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New York Telephone Company
New York City, New York

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PREFACE

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ACKNOWLEDGEMENTS AND AVAILABILITY OF REPORT

This report was prepared by C. Eugene Moss, HP, CSS, of the Hazard Evaluations and Technical Assistance Branch, Division of Surveillance, Hazard Evaluations and Field Studies (DSHEFS), with assistance from Don Booher, Laboratory Technician, Industrywide Studies Branch. Desktop publishing by Ellen E. Blythe.

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New York Telephone Company, New York City, New York
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SUMMARY

On October 26, 1990, the National Institute for Occupational Safety and Health (NIOSH) received a request from the Communication Workers of America (CWA) Headquarters in Washington, D.C. The CWA was concerned about possible health effects to workers in the telecommunication industry from exposure to electromagnetic fields (EMF), and requested NIOSH to perform a health hazard evaluation (HHE). As a result of discussions with the CWA, the HHE was undertaken jointly with both CWA workers and the Bell Communications Research Company (BCC), and was performed only as an exposure assessment with no epidemiological components.

The exposure assessment was performed in five different phases:

- Phase 1. Review of methods and data from an ongoing BCC study that included more than 1200 hours of collected monitoring data from 249 workers in nine states over a six month period. The mean EMF exposure ranged from 1.66 to 8.21 milligauss (mG) over nine different work environments.

- Phase 2. Measuring EMF levels at an operating telephone crossbar switching facility located at 240 East 38th Street in New York City. These measurements helped to estimate the EMF levels at a operational crossbar switching facility that used older equipment.

- Phase 3. Magnetic field transient data results were obtained by NIOSH investigators at the facility identified in phase 2 in conjunction with the American Telephone and Telegraph (AT&T) Company research laboratory personnel. These measurements were performed since it had been hypothesized by scientists that transient fields might be a better indicator for correlating human health effects than measurements of electric and magnetic field intensity values.

- Phase 4. Review of results previously reported in a NIOSH HHE (HETA 92-0009-2362) performed at a New York Telephone Company (NYNEX) central office facility (COF) located in White Plains, New York. Employees who worked at that COF were concerned about a perceived high incidence of cancer and believed they were exposed to high levels of EMF that contributed to their disease. During this HHE, NIOSH investigators also evaluated EMF exposure at another NYNEX facility. The measurements obtained in that evaluation were useful for estimating the range of EMF exposures for typical COF operations.

- Phase 5. Collection of EMF measurements on outside plant assistants and splicers on December 7-8, 1993, at several NYNEX locations on Long Island, New York. The EMF levels obtained in this phase helped to establish the range and magnitude of fields that NYNEX employees working outside might experience in performing their jobs.

Based on detailed exposure assessments of occupational EMF exposures at various NYNEX telephone company sites, NIOSH investigators concluded:

EMF electric and magnetic field levels measured at the various facilities did not exceed the American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Values (TLVs).

Levels of extremely low frequency (ELF) are quite low throughout various activities telephone workers perform. Rarely are the average levels above 6 milligauss (mG) and when they are at these upper levels they result mainly from being in the vicinity of equipment operating at power line frequency and not from emissions from any unique telephone associated devices. The levels found generally approximate the same levels NIOSH and other investigators have measured and reported on at other similar occupational settings.

Crossbar switching equipment racks containing vacuum tubes, each having at least 1 microcurie (μCi) of radium bromide, were found to have been in widespread use at telephone COFs for many years. Exposure to these sources could have occurred from carrying tubes in clothing, handling broken tubes, or working near intact tubes arrayed in racks. While few telephone workers are currently exposed to these sources, their presence in the past may have introduced a major confounder-ionizing radiation. The role of ionizing radiation (radium) should be considered in any study of cancer, either retrospective or current, among telephone COF workers involved with switching equipment.

Based on 94 samples measured on October 19, 1992, most of the maximum ELF time rate of change of magnetic field transients, expressed as dB/dt, were in the range of 1 to 2 millitesla per second (mT/s), and the peak dB/dt level was less than 9 mT/s. Furthermore, most of the transients measured had their highest intensity levels at frequency values less than 30 hertz (Hz). Unfortunately, very limited data exists from either animal or human tests to confirm that any value of dB/dt is either relevant to a yet undetermined biological endpoint or can produce adverse biological effects.

Keywords: SIC 3661 (telephone and telegraph apparatus), switching equipment, transients, radium bromide, EMF.

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INTRODUCTION

On October 26, 1990, the National Institute for Occupational Safety and Health (NIOSH) received a request from the Communication Workers of America (CWA) Headquarters in Washington, D.C. The CWA was concerned about possible health effects to workers in the telecommunication industry from exposure to electromagnetic fields (EMF), and requested NIOSH to perform a health hazard evaluation (HHE). As a result of discussions with the CWA, the HHE was undertaken jointly with both CWA workers and the Bell Communications Research Company (BCC), and was performed only as an exposure assessment with no epidemiological components. The decision to include Bellcore in this evaluation effort was based on the fact that BCC, and before it the American Telephone and Telegraph (AT&T) Company, had employed CWA workers for many years, and BCC had just initiated its own comprehensive EMF exposure measurement study for the telecommunications industry and the opportunity existed to share common interests.

In the mid-1980s, a study of leukemia incidence in telephone linemen was conducted by the School of Hygiene and Public Health of The Johns Hopkins University (JHU).[1] That study, funded by the Electric Power Research Institute (EPRI) and based on an AT&T mortality database, reached the following conclusions, "Neither all linemen analyzed as a group, nor subgroups of linemen analyzed by job title, nor subgroups of linemen categorized by estimated relative exposure to electric and magnetic fields, were found to be at increased risk for acute myelogenous leukemia or chronic myelogenous leukemia. The results were not affected by limiting the analyses to particular age groups, active or retired status, or calendar periods of hire. Adjustment for education and management status did not alter the results. No dose response by categorized relative exposure was evident." After this data was reported, a subset of the data was analyzed by other JHU researchers who claimed there was increased mortality from leukemia among cable splicers and an increased incidence of male breast cancer among central office technicians.[2]

As a result of these reports, and a growing concern among personnel in the telecommunication industries about EMF exposures, a steering committee of occupational safety and health professionals from BCC, BCC client companies, and AT&T Laboratories were assembled in 1990 to address this issue. An important outcome from this activity was the recommendation that BCC provide quantifiable assessments of magnetic field exposure in different telecommunications work environments in urban, suburban, and rural locations by conducting a study to verify occupational exposure to EMF at various telephone facilities. EMF exposure data from various BCC and AT&T worksites in nine states, using EMDEX-C monitors that records ELF fields, would be collected over a six month period. All of the EMDEX-C readings, along with work environment logs, would be downloaded into computer programs for storage, plotting, and statistical analyses. Prior to performing this study, the group decided to initiate a feasibility study. NIOSH became aware of this measurement effort when it was asked to review the BCC protocol for the feasibility study. Following a successful feasibility study a large scale measurement was undertaken. The results of that effort was published by BCC in 1992.[3-4]

BACKGROUND

Contact was made with appropriate BCC representatives about plans for their EMF study since it was believed those results would assist NIOSH in its pending evaluation. As a result of these contacts, NIOSH investigators learned that a few present-day COFs in New York state were still using crossbar switching equipment which was at least 25 years old. Visits were made to two such facilities and one was selected jointly by

NIOSH, CWA, and BCC investigators where measurements might be representative of both present and past occupational EMF exposure levels.

Operation of Telephone Switching System

The switching system used to process calls at the 38th Street COF in New York City was a #5 crossbar automatic call distributor (ACD). The ACD system, located on the 5th floor of the COF, was not a complete #5 crossbar system since it only operated a small system and had only one worker. The system was being used to locate available 411 (information) Manhattan operators. The operating system is shown schematically in Figure 1. Telephone calls enter the switching center which controls 1500 lines through the incoming trunk relays. These calls are relayed to the line link portion of the system, which processes them through two parts of the system denoted connector and marker components. Once that activity is completed, the marker connects the call to the position link via the ACD trunk link. The completion of the second activity permits the operator to talk with the caller. At the same time, the marker and connector close-off and become available to process another call. While all calls go through the system as shown in Figure 1, not all relays are needed on every call.

A completed telephone call at this exchange will involve the movement of small electromagnets. In fact, the crossbar equipment operates mechanically using a wire or flat spring to both open and close switches and relays. The connection and disconnection patterns (waveforms) of the electromechanical switches can be observed with a fast responding oscilloscope. Figures 2-4 show typical waveform patterns, and their transients, from 38th Street on the days of evaluation. It is obvious that a completed call does involve components that produce varying and unique transients. While it is true that workers can be exposed to these transients at a specific location, it would be difficult for one person to be exposed to all transients at a single time since they are produced at many locations in the switching room.

The marker portion of the switching system gets the most traffic since every call must be processed by it. Each marker acts as a switchboard to find an available operator to handle the 411 call. Since markers handle the most traffic, they tend to require more repair. It is assumed that they may generate more EMF exposure than other components and would, therefore, be an important system element on which to obtain exposure information.

In the past, the various system components would have been worked on by different workers such as switchmen, frame attendants, and power technicians, rather than just one worker, as was the case in this evaluation. It is reasonable to expect that EMF exposures will vary depending upon such factors as job task, type of equipment used, whether exposure is constant or transient, location of worker relative to exposure source, and volume of calls being made.

Time Rate of Change of Magnetic Fields

It has been suggested that some property of a magnetic field, not presently being measured, might correlate better with some biological endpoints. The variation of a magnetic field with time comprises one such potential property. At the COF studied in this evaluation, the operation of many electrical systems and devices results in magnetic fields having complex waveforms and whose field strength changes over time. Measurements were made of the waveforms of extremely low frequency (ELF) magnetic fields produced by components in the telephone switching system. Such measurements involve the determination of intermittent changes in the magnetic field (see Figure 5).

This ability to determine the rate of change associated with magnetic fields may be related to the ability of the field to induce currents in the body. Currents induced by magnetic fields circulate in the cross section area of the tissue by eddy currents and are directly proportional to the time-rate-of-change of the magnetic field, expressed as dB/dt. The greater the value of dB/dt, the greater the magnitude of the induced current, assuming the peak magnitude of the field remains constant. While magnetic field waveforms might have the same root mean square value, they may induce very different peak currents depending on their relative rise and fall times.

Unfortunately, very limited data exists from either animal or human tests to confirm that any value of dB/dt is either relevant to a yet undetermined biological endpoint or can produce adverse biological effects.

EVALUATION DESIGN AND METHODS

General Evaluation Design Concept

During the time period that this evaluation was in progress, NIOSH received another health hazard evaluation (HHE) request to evaluate occupational exposure to EMF at a NYNEX COF located at White Plains, New York.[5] This White Plains COF study has been completed and will be referred to in this present evaluation since it, and portions of this evaluation, were similar in scope and content.

In addition to EMF data derived from COF measurements, NIOSH investigators also obtained EMF results from other telephone workers who did not work at COFs. The accumulation of measurement data on as many workers as possible would provide a better comparison with the data obtained in the more detailed BCC study referred to above. Measurements, therefore, were performed with non-COF based telephone linemen who worked on poles that contained both electrical and telephone cables (so-called shared poles) at several locations in the greater New York City area. On December 7, 1993, NIOSH investigators made ELF measurements on several three-person NYNEX teams, containing outside plant assistants and splicers, working on Long Island, New York, in Nassau County.

Due to interest generated in scientific papers about transients, NIOSH investigators, in conjunction with representatives of NIOSH, AT&T, BCC, NYNEX, and CWA collected transient data from crossbar switches and relays.

The complete NIOSH evaluation consisted of five separate phases that took months to complete and often overlapped each other since they were being conducted at different time periods. These phases are:

Phase 1. Review of methods and data from an on-going BCC study.

Phase 2. Measuring EMF levels at an operating telephone COF located at 240 East 38th Street in New York City.

Phase 3. Collection of magnetic field transient data acquired at the facility identified in the second phase by NIOSH and AT&T research laboratory investigators.

Phase 4. On October 7, 1991, NIOSH received a request from employees of the NYNEX COF located in White Plains, New York. These employees worked on the third floor of the COF and were concerned that EMF exposures may have contributed to perceived high incidence of cancer among employees working on that floor. Employees were also concerned about workplace environmental conditions including indoor air quality and chemical exposures. An initial site visit was conducted on December 23, 1991. On July 27-29, 1992, a follow-up site visit by a NIOSH industrial hygienist, epidemiologist, and health physicist was conducted to further evaluate the building. NIOSH investigators measured EMF levels throughout the facility, assessed potential chemical exposures, and evaluated the indoor environmental quality within the building. NIOSH investigators also interviewed employees and observed work practices. In addition, NIOSH investigators evaluated EMF exposure at another NYNEX facility where older telephone switching equipment was in operation. The complete report of this HHE was published by NIOSH in 1994.[5]

Phase 5. EMF measurements were made on December 7-8, 1993, at several NYNEX locations on Long Island, New York, at the invitation of the NYNEX Health and Safety Department. The first day measurement results were obtained in Nassau County for typical work performed both by outside plant assistants (OPT) and splicers. In addition, EMF measurements were also made in a controlled environmental vault (CEV). The second day measurement results were obtained in Yonkers for typical work also performed by splicers and OPT personnel. The work performed on both days for the two work groups was typical, yet quite different.

