei has accumulated most rapidly over the past few years.”

Discoveries that weak EM fields can affect living organisms heralds what prominent medical researcher Dr. Ross Adey has called “a biological revolution as fundamental as any since Descartes.” Biologists are becoming aware that our bodies’ communication network of hormones and nerve impulses is “supplemented by a ‘radio network’ of weak electromagnetic fields.” This may mean that our bodies are far more sensitive to external electromagnetic fields than was previously thought. For this reason, ongoing research in this area could have important implications for healing uses of EM fields — and for people exposed to EM fields from high-voltage power lines, radar and broadcast towers, walkie-talkies, and other electronic devices. It will also matter to VDT operators and computer buffs who are exposed to weak EM fields from their terminals — particularly fields affected by extremely low-frequency radiation (ELF), hitherto ignored as a possible health hazard.

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<tr>
<th>Frequency in hertz (cycles per second)</th>
<th>Biological Effects</th>
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<td>10^0</td>
<td>Increased excitability of nerve cells; Adey</td>
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<tr>
<td>10^1</td>
<td>Brain wave changes in people; Von Bis</td>
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<td>10^2</td>
<td>Corrects heart arrhythmias; Von Bis</td>
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<td>10^3</td>
<td>Increased lymphocytes/enhanced adrenal glands in rats; Chou/Guy</td>
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<td>10^4</td>
<td>Human brain wave entrainment; Von Bis</td>
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<tr>
<td>10^5</td>
<td>Approximates median human alpha brain wave; Walter</td>
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<td>10^6</td>
<td>Disturbed chicken cell embryos; Delodo</td>
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<td>10^7</td>
<td>Entaining human circadian rhythms; Marino, Berger, Austin/Weller</td>
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<td>10^8</td>
<td>Inhibits bone cell reaction to hormone; Luben</td>
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<td>10^9</td>
<td>Greater calcium efflux in cat brains; Adey</td>
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“Observed Frequencies in Personal Computers” were measured by Rauscher and Von Bis in our offices. This is what they found between 0 and 1000 Hertz. The measurements have never been duplicated, in a lab or in our offices.

Each item in “Biological Effects” refers to a published scientific article where the experimenter found a particular biological effect at a particular frequency within that 0-1000 Hertz range.

There is no demonstrable causal relationship between observed frequencies and biological effects. Just because a 50-Hertz frequency once changed some rabbit brain cell doesn’t mean you should sell your Kaypro. There could be differences in the wave shapes or differences in the environment that triggered the bio-effect; the reference could have been misread, or Von Bis and Rauscher could have mismeasured the Kaypro.
Extremely Low Frequency Radiation (ELF)

Below 3,000 Hertz

DIANA HEMBREE and KERRY NELSON: One particular set of dramatic findings from Spain are causing many researchers to take a harder look at ELF radiation — nonionizing radiation below 3,000 cycles per second in frequency. In 1982, associates of Dr. Jose Delgado’s research laboratory at the Ramon y Cajal Hospital in Madrid discovered that extremely weak pulsed magnetic fields — as much as 500 times weaker than the Earth’s non-pulsing magnetic field (which is, in turn, 1/10,000 of the intensity of a typical industrial electromagnet) — had a profound impact on the development of chick embryos. The researchers found that Extremely Low Frequency (ELF) radiation (10, 100, and 1000 Hertz) at field intensities ranging from 1.2 to 129 milligauss disturbed the cell organization of the embryos, resulting in malformed hearts and central nervous systems.

These exceptionally unusual findings were first reported in the professionally refereed journal of Anatomy; then in VDT News, a newsletter that focuses on VDT health and safety issues. The experiments aroused skepticism and amazement among many researchers, who found it difficult to believe that such weak radiation could have such powerful effects. Delgado’s experiments were replicated more recently by Dr. Kjell Hanson Mild of the Swedish National Board of Occupational Safety and Health, who confirmed that he found similar effects.

“The very fact that Delgado is getting effects at such low levels [of pulsed magnetic fields] deserves a lot of attention in the scientific community,” said Dr. Arthur Guy, director of the Bioelectromagnetics Laboratory at the University of Washington School of Medicine in Seattle. Guy also said that the intensity of the current induced by at least some VDTs is “about the same” as that induced in Delgado’s experiment. He cautioned, however, that “even a very slight difference [in the shape of the magnetic waveforms] may mean that the VDT waveform is not biologically active.”

Despite these reservations, in a report to IBM that the company has not yet released to the public, Dr. Guy compared the results of his experiments with those of Delgado. He concluded that “it can be seen that induced currents where [Delgado] observed teratogenic effects in chicken embryos can be produced in human tissue exposed to VDT magnetic fields.” Because of the high electric field strengths measured from some VDTs, he recommended to IBM that terminals be shielded.

Although Dr. Guy has published a number of papers which say that he does not believe VDT emissions to be hazardous, he stresses the need for further study.

