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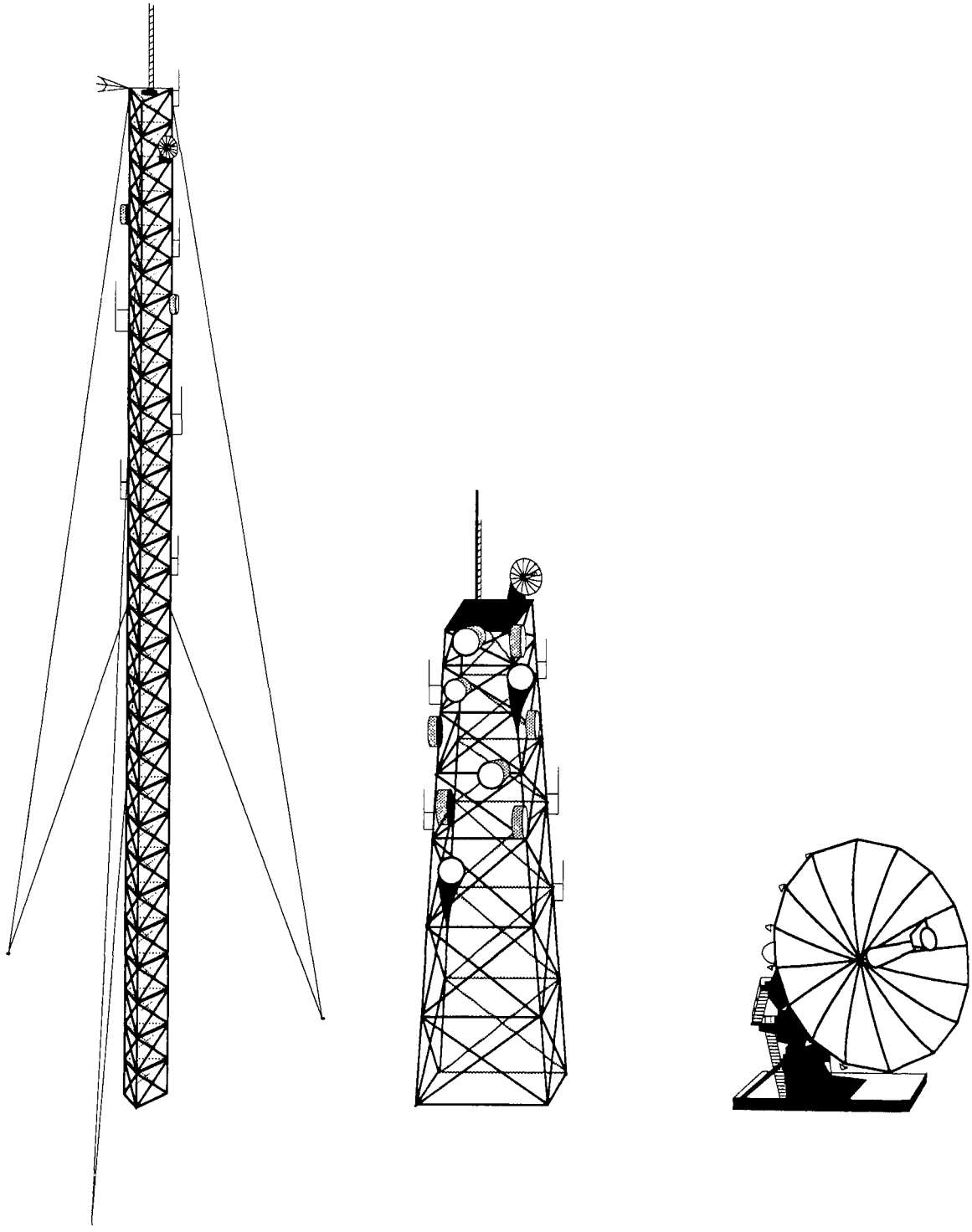
Office of Air and Radiation &
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Summary and Results of the April 26-27, 1993 Radiofrequency Radiation Conference

Volume 1: Analysis of Panel Discussions



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DISCLAIMER

Statements, recommendations, and conclusions expressed by participants of the Radiofrequency Radiation Conference (Bethesda, Maryland, April 26 and 27, 1993) and summarized in this document are their own and do not necessarily represent the views of the U.S. Environmental Protection Agency (EPA). Furthermore, mention of trade names or commercial products does not constitute endorsement or recommendation for use by EPA.

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ABSTRACT

On April 26 and 27, 1993, the U.S. Environmental Protection Agency (EPA) Office of Air and Radiation and Office of Research and Development held a conference to assess the current knowledge of biological and human health effects of radiofrequency (RF) radiation and to address the need for and potential impact of finalization of federal guidance on human exposure to RF radiation. More than 200 people attended the conference. Attendees represented the federal government, academia, the private sector, trade associations, the media, and the public. Plenary papers presented at the meeting focused on current research findings on a variety of topics, including exposure assessment, dosimetry, biological effects, epidemiology, the basis for exposure limits, and emerging health issues. Panel discussions focused on identifying key scientific information needs for and the policy implications of the development of further EPA guidance on human exposure to RF radiation. This document, Volume 1, provides a record of much of the information presented at the conference, outlines key recommendations provided to EPA by conference participants, and presents the EPA strategy for addressing RF radiation. Volume 2, under separate cover, provides the plenary papers presented by invited speakers.

Two key conclusions emerged from the conference: (1) there is sufficient information on thermal exposure/effects on which to base an RF radiation exposure standard; and (2) EPA should develop some type of RF radiation exposure guidelines. These conclusions were considered by EPA in its decision to proceed with the development of guidelines on human exposure to RF radiation and to develop a longer term strategy to address remaining issues. Part of this strategy has involved creating an inter-agency work group and requesting the National Council on Radiation Protection (NCRP) to assess several remaining issues. Information provided at the conference also was used as a basis for EPA comments to the Federal Communications Commission (FCC) 1993 proposal to adopt the RF radiation exposure guidelines developed in 1992 by the American National Standards Institute (ANSI) and the Institute for Electrical and Electronics Engineers (IEEE).

EXECUTIVE SUMMARY

This document describes some of the U.S. Environmental Protection Agency (EPA) past and current activities concerning radiofrequency (RF) radiation. This description is a distillation of the information provided to EPA during the April 26 and 27, 1993 RF Radiation Conference held in Bethesda, Maryland.

HISTORY OF RF RADIATION GUIDANCE AT EPA

The Administrator of EPA is responsible for providing "guidance for all federal agencies in the formulation of radiation standards..." (42 U.S.C. 2021(h)). Within the scope of that responsibility, EPA published a September 1984 document, *Biological Effects of Radiofrequency Radiation* (Office of Research and Development, EPA-600/8-83-026F; this report on RF radiation (RFR) is referred to hereafter as the "1984 RFR Report"). As a result of the findings of that report, EPA published a July 1986 proposal in the *Federal Register* (Vol. 51, No. 146, pp. 26318-27339) that outlined alternative recommendations for limiting the public's exposure to RF radiation. A July 1987 internal EPA report, "A Reassessment of the Biological Effects of Radiofrequency Radiation: Non-Cancer Effects," also was prepared (hereafter referred to as the "1987 Reassessment Report").

In 1990, EPA published a draft of an assessment of the literature on the carcinogenic and related biological effects of electromagnetic fields (EMF) resulting from both extremely low frequency (ELF) and RF sources. This draft, *Evaluation of the Potential Carcinogenicity of Electromagnetic Fields* (Office of Research and Development, EPA/600/6-90/005B), was reviewed by the EPA Science Advisory Board (SAB). SAB subsequently recommended that the Agency complete the RF radiation guidance effort. In response to this recommendation, the EPA Office of Radiation and Indoor Air and Office of Research and Development convened a group of scientists and other experts at a conference held on April 26 and 27, 1993 in Bethesda, Maryland, to examine the current state of knowledge about the human health effects of RF radiation.

SCOPE OF THE CONFERENCE

The goals of the RF radiation conference were to assess the current knowledge of biological and human health effects of RF radiation and to address the need for and potential impact of finalization of federal guidance on human exposure to RF radiation. As part of these goals, the Agency hoped to address the unresolved issues that arose during the development of the 1986 proposed RF guidelines, as well as to identify and address any new issues.

To help meet the goals of the conference, EPA developed six tasks for the conference speakers and panelists: (1) review the post-1982 literature on exposure assessment, dosimetry, biological effects, and health effects of RF radiation (10 kHz-100 GHz); (2) provide the basis for considering modifications to the conclusions reported in the 1984 RFR Report; (3) identify uncertainties associated with exposure assessment, dosimetry, biological effects and health effects of RF radiation; (4) introduce and discuss emerging health issues; (5) address the biological effects basis for exposure limits; and (6) address the need for EPA action to control exposure and the anticipated effects of such action on the activities of federal, state, and private agencies and organizations. To help the participants complete these tasks, EPA developed a number of questions and distributed them prior to the conference.

ORGANIZATION OF THE CONFERENCE

To help set the stage for the conference, EPA selected nine topic areas for the development of plenary papers, with each area addressing a specific aspect of potential human health effects of exposure to RF radiation. The nine presentations (one for each topic area) covered the following areas: exposure assessment; dosimetry; RF shocks and burns; human thermal responses; epidemiology; animal studies; molecular/cellular studies; ELF-modulated RF radiation; and emerging health issues.

In addition, eight panels of scientific experts were convened to discuss the scientific and policy implications of the information presented in the plenary papers and elsewhere. The plenary panel, which was convened during the full conference assembly following the plenary speakers, was entitled "Need for EPA to Finalize Federal Radiation Protection Guidelines for RF Radiation; and Possible Effects of Actions on Federal, State, and Private Agencies and Organizations." Six panels met separately to discuss the following topics: Panel 1—Exposure and Dosimetry (Exposure Assessment, Dosimetry, RF Shocks and Burns); Panel 2—Thermal Responses (Human, Animal, Thermal Modeling, Perception); Panel 3—Epidemiology; Panel 4a—Animal Studies (Behavior, Nervous System, Endocrinology, Reproduction); Panel 4b—Animal Studies (Chronic Studies, Immunology, Ocular Effects); and Panel 5—Molecular and Cellular Effects. The eighth panel, "Biological Effects Basis for Exposure Limits," convened during the full assembly. Each of the chairs of the eight panels summarized the panel discussions and conclusions to the full conference assembly.

CONFERENCE SUMMARY

Following the conference, EPA reviewed the panel summaries and the supplementary information provided by participants. Two key conclusions (shown in bold type below) were identified.

(1) **There is sufficient information on thermal exposure/effects on which to base a standard.** However, participants generally felt that more information needs to be obtained on nonthermal effects.

(2) The overwhelming consensus was that **EPA should develop some type of RF radiation exposure guidelines**, even if EPA does so on an interim basis only. The foremost reason provided for this recommendation was that, since federal exposure limits for RF radiation do not as yet exist, a number of different exposure limits currently are being used (if at all) at the local level. Nationally based EPA exposure limits thus would help ensure a more consistent level of public health protection while also significantly easing the burden on industry caused by the current patchwork of standards (e.g., a reduction in expensive litigation, an improvement in U.S. competitiveness abroad).

EPA ACTIVITIES FOLLOWING THE CONFERENCE

EPA used much of the information provided by the conference to develop comments on the Federal Communications Commission (FCC) proposed adoption of RF radiation guidelines. EPA then developed a specific RF radiation strategy that included (1) creating an inter-agency work group to help address issues associated with establishing near-term RF radiation exposure guidelines, and (2) requesting the National Council on Radiation Protection (NCRP) to assess one of the key remaining issues (i.e., the influence of modulation).

EPA Comments on the FCC Proposed Adoption of RF Radiation Exposure Guidelines

Soon after the RF radiation conference (November 1993), EPA provided comments on the FCC proposed adoption of the 1992 American National Standards Institute (ANSI)/Institute for Electrical and Electronics Engineers (IEEE) standard (58 Federal Register 19393, April 14, 1993). In those comments, EPA recommended that the 1992 ANSI/IEEE standard be used only with some modification. Some issues of concern to EPA included the criteria used to select studies on which the 1992 ANSI/IEEE standard is based, the possible need for more protective exposure limits at lower and higher frequencies, the lack of a distinction between occupational and general public exposure, the need to consider athermal effects, and the need to consider pulse- and ELF-modulated RF radiation.

Creation of an Inter-agency Work Group on RF Radiation

EPA convened an inter-agency work group in August 1994 to address the development of RF radiation exposure guidelines. This work group, which meets regularly, is composed of representatives from various federal agencies, including EPA, FCC, the Food and Drug Administration (FDA), the National Institute for Occupational Safety and Health (NIOSH), the National Telecommunications and Information Administration (NTIA), and the Occupational Safety and Health Administration (OSHA). The work group provides a forum to address health and regulatory issues pertaining to RF radiation, and provides a basis for coordination among member agencies in their approach to RF issues. EPA expects to release RF radiation exposure guidelines in 1995.

NCRP Study on Modulated RF Radiation

As part of its long-term strategy, EPA entered into a cooperative agreement with NCRP to address the issue of modulated RF radiation. NCRP intends to address the potential role of this issue in developing new RF radiation exposure limits. Factors that NCRP will consider include frequency dependence, time-averaging, modulation characteristics (e.g., wavetrain, frequency, pulse width, repetition rate), selection of an adverse effects basis, and use of uncertainty factors. The NCRP assessment of these issues may result in a recommendation that EPA include additional factors in establishing new RF radiation limits.

ORGANIZATION OF THIS DOCUMENT

This document, Volume 1, is organized as follows.

- **Section 1—Introduction** discusses the history of RF radiation guidance at EPA, the scope of the conference, and the organization of the conference.
- **Section 2—Opening Remarks**, by Margo T. Oge, provides an overview of the conference.
- **Section 3—Panel Summaries** describes the major discussion points, recommendations, and conclusions of each panel.
- **Section 4—Closing Remarks**, by Charles Susskind, frames many of the key conclusions reached by conference participants.

