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13. ABSTRACT (Maximum 200 words)

To assess the state of knowledge about anticipated electric and magnetic field (EMF) exposures from electrical transportation systems, including electrically powered rail and magnetically levitated (maglev), research concerning biological effects of EMF exposure, with special emphasis on broad spectrum or broadband magnetic fields, was reviewed. A primary objective of this report was to consider, based on present knowledge, the potential for adverse health effects from maglev-associated EMF. Because maglev technology is known to generate magnetic fields at a variety of frequencies, this document addresses the broadband frequency characteristics (including pulses, intermittent fields, and other transient phenomena).

One objective of this review was to consider whether, based on present knowledge, exposure to maglev-associated magnetic fields would warrant any special consideration related to possible adverse health effects. There may be unique combinations of ac and dc fields associated with maglev operation, but there is no evidence that such combinations have any special properties in terms of their potential biological effects. From currently available occupational epidemiologic data for electrical transport workers, available clinical and laboratory data on EMF biological effects, and available information on maglev-generated magnetic fields, we conclude that maglev is not likely to represent greater risk, if any, than that from electrical transport systems already in use.

14. SUBJECT TERMS
Electric and Magnetic Fields (EMF), Maglev, Electrified Rail Systems, EMF Exposure, Guidelines, Standards and Regulations, International, Federal, State and Local EMF Activities

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PREFACE

This report provides information on existing and proposed electric and magnetic fields (EMF) guidelines, standards, and regulations at the international, national, state, and local levels. It covers fields in the frequency range of 0-100 Ghz and includes EMF exposures for both the general public and workers.

Several studies were conducted under the FRA EMF Research Program relating to the potential health implications of public exposure to EMF with emphasis on those fields associated with magnetically levitated (maglev) vehicles and advanced high-speed rail systems.

Although there are no maglev or other advanced high-speed rail systems currently operating in the United States, EMF exposure is still of concern as it relates to 60 hertz (Hz) power transmission and distribution lines and electrical appliances. While there are no federal regulations in the United States for exposure to 60 Hz EMF, several states have formally adopted standards to limit the permissible EMF strengths along rights of way of transmission lines. EMF is an issue internationally, for both 50 Hz and 60 Hz electric power systems.

This document was prepared for the U.S. Environmental Protection Agency (EPA), Office of Radiation and Indoor Air (ORIA), Radiation Studies Division (RSD), under an interagency agreement with the Department of Transportation (DOT) Research and Special Programs Administration (RSPA), John A. Volpe National Transportation Systems Center (Volpe Center), on behalf of the Federal Railroad Administration (FRA).

At Sanford Cohen and Associates the Project Officer was Don Goellner, and the primary authors were Barbara Zackhiem and Melissa Bockleman. At the Environmental Protection Agency the Work Assignment Manager was Lynne Gillette, the Interagency Agreement Manager was Norbert Hankin, and the Radiation Studies Branch Chief was Barbara Hostage.

The technical monitor for this report was Dr. Aviva Brecher of the Volpe Center who manages the EMF Research Program for the FRA. Guidance and program support was provided by Robert Dorer, the High Speed Guided Ground Transportation Safety Program Manager at the Volpe Center. At the FRA, Arne Bang served as sponsor and is the Manager of Special Programs.

SYSTÈME INTERNATIONAL (SI) UNIT DEFINITIONS AND CONVERSIONS USED IN THIS REPORT

DISTANCE (ENGLISH-TO-SI CONVERSION):

1 inch (in)	= 2.54 centimeters (cm)	= 0.025 meters (m)
1 foot (ft)	= 30.5 centimeters (cm)	= 0.305 meters (m)
1 yard (yd)	= 91.4 centimeters (cm)	= 0.914 meters (m)
1 mile (mi)	= 1.61 kilometers (km)	= 1,610 meters (m)

ELECTRICAL QUANTITIES:

Electric Fields

1 volt/meter (V/m)	= 0.01 volts/centimeter (V/cm)
1 kilovolt/meter (kV/m)	= 1000 volts/meter (V/m)
1 kilovolt/meter (kV/m)	= 10 volts/centimeter (V/cm)

Magnetic Flux Densities (English-to-SI Conversion)

10,000 gauss (G)	= 1 tesla (T)
10 milligauss (mG)	= 1 microtesla (μT)
1 milligauss (mG)	= .1 microtesla (μT)
0.01 milligauss (mG)	= 1 nanotesla (nT)

Electromagnetic Frequency Bands

1 cycle per second	= 1 hertz (Hz)
1,000 cycles per second	= 1 kilohertz (kHz)

Ultra Low Frequency (ULF) Band	= 0 Hz to 3 Hz
Extreme Low Frequency (ELF) Band	= 3 Hz to 3 kHz
Very Low Frequency (VLF) Band	= 3 kHz to 30 kHz
Low Frequency (LF) Band	= 30 kHz to 300 kHz

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1. INTRODUCTION

Under an Interagency Agreement, the EPA Office of Radiation and Indoor Air (ORIA) and the Department of Transportation (DOT) Research and Special Programs Administration (RSPA) John A. Volpe National Transportation Systems Center (Volpe Center) on behalf of the Federal Railroad Administration (FRA), have conducted several studies related to the potential health implications of public exposure to electromagnetic fields (EMF), with emphasis on those fields associated with magnetically levitated (maglev) vehicles and advanced high speed rail systems.

Although there are no maglev or other advanced high-speed rail systems currently operating in the United States, EMF exposure is still of concern as it relates to 60 hertz (Hz) power transmission and distribution lines and electrical appliances. While there are no federal regulations in the United States for exposure to 60 Hz EMF, several states have formally adopted standards to limit the permissible EMF strengths along rights of way of transmission lines. Furthermore, EMF exposure is an issue internationally, for both 50 Hz and 60 Hz electric power systems.

This report provides information on existing and proposed EMF guidelines, standards and regulations at the international, national, state, and local levels. It covers fields in the frequency range of 0-100 Ghz and includes EMF exposures for both the general public and workers. Whereas the above frequency range includes radio frequencies and microwave frequencies, the main focus for the United States is on extremely low frequencies (ELF), such as those associated with the use of electric power. However, there is some discussion of regulation of higher frequency ranges in other countries.

The report comprises information derived from both primary and secondary sources and is current as of June 1993. It is organized into the following sections:

- Existing state and local EMF limits -- where guidelines, standards, and/or regulations have already been set;
- Pending state and local EMF limits -- where legislation has been introduced, but is still under consideration;
- U.S. technical organization guidelines -- organizations such as the American National Standards Institute (ANSI);
- Multinational agency guidelines -- agencies such as the World Health Organization (WHO);
- Existing international EMF limits.

A summary table appears at the beginning of most of these sections to highlight important data referenced in the text. Where applicable, the basis for the guideline, standard or

regulation is documented in the table. Although this information was felt to be very important, in several instances the basis was not known by the primary source or not documented by the secondary source. In cases of electric field strength limits, this may be due to the fact that the guideline, standard or regulation was probably set for basic public health and safety concerns of shock or burn, rather than concerns of exposure to EMF.

The final section of the report provides a discussion of maglev technology and its related EMF exposure environment. The maglev exposure environment is compared to the voluntary guidelines and standards developed by U.S. technical organizations as presented in Section 5. An appendix discusses other domestic and international activities, such as failed legislative initiatives and literature reviews, which have relevance to the potential health-related impacts of EMF.

2. EXISTING STATE AND LOCAL EMF LIMITS

This section describes U.S. state and local EMF limits that were in existence as of June 1993. These limits all apply to the U.S. electric power frequency of 60 Hz. Table 2-1 summarizes the key features of the standard, guideline or regulation described in sections 2.1 to 2.11.

2.1 CALIFORNIA

As a result of concern about the potential adverse health effects of EMF, the California Department of Education implemented a policy of prudent avoidance which included guidelines for specifying the distances schools must be from power lines. The Department of Education adopted these guidelines in 1989 and has recently proposed making them enforceable state regulations.

Sources: California School Site Selection and Approval Guide, p. 4. 1989; Schools Facilities Planning Division, California Department of Education, P.O. Box 944272, Sacramento, CA 94244.

City of Irvine - In 1991, The City of Irvine enacted a zoning ordinance limiting residential development and the location of childcare facilities near the Southern California Edison right of way. The ordinance, which only applies to Planning Area 38, requires applicants to show that the proposed structures will not be exposed to magnetic field levels above 4 mG. Applicants are required to physically measure the field strength around the property and indicate a 4 mG contour line on all site plans. The ordinance was enacted in response to local concern about the possible adverse health effects of EMF. The 4 mG limit was conceived as a result of negotiations between developers, city officials, and Southern California Edison representatives. It was based on various scientific studies and expert opinions. The ordinance also requires future applicants to submit studies showing the status of current EMF research. This information could subsequently change the existing 4 mG limit.

Sources: Zoning Ordinance, City of Irvine, California; Conversations with City of Irvine Zoning Commission.

2.2 CONNECTICUT

On February 11, 1993, the Connecticut Siting Council, which regulates electric utility transmission lines and substations, adopted Electric and Magnetic Field Best Management Practices. The practices expand public notice and participation, require the adoption of uniform EMF measurement protocol, and require individual project-specific assessments of EMF and exposure limits for EMF. Although the practices do not set actual limits, the process is established to reserve the right to do so if they feel it is necessary.

TABLE 2-1. EXISTING STATE AND LOCAL POWER FREQUENCY ELECTRIC AND MAGNETIC FIELD LIMITS: TRANSMISSION AND DISTRIBUTION LINES

State/Agency/Date	Given Power Line	Electric Field Strength Limits (kV/m)		Magnetic Field Strength Limits (mG)	Distance from Power Line (Ft.)	Basis
	Voltage (kV)	RoW	Edge of RoW			
CALIFORNIA Department of Education - 1989	50-133				100	A policy of "prudent avoidance" and general concern about potential adverse health effects of EMF
	220 - 230				150	
	500-550				350	
CALIFORNIA City of Irvine - May 15, 1989				4		Concern about potential adverse health effects of EMF
FLORIDA New Transmission Lines	230 and smaller	8	3	150[1]		Concern about potential adverse effects of EMF on public health
Department of Environmental Regulation - 1989; Amended January 7, 1993	500	10	2	200[1]		
	500 double circuit	10	2	250[1]		
FLORIDA Standard for Lake Tarpon - Kathleen Transmission Line		8.94	1.56	35 <500 MW[1] 229 >500 MW[1]	100[2]	Concern about potential adverse effects of EMF on public health
Department of Environmental Regulation		8.80	1.90	24 <500 MW 154 >500 MW	190[2]	

1 Magnetic Field Strength Limits at Edge of RoW
2 Width of RoW

TABLE 2-1. EXISTING STATE AND LOCAL POWER FREQUENCY ELECTRIC AND MAGNETIC FIELD LIMITS: TRANSMISSION AND DISTRIBUTION LINES (Continued)

State/Agency/Date	Given Power Line	Electric Field Strength Limits (kV/m)		Magnetic Field Strength Limits (mG)	Distance from Power Line (Ft.)	Basis
	Voltage (kV)	RoW	Edge of RoW			
MINNESOTA Environmental Quality Board - 1976		8				Standard is based on incidence of electric shock.
MONTANA Board of Natural Resources and Conservation - 1984	69 and above		1			Public health criterion.
NEW JERSEY Commission on Radiation Protection - 1981			3			Protection of public health without unduly inhibiting economical power transmission
NEW YORK Public Service Commission - 1990	345			200 at edge of RoW		Prudent avoidance policy
NEW YORK Public Service Commission - 1978			1.6			Protection of public health
NORTH DAKOTA		9				*
OREGON - 1979		9				Reduction of probability of electric shock or burn

TABLE 2-1. EXISTING STATE AND LOCAL POWER FREQUENCY ELECTRIC AND MAGNETIC FIELD LIMITS: TRANSMISSION AND DISTRIBUTION LINES (Continued)

State/Agency/Date	Given Power Line	Electric Field Strength Limits (kV/m)		Magnetic Field Strength Limits (mG)	Distance from Power Line (Ft.)	Basis
	Voltage (kV)	RoW	Edge of RoW			
RHODE ISLAND Energy Facility Siting Board (regulates siting of transmission lines) - Signed by Governor July 1992	69 and above					Prudent avoidance approaches in construction of transmission lines
TENNESSEE City Commission of Brentwood - April 1991	120 and larger			4[1] at edge of RoW		Protection of public health, safety and welfare

These limits do not always explicitly state the relevant bandwith; however, because they relate specifically to electric power transmission, they are assumed to apply only to 60 Hz frequencies.

1 Magnetic Field Strength Limits at Edge of RoW
* Not stated or documented (see Section 1.0)

1 Magnetic Field Strength Limits at Edge of RoW
2 Width of RoW

Sources: Connecticut Siting Council Best Management Practices; Discussions with Connecticut Department of Public Utility Control, Connecticut Siting Council; *EMF Health & Safety Digest*, October 1992, p. 12; *EMF Health & Safety Digest*, February 1992, p. 6-7.