Intrigued by the “Delgado effect,” other experts are, for the first time, “openly speculating that non-ionizing radiation from VDTs can have biological effects,” reported VDT News. Dr. Richard Tell, a physicist with the Environmental Protection Agency, has said that the possibility of health effects cannot be ruled out. The EPA, meanwhile, is planning to try to replicate Delgado’s experiments.

ART KLEINER: Cathode-ray tube based computers produce ELF radiation at a variety of frequencies, depending on the type of computer and possibly even what type of program is running (see “Testing Computers for VLF and ELF” later in this article). Some of this radiation is generated from the pulses which move the electron beam vertically to refresh the full screen.

Rauscher and Von Bise measured the electromagnetic frequency radiating from five computers. They photographed each significant surge of power they found. In this image, the game LODE RUNNER is played on an Apple IIe, with an Apple III monitor with green letters on a black background. The oscilloscope photo shows both the electric and magnetic components of the detected radiation. The range for both halves is 0-20 Hertz. The top half is taken from a mostly-dark screen; the bottom half from a screenful of moving characters.

DIANA HEMBREE and KERRY NELSON: Until the news about the Delgado experiments broke, the growing concern over VDT pulses had focused on VLF (Very Low Frequency) Radiation. The furor over VLF erupted in 1982, when Dr. Karel Marha of the Canadian Centre for Occupational Health and Safety (CCOSH) measured “relatively strong” pulsed VLF emissions from some VDTs and suggested that a
Unfortunately, no one (still) has conducted studies on the biological effects of VLF pulsed electrical fields," Dr. Marha said recently. According to one researcher at CCOHS, pulsed VLF is "an extremely hot research topic right now." In computers, the VLF frequency radiation comes generally from the cathode ray tube's high-voltage power source, known as the flyback transformer. The transformer uses an electrical pulse to move an electron beam horizontally across the screen; as it does so, it emits pulses of radiation — almost 16,000 per second, or 16 kilohertz.

Testing Computers for ELF and VLF

ART KLEINER: We know of only a few scientists who have made an effort to measure computers or computer terminals for VLF/ELF radiation, and check the results against radiation frequencies with observed biological effects. One is a Canadian physician, Dr. Hari Sharma of the University of Waterloo in Toronto, who released a paper earlier this year based on experiments done at the Surrey Memorial Hospital, Vancouver, B.C. Responding to complaints at the hospital of fatigue and pregnancy problems among workers at some types of VDTs (those made by Perkin-Elmer) but not at others, Dr. Sharma measured all the VDTs for every type of radiation and several other types of possibly toxic agents. He found one difference between the terminal brands: "The electric and magnetic fields in the very-low-frequency region were found to be relatively high in the P-E terminals. . . . The data on adverse pregnancy outcomes from employees working with the P-E terminals in eight hospitals indicated that there might be linkage between exposure to EM fields and adverse pregnancy outcomes."11

Another researcher of this topic is Dr. Elizabeth A. Rauscher, a physicist specializing in radiation, formerly with the University of California at Berkeley. With her partner, electronics engineer William Von Bise, Dr. Rauscher came to the Whole Earth offices in February and measured the electric and magnetic fields emanating from five different brands of personal computer.

As it pulses, electromagnetic radiation creates two distinct phenomena which alternate rapidly across the region of the electromagnetic field. One is a dynamic electric field, with a detectable electric charge that constantly changes from positive to negative; the other is a magnetic field, or flow of magnetic force, constantly changing polarity. The two components, which incidentally oscillate at right angles to each other, may produce different biological effects, are shielded by different metals, and may produce ambiguous results when measured together — so Rauscher and Von Bise measured them separately.

The tests were preliminary, and we only had one day to work in — so we didn’t get to compare the five computers against, say, a regular TV set or a dumb video-display terminal. But the tests do suggest some very interesting preliminary indications.15
Rauscher and Von Bis used an electrostatic voltmeter, shown here in front of the Macintosh, to measure electrostatic fields (static electricity) from each of the computers. Their probe uses a ferrite rod tuned to a particular frequency. It responds to each change in magnetic field intensity as a change in that frequency.

As Eric Lerner of the IEEE Spectrum reminded us in conversation, many of the symptoms people attribute to radiation—eyestrain, headaches, dizziness, stress, and possibly even permanent eye damage—might be caused or exacerbated by prolonged exposure to glare. Much of the evidence against glare is anecdotal. Our computer network correspondents debated about screen color:

RICHARD DALTON (regular contributor to Whole Earth computer coverage): A report issued by the Journal of Applied Psychology recently found that screens with reversed type (white on black or color) reduce reading speed by 11 percent. That may explain why I’ve come to like black on amber for text production.

ERIC WUJCIC (computer columnist, the Detroit News): I’m glad I’ll never have to use a black-and-white display again. Up till ten months ago the Detroit News had old-fashioned monitors. Every time a column was due I ended up with incredible eyestrain. I haven’t ever had that problem on green phosphor or color monitors. And I find the soothing blue and white of ATARIWRITER to be a source of comfort.