- **Section 5—Summary and Next Steps** presents the main findings of the conference and discusses several RF radiation-related activities that have occurred following completion of the conference.

- **Appendix A—A Reassessment of the Biological Effects of Radiofrequency Radiation: Noncancer Effects**, by Joe A. Elder, provides a focal point for much of the discussion at the conference.

- **Appendix B—Speakers and Panelists** provides information on many of the key participants of the conference.

- **Appendix C—Other Conference Attendees** lists the names and affiliations of the other participants and observers.

Volume 2, under separate cover, provides the plenary papers presented by invited speakers.

1. INTRODUCTION

Radiofrequency (RF) radiation is an integral part of modern society. Applications of RF radiation include communications, transportation, manufacturing, consumer products, defense, security, and medicine. In recent years, the number and power of RF radiation sources have increased dramatically, and their uses have diversified substantially. The result has been a general increase in the type and level of human exposure. This exposure, along with a growing body of research on the potential for RF radiation health effects, has fueled significant public, scientific, and medical concern in recent years.

This document describes some of the U.S. Environmental Protection Agency (EPA) past and current activities addressing RF radiation exposure. The focus of this description is a distillation of the information provided to EPA during the April 26 and 27, 1993 RF Radiation Conference that was held in Bethesda, Maryland. First, a brief description is provided on the history of RF radiation guidance at EPA, the scope of the conference, the organization of the conference, and the organization of this document.

HISTORY OF RF RADIATION GUIDANCE AT EPA

The Administrator of EPA is charged with the responsibility of providing "guidance for all federal agencies in the formulation of radiation standards..." (42 U.S.C. 2021(h)). Within the scope of that responsibility, EPA published a September 1984 document, *Biological Effects of Radiofrequency Radiation* (Office of Research and Development, EPA-600/8-83-026F; this report is referred to hereafter as the "1984 RFR Report"). As a result of the findings of that report, EPA published a July 1986 proposal in the *Federal Register* (Vol. 51, No. 146, pp. 26318-27339) that outlined alternative recommendations for limiting the public's exposure to RF radiation. In general, these limits (1) were based on exposures that could produce thermal effects in animals and humans; (2) were generally protective against thermally related health effects; (3) stated that "RF radiation should, for now, be treated as a non-carcinogen"; and (4) used uncertainty factors to derive proposed exposure limits.

A July 1987 internal EPA report, "A Reassessment of the Biological Effects of Radiofrequency Radiation: Non-Cancer Effects," also was prepared (hereafter referred to as the "1987 Reassessment Report"; see Appendix A). EPA research on the biological effects of RF radiation exposure stopped in 1987, and the development of RF radiation guidance stopped in 1988. Nevertheless, numerous health issues remained unresolved at that time, including the effects associated with low-frequency modulated RF fields; the role of RF radiation exposure in carcinogenesis; potential effects of low-level, long-term exposure; and biophysical mechanisms.

In 1990, EPA published an external review draft of an assessment of the literature on the carcinogenic and related biological effects of electromagnetic fields (EMF) resulting from both extremely low frequency (ELF) and RF sources. This draft, *Evaluation of the Potential Carcinogenicity of Electromagnetic Fields* (Office of Research and Development, EPA/600/6-90/005B; hereafter referred to as the "1990 EMF Report"), was reviewed by the EPA Science Advisory Board (SAB). SAB subsequently recommended that the Agency complete the RF radiation guidance effort. In response to this recommendation, the EPA Office of Radiation and Indoor Air and Office of Research and Development convened a group of scientists and other experts at a conference held on April 26 and 27, 1993 in Bethesda, Maryland, to examine the current state of knowledge about

the human health effects of RF radiation. The results of this conference would be considered in the EPA deliberations on whether to proceed with the federal guidance initiative.

SCOPE OF THE CONFERENCE

The goals of the RF radiation conference were to assess the current knowledge of biological and human health effects of RF radiation and to address the need for and potential impact of finalization of federal guidance on human exposure to RF radiation. As part of these goals, the Agency hoped to address the unresolved issues that arose during the development of the 1986 proposed RF guidelines, as well as to identify and address any new issues.

To help meet the goals of the conference, EPA developed six tasks for the conference participants (i.e., speakers and panelists):

(1) Review the post-1982 literature on exposure assessment, dosimetry, biological effects, and health effects of RF radiation (10 kHz-100 GHz);

(2) Provide the basis for considering modifications to the conclusions reported in the 1984 RFR Report;

(3) Identify uncertainties associated with exposure assessment, dosimetry, biological effects and health effects of RF radiation;

(4) Introduce and discuss emerging health issues;

(5) Address the biological effects basis for exposure limits; and

(6) Address the need for EPA action to control exposure and the anticipated effects of such action on the activities of federal, state, and private agencies and organizations.

To help the conference participants complete these tasks, EPA developed a number of questions and distributed them prior to the conference (along with other information). These questions are as follows:

- What could be the biological and health effects basis for guidelines today?
- How well understood are RF exposure hazards such as tissue heating and heat stress resulting from acute exposure?
- The 1986 "Notice of Proposed Recommendations for RF Radiation" published in the Federal Register stated that RF radiation should be treated as a non-carcinogen. Should RF radiation still be assumed to be non-carcinogenic?
- What is an appropriate safety factor(s) and how can safety factors be related to uncertainties in the data base?
- What is the relevance of extremely low frequency (ELF) research to ELF-modulated RF radiation biological and health effects?
- What approach could be used to assess the relationship between continuous wave exposure and pulsed and ELF-modulated exposure?

- What are the advantages and disadvantages in the use of dose rate (SAR) as the effective exposure parameter?

- Are there limitations and/or deficiencies in existing voluntary RF guidelines that should be addressed in any future EPA guideline?

Another set of questions were especially relevant to the need for EPA guidelines for RF radiation. These questions are:

- Is there a need for EPA guidelines? Why?

- What purpose would EPA action serve? Who would be protected? Who should be protected (that would not be protected by other standards or guidelines)?

- What might be the overall effect on the public and private sectors, and on local, state, and federal governments?

- Is there information indicating how many locations/systems may be affected by the revision of the IEEE/ANSI guideline for uncontrolled environmental exposure situations that would comply with the 1982 guidelines?

ORGANIZATION OF THE CONFERENCE

To help set the stage for the conference, EPA selected nine topic areas for the development of plenary papers, with each area addressing a specific aspect of potential human health effects of exposure to RF radiation. The nine presentations (one for each topic area) took place at the beginning of the first day and covered the following areas:

- Exposure assessment;
- Dosimetry;
- RF shocks and burns;
- Human thermal responses;
- Epidemiology;
- Animal studies;
- Molecular/cellular studies;
- ELF-modulated RF radiation; and
- Emerging health issues.

In addition, eight panels of scientific experts were convened to discuss the scientific and policy implications of the information presented in the plenary papers and elsewhere. The plenary panel, which was convened during the full conference assembly following the plenary speakers, was entitled "Need for EPA to Finalize Federal Radiation Protection Guidelines for RF Radiation; and Possible Effects of Actions on Federal, State, and Private Agencies and Organizations." Six panels then met separately at the beginning of the second day and were organized as follows:

- Panel 1–Exposure and Dosimetry (Exposure Assessment, Dosimetry, RF Shocks and Burns);

- Panel 2–Thermal Responses (Human, Animal, Thermal Modeling, Perception);

- Panel 3—Epidemiology;
- Panel 4a—Animal Studies (Behavior, Nervous System, Endocrinology, Reproduction);
- Panel 4b—Animal Studies (Chronic Studies, Immunology, Ocular Effects); and
- Panel 5—Molecular and Cellular Effects.

In the afternoon, the eighth panel, "Biological Effects Basis for Exposure Limits," convened during the full assembly. Each of the chairs of the eight panels then summarized the panel discussions and conclusions to the full conference assembly. One of the panel chairs, Dr. Charles Susskind, provided closing remarks for the conference.

Following the conference, many of the speakers and panelists provided EPA with supplementary information (e.g., lists of relevant literature, overheads used during presentations, analyses of data). Also, speakers provided papers based on their plenary talks. Appendix B lists the names and addresses of the speakers and panelists.

To develop panel summaries, EPA first developed transcripts of each panel discussion. EPA then examined the brief summaries that were presented by panel chairs at the end of the second day of the conference, and then expanded on these summaries using the panel transcripts. This latter step helped ensure that the summaries fully addressed the issues that are relevant to the EPA concerns.

ORGANIZATION OF THIS DOCUMENT

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- **Appendix A—A Reassessment of the Biological Effects of Radiofrequency Radiation: Noncancer Effects**, by Joe A. Elder, provides a focal point for much of the discussion at the conference.
- **Appendix B—Speakers and Panelists** provides information on many of the key participants of the conference.

- **Appendix C—Other Conference Attendees** lists the names and affiliations of the other participants and observers.

Volume 2, under separate cover, provides the plenary papers that were presented by speakers.

2. OPENING REMARKS

*Margo T. Oge**

We are all aware that extremely low frequency (ELF) and radiofrequency (RF) issues have become increasingly significant public issues. In that regard, I would like to focus my remarks in two areas. First, I'd like to put this conference into context. Why are we here today? Second, I'd like to challenge you with some questions that I would like to see the participants address throughout the conference.

We go back a long way with this issue. The U.S. Environmental Protection Agency (EPA) first got involved in the early 1970's. Even though we have accomplished an awful lot, we have not finalized RF radiation guidance. EPA started with this work because we were concerned with the thermal effects of RF exposure to the general public. The EPA Office of Research and Development initiated work to assess not only the thermal health effects associated with RF but also the other potential biological and health effects. They developed a report that was completed in 1984. Based on that report, the Agency proceeded to put forward guidelines.

As you probably know, EPA is responsible for recommending guidance to the president and other federal agencies on radiation issues that affect the public health. The guidance that EPA was proposing in the 1980's was not regulatory. It was to be guidance to the other federal agencies having regulatory responsibility for sources of RF radiation.

The proposal we put forward laid out four options. In the first option, the Agency would do absolutely nothing. The other three options were more prescriptive. They were basically levels of public health protection against RF thermal effects. The document was very clear that RF was not to be considered carcinogenic. We received a number of comments at that time. The Agency reviewed the comments but never really proceeded to finalize those guidelines, for a number of reasons. The most critical reason was that when we looked at priorities within the Office of Radiation and Indoor Air (ORIA) vis-à-vis completing the guidelines, we decided to put our efforts into other issues that were much more critical at that time. So we put aside the RF guidance and never completed them.

A year ago, the Science Advisory Board (SAB) gave the Agency recommendations in a risk document that deals with the potential health effects of EMF. One of the recommendations that they made was that the Agency finalize the guidance proposed in 1986. At the same time there were various Congressional hearings on RF, and there was pressure put on EPA by various Congressmen to go back and finalize the guidance. And that's why we're here today.

What we would like to do at this conference is to ask the participants and the panel members to address two issues. First, what is the current state of knowledge of RF health effects? Second, what EPA actions should there be in this area?

Looking at the health effects, we feel it is critical to figure out how well understood are the acute RF exposure hazards, such as tissue heating and heat stress. We would like to know how relevant the health effects of ELF are to RF exposure. We would like to know what safety factors EPA ought to consider if we go forward in proposing guidance to protect the public from RF

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* Director, 1991-1994, Office of Radiation and Indoor Air, U.S. Environmental Protection Agency.

exposure. We would like the participants to address the extent to which EPA should go forward and set guidelines. Why do we need EPA to play a role in this area? To what extent are existing guidelines – and there are a number of them, including the American National Standards Institute (ANSI) guidelines – appropriate to protect public health? And at this point does EPA need to go forward with another set of guidelines from the federal government? If we do go ahead and develop guidelines, what should the scope of those guidelines be? Should EPA guidelines just address the potential thermal health effects from exposure to RF, or should EPA address the potential non-thermal health effects of RF? What are the impacts of such guidelines to the public, the private sector, the state and local governments?

We clearly understand that you are not going to be able to fully answer all of these questions, but we welcome the dialogue that is going to start today and tomorrow at this conference. We are going to look at the outcome of this conference to help us make some informed decisions in this area. I'm not here today to promise you that EPA is going to go forward and finalize the guidance or not. I am going to be personally looking at the results of this conference, after which I have to compare what we could be doing in this area versus what we could be doing in other areas that ORIA deals with. As you know, under today's budget constraints we have to be very careful about how we spend our resources and what issues we are addressing. We have to address the issues that result in the biggest benefit based on the limited resources that we can set aside.

With that, I would like to wish you two very informed days here. I hope we will learn from you and you will learn from each other. I look forward to getting the results of this conference.

3. PANEL SUMMARIES

PLENARY PANEL: NEED FOR EPA TO FINALIZE FEDERAL RADIATION PROTECTION GUIDELINES FOR RF RADIATION; AND POSSIBLE EFFECTS OF ACTIONS ON FEDERAL, STATE, AND PRIVATE AGENCIES AND ORGANIZATIONS

Dr. Charles Susskind (Chair)
Dr. Robert F. Cleveland, Jr.
Dr. David N. Erwin
Ms. Janet Healer
Mr. Clifford Marks
Dr. John M. Osepchuk

INTRODUCTION

This panel was asked to consider the need for EPA to develop or endorse federal guidelines for radiofrequency (RF) radiation protection, and the possible consequences of this action. Members of the panel were representatives from academia and both the regulating and regulated communities. Because this panel met during the plenary session of the conference, it also incorporated significant audience participation in its discussions.