2.3 FLORIDA

In 1989, the Florida Department of Environmental Regulation (DER) issued regulations limiting EMF from new 60 Hz electrical transmission lines and new substations rated at 69 kV or greater. Amendments to these rules were published on January 7, 1993. The Florida standards (see Table 2-1) were enacted to provide reasonable protection to public health and welfare from EMF associated with transmission lines, distribution lines, and substations. To develop the regulations, the Environmental Regulatory Commission, an appointed body, held public hearings and amassed testimony on EMF. The Commission determined that there was no conclusive information on which to create health-based standards. Instead, the Florida standards (shown below) were based on a range of measurements taken from existing lines and were formulated to ensure that new lines do not exceed the emissions level of existing lines.

The DER enacted different, more stringent standards for the Lake Tarpon-Kathleen Transmission line which crosses the Florida Everglades. The DER regulations do not explain why this line is subject to a more stringent standard. However, secondary sources indicate that these limits may be more closely linked to politics than science. Residents of Hillsborough County, through which the line crosses, were bitterly opposed to the construction of this line and the stringent EMF limits may have been enacted in recognition of their concern.

Sources: Florida Regulation; *EMF Health & Safety Digest*, October 1992, p. 7; Discussions with Florida Legislative Status Office and Florida Department of Environmental Regulation Staff; *EMF REGULATION: A Look at the Present Status*,"A Case Study: The Florida Environmental Regulation Commission," presented by Robert S. Banks at the Northwest Public Power Association Workshop on Electric and Magnetic Fields; Oregon, January 24, 1990.

2.4 MINNESOTA

Since 1976 the Minnesota Environmental Quality Board has stipulated a right-of-way guideline of 8 kV/m that is applied in all power line construction permits. The standard was enacted to protect against the incidence of shock.

Source: Conversation with George Durfee, Minnesota Environmental Quality Board.

2.5 MONTANA

In December 1984, the Board of Natural Resources and Conservation (BNRC) adopted a rule limiting electric field strength to 1 kV/m at the edge of a right-of-way. This covers all transmission lines above 69 kV, but applies only in residential areas. This requirement can be waived by a landowner or the owner/operator can get a waiver from a landowner. The rule was

imposed as a "public-health criterion," in connection with certification of the proposed double-circuit 500 kV Garrison-Spokane Transmission Project.

Source: "Montana Major Facility Siting Act," Title 85, Chapter 20, Administrative Rules.

2.6 NEW JERSEY

In February 1981, the New Jersey Bureau of Radiation Protection adopted an interim guideline limiting electric field strength at the edge of electric power rights-of-way to 3 kV/m. The basis for the guideline is protection of the public health without unduly inhibiting the economical transmission of power.

Sources: New Jersey Bureau of Radiation Protection, "Resolution," February 18, 1981.

2.7 NEW YORK

In September 1990, the Public Service Commission adopted an interim policy to limit magnetic fields to 200 mG at the edge of future major electric transmission line rights-of-way (for all 345 kV circuits). The Commission made it clear that this was not a health-based standard, but rather pursuant to a policy of prudent avoidance. In addition to this standard, in 1978, the Commission adopted an interim electric field limit of 1.6 kV/m at the edges of future transmission line rights-of-way.

Sources: State of New York Public Service Commission, "Statement of Interim Policy on Magnetic Fields of Major Electric Transmission Facilities, September, 1990; State of New York Department of Public Service, "Procedural History," January 11, 1988; Conversation with Daniel Driscoll, New York Public Service Commission.

2.8 NORTH DAKOTA

The Public Service Commission has a requirement that electric fields within the right-of-way not exceed 9 kV/m.

Source: *CRC Handbook of Biological Effects of Electromagnetic Fields*, 1986.

2.9 OREGON

The Oregon Energy Facilities Siting Council has adopted a prudent avoidance policy regarding EMF and it appears that no rules or standards will be imposed on power lines in the near future. The Council does have an electric field limit of 9 kV/m at rights-of-way, which was adopted in the late 1970s as a safety standard to reduce the likelihood of electric shock or burn.

Sources: Conversation with Tom Meehan, Oregon Energy Facility Siting Council.

2.10 RHODE ISLAND

On July 21, 1992, the Governor signed into law the "Electric Transmission Siting and Regulatory Act" (Title 39, Chapter 25). This law expanded the jurisdiction of the Energy Facility Siting Board over the siting of transmission lines 69 kV or greater and authorized the Board to establish rules and regulations for construction of such lines. The law encourages the use of prudent avoidance approaches.

Sources: "Electric Transmission Siting and Regulatory Act," Title 39, Chapter 25, 1992; *EMF Health & Safety Digest*, November-December 1992, p. 12

2.11 TENNESSEE

Brentwood - In April 1991, the City Commission passed local ordinance 91-3 imposing magnetic field limits of 4 (mG) for 120 kV and larger lines at the edges of rights-of-way. Transmission lines in place as of January 31, 1991 are required to meet these limits by 1996. The ordinance is intended to "protect the health, safety, and welfare of its citizenry," and recognizes that "a reasonable doubt exists as to potential long-term health effects produced by electromagnetic fields....."

Source: Brentwood Ordinance.

3. PENDING STATE AND LOCAL ELECTRIC AND MAGNETIC FIELD LIMITS

This section provides information on EMF-related legislation that was pending in several states and local jurisdictions as of June 1993. These proposed actions include literature reviews and research, transmission line construction moratoria, and magnetic field limitations.

3.1 CALIFORNIA

On March 5, 1993, Assemblywoman Vivian Bronshvag introduced Assembly Bill (A.B.) 2028 which would implement the recommendations contained in the Report of the California Electromagnetic Field Consensus Group dated March 20, 1992. These recommendations would be included in a new section of the Public Utility Code, Section 701.7, and would recommend specific actions on research, education, and policy dealing with EMF radiation. A.B. 2028 would also create a new category of crimes which would apply if the rules were violated. The bill was introduced in response to public citizen concerns about the potential adverse health effects from exposure to EMF, though it recognizes that research has not conclusively demonstrated a causal effect between exposure and adverse health effects.

The bill has completed the Assembly committee process and has been put on the consent calendar. Therefore, barring unforseen opposition, it is likely to be automatically passed by the Assembly and then considered by the State Senate.

Sources: Conversations with the Office of the Chief Clerk of the Assembly and the Office of the Secretary of the Senate; A.B. No. 2028.

3.2 CONNECTICUT

Public Act No. 91-317 was enacted to examine the need for and to develop public health recommendations concerning prudent methods of avoiding exposure to EMF. The Act required individual electric utilities to pay an assessment of $150,000 during Fiscal Year 1992 to fund the State interagency EMF task force's efforts to conduct a literature review, develop a policy of prudent avoidance, and conduct health research. The Task Force's 1993 Report outlined a policy it calls "Voluntary Exposure Control" which recognizes the role of the State in informing citizens of what is known and unknown about EMF. The Task Force does not recommend establishing EMF standards at this time, but will issue a final report and recommendations to the Connecticut General Assembly by 1995.

Sources: Discussions with Connecticut Department of Public Utility Control, Connecticut Siting Council; *EMF Health & Safety Digest*, December 1991; *EMF Health & Safety Digest*, October 1992, p. 12; *EMF Health & Safety Digest*, February 1992, p. 6-7.

3.3 ILLINOIS

On February 24, 1993, Representative Balanoff introduced House Bill 0662 which would, among other things, impose a three-year moratorium on the construction of electric transmission lines that operate at greater than 60 kilovolts. The bill also would require the Illinois Commerce Commission, in consultation with the Department of Nuclear Safety, to conduct a study on electromagnetic radiation and associated health issues.

Sources: H.B. 0662; Conversations with the Office of Illinois Legislative Information.

3.4 INDIANA

In January 1993, Senator Robert L. Meeks introduced S.B. 370 which would require the Indiana Utility Regulatory Commission (IURC) to determine whether rules are necessary to protect public health from EMF associated with high voltage transmission lines, and if so, to establish requirements concerning the safety of EMF. *EMF Health & Safety Digest* reported that Senator Meeks hopes to place the responsibility of regulating EMF with the IURC rather than the Indiana State Board of Health which is not highly regarded in matters relating to the environment. S.B. 370 passed the Senate and was reported by the House Commerce Committee.

Sources: Conversations with Indiana Office of Legislative Information; S.B. 370.

3.5 MASSACHUSETTS

Four bills are now pending before the legislature. Representative Barbara Gardener introduced S.B. 4106 which would mandate an EMF literature review, an evaluation of human exposure to electric facilities, a field mitigation study, standards concerning EMF dosages, and a $250,000 assessment imposed on utilities to implement the act. Hearings were held on April 8. The bill is very similar to legislation Representative Gardener introduced last year, H.B. 3571, which died in committee.

On January 6, State Senators Amarello and Belisle introduced the following three bills:

- S.B. 369 would require real estate sellers to disclose to "potential buyers that extremely low levels of electromagnetic radiation may cause adverse health effects." The bill specifies that properties in question are those within 1,000 feet of 69 kV and above transmission lines. Utilities would have to inform sellers and buyers of the disclosure requirement in their monthly bills. The legislation also would require the Massachusetts Department of Public Utilities (DPU) to prepare a summary of EMF health studies.

- S.B. 370 requires establishment of a fund to finance corrections of "residential electromagnetic radiation exposure over 2 mG created by high voltage transmission lines (69 kV and above) and distribution lines." The fund would be generated by assessing 5 percent of electric utilities' profits after taxes. The DPU would maintain a list of residences with magnetic levels over 2 mG. The bill would authorize the DPU to "promulgate rules and regulations establishing standards under which electric utilities must comply with when correcting exposure to EMF for residential purposes."

- S.B. 371 requires electric utilities to inform their employees about EMF health effects by providing them "with health studies which indicate the potential of actual adverse health effects due to exposure to electromagnetic radiation."

All three bills were referred to the Senate Government Regulations Committee, and hearings were held on March 30.

Senator Belisle has been very active on EMF-related issues and was Chairman of a committee formed by residents of the town of Millbury, MA in response to proposals by local electric utilities to upgrade transmission lines and substations in the area. The town has 23 transmission lines that pass through it, with associated residential magnetic field levels ranging from 12 to 30 mG. The Millbury EMF committee was particularly concerned about adverse effects from EMF exposure and were seeking funding from NIH and others to conduct a study of EMF health effects other than cancer. Last year the town passed a resolution, modeled on the Brentwood, Tennessee ordinance, limiting magnetic fields to 4 mG at the edge of the right-of-way. The resolution was declared invalid by the state attorney general.

Sources: *EMF Health & Safety Digest*, November-December 1992, p.12; Conversation with Massachusetts Legislative Status Office, *EMF Health & Safety Digest*, March 1993, p. 4.

3.6 MINNESOTA

There have been several developments in the State Legislature this session:

- H.F. 960 was introduced into the House on March 11, 1993 by Representative Wenzel and was referred to the Committee on Agriculture. This bill seeks to make the owner or operator of a high voltage transmission line liable for damage to livestock and crops caused by stray voltage associated with the transmission line.

- House Advisory (H.A.) No. 6, introduced by Representative Wenzel on March 31, 1993, proposes that the Committee on Agriculture study the responsibility and liability issues arising from stray voltage and EMF damage to agricultural health and productivity.

- S.F. 1609 was introduced into the Senate on April 15, 1993 by Senators Sams, Morse, and Murphy and was referred to the Committee on Jobs, Energy, and Community Development. This bill seeks to have the Minnesota Planning Commission (1) establish a formal complaint procedure for persons allegedly injured by stray voltage, and (2) convene a task force to undertake a comprehensive review of the sources of stray voltage and EMF and the risks posed by them to human and animal health and the environment.

Sources: H.F. 960; H.A. No. 6; S.F. 1609.

3.7 NEW JERSEY

S.B. 164, introduced by Senator Joseph Kyrillos in January 1992 and carried over into 1993, would require the Commission on Radiation Protection to: adopt interim measures for EMF "prudent avoidance" standards; adopt EMF measurement protocols; conduct an EMF literature review and a study of the costs of "field mitigation" measures; and monitor EMF developments. The bill also requires the New Jersey Department of Environmental Protection and Energy to certify the use of prudent avoidance techniques for proposed electric facilities, transmission lines or the upgrade thereof. Since the New Jersey legislature has a two-year session, the bill is still in committee.

Sources: *EMF Health & Safety Digest*, November-December 1992, p. 12; New Jersey Legislative Information Service.

3.8 NEW YORK

S. 2858, which was introduced by Senator Oppenheimer and others on March 2, 1993, seeks to amend the general business law by requiring a notice of the highest magnetic field reading (in milligauss) for electric blankets and electric comforters. The bill was referred to the Committee on Consumer Protection.

Sources: S. 2858; Discussions with New York Legislative Bill Drafting Commission.

3.9 OREGON

H.B. 3608 was introduced by State Representative Lisa Naito on March 12, 1993 and was referred to the General Government Committee. This bill seeks to have utilities with power lines or stations within 500 feet of public schools make measurements of the surrounding EMF. It also seeks corrective action to prevent human exposure to magnetic field strength above 2.0 mG. This bill does not have strong support and has had no action to date.