LOUIS JAFFE: I don’t like white-background, black-text displays because I’m quite sensitive to flicker, and it’s much easier to see flicker in a large area of light video, like on the Macintosh. I don’t like amber displays either. Amber was chosen because the human eye’s spectral sensitivity peaks on amber; therefore it’s supposed to make the most efficient human-machine system. But some esoteric students of color therapy claim that amber can produce all sorts of negative excitations in people. I can believe this after viewing amber displays even for very short periods. Green, on the other hand, has long been recognized for its restful qualities. My only problem with green is the way everything looks amber or purple when you look away after staring at the display for a long time.

ART KLEINER: We don’t know of any credible research on the health effects of various colors from computer screens—but we have solid advice (in the “remedies” section of this article) on reducing and coping with glare.

Ionizing Radiation (X-Rays and Cosmic Rays)

ART KLEINER: They don’t give off cosmic rays—at least not outside of comic books—but VDTs do give off X-rays as a by-product of the impact of high-speed electrons on the viewing screen. This radiation is called “ionizing” because it alters the molecular structure of substances it passes through, creating ions. However, the consensus among researchers is that X-rays from computer terminals are relatively low-intensity; they’re absorbed by the glass screen and by metal shielding built into the computer. IBM tests several out of every hundred terminals and computers that it produces for X-ray leaks. The National Institute for Occupational Safety and Health (NIOSH) measures workplace VDTs for X-rays. I had a typesetting terminal tested by them in 1979; the measurer said he had checked hundreds of terminals and had never found ionizing radiation leaking through. Although you’ll hear scare warnings from companies selling lead-impregnated shields, the only legitimate concern we’ve heard about X-rays involves older terminals with incomplete or corroded shielding.
Static electricity
DIANA HEMBREE: When Scandinavian office workers reported a wave of mysterious facial rashes in 1981, Norwegian scientist Walter Olsen began an investigation. After numerous experiments, he linked the rashes to an unexpected interaction between strong static electric fields generated by the VDTs and the bodies of the people at the keyboards.

Olsen discovered that unless the VDTs were deliberately shielded to block electric fields, "high voltages may extend into the air surfaces surrounding the units," with some terminal operators receiving static charges of as much as 2,000 volts per square meter. By measuring levels of airborne pollutants, Olsen also found that dust, tobacco smoke, and other contaminants floating in front of the VDT became positively charged and sought out the nearest grounded or oppositely charged surface — usually the operator's face. Then the particles clung to the face, causing rashes, itchy eyes, and dry skin. Olsen taped an adhesive-coated "collection device" on the faces of people sitting at VDTs, and measured the deposits hours later. He found microscopic particles "rained" on subjects' faces at a rate at least ten times higher with a VDT than without one. In one experiment the deposit rate topped 100,000 submicroscopic particles per square millimeter per hour.

Since Olsen's study, researchers in the U.S. have demonstrated that the positively charged field around a VDT tends to neutralize negative ions around the unit, creating what they believe to be an unhealthy buildup of positive ions. Air ions appear to cause changes in the body through their impact on blood levels of serotonin, a powerful hormone that affects the endocrine glands and central nervous system. Some researchers have linked high positive ion concentrations with nausea, fatigue, metabolic disorders, irritability, headaches, and respiratory problems.19

ART KLEINER: Where does the static electricity come from, you ask? According to Bob DiMatteo's book, Terminal Shock, it's "produced as a result of electrons being ejected from the electron beam. These electrons build up on the screen and in surrounding space."20 Static electricity is a by-product of the same force that projects electromagnetic radiation, and is thus linked in intensity to the electromagnetic field around the computer. The more intense the electromagnetic field, the greater the static electricity. Unintentional electromagnetic radiation, static electricity builds up only in the direction the electron beam is focused — the front of the computer.

Sound
ART KLEINER: The "evidence" that computers and VDTs give off ultra-high-pitched sounds is largely anecdotal. Some people can hear if a CRT is on in the general area, and claim to be irritated by the sound. The following exchange of letters in the January 1984 Byte magazine highlighted the problem, saying that flyback transformers, as they produce 15 kilohertz electromagnetic radiation, also produce sound waves at the same frequency. Sound waves themselves are not electromagnetic rays (thus, they don't travel at the speed of light), but ripples of vibration passing through substances.

WILLIAM G. UNRUH (Department of Physics, University of British Columbia): [The high-frequency noise from computers] is a ubiquitous problem caused, I believe, by the fact that the monitors are designed by deaf engineers. Most men have lost their hearing at 15.7 kHz by their early twenties and thus build and design the monitors with cheap flyback transformers that vibrate at the flyback frequency. Measurements near the cooling holes of many monitors give readings as high as 90 decibels.