The panel was unanimous in its recommendation that federal RF radiation exposure guidelines are needed, and that a federal government health regulatory agency, such as EPA, is the appropriate body to undertake such an endeavor. The panel was also unanimous in its recommendation that EPA does not necessarily need to develop an entirely new standard or conduct new analyses; instead, EPA could simply endorse or modify an existing standard, such as the new ANSI/IEEE standard.

This panel's discussion was organized into the following two major topics:

- The need and approach for EPA guidelines; and
- The overall effect on public and private sectors in local, state, and federal government.

NEED AND APPROACH FOR EPA GUIDELINES

The panel unanimously agreed that there is a need for federal guidelines to be established by a credible, federal agency with expertise and jurisdiction in the field. Panelists cited several reasons for this need.

- First, there are no federal guidelines that limit RF radiation exposure to workers or the public. According to some panelists, this lack of guidance raises several safety issues.
- Second, state and local bodies are adopting standards on their own, often without the necessary scientific expertise. The lack of a federal standard or guideline, therefore, has led to a patchwork of state and local regulations that has contributed to public apprehension, controversy over the potential risks to public health from existing and developing technology, and expensive litigation.
- Finally, in many other countries, such as Great Britain, Japan, and Germany, RF radiation guidelines exist. Because U.S. industries are subject to a variety of

inconsistent standards, they are placed at a competitive disadvantage in the international marketplace with regard to telecommunications devices and other technologies. New technology must often undergo denials of permits and demands for additional safety confirmations, which are expensive and delay products, services, and systems.

Panel members suggested that EPA fulfill this need for guidelines by making a statement regarding the validity of existing guidelines; and/or by developing different guidelines (if indicated) by sponsoring additional research to fill some of the gaps in existing scientific literature.

The panel felt strongly that EPA should not wait until all or most of the uncertainties about the RF radiation issue are resolved, as long as those uncertainties are clearly identified. A guideline supported by EPA, the panelists stated, will still be effective and helpful to all involved, even if it has caveats, uncertainties, and unresolved issues. To address the uncertainties, the panel suggested that EPA call the standard an "interim standard", and revise it as research clarifies and resolves issues.

OVERALL EFFECT ON PUBLIC AND PRIVATE SECTORS IN LOCAL, STATE, AND FEDERAL GOVERNMENT

The panelists agreed unanimously that the overall effect of an RF radiation guideline would be to provide a scientifically sound, respected basis for regulations. This guideline, the panelists felt, would affect all groups represented on the panel.

- The Federal Communications Commission (FCC), which licenses and authorizes thousands of transmitters for broadcast and non-broadcast use, and has responsibilities under the National Environmental Policy Act (NEPA) to evaluate environmental impacts on public health from these emissions, would be assisted significantly by federal guidance. The FCC depends on health and safety organizations such as EPA for the standards that the FCC then would enforce. FCC has suggested that EPA endorse the 1992 ANSI/IEEE guidelines.

- The Department of Defense (DoD) (as well as the National Weather Service and other federal agencies) also would benefit greatly if there were federal guidelines. The current lack of an EPA guideline and the patchwork of numerous and diverse local regulations cost DoD and the other federal agencies in time, money, and delays and interference with activities. A national guideline would simplify the work of DoD and other federal agencies in this area. (The Tri-Service Panel of DoD, which coordinates research on RF radiation health effects and safety and recommends guidelines for DoD, has recommended the ANSI/IEEE standard for use within DoD.)

- The National Telecommunications and Information Administration (NTIA), which authorizes and manages all federal government use of the RF spectrum, gave several reasons why a federal guideline would be helpful to them. NTIA also described some of the detrimental effects that have occurred while working without a federal guideline. For example, the lack of federal guidelines has had costly and disruptive effects on the telecommunications industry, and has eroded public confidence. Furthermore, several major government systems have faced obstacles in getting permits to install or operate telecommunications systems, leading to lengthy delays in projects and spending extra money on additional safety studies.

- Difficulties in having to develop a standard at the local level was discussed by a local government representative. Local governments often have to make decisions without a wide base of scientific knowledge, and face citizens with a variety of views on the issues. The public also generally lacks information and feels that it needs guidance from more than just the local government. For example, the public is generally uncomfortable with allowing the local government to decide RF radiation safety issues, which are often felt to be health policy issues that are better addressed by a health and safety agency such as EPA.

In summary, this panel believed that federal radiation protection guidelines endorsed or created by EPA would be beneficial to all parties involved with RF and would limit controversy, increase public confidence, decrease litigation, and improve the position of the U.S. in the international marketplace.

PANEL 1: EXPOSURE AND DOSIMETRY (EXPOSURE ASSESSMENT, DOSIMETRY, RF SHOCKS AND BURNS)

Mr. Edwin Mantiply (Chair)
Dr. C. K. Chou
Dr. Robert F Cleveland, Jr.
Dr. David L. Conover
Dr. Carl H. Durney
Dr. Om P. Gandhi
Dr. A. William Guy
Dr. Ronald C. Petersen

INTRODUCTION

Panel 1 focused on exposure assessment and dosimetry issues. This panel also discussed several issues raised by speakers – primarily Mantiply, Guy, and Gandhi (see Volume 2) – during the plenary session. The topics on which Panel 1 focused included:

- RF radiation dosimetry;
- The relationship between continuous and pulse- and ELF-modulated RF radiation exposure; and
- Adoption of a standard.

RF RADIATION DOSIMETRY

The panel noted the importance of RF radiation dosimetry in the assessment of biological effects, whether thermal or nonthermal. Considered in broad terms, dosimetry was characterized as the association of external fields with the internal fields in the tissues, and it involves the description of all exposure parameters, and the relation to specific absorption rate (SAR), internal electric and magnetic fields, and internal current densities.

The panel divided their discussion of dosimetry into three categories: (1) use of SAR in RF radiation dosimetry; (2) progress in dosimetry; and (3) the need for better dosimetric methods.

Use of SAR

SAR was considered by much of the panel to apply to both thermal and athermal effects, and was generally felt to be the most important physical quantity associated with dosimetry. The panelists discussed several controversies, however, over the use of SAR as a means – especially the sole means – of quantifying effects. At low frequencies, for example, most panelists felt that SAR is meaningless since individuals may be electrocuted with negligible SARs (i.e., shocks and burns are related to current density). Conversely, one panelist noted that SAR can be quite high with negligible levels of current. The consensus of the panel was that all parameters (i.e., current densities, internal fields, and SAR) should be described when discussing RF radiation effects.

Progress in Dosimetry

Significant progress was reported and discussed in the area of local dosimetry of contact currents, nonuniform fields, multiple sources, and small sources. There are new technologies and higher spatial resolution models to use for assessing dose. These new methods should be included in any update of the 1984 RFR Report on the biological effects of RF radiation. Several panelists also agreed that the 1984 RFR Report – perhaps Conclusion #3, which addressed the

thermoregulatory effects of RF radiation (see Appendix A) – should be updated to emphasize the use of averaging time for shocks and burns.

Need for Better Dosimetric Methods

Several recommendations were made for improving existing dosimetric methods.

- There is a need for more spatial or three-dimensional SARs, since local SARs may be up to 100 times higher than the whole-body average SARs.
- Develop approaches for combining local SAR criteria (e.g., for personal communication devices) with power density limits for far-field whole body exposure.
- To help biologists address mechanisms, more emphasis must be placed on microdosimetry.
- In general, physical scientists must work more closely with biologists in improving dosimetric methods used in studies.

RELATIONSHIP BETWEEN CONTINUOUS WAVE AND PULSE- AND ELF-MODULATED EXPOSURE

The panel focused on the interest in an approach to assessing the relationship between continuous wave and pulse- and ELF-modulated exposure.

Assessing Continuous vs. Pulse- and ELF-Modulated Waves Exposure

The differences between the effects from continuous and pulse- and ELF-modulated RF radiation were discussed by the panelists. One panelist cited research that indicates that pulse-modulated RF radiation produces effects at nonthermal SARs, while continuous wave RF radiation at the same SARs does not produce these effects. Most panelists felt that important questions are raised with regard to time averaged SAR and the need for different dose measures for modulated and continuous wave RF radiation.

One of the panelists proposed an approach that may address the relationship between continuous wave and pulse- and ELF-modulated RF radiation. This approach is based on a Fourier series expansion of the RF radiation pulse train. The summation of the SARs found for each Fourier series sinusoidal harmonic of the pulse train would be a way to connect to the results of exposure to the continuous wave case. This panelist noted, however, that the validity of this approach would depend on the interaction mechanism (e.g., the approach may not be completely valid if the response mechanism is nonlinear), and as yet there is no information on the response mechanisms associated with modulated RF radiation.

Linking ELF Radiation Research to ELF-Modulation of RF Radiation

A significant amount of discussion addressed ELF-modulated RF radiation issues, primarily those related to linking ELF and ELF-modulated RF radiation research. One panelist described the difference between the internal fields from "direct" ELF (e.g., from power lines) and fields generated from RF radiation, where the latter fields are much greater (by as much as 100,000 times). Thus, the panelist noted, the internal ELF fields from ELF-modulated RF radiation may be more significant than from direct ELF. Another panelist commented that effects due to ELF-modulated RF radiation

that are similar to direct ELF fields have been observed experimentally, although the results have not been conclusive. The panelists agreed that ELF-modulated RF radiation exposure is an important area, but that significant additional research is needed before any conclusions can be reached.

ADOPTION OF EXPOSURE STANDARDS

The panel strongly recommended that EPA adopt some form of an exposure standard, such as the ANSI/IEEE standard. During discussion of this recommendation, the panel addressed several issues or points, including deficiencies/limitations of the ANSI/IEEE standard, cost implications, and performance standards.

Deficiencies or Limitations in the ANSI/IEEE Standard

The panel felt that the ANSI/IEEE standard should be updated to correct the following deficiencies/limitations as more data becomes available.

- Averaging time for contact current. Some panelists felt that the standard's 1 second averaging time should be used only below 100 kHz (to protect against shock), and that a longer averaging time could be used for frequencies above 100 kHz and up to 100 MHz.

- Transient discharges. Panelists agreed that transient discharge, which is a problem that occurs during contact with an object containing an RF voltage, results in a pulse of current that can cause a shock or a short-term burn. Little information on transient discharges as a function of frequency exists, however, and therefore the standard should more clearly address limitations in protection against shocks or burns due to transient discharge.

- Calculating SAR for a cubic shapes of tissue. Some panelists felt that there are certain problems with calculating SAR for 1 or 10 grams of tissue in the shape of a cube, since certain parts of the body, such as the ear lobe or the hand holding a device, cannot be identified as cube shaped.

- Frequency cutoff. Some panelists noted that the frequency cutoff for induced and contact currents of 100 MHz may result in certain problems (e.g., for assessing mixtures of exposure) because the FM radio band is 88 to 108 MHz.

- Conflicting components of standard. One panelist noted that the standard allows the possibility of compliance with electric field strength, but not with induced current limit at some frequencies.

Cost Implications of Standard

The panel identified some of the cost implications of adopting the ANSI/IEEE standard. In addition to the potential impact on the FM radio industry because of the 100 MHz cutoff, the body current limitations could significantly increase the cost of AM broadcast compliance. In addition, the panel noted, FM stations that are in compliance now with the 1982 ANSI standard may not be with the 1992 standard.

Using the ANSI/IEEE Standard to Develop Performance Standards

Suggestions were made to use the ANSI/IEEE standard as a cap on environmental exposure, and then establish case-by-case performance standards to achieve lower fields for particular sources where it may be easy to limit exposure down to levels lower than the standard (e.g., raising the height of radar devices on pleasure boats to reduce exposure).

CONCLUSIONS/RECOMMENDATIONS

The panel discussed several of the major advantages and disadvantages of SAR. SAR was generally considered to be the most important dosimetric quantity applicable to both thermal and athermal effects. The panel also highlighted several areas – including contact currents, nonuniform fields, multiple sources, and small sources – in which major improvements have taken place recently in the field of dosimetry. Furthermore, the panel identified areas for additional dosimetry research, such as spatial or three-dimensional SARs; combining local SAR criteria (e.g., for personal communication devices) with power density limits for far-field whole body exposure; and microdosimetry.

The panel addressed several issues associated with pulse- and ELF-modulated RF radiation, including potentially lower thresholds for effects from these fields compared to continuous wave RF radiation; the possible relevance of ELF research to effects of ELF-modulated RF radiation; and the additional research that is needed overall. The panel also concluded that some changes were needed in the 1987 Reassessment Report (see Appendix A), including updates on new methods for exposure assessment and dosimetry; and an update of electric shock and burn (perhaps for Conclusion #3). The panel also strongly recommended that EPA adopt RF radiation exposure guidelines, such as the ANSI/IEEE standard (or some form of it).

PANEL 2: THERMAL RESPONSES (HUMAN, ANIMAL, THERMAL MODELING, PERCEPTION)

Dr. Daniel J. Schaefer (Chair)
Dr. Eleanor R. Adair
Dr. T. Whit Athey
Dr. Melvin R. Frei
Dr. Christopher J. Gordon
Dr. James C. Lin
Dr. Frank G. Shellock
Dr. Ronald J. Spiegel

INTRODUCTION

Panel 2 addressed thermal responses to RF radiation. The discussion focused on magnetic resonance imaging (MRI) issues, such as those described in the plenary paper presented by Shellock (see Volume 2). Panel 2's discussion is organized as follows:

- MRI data;
- Frequency effects;
- Local SAR limits;
- Measurable thermoregulatory effects;
- Ambient temperature;
- General subject of setting standards; and
- Conclusions/recommendations.

MRI DATA

Panel 2 initially concentrated on MRI studies that provide human research data. The panelists agreed that the MRI studies were helpful in characterizing thermal effects, and that guidelines for whole body average exposure should make use of the studies. There was disagreement, however, regarding the use of the MRI data for far field exposure scenarios. Some differences noted in the nature of the exposure of MRI compared to typical far field exposure include the following:

- In MRI, the magnetic field vector causes induction heating, and the energy is deposited more peripherally compared to far field exposure (at lower radiofrequencies). This peripheral deposition allows for energy to be more easily released to the environment.