Equipment Used in the Evaluation

During the conduct of this evaluation, emphasis was placed on assessing occupational levels of sub-radiofrequency electric and magnetic fields found at various worker locations within selected telephone facilities. The entire evaluation process was designed to survey actual worker exposures to EMF fields during the performance of given work tasks. The number of measurements taken in this evaluation was not intended to represent an in-depth evaluation of the EMF at the site, but was rather intended to approximate occupational exposure levels found on the days of measurement.

Worker exposure to the various EMFs found at NYNEX facilities was documented using the following equipment:

* A Holaday Industries, Inc. model HI-3602 ELF sensor, connected to a HI-3600 survey meter, was used to document both the magnitude of ELF electric and magnetic fields and the electrical frequency (as well as the waveforms) produced by such fields. The electric field strength was measured in units of volts per meter (V/m) and the magnetic field strength was measured in units of milligauss (mG).

* Holaday Industries, Inc. model HI-3627 3-axis ELF magnetic field meter was used to make isotropic measurements of the magnetic field in and around different workstations. The magnetic field is measured over the frequency region from 30 to 2000 Hertz (Hz) and the dynamic range of the instrument is from 0.2 mG to 20 gauss (G).

* Selected measurements were made with the EMDEX II exposure system, developed by Enertech Consultants, under project sponsorship of the Electric Power Research Institute, Inc. The EMDEX II is a programmable data-acquisition meter which measures the orthogonal vector components of the magnetic field through its internal sensors. Measurements can be made in the instantaneous read or storage mode. The system was designed to measure, record, and analyze power frequency magnetic fields in units of mG in the frequency region from 40 to 800 Hz. The meter has the capability of displaying magnetic field values in three different frequency bandwidths; broadband which measures from 40 to 800 Hz, harmonic that measures from 100 to 800 Hz, and the fundamental bandwidth which measures at 60 Hz.

* Average magnetic fields were documented by use of the AMEX-3D exposure meter. This small, lightweight three-axis magnetic field meter can be worn by a worker to monitor average magnetic field exposures that are produced at small levels. The AMEX-3D stores an electrical charge, proportional to the time-

integral of the magnetic field, which can then be read-out and converted into average magnetic field value. The AMEX-3D exposure meter is manufactured by Enertech Consultants, Inc. located in Campbell, California.

* There were two waveform capturing systems used to document transients. The first system consisted of a M-123 module and signal-conditioning interface manufactured by EFM Company, a Toshiba T5200/100 personal computer (PC), an LPM-16 data acquisition card from National Instrument, and a PC-Matlab software package from the MathWorks, Inc. The software package was used to perform the fast Fourier transforms (FFT) and other spectral transformation functions on the PC. The second system consisted of an Eaton Corp Model 94605-1 loop antenna, a signal integrator, and a HP 3560A Portable Dynamic Signal Analyzer. The HP 3560A is a FFT-based instrument capable of measuring signals in both the time and frequency domains.

Extremely low frequency (ELF) electric and magnetic fields results were documented with EMDEX, AMEX, and Holaday systems. At some locations, measurements were made for very low frequency (VLF) EMF levels using the Holaday meters. Due to the vast number of measurements required for this evaluation and the imposed time constraints, the EMDEX II units and the Holaday meters were used in a walk-around monitoring mode by NIOSH investigators to determine the lowest and highest levels found in a particular worksite. When levels were recorded that appeared to be far outside of the normal range being documented, that particular area was scanned again at a slower rate to confirm the presence of a localized elevated level. No attempt was made to determine an individual worker's time weighted average exposure when in the walk-around mode. When operating in this mode, the meters were held at chest height and slowly moved over a small area while walking at a slow pace.

The AMEX units were positioned at various instrument locations in several rooms on different floors to verify the presence of ELF near instrument racks. All measurements were made during the first two shifts with equipment held at waist height.

A few limited EMF measurements using some of the above equipment were made at the Yonkers COF. Selected transient waveform measurements were also performed at a Manhattan COF using specialized equipment. Finally, a limited ionizing radiation survey was performed, both at the White Plains and Yonkers COFs for both occupational exposure from present day use of radioactive tubes and possible contamination of the worksite from use of these tubes in the past.

All equipment used to document exposure to electric and magnetic fields had been calibrated within six months use either by NIOSH or their respective manufacturer. Most measurements were taken at positions considered to be typical of occupational exposure (one meter away and one meter from the floor).

EVALUATION CRITERIA

Sub-radiofrequency (RF) Fields

At the present time, there are no OSHA or NIOSH exposure criteria for sub-radiofrequency (RF) fields. The ACGIH has published TLVs for sub-radiofrequency electric and magnetic fields.[6] The TLV for magnetic fields (B_{TLV}) states, "routine occupational exposure should not exceed:

$$B_{TLV} \text{ (in mT)} = 60/f$$

where f is the frequency in hertz." One millitesla (mT) equals 10 G. Conversely, the electric field TLV states, "occupational exposures should not exceed a field strength of 25 kilovolts per meter (kV/m) from 0 to 100 hertz (Hz). For frequencies in the range of 100 Hz to 4 kilohertz (kHz), the TLV is given by:

$$E_{TLV} \text{ (in V/m)} = 2.5 \times 10^6/f$$

where f is the frequency in hertz. A value of 625 V/m is the exposure limit for frequencies from 4 kHz to 30 kHz."

This means, for example, at 60 Hz, which is classified as ELF, the electric field intensity TLV is 25,000 V/m and the magnetic flux density TLV is 1 mT or 10,000 mG.

The basis of the ELF E-field TLV is to minimize occupational hazards arising from spark discharge and contact current situations. The H-field TLV addresses induction of magnetophosphenes in the visual system and production of induced currents in the body. Prevention of cancer is not a basis for either of these TLVs because exposure has not been conclusively linked to cancer.

It should be recognized that the ACGIH has recently adopted new TLVs for the sub-radiofrequency region that will alter the above levels. The new TLV for magnetic flux density (B_{TLV}) in the sub-radiofrequency region recommends the use of the same magnetic field equation TLV but has adopted a ceiling value of 1 mT (10 G) from 1 to 300 Hz and a ceiling value of 0.2 mT (2 G) from 300 to 30,000 Hz. The new TLV for electric field strength is now a ceiling value.

Transient Fields

There is no occupational exposure standard for the measure of dB/dt. However, several years ago the Swedish government adopted a Video Display Terminal (VDT) procurement specification that calls for ELF/VLF dB/dt levels to be below 25 millitesla/second (mT/s) at a distance of 50 centimeters (cm) from the VDT.[7] This number was not based on any scientifically derived results and is really a number that most VDTs tested could meet. NIOSH conducted a study[8] that measured ELF dB/dt ranging from 0.25 to 1.8 mT/s at 50 cm from several IBM VDTs. Another study, by Paulsson, reported dB/dt levels from 44 VDTs to range from 7 to 170 mT/s.[9]

Simske, et al. in 1991, reported on the effects of localized pulsed EMFs on tail suspension induced osteopenia in male mice.[10] Mice exposed to peak changes in magnetic fields from 10 to 20 Tesla per second (T/s) showed significantly fewer osteopenia effects than did untreated mice.

In 1990 Berman, et al. reviewed the developmental effects literature for exposure of animal embryos to low frequency, low intensity pulsed magnetic fields.[11] One of their findings was that there may be a greater ratio of positive demonstrations of effects when the repetition rate is 60 to 100 Hz and the dB/dt is over 0.1 μT/μs (or 1 mT/s). Generally, they concluded that data was not available to extrapolate to human effects. In dealing with EMF transients, it should be stressed that very strong transient fields can and do occur when the coils or switches are rapidly switched off and on. Figure 5 gives examples of the differences in flux density and dB/dt waveforms.

RESULTS

Phase 1. Involvement with Bellcore Study

Immediately after initiating this evaluation, BCC personnel were contacted about the status of their study. NIOSH was informed that the pilot study had been completed and that work had started on the planned study. The pilot study had involved three companies and 55 workers. The major findings of the pilot study was that occupational exposure from magnetic fields seem to be related more to type of work done than job title, forms used to record information had to be improved, certain techniques used to gather data were improved, and that they knew the approximate occupational magnetic field levels workers were exposed to during a workday.

On August 8, 1991, NIOSH investigators were invited to New Jersey by BCC representatives and received a detailed review of the background associated with the study, pilot study background data, and an overview of how the formal study was proceeding. Following this meeting, the NIOSH investigator was invited to observe portions of the New York City data collection phase scheduled for September 23, 1991.

Observing the data collection phase was very informative since it demonstrated how the data was collected over a typical workday. Selected workers were assembled in the morning, briefed about the study, and showed how the EMDEX-C meter worked. Normally one surveyor (generally a safety professional) accompanied each worker for time periods from 4 to 8 hours. When 4-hour samples were collected in the morning, the surveyor turned off the meter in the afternoon and put a different meter either on the same or on another worker. The workers wore the meter on a belt around their waist. Additional details about the sampling procedures are available in references.[3-4] The NIOSH observer spent the day in the Bronx section of New York City observing several telephone installations in homes and apartments. Magnetic field levels recorded appeared to be relatively low (i.e., 1-3 mG) during most of these installations and became higher (i.e., 4-6 mG) when the worker had to move closer to electrical devices such as lamps, stoves, clocks, and radios. This pattern of exposure suggests that field workers received exposure not from telephone devices or installation procedures, but from proximity to household electrical devices.

Of particular interest to NIOSH investigators were the measurements performed in the COF since published reports had expressed concern that the EMF levels were related to operations of electromagnetic switching components. Most of the measurements in the Bellcore study had been performed in modern offices that had replaced the older switching systems, and the NIOSH investigators believed that additional measurements should be made on the older systems before they were completely replaced. During this observational period, the NIOSH investigator became aware of a number of NYNEX COFs in New York City that still contained old crossbar switching systems and made arrangements to visit these facilities at a later date.

The BCC completed its magnetic field exposure study in late 1991 and invited the NIOSH project officer to a meeting on February 11, 1992, to hear the final results. Representatives of each participating company and the CWA were also invited to the same meeting.

The results of the BCC study were based upon more than 1200 hours of collected monitoring data from 249 workers in nine states over a six month period. Based on the 1.5×10^6 data points collected using EMDEX-C monitors, the mean exposures and standard errors were determined for telephone company work environments and are shown in Table 1. The mean exposure ranges from 1.66 to 8.21 mG over nine different work environments. The data collected by BCC and presented in Table 1 is important to this NIOSH evaluation since it represents the only large-scale published data by a telecommunication company, as of its date, relating to occupational exposure of telecommunication workers to EMF fields and therefore can serve as a marker against which comparisons can be made.

Phase 2. 38th Street COF EMF Assessment

During this phase of the evaluation, several different measurements were performed to better understand the nature of exposure that could occur in the switching room. Results were obtained that: (1) compared EMF levels produced by switching equipment with time, (2) measured EMF fields as a function of distance from the switching racks, (3) measured EMF at various locations in the switching room with different instruments, (4) compared the number of calls processed with measured EMF levels near the switching equipment, (5) verified the presence of transients, and (6) made personal measurements on the worker assigned to the area.

EMF levels over different days

Table 2 shows the measurement results obtained on workers that wore EMDEX meters around their waist. Since there was only one worker in the switching room, additional personal data was obtained by having the two NIOSH investigators wear EMDEX meters.

Table 2 shows that on the day of measurement, the mean magnetic fields for the frequency range from 30 to 800 Hz were less than 2 mG for the three personal meters. The designations of Area 1B and 1F in Table 2 represent two EMDEX meters placed on the back and front side of a crossbar switching rack for 4.5 hours. The mean levels associated with the Area 1B measurement (rack back) are below 2 mG and are of the same magnitude as the three personal EMDEX results. The mean level of the Area 1F (rack front) measurement are over twice the level of the Area 1B result.

The same measurements performed on December15th were repeated on December 16th with all the EMDEX meters in the exact same locations. However, there were two differences in the data of day two from day one. First, the data was acquired over 3 hours rather than 4.5 hours, and second, there is a difference in NYNEX and NIOSH individuals performing different work tasks on the second day from those performed the first day. The two individuals performed walk-around measurements at another location on the floor and their EMDEX meter recorded maximum exposures of 210 and 215 mG as shown in Table 2. However, even with this elevated short-term exposure, the average of the three personal samples were all less than 2 mG, the same as recorded on December 15, 1991.