GARY KEENE [quoting a letter in the October 1984 Softalk, p. 43]: J. Barry Smith of Massachusetts, a professional audiologist, was able to measure 15-kHz sound-pressure levels as high as 44 decibels at the operator's ear. I think this problem may be widespread, especially among the female population of computer operators, who typically have more acute hearing than men.21

Posture, stress, chemicals, gas
ART KLEINER: Bad posture — from prolonged sitting at a poorly designed workstation — may be the most widespread computer health hazard of all. The "remedies" section of this article contains much information on posture problem prevention.

According to Eric Lerner, stress seems to exacerbate other problems — particularly glare and posture. Perhaps that's why VDT workers, whose work output is often automatically measured against time, show more symptoms as a group than personal computer users (except those of us stressed by deadlines).

Just in case you were wondering, Dr. Hari Sharma performed a chemical and gas analysis of his VDTs. He found no significant trace of PCB, environmental toxins, ozone, carbon dioxide, or carbon monoxide.22 We have heard no other charge that VDTs produce toxic chemicals or gases. Whew!

Nagging question #1:
Why worry about computer terminals and not about TV sets?

DR. ARTHUR FRANK (chairman, Dept. of Preventive Medicine and Environmental Health, University of Kentucky at Lexington): A television set is basically the same kind of
equipped as a computer terminal — in fact, some of your home computer manuals say "hook it up to your home television set." There are some differences, though, from a medical point of view. With the exception of little kids like my own, who like to sit right in front of the tube and kiss Mr. Rogers in the afternoon, most of us don't watch television within 18 inches of the screen — as we do with terminals. And radiation diminishes by the square of the distance. So the level of radiation of whatever type that you get sitting six or eight feet across the room is orders of magnitude less than what you get sitting 18 inches from a screen.

Televisions have indeed been around for a long time and if they have health effects they are obviously not major compared to other factors in our lives. Those health problems would either be acute and we would have seen something by now, or it may be that a generation with 30, 40, or 50 years of exposure may have some health problems in older age different from any previous generation. But that's hard to study, because some of the other factors change as well. If TV watching adds one percent to mortality and you reduce it three percent by modifying your diet, you get a net loss of two percent mortality at a given age, let's say, and a researcher will miss the cause-effect relationship.

DIANA HEMBREE and KERRY NELSON: Many government and industry officials assure computer users that VDT radiation falls within federal standards, but this claim is misleading. The U.S. has NO standards — only voluntary guidelines — that limit employee exposure to non-ionizing radiation from VDTs. What's more, the U.S. has no standards at all for pulsed VLF or ELF radiation — the VDT emissions most suspicious now as possible hazards. Ironically, VDTs are not subject to the compulsory testing, reporting, and labeling requirement that the U.S. government has developed for that other common cathode ray tube product — the TV set.4

Even if government guidelines on non-ionizing radiation did apply to VDTs, the guidelines themselves are too weak, according to some scientists. "We're already seeing profound biological effects at exposure to radiation levels well below our current standards," insists Dr. Eldon Byrd, until recently a physicist at the Naval Surface Weapons Institute in Silver Springs, Maryland. This point was recently underscored by the findings of Dr. Przemyslaw Czeraski, a leading Czech radiation researcher and visiting scientist at the U.S. Public Health Service:

microwaves may, under some circumstances, cause chromosome damage in mice at power levels eight times below the recommended safety standard for humans.23 VDTs do not emit microwaves, but since radars, microwave ovens, and many other products do, this finding caused a small stir.

Industry has recently started a drive to regulate electromagnetic radiation, partly to deter state and local governments from setting their own, possibly stricter standards. Meanwhile, current U.S. guidelines for non-ionizing radiation may provide only an illusion of safety. At NIOSH, William Murray reports that his agency is now studying "how to take correct measurements [of non-ionizing fields] from VDTs." This suggests that the previous guidelines may be outdated, since the old measurements may be invalid.

One physician, Dr. Robert Becker, is worried about standards for extremely low frequency (ELF) radiation in particular. A former professor of orthopedic surgery at the State University of New York, Becker helped pioneer the use of ELF to heal bone fractures. He also took part in a federally sponsored study which linked 60 Hertz ELF to psychological disturbances.27 He has said that there is more than enough evidence for government regulations.

"I don't want to wave a red flag," he said at a 1982 conference on VDTs and non-ionizing radiation held in Ottawa, "but at the same time, I feel obliged, as a physician . . . to spell these things out . . . I trust and hope I will live long enough to finally see a response from the federal government that 'yes, there are biological effects from low-frequency radiation, and yes, they are serious, and yes, we ought to do something about it.'"

Nagging question #3:

Is radiation such a danger, why aren't there epidemics of cataracts and birth defects? Why do they appear in isolated clusters?

ART KLEINER: Not an easy one to answer, with certainty. I've heard six different contradictory responses while editing this article.

1) The clusters are isolated now, just among people who use the terminals most; since cataracts develop slowly, their incidence will appear more widespread later.

2) The clusters are not as isolated as they appear — partly because low-level health problems are often not reported, partly because no systematic effort has been made to catalog all the reported cases, and partly because it's hard to recognize clusters in uncontrolled environments where cause-and-effect relationships are murky.