- Most MRI systems now use quadrature excitation, which means that the magnetic field vector is circularly polarized. The effect is that any homogeneities that might produce hot spots tend to get "stirred," which is quite different than what is found in a far field exposure.

- MRI exposure is acute, being no greater than approximately 2 W/kg with a duration up to one hour. For environmental exposure to far field RF radiation, people could be exposed for much longer periods of time.

FREQUENCY EFFECTS

The panelists agreed that any new guidelines should take into account the effect of frequency on energy deposition. Panelists discussed several differences between effects at various frequencies (e.g., high vs. low, resonant vs. non-resonant). One panelist noted, for example, the recent MRI data on the peripheral heating that can occur at very low frequencies. This panelist also discussed data

on the high amount of peripheral heating relative to core heating that occurs at super resonant frequencies (i.e., above 3 GHz), noting that this is believed to be similar to the situation that occurs with an induced magnetic field, and that these effects may have serious implications for cardiovascular and cardiorespiratory function.

LOCAL SAR LIMITS

Panelists discussed at length the importance of local SAR limits. This discussion addressed issues such as the high local SARs that can occur even at low whole body average SARs and the frequency dependence of local SARs (e.g., the potential for high local power deposition at super resonant frequencies). Panelists agreed that local SAR limits must be addressed in addition to whole body averages. Furthermore, many of the panelists considered an SAR of about 1.6 W/kg to be appropriate for a local limit.

MEASURABLE THERMOREGULATORY EFFECTS

One panelist noted that effects from exposure to 0.4 W/kg are not measurable. This panelist also cited data showing that a 1.2 W/kg whole body exposure does not appear to generate an increase in body temperature. Some panelists noted that an increase in body temperature from RF radiation (e.g., at 0.4 W/kg) is less than the diurnal variations of 0.5 or 1 degree or the increase obtained through exercise or even the use of extra clothing. Other panelists, however, questioned whether such mechanisms can be compared since exposure to RF radiation may not mobilize the thermoregulatory responses of the body in the same manner.

AMBIENT TEMPERATURE

The panel further discussed whether – because thermal responses are a function of environmental temperature – operative ambient temperatures should be considered in SAR limits. One panelist noted that environmental engineers use the concept of operative ambient temperature to account for all energy sources in the environment that are affecting an organism. Such an approach may complicate the standard, panelists noted, but the guidelines would be better suited to different ambient conditions.

AVERAGING TIME FOR PULSE AND CONTINUOUS WAVE EXPOSURE

The panelists agreed that a standard should differentiate between pulsed and continuous wave exposure scenarios. The panel generally felt that 15 minutes may be an appropriate averaging time for continuous wave exposure and 100 milliseconds may be appropriate for pulsed wave exposure. One panelist demonstrated how averaging time is crucial by providing a hypothetical exposure scenario: if the standard were 1 W/kg and the averaging period were 10 minutes, then a 10 W/kg exposure could occur for 1 minute with a resting period of 9 minutes (alternatively, if the averaging period were 30 minutes, then a 30 W/kg exposure could occur for one minute).

STANDARDS SETTING

In general, the panelists agreed that EPA should develop a standard, and that, as a basic philosophy, the standard setting process should begin at the level of measurable thermal physiological consequences, with a systematic application of safety and uncertainty factors. Given sufficiently large uncertainty factors, the panelists felt, athermal effects could be addressed by default.

Panelists discussed four options, in terms of allowable effects, for the general approach to setting standards. That is, the standard could allow either

(1) No demonstrable physiological effects;
(2) Measurable physiological effects but no known consequences;
(3) Minimal physiological consequences; and
(4) Adverse effects on bodily functions/organisms.

The panel ultimately decided that the standard should start at the "break point" where thermal physiological effects are measurable; the standard should then apply safety and uncertainty factors to regulate below the level of measurable effects. Panelists generally agreed that a safety factor of four or five would be appropriate. To account for other uncertainties (i.e., pathologies, age, ambient temperatures), the panelists generally agreed that a factor of 10 would be appropriate. Starting with an SAR of about 4 W/kg (from the MRI data) as the level at which significant physiological effects are manifested, these two adjustments led the panel to recommend a whole body average SAR exposure limit of about 0.08 W/kg.

CONCLUSIONS/RECOMMENDATIONS

The panelists provided several conclusions and recommendations:

- EPA should write an RF radiation standard for environmental exposure. This standard could be based on measurable thermal effects considerations, but with adequate uncertainty factors. The standard should address ambient temperatures, frequency effects, localized effects, and continuous vs. pulsed waves.

- Additional funding and research is needed on measurable thermoregulatory effects of long term RF radiation exposure. Little data exist now, they argued, and standard setting would have a firmer scientific foundation given more research in the area. MRI research is useful, the panel noted, but it is not a direct substitute for long term – especially far field – RF radiation exposure.

- One panelist argued for additional research into normalizing energy deposition by the surface area of the body rather than by mass. If a standard used surface area and not mass, he stated, a totally different standard would result (i.e., about five times less).

PANEL 3: EPIDEMIOLOGY

Dr. Doreen Hill (Chair)
Dr. Genevieve Matanoski
Dr. Samuel Milham, Jr.

INTRODUCTION

Panel 3's discussions on the epidemiological evidence for human health effects of RF radiation addressed the literature on the topic, which was introduced in the plenary presentation by Matanoski (see Volume 2). The discussion by this panel focused primarily on results from cohort studies of specific human populations exposed to RF radiation. Also discussed were the limitations of the usefulness of data in the existing body of literature on RF radiation.

This summary of the panel discussion is organized as follows:

- Supplemental information;
- Recent occupational studies;
- Problems with the epidemiological data; and
- Conclusions/recommendations.

SUPPLEMENTAL INFORMATION

The panel first examined a list of studies (compiled by one of the panelists) to identify any that were not included in the data compilations developed thus far (i.e., the 1984 RFR Report, the 1987 Reassessment Report, and the 1990 EMF Report). Identified as missing were the following:

- Long-term mortality studies on amateur radio operators in Washington State and California;
- Recent Norwegian studies based on occupation;
- A study on electromagnetic pulse (EMP) workers;
- A study on heart disease;
- A study on reproductive effects on diathermy workers; and
- Thesis work on female physiotherapists.

A summary of discussions on some of these studies is provided in the next section.

RECENT OCCUPATIONAL STUDIES

The panel examined several recent epidemiological studies that examined potential occupational exposure.*

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* No specific epidemiological information on non-occupational studies was presented.

- Occupational mortality studies were the first studies reviewed by the panel. A study by one of the panelists, Milham, looked at health statistics from 1940 to 1989 in Washington state, focusing on radio operators/telegraphers and radio and TV repairmen. Although the population was based on small numbers, the studies showed an increase in mortality from leukemia, hematolymphoma, and brain cancer in these groups.

- A 1992 study by Mumm looked at people involved in EMP testing. The medical cohort was defined by all those who had EMP medical exams because they worked around pulsed fields. This group showed an increase in chronic myelocytic leukemia (four in a population of 304 individuals).

- Swedish epidemiological data (from Tynes) on radio and TV repairmen, based on census data, showed significant excess leukemia rates, but they may also have been exposed to ionizing radiation due to older TV sets that can emit x-rays.

- In a more recent Swedish study on a cohort of workers at a Norwegian hydropower plant, based on workers at both the power stations and at power lines, no leukemia or brain tumors were found. Tynes questioned the difference between the previous finding and this one (i.e, is it the actual jobs the workers perform, or are there differences in the electromagnetic fields to which the different workers are exposed?).

- In contrast to the previous study, a study of hydroelectric workers in Washington State has shown a large excess of non-Hodgkins lymphoma in workers in the Columbia River power house.

- One panelist, Hill, presented data involving radar developers at MIT. This study showed no increased risk of leukemia or brain cancer, but an unusual result of increased risk of Hodgkins disease and gall bladder and bile duct cancer. Those who developed Hodgkins were in a group that was determined to be subject to "low exposure" This result is confounded by the possibility that Hodgkins may have an infectious origin. Hill also saw an increase in cirrhosis in this population that does not appear in the cancer data.

- A current study on reproductive effects of RF radiation on MRI technicians has shown no effects thus far.

- Other occupational studies that were cited, including those examining ocular effects of RF radiation on Navy personnel and a study on U.S. Embassy personnel in Moscow, were not thought to be useful because the pathology rates were not statistically significant.

- No studies on the ocular effects of RF radiation exposure have been conducted since 1984.

PROBLEMS WITH THE EPIDEMIOLOGICAL DATA

The panel presented numerous criticisms about the data that show relationships between RF radiation and cancer, leukemia, brain tumors, and other pathologies. These criticisms can be summarized as follows:

- In studies that define populations by job title, it is virtually impossible to know the type, intensity, and duration of the RF radiation to which the population has been exposed.

- Cohort studies of all kinds lack long-term follow-up. Many of these populations can be studied during, and for many years after, their occupational exposure. This has not been done for any study.

- Most previous studies have focused on 60 Hz exposure, with little attention to frequency distributions. People in many occupations, however, are exposed to different electrical field powers and frequencies, and in these studies, no field measurements were provided that could elucidate the potential source and type of radiation to which these populations were exposed. Therefore, information gleaned from most previously published studies is not directly useful for assessing RF radiation effects on human health.

- Most effects that have been seen from RF radiation are thermal effects. There is little data on the non-thermal effects of exposure to RF radiation in humans. In addition, it is difficult to determine whether effects from RF radiation exposure result from thermal or non-thermal processes in humans.

- Studies have not been careful to delineate whether populations have been exposed to continuous wave/non-pulsed (e.g., radio and TV signals) or pulsed (e.g., radar) energy radiation. Results from EMP studies show that there may be significant differences in the effects of continuous wave versus pulsed radiation.

- People in many occupations are exposed to numerous sources of RF radiation at once, or switch jobs within their lifetimes, changing the nature of their exposure. This makes it difficult to pinpoint the nature of the relationship between exposure and particular pathologies. For example, many occupations (e.g., television repair) that expose individuals to RF radiation also expose them to ionizing radiation. In addition, it is difficult to follow the medical histories of these groups as they age. A further complication is the difficulty of isolating normal aging processes and increased risks of cancers such as leukemias from RF radiation exposure.

CONCLUSIONS/RECOMMENDATIONS

The members of Panel 3 developed four general conclusions about the epidemiological evidence for human health effects of RF radiation:

(1) Human data are currently limited and incomplete, and in general do not indicate any obvious relationship between prolonged low-level RF radiation exposure and increased mortality or morbidity, including cancer. This conclusion is based on general occupational studies and cohort studies, as well as additional studies that focused on reproductive, neurological, and ocular effects. This situation has not changed appreciably since 1984, when EPA concluded that too little human epidemiological data existed on which to base an RF radiation exposure standard.

(2) The thermal effects of RF radiation are well-documented in human populations. However, EPA cannot presently develop standards for non-thermal RF radiation,

given the uncertainties that exist about the specific types of exposure to RF radiation incurred by human populations.

(3) Some uncertainty exists about whether RF radiation should continue to be considered a non-carcinogen. Some members of the panel felt that, because of this uncertainty, EPA should not continue to state with certainty that RF radiation is not a carcinogen.

(4) More research, including longer-term cohort studies that incorporate careful measurements of occupational exposure, including exposure type (pulsed vs. continuous wave, high vs. low frequencies, etc.), duration, and information about confounding variables (including multiple exposures) must be conducted before EPA takes further regulatory action to control human exposure to RF radiation.

PANEL 4a: ANIMAL STUDIES (BEHAVIOR, NERVOUS SYSTEM, ENDOCRINOLOGY, REPRODUCTION)

Dr. Mary Ellen O'Connor (Chair)
Dr. John D'Andrea
Dr. John DeLorge
Dr. Henry Lai
Dr. Joseph Lary
Dr. Gregory W. Lotz
Dr. Shin-Tsu Lu
Dr. Michele Marcus

INTRODUCTION

Panel 4a discussions on animal studies focused on five specific areas:

(1) general issues;
(2) behavior;
(3) nervous system;
(4) endocrinology; and
(5) reproduction/development.

Much of the discussion involved information presented in a plenary paper by Elder (see Volume 2).

The primary objective of the panel's discussion was to review and evaluate data from 1982 onwards. A second objective of the discussion was to establish whether or not there are more data – in addition to the currently more promising information on behavior – to establish a standard. Finally, a third objective was to provide guidance to EPA concerning the biological basis (relevant to the areas covered by this panel) for RF radiation guidelines.

GENERAL ISSUES

The panel addressed the following general areas before proceeding to the more specific topics.

- "Athermal"/SAR issues. The panel concluded that the question of how to express athermal interactions in terms of SAR is too complicated. They pointed out that SAR depends on such factors as frequency and the size of the animal, and that SAR is not very meaningful at lower frequencies.

- Thermal, basal metabolic rate (BMR), and body temperature. The panel emphasized the importance of clearly defining these terms. Some panelists discussed whether a mechanistic shift toward a thermal phenomenon could be said to occur at $\geq$ 100 kHz, although they emphasized that a thermal increase does not necessarily mean that the mechanism is thermal.

- Frequencies to which SAR applies. The problem of determining how low in frequency does the SAR concept apply was considered, and no definitive conclusions could be reached.

- Use of induced electric field as a measure of dose. The panel debated the possibility of using induced electric field (which is proportional to SAR) as a measure of dose; however, no clear conclusion could be achieved.

- Long-term exposure. The panel was concerned about whether or not the 1992 ANSI/IEEE standard of ≥ 6 minutes averaging time constituted an adequate assessment of long-term exposure. Some panel members considered the 6 minute cut-off to be inadequate for some effects.