On the second day (12/16/91) the EMDEX meters, designated 1B and 1F, that were placed at the same exact front and back location they were in on 12/15/91 (and left there for 3 hours), produced magnetic field levels that were higher than on 12/15/91 on both sides — with the highest levels found again on the front side (1F side) as shown in Table 2. Figures 6 and 7 shows the time-intensity distribution for the two front side measurements made on both days. These EMDEX results suggest that the average magnetic fields produced in and around the switching equipment not only will vary as a function of telephone call volume, but will be higher than the average levels found at distances far removed from the switching equipment.

Additional EMF area measurements were made, using survey meters that could be positioned closer to the various components, that confirmed the difference in magnetic field levels between the front and back sides of the racks. For example, at a distance of 0.5 inches the magnetic fields ranged from 200 to 600 mG when measured close to various relays and switches at the front of the racks. On the back side of the racks, at distances of 0.5 inches, levels ranged from 2 to 20 mG. The variation in EMF levels from the front and back is probably due to measurement of fields from multiple switching sources. These results, from the EMDEX data and area surveys, suggest that exposure to the hand, wrist, and fingers would be the highest for work performed on the front side of the racks, a location where switch work is performed. The CWA worker in the switching room informed the NIOSH investigators that, in the past, workers were instructed to perform required tasks when the system was in a down mode rather than an active mode. This suggests that actual EMF exposure could be much less than what these measured levels demonstrated.

AMEX data obtained in switching room

NIOSH was informed that the number of telephone calls coming into this particular switching center was much higher on Monday morning than any other time period of the week. In order to determine the relative importance of telephone activity with EMF activity, NIOSH investigators asked NYNEX to log the number of calls processed over the days of measurements. At the bottom of Table 3 the average number of calls per minute made into the system is shown. Notice that the average number of calls made per minute into the system on the days of measurements were over four times more on Monday than Sunday.

AMEX dosimeters were placed at various locations in the switching room and the data was taken over both Monday and Sunday. Table 3 shows the magnetic field levels as a function of location and number of telephone calls made. Notice that there is not much difference in the levels recorded at the same location for the two days. This suggests that, while there are more calls being made, the magnetic field levels in the room away from the switches and relays do not vary by the same ratio as the number of calls made. Figure 8 shows a map of the switching room indicating where AMEX meters were located as well as other pertinent information.

EMF levels as function of distance from switching equipment

The magnetic fields dropped off very quickly as a function of distance from the racks. The measured levels in the center of the walkway (located between opposite racks) ranged from 2 to 6 mG depending upon the presence of ceiling lights or other electrical devices. The width of the walkways varied at different locations in the room, but generally averaged about 30 inches. In fact, one did not need to move to the middle of the walkway to measure such field reductions since, in some situations, the drop-off was seen in a distance as little as 12 inches from the racks—depending upon the geometry associated with the switching equipment. It was also observed that magnetic levels at the center of the walkway would drop-off rapidly as a function of the distance from one rack, only to increase as one moved closer to racks on the other side of the walkway. Keep in mind that current occupational EMF exposure was limited in the room since only one worker was presently involved with system operations.

Documentation of transient fields

Figure 9 shows a typical capturing of magnetic field transients from the switching components. However, other than ability to document the presence of such transients, NIOSH did not have the appropriate equipment to measure these transients at the time data was collected for this phase of the evaluation. The NIOSH investigators believed that most of the transients induced by the old switching equipment were not necessarily 60 Hz, but were probably of lower frequency. If the transients were produced at 20 to 30 Hz, their evaluation using the EMDEX meter would not be appropriate due to frequency limitation of these meters. In addition, since most of the recorded transients were of the order of 100 to 200 milliseconds (ms), then measurement with the EMDEX set at 3 seconds would create problems in determining a single switching event. Further assessment of these transients was performed at a later date (see Phase 3).

Documentation of EMF levels in other parts of the COF

While emphasis in this phase was on documenting EMF levels on crossbar switching equipment, some walk-around measurements were acquired in other parts of the COF away from the short range transient fields associated with the switches.. On the 6th floor, magnetic fields ranged from 1 to 4 mG at locations where employees were seen working, while on the 4th floor, levels ranged 0.4 to 3.0 mG. Measurements were also taken outside the building, at every corner of the building, and at various exits and entrances for the building. Levels measured outside were all less than 2.2 mG.

Measurements at other parts of the 5th floor, but outside of the switching room, ranged from 0.8 to 215 mG. The two highest recorded levels, 210 and 215 mG, occurred at an electrical panel box. It did appear that the ELF magnetic field levels were slightly higher at these other 5th floor locations and are probably due to the presence of power line frequency sources. It was noted that few workers were at any of these locations.

Phase 3. Transient Evaluations at 38th Street COF

There were 94 waveforms captured in the crossbar switching room on October 19, 1992. Figure 10 depicts techniques used to capture the transients near the switching equipment. There were three plots produced using the data from each of the waveforms captured by the M-123 system: (1) time-domain plot of the sensor coil voltage (Figure 11), (2) time-domain plot of the reconstructed magnetic field from plot 1 (Figure 12), and (3) frequency domain plot of the amplitude of the magnetic field up to 800 Hz (Figure 13). The maximum deviation of coil voltage in millivolts (mV) can be obtained from each of the sensor coil voltage versus time plots and then multiplied by 106.63 µT/s/mV to yield dB/dt levels. Based on 94 samples measured on October 19, 1992, most of the dB/dt levels were approximately 1-2 mT/s and the maximum dB/dt level was less than 9 mT/s.

The magnitude, frequency, polarization, and initiation of these transient ELF magnetic fields produced by the older switching equipment are complex. Most of the peak frequency components were non-sinusoidal random pulses of 5 to 50 ms duration and magnitudes up to 250 mG. Most of the fields produced in these transients had their highest intensity levels at frequency values less than 30 Hz.

Phase 4. White Plains COF EMF Assessment

Medical findings

Twelve cases of cancer were identified by employees over the past 13 years, six within the last three years. No one form of cancer predominated in the White Plains facility. Because of this finding, the small size of the work force at White Plains, the presence of confounders (other potential risk factors for cancer), and the inability to accurately assess the past EMF exposure due to major changes in the type of equipment used in the telephone industry, epidemiological investigation of the role played by EMF in the development of cancer at this site was not feasible.

EMF measurements

On July 27-29, 1993, measurements of ELF and VLF electric and magnetic fields were performed with various detectors on every floor of the COF and are shown in Table 4. This table shows that the ELF magnetic fields levels ranged from 0.1 to 2100 mG while VLF magnetic fields ranged from 0.1 to 30 mG. Measurements of ELF electric fields ranged from 2 to 5.8 V/m and VLF fields ranged from 1.8 to 300 V/m. All measurements reported in Table 4 were within the ACGIH occupational exposure standards for ELF/VLF fields. The mean value of 2.23 mG given for the COF from the Bellcore study (Table 1) can be compared with the mean levels ranging from 1.90 to 6.73 mG found in Table 5 measured by NIOSH investigators at the White Plains COF.

Radium bromide tubes

During the course of this evaluation, NIOSH investigators confirmed that radioactive vacuum tubes had been in widespread use at telephone

COFs for many years. The Western Electric (WEC) and AT&T companies used up to 1 microcurie (µCi) of radium bromide (RaBr) in the envelope of cold-cathode gas tubes as a stabilizing agent for many years. Around 1960, a major effort was made by the telephone companies to use Krypton-85 (Kr-85) as the residual ionization source instead of RaBr because it would reduce occupational radiation exposure and be more efficient to manufacturer.

At least three groups of workers were potentially exposed to the RaBr radiation: (1) electron tube manufacturing personnel, (2) personnel assigned to the disposal of spent or completed tubes, and (3) workers in areas where the tubes are used (switching rooms at COFs). Since large banks of RaBr tubes were no longer in use, company data was used to review previously exposure. An estimate of the relative radiation intensity that could be achieved from an array of tubes containing radium versus the replacement tube with Kr-85 is shown in Table 6. The NIOSH investigators visited the COF at Yonkers, New York, and measured some of the remaining RaBr tubes at that facility. This data is shown in Table 7.

While the data shown in Table 6 is different than what is shown in Table 7, the results demonstrate three points. First, the RaBr tubes gave much higher radiation levels than the Kr-85 tubes. Second, the drop-off in radiation activity is quite similar to that reported in the telephone company report. Third, RaBr tubes were in use in 1992 in at least one COF. While it is realized that exposure to ionizing radiation from the radium bromide tubes can only be hypothesized since no RaBr tubes were actually seen at the White Plains facility on the days of evaluation, it is very likely that some exposure occurred at all COFs, having crossbar switches, from the large banks of RaBr tubes associated with the equipment (i.e., five rows of 12 tubes = 60 tubes per array per rack).

The NIOSH investigators concluded that exposure to RaBr tubes could have occurred from carrying tubes in clothing, broken tubes, and working near intact tubes arrayed in racks. While the contribution from each of these exposure routes is not known, it does seem apparent from observations, interviews with employees, and discussion with past and present company officials that past workers could have been exposed to ionizing radiation, at some level, from one or all the above routes. It is also appropriate to note that few telephone workers today are exposed to these radiation sources. This finding could possibly introduce a major confounder in assessing past workplace exposure and cancer.

Electrical shock

Employees, who performed cable wiring functions at the White Plains COF, reported many incidents of electrical shock, sometimes involving high voltage, as a result of their work. Employees reported that current was high enough to "melt" screwdrivers if they touched the wrong wires, particularly in the vicinity of transformers used in the older telephone equipment.

Environmental measurements

Industrial hygiene measurements revealed adequate ventilation of the workspace, but several areas exceeded American Society of Heating, Refrigerating, and Air-conditioning Engineers (ASHRAE) guidelines with regard to humidity.

Phase 5. Shared Pole ELF Assessment

Day 1 measurements

The first set of measurements was performed on two OPT workers and one NIOSH investigator. The duties of the OPT workers involved replacing old telephone cable on poles with new cable. The telephone poles were located in a residential section and they were shared (i.e., electrical cables were also located on the poles). Three telephone workers were involved with this operation. One of the workers climbed the poles to pull the cable through drilled holes while the other two workers were stationed on the ground and maneuvered the cable from pole to pole. The worker who climbed poles wore the EMDEX meter around the neck, while the other two individuals wore the meter around their waist. EMDEX data for this measurement portion is shown in the top three columns of Table 8. Data was collected with EMDEX meters set at 3 second intervals.

The highest magnetic field level obtained in this first set of measurements was 718 mG and occurred on a worker who was using a gasoline powered drill for a two minute interval (Figure 14). This is demonstrated in Table 8 by higher levels being reported under the harmonics mode and in Figure 15 which shows the impact of the drill on the total exposure. NIOSH investigators were informed that the use of a gasoline drill is a relatively new practice, since in prior years workers would have used a hand drill. The means of broadband magnetic field exposure for the three monitored individuals ranged from 1.81 to 14.84 mG. However, as Figure 15 suggests, without the impact of the gas drill, these levels would be much smaller. On the other hand, preliminary measurements by NIOSH investigators indicate that similar drills produce EMF frequencies with components much higher than 60 Hz depending on the drill load. Some frequencies were higher than 800 Hz, and therefore, the exposure may be significantly different than what the EMDEX meters were able to record. It is noted that, on some poles, workers are exposed to both electric and magnetic fields from 7.6 to 13.2 kV transformers. The highest electric field measured by the pole climber in this evaluation was 70 V/m.

The second set of measurements, performed on the first day, was made on three splicers connecting a 200 pair telephone cable (400 wires have to be spliced) at another residential site in Nassau County on Long Island. The splicers generally worked by themselves on a ladder for several hours. The splicers tend to remain at a location on a ladder longer than the OPT personnel. Splicers are also potentially exposed to lead if they have to cut old cables. This practice is changing, however, since plastic sheaths are now being used. Figure 16 shows the splicers performing their trade while located at close distances to electrical wires and transformers.

The average broadband magnetic field level obtained on splicers in the second set of measurements ranged from 2.37 to 3.76 mG (Table 8). Two of the workers (splicers 2 and 3) wore EMDEX meters around the neck and splicer 1 wore the meter at the waist. The highest electric field recorded was 20 V/m.

The final set of measurements on the first day was made in a CEV, which is a small scale COF located underground (Figures 17 and 18). The CEV visited was about 30 feet long, 10 feet wide, and was 9 feet tall. EMF levels ranged from 3-5 mG in the middle of the vault and 3-5 V/m throughout the vault. Workers are not normally stationed in these vaults for any lengthy time period since minimal maintenance is required for the modern electrical devices used by the telephone company and built-in system redundancy negating the need for frequent worker intervention.

Day 2 measurements

The first set of measurements on the second day was made outside of a nursing home in Yonkers. Two splicers were installing a 200 to 400 pair cable on a new shared pole using a boom (lift) truck as shown in Figure 19. The boom truck has lift motors mounted onto the chassis which can be operated from within the boom. The splicers informed the NIOSH investigators that the new pole was higher than the old pole and therefore the separation distance between the telephone and power lines was greater than normal. Hence, occupational EMF exposures were probably smaller in these measurements than might be documented under different conditions.