3) Indeed the so-called "clusters" are statistical coincidences, and demonstrate no radiation danger.

4) Since ELF measurements differ so much from one brand of VDT to the next, and since biological effects vary with changes in radiation pulse frequency, some VDT models produce problem "clusters" and others do not.

5) As with allergies, some people may be affected while others are not.

6) Even one cluster is too many if it can be proven that the damage is related to radiation from VDTs.

DIANA HEMBREE and JENNIFER McNULTY (Center for Investigative
Reporting): Government health agencies in the U.S. assure the public that alleged problem pregnancy clusters are statistical flukes. Yet, interestingly, government researchers investigating these clusters—at sites in Dallas, Georgia, San Francisco, and Michigan—have consistently refused to test the VDTs themselves for radiation emissions.

For example: more than 240 women work at the reservations desk of United Airlines in San Francisco. When an informal office survey showed a 50 percent rate of problem pregnancies between 1979 and 1983, the women became alarmed about possible harmful effects from VDTs. (The average miscarriage rate in the U.S. approaches 20 percent; the average birth defect rate is 2 percent.) Employees requested an investigation by NIOSH and were surprised when the agency failed to test the machines for radiation emissions.

When Dr. Peter Lichy, the NIOSH medical officer in charge of this investigation, was asked why there was no VDT radiation testing in the San Francisco cluster, he said that it would have been "a big deal to fly a couple of techs and a hundred of pounds of equipment" out to the office to measure what he described as standard equipment. In a similar case in Alma, Michigan, Lichy reportedly told the employees that testing for non-ionizing radiation would be too expensive.

Diana Roose, research director for 9 to 5, National Association of Working Women, says that her organization has repeatedly asked that VDTs in every problem pregnancy cluster be tested for all frequencies of radiation. NIOSH has consistently failed to do so. Currently, NIOSH is planning a large-scale investigation into VDTs and reproductive risks that is slated to survey 4000 women—but which will not test the VDTs for radiation emissions. In the words of Laura Stock, coordinator of a group of 25 unions called the VDT Coalition, "to rule out radiation as a possible source of problem pregnancies without testing the machines themselves is "not giving us a complete picture of what the situation is.''

ART KLEINER: What’s really needed is systematic laboratory testing of all computer and terminal brands for ELF and VLF—under a variety of conditions, running a variety of types of software. The kind of tests that Rauscher and Von Bise began to do in our offices, that Sharma has done at the University of Water-

### Remedies

**ART KLEINER:** Many remedies are aimed at more than one hazard—hence they’re described separately. Much of this section is anecdotal, but we included only material about which we had reasonable confidence and agreement. Me? I use a grounded electrostatic shield (which I should report was a gift from Mike Skaar, one of the contributors to this article); I keep a houseplant near the computer to counteract positive ions; I turn down the brightness; I often use my non-VDT Radio Shack Model 100 instead of my VDT-based Kaypro II; and I stop periodically to rest my eyes, rub my neck, take a walk. All of these make a difference that I perceive—whether it’s an actual difference or a placebo effect, I do not know.

**Controlling the light**

**ART KLEINER:** Have symptoms like eyestrain and headaches? Worried about radiation? Check these remedies against glare first—it produces the same symptoms.

**ERICK WUJCiK:** First rule of glare and light: if it hurts, stop doing it! Nothing is right for everyone. You’ve got to experiment to get it right. If your eyes are getting sore and itchy, get up, look around at different things, change your lighting environment. Don’t let bare bulbs or direct sunlight bounce off your computer screen. Indirect, diffused lighting is best. All too often I’ve seen work-
places with floor-to-ceiling glass, bare fluorescent bulbs, and computer tubes turned up to full contrast to compensate.

Never, never, never use fluorescent lights anywhere near video terminals. This can create a really nasty flicker that only your subliminal unconscious mind and neutral system will be aware of.

The room light intensity should match the light from the screen. My own rule of computer lumiance (not supported by any scientific studies or government agencies) says that if your monitor light can cast shadows then the room light is too dim.

LOUIS JAFFE: Use the minimum contrast setting at which you can comfortably see the text. Try setting a monitor contrast level that feels a bit dimmer than you thought comfortable. This is because when you change the setting it takes your eyes a few moments to adjust. You will probably find that you can work longer at relatively low contrast settings. I use very low contrast and have only had eyestrain during inordinately long sieges of work.

On the Kaypro, Compaq, and many other machines, the so-called 'brightness' control, which is the only external adjustment for the monitor, is actually the contrast control. If one of these systems shows brightness across the whole screen in normal use, then the internal brightness control needs to be turned down. In a Compaq this is a simple screwdriver adjustment accessible by removing the top cover. Not sure about Kaypro.

Choosing a radiation shield

ART KLEINER: Shields, fitting over the front of the computer screen, stop glare and seem to stop some other hazards too. I asked Mike Skaar, whose company Ergonomic Computer Products in San Francisco evaluates and sells filter shields for VDTs, to explain the differences between different models.