Source: Conversation with Oregon legislative offices; *EMF Health & Safety Digest*, April 1993, p. 6.

3.10 PENNSYLVANIA

On February 10, 1993, Representative Carone introduced H.B. 380, which provides for the establishment of an EMF exposure avoidance program. This bill, which was referred to the Committee on Conservation, authorizes the Pennsylvania Public Utility Commission to develop and implement a program based on the concept of prudent avoidance which will be designed to eliminate, reduce or control public exposure to the EMF associated with electric power lines.

Sources: H.B. 380; Pennsylvania Legislative Reference Bureau.

3.11 RHODE ISLAND

93-S 570 and 93-H 6882 were introduced into their respective houses in February 1993. 93-S 570 was referred to the Committee on Health, Education, and Welfare, and 93-H 6882 was referred to the Committee on Corporations. Both bills seek to prohibit the construction of above-ground high voltage power transmission lines of 69 kV or greater.

Sources: 93-S 570; 93-H 6882; Discussions with Rhode Island Legislative Data Systems office.

4. FEDERAL GOVERNMENT REGULATORY ACTIVITIES

This section briefly describes the U.S. Food and Drug Administration (FDA) action regarding EMF emissions standards for video display terminals (VDTs).

4.1 FOOD AND DRUG ADMINISTRATION

According to F. Alan Anderson, Director of FDA's Office of Science and Technology, the FDA is developing voluntary EMF emissions standards for VDTs along the lines of a voluntary standard introduced by Sweden. Several major U.S. manufacturers of VDTs, including IBM and Sigma Designs, Inc., now offer monitors that meet the Swedish standard (a discussion of the Swedish standard is provided in Section 7.4).

Source: Congressional Quarterly: *Editorial Research Reports*, 4/26/91, No. 16.

4.2 FEDERAL COMMUNICATIONS COMMISSION

In March of 1993 the Federal Communications Commission (FCC) adpoted a Notice of Proposed Rulemaking (NPRM), a proposal to adopt the 1992 American National Standards Institute (ANSI) standards for limiting exposure to radiofrequency EMF (ANSI C95.1-1992). The FCC is soliciting comments from public, industry, other agencies and organizations on this proposal.

4.3 DEPARTMENT OF DEFENSE

In May of 1993 the Department of Defense (DoD) issued a draft "instruction" number 6055.11 for "Protection of DOD Personnel from Exposure to Electromagnetic Fields (EMF) at Radio Frequencies (RF) from 3 Kilohertz (kHz) to 300 Gigahertz (GHz)". This will replace the 1986 DoD instruction of the same number and sets permissible exposure limits derived from ANSI/IEEE C95.1-1992.

4.4 ENVIRONMENTAL PROTECTION AGENCY

In April 1993 the Environmental Protection Agency (EPA) held the Radiofrequency (RF) Radiation Conference. The purpose of the conference was to assess the current state of knowledge about biological and health effects of RF radiation. The conference was scheduled to gather the information necessary to response to a request by EPA's Science Advisory Board that EPA resume its past effort to develop Federal guidance to control exposure to RF radiation. The EPA has not announced intentions resume its RF guidance activities.

4.5 NATIONAL EMF RESEARCH AND COMMUNICATION PROGRAM

Although not a regulatory activity, a large scale national EMF program is underway. The Energy Policy act of 1992 authorizes a $65 million, 5-year research and public information program, to be jointly funded by government and industry. The Department of Energy

shares responsibility for implementation of this program with the National Institute of Environmental Health Sciences.

5. U.S. TECHNICAL ORGANIZATION GUIDELINES

This section details the current guidelines for limitations on exposures to electromagnetic fields as set by three U.S. techinal organizations: the American Conference of Governmental Industrial Hygienists (ACGIH); ANSI; and the Institute of Electric and Electronics Engineers (IEEE).

5.1 AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS (ACGIH)

The ACGIH is an organization devoted to the administrative and technical aspects of occupational and environmental health. The guidelines and recommendations developed by the ACGIH are intended only for use in industrial hygiene by trained professionals. The threshold value limits (TLVs) shown in Table 5-1 for electric and magnetic fields present either time weighted averages (TWAs) or ceiling values below which most workers can be repeatedly exposed without adverse health effects.

The basis for the TLVs are specific to the field type and frequency range. No specific target organs have been identified for deleterious effects due to static magnetic fields. The ceiling value has been set at a level below which no deleterious effects have been demonstrated in humans or animals. The whole body TWA has been set at the level used by Lawrence Livermore National Laboratory to limit the potential in the large aorta of an adult human to 1 mV. The ceiling for pacemaker wearers is based on the observation that the reed relay switch in pacemakers can be closed by flux densities as low as 17,000 mG, placing the pacemaker in an asynchronous pacing mode. Certain implanted medical devices such as aneurysm clips may experience significant magnetic forces and torques in strong flux densities if they contain ferromagnetic materials. No basis has been given for extremity limits.

The limits for magnetic fields in the 1 Hz to 30 kHz (sub-RF) range have been set to limit the maximum induced current density within the human body to 10 mA/m^2 (rms). Other than the currently unresolved issue of cancer risk of power frequency fields, there is no evidence of harmful effects from sub-RF magnetic fields that induce current densities in the body below 10 mA/m^2. The limits for pacemaker wearers are designed to avoid electromagnetic interference (EMI) that has been demonstrated to cause certain models to revert to an asynchronous mode or exhibit abnormal pacing characteristics at 60 Hz flux densities as low as 1,000 mG. At very low frequencies approaching DC there is concern that pacemaker reed switches may be closed by the field.

The basis for the electric field limits below 30 kHz are identical to the case of magnetic fields: maintaining induced current densities within the body below 10 mA/m^2. The limits for electromagnetic fields between 30 kHz and 3 MHz have been set to protect against shock and burn hazards. For the entire frequency range from 30 kHz to 300 GHz, the threshold limit values are intended to limit the average whole body specific absorption rate (SAR) to 0.4 W/kg. The primary concern is thermal damage.

Sources: "1992-1993 Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices," ACGIH; "Documentation of the Threshold Limit Values," ACGIH.

TABLE 5-1. AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS THRESHOLD LIMIT VALUES

Frequency	Electric Field Strength Limits (kV/m)	Magnetic Field Strength Limits (mG)	Comment
< 1 Hz	--	600,000	Whole Body Daily TWA
0	--	6,000,000	Extremity Daily TWA
0	--	20,000,000	Ceiling Value
1Hz - 30 kHz	--	$600{,}000/f$	f is frequency in Hz for f=60 Hz limit is 10,000 mG
< 6 Hz	1	10,000	Pacemaker Wearer Ceiling
6 Hz - 30 kHz	1	$60{,}000/f$	Pacemaker Wearers f is frequency in Hz for f=60 Hz limit is 1,000 mG
< 100 Hz	25		
0.1 - 4 kHz	$2{,}500/f$		f is frequency in Hz
4 - 30 kHz	0.63		
.03 - 3 MHz	0.61	20	
3 - 30 MHz	$1.8/f$	$61/f$	f is frequency in MHz
30 - 100 MHz	0.061	2.0	
0.1 - 1 GHz	$0.006\sqrt{f}$	$0.2\sqrt{f}$	f is frequency in MHz
1 - 300 GHz	0.19	6.5	
TWA = Time Weighted Average			

5.2 AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI) & INSTITUTE OF ELECTRIC AND ELECTRONICS ENGINEERS (IEEE)

In 1992, IEEE published its "Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz" (IEEE C95.1-1991). This was

subsequently adopted by ANSI as an American National Standard. The standard is not compulsory except to the degree that it is subsequently adopted or adapted as a basis for regulation by bodies such as the Federal Commerce Commission, Occupational and Safety Health Administration, or the military.

The portions of the standard that limit whole body electric and magnetic field strengths (as opposed to induced and contact currents) are summarized in Table 5-2. The maximum permissible exposures (MPEs) presented specify the field strengths or power densities to which a person may be exposed "without harmful effect and with an acceptable safety factor." The MPEs shown are spatially averaged over a vertical cross section of the body and temporally averaged over the time periods specified in Table 5-3. There are relaxed standards for partial body exposures.

A distinction is made between controlled and uncontrolled environments. An uncontrolled environment is one where individuals have no knowledge or control of their exposure, such as a non-work environment. A controlled environment is a location where the exposure may be incurred by persons who are aware of the potential for exposure.

The IEEE has a subcommittee charged with developing safety levels with respect to human exposure in the 0-3 kHz range; however, no standard has been published to date.

The MPEs for controlled environments have been set at a level that results in specific absorption rates below about 0.40 W/kg. The electric field limits for low frequencies in controlled environments are designed to:

- Limit induced currents in the ankles during free-field exposure, and,
- Lower the probability of inducing large body currents when conducted objects are touched.

Source: "IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz" IEEE C95.1-1991, 1992.

TABLE 5-2. ANSI/IEEE STANDARD C95.1-1991

Frequency	Electric Field Strength Limits (kV/m)	Magnetic Field Strength Limits* (mG)	Comment
Controlled Environments Maximum Permissible Exposure (MPE)			
3 - 100 kHz	0.61	2,000	
0.1 - 3 MHz	0.61	$200/f$	
3 - 30 MHz	$1.8/f$	$200/f$	
30 - 100 MHz	0.061	$200/f$	
0.1 - 0.3 GHz	0.061	2.00	
0.3 - 3 GHz	$0.0035\sqrt{f}$†	$0.12\sqrt{f}$†	$S = f/(300)$
3 - 300 GHz	0.19†	6.5†	S = 10
Uncontrolled Environments Maximum Permissible Exposure (MPE)			
3 - 100 kHz	0.61	2,000	
0.1 - 1.3 MHz	0.61	$200/f$	
1.3 - 30 MHz	$0.82/f$	$200/f$	
30 - 100 MHz	0.028	$2{,}000/f^{1.688}$	
0.1 - 0.3 GHz	0.028	0.92	
0.3 - 15 GHz	$0.0016\sqrt{f}$†	$0.053\sqrt{f}$†	$S = f/(1{,}500)$
15 - 300 GHz	0.19†	6.5†	S = 10

* Standard gives magnetic field strength (H). Flux density was calculated from $B = \mu_o H$ (B in T, H in A/m, $\mu_o = 12.566 \times 10^{-7}$ Henries/m)

† Standard is written for power density, S (mW/cm^2). Equivalent fields were calculated from $S = E^2 / 377 = 377 H^2$ (S in W/m^2, E in V/m, H in A/m)

Note: f is in MHz

TABLE 5-3. ANSI/IEEE STANDARD C95.1-1991 AVERAGING TIMES

Frequency	Controlled Environments	Uncontrolled Environments	
	$\|E\|^2$, $\|B\|^2$, or S (minutes)	$\|E\|^2$, S (minutes)	$\|B\|^2$ (minutes)
3 - 100 kHz	6	6	6
0.1 - 1.34 MHz	6	6	6
1.34 - 3 MHz	6	$f^2/0.3$	6
3 - 30 MHz	6	30	6
30 - 100 MHz	6	30	$0.0636f^2$
0.1 - 0.3 GHz	6	30	30
0.3 - 3 GHz	6	30	†
3 - 15 GHz	6	$90,000/f$	†
15 - 300 GHz	$616,000/f^{1.2}$	$616,000/f^{1.2}$	†

Note: f is in MHz

† Standard is written for power density, S

6. MULTINATIONAL AGENCY GUIDELINES

This section describes the actions taken by three multinational agencies in setting limits on human exposure to EMF. These agencies are the International Commission on Occupational Health (ICOH), the International Radiation Protection Association (IRPA), and WHO. Table 6-1 summarizes the guidelines set by IRPA and WHO.

6.1 INTERNATIONAL COMMISSION ON OCCUPATIONAL HEALTH (ICOH)

ICOH's Radiation and Work Committee drafted a resolution stating "...the evidence regarding EMFs and long-term health effects does not justify making changes to currently recommended industrial operating practices." The committee, however, intends to keep this matter under review.

Source: *EMF Health & Safety Digest*, November-December 1992, p.5.

6.2 INTERNATIONAL RADIATION PROTECTION ASSOCIATION (IRPA)

In 1990, IRPA issued interim exposure recommendations (IRPA39,4) for the general public and workers for 50/60-Hz EMF. The IRPA/International Non-Ionizing Radiation Committee (INIRC) guidelines are derived from a single criterion: induced body current. They are temporary standards, designed to provide direction only, and carry the weight of expert opinions. They have no force of law until governments codify them into rules or regulations.

Sources: IRPA interim guidelines; *EMF Health and Safety Digest*, July-August 1992, p. 10.

6.3 WORLD HEALTH ORGANIZATION (WHO)

The WHO is working with the INIRC of the IRPA to develop health criteria documents on non-ionizing radiation. It published recommendations on intermittent and long-term exposure to 50/60 Hz electric fields. WHO recommends a general public intermittent exposure limit of 10 kV/m to electric field strengths. In collaboration with the United Nations Environment Program and IRPA, it has published a magnetic fields health and safety guide.