The EMDEX meters were placed on the two splicers and a NIOSH investigator. The two splicers wore the EMDEX meter around the neck and the NIOSH investigator wore the meter around the waist. The average broadband magnetic field level obtained on splicers and the NIOSH investigator, shown in the first three lines of Table 9, ranged from 2.94 to 6.11 mG. The two highest average readings occurred on individuals who had entered the nursing home to review the status of inside telephone hookups. There are two possible reasons why these results are higher: (1) the presence of the boom motors, and their EMF fields, exposing individuals, and (2) possibility of higher fields inside the nursing homes than fields present at the telephone lines. This observation of higher EMF fields from electrical sources in buildings than from telephone equipment was also seen by the NIOSH investigator who participated in the BCC study in the Bronx discussed in Phase I.

The second set of measurements on the second day occurred at a residential section in Yonkers. At this location, four OPT workers were involved with removing old telephone cable from shared poles and winding the cable onto large wooden spools for removal to a storage site (Figure 20). Three OPT workers were selected to wear the EMDEX meter. All three workers wore the meter around their necks and the average broadband magnetic field exposure recorded ranged from 1.31 to 2.82 mG.

The telephone cable being removed was old and therefore contained lead. The NYNEX representative was concerned over the possible problem of lead contamination and the lack of appropriate control measures, such as gloves, no covering material, and no wet-down procedures, and therefore stopped work after limited EMF data was acquired.

Table 10 shows all OPT telephone worker exposure results obtained over the two day measurement exercise. Measurements were made on different splicers and OPT personnel at different locations performing different worktasks. The means calculated from the limited ELF exposure results obtained from telephone installers, repairers, and line (pole) personnel ranged from 1.3 to 14.8 mG. With the exception of the use of the gas drill, no mean worker measurement exceeded 3.53 mG. These range of values are supported by the Bellcore data shown in Table 1. These levels also approximate the same levels NIOSH investigators have found in office settings, where sporadic exposure to electrical devices such as pencil sharpeners, computers, fans, computers, and other equipment similarly skews the mean values upward.

Discussion and Conclusions

Radium Bromide Tubes

The findings that the crossbar switching equipment racks, historically used in the COF investigated in this evaluation, contained as many as 60 vacuum tubes per rack (each having at least 1 µCi of radium bromide) suggest the presence of a major confounder—ionizing radiation. While these crossbar switches have been replaced by more modern equipment that do not utilize such tubes, they were still in use, in at least one COF, as late as 1992. Of potential importance to the issue of breast cancer being reported in some of these workers was the finding that COF workers may have carried these tubes in shirt pockets. The role of this potential exposure to a well-established carcinogenic agent in the development of breast cancer among COF workers has not yet been evaluated, but it should not be ignored when studying breast cancer and COF workers.

Review of all Acquired EMF Data

- The results of measurements performed in Phase 2 does agree fairly well with those obtained in the BCC study. For example, the mean level found in the BCC study for the COF work environment was 2.23 mG. This compared with six EMDEX meter results that reported less than 2 mG for two different exposure days.

- Magnetic fields in the switching room ranged from 0.62 to 4.3 mG for 13 AMEX dosimeters placed at different locations in the room for two different exposure days. Magnetic fields in the close proximity to switches on the same two day exposure period ranged on the rack front from 2.7 to 7.1 mG while on the rack back ranged from 1.3 to 1.5 mG.

- There is no way to compare the transients results obtained in Phase 3 with BCC data since they did not obtained such information.

- The mean magnetic field levels collected in Phase 4 (also from a COF) ranges from 1.90 to 6.73 mG. This range compares favorable to the BCC published value of 2.23 mG for the COF work environment.

- Finally, magnetic field mean results from Phase 5, which address pole climbers on shared poles, ranged from 1.3 to 14.8 mG. The highest value measured was obtained from a worker who was using a gas powered drill for a two minute interval, and not from exposure to either telephone wires, 48 volt DC current, or to overhead 60 Hz power lines. The use of the gas drill is relatively new, since in prior years workers would use a hand drill. With the exception of the use of the drill, no mean worker measurement exceeded 4.5 mG. This level is supported by the findings of the BCC study for shared poles of 4.65 mG. These levels also approximate the same levels NIOSH investigators have found in office settings, where sporadic exposure to electrical devices such as pencil sharpeners, computers, fans, and other equipment similarly skews the mean values upward.[12]

Further support that ELF magnetic field exposures in the telephone industry may not be any higher than those of many other occupational groups of workers comes from a 1993 publication involving a payroll office environment by Breysse, et al.[13] The exposure estimates made in that survey were compared to those for telephone company office workers, cable splicers, and electrical distribution linemen. Breysse, who was involved with one of the telephone studies, choose telephone company office workers for comparison because they had similar exposures to the clerical workers in the payroll environment. The telephone splicers represent a group with low field exposures, while electrical linemen have higher exposure. The data in Breysse's article shows that telephone cable splicers had exposures slightly higher than clerical workers. These results by Breysse further supports the findings of low magnetic field levels reported in this evaluation.

In the two NIOSH evaluations made at COFs, it was found that there are two major groups of workers occupationally exposed to EMF. These groups are: a. office workers who received their exposure from close proximity to electrical equipment/devices found in office work (i.e., VDTs, electric typewriters, lamps, etc.). Exposure to these office sources are almost exclusively to power line frequencies and occur normally at a distance of 1 to 2 inches throughout the day. Exposure to these office sources is almost impossible to prevent since the equipment that produces such fields is universally used. However, many of these office sources may not be considered as absolutely "work-essential," such as refrigerators, microwave units, etc.) and their presence or the reason for their use should probably be re-evaluated by all parties concerned about overall potential EMF exposure. It was noted that many of these so-called non-essential sources that are in the office world of today were not in use prior to the 1960's.

b. some workers may have job tasks that require them to be near, or come into contact with, old/new electronic equipment/devices found in switching and power rooms. Exposures to these sources are generally restricted to 3 foot wide racks located on both sides of walkways. In the past, exposure to these types of sources may have been higher or more frequent because of the need for connecting, wiring, and repairing a large number of components. However, occupational exposure today is generally limited to short time periods for two reasons: (1) little maintenance is required for the operating systems, and (2) built-in system redundancy for switching components permits circuits to complete "electrical paths," negating the need for worker intervention. Major changes in equipment design and power consumption, decreased number of workers in the area, and system redundancy are but some of the reasons why present day exposure levels differ from those in the past.

Transient Data

Measurements of the EMF fields at the two COFs indicated the following: (1) various sources of EMF exposure do exist, including ELF fields, (2) 48 volt direct current (DC) fields were present, and (3) that this DC current was applied to small magnetic switches causing then to open and closed quickly causing the production of quasiELF- like transients.

The primary source of magnetic fields in the telephone switching office is from DC currents (at 48 volts). The only ELF component of the magnetic field, outside of power line frequency operating devices, occurred when the DC signal is switched off and on by relays and switches during the routing of a phone call. Hence, the switching field has only a small, intermittent, part of its intensity in the ELF region. Most measurements made in this phase of the evaluation were to determine the ELF component and not the DC component. Some very limited measurements were taken of the DC fields using a single axis Fluxgate Magneto Meter. Direct current magnetic field adjacent to the switches measured as high as 800 mG, and varied by as much as 400 mG. Whether or not these levels could be of biological importance is just not known.

In order to present a perspective for DC field, the following information is offered: first, the geomagnetic field of the earth, to which all workers are exposed, is about 500 mG and second, NIOSH has recently made evaluations in aluminum reduction facilities where occupational exposure have been recorded as high as 200,000 to 300,000 mG on a time-weighted average basis.[14] Workers at these facilities have been exposed to such levels for 20 to 30 years.

At the present time, the general consensus is that ELF fields may be more linked to adverse biological effects than DC magnetic fields.[15] It should be noted that magnetic fields measured in this evaluation were higher within 3 to 5 inches of the racks and were at background levels 12 to 24 inches away.

Most of the dB/dt levels measured in and around switching components (i.e., distance of 1 to 2 cm) were on the order of 1-2 mT/s with the maximum dB/dt level found to be less than 9 mT/s for the 94 measurements made. NIOSH has published data for dB/dt levels measured on VDTs and found them to be in the range of 0.25 to 1.8 mT/s at 50 cm. While limited dB/dt measurements have been reported in the literature, those that have been made, suggest that levels may need to be at least the 1 T/s region in order to represent possible biological, but not necessarily hazardous, significance. The measurements made at the 38th Street COF are approximately three orders of magnitude below this level. At present, no biological significance can be associated to these values.

Other Pertinent Information

During these evaluations, the investigators observed workers performing soldering connections at equipment racks whenever a telephone is installed, removed, or the number changed. The question about soldering fumes was raised several times but this exposure was not documented. However, NIOSH in 1980 did investigate this procedure at a NYNEX facility and found no hazard from exposure to contaminants generated during these soldering procedures.[16]

RECOMMENDATIONS

The following recommendations are offered to reduce potentially significant occupational exposures and safety risks at the telephone sites visited in this evaluation and perhaps at other telephone locations:

1. The NIOSH investigators were informed that almost all equipment utilizing radioactive vacuum tubes has been replaced, or is scheduled to be replaced, with more modern equipment. Until such time that the replacement is complete, all existing RaBr tubes in the phone company should be eliminated immediately and replaced with the less radioactive krypton tubes.

2. Further documentation of EMF associated with boom motors, gas drills, and CEV need to be performed by NYNEX health and safety personnel.

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Table 1
Mean Exposure and Standard Errors (mG)
for Various Work Environments
American Telephone and Telegraph Measurements
New York Telephone Company
New York City, New York
HETA 91-0048

Work Environment	Mean	Standard Error
Telecommunication Vault	8.21	1.23
Shared Pole	4.65	0.59
Residence Premises	2.30	0.15
Business Premises	3.27	0.48
Central Office	2.23	0.23
Work Center	1.66	0.15
Work Area Setup	3.24	0.18
Travel	2.26	0.09
Lunch/Break	1.82	0.13

mG = milligauss

Table 2
EMDEX Meter Results Collected (mG) on December 15-16, 1991
in Switching Room at 38th Street COF
New York Telephone Company
New York City, New York
HETA 91-0048

	Minimum	Maximum	Mean	Standard Deviation	Median
Sunday 12/15/91					
NYNEX	0.2	10.4	1.67	0.73	1.6
NIOSH-1	0.2	10.4	1.61	0.56	1.5
NIOSH-2	0.2	10.1	1.78	0.74	1.8
Area 1B	0.8	5.6	1.46	0.47	1.3
Area 1F	0.9	28.1	3.95	2.42	2.7
Monday 12/16/91					
NYNEX	0.2	214.5	2.20	5.17	1.5
NIOSH-1	0.2	18.5	1.70	1.16	1.5
NIOSH-2	0.2	209.9	2.06	5.34	1.6
Area 1B	0.6	9.6	2.03	1.21	1.5
Area 1F	0.6	31.5	7.59	3.67	7.1

Area 1B located at ACD, M4
Area 1F located at ACD between M2 and M4
All data collected with EMDEX set at 1.5s

Table 3
Measurement of Magnetic Fields (mG)
with AMEX Dosimeters on December 15 and 16, 1991
at Different Locations in the Crossbar Switching Room
New York Telephone Company
New York City, New York
HETA 91-0048

Location	Sunday	Monday
Work Desk	0.86	0.84
End of 1st Rack	4.26	3.07
End of 2nd Rack	1.37	1.52
On Side Wall	2.80	3.20
Near Entrance	0.62	0.70
Back of Last Rack	2.24	2.27
Rear of Audio System	1.71	1.80
End of Rack	2.68	2.51
On Column	0.95	1.30
On Column	--	1.34
Aisle 510	2.60	2.47
Aisle 511	0.95	1.07
Near Front Window	--	0.66
Average Number of Calls per Minute	92	435

Table 4
Summary of All EMF Measurements Recorded with Different Equipment
New York Telephone Company
New York City, New York
July 27-29, 1993
HETA 91-0048

Location	Holaday ELF		Holaday VLF		Holaday ELF (mG)	AMEX (avg) (mG)	EMDEX ® II (logged) (mG)	EMDEX ® II (monitor) (mG)
	V/m	mG	V/m	mG				
Vault Area	1.8-4(7)				0.2-7.3(8)			0.3-6.2(7)
1st floor	1.8-4.8(3)				0.3-8.9(25)			0.8-15.4(20)
2nd floor	1.8-15.5(10)	3-35(15)			0.2-100(77)			0.4-80(32)
3rd floor	1.8-300(10)			0.1-2.3(33)	0.2-400(230)	0.3-9.2(14)	0.3-12.1 (3154)	0.3-300(20)
4th floor	5-15(7)				0.2-100(150)	0.1-61.3(14)	0.2-291.3 (23514)	0.2-2100(55)
5th floor	1.8-5.3(7)				0.2-200(33)			0.3-100(8)
6th floor			2-5.8(4)	0.1-30(10)	0.2-6(220)	0.6-7.3(14)	0.2-1313 (15161)	0.6-222(45)
7th floor	2.0-6.0(6)				0.2-20(31)			0.4-17(12)
8th floor					0.3-880(6)			0.2-2000(15)
Roof	2.0-3.0(3)							1.0-3.0(10)
Totals	1.8-300(53)	3-35(15)	2-5.8(4)	0.1-30(43)	0.2-880(780)	0.1-61.3(42)	0.2-1313 (41829)	0.2-2100 (225)

mG = milligauss **V/m = volts per meter**
TOTAL MEASUREMENTS 42,991
Range: **VLF** Electric (E) field: 1.8 - 300 V/m
Magnetic (H) field: 0.1 - 30 mG
ELF E field: 2 - 5.8 V/m
H field: 0.1 - 2100 mG