MIKE SKAAR: The two most affordable types of VDT filters are fiber mesh, which cuts glare the way a venetian blind does; and coated film or glass, which diffuses glare. But we recommend either type only with the enhanced protection of electrostatic grounding (which adds about $25 to the cost), because it neutralizes the static electricity fields created by VDTs. This eliminates positive ions in the air, and greatly reduces the amount of dust that an electrostatic field will either attract to the VDT (which means you have to clean the shield constantly) or propel into your eyes.

You should consider how many hours a day you use your computer. Five minutes a day at the terminal doesn’t justify buying a filter. What’s the cutoff point before a shield is worth buying? The state of California has vacillated between one hour and four hours in determining their legislation. For now they’ve settled at two hours nonstop or four hours overall during a single day. That’s just one legislature’s opinion, but it seems reasonable to me.

ART KLEINER: Subjectively, electrostatically grounded shields feel much better than the other kind. I always felt a subtle stress from my Kaypro II. I feel it much less with the shield in place, and it returned a bit when I disconnected the ground wire.

Specific models? Right now (May 1985), there are two surface-mounted fiber-mesh shields with electrostatic grounding. They both work comparably well. The less expensive is made by Screen Data Corporation ($50 and up); the more expensive by Sunflex ($70 and up).

Optical Coating Laboratories makes the least expensive optical glass shield with an electrostatic ground — it runs $99 and up. These shields are all available without electrostatic grounding — but that makes them much less effective. Avoid lead-coated shields — they safeguard only against X-rays, which are already shielded against in your computer. On the other hand we have this report . . .

PAUL SMITH (correspondent on CompuServe): I purchased a lead-screened shield for my Macintosh last summer just after I got the computer. I had no idea just exactly what I was protecting myself from, but I also didn’t trust the safe levels of radiation that VDTs put out. My sales rep had a real laugh when he saw it. Then in October a friend of mine, who is trying to get the Canadian Broadcasting Company to remove the communications tower from just across the road at his summer home, brought in a meter that read ELF radiation levels. He brought it over and tested it out on my Mac. With the screen off, the meter read very high from the center of the display. With the shield in place there was little movement of the needle in front of the display, but behind the computer there was a high reading. The meter was borrowed from the University of Waterloo and was especially accurate in readings under high-voltage transmission lines.

Shielding the outside

MIKE SKAAR: At my ergonomic consulting firm, we still have doubts about whether EM radiation will ultimately turn out to be harmful. If it does, placing a filter on the front of the VDT may offer little protection. Many of the radiation sources are at the back of the machine, so the entire cabinet of the VDT must be shielded.

DIANA HEMBREE: First, make sure that your computer or terminal has metal shielding that covers the flyback transformer. If your terminal is a post-1980 model, it will contain at least some shielding, because the
Federal Communications Commission ruled in 1979 that manufacturers had to shield the source of electromagnetic signals that had been interfering with radio and military communications. In some models, the shielding may not cover the entire flyback transformer; you can often check with the manufacturer for specifics. The cost of installing copper or aluminum foil for shielding can be as little as $5 per machine, but it should be done by a technician (it's too easy to shock yourself with current stored in the monitor's capacitors, even after it's turned off) and may void some warranties.

Another shielding option, recommended by the Canadian Centre for Occupational Health and Safety (CCOHS), is a do-it-yourself metal shielding hood. CCOHS researchers have found that a copper mesh foil glued to cardboard, attached to a ground wire, and covering the five sides of the VDT, cuts VLF emissions to almost zero. The tops of terminal units with built-in printers do not require shielding since the printer itself blocks VLF emissions.

JAMES STOCKFORD: It is very important that the foil interior be grounded. All foil surfaces must be connected to each other in such a way that they will conduct electricity, and they must be surely connected to a wire that runs to a real ground. That connection is extremely important. The safety ground (round hole) in some wall outlets is not always grounded electrostatically. Use a cold-water pipe or be sure that the receptacle is truly grounded, not just shock grounded.

ART KLEINER: Unfortunately, ordinary metal shielding does not block a VDT's ELF magnetic fields. To do so, one must use a special alloy called Mu metal, which is difficult to obtain commercially and may require special training to install.

DIANA HEMBREE: Even with shielding, do not sit directly behind or to the side of another terminal. Since the computer's high-voltage power source, the flyback transformer, is located in the back or side of a VDT, the radiation levels are highest at the back of a terminal. On pre-1975 models, Dr. Arthur Guy has measured electric fields one centimeter from the set with intensities up to 40,000 volts per meter - readings which he calls "astronomical, what you'd get under high voltage wires."

ERICK WUJCIK: I couldn't agree more about the problems of exposure to the sides and backs of computer terminals. Don't forget that the machines in office environments are often MUCH more highly powered (in voltage) than most PCs at home. And workers in office environments are often placed directly next to, or in back of, the terminals. I can think of at least four places in the newsroom of the Detroit News where workers routinely use the backs of terminals to lean on . . .