Source: *CRC Handbook of Biological Effects of Magnetic Fields*, 1986.

TABLE 6-1. MULTINATIONAL AGENCY GUIDELINES

Agency/Date	Frequency (Hz)	Electric Field Strength Limits (kV/m)	Magnetic Field Strength Limits (mG)	Basis
International Radiation Protection Association (IRPA): 1990	50/60	Occupational 10 - Whole Day 30 - Short Term	Occupational 5,000 - Whole Day 50,000 - Short Term 250,000 - For Limbs	To limit induced body current
		General Public 5 - Whole day 10 - Few hours per day	General Public 1,000 - Whole Day 10,000 - Few hours per day	To limit induced body current
World Health Organization (WHO)	50/60	General Public 10 - Intermittent exposure		

7. EXISTING INTERNATIONAL ELECTRIC AND MAGNETIC FIELD LIMITS

This section presents EMF strength limits in various countries. Except for Sweden, these countries have set limits for power transmission and distribution lines. In the case of Sweden, limits have been set for VDTs. Table 7-1 summarizes the key features of the standards, regulations, or guidelines described in sections 7.1 to 7.6.

7.1 AUSTRALIA

Australia has reportedly adopted "general" magnetic field limits based on the IRPA recommendations of a whole day limit of 5,000 mG for occupational exposure and a whole day limit of 1,000 mG for the general public. Only New South Wales and Victoria have guidelines for the construction of 500 kV transmission lines. The Electricity Commission of New South Wales has an internal design standard limiting electric field strength to 2 kV/m at the edge of RoW. The Victoria State Electricity Commission limits electric field strength to 10 kV/m in the RoW or 2kV/m at the edge of the RoW when measured 1 m above the ground.

Source: Presentation by Dr. Brian J. Maddock at the CIGRE Conference held August 3 through September 5, 1992, Paris, as reported in *EMF Health & Safety Digest*, November-December 1992, p.5. *WHO*, *"Extremely Low Frequency Fields,"* 1984.

7.2 GERMANY

Germany has reportedly adopted magnetic field limits of 50,000 mG for both occupational and general public exposure.

Source: Presentation by Dr. Brian J. Maddock at the CIGRE Conference held August 3 through September 5, 1992, Paris, as reported in *EMF Health & Safety Digest*, November-December 1992, p.5.

7.3 ITALY

EMF exposure limits were established by a decree approved on April 23, 1992 by Prime Minister Julio Andreotti. These limits were recommended by the Minister of the Environment, Georgio Ruffolo, and the Minister of Health, Francesco DeLorenzo. The decree, equivalent of a U.S. federal regulation, also calls for a report on the EMF health effects issue which is to include prioritized recommendations for action based on population exposure estimates. Utilities with structures not in compliance must develop and implement remedial plans by 2004.

TABLE 7-1. EXISTING INTERNATIONAL ELECTRIC AND MAGNETIC FIELD STRENGTH LIMITS

Country/Agency/Date	Frequency (Hz)	Electric Field Strength Limits (kV/m)	Magnetic Field Strength Limits (mG)	Comments/Basis
AUSTRALIA 1976/1990	50/60	2 At Edge of RoW[1]	Occupational 5,000 whole day	Magnetic field limits based on IRPA recommendations.
		10 In RoW[2] 2 At Edge of RoW[2]	General public 1,000 whole day	Electric field limits based on values in other standards, including USSR
GERMANY	50		50,000	Magnetic field limits for both occupational and general public exposure.
ITALY April 23, 1992	50	5 for extended exposure	1,000 for extended exposure	Exposure limits established by decree, which also calls for report on EMF health effects.
		10 for limited exposure	10,000 for limited exposure	
SWEDEN SWEDAC (Swedish procurement agency) December 31, 1990	5 Hz-2 kHz	25 V/m 50 cm from the display	2.5 50 cm around the display	Limits apply only to Video Display Terminals (VDTs) purchased by the state.
	2 kHz-400 kHz	2.5 V/m 50 cm around the display	0.25 50 cm around the display	
UK National Radiological Protection Board (NRPB), 1988 (NRPB GS-11)	50	10[3]	20,000[3]	Protection against thermal effects of the absorption of electromagnetic energy and the possibility of electric shock or burn.
FORMER USSR, 1975	50/60	10 -25	18,000 - 54,000[4]	"General" magnetic field limits. Electric Field limits are occupational and relate only to transmission line 400 kV and above. (see Table 7-2)

[1] New South Wales
[2] Victoria
[3] For both workers and public
[4] Occupational standard cited in *EMF Health & Safety Digest*, September 1992, p. 9.

Details of the decree, which specifically exclude occupational exposures, are as follows:

	Electric Fields	Magnetic Fields
For extended exp.:	5 kV/m	1,000 mG
For limited exp.:	10 kV/m	10,000 mG

The minimum distance limits, which apply to existing and future transmission lines and substations, are:

10 m for 132 kV lines or substations
18 m for 220 kV lines or substations
28 m for 380 kV lines or substations.

In the future, the Technical and Scientific Committee is expected to recommend distance limits for lines greater than 380 kV.

Source: *EMF Health & Safety Digest*, September 1992, 0. 9.

7.4 SWEDEN

Although Sweden has limits on VDTs, as opposed to power lines, there is continuing research in the area of power lines. The Swedish National Board for Industrial and Technical Development (NUTEK), one of the government agencies that sponsored two highly-publicized studies (residential and occupational EMF epidemiologic studies), plans to inventory schools and day care facilities located near power lines. Vattenfall, the Swedish utility, will help measure EMF exposure levels. There is speculation that, should magnetic field levels exceed 2 mG (one of the cut off points used in the residential study), the schools may be moved or closed and the children relocated.

The Swedish procurement agency requires that VDTs purchased by the state meet the values presented below, in effect establishing an EMF requirement. These guidelines were established in 1990 by SWEDAC, the Swedish National Board for Measurement and Testing.

Electric Field

5 Hz - 2 kHz
25 V/m, 50 cm (20") from the display
2 kHz - 400 kHz
2.5 V/m 50 cm around the display

Magnetic Field

5 Hz-2 kHz
2.5 mG, 50 cm around the display
2 kHz-400 kHz
0.25 mG, 50 cm around the display

Sweden is currently considering setting limits for new electric utility structures near schools, houses and day care facilities, as well as limits for new construction near power lines.

Sources: *EMF Health & Safety Digest*, April 1992, p. 8.; *EMF Health & Safety Digest*, May 1993, p. 14.

7.5 UNITED KINGDOM

In November 1988, the National Radiological Protection Board (NRPB) in the U.K. established reference levels for exposure to EMF at ELF frequencies. These levels are based on and in response to the guidelines recommended by the INIRC. Although the INIRC guidelines limit exposures to EMF between 100 kHz and 300 GHz, the NRPB reference levels apply to all frequencies up to 300 GHz. The NRPB limits occupational and general public magnetic field exposure to 20,000 mG. The NRPB recommends limiting occupational and general public exposure to a field strength of 10 kV/m. The NRPB levels are intended to protect against the thermal effects of the absorption of electromagnetic energy and against the possibilities of electric burn and shock. Appendix B presents a recent draft statement by the NPRB, setting restrictions on human exposure to various kinds of EMF, including ELF.

Source: NPRB, "Guidance on Standards: Guidance as to Restrictions on Exposures to Time Varying Electromagnetic Fields and the 1988 Recommendations of the Internal Non-Ionizing Radiation Committee," May 1989.

7.6 USSR/COMMONWEALTH OF INDEPENDENT STATES

In 1975, the Soviet Union imposed occupational safety standards limiting exposure to electric fields. The Soviet standards apply to workers in substations or on transmission lines operating at 400 kV and above. The standards, shown in Table 7-2, were imposed for health-related reasons, although specific health effects were not identified.

TABLE 7-2. ELECTRIC FIELD EXPOSURE LIMITS FOR WORKERS IN INSTALLATIONS OF 400 KV AND HIGHER IN THE USSR, 1975

Electric Field Strength (kV/m)	Permitted Exposure Duration per Day (min)
5	Unrestricted
10	180
15	90
20	10
25	5

The Soviet standard stipulates that workers exposed to fields of 10 kV/m or more for the full time allowed must then remain in fields less than 5 kV/m for the rest of the day.

A 1975 Soviet standard for general public exposure was also recommended, but this does not appear to have been adopted. This recommendation set limits of 1 kV/m for continuous exposures and 12 kV/m for short duration exposures where transmission lines crossed the road. A limit of 20 kV/m was recommended as a maximum exposure in unpopulated areas.

Sources: WHO, *Extremely Low Frequency (ELF) Fields*, 1984; "CRC Handbook of Biological Effects of Electromagnetic Fields," 1986.

8. MAGNETICALLY LEVITATED VEHICLES (maglev)

8.1 BACKGROUND

Maglev vehicle technology is currently being evaluated as a possible future component of the U.S. ground transportation system. Maglev vehicles operate along a guideway instead of on rails. During operation, the vehicle does not touch the guideway, but is suspended above it by means of either repulsive or attractive magnetic forces. This technology offers advantages in speed and comfort for surface transportation and is being considered as a means of reducing congestion in heavy traffic corridors.

Prior to adopting the technology, an assessment of the likely ELF-EMF environment associated with the system is being conducted. The U.S. Department of Transportation has commissioned and received a number of studies characterizing the magnetic fields generated by various electrically powered rail systems.

This section briefly summarizes the results of a study of magnetic fields associated with the operation of a particular maglev system; discusses the applicability of the guidelines, standards and regulations discussed in this report to maglev technology; and compares the magnetic fields of the demonstration maglev to the ACGIH exposure guidelines.

8.2 MAGLEV EMF EXPOSURE PROFILE

Magnetic fields associated with maglev vehicle operation at the Emsland Transrapid (TR07) maglev Demonstration Facility in the Federal Republic of Germany were recently characterized in a field study conducted by Electric Research and Management for the U.S. Department of Transportation. The Transrapid (TR07) system is a non-superconducting electromagnetic system (EMS), which adjusts magnet currents on a continuous basis to maintain levitation and speed as required.

There are numerous field sources throughout the Transrapid system related to the power supply, levitation and drive systems. The study reported field characteristics in five areas: passenger compartments, near the guideway, passenger station, power equipment, and feeder cables.

Table 8-1 shows the magnetic fields near the floor of the engineer section on board the vehicle. This area is represented because it may contain the highest average fields in the controlled areas of the facility. Table 8-2 shows the magnetic fields in the passenger compartment, chosen because it may have the highest average fields in the uncontrolled (public) areas.

Electric fields were not surveyed as they were deemed to be insignificant. Likewise, magnetic fields over 2,560 Hz were deemed to be minimal.

TABLE 8-1. MAGNETIC FIELDS IN REAR ENGINEER SECTION AT 12.7 cm ABOVE FLOOR

Frequency	Magnetic Field Strength Limits (mG)			
	Minimum	Maximum	Average	Standard Deviation
Static	792	1100	986	76.1
5 - 45 Hz	31.1	180	75.5	37.7
50 - 60 Hz	3.08	29.4	16.3	6.88
65 - 300 Hz	24.6	85.5	55.3	16.0
305 - 2560 Hz	0.94	4.28	2.09	0.89
5 - 2560 Hz	39.8	191	96.6	37.6

TABLE 8-2. MAGNETIC FIELDS IN PASSENGER COMPARTMENT AT 12.7 cm ABOVE FLOOR

Frequency Range	Magnetic Field Strength Limits (mG)			
	Minimum	Maximum	Average	Standard Deviation
Static	167	1500	834	304
5 - 45 Hz	31.4	236	89.8	39.8
50 - 60 Hz	3.76	42.6	14.8	8.36
65 - 300 Hz	10.7	88.2	32.5	17.1
305 - 2560 Hz	0.45	4.57	1.93	0.96
5 - 2560 Hz	34.8	253.5	98.4	40.1

Source: "Final Report on Magnetic Field Testing of TR07 MAGLEV Vehicle and System," Electric Research and Management, Inc., State College, PA, prepared for the Federal Railroad Administration under Contract No. DTFR53-91-C-00047, February 1992.

8.3 APPLICABILITY OF GUIDELINES, STANDARDS AND REGULATIONS

There currently are no federal regulations that apply to extremely low frequency EMF generated by maglev systems. None of the state and local limits detailed in this report explicitly mention maglev or are intended to apply to maglev systems. The guidelines developed by technical organizations are only recommendations and have no actual domain as such, unless they are subsequently adopted or adapted as a basis for regulation.

It should be noted that the ANSI/IEEE standard does not currently set limits for frequencies below 3 kHz. Frequencies above 3 kHz have not been characterized for maglev systems, because they are believed to be insignificant. The threshold limit values set forth by the ACGIH does include the range characterized for a maglev demonstration system. The comparison, along with the necessary caveats, is made below.

8.4 COMPARISON OF MAGLEV ELF MAGNETIC FIELDS TO ACGIH STANDARDS

As noted in Section 5.1, the ACGIH standards are designed to be used by industrial hygienists in occupational settings. The comparison made in this section does not constitute an application of the guidelines as they were intended.