Table 5
EMDEX ® II Dosimeter Results
New York Telephone Company
New York City, New York
July 27-29, 1992
HETA 91-0048

Dosimeter Measure	Location (Floor)	Minimum (mG)	Median (mG)	Mean & Std. Deviation (mG)	Maximum (mG)	Geo.Mean & Geo.Std Deviation (mG)	Data Points (N)	Fraction exceeding		
								2 mG	4 mG	10 mG
1	3	0.3	1.8	1.90±1.37	12.1	1.41±2.40	3154	.450	.054	.004
2	4	0.2	1.9	3.12±4.08	47.3	1.70±3.07	5847	.471	.246	.055
3	4	0.2	0.6	1.94±5.97	140.7	0.97±2.65	5890	.282	.079	.011
4	4	0.2	0.8	4.32±14.63	291.3	1.14±4.18	5865	.335	.199	.083
5	4	0.2	1.3	5.17±20.43	281.7	1.31±3.67	5912	.345	.143	.057
6	6	0.2	2.2	3.17±3.82	37.1	2.35±1.97	4747	.624	.126	.058
7	6	0.2	2.5	2.35±0.73	5.9	2.16±1.62	1954	.873	.024	.000
8	6	0.2	0.6	6.73±61.67	1313	0.77±2.80	8460	.118	.070	.030

mG = milligauss

Table 6
Radiation Level from RaBr and Kr85 Tubes
at Different Distances
American Telephone and Telegraph Data
New York Telephone Company
New York City, New York
July 27-29, 1993
HETA 91-0048

Distance from Array (inches)	Milliroentgen Per Hour	
	RaBr	Kr-85
0 (contact)	4.0	0.15
2	2.5	0.10
4	0.7	0.03

(Cassidy, 1960)

Table 7
Radiation Level from RaBr and Kr85 Tubes
At Different Distances
NIOSH Data
New York Telephone Company
New York City, New York
July 27-29, 1993
HETA 91-0048

Distance from Array (inches))	Milliroentgen Per Hour	
	RaBr	Kr-85
contact	66.7	1.2
3	7.6	0.35
6	3.3	0.1

Table 8
Measurement of Magnetic Fields (mG) for OPT Workers using EMDEX Meters on First Day
New York Telephone Company
New York City, New York
HETA 91-0048

Worker	Mode	Min. (mG)	Max. (mG)	Mean (mG)	St. Dev. (mG)	Median (mG)	Geo. Mean (mG)	Geo. St. Dev. (mG)	Fraction Exceeding			N
									2 mG	4 mG	10 mG	
OPT-1 Pole Climber	B F H	0.6 0.1 0.1	718 602 519	14.84 11.48 6.22	64.09 53.55 37.70	5.7 5.6 0.4	5.07 4.47 0.40	2.69 2.79 3.42	0.985	0.971	0.622	633
OPT-2 On Ground	B F H	0.4 0.1 0.2	10.6 10.6 1.1	2.35 2.25 0.22	1.41 1.41 0.11	2.0 2.0 0.2	2.06 1.94 0.20	1.64 1.73 1.48	0.704	0.221	0.008	594
NIOSH Observing	B F H	0.8 0.6 0.1	3.5 3.3 0.4	1.81 1.71 0.16	0.45 0.45 0.04	1.8 1.6 0.2	1.76 1.65 0.16	1.28 1.30 1.20	0.456	0	0	649
Splicer-1 On Pole	B F H	0.6 0.3 0.2	13.4 13.4 0.9	3.76 3.66 0.50	2.13 2.13 0.14	3.5 3.3 0.6	3.26 3.13 0.,47	1.73 1.79 1.37	0.944	0.549	0.091	1385
Splicer-2 On Pole	B F H	0.4 0.3 0.2	8.4 8.3 1.1	2.85 2.72 0.66	1.42 1.43 0.24	2.5 2.5 0.8	2.49 2.34 0.61	1.71 1.77 1.52	0.816	0.409	0	1424
Splicer-3 On Ground	B F H	0.3 0.3 0.2	7.8 7.8 0.6	2.37 2.27 0.27	1.40 1.40 0.07	1.9 1.8 0.3	2.01 1.89 0.26	1.79 1.85 1.31	0.681	0.392	0	1352

Table 9
Measurement of Magnetic Fields (mG) for OPT Workers
using EMDEX Meters on Second Day
New York Telephone Company
New York City, New York
HETA 91-0048

Worker	Mode	Min. (mG)	Max. (mG)	Mean (mG)	St. Dev. (mG)	Median (mG)	Geo. Mean (mG)	Geo. St. Dev. (mG)	Fraction Exceeding			N
									2 mG	4 mG	10 mG	
CWA-7 Splicer (part time)	B F H	0.2 0.1 0.1	28.1 27.9 5.6	3.53 3.41 0.61	3.39 3.39 0.42	2.8 2.7 0.6	2.61 2.45 0.50	2.11 2.25 1.90	0.868	0.463	0.299	1296
CWA-8 Splicer	B F H	0.6 0.1 0.2	10.9 10.8 1.3	2.94 2.83 0.65	1.37 1.39 0.13	2.7 2.5 0.6	2.70 2.55 0.63	1.50 1.57 1.28	0.900	0.285	0.003	1318
CWA-9	B F H	0.3 0.1 0.2	98.9 98.7 7.3	6.11 6.00 0.53	13.22 13.19 0.81	2.5 2.3 0.3	2.66 2.49 0.34	2.94 3.09 2.13	0.903	0.779	0.599	1302
CWA-10 In Boom	B F H	0.6 0.1 0.1	17.5 16.8 7.8	2.82 2.71 0.27	3.00 2.99 0.37	1.3 1.1 0.2	1.81 1.67 0.21	2.41 2.54 1.77	0.750	0.671	0.197	1473
CWA-11 Ground	B F H	0.4 0.3 0.2	5.3 5.2 1.8	1.35 1.24 0.19	0.66 0.65 0.10	1.1 1.0 0.2	1.23 1.12 0.17	1.49 1.54 1.36	0.211	0.044	0	1455
CWA-12 Ground	B F H	0.4 0.1 0.1	5.3 5.3 4.6	1.31 1.21 0.17	0.60 0.60 0.13	1.1 1.0 0.2	1.20 1.09 0.17	1.47 1.53 1.29	0.246	0.001	0	1434 (>60 min)

Table 10
Summary of all Magnetic Field Results
Made on OPT Personnel
New York Telephone Company
New York City, New York
HETA 91-0048

Location		File	Broadband				
			Min.	Max.	Mean	Median	
On Pole	OPT	CWA-2	0.6	718	14.84 ± 64.09	5.7	Cable Pullers - Drill
On Ground	OPT	CWA-3	0.4	10.6	2.35 ± 1.41	2.0	
On Pole	SPL	CWA-4	0.6	13.4	3.76 ± 2.13	3.5	Splicers
On Pole	SPL	CWA-5	0.4	8.4	2.85 ± 1.42	2.5	
On Ground	SPL	CWA-6	0.3	7.8	2.37 ± 1.40	1.9	
On Pole	SPL	CWA-8	0.6	10.9	2.94 ± 1.37	2.7	Splicers
On Pole/Ground	SPL	CWA-7	0.2	28.1	3.53 ± 3.39	2.8	
On Pole (Boom)	OPT	CWA-10	0.6	17.5	2.82 ± 3.00	1.3	Removing Cables
On Ground	OPT	CWA-11	0.4	5.3	1.35 ± 0.66	1.1	
On Ground	OPT	CWA-12	0.4	5.3	1.31 ± 0.60	1.1	

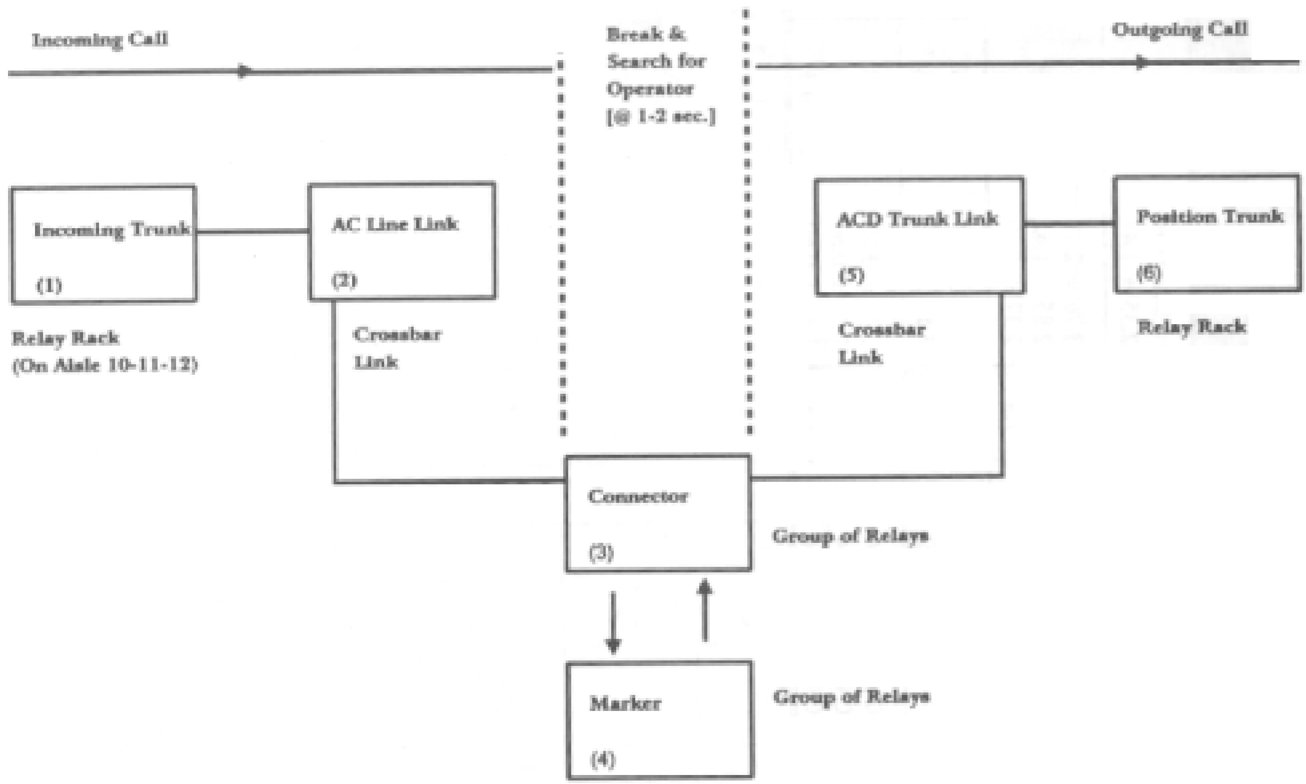
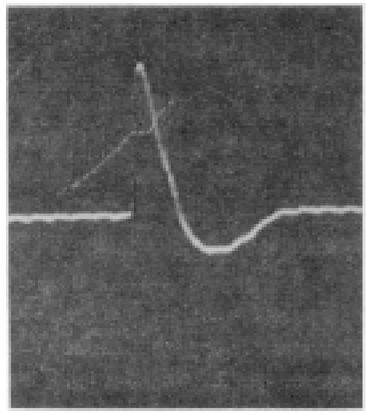
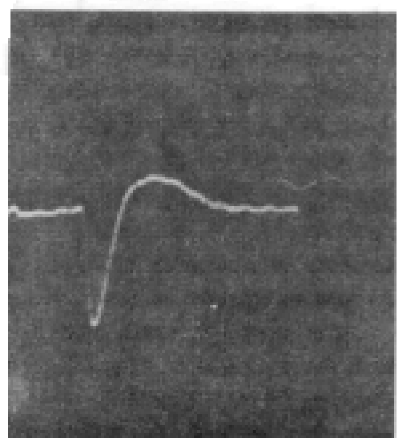


FIGURE 1. Schematic of #5 Crossbar Automatic Call Distributor System at 38th Street



(a)



(b)

FIGURE 2. Transient waveforms associated with (a) magnet collapse – or simple disconnect and (b) magnet expansion – or simple connect. Traces obtained from storage oscilloscope at 38th Street