**Combating static electricity**

DIANA HEMBREE: Besides using filters and grounds, there are other ways to cut static electricity near a CRT. Keep windows open to combat the "tight-room" syndrome; wash your face frequently to prevent particle adhesion; keep indoor relative humidity above 40 percent; grow leafy houseplants near the terminal; and/or install a negative ion generator.

**Posture**

LOUIS JAFFE: There are detailed ergonomic standards developed in both the USA and Europe which address the questions of just how a computer operator should be seated and oriented to his/her equipment. The advent of the detached, low-profile keyboard is one industry response to this research. Generally speaking, some things to watch are: Make sure you have a comfortable chair, adjustable for seat height, backrest height, and backrest angle; and experiment with the height settings till it feels just right for you. Don't use any furniture which forces you into an unnatural posture. Monitor viewing distance is partly a matter of taste and partly dictated by the screen size. Generally, portable computers with a built-in nine-inch screen need to be elevated or angled up quite a bit for a comfortable viewing angle.

To see if the monitor is the right height, close your eyes and incline your head to what feels like the most comfortable sitting position; then open your eyes and see if you're in fact looking at the monitor or above or below it. Adjust the monitor height to your sitting position, not the other way around.

ERICK WUJCIK: People weren't made for staring up. Not as a steady thing anyway. Make sure that you're looking at a screen that's slightly (from 5 to 35 degrees) BELOW eye level. Keep your arms straight! You shouldn't be reaching either UP or DOWN to type on a keyboard. In a normal sitting position your upper and lower arms should form a right angle and your hands should reach DOWN just a tad bit towards the keyboard. Nobody has perfect posture. As the keyboard you should slump BACKWARDS instead of FORWARDS. Straight is best, but it's sort of an idealized goal.

**VDTs and pregnancy**

DIANA HEMBREE: Experts disagree whether pregnant women should avoid VDT work entirely. A growing number of employers, including Boston University and the City of San Francisco, have agreed to provide alternative non-VDT work during pregnancy. ➾ 91
Warning: although there has been a recent surge of interest in lead aprons for pregnant operators, would-be users should know that they do not block low-frequency radiation — only ionizing radiation which is already shielded out. Also, the CCOHS has warned that wearing a lead apron could be hazardous by causing postural problems and putting extra weight (and possibly extra stress) on the fetus. Concluding that lead aprons provide "no benefit whatsoever," CCOHS advises women NOT to use such equipment.

DR. ARTHUR FRANK: I get called not infrequently by women who say "I am pregnant or want to be pregnant, should I work with the screen?" And I say that within whatever your company policy is, try to reduce your exposure and get shifted to another job for a while if you can, BUT the evidence isn't there yet that you know you ought to go to the wall and lose your job over this. These are complex issues from a public-health perspective and an acceptable-risk perspective.

Buying a computer

ART KLEINER: It would be lovely to say, "such-and-such a monitor is safe; so-and-so is not." Unfortunately, nobody has systematically tested personal computer monitors yet. We can't even definitively recommend color monitors over black-and-white or vice versa.

DIANA HEMBREE: Radiation specialists I interviewed disagreed whether color monitors on VDTs were likely to emit more radiation. They said unanimously that color monitors generate more radiation due to higher voltages, but some contend that the terminals' shielding blocks such radiation, making the difference negligible.

LOUIS JAFFE: Video reigns now for computer displays only because it is inexpensive and versatile. But besides the safety questions, it is power-hungry, heavy, and bulky. In the next year, for the first time, I think we'll see new technologies give video a run for its money.

The principal contenders are Liquid Crystal (LCD), Electroluminescent (EL), and Plasma displays. Very simply: All are flat sandwiches with outer, sealing layers, and inner, active layers. In an LCD (like that on the Radio Shack Model 100), crystals suspended in a liquid rotate to either pass or block light (reflected or backlight). In EL, a solid chemical layer glows. In plasma, a layer of sealed gas glows.

LCDs have been plagued by poor contrast, jerky scrolling, and restricted viewing angles, but solutions to these problems are at hand. Truly legible, full-screen LCDs are out of the labs, will reach the retail market in the next generation of portable computers, and will be cost-competitive with video.

Full-screen EL displays are standard equipment on the Grid Compass, and on HP's new integral. If you've seen either of these machines you know their displays are sharper than any video screen. EL displays still cost $800 at the factory level, which is why they've appeared only in premium hardware. With mass production, the price could fall drastically.

Plasma has been used for years in military graphics displays. The only civilian product I know of is a 17-inch screen from IBM that costs about $6000. It must be seen to be believed. It does something like 800 x 1200 pixel graphics with perfect linearity, or it can have four windows on screen at once, each showing 25 x 80 characters.

RICHARD DALTON: At present, LCD is certainly the most practical alternative to CRTs, yet there is the nagging problem of poor contrast under many ambient lighting conditions. Morrow claims to have achieved a modest breakthrough in this area with their Pivot portable. Apparently, they are using electroluminescence as a background to markedly increase LCD contrast.