Table 8-3 displays the maximum and time weighted average magnetic field levels measured in the engineer's section of the TR07 with the ACGIH time weighted average threshold limit values for the most restricted frequency in each frequency range measured. The threshold limit values are meant to be averaged over the entire body. The values presented for the TR07 are measured at a distance of 12.7 cm above the floor. The field strengths decrease with height so that the values at 12.7 cm are greater than a whole body average in any position other than lying on the floor of the vehicle.

Table 8-3 shows that the average magnetic fields measured at this location in the Transrapid vehicle are at least an order of magnitude below the ACGIH threshold limit values and are generally at least two orders of magnitude below the TLVs.

TABLE 8-3. TR07 MAGNETIC FIELDS AND ACGIH THRESHOLD LIMIT VALUES

Frequency	Magnetic Field Strength Limits (mG)		
	Measured in TR07		ACGIH Threshold Limit Value
	Maximum	Average	Average
Static	1100	986	600,000
5 - 45 Hz	180	75.5	13,333
50 - 60 Hz	29.4	16.3	10,000
65 - 300 Hz	85.5	55.3	2,000
305 - 2560 Hz	4.28	2.09	235

APPENDIX A

OTHER DOMESTIC AND INTERNATIONAL ACTIVITY

OTHER DOMESTIC AND INTERNATIONAL ACTIVITY

In addition to the activities described in the body of this report, there have been a variety of efforts to address possible health-related EMF impacts. Many of these have not resulted in regulations, guidelines, or standards but are included as they could be important in the future. These efforts include state legislative initiatives that have failed, many of which sought to impose moratoria on the construction of new power lines. In fact, during 1992, over 22 EMF-related bills were introduced at the state level, though only three were passed. Many states have also conducted EMF literature reviews to expand their knowledge base and, in some cases, to prepare for broader research/policy studies; these efforts are not included here.

Also presented are summaries describing both recently completed actions of state regulatory bodies and task forces as well as those activities which are currently underway and could conceivably lead to the development of EMF limits. Outside the U.S., several governments are taking actions which demonstrate an interest in EMF issues and which could also lead to consideration of EMF limits.

A.1 DOMESTIC ACTIVITY

A.1.1 Colorado

During 1992, the Colorado Public Utility Commission conducted a rulemaking relating to EMF. The final rule, which went into effect in October 1992, requires electric utilities which are seeking approval of transmission upgrades or new transmission to describe what they have done to institute standards of prudent avoidance. The final rule did not set edge of right-of-way magnetic field limits, though such limits were considered during the rulemaking process.

Sources: Morey Wolfson, Assistant to the Commissioner, Colorado Public Utility Commission, *EMF Health & Safety Digest*, September 1992, p. 5.

A.1.2 Illinois

During the 1991-1992 legislative session, the following EMF bills died in committee:

- House Bill (H.B.) 2863, introduced by Representative Suzanne Deuchler, would also have imposed a three-year moratorium on 60 kV and above transmission line construction.

- Senate Bill (S.B.) 1436, introduced by Senator Berman, would have required the relocation of existing transmission lines near schools and prohibited construction of new transmission lines producing more than 2 mG.

Sources: *EMF Health & Safety Digest*, November/December 1992, p. 11; *EMF Issue Development Briefing*, February 1992, p. 11; Conversations with the Office of Illinois Legislative Information.

A.1.3 Indiana

During 1992, the following bills were introduced and subsequently died or were withdrawn:

- S.B. 223, introduced by Senator Meeks, proposed the establishment of EMF limits for 230 kV and above transmission lines. It was subsequently amended to recommend a literature review only.

- S.B. 224, introduced by Senator Robert Meeks, proposed a three-year moratorium on construction of 230 kV and above transmission lines.

- H.B. 1206, introduced by Representative Brad Fox, would have required a three-year moratorium on the construction of 230 kV and above transmission lines.

Sources: Conversations with Indiana Office of Legislative Information; S.B. 370; *EMF Issue Development Briefing*, February 1992, p. 11.

A.1.4 Maryland

Although Delegate Joan Pitkin introduced an EMF-related resolution during last year's legislative session, no EMF bills have been introduced this session. Joint Resolution 18, introduced in January 1992 and withdrawn in May, called for the Maryland Department of Environment to conduct an EMF literature review. Citing cancer statistics, it advocated "considering precautionary measures to limit exposure" and recommended that they be taken pending the outcome of the literature review.

Since 1989, the Maryland Department of Natural Resources has been under a mandate to extensively monitor EMF research and present its findings to the Legislature. So far three reports have been issued and no conclusive evidence linking EMF exposure and cancer has been reported.

Sources: "Status Report on Potential Human Health Effects Associated with Power Frequency Electric and Magnetic Fields," Maryland Department of Natural Resources; *EMF Issue Development Briefing*, February 1992, p. 4.

A.1.5 Michigan

Although two EMF-related bills were introduced into the House by Representative Glenn Oxender in 1991, no bills have been introduced during the 1993 legislative session, and Representative Oxender is no longer in office.

The 1991 bills were H.B. 4087, which would have imposed a two-year moratorium on the construction of 100 kV and above transmission lines, and H.C.R. 25, which sought to establish a health dangers committee for lines greater than 100,000 volts and called for a joint committee to track EMF research. Both bills died in committee.

Sources: Michigan Legislative Service Bureau; *EMF Health & Safety Digest*, November-December 1992, p. 12.

A.1.6 Nebraska

In March 1992, Senator Thomas Horgan introduced legislative resolution 330, which called for a study of potential EMF legislation in Nebraska. The resolution was intended to evaluate EMF legislation in other states and determine whether such legislation was "a valid and realistic response" to public concerns over the EMF issue. The resolution was referred to the Natural Resources Committee, where it was determined, in an August hearing, to be of low priority. It was not reintroduced in the 1993 session.

Sources: *EMF Health & Safety Digest*, November-December 1992, p. 12; Nebraska Legislative Hotline.

A.1.7 New York

On March 23, 1993, the State Attorney General, Robert Abrams, announced that he had obtained voluntary agreement from each of eight New York State electric utilities to undertake a comprehensive survey to identify the location of power lines of 69 kV and above near schools and to determine the strength of the electromagnetic fields they create. This announcement came soon after Niagara Mohawk agreed to take a number of actions to reduce EMF emanating from two power lines within 70 feet of a school in Albany County. Niagara Mohawk's actions were prompted by general public concern.

Source: Press Release, "Abrams Obtains Utilities Pledge to Measure Electromagnetic Fields Near Schools," March 23, 1993.

A.1.8 Oregon

A law passed in 1991 required the Energy Facilities Siting Council to establish an EMF committee comprised of representatives from the public, utility, and government sectors to track EMF research developments. The Committee set up by the Council has established three working groups to consider EMF biological effects, engineering effects, and public policy issues, respectively. The first of a series of reports to be prepared by the Committee was presented to the Council on March 30, 1993 and was passed on to the Legislative Assembly.

Source: Conversation with Tom Meehan, Oregon Energy Facility Siting Council.

A.1.9 South Carolina

H. 3478, introduced in December 1992 by Representative James Bailey, sought to prohibit construction of transmission lines near schools. Specifically, the bill would have prohibited the construction either above or below ground of electrical light and power wires, transmission lines, or systems capable of transmitting more than 50 kV of electricity within 250 yards of any kind of school. The bill died in the Medical, Military, Public and Municipal Affairs Committee on April 13, 1993.

Sources: H. 3478; South Carolina Legislative Information Systems.

A.1.10 Washington

Spokane - The Spokane Electric/Magnetic Field Task Force made recommendations specifically excluding health or safety limits, but including monitoring-type activities, in a June 29, 1992 memorandum to the mayor and city council. The task force noted:

> We do not have the scientific data on which to base such standards. If arbitrary standards were adopted, there would be the implication that compliance with those standards would insure immunity from EMF effects. Such an implication could raise a liability burden for the City if those arbitrary standards were proven later to be deficient in some manner.

There has been no activity on EMF since that report.

Source: "Electric/Magnetic Field Task Force Memorandum," June 29, 1992.

A.1.11 Wisconsin

A.B. 698, introduced in November 1991 by Representative Maxine Hough, would have imposed a three-year moratorium on the construction of new 69 kV transmission lines and would have required the Wisconsin Radiation Protection Council to study EMF health effects. The bill was referred to several committees, where it died. No other similar bills have been introduced to date.

Sources: Wisconsin Legislative Hotline; *EMF Health & Safety Digest*, November-December 1992, p. 12.

A.2 INTERNATIONAL ACTIVITY

A.2.1 Canada

Winnipeg, Manitoba has requested an epidemiologic study of the area to determine if exposure to transmission lines has increased the risk of cancer for residents. The study should be completed by December.

Source: *EMF Health & Safety Digest*, September 1992, p. 8.

A.2.2 Denmark

In response to studies, Minister of Health Ester Larsen is evaluating the need to establish siting rules with respect to the location of transmission lines near residences. The opposition party has asked for a moratorium on transmission line construction and the development of EMF limits for VDTs and power lines.

Source: *EMF Health & Safety Digest*, November-December 1992, p. 5.

A.2.3 Hong Kong

A legislator and local government head has called for government action on possible health effects from transmission lines. His district, referred to as the New Territories, is reported to have an unusually high number of power lines, including two 400 kV transmission lines. Secretary for Health and Welfare, Elizabeth Wong, remains skeptical about the existing scientific evidence. There is also local opposition to the 400 kV Black Point transmission line and substation project proposed by China Light & Power Company, Ltd (CLP). The Environmental Pollution Advisory Committee (EPCOM) has asked CLP for further information on EMF health effects.

Source: *EMF Health & Safety Digest*, January 1993, p. 5.

A.2.4 Netherlands

A new report finds insufficient evidence to justify regulatory action. It does, however, recognize that extremely high occupationalexposures can result in acute health effects and recommends that the INIRC/IRPA guidelines be used to set exposure limits.

Source: *EMF Health & Safety Digest*, September 1992, p. 9.

APPENDIX B

U.K. NATIONAL RADIOLOGICAL PROTECTION BOARD

DRAFT STANDARD

Restrictions on Human Exposure to Static and Time Varying Electromagnetic Fields and Radiation

Scope

1 The Board has responsibility for providing advice on appropriate restrictions on the exposure of people to electromagnetic fields and radiation. These include static, power frequency (50 Hz) and other extremely low frequency (ELF) electric and magnetic fields, and radiofrequency (RF) fields and radiation. Previous guidance limiting exposure to time varying electric and magnetic fields was issued in 1989[1].

2 These revised recommendations are based on an assessment of the possible effects on human health derived from biological information[2-4], from dosimetric data[5,6] and from studies of exposed human populations[7,8]. They apply equally to workers and to members of the public but not to people who are exposed to electromagnetic fields and radiation for medical diagnostic or therapeutic purposes; guidance for the protection of patients and volunteers during clinical magnetic resonance diagnostic procedures has been issued separately[9]. These recommendations are intended to provide a framework for a system of restrictions on human exposure to these fields and radiations[10].

Principles

3 A large number of studies of human populations exposed to electromagnetic fields and radiation have been carried out. They have examined general health, birth outcome and cancer incidence. These epidemiological studies have been reviewed elsewhere[7]. In addition, an Advisory Group set up by the Board has examined in detail the evidence for an association between the incidence of childhood and adult cancers and exposure to electromagnetic fields[8].

4 It can be concluded from these reviews that there is no clear evidence of adverse health effects at the levels of electromagnetic fields to which people are normally exposed. In particular, the epidemiological data do not provide a basis for restricting human exposure to electromagnetic fields and radiation; the revised guidance is based on available biological data describing thresholds for well-established direct and indirect effects of acute exposure.

5 Direct effects are those resulting from the interaction of electromagnetic fields or radiation with the human body, whereas indirect effects are those resulting from an interaction between electromagnetic fields or radiation, an external object such as a vehicle or other metallic structure, and the human body.

Direct effects

6 The adverse consequences of direct effects of exposure are avoided by complying with appropriate basic restrictions derived from a consideration of biological responses.

7 It is not possible to recommend basic restrictions to avoid the direct effects of human exposure to static electric fields; guidance is given for the avoidance of the

annoying effects of direct perception of the surface electric charge and for indirect effects such as electric shock.

8 The restrictions on acute exposure to static magnetic fields are based on avoiding acute responses such as vertigo or nausea and adverse health effects resulting from cardiac arrhythmia and impaired mental function. In view of the relative lack of information from studies of exposed populations regarding possible long-term effects of high fields the Board considers it advisable to restrict long-term (time-averaged) exposure to levels of one-tenth of that intended to prevent acute responses.

9 The restrictions on exposure to ELF electric and magnetic fields are intended to avoid the effects of induced electric currents on functions of the central nervous system such as the control of movement and posture, memory, reasoning and visual processing. Exposure to much higher electric or magnetic fields has been reported to result in headaches and nerve and muscle stimulation.