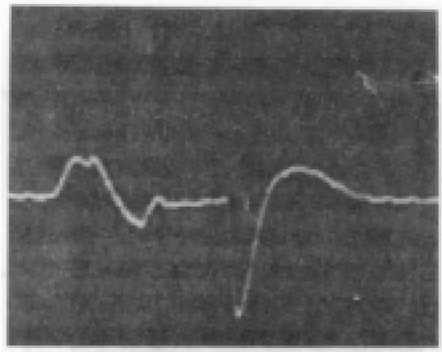


FIGURE 3. Sequence of disconnect and connect events from same relay

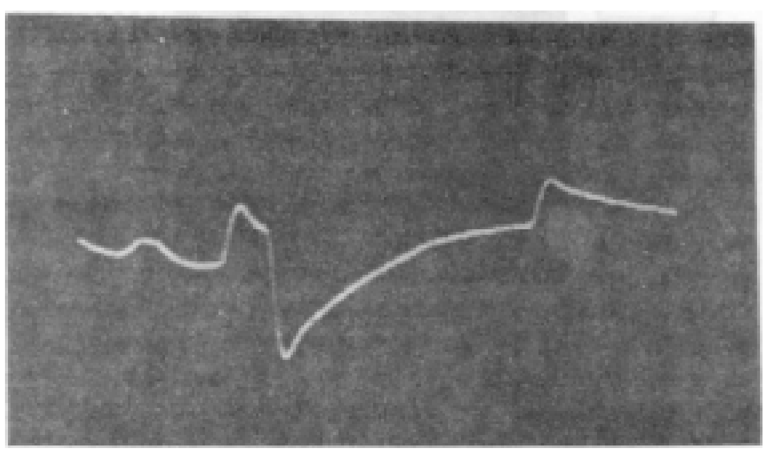


FIGURE 4. Typical signal pattern from marker portion of switching system

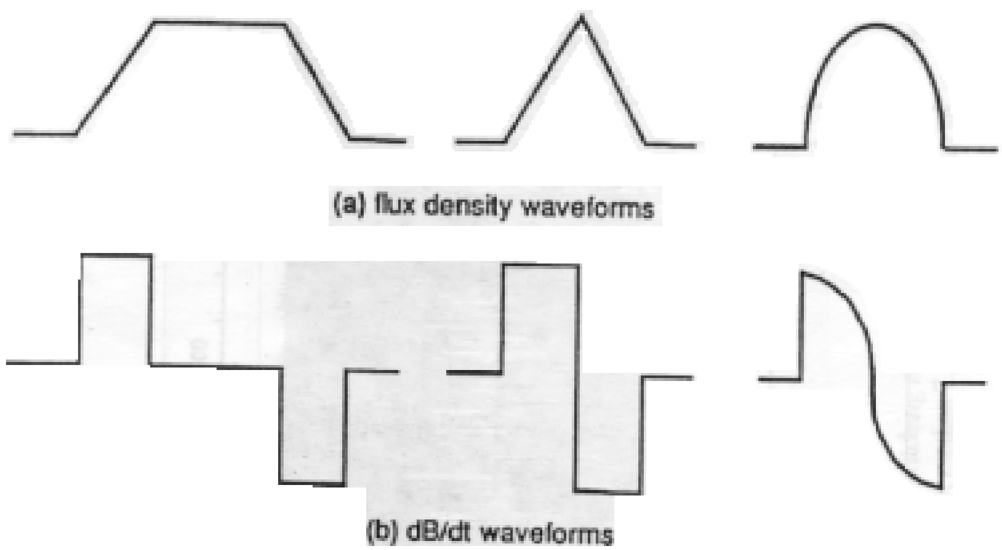


FIGURE 5. Examples of magnetic flux density and the time-rate-of-change of the magnetic field (dB/dt) waveforms

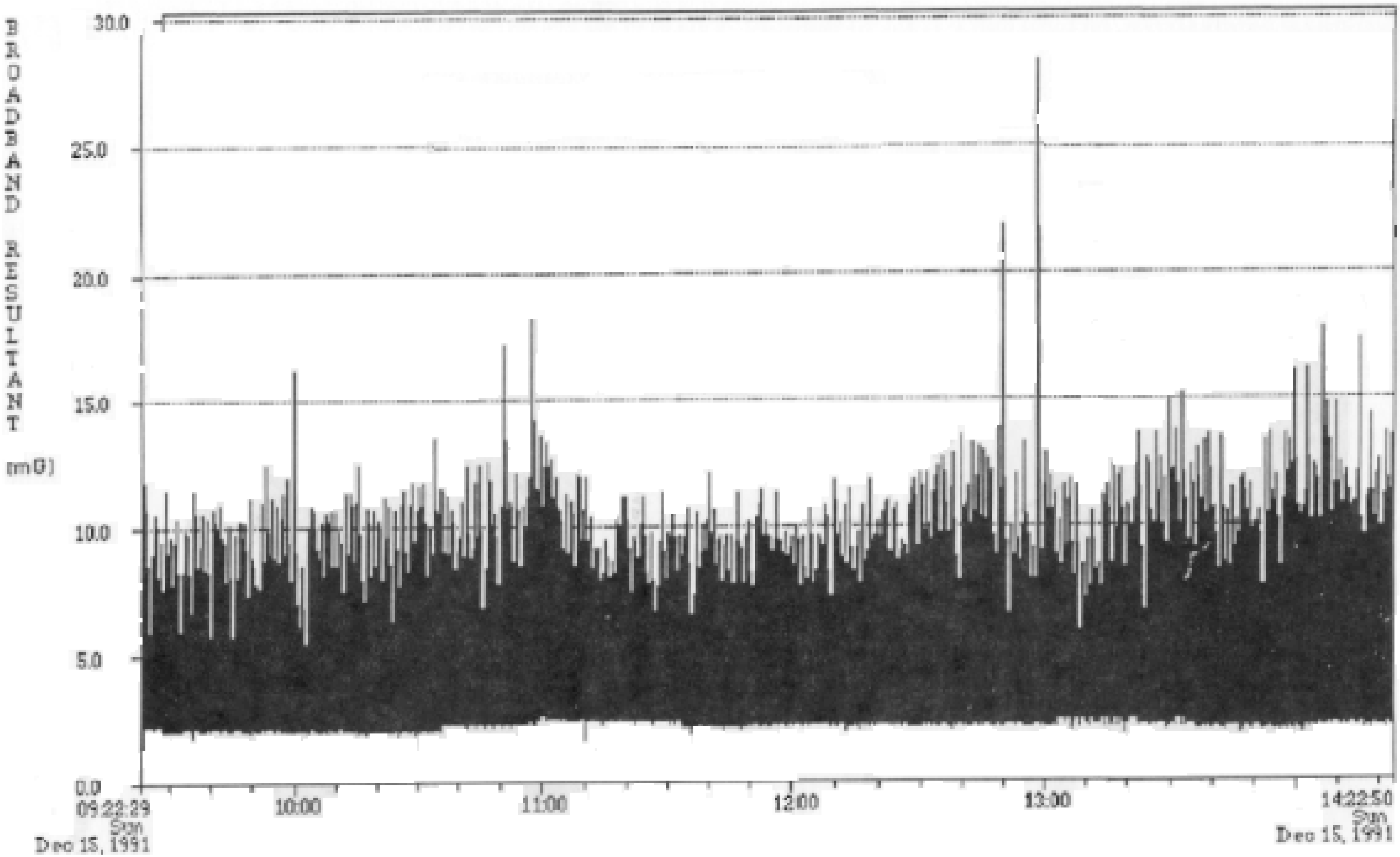


FIGURE 6. Time-intensity distribution of EMDEX meter placed on front side of switching rack on December 15,1991. The following characteristics apply to this data: minimum 0.9 mG, maximum 28.1 mG, mean 3.95 ± 2.42 mG, median 2.7 mG, and meter was set at 1.5 seconds

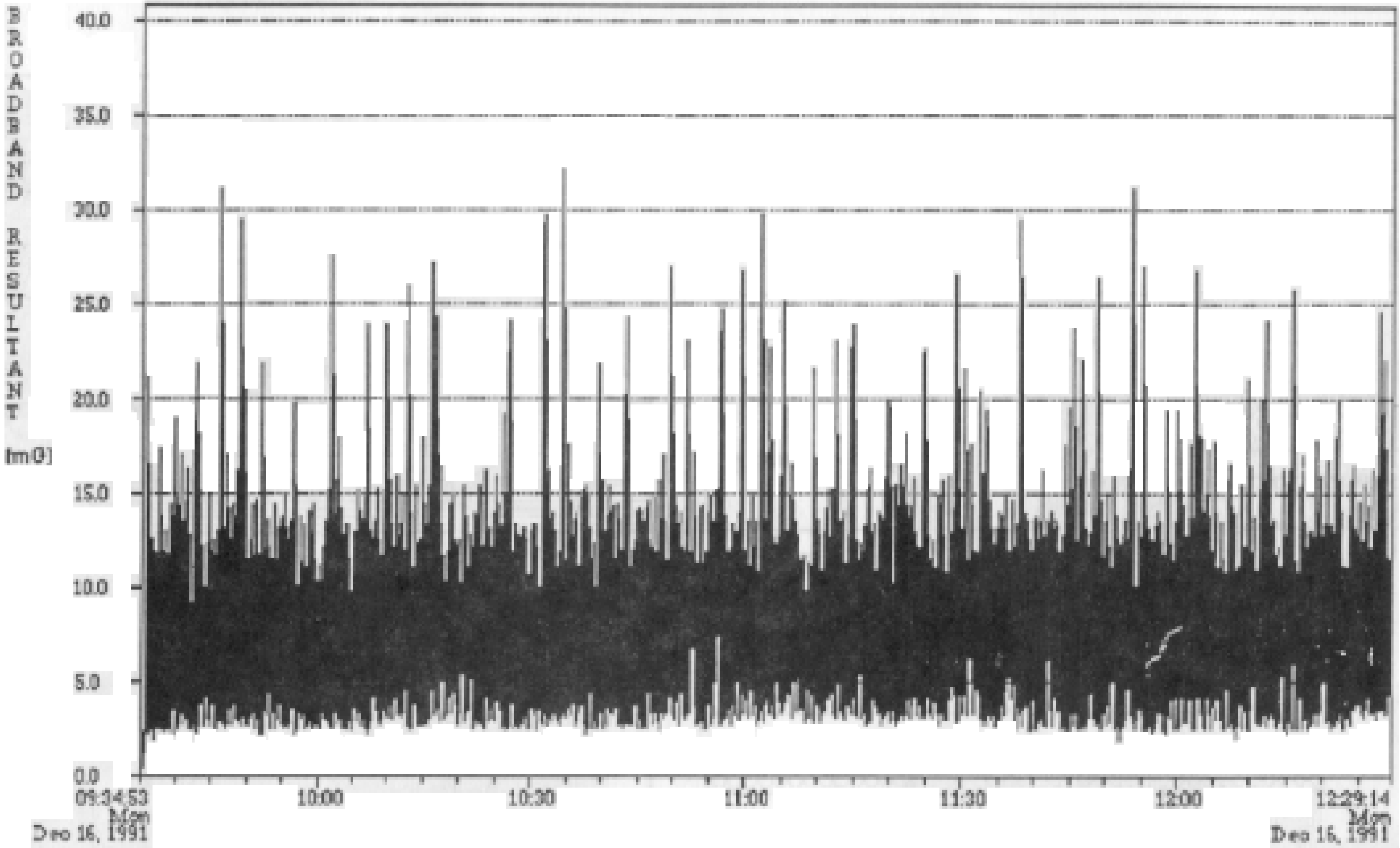


FIGURE 7. Time-intensity distribution of EMDEX meter placed on front side of switching rack on December 16, 1991. The following characteristics apply to this data: minimum 0.6 mG, maximum 31.5 mG, mean 7.59 ± 3.67 mG, median 7.1 mG, and meter was set at 1.5 seconds