- Health effects versus health hazard. The importance and difficulty of differentiating a health effect from a health hazard was stressed. For example, the panel discussed whether or not effects on the visual system are a health effect or a health hazard.

- Safety factor. The panel discussed applications for safety factors. For example, the panel felt that a safety factor of 10 may not be appropriate for all endpoints (e.g., behavioral effects may require a smaller safety factor than retinal damage).

BEHAVIOR

After evaluating the impact of new studies on the effects of RF radiation on behavior, the panel concluded that the 1982 ANSI/IEEE guideline threshold for behavior (established, according to the panel, as 4 W/kg based on disruption of performance in small laboratory animals) was supported by new data, and that behavior was still an important point for setting a standard or guideline.

The panel discussed the results of studies that attempted to generalize eye injury to behavior. It was noted that there were no changes in visual performance (as assessed by the visual contrast sensitivity paradigm) in monkeys exposed to high peak power pulsed radiation. In addition, it was emphasized that the visual contrast sensitivity studies were not an attempt to replicate the findings of studies that have demonstrated retinal injury.

The panel also discussed data showing that vigilance was not disrupted by high peak power radiation. Although some data have demonstrated decreased physical endurance and memory impairment in rats with a paradigm utilizing a high peak power TEMPO system and two behavioral endpoints (bisection as an operant technique and the Y maze), the panel felt that it was premature to set a standard based on these endpoints. Previous standards, however, have not limited exposure to high peak power radiation.

NERVOUS SYSTEM

The panel discussed data showing evidence that RF radiation can result in various neurochemical changes (such as neurotransmitter and synaptic function), that often precede the behavioral changes. Neurochemical effects have been reported at exposure levels as low as 0.3 W/kg (whole-body exposure). Summary data on neurochemistry findings were presented and include the following:

(1) Changes in the cholinergic system at 0.45 W/kg (whole-body exposure);

(2) Changes in short-term memory at 0.6 W/kg (whole-body exposure);

(3) Changes in ATPase function and energy transfer in the CNS when the cortex was irradiated with 591 MHz at SARs down to 0.026 W/kg; and

(4) Interactions with chemicals, such as psychoactive drugs, at SARs as low as 0.2 W/kg.

The panel discussion also focused on the possibility that the neurochemical changes may be stress-related.

ENDOCRINOLOGY

The panel noted that there are only a few recent studies on the endocrine effects of RF radiation. The panel concluded that these studies contribute to the concept of stress, and confirm previous work on the influence of RF radiation on endocrine function.

REPRODUCTION/DEVELOPMENT

The panel recognized that there were no major changes since the 1987 Reassessment Report (see Appendix A) with regard to the reproductive effects of RF radiation. However, it was pointed out that some studies have shown that experimental levels of RF radiation as low as 0.05 W/kg can have effects on mouse spermatocytes. With regard to developmental effects, concerns about embryo lethality and embryo toxicity were supported by a number of avian and mammalian studies showing effects at 10 to 20 kHz (approximately 0.01 W/kg). Human studies were considered by the panel to be inadequate to evaluate reproductive/developmental effects of RF radiation in humans because exposure levels were not well characterized.

CONCLUSIONS/RECOMMENDATIONS

The following recommendations were made for research on RF radiation and animal studies:

- Conduct studies to replicate findings. The need to replicate findings became apparent. For example, the panel noted that additional studies are needed on ocular effects such as retinal damage.

- Conduct low-level, long-term exposure studies. Particular emphasis was placed on these types of studies since this is a scenario most frequently encountered in human exposure. The panel felt that chronic exposure studies also need to be conducted at different frequencies.

- Conduct studies in more species. The panel concluded the need for studies in species besides the rat (e.g., primate studies).

- Conduct studies comparing pulsed vs. continuous wave radiation. The panel noted that different exposure systems (e.g., multimode cavity and circular polarized waveguide) have produced different effects, thereby affecting the outcome of the studies.

PANEL 4b: ANIMAL STUDIES (CHRONIC STUDIES, IMMUNOLOGY, AND OCULAR EFFECTS)

Dr. Joe Elder (Chair)
Dr. Ewa Czerska
Dr. Henry A. Kues
Dr. Larry L. Kunz
Dr. Robert P. Liburdy
Dr. Robert E. McGaughy
Dr. John C. Monahan
Dr. Ralph J. Smialowicz
Dr. James C. Toler

INTRODUCTION

Panel 4b's discussion focused on the adverse physiological effects observed in animal studies – in particular, chronic, immune system, and ocular effect studies – following exposure to RF radiation. The panel used the findings and conclusions of the EPA 1987 Reassessment Report as a guide to the discussion (see Appendix A). The plenary paper on animal studies, which Elder presented the previous day (see Volume 2), also provided a starting point for this discussion section. This summary is organized around five major topics:

- General observations;
- Immune system;
- Ocular system;
- Chronic effects; and
- Conclusions/recommendations.

GENERAL OBSERVATIONS

At the outset of this session, two general observations by the panel were highlighted:

(1) Conclusion #1 in the 1987 Reassessment Report (see Appendix A) states that most of the animal studies investigating the adverse physiological effects associated with RF radiation exposure have used radiofrequencies between 27 MHz and 3 GHz, yet the vast majority of studies actually have used only two frequencies – 915 and 2,450 MHz. Extrapolating from such a discrete set of frequencies to a broad range of frequencies is a potentially significant uncertainty that should be considered during any standard-setting process.

(2) SAR is useful for normalizing the rate of energy absorption across the frequency range of 0.5 MHz and 100 GHz. Some panelists felt, however, that it may no longer be appropriate to further state – as in Conclusion #2 of the 1984 RFR Report (see Appendix A) – that SAR is useful as a metric for evaluating the biological effects associated with RF radiation exposure over this range, because that may imply that the biological effect results only from the energy absorption, which may not be the case.

EFFECTS ON THE IMMUNE SYSTEM

The panel examined whether Conclusion #8 in the 1987 Reassessment Report – which addresses the lack of convincing evidence for RF radiation effects on hematologic and immunologic systems without some form of thermal involvement (see Appendix A) – needs revision. Panelists generally felt that this conclusion should not be revised, and that there remains a lack of convincing

evidence for RF radiation effects on the immune system without some type of thermal involvement. The panel also generally felt that no revision is needed to Conclusion #8's statement that RF radiation effects on hematologic and immunologic systems appear to be reversible.

EFFECTS ON THE OCULAR SYSTEM

The panel examined whether Conclusion #17 of the 1987 Reassessment Report relative to ocular effects – in particular, that no data exist to support a conclusion that low level, long term exposure to RF radiation induces cataracts (see Appendix A) – needs revision. The panel briefly discussed the well-established observations that acute exposure to high intensity RF radiation can induce cataract formation, and that the development of cataracts is related to a significant temperature increase in the lens of the eye.

The panel then went on to discuss other types of ocular effects associated with RF radiation exposure – including effects on the iris and cornea – at very low SARs. One panelist, Kues, described research indicating that corneal lesions can result from an RF radiation-induced increase in iris vascular permeability in primate eyes exposed to pulsed RF radiation at 2.6 W/kg or higher. This panelist also presented data that indicated pulse length and frequency may be factors in the corneal effects.

This panelist further hypothesized – based on some data and on current theories of cancer promotion caused by the interaction of microwaves with melanin and the generation of free radicals – that RF radiation effects on the cornea result from microwave interactions with the pigmented melanin layer in the iris, which cause a cascade of effects such as the formation of free radicals, which lead to a break down in the vasculature of the iris, which cause toxins to leak out and poison the corneal endothelium.

The effective SAR for corneal effects was reduced by a factor of 10 – down to 0.26 W/kg or higher – if the eye had been pretreated with one or more commonly prescribed drugs for glaucoma. One panelist noted that these findings may indicate the presence in the population of a sensitized subpopulation (i.e., over 1 million people in the U.S. who are being treated for glaucoma).

CHRONIC EFFECTS

The panel next addressed chronic animal studies. The panelists specifically addressed Conclusion #20 in the 1987 Reassessment Report, which states that there is no convincing evidence that exposure to RF radiation shortens the life span of human beings or experimental animals or that RF radiation is a primary carcinogen (cancer inducer) (see Appendix A). Panelists felt that, in light of recent research findings, this statement needed revision.

First, the panelists felt strongly that the issues of cancer and lifespan should be considered separately. With respect to the influence of RF radiation exposure on lifespan, one panelist described recent research that showed a decrease in lifespan in mice exposed at 6.8 W/kg, but no decrease at exposures less than or equal to 2 W/kg.

With respect to cancer, the panel discussed some older research that was conducted at the University of Washington. According to panelists, that research suggested that (1) RF radiation exposure is associated with an increase in benign adrenal medulla tumors, and (2) there was an overall increase in non-specific tumors across sites, although there was no increase in any specific tumor at any given site. Panelists generally agreed that, for a variety of reasons, this research was not conclusive.

MISCELLANEOUS ISSUES

Other miscellaneous points that were discussed by the panel include the following:

- Several panelists commented on the importance of distinguishing between adverse physiological outcomes induced by thermal effects at the microcellular level and truly athermal adverse effects. These panelists stated that RF radiation exposure can change cellular physiology to give the appearance of a radiation-induced change, even though the changes observed may have been brought about by microheating effects at the cellular and subcellular levels.

- Several panelists noted that some *in vitro* studies suggest a difference between effects induced by pulsed wave exposure and those induced by continuous wave exposure. One panelist stated that exposure to pulsed waves can cause spontaneous transformation in human lymphocytes, while continuous wave exposure does not cause this effect. Some panelists speculated that the pulsed exposure may be causing microheating of cells that cannot be detected by direct measurements. Nevertheless, panelists generally felt that EPA should differentiate between pulsed and continuous wave exposures and establish separate exposure guidelines for them.

CONCLUSIONS/RECOMMENDATIONS

In addition to the conclusions described above, the panel also discussed three future research needs.

(1) Future immunology studies should consider the current findings from the epidemiology literature on cancers that are related to effects on the immune system (e.g., some forms of leukemia).

(2) Future immunology studies also should be very careful with choosing the proper animal model.

(3) A potential mechanism of action to consider when designing animal studies is the production of free radicals from RF radiation exposure and the ability of free radicals to produce the adverse physiological effects associated with RF radiation.

PANEL 5: MOLECULAR AND CELLULAR EFFECTS

Dr. Stephen F. Cleary (Chair)
Dr. Carl F. Blackman
Dr. Craig V. Byus
Dr. Kenneth R. Foster
Dr. Theodore Litovitz
Dr. Martin L. Meltz
Dr. Mays Swicord

INTRODUCTION

This discussion on molecular and cellular effects addressed many of the issues raised in the plenary paper presented by Cleary (see Volume 2). These and other issues, however, were the subject of much debate during the panel session.

The most deliberated issues during these discussions were the degree to which significant *in vitro* low intensity athermal* effects from RF radiation have been seen, and the extent to which such effects can be used to design future experiments, elicit mechanisms of action, or indicate potential adverse health effects in humans or other higher-level organisms.

Panel 5's discussion centered around four main topics:

- *In vitro* effects under low intensity conditions;
- Use of *in vitro* studies;
- Relevance of ELF research; and
- *In vitro* basis of the 1992 ANSI/IEEE standard.

IN VITRO EFFECTS UNDER LOW INTENSITY CONDITIONS

In the 1984 RFR Report, EPA stated in Conclusion #5 that no consistent *in vitro* effect had yet been found under athermal RF radiation exposure. In the 1987 Reassessment Report on noncancer effects (see Appendix A), this statement was revised to say that *in vitro* effects subsequently had been seen that do not appear to be due to the thermalization of RF energy. Panel 5 felt that under RF radiation exposure conditions that cause general temperature increases, numerous *in vitro* effects – including enzyme alterations, changes in neuronal activity, genotoxicity, and cell killing – clearly occur. Under lower intensity athermal conditions, however, these effects appear to be less certain. Thus, although most panel members agreed that more evidence does indeed exist concerning the likelihood of athermal effects, some members disagreed, arguing against drawing any conclusions on this subject.

The discussion on low intensity athermal *in vitro* RF radiation effects addressed the general weight of evidence for five types of effects:

(1) Alterations in membrane ion transport and receptor binding;
(2) Changes in neuronal activity and single ion channel kinetics;
(3) Proliferation/activation effects;
(4) Transformation effects; and

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* Athermal effects are defined for the purposes of this panel as effects that occur in the presence of RF exposures that are not associated with a temperature increase.

(5) Membrane signal transduction effects.

The panel discussed the extent to which some of the effects may be the result of interactions of RF radiation with other agents (e.g., tumor promoters), and some effects may be related to other effects (e.g., membrane signal transduction and transformation). Also, the type and degree of effect are believed to depend on the characteristics of exposure, such as pulsed versus continuous wave fields, and high frequency versus low frequency.

The panel generally agreed that, given the paucity of data and/or lack of a comprehensive review and weighing of all available evidence, specific conclusions about these relationships are inappropriate at this time. As indicated previously, some panelists extended this concern to athermal effects in general.

POTENTIAL USES OF *IN VITRO* STUDIES

The panel identified two major uses of *in vitro* molecular and cellular studies: (1) characterizing mechanisms of action and (2) designing new studies. A third potential use, extrapolating to health effects, was the subject of significant discussion and debate.

Characterizing Mechanisms of Action

The panel appeared to generally agree that one of the greatest advantages of *in vitro* studies is the ability to characterize the mechanisms of action of RF radiation on molecular, cellular, and possibly even higher level systems. Currently, there is a profound lack of understanding of mechanisms that *in vitro* studies may help elucidate. One area that could benefit greatly from *in vitro* studies is the controversy concerning the degree to which biological effects are the result of general or local temperature increases. Also benefiting would be theoretical models regarding the cell plasma membrane as the most prominent site of RF radiation interaction, compared to more direct interactions (e.g., with the genome).