10 Heating is a major consequence of exposure to RF (including microwave) radiations. Restrictions on exposure are intended to prevent adverse responses to increased heat load and elevated body temperature. These responses include increased cardiac output associated with elevated skin blood flow and sweating. Increased body temperature may result in decreased mental function and other physiological changes. At very high power absorption, such exposures may eventually result in headaches, nausea, dizziness and, eventually, circulatory collapse and loss of thermoregulatory control, and in extreme cases can be fatal. The advised restriction of the specific energy absorption rate (SAR) averaged over the whole body incorporates a sufficient margin of safety so that it is not necessary to account for additional environmental factors and work loads.

11 For those exposures in which the distribution of absorbed power within the body is highly non-uniform, exposure may be limited primarily by restrictions placed on localised heating. Restrictions on exposure are intended to prevent adverse effects of elevated local tissue temperatures. It is considered that tissues of the trunk and limbs are less sensitive to elevated temperature than are tissues of the head. In particular, heating of the eye can eventually result in lens opacities, and localised heating of brain tissue can induce inappropriate physiological responses.

12 Heat has been shown to be teratogenic in various animal species, including primates, and has been associated with central nervous system and facial defects in children whose mothers experienced moderate to severe hyperthermia, especially during the first trimester of pregnancy. Restrictions on localised SAR within the embryo and fetus are intended to prevent such adverse developmental outcomes. It is considered, however, that compliance with the advised restrictions on whole body and localised SAR in the mother will afford sufficient protection.

13 As frequency increases, the depth of penetration in the body decreases and the deposition of energy becomes more superficial. For frequencies greater than about 10 GHz the absorption of microwave energy becomes confined to increasingly superficial layers of the skin and to the cornea. It then becomes more appropriate to use power flux density as the quantity in which the basic restriction on exposure is expressed rather than SAR averaged over a broad expanse of a thin layer of skin.

14 Pulsed RF (including microwave) radiation can interact with tissue to produce effects which are different from those elicited by continuous wave (CW) radiation. Some of these responses seem to be well established, such as the microwave-induced auditory response which probably results from very rapid thermoelastic expansion of the brain creating a

RF burns may be determined by the measurement of contact current. Such effects may be avoided by limiting the external electric field or by other engineering or administrative controls.

16 Pacemakers or other electrically or magnetically sensitive prosthetic devices may be affected by electric and magnetic field strengths lower than those that comply with the basic restrictions, but these effects are not considered explicitly[10]. Advice on their use should be obtained from the manufacturers or those responsible for implanting such devices.

Basic restrictions

17 Restrictions on the effects of exposure to time varying electric and magnetic fields and electromagnetic radiations are based on biological considerations and are termed 'basic restrictions'. Depending on frequency, the physical quantities used to specify the basic restrictions are: current density (unit ampere per square metre, A m^{-2}), specific energy absorption rate (SAR) (unit watt per kilogram, W kg^{-1}) and, for pulsed radiation, specific energy absorption (SA) (unit joule per kilogram, J kg^{-1}) and power flux density (unit watt per square metre, W m^{-2}). These dosimetric quantities cannot be obtained directly by means of a measuring instrument, except for power flux density which can be related to measurement of electric and magnetic field strengths. The basic restriction for static magnetic fields is given in terms of magnetic flux density (unit tesla, T) which can be measured directly.

Investigation levels

18 Investigation levels are values of electric field strength, magnetic field strength, magnetic flux density, power flux density, and contact current provided for the purpose of comparison with values of measured field quantities for investigating whether compliance with basic restrictions is achieved. If the measured values are greater than the relevant investigation levels, it does not necessarily follow that the basic restrictions are exceeded.

19 For electric fields, electric field strength investigation levels may be used to indicate whether there is a need to take appropriate action to prevent shock and/or RF burn. It is emphasised that:

Investigation levels are not limits on exposure.

20 The investigation levels for electric and magnetic fields have been chosen to provide values of electric and magnetic field strengths (and power flux density) set close to calculated values based on relevant basic restrictions on exposure using conservative but nevertheless realistic assumptions of exposure.

21 If the field to which a person is exposed exceeds the relevant investigation level then it is necessary to investigate compliance with the basic restriction. Factors that might be considered in such an assessment include, for example, the efficiency of the coupling of the person to the field, the spatial distribution of the field across the volume of space occupied by the person, and the duration of exposure.

22 If the magnitude of the measured quantity does not exceed the relevant investigation level then the basic restriction will not be exceeded. However, action may be required even at values of electric field strength less than the investigation level to prevent shock and/or RF burn.

Electric field investigation levels

23 For exposure to static electric fields and for time varying fields of frequency less than 24 Hz, the electric field investigation level is based on avoiding the annoying effects of surface charge on an exposed person.

24 At the power frequency of 50 Hz the electric field investigation level is chosen to prevent annoyance associated with surface charge effects on an exposed person. For all other frequencies between 10 Hz and 100 kHz, the electric field investigation levels reflect the frequency dependence of nerve tissue responses to induced electric current. For frequencies greater than 100 kHz, the electric field investigation levels are set at or below values calculated from the relevant basic restrictions on whole body or localised SAR.

Magnetic field investigation levels

25 For frequencies less than about 1 MHz, magnetic field investigation levels are set below values of magnetic field strength (and magnetic flux density) calculated from the relevant basic restriction on induced current density. At higher frequencies, they correspond to electric field investigation levels assuming plane wave exposure conditions.

Contact current investigation levels

26 These are values of current flowing from an object to a person in contact with it, below which shock and/or RF burn will not occur.

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RESTRICTIONS ON HUMAN EXPOSURE TO STATIC AND TIME VARYING ELECTROMAGNETIC FIELDS AND RADIATION

The Scientific Basis and Recommendations for the Practical Application of the Board's Statement

ABSTRACT

The Board has revised its advice, previously issued as NRPB-GS11, on restrictions on human exposure to electromagnetic fields and radiation. The revised recommendations are based on an assessment of the possible effects on human health derived from biological information, from dosimetric considerations of the interaction of electromagnetic fields with people and from studies of exposed populations, and are intended to provide the rationale and conceptual framework for a system of restrictions on human exposure to these fields and radiations; it is intended to develop additional guidance for specific exposure situations in the workplace. The recommendations are designed to prevent acute, direct effects of exposure such as vertigo and nausea caused by exposure to static magnetic fields, the effects of induced, low frequency electric current on the functions of the central nervous system, and adverse responses to increased heat load and elevated tissue temperature resulting from exposure to radiofrequency and microwave fields and radiation. In addition, guidance is given for the avoidance of the annoying effects of the direct perception of surface electric charge, and for the avoidance of indirect effects such as repeated micro-shocks (spark discharges), electric shock and radiofrequency burn. The recommendations apply equally to workers and to members of the public but not to people who are exposed to electromagnetic fields for medical diagnostic or therapeutic purposes.

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RESTRICTIONS ON EXPOSURE TO STATIC AND TIME-VARYING ELECTROMAGNETIC FIELDS AND RADIATION

A SUMMARY OF THE BOARD'S GUIDANCE

1 Introduction

1.1 Basic restrictions

1.1.1 Direct effects

Direct effects are those resulting from the interaction of the electromagnetic field or radiation with the human body. The adverse consequences of exposure are avoided by complying with appropriate basic restrictions derived from a consideration of biological responses.

Static electric fields

For most people, the annoying perception of surface electric charge will not occur during exposure to static electric field strengths of less than 25 kV m^{-1}. Electric shock from low impedance sources will be prevented by following established electrical safety procedures relevant to such equipment.

Static magnetic fields

Restrictions on acute exposure to less than 2 T will avoid acute responses such as vertigo or nausea and adverse health effects resulting from cardiac arrhythmia and impaired mental function. In view of the relative lack of information regarding possible long-term effects of these fields, the time-weighted average exposure over 24 hours should be restricted to less than 200 mT. These levels apply also to time-varying fields of frequencies less than 1 Hz. Pacemakers or other electrically or magnetically sensitive prosthetic devices may be affected by fields as low as 0.5 mT.

ELF and RF electric and magnetic fields of frequencies less than 100 kHz

Restrictions on exposure of people to ELF and RF electric and magnetic fields of frequencies less than 100 kHz are based on responses to induced current density.

Surface charge

Stress due to the perception and annoyance of surface charge effects should be avoided. Such effects will not occur at field levels below the investigation levels in table 3.

Induced current density

It is recommended that induced current density in the head, neck and trunk should not exceed 10 mA m^{-2} at frequencies between 10 Hz and 1 kHz to avoid effects on central nervous system functions such as the control of movement and posture, memory, reasoning and visual processes. The frequency dependence of appropriate current densities at below 10 Hz and above 1 kHz is set out in table 1.

RF and microwave radiation of frequencies greater than 100 kHz

Restrictions on acute exposure to RF radiation of frequencies greater than 100 kHz are based on avoiding adverse effects resulting from whole body and partial body heating and on avoiding possible adverse effects resulting from pulsed radiation

It is recommended that the whole body average SAR is limited to 0.4 W kg^{-1} averaged over any 15 minute period. This should incorporate a sufficient margin of safety such that it should not be necessary to account for additional environmental factors and work loads.

It is recommended, that in order to avoid excessive localised temperatures, the SAR should not exceed 10 W kg^{-1} in any 10 g of the head and fetus, and in any 100 g of any other part of the body excluding the extremities. For whole body plane wave exposure compliance is ensured by the restriction of 10 W kg^{-1} in any 100 g of the neck and trunk. The SAR in any 100 g of a limb should not exceed 20 W kg^{-1}. All of the localised SAR restrictions should be averaged over any 6 minute period. At 10 GHz, absorption is confined to the skin and the cornea: power flux density should not exceed 100 W m^{-2}; the appropriate averaging time is 6 minutes. For frequencies greater than 20 GHz, absorption and direct heating become restricted to the superficial layers of the skin; the appropriate averaging time is 10 seconds.

Pulsed microwave and RF radiations can interact with tissue to produce effects which are different from those elicited by continuous wave radiation. Some of these responses, such as microwave hearing seem well-established and probably result from very rapid thermoelastic expansion of the brain creating a sound wave in the head. Conditions under which the auditory effect can be invoked in people with normal hearing should be avoided. At 2.45 GHz, this will be avoided if, in any 30 μs interval, the specific energy absorption in the head is less than 10 mJ kg^{-1}, corresponding to an incident energy density of 280 mJ m^{-2}.

1.1.2 Indirect effects

Indirect effects are those resulting from an interaction between electromagnetic fields or radiation, an external object such as a vehicle or other metallic structure, and a human body. The adverse consequences of such effects may be avoided by engineering or administrative controls or by limiting the external field or the contact current.

Static electric fields

Stress due to perception of repeated spark discharges should be avoided.

Static magnetic fields

Various potential hazards may arise from the exposure of people with ferromagnetic implants, from the magnetically-induced movement of external ferromagnetic materials by magnetic fields below the investigation levels. In addition, pacemakers or other electrically or magnetically sensitive prosthetic devices may be affected by electric and magnetic field strengths lower than these values.

At fields of magnetic flux density of more than 3 mT precautions should be taken to prevent the hazards from the movement of ferromagnetic objects.

Time-varying electric and magnetic fields

Shock and RF burn resulting from contact with objects in the field should be avoided.

The likelihood of such effects occurring can be assessed by comparing measured values of contact current with those investigation levels set out in table 6.

1.2 Investigation levels

Electric field investigation levels

Static fields

For static fields, the investigation level is set at 25 kV m^{-1} and is based on avoiding the effects of electric charge on the surface of the body.

Time-varying fields of frequency less than 100 kHz

At 50 Hz, the electric field investigation level is set at 12 kV m^{-1} and is based on avoiding effects of electric charge on the surface of the body. This value is below the value of electric field strength calculated from the basic restriction of 10 mA m^{-2}, as illustrated in figure 1. At frequencies below 50 Hz, the electric fields required to induce a current density of 10 mA m^{-2} increase progressively as frequency decreases; a investigation level of 25 kV m^{-1} is advised below 24 Hz based on the effects of electric charge on the surface of the body and as a cautionary measure against the possibility of electric shock. The investigation levels at other frequencies up to 100 kHz follow the frequency dependence of calculated fields based on the basic restriction on current density.

Pacemaker interference is unlikely to occur if wearers are exposed to time-varying electric fields of less than 2 kV m^{-1} and magnetic flux densities of less than 20 μT.

Fields of frequencies greater than 100 kHz

The investigation levels are set at or below values of electric field strength calculated from the basic restrictions on SAR and are illustrated in figure 1. The values are particularly frequency dependent over the range of frequencies where whole body resonance phenomena occur. Here, the investigation levels are set by consideration of the interaction of small children with the field. Where the exposure is limited to adults a relaxation in the investigation level is appropriate as indicated in the notes to table 5.

Magnetic field investigation levels

The investigation levels are set at values of magnetic field strength and magnetic flux density calculated from the basic restrictions for frequencies up to about 1 MHz, figure 2. At higher frequencies they are calculated using the relevant electric field investigation level assuming plane wave conditions.