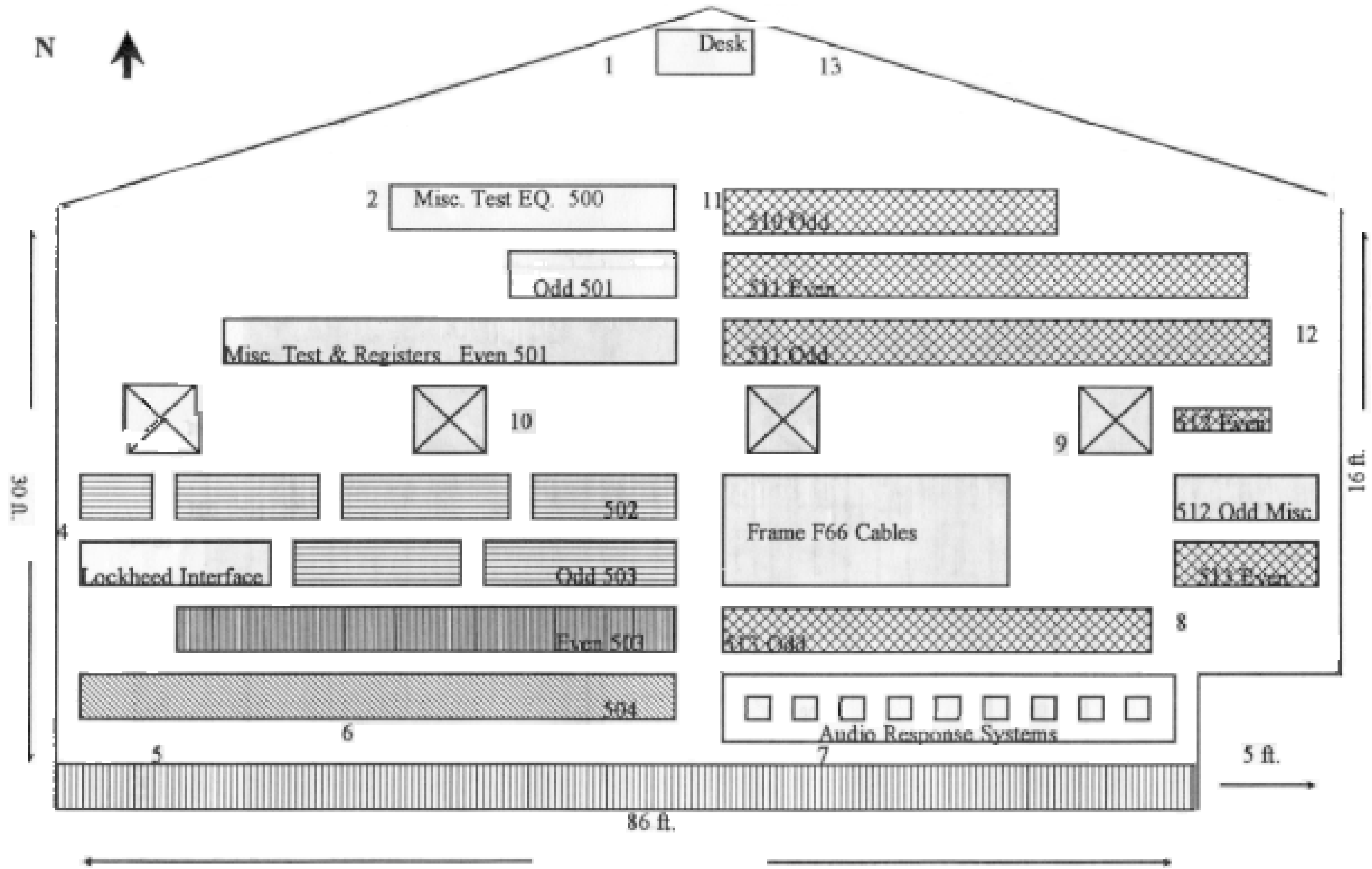


Figure 8. Schematic map of switching room showing location of AMEX meters

FIGURE 9. Illustration of "capturing" magnetic field transients from switching equipment.

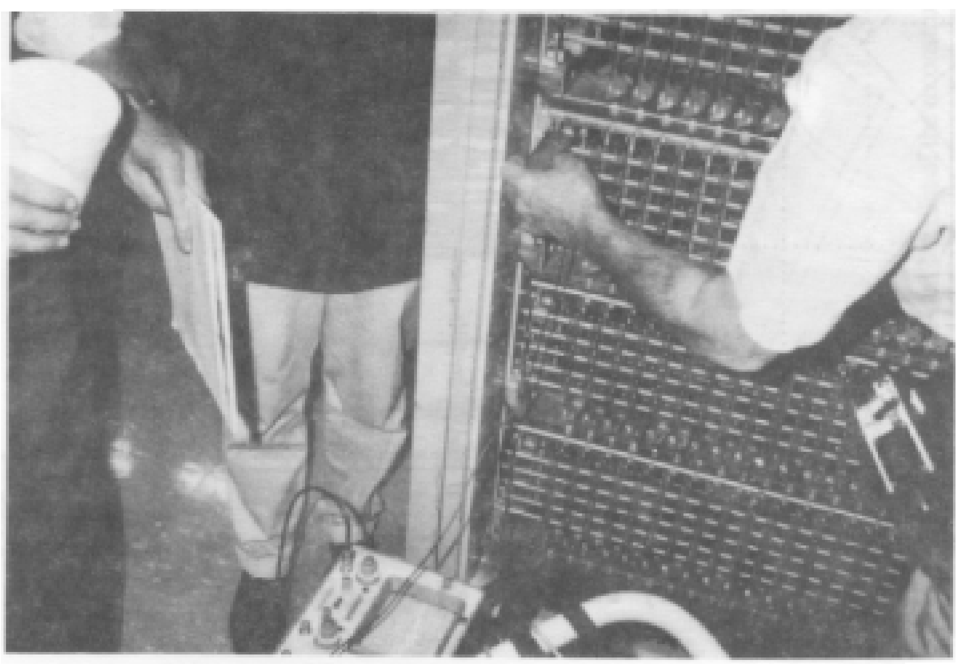


FIGURE 10. Illustration of using the M-123 system to capture and analyze transients

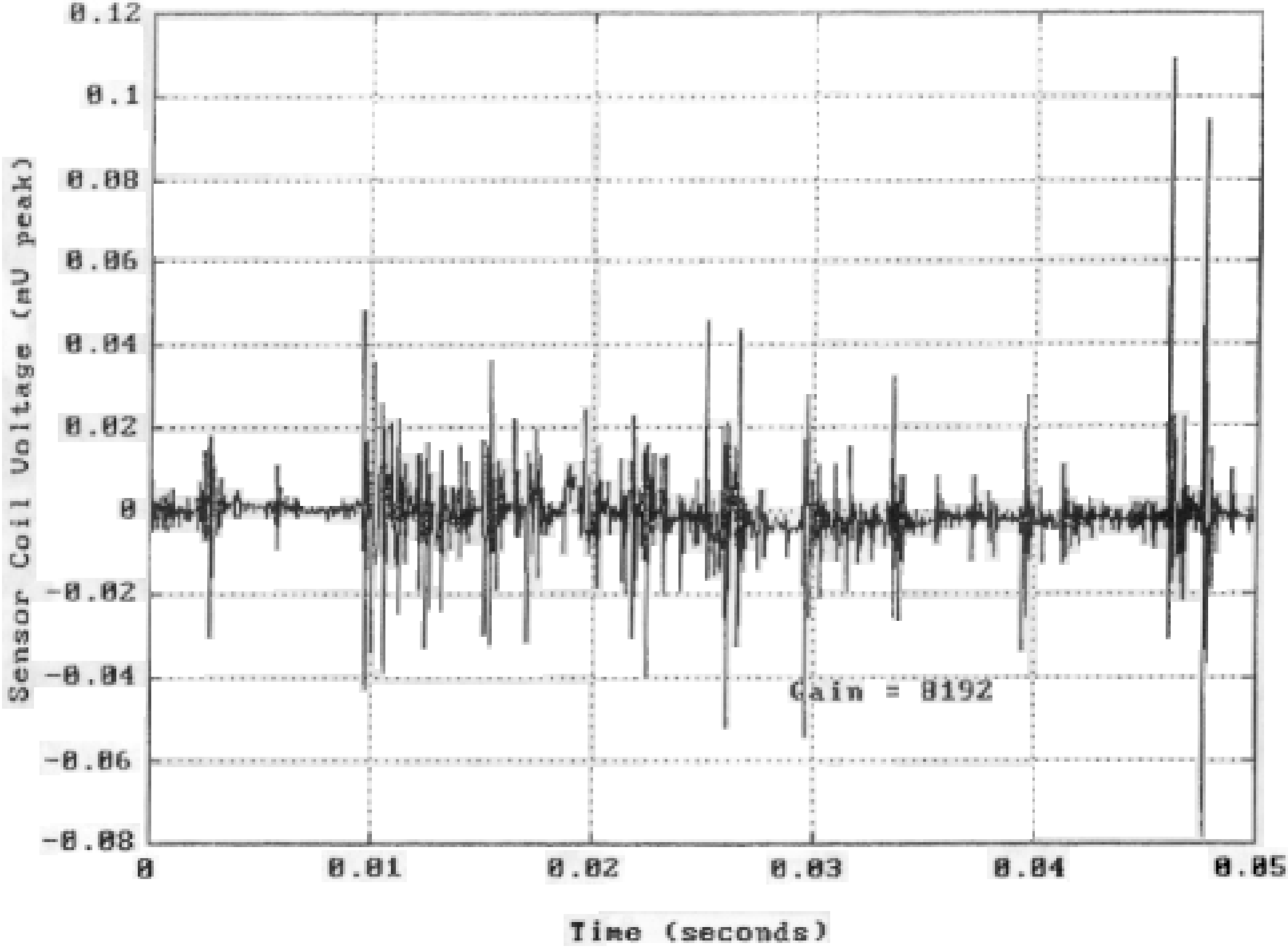


FIGURE 11. Time-domain plot of sensor coil voltage from Event A using M-123 system

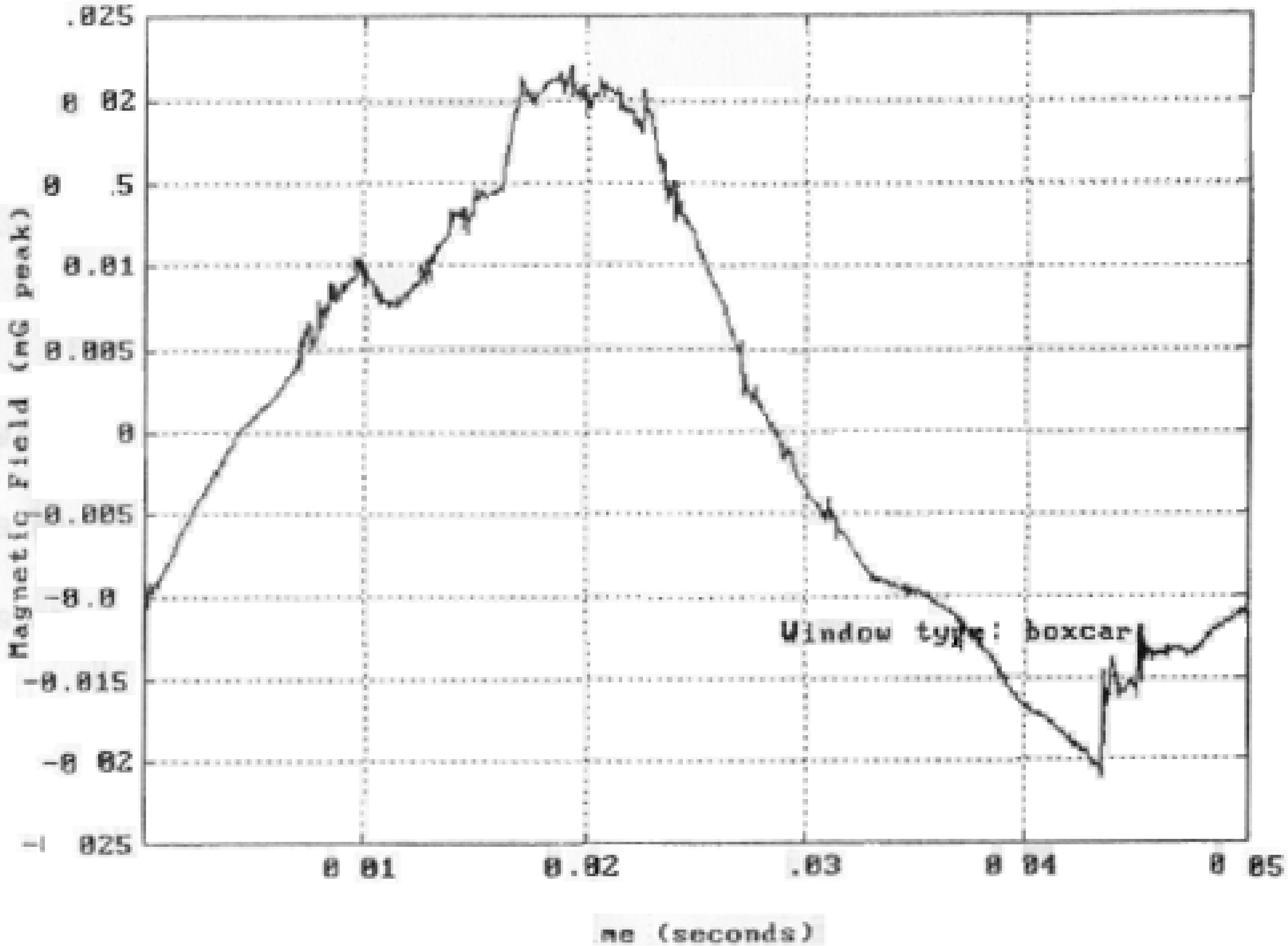


FIGURE 12. Time-domain plot of the reconstructed magnetic field for Event A using M-123 system