Designing Experiments

Another significant use of *in vitro* RF radiation studies is in the design of new studies. For example, molecular and cellular studies can help identify precise exposure conditions of interest, either for further *in vitro* studies or for *in vivo* studies.

Extrapolating to Health Effects

The panel generally agreed that no obvious indications of human health hazard currently can be concluded from *in vitro* RF radiation research results. This was felt to be due to an inherent limitation of *in vitro* studies. At present, most uses for such studies are – and perhaps only should be – for those described previously (i.e., characterizing mechanisms, designing experiments). According to some panel members, however, *in vitro* studies conceivably could even be used in the future to make inferences concerning health effects from RF radiation – similar to the current use of *in vitro* studies for chemical hazards. Another example of such a use might be in helping to determine whether ELF- and pulse-modulated waves need to be addressed in any standard-setting exercise.

RELEVANCE OF ELF RESEARCH

Some of the discussion on the relevance of ELF research addressed the results of studies that have indicated similar molecular and cellular responses between ELF and RF radiation exposure. Most of the discussion, however, focused on ELF-modulated RF radiation fields, and the possibility that effects seen in these studies may highlight the relevance of ELF research to RF radiation effects.

IN VITRO BASIS OF THE 1992 ANSI/IEEE STANDARD

The panel generally agreed that the 1992 ANSI/IEEE standard does not adequately include or address *in vitro* effects, but rather addresses only systemic effects. Some panel members felt that, at the minimum, a more thorough discussion of *in vitro* effects should have been included with the standard, if only to more explicitly describe the assumptions used during development of the standard.

CONCLUSIONS/RECOMMENDATIONS

Because of the disagreement surrounding the issues discussed by this panel, few conclusions/recommendations ultimately were provided. Nevertheless, concerning the unresolved *in vitro* issues existing in 1987, the panel generally felt that these issues remain largely unresolved. Furthermore, the panel noted that new issues have surfaced that would need to be taken into consideration if EPA were to develop RF radiation guidelines. For example, the panel generally felt that additional research and review is needed in areas such as the following:

- Low intensity athermal effects;
- Mechanisms of action;
- Effects from pulse- or ELF-modulated RF radiation;
- Relevance of ELF research;
- Replication of past studies; and
- Balancing positive and negative research results.

Finally, the panel concluded that the 1992 ANSI/IEEE standard does not provide sufficient detail concerning its use of *in vitro* effects research.

PANEL 6: BIOLOGICAL EFFECTS BASIS FOR EXPOSURE LIMITS

Dr. Samuel Koslov (Chair)
Dr. Craig Byus
Dr. Om Gandhi
Dr. Doreen Hill
Dr. James C. Lin
Dr. Mary Ellen O'Connor

INTRODUCTION

Panel 6 primarily addressed the overall question of whether the biological research base, including the evidence for any effects, was adequate for developing an RF radiation exposure standard. This discussion was organized into three categories:

- Overall approaches for a standard;
- Biological basis for a standard; and
- Conclusions/recommendations.

OVERALL APPROACHES FOR AN RF RADIATION STANDARD

Federal Involvement With a Standard

The panel generally agreed that any RF radiation standard should be in some form of federally mandated or approved maximum exposure limits. Furthermore, the panelists agreed, this federal involvement should be from a health and safety agency such as EPA.

Such federal involvement with an RF radiation standard, however, raised questions for some panelists about what the standard would mean legally. They felt that a standard cannot be required and enforced by a federal agency unless Congressional action takes place. Nevertheless, the panel strongly felt that an agency such as EPA must be at the center of any standard development, and that this agency must review and approve the scientific research on which the standard is based. If this overall approach is not used, the panel felt, then the public will not accept the standard and therefore the undesirable experiences – discussed primarily by the plenary panel – that have occurred for the past 20 or so years with local and state standards will continue.

Degree of Consensus

Another issue on overall approaches that was discussed by Panel 6 addressed the mechanics of standard setting. Some panelists questioned whether a consensus could be reached on a standard in light of the significant uncertainties and debates over health effects and policy issues. Other panelists noted that a consensus approach may result in significant data being discarded, which may not be appropriate given the lack of data overall. These panelists felt that perhaps a perfect consensus approach may not be desired.

Interim Standard

The concept of an interim standard was discussed as a means for addressing the uncertainty of health effects. The panelists agreed that, as with other types of standards, a plan is needed to modify the RF radiation standard if new information becomes available that warrants such a modification. At first, the panel suggested, a standard-setting process should use best professional judgment with enough margin of safety added for areas that have significant uncertainty (i.e., that are

capable of producing injury if indeed the effects are true), and then should continue to reduce the uncertainty and adjust the standard over time.

Design of Review Process

One recommendation expressed by several panelists was that any federal standards development activities must carefully design the review process to avoid some of the problems that have occurred during the development of some of the non-federal RF radiation standards. These panelists felt, for example, that different criteria have been placed in the past on the selection of papers to use during the development of these non-federal standards. They also felt that overall there must be more willingness to accept certain publications, even though, because of reasons such as constrained funding, the results might not have had what might be considered by some to be adequate replication; any ensuing uncertainty resulting from such an approach can be incorporated into the standard.

BIOLOGICAL BASIS FOR A STANDARD

Relationship Between Metrics and Underlying Mechanisms

The panel discussed issues associated with various exposure measures and their implications for underlying mechanisms. Some panelists stated that although metrics such as power density, electric and magnetic field intensities, and SAR are useful metrics for exposure, they do not provide information – at least directly – about underlying RF radiation interaction mechanisms. These underlying mechanisms, these panelists stated, form the basis for an RF radiation standard that is designed to protect against adverse health effects.

One panelist noted that the selection of exposure measures should be done with care because of the implications they have for the assumptions about underlying mechanisms. This panelist cited the example of the frequency independence (within a range) of a whole-body average SAR, and how this SAR implies that effects from exposure are systemic (i.e., the whole body is involved) and occur at any frequency. Others argued, however, that SAR is mechanism-independent and is nothing more or less than a unit of measure.

Basis of the ANSI/IEEE Standard

The panel conducted a significant amount of discussion on the basis of the 1992 ANSI/IEEE standard, and whether the standard can be characterized as based on a particular response. Several panelists stated that the standard is based on a thermally-independent behavioral response to whole-body exposure in experimental animals. Others argued that the behavioral response is simply a reaction to a thermal increase. Still others argued that the standard is based, in a sense, on all endpoints. These panelists noted that, because of uncertainty factors applied to the standard, even endpoints that are questionable are incorporated.

Nonthermal Basis for a Standard

There was significant discussion concerning the question of whether there is enough evidence to accept a standard based on athermal effects. Panelists agreed that on the basis of purely thermal effects at higher exposure levels, there clearly are enough data at this point. Several panelists felt, however, that there probably are effects that are not purely thermal, as well as thermal effects that are not completely understood. The panel noted that as exposure levels decrease, uncertainty increases and consensus becomes more difficult to reach.

Epidemiological Basis for a Standard

The panel briefly examined whether there is an epidemiological basis for setting a standard. They seemed to agree that the human data is not sufficient to form a basis for standards development.

Pulse-modulated RF Radiation

The panel agreed that pulsed wave exposure deserves special attention. They noted that the general population is not typically exposed to high levels of this type of RF radiation, although several subpopulations (e.g., military, special services industries) are exposed to higher levels than typically measured in public areas. The panel felt that this area needed additional research.

CONCLUSIONS/RECOMMENDATIONS

The panel provided two broad recommendations:

(1) EPA should develop exposure standards or guidelines, but it may need to do so in an interim, stepwise fashion and without using a completely consensus approach.

(2) A sufficient basis is available for setting a thermal standard. Beyond thermal issues, EPA should acknowledge and identify the uncertainty associated with nonthermal exposure and effects.

Concerning the general question of a biological research base, several remarks were made that some reform of the process is needed. In particular, the funding for the last few years was described as significantly reduced from previous levels, and is believed by most panelists to be inadequate.

Partnerships between groups such as industry, academia, and the federal government were discussed as approaches to research that would be very useful. Several examples of partnership approaches – such as the current DoD funding pool that would allow the use of federal laboratories – were described.

4. CLOSING REMARKS

*Charles Susskind**

The Radiofrequency Radiation Conference, held in Bethesda, Maryland, on 26-27 April 1993 was convened by the U.S. Environmental Protection Agency Office of Air and Radiation, and Office of Research and Development, in response to a recommendation by the EPA Science Advisory Board that EPA should resume and complete its past efforts to develop federal guidance to control human exposure to RF radiation. More than 200 persons attended and participated in the discussions.

The most notable result of the conference was the overwhelming consensus that it was imperative for EPA to proceed promptly to provide guidelines on public and occupational human exposure to RF radiation by issuing the requisite federal guidance or, preferably, by endorsing the existing 1992 guide developed and promulgated by the Institute of Electrical and Electronics Engineers and approved by the American National Standards Institute. This protection guide, known as ANSI/IEEE C-95.1-1992, has been in the making for several years with wide participation of experts from universities, government agencies, and industries, and its adoption by EPA is widely perceived as a short-cut to a highly desirable goal whose attainment may otherwise take many years more.

Adoption of voluntary standards by government agencies in whole or in part is sanctioned, and indeed recommended, by Office of Management and Budget (OMB) Circular A-119, as revised in 1982, which states that such standards "will be used for federal agencies in lieu of developing and using in-house standards when voluntary consensus standards will serve the agency's purpose and are consistent with applicable laws and regulations."

All guidelines should state their limitations and acknowledge any remaining uncertainties. In the present case, one such limitation is that the ANSI/IEEE 1992 protection guide is expressed in terms of specific absorption rate, the SAR, which is to say that it is based on thermal effects, whereas effects that may due to mechanisms other than heating have been reported, although they have not been unequivocally shown to have adverse health consequences. Examples include the ocular effects observed at low SARs in association with common ophthalmic drugs, and effects on processes known to be associated with cancer.

The possible consequences of such effects must be regarded as subjects for research, as well as a possible basis for updating and improving the protection guidance in years to come, and not as reasons for delaying the issuance of guidance based on current knowledge with whatever qualifications may be deemed to be necessary. Timely issuance of RF radiation exposure guidelines will also be of inestimable value to other federal agencies, and to state and local regulatory authorities that are now forced to select guidance from a confusing menu of diverse criteria or else to establish criteria on their own, often with very little scientific basis or rationale for doing so.

I want to end by saying that the conference expressed full confidence in the ability of EPA to develop the requisite guidance, stressing repeatedly that only an agency with the expertise, authority, and public recognition of EPA can issue effective guidance, one that will be of great value to U.S. participation in international radiation protection and telecommunication standards and activities.

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5. SUMMARY AND NEXT STEPS

Following the conference, EPA conducted a number of RF radiation-related activities. These activities included a review and analysis of the information provided during and after the conference, the submission of comments on a Federal Communications Commission (FCC) proposal to adopt RF radiation guidelines, and the development of an RF radiation strategy. The following discussions provide additional details on these topics.

KEY CONCLUSIONS OF CONFERENCE SPEAKERS AND PANELISTS

Two key conclusions were provided by speakers, panelists, and other attendees of the conference.

(1) **There is sufficient information on thermal exposure/effects on which to base a standard.** However, participants generally felt that more information needs to be obtained on nonthermal effects.

(2) The overwhelming consensus was that **EPA should develop some type of RF radiation exposure guidelines**, even if EPA does so on an interim basis only. Several reasons were provided for this recommendation, the foremost being that, since federal exposure limits for RF radiation do not as yet exist, a number of different exposure limits currently are being used (if at all) at the local level. Nationally based EPA exposure limits thus would help ensure a more consistent level of public health protection while also significantly easing the burden on industry caused by the current patchwork of standards (e.g., a reduction in expensive litigation, an improvement in U.S. competitiveness abroad).

In addition, speakers and panelists provided numerous specific conclusions and recommendations, as described in Section 3.

EPA used much of the information provided to develop comments on the FCC proposed adoption of RF radiation guidelines and to develop an RF radiation strategy that includes, in the near term, developing exposure guidelines based on established health effects and, over the longer term, addressing modulation. These activities are described below.

EPA COMMENTS TO FCC

Soon after the RF radiation conference (November 1993), EPA provided comments on the FCC proposed adoption of the 1992 American National Standards Institute (ANSI)/Institute for Electrical and Electronics Engineers (IEEE) standard (58 Federal Register 19393, April 14, 1993). In those comments, EPA recommended that the 1992 ANSI/IEEE standard be used only with some modification. Some issues of concern to EPA included the criteria used to select studies on which the 1992 ANSI/IEEE standard is based, the possible need for more protective exposure limits at lower and higher frequencies, the lack of a distinction between occupational and general public exposures, the need to consider athermal effects, and the need to consider pulse- and ELF-modulated RF radiation.

EPA RF RADIATION STRATEGY

Following the conference, EPA decided to develop a specific RF radiation strategy that included (1) creating an inter-agency work group to help address issues associated with establishing near-term RF radiation exposure guidelines, and (2) requesting the National Council on Radiation Protection (NCRP) to assess several of the remaining issues (e.g., the influence of extremely low frequency (ELF) and pulse modulation).

Creation of an Inter-agency Work Group on RF Radiation

EPA convened an inter-agency work group in August 1994 to address the development of RF radiation exposure guidelines. This work group, which meets regularly, is composed of representatives from various federal agencies, including EPA, FCC, the Food and Drug Administration (FDA), the National Institute for Occupational Safety and Health (NIOSH), the National Telecommunications and Information Administration (NTIA), and the Occupational Safety and Health Administration (OSHA). The work group developed a charter that describes their purpose as providing a forum to address health and regulatory issues pertaining to RF radiation, and providing a basis for coordination among member agencies in their approach to RF issues. Some critical issues that have been discussed thus far by the work group and that may be incorporated into the developing RF radiation guidelines include the following:

- General population versus worker exposures;
- Appropriate safety factors;
- The overall basis for the exposure limit;
- An acceptable temperature increase for a given SAR; and
- Local versus whole body exposures.