Contact current investigation levels

The investigation levels are set at values of current below those which will result in adverse effects of electric shock, discomfort and burn. Where the exposure is limited to adults, a relaxation in the investigation level is appropriate as indicated in the notes to table 6.

2 Summary of basic restrictions and investigation levels

2.1 Basic restrictions

Basic restrictions on exposure to electric and magnetic fields in the frequency range 0 to 100 kHz are presented in table 1, and those for electromagnetic radiation in the frequency range 100 kHz to 300 GHz in table 2.

2.2 Investigation levels

Investigation levels for electric fields for the frequency range 0 to 12 MHz are set out in table 3 and are illustrated in figure 1.

Investigation levels for magnetic fields for the frequency range 0 to 12 MHz are set out in table 4 and are illustrated in figure 2.

Investigation levels for electric and magnetic fields for the frequency range 12 MHz to 300 GHz are set out in table 5 and are illustrated in figure 1 (electric field strengths), figure 2 (magnetic flux densities) and figure 3 (power flux densities).

Investigation levels for contact currents are set out in table 6 and are illustrated in figure 4.

2.3 Simultaneous exposure to fields of different frequencies

When simultaneous exposure to fields of different frequencies occurs, the possibility should be examined whether these exposures will be additive in their effects. For the purpose of assessing an effective investigation level, simultaneous exposures to fields that may result in additive thermal or additive electrical stimulation effects on the body should be combined, similarly exposures to fields that do not produce such additive effects should not be combined. In the range of frequencies 100 kHz to 12 MHz the basic restrictions address both thermal and electrical effects and exposures in this frequency range should be examined for additivity with exposures in the range of frequencies less than 100 kHz and above 12 MHz.

The exposure can be considered to be less than the effective investigation level if

$$\sum_{0\ Hz}^{12\ MHz} R_f \leq 1 \qquad \textit{(Field values apply)}$$

and

$$\sum_{100\ kHz}^{300\ GHz} R_f \leq 1 \qquad \textit{(Power flux density values apply)}$$

where R_f is the ratio of the measured value to the investigation level at the frequency f.

Table 1: Basic restrictions on exposure to electric and magnetic fields in the frequency range 0 to 100 kHz

Frequency range	Basic restriction	Comments
0 - 1 Hz	200 mT 2 T 5 T 100 mA m^{-2}	Averaged over 24 h Maximum value Maximum value, limbs only
1 - 10 Hz	100/f mA m^{-2}	
10 Hz - 1 kHz	10 mA m^{-2}	
1 kHz - 100 kHz	f/100 mA m^{-2}	

Notes to Table 1

(1) All basic restrictions for time varying fields are expressed as root mean square (rms) values.

(2) f in Hz.

(3) Unless otherwise specified, the values apply to the head, neck and trunk.

(4) The majority of cardiac pacemakers are likely to be unaffected by exposure to static magnetic fields of less than 0.5 mT. Pacemaker interference is unlikely to occur for time-varying electric fields of less than 2 kV m^{-1} and time-varying magnetic fields of less than 20 μT.

(5) In static magnetic fields where the magnetic flux density exceeds 3 mT precautions should be taken to prevent the hazards from the movement of ferromagnetic objects.

Table 2. Basic restrictions on exposure to electromagnetic radiation in the frequency range 100 kHz to 300 GHz

Frequency range	Basic restriction	Comments
100 kHz - 10 MHz	0.4 W kg^{-1} *	SAR averaged over the body
	10 W kg^{-1} (10 g) #	SAR in the head and fetus$^{\Phi}$
	10 W kg^{-1} (100 g) #	SAR in the neck and trunk
	20 W kg^{-1} (100 g) #	SAR in the limbs
	f(Hz)/100 mA m^{-2}	current density in the head, neck and trunk
10 MHz - 10 GHz	0.4 W kg^{-1} *	SAR averaged over the body
	10 W kg^{-1} (10 g) #	SAR in the head and fetus$^{\Phi}$
	10 W kg^{-1} (100 g) #	SAR in the neck and trunk
	20 W kg^{-1} (100 g) #	SAR in the limbs
10 GHz_{5} - 300 GHz	100 W m^{-2} $	power flux density on any part of the body

Notes to Table 2

(1) Averaged over the masses indicated in brackets.

(2) * Averaged over any 15 minute period.

(3) # Averaged over any 6 minute period.

(4) $ For frequencies between 10 GHz and 20 GHz averaged over 6 $(10/f)^5$ minutes (f in GHz). For frequencies greater than 20 GHz averaged over any 10 second period.

(5) For exposure to pulsed RF/microwave radiation, conditions under which the auditory effect can be invoked in people with normal hearing should be avoided. At 2.45 GHz, this will be achieved by limiting the specific absorbed energy in the head to 10 mJ kg^{-1} in any 30 μs interval of a pulse.

(6) Φ It is considered that compliance with the advised restrictions on whole body and localised SAR in the mother will protect embryo and fetal development.

Table 3: Investigation levels for electric fields in the frequency range 0 to 12 MHz

Frequency range	Electric field strength
	V m^{-1}
< 24 Hz	25000
24 Hz - 600 Hz	600/f (kHz)
600 Hz - 600 kHz	1000
600 kHz - 12 MHz	600/f (MHz)

Notes to Table 3

(1) All investigation levels are expressed as root mean square (rms) values.

(2) f in units as indicated in brackets.

(3) For the frequency range up to 100 Hz, exposure of a person to an electric field of field strength of a few kV m^{-1} could result in microshocks if the person exposed comes into contact with a grounded conducting object. Such effects can be avoided by engineering controls or other measures.

(4) Where ungrounded conducting objects are present in an electric field these will result in the flow of current to a person coming into contact with them. For a sufficiently large ungrounded conducting object, such as a large vehicle, shock or burn may result from such a contact at levels of electric field strength below the investigation level. The likelihood of such effects occurring can be established by comparing measured contact currents with those set out in table 6.

(5) Interference with the normal operation of electronic devices can arise at levels below those given in the table. In some circumstances localised heating of metallic implants may arise. Advice on acceptable electric and magnetic field levels for people with metallic implants or medical electronic devices such as pacemakers should be obtained from the manufacturers and those responsible for implanting such devices.

(6) The investigation levels set out in this table are illustrated in figure 1.

Table 4: Investigation levels for magnetic fields in the frequency range 0 to 12 MHz

Frequency range	Magnetic field strength	Magnetic flux density
	A m^{-1}	μT
< 0.4 Hz	1.6×10^5	2×10^5
0.4 Hz - 1 kHz	64000/f (Hz)	80000/f (Hz)
1 kHz - 535 kHz	64	80
535 kHz - 12 MHz	$18/f^2$ (MHz)	$23/f^2$ (MHz)

Notes to Table 4.

(1) All investigation levels are expressed as root mean square (rms) values.

(2) f in units as indicated in brackets.

(3) Interference with the normal operation of electronic devices can arise at levels below those given in the table. In some circumstances localised heating of metallic implants may arise. Advice on acceptable electric and magnetic field levels for people with metallic implants or medical electronic devices such as pacemakers should be obtained from the manufacturers and those responsible for implanting such devices.

(4) The investigation levels set out in this table are illustrated in figure 2.

Table 5: Investigation levels for electric and magnetic fields and electromagnetic radiation in the frequency range 12 MHz to 300 GHz

Frequency range	Magnetic field strength	Magnetic flux density	Electric field strength	Power flux density
	A m^{-1}	μT	V m^{-1}	W m^{-2}
12 MHz - 200 MHz	0.13	0.16	50	6.6
200 MHz - 400 MHz	0.66 f	0.79 f	250 f	165 f^2
400 MHz - 800 MHz	0.26	0.31	100	26
800 MHz - 1.55 GHz	0.33 f	0.4 f	125 f	41 f^2
1.55 GHz - 300 GHz	0.52	0.62	194	100

Notes to Table 5.

(1) All field investigation levels are expressed as root mean square (rms) values.

(2) f in GHz.

(3) Where it can be established that there is no possibility of small children being exposed, the following electric field strength and power flux density investigation levels may be used over the range of frequencies indicated.

Frequency range	Electric field strength	Power flux density
	V m^{-1}	W m^{-2}
10 MHz - 60 MHz	60	10
60 MHz - 137 MHz	10^3 f	2.7 10^3 f^2
137 MHz - 1.1 GHz	137	50
1.1 GHz - 1.55 GHz	125 f	41 f^2

(4) For exposure to pulsed RF/microwave radiation, conditions under which the auditory effect can be invoked in people with normal hearing should be avoided. At 2.45 GHz, this will be achieved by limiting the specific absorbed energy in the head to 10 mJ kg^{-1} in any 30 μs interval. This is equivalent to an energy density of 280 mJ m^{-2}.

(5) Where ungrounded conducting objects are present in an electric field these will result in the flow of current to a person coming into contact with them. For a sufficiently large ungrounded conducting object, such as a large vehicle, shock or burn may result from such a contact at levels of electric field strength below the investigation level. The likelihood of such effects occurring can be established by comparing measured contact currents with those set out in table 6.

(6) Interference with the normal operation of electronic devices can arise at levels below those given in the table. In some circumstances localised heating of metallic implants may arise. Advice on acceptable electric and magnetic field levels for people with metallic implants or medical electronic devices such as pacemakers should be obtained from the manufacturers and those responsible for implanting such devices.

(7) The investigation levels set out in this table are illustrated in figures 1 to 3.

Table 6: Investigation levels for contact currents

Frequency range	Current (mA)
0.1 Hz - 370 Hz	0.5
370 Hz - 70 kHz	$f^{0.7}$
70 kHz - 100 MHz	20

Notes to Table 6.

(1) f in kHz.

(2) Where it can be established that there is no possibility of children being exposed, the following contact current investigation levels may be used

Frequency range	Current (mA)
0.1 Hz - 1 kHz	1.0
1 kHz - 130 kHz	$f^{0.7}$
130 kHz - 100 MHz	30

(3) The investigation levels set out in this table are illustrated in figure 4.