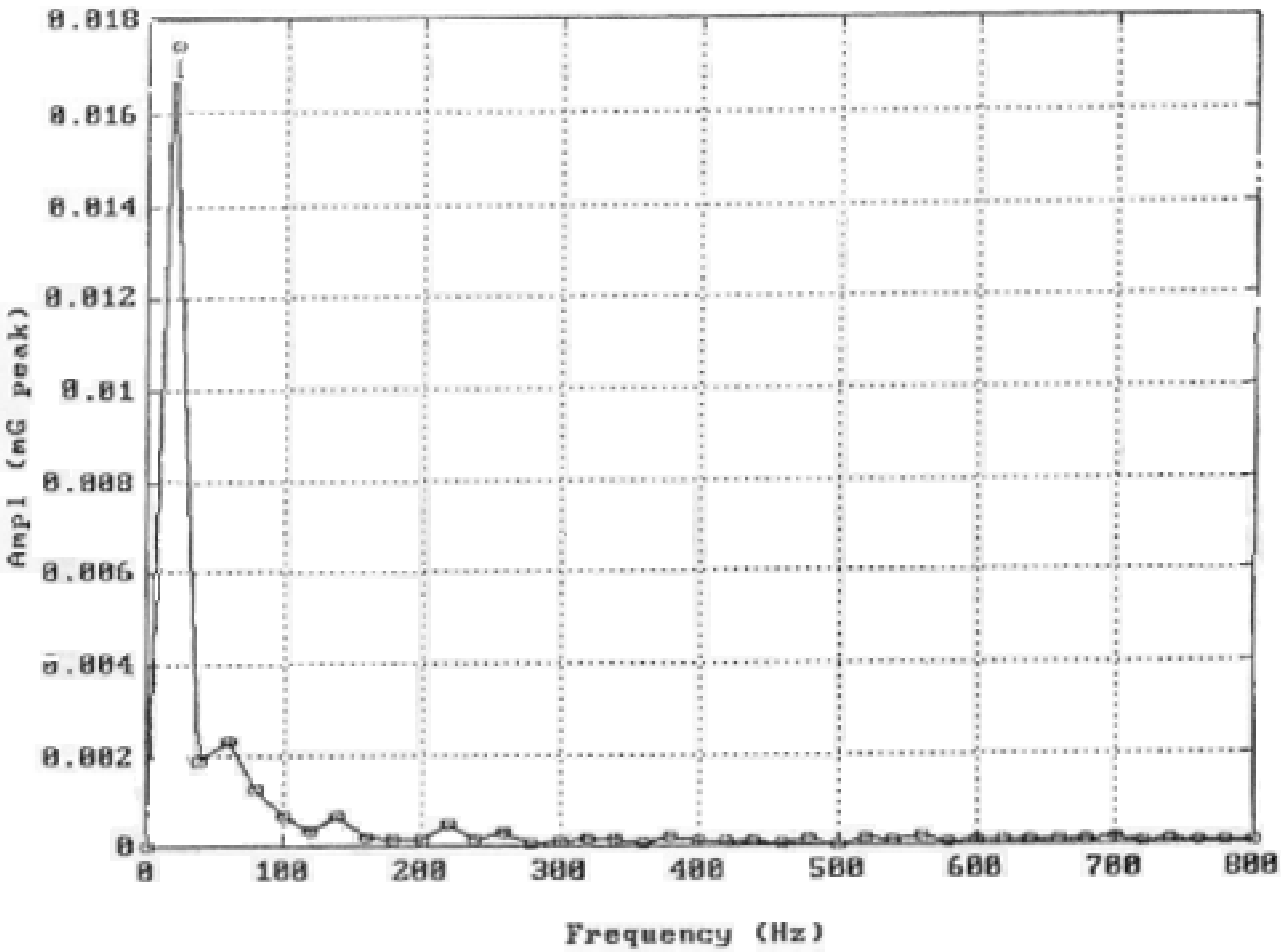


FIGURE 13. Frequency domain plot of the magnetic field amplitude up to 800 Hz produced by Even A using the M-123 system

FIGURE 14. NYNEX worker on pole with a gasoline powered drill. Drill time was approximately 2 minutes. EMDEX meter was positioned around neck.

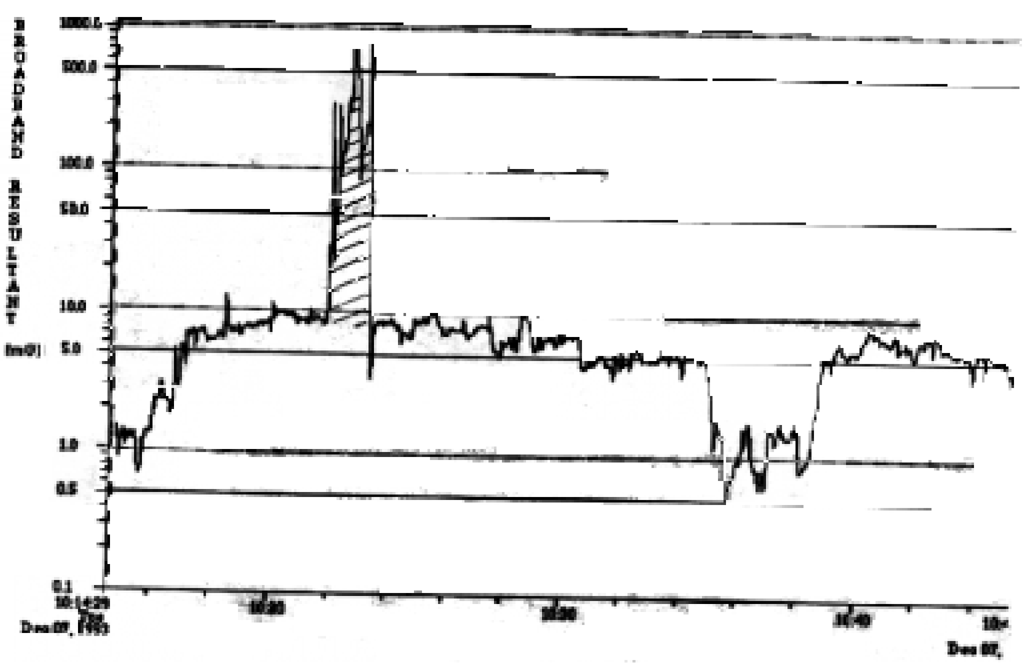


FIGURE 15. Time-intensity distribution for EMDEX meter illustrated in Figure 14. Shaded area represents contribution of gas drill

(a)

(b)

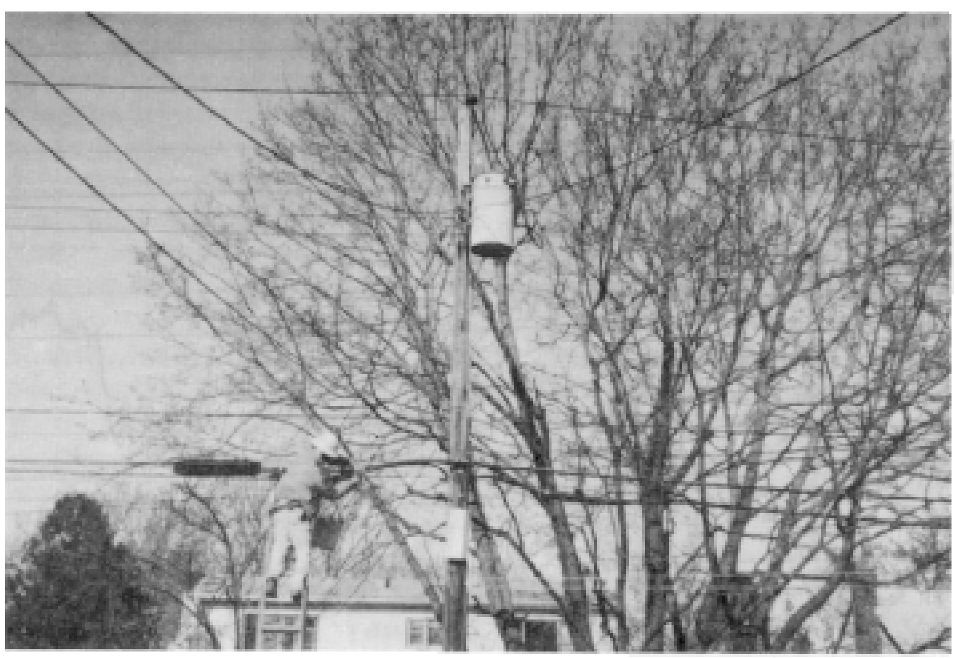


FIGURE 16. Two different splicers working in residential section illustrating (a) no transformer and (b) presence of transformer.

FIGURE 17. Entrance to typical NYNEX underground controlled environmental vault (CEV)

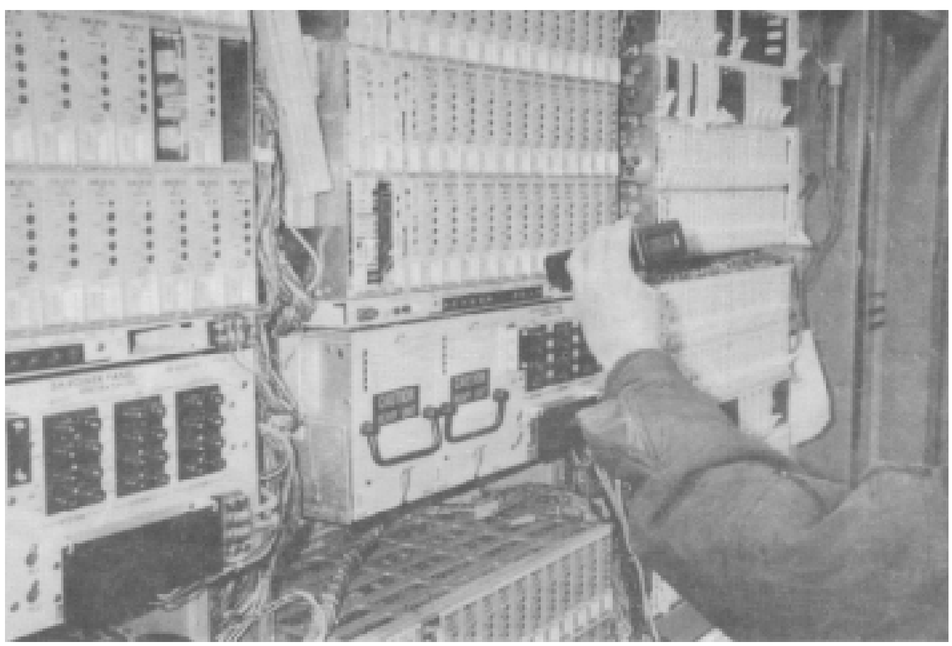


FIGURE 18. Equipment found in CEV

FIGURE 19. Splicers in boom installing new cable on shared pole

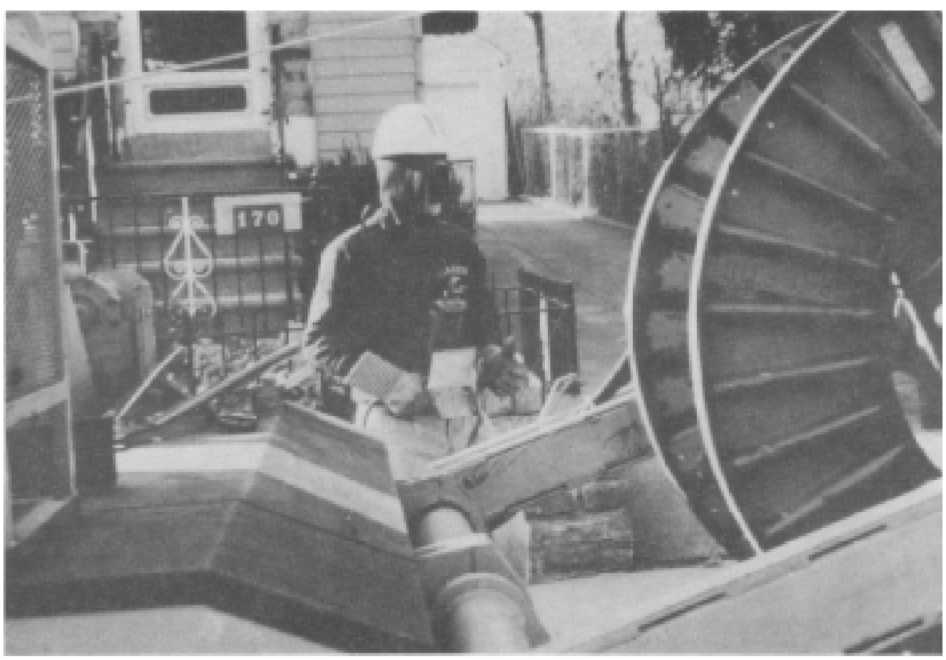


FIGURE 20. OPT workers removing old telephone cable onto wooden spools