EPA expects to release RF radiation exposure guidelines in 1995.

NCRP Study on Modulated RF Radiation

As part of the its long-term strategy, EPA entered into a cooperative agreement with NCRP to address the issue of modulated RF radiation. NCRP intends to address the potential role of this issue in developing new RF radiation exposure limits. Factors that NCRP will consider include frequency dependence, time-averaging, modulation characteristics (e.g., wavetrain, frequency, pulse width, repetition rate), selection of an adverse effects basis, and use of uncertainty factors. The NCRP assessment of this issue may result in a recommendation that EPA include additional factors in establishing new RF radiation limits.

* * *

The RF radiation conference has generated much discussion, several recommendations, and a large amount of data. Using these results, in concert with the inter-agency work group findings and the NCRP report, EPA expects to develop guidelines in the near future and to continue monitoring the research that may result in modifications to these guidelines.

APPENDICES

APPENDIX A
A REASSESSMENT OF THE BIOLOGICAL EFFECTS OF RADIOFREQUENCY RADIATION: NONCANCER EFFECTS*,**

*Joe A. Elder****

This report is a reassessment, based on the literature available in May 1987, of the major conclusions and generalizations in the EPA report entitled Biological Effects of Radiofrequency Radiation published in 1984 (Elder and Cahill, 1984). The format of the report is as follows. Each of the 21 major conclusions and generalizations in Section 6.1 of the EPA report are given below; these are numbered 1984-1 to 1984-21. After each, a reassessment of the subject area is given based on the available literature; these are numbered 1987-1 to 1987-21. The subject areas addressed in these statements are thermal physiology; lethality; molecular, subcellular, and cellular systems; hematology and immunology; reproduction; nervous system; behavior; visual system; auditory system; cutaneous perception; endocrinology, physiology, and biochemistry; genetics and mutagenesis; and lifespan. An important subject area that is not reviewed in this report is cancer; the literature on this subject is discussed in another report.**

MAJOR CONCLUSIONS AND GENERALIZATIONS

1984-1. Radiofrequency (RF) radiation is a form of nonionizing electromagnetic radiation of very low photon energies and frequencies (0-3000 GHz), as distinguished from the very high photon energies and frequencies associated with ionizing electromagnetic radiation, e.g., X and gamma rays. Included in the RF-radiation spectrum are AM and FM radio, UHF and VHF TV, radar, and microwave communication frequencies. The frequency range of concern in this document is 0.5 MHz to 100 GHz, which includes nearly all the significant sources of population exposure except 60-Hz electrical power systems. However, there is very little information on effects in human beings at any of these frequencies and limited data on responses of animals exposed at frequencies above 10 GHz and below 10 MHz; most of the animal research is concentrated in the range of 900 MHz to 3 GHz.

1987-1. Revision: The latter part of the last sentence is changed to read: most of the animal research is concentrated in the range of 27 MHz to 3 GHz.

1984-2. RF-energy absorption by biological systems is a complex function of frequency and the dimensions, orientation, and dielectric properties of the absorber and the complexity of the

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* A Report to the Office of Radiation Programs, U.S. Environmental Protection Agency, July 21, 1987. This report is published as an appendix in these proceedings because of the importance of this assessment to the conference goal to review the post-1982 literature on biological and health effects of RF radiation. The report was written as an internal EPA document but has been distributed to the public upon request. As the title indicates, the report addressed noncancer effects.

** The more recent EPA report, Evaluation of the Potential Carcinogenicity of Electromagnetic Fields (EPA/600/6-90-005B, Review Draft, October 1990) includes a review of the literature on cancer and RF radiation. The 1990 report may be purchased from the National Technical Information Service (NTIS), 5285 Port Royal Road, Springfield, VA 22161 by requesting NTIS report #PB 91 133 231.

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incident radiation fields. Resonant frequencies (and their related wavelengths) for an absorber are those at which maximum RF energy is coupled into the absorbing system. Resonance occurs when the long dimension of the absorber is approximately 0.4 times the wavelength of the incident RF radiation, if the object is located in free space. Under these conditions, the whole-body resonant frequency range for humans (from adults to infants) is approximately 30 to 300 MHz. In this document, whole-body average specific absorption rate (SAR) is used to normalize the rate of energy absorption across the frequency range, 0.5 MHz to 100 GHz, and to quantitate the relation between biological effect and dose rate of RF radiation. SAR is the mass-normalized rate at which the energy of an electromagnetic field is coupled into an absorbing body; the units of SAR are watts per kilogram (W/kg).

1987-2. No revision.

1984-3. High level RF radiation is a source of thermal energy (e.g., microwave ovens) that carries all of the known implications of heating for biological systems. At a given incident field strength, maximal heating occurs at the resonant frequency (D'Andrea et al., 1977). In general, the data are consistent with the hypothesis that the SAR required to raise body temperature of laboratory animals decreases as body mass increases.

1987-3. Revision: Thermoregulatory effectors such as peripheral vasodilation, evaporation, metabolism, and behavior are activated during exposure to RF radiation; many effectors are activated in the absence of any measurable change in deep-body temperature. In general, the data are consistent with the hypothesis that the SAR required to increase activity of thermoregulatory effectors and to raise body temperature of laboratory animals decreases as body mass increases (Gordon and Ferguson, 1984). For example, the four effectors listed above are activated in the squirrel monkey by SARs of 0.6-1.5 W/kg (Adair, 1981; Adair and Adams, 1980ab, 1982) whereas 5.3-29 W/kg are required for the mouse (Gordon 1982, 1983, 1984; Ho and Edwards, 1977).

High-level RF radiation is a source of thermal energy (e.g., microwave ovens) that carries all of the known implications of heating for biological systems. At a given incident power density, maximal heating occurs at the resonant frequency (D'Andrea et al., 1977; Lotz, 1985). Thermoregulatory effectors activated in mammals during RF radiation exposure at levels that produce heat stress are similar to those which respond to high ambient temperature. Because of heating by RF energy absorption, dose rates of 3.6-7 W/kg are lethal to rats, rabbits, dogs, and rhesus monkeys exposed for 1-4 h at normal laboratory conditions of temperature and humidity.

1984-4. In most of the animal studies that report a biological effect of RF radiation, exposures occurred at ambient temperatures of 20 to 25°C and relative humidities of 50 to 70 percent. At more thermally stressful conditions, e.g., higher ambient temperature and the same or higher relative humidity, the experimental results show that lower SARs cause a similar biological effect. For example, Rugh et al., (1974) found that the lethal dose of 2450-MHz radiation for mice was inversely related to the temperature-humidity index. Gage (1979) showed that a 2450-MHz exposure at 22°C resulted in a reduced behavioral response rate in rats at 3 W/kg, but that similar exposures at 28°C caused reduced rates at 1, 2, and 3 W/kg.

1987-4. No revision.

1984-5. No consistent biological effect has yet been found with molecular and subcellular systems exposed in vitro to RF radiation other than effects occurring at SARs that cause general temperature increases. Conclusions regarding effects of in vitro exposure of higher-order biological systems, such as single cells and brain tissue, are given below.

1987-5. Revision: Molecular, subcellular, and cellular systems exposed in vitro to RF radiation are affected at SARs that cause general temperature increases. An example is enzyme activity which increases as the temperature of the solution is increased until thermal denaturation of the enzyme occurs. In addition to the thermal effects, there are in vitro effects on molecular, subcellular, and cellular systems, especially the cell membrane, which do not appear to be due to thermalization of RF energy. Examples include (1) modification of the structure of soluble and membrane-bound proteins that apparently affect receptor binding on the cell surface (Liburdy, 1982; Liburdy and Wyant, 1984), (2) effects at specific temperatures on ion transport across the cell membrane in both whole cells and membrane systems (Cleary et al., 1982; Fisher et al., 1982; Allis and Sinha-Robinson, 1987), (3) chain-length-dependent microwave absorption by DNA (Swicord et al., 1983), and (4) frequency-specific alterations in growth rate of yeast cells (Grundler et al., 1977; Grundler and Keilmann, 1983). Conclusions regarding electrophysiological effects on cells and other effects on central nervous system tissue exposed in vitro are given below.

1984-6. The electrophysiological properties of single cells, especially the firing rates of neurons in isolated preparations, may be affected by RF radiation at SARs as low as 1 W/kg in a manner different from generalized heating.

1987-6. No revision. The reports by Arber and Lin (1984, 1985) support the statement above.

1984-7. In general, no changes in chromosomes, DNA, or reproductive potential of RF-exposed animals have been reported and corroborated in the absence of significant rises of temperature. Similarly, RF radiation does not appear to cause mutations or genetic changes in bacterial test systems unless temperatures well above the normal physiological range are produced.

1987-7. No revision is warranted, but special mention is made of two similar studies that examined mouse sperm cells for chromosomal aberrations. Manikowska-Czerska et al. (1985) reported effects whereas Beechey et al. (1986) reported no effects over the same SAR range of 0.05-20 W/kg.

1984-8. Effects on the hematologic and immunologic systems have been reported at SARs > 0.5 W/kg; however, there is a lack of convincing evidence for RF-radiation effects on these systems without some form of thermal involvement. Some of the reported effects of RF radiation on the hematologic and immune systems are similar to those resulting from a stress response involving the hypothalamic-hypophyseal-adrenal axis or following administration of glucocorticoids. In those few cases where the reversibility of RF radiation effects on the hematologic and immunologic systems has been examined, the effects have proved to be transient.

1987-8. No revision.

1984-9. RF radiation is teratogenic at high SARs (> 15 W/Kg) that approach lethal levels for the pregnant animal. High maternal body temperatures are known to be associated with birth defects. There appears to be a threshold for the induction of experimental birth defects when a maternal rectal temperature of 41 to 42°C is reached. Any agent capable of producing elevated internal temperatures in this range, including RF radiation, is a potential teratogen.

1987-9. Revision: The reports by Berman et al. (1982) and Lary et al. (1982, 1983, 1986) support the above conclusions but show that RF radiation is teratogenic in laboratory animals at SARs of 9-11 W/kg. The exception to the preceding conclusions that are based on a number of

reports in general agreement in this subject area is the finding of terata in rats exposed at an SAR as low as 0.0001 W/kg (Tofani et al., 1986).

1984-10. Reduced fetal mass seems to occur consistently in rodents exposed during gestation to teratogenic levels of RF radiation, or at SARs somewhat less than those which cause death or malformation.

1987-10. No revision. The reports by Berman et al. (1984) and Marcickiewicz et al. (1986) support the statement above.

1984-11. There is evidence that exposure of rodents during gestation to RF radiation may cause functional changes later in life. For example, Johnson et al. (1978) observed lower body weight at weaning and in young adult rats exposed at 2.5 W/kg for 20 h/day during 19 days of gestation, and Chernovetz et al. (1975) found increased postnatal survival of rats exposed at 38 W/kg for 10 min during gestation.

1987-11. No revision.

1984-12. Permanent changes in reproductive efficiency have been directly associated with RF-radiation exposures that caused temperatures in animal testes greater than 45°C. At temperatures of 37 to 42°C mature sperm may be killed with a temporary loss of spermatogenic epithelium. Irradiation of rats at an SAR of 5.6 W/kg, which produced a core temperature of 41°C, resulted in temporary infertility.

1987-12. No revision.

1984-13. Neurons in the central nervous system (CNS) of experimental animals have been reported to be altered by acute high-level and by chronic low-level exposures (> 2 W/kg). Pulsed RF radiation may have a potentiating effect on drugs that affect nervous system function. Some of the early reports of RF-radiation effects on the blood-brain barrier (BBB) at SARs < 2 W/kg have not been substantiated by later investigations.

1987-13. No revision. The reports by Frey and Wesler (1983, 1984), Lai et al. (1983, 1984abc, 1986ab, 1987), and Thomas et al. (1979) support the statement that RF radiation, especially pulse-modulated radiation (SAR = 0.1 0.6 W/kg), may have a potentiating effect on drugs that affect nervous system function. The reports by Ward et al. (1982), Ward and Ali (1985) and Williams et al. (1984) support the statement on the blood-brain barrier.

1984-14. An increased mobilization of calcium ions occurs in brain tissue exposed in vitro to RF radiation, amplitude modulated at frequencies recorded in the electroencephalogram (EEG) of awake animals. The response appears to be based on the intensity of the electric field within the tissue, which can be related to SAR; the lowest effective SAR in in vitro samples is estimated to be 0.0013 W/kg. Calcium-ion efflux is a nonlinear effect in terms of both AM frequency and field intensity; that is, the response occurs at specific frequencies and electric field strengths. The physiological significance of this effect has not been established.

1987-14. Revision: An increased mobilization of calcium ions occurs in brain tissue exposed in vitro to RF radiation, amplitude modulated at frequencies recorded in the electroencephalogram (EEG) of awake animals. The lowest effective SAR in in vitro samples is estimated to be 0.0013 W/kg. Calcium-ion efflux is a nonlinear effect in terms of both amplitude-modulated frequency and field intensity; that is, the response occurs at specific frequencies and electric field strengths (Bawin

et al., 1975; Blackman et al., 1979, 1985; Dutta et al. 1984). Amplitude-modulated RF fields have also been shown to cause changes in calcium-ion efflux (Adey et al., 1982) and the EEG of live animals (Takashima et al., 1979).

1984-15. Some types of animal behavior are disrupted at SARs that are approximately 25 to 50 percent of the resting metabolic rates of many species. For example, changes in locomotor behavior in rats occur at an SAR of 1.2 W/kg, and alterations in thermoregulatory behavior in squirrel monkeys occur at an SAR of 1 W/kg. Decreases in other operant or learned behavioral responses during exposure have been found at an SAR of 2.5 W/kg in the rat and at 5.0 W/kg in the rhesus monkey. The reported behavioral alterations appear to be reversible with time.