A call to arms

DIANA HEMBREE: Keep track of the health problems, if any, that you and others in your home or office think might be VDT-related: 9 to 5 and other labor groups who monitor this information would appreciate hearing from you. Also, keep a record of the model and date of manufacture of your terminal, as well as the time period that you used it. If you should ever seek compensation for a health problem that you associate with your VDT work, you'll need documentation.

While electronics companies campaign to convince users that computers are safe, unions and women's groups are pressuring the government to set safety guidelines for VDT use on the job and to further investigate potential hazards. Including those of radiation. NIOSH is planning a mass survey of 4000 American women to determine whether there appear to be more reproductive problems among VDT users than non-users, but more needs to be done. VDT radiation may prove to be harmless, but only further investigation will determine its safety and reassure worried users.

ART KLEINER: The Computer and Business Equipment Manufacturer's Association argues fervently in their literature against government regulation of VDTs. The question of government regulation is important.
for clerical workers trapped in their jobs, but for personal computer owners it’s not nearly as important as clear information. If manufacturers released the data on how much they shield their machines, it would be a tremendous help to us concerned purchasers. A downright humanitarian deed.

Not knowing the final word is frustrating. There’s enough evidence of danger to be concerned; not enough to be convinced. It’s not time to scream “fire!” in the maternity ward yet, but I feel personally encouraged that people are in here sniffing for smoke. ■

Addresses

Canadian Centre for Occupational Health and Safety: 250 Main Street East, Hamilton, Ontario L8N 1H6, Canada.

9 to 5, National Association of Working Women: 1224 Hunon Road, Cleveland, OH 44115.

A wide selection of VDT filter shields is available from: Ergonomic Computer Products, 1850 Union Street, Suite 125, San Francisco, CA 94123.

William Von Bise suggests one source for Mu metal: A-Vance Magnetics, 625 Monroe Street, Rochester, IN 46775; 219/223-3158.

A manufacturer of VDT shields: Sunflex, 20 Pimental Court, Novato, CA 94947.

Acknowledgements

Ledger Haviland helped articulate some of the scientific descriptions. Annette Floystrup of Sunflex, Inc., provided essential background material. Diana Hembree and Mike Skaar contributed research and help far beyond what shows here. Paul Hawk and Richard Dalton produced this article into existence. Levi Thomas, Dr. Arthur Frank, and VDT News editor Mark Pinsky advised and helped.

Notes

1) Dr. Karel Marka, “The State of Knowledge Concerning Radiation Emissions from Video Display Terminals” (paper presented as “Science Focus,” Ottawa, Canada, 1982).


7) Ibid.

8) Ibid.

9) Ibid.


13) Dr. Hari D Sharma, The Investigation of a Cluster of Adverse Pregnancy Outcomes and Other Health-Related Problems among Employees Working with Video Display Terminals in the Accounting Office at the Surrey Memorial Hospital, Vancouver, B.C., 1985. (200 postpaid from Radiation and Environment Management Systems, P.O. Box 1, Waterloo, Ontario N3J 2S4, Canada.)

14) Physicist Elisabet Rauscher and electronics engineer William Von Bise co-founded Tecnica Research Laboratories, P.O. Box 667, San Leandro, CA 94577, in 1983.

15) Rauscher and Von Bise measured ELF electromagnetic radiation (0-10,000 Hz) from five computers — IBM PC with Princeton Graphics color monitor, Apple Macintosh, Apple II with monochrome monitor, Kaypro II, and Compaq portable. Their observations:

Color images emitted significant electromagnetic radiation at many more frequencies than black-and-white images. On the color IBM PC, moving text emitted significant radiation at more frequencies than stationary text. On the black-and-white Mac and Compaq, it did not.

On the Apple II (black-and-white), graphic games (LODE RUNNER and CHOPPER) emitted more significant radiation at different frequencies than text (stationary or moving) on the same computer.


17) This “consensus” is partly detailed in Dr. Sharma’s paper (see note 13 above). Also see Harvard Medical School Health Letter, April 1983.


19) Charles Wallach, Possible Health Hazards of VDT’s, 1982. (Report Prepared by Design and Decision, Inc., 8400 West Park Dr., Suite 600, McLean, VA 22101.)


22) Dr. Hari Sharma, op. cit. (see note 13 above).

23) Eric J. Lerner, op. cit. (see note 6 above).


25) Eric J. Lerner, op. cit. (see note 6 above).

26) Eric J. Lerner, op. cit. (see note 6 above).


Another unpublished paper, although it does not specifically cover ELF in depth, suggests that the waveforms that produce biological effects are very different from the waveforms produced by VDT. The paper: Arthur W. Guy, “Health Hazards Assessment of Radio Frequency Electromagnetic Emissions by Video Display Terminals,” 1984. We received our copy from the American Electronics Association, 2670 Hanover Street, Palo Alto, CA 94303.