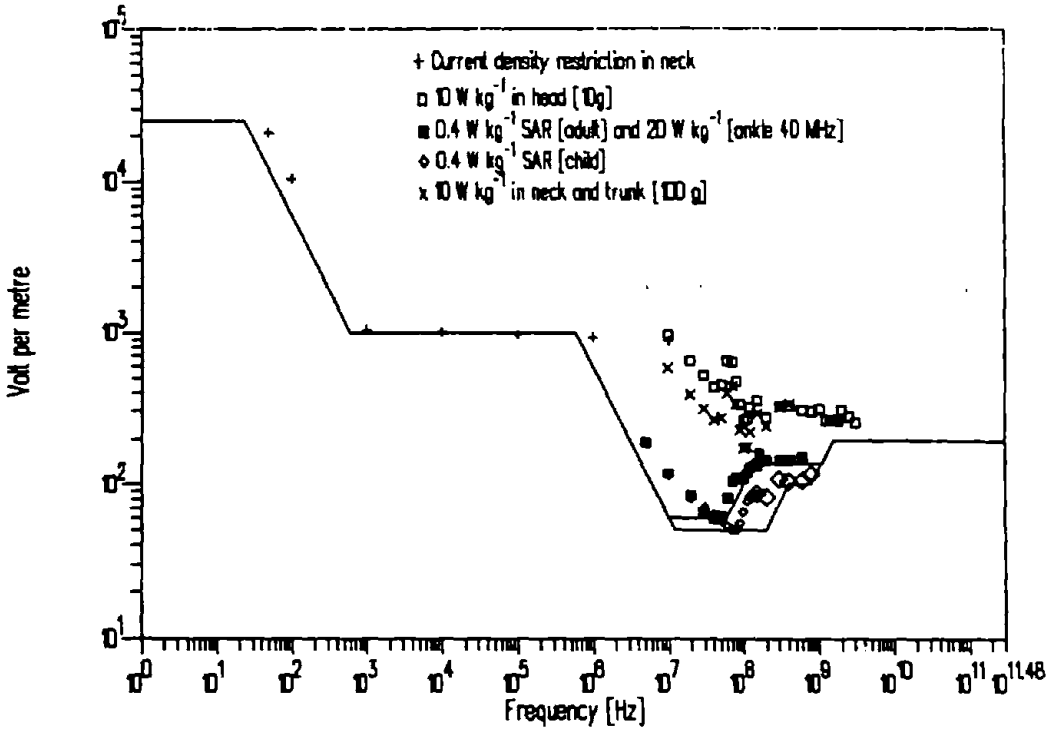

Figure 1 Proposed investigation levels for electric fields, 0-300 GHz

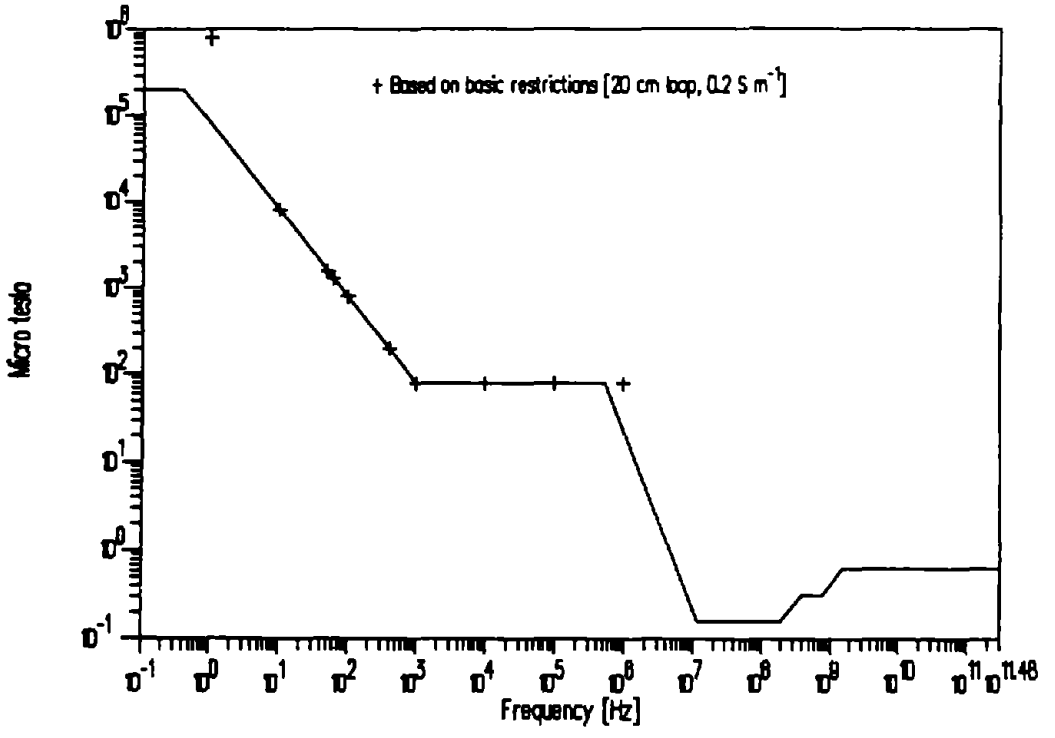

Figure 2 Proposed investigation levels for magnetic fields, 0-300 GHz

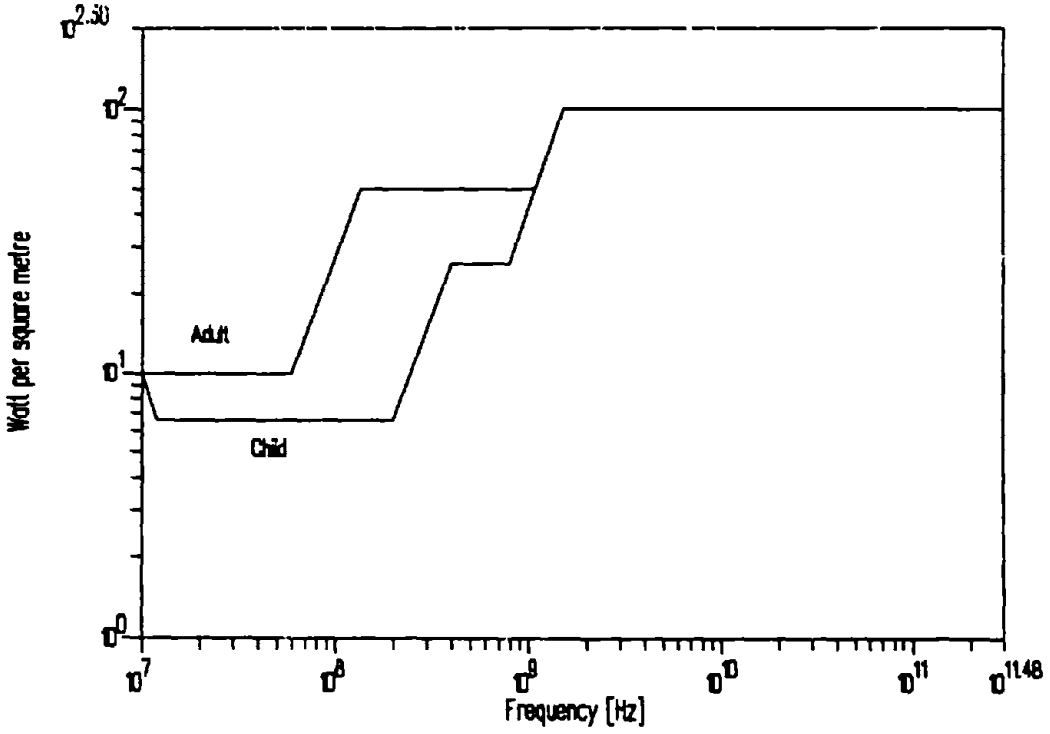

Figure 3 Proposed investigation levels for electromagnetic radiation, 10 MHz to 300 GHz

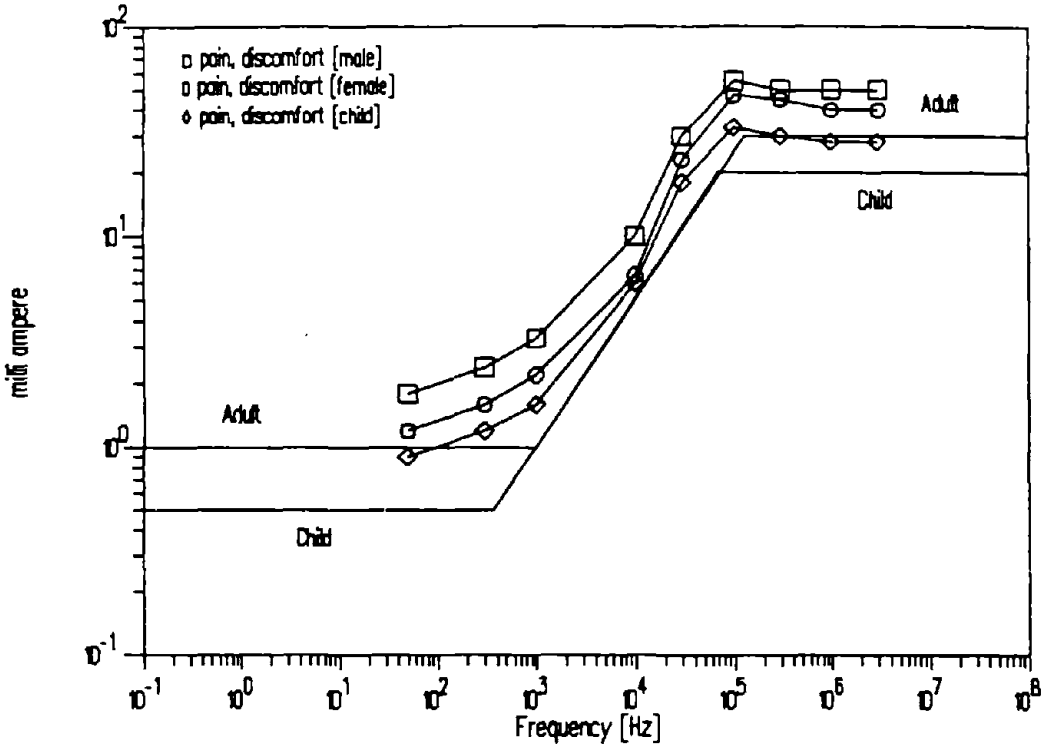

Figure 4 Proposed investigation levels for contact current

GLOSSARY

AC: The abbreviation for alternating current. An AC current, or an AC field, changes strength and direction in a rhythmically repeating cycle.

AMP: The units used to measure current. Abbreviated A.

CHARGE: The electrical property of matter which is responsible for creating electric fields. There are two kinds of charge labeled positive and negative. Electric fields begin on positive charges and end on negative charges. Like charges repel each other. Unlike charges attract each other.

CONTACT CURRENT: The current that flows in the body when a person touches a conducting object (e.g. a metal refrigerator) that has a voltage induced on it because it is in an AC field.

CURRENT: An organized flow of electric charge. Current in a power line is analogous to the rate of fluid flow in a pipeline. All currents produce magnetic fields. Current is measured in amps.

DC: The abbreviation for direct current. A DC current, or a DC field, is steady and does not change strength or direction over time.

DISTRIBUTION LINE: A power line used to distribute power in a local region. Distribution lines typically operate at high voltages of between 5 and 35 kV, much lower than the voltages of transmission lines. However, the currents on some distribution lines can be comparable to transmission line currents.

DOSE: The amount of exposure of a kind that produces effects. In the case of chemical pollutants, dose is usually the amount of chemical that gets into the body. In the case of fields, it is often unclear what aspect of the field, if any, is involved in producing effects, Hence, it is not clear how to measure dose form electromagnetic fields.

ELECTRIC FIELD: A representation of the forces that fixed electric charges exert on other charges at a distance. The electric field has a strength and direction at all points in space which is often represented diagrammatically by field lines. Electric field lines begin on positive charges and end on negative charges.

ELECTROMAGNETIC FIELD: A field made up of a combination of electric and magnetic fields.

EPIDEMIOLOGY: The study of the distribution and factors that cause health related conditions and events in groups of people, often making use of statistical data on the incidence of disease or death.

GAUSS: A common unit of measure for magnetic fields. Abbreviated G. There are 10,000 gauss in one tesla.

HERTZ: A cycle per second. A unit used to measure frequency. AC power has a frequency of 60 Hz. In most of Europe, AC power has a frequency of 50 Hz. Radio waves have frequencies of many thousands or millions of hertz. Abbreviated Hz.

Hz: The abbreviation for hertz. A cycle per second.

IMPEDANCE: The electrical property of a conductor or circuit which resists the flow of an electric current. Impedance is similar to resistance (see below) but may involve a change in the current's phase.

kV: The abbreviation for kilovolt. A thousand volts.

kV/m: The abbreviation for kilovolt per meter. A thousand volts per meter. The strength of an electric field is measured in volts per meter.

MAGNETIC FIELD: A representation of the forces that a moving charge exerts on other moving charges because they are moving. The magnetic field has a strength and direction at all points in space which is often represented diagrammatically by field lines. Magnetic field lines form closed continuous loops around currents. All currents produce magnetic fields.

MICROWAVES: Electromagnetic waves which have a frequency of between roughly 1 billion and 300 billion Hz (a wave length of between roughly 30 centimeters and 1 millimeter). Microwaves have a frequency higher than normal radio waves but lower than heat (infrared) and light. In contrast to x-rays, microwaves are a form of non-ionizing radiation (see x-rays below). Strong microwaves can produce biological damage by heating tissue. 60 Hz fields cannot do this.

PHASE: The timing with which an alternating current, voltage or field is changing strength and direction. See "three phase power" below.

PRUDENT AVOIDANCE: The exercise of sound judgement or prudence to avoid a potential risk. In this context, the avoidance of potential risk from human exposure to electric and magnetic fields.

RADIATION: Any of a variety of forms of energy propagated through space. Radiation may involve either particles (for example alpha-rays or beta-rays) or waves (for example, x-rays, light, microwaves or radio waves). Ionizing radiation such as x-rays carries enough energy to break chemical and electrical bonds. Non-ionizing radiation like microwaves does not. Most of the energy in the 60 Hz fields associated with power lines, wiring and appliances does not propagate away from them through space. Hence, it is best not to refer to these fields as radiation.

RESISTANCE: The electrical property of a conductor that resists the flow of an electric current without changing its phase.

STRAY VOLTAGE: A condition occurring on dairy farms in which cows are subjected to small but perceptible electrical shocks which can lead to changes in animal behavior and reductions in milk production. The problem can usually be fixed with proper grounding of equipment. The problem is not a direct effect of exposing the cows to fields and can occur without large power lines being involved.

THREE PHASE POWER: Ordinary 60 Hz current involves only one "hot" wire or phase. Most high voltage transmission lines involve three "hot" wires or phases. The voltage and current in these three wires do not all reach their peak values at the same time. First one, then the next, then the third, reaches maximum, 1/180th of a second apart. The three work together as one line for transmitting electric energy. Three phase power is used because it is a more efficient way to transmit electric power than single phase power.

TESLA: A unit of measure for magnetic fields. Abbreviated T. There are 10,000 gauss in one tesla. A microtesla (μT) is one millionth of a tesla or .01 gauss.

TRANSMISSION LINE: A power line used to carry large quantities of electric power at high voltage, usually over long distances. Transmission lines typically operate at voltages of between 69 and 765 kV. They are usually built on steel towers or very large wooden poles.

VOLTAGE: A measure of electric potential, the amount of work that must be done to move a charge from ground to a location in space such as a power line conductor. Voltage in a power line is analogous to pressure in a pipe line. Voltage is measured in volts. Abbreviated V.

V/m: Abbreviation for a volt per meter. The strength of an electric field is measured in volts per meter, or sometimes in thousands of volts per meter (kV/m).

WHOLE DAY LIMIT: Continuous occupational exposure during the working day.

X-RAYS: A form of electromagnetic waves similar to light but with a shorter wavelength (higher frequency). X-rays are a form of ionizing radiation. They can damage biological systems by breaking chemical or molecular bonds. 60 Hz fields cannot do this.

*U.S. G.P.O.:1993-301-717:80331