1987-15. No revision.

1984-16. Changes reported in endocrine gland function and blood chemistry are similar to those observed during increased thermoregulatory activity and heat stress, and are generally associated with SARs > 1 W/kg. Exposures of sufficient intensity to produce whole-body heating produce an increase in heart rate similar to that caused by heating from other sources. Changes in whole-body metabolism have been reported following exposures at thermal levels (~10 W/kg), and brain energy metabolism is altered at levels as low as 0.1 W/kg following irradiation of the exposed surface of the brain of anesthetized animals.

1987-16. Revision: Changes reported in endocrine gland function and blood chemistry are similar to those observed during increased thermoregulatory activity and heat stress, and are generally associated with SARs > 1 W/kg. Exposures of sufficient intensity to produce whole-body heating produce an increase in heart rate similar to that caused by heating from other sources. Frequency-dependent changes in brain energy metabolism have been reported following irradiation of the exposed surface of the brain of anesthetized animals (Sanders and Joines, 1984). The effect of RF radiation on whole-body metabolism, a thermoregulatory effector, is included in 1987-3.

1984-17. A single acute exposure of the eye to high-intensity RF radiation, if applied for a sufficient time, is cataractogenic in some experimental animals. In the rabbit, the animal most often used in ocular studies, the cataractogenic threshold for a 100-min exposure is 150 mW/cm^2 (138 W/kg peak absorption in the lens). The cataractogenic potential of microwave radiation varies with frequency; the most effective frequencies for cataracts in the rabbit eye appear to be in the 1- to 10-GHz range. Cataracts were not produced in primates exposed acutely to RF-radiation conditions that caused cataracts in lower mammals such as the rabbit. The absence of cataracts in the primate is attributed to the different facial structure that caused a different pattern of adsorbed energy in the eye. No cataracts have been reported in rabbits after whole-body, far-field RF-radiation exposures, even at near-lethal levels (SAR = 42 W/kg for 15 min). No data at present support a conclusion that low-level, chronic exposure to microwave radiation induces cataracts in human beings, although some studies have associated ocular-lens defects with microwave radiation exposure.

1987-17. No revision in the statement on cataracts and other ocular-lens effects is warranted. An effect on another part of the eye has been reported by Kues et al. (1985) who found that exposure of the primate eye to pulsed RF radiation (average SAR = 2.6 W/kg) caused death of corneal endothelial cells.

1984-18. Pulsed RF radiation in the range 216 to 6500 MHz can be heard by some human beings. The sound associated with the "RF hearing" varies with pulse width and pulse-repetition rate and is described as a click, buzz, or chirp. The threshold for human perception of this effect is approximately 40 $\mu J/cm^2$ (incident energy density per pulse). The most generally accepted mechanism

for the RF-auditory sensation is that the incident pulse induces a minuscule but rapid thermoelastic expansion within the skull, which results in a pressure wave that is conducted by the bone to the cochlear region of the ear.

1987-18. No revision.

1984-19. For the broad range of frequencies between 0.5 MHz and 100 GHz, cutaneous perception of heat and thermal pain may be an unreliable sensory mechanism for protection against potentially harmful RF-radiation exposure levels. Many frequencies deposit most of their energy at depths below the cutaneous thermal receptors.

1987-19. Revision: For the broad range of frequencies between 0.5 MHz and 100 GHz, cutaneous perception of heat and thermal pain may be an unreliable sensory mechanism for protection against potentially harmful RF radiation exposure levels because (1) RF energy can be absorbed below the cutaneous thermal receptors and (2) adverse effects occur at temperatures below the threshold (45°C) of thermal pain.

1984-20. There is no convincing evidence that exposure to RF radiation shortens the lifespan of human beings or experimental animals or that RF radiation is a primary carcinogen (cancer inducer); however, (1) few studies have used longevity or cancer incidence as endpoints, and (2) human studies have lacked statistical power to exclude life shortening or cancer. There is evidence from one group of investigators that chronic exposure to RF radiation (SAR = 2 to 3 W/kg) resulted in cancer promotion or co-carcinogenesis in three different tumor systems in mice; the incidence of cancer was comparable to that observed in mice exposed to chronic stress conditions only.

1987-20. The statement on the effect of RF radiation exposure on the lifespan of experimental animals remains valid.

The literature on cancer and RF radiation is reviewed in another EPA report.**

1984-21. Human data are currently limited and incomplete but do not indicate any obvious relationship between prolonged low-level RF-radiation exposure and increased mortality or morbidity, including cancer incidence.

1987-21. The literature on cancer and RF radiation is reviewed in another EPA report.**

Revision: Mathematical models of thermoregulatory responses in human beings can be used to predict RF exposure conditions which may cause undesirable temperatures in the body. At conditions such as those that occur in heat-wave episodes, whole-body SARs of 1-4 W/kg at 70 MHz are estimated to cause an undesirable core temperature (39.2°C) in healthy human beings in one hour (Durney et al., 1978). A more sophisticated model predicts significant temperature increases in various parts of the human body at a whole-body SAR of 2.25 W/kg at 80 MHz and an ambient temperature of 30°C (Spiegel et al., 1980).

Spiegel (1982) has also modeled the thermal response of the human being in the near-zone of a 45 or 200-MHz antenna. The lower frequency antenna was located 18.6 cm in front of the human body and the other antenna was placed 10 cm in front of the face. The 45 MHz frequency represents the resonant frequency for an adult human being (electrically grounded) and the 200 MHz frequency is near the resonant frequency (375 MHz) of the head (Hagmann et al., 1979). In a thermally neutral environment (30°C, 30% relative humidity), high RF power produced temperature increases in various body regions that are clearly hazardous. For example, at 200 MHz (400 W

antenna input power), a whole-body SAR of 2.44 W/kg caused a 5°C rise in neck temperature to the critical temperature of 42°C where protein denaturation and other adverse cellular effects occur. At 45 MHz (600 W antenna input power), a whole-body SAR of only 0.64 W/kg produced 42°C in the ankles. In all mammals tested, the threshold temperature (42°C) of cellular injury is below the threshold (45°C) of thermal pain (Hardy et al., 1967).

The limitations in knowledge of the effects of RF radiation on blood flow, sweating, and vasodilation, lead to the concluding remarks on the combined RF-heat-transfer models. The physiologic responses incorporated into the models are those of humans exposed to high ambient temperatures and/or exercise, but not to RF-radiation. Thus, the models calculate physiologic responses to RF-radiation exposure as if the responses are the same as those of humans subjected to natural forms of heat stress (e.g., exercise and/or radiant or convective heat). At this time, the similarity of response between RF-radiation exposure and heat stress from exercise or exposure to high ambient temperature or febrile responses is under debate because of the uniqueness of RF-energy absorption within the body. Nevertheless, the models are useful approximations for predicting hazardous core and localized temperatures in the human body exposed to ambient conditions that exist both in the work place and in the environment.

SUMMARY

The conclusion of the 1984 EPA report on the Biological Effects of Radiofrequency Radiation is as follows: The review of the currently available literature on RF radiation provides evidence that biological effects occur at an SAR of about 1 W/kg; some of them may be significant under certain environmental conditions. Based on the review of the literature available in May 1987 on noncancer effects, it is concluded that exposure to RF radiation causes biological effects at SARs above and below 1 W/kg; some of the effects which occur at about 1 W/kg may be significant under certain environmental conditions. The biological significance of the effects which occur at SARs below 1 W/kg including those which occur at specific temperatures different from the physiological temperature range, specific frequencies or at specific amplitude-modulation conditions is not established.

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This report has been subjected to the scientific peer review procedure of the Health Effects Research Laboratory. The conclusions are those of the author, therefore the report does not necessarily reflect the views of the Agency.

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APPENDIX C
OTHER CONFERENCE ATTENDEES

Approximately 150 other people (i.e., in addition to the speakers and panelists) attended EPA's April 26 and 27, 1993 Radiofreqruency Radiation Conference that was held in Bethesda, Maryland. These attendees represented a wide range of organizations, including international, federal, state, and local governments/groups; academia; the private sector; trade/professional/environmental associations; and the general public. Furthermore, the conference was covered extensively by the television, radio, and print media.

Many of these other conference attendees, and their organizations (if known), are listed below.

Attendee	Organization
Yahya Akyel	Ogden BioServices Corp.
Patricia Axelrod	--
Elizabeth Balcer-Kubiczek	University of Maryland, School of Medicine
Charles Barna	Multi-National Business Services, Inc.
Howard Bassen	U.S. Food and Drug Administration
Jim Beddard	U.S. Naval Medical Research and Development Command
J. P. Blanchard	Bechtel Corporation
Robert Blank	R & B Enterprises
William Boivin	U.S. Food and Drug Administration
Aviva Brecher	U.S. Department of Transportation, Volpe National Transport Systems Center
John Brewer	U.S. Air Force
Christine Brito	Bearco, Inc.
Michael Buccigrossi	U.S. EPA, Region 2
George Carlo	Health and Environmental Sciences Group
Candy Castle	McCaw Cellular Communications
John W. Cavilia	Travelers Insurance Company
Steven V. Chiusano	U.S. Department of Defense
Bill Clark	Tennessee Valley Authority
Harvey D. Cohen	Midwest Research Institute
Jules Cohen	Jules Cohen and Associates
Cilie Collins	Cellular Telecommunications Industry Association
S.C. Crawford	MPH Industries, Inc.
Larry Cress	U.S. Food and Drug Administration
Robert Damiano	Loral Microwave Narda
John Davidson	U.S. EPA, Office of Policy, Planning and Evaluation
Christopher C. Davis	University of Maryland, Electrical Engineering Department
Evan B. Douple	National Academy of Sciences
S.K. Dutta	Howard University, Department of Biology
Steven Einhorn	Burson-Marsteller
Kenneth S. Eisenberg	Bearco, Inc.
Elizabeth Ellis	Electronic Industries Association
Wagih Z. Fam	--
David E. Farrand	U.S. Marine Corps, Headquarters

Attendee (cont'd)	Organization (cont'd)
Maurice Foushee	National Capital Planning Commission
James Futch	State of Florida, Department of Health and Rehabilitative Services, Office of Radiation Control
Thomas D. Gallacher	The Boeing Company
Paul Gehrmann	IBM Corp.
Diana Giammarco	Biotechnology, Inc.
Lynne Gillette	U.S. EPA, Office of Radiation and Indoor Air
Michael Ginevan	Step 5 Corporation
Zory R. Glaser	U.S. Food and Drug Administration, Office of Medical Devices and Diagnostic Products
David Glassman	Travelers Insurance Company
Daniel Gluck	The Johns Hopkins University, Applied Physics Laboratory
Melissa Julia Gluck	--
Robert Goldberg	Information Ventures, Inc.
Ricardo Gonzalez	University of Puerto Rico, Department of Radiological Sciences
Robert D. Greenberg	U.S. Federal Communications Commission
Martin Halper	U.S. EPA, Office of Radiation and Indoor Air, Radiation Studies Division
G. H. Harrison	University of Maryland, School of Medicine
Dwight Heasty	Eldyne, Inc.
Paul Heroux	McGill University, School of Occupational Health
Susan Hersemann	Health and Environmental Sciences Group
Charles W. Hicks, Jr.	U.S. Army Environmental Hygiene Agency
Edward L. Hunt	--
Dave Janes	Risk Analysis Corporation
Ana Gutierrez Johnson	--
Ronald Kaczmarek	U.S. Food and Drug Adminstration
Sharon Katz	Electronic Industries Association
John J. Keller	The Wall Street Journal
William P. Kirk	PA Department of Environmental Resources, Bureau of Radiation Protection
K. Jack Kooyoomjian	U.S. EPA, Science Advisory Board
Terry Kues	Johns Hopkins University, Applied Physics Lab
John M. Kusek	Kustom Signals, Inc.
Emanuel Landau	American Public Health Association
Sean P. Lannon	Datawaze, Inc.
John A. Leonovitch	Batelle Pacific Northwest Laboratory
A. George Lieberman	National Institute of Standards and Technology, Office of Law Enforcement Standards
Daniel E. Lilly	Travelers Insurance Company
Gregory Liposchak	Rayethon Company
Carol Lippincott	Ketchum Public Relations
Eugene Lipsky	International Medical Equipment, Ltd.
Gary R. Login	Beth Israel Hospital, Harvard University, Department of Pathology
Garner Lowe	U.S. Department of Defense
Ilmar Lusis	Lockheed Corporation

Attendee (cont'd)	Organization (cont'd)
Dan Lyle	U.S. Food and Drug Administration, Radiation Biology Branch
Charles Lynk	Motorola
Joyce Malleck	Motorola
Johnna Matthews	Burson-Marsteller
Stewart Maurer	New York Institute of Technology, Department of Electrical Engineering
Paul McClashey	--
Dinah D. McElfresh	Electromagnetic Energy Policy Alliance
Michael E. McKaughan	U.S. Coast Guard Academy
Nancy McVeker	Sun Sentinnel
Karl Mendenhall	U.S. Navy, Bureau of Medicine and Surgery
Bill Miller	Environmental Priorities, Inc.
Ray Millington	Motorola
DeLee F. Minner	Howard University, Department of Physiology and Biophysics
Patrick Moyroud	Computer Chronicles
A.S.M.I. Nazar	Howard University, Department of Biology, Molecular Biology Laboratory
Jeremy Nobel	Harvard School of Public Health, Department of Environmental Health
Mark Oivm	O'Connor, Cohn, Dillon, & Barr
Bill Orlando	Nuero Magnetic Systems
Alakananda Paul	Howard University, Electrical Engineering Department
Carl S. Pavetto	Mission Research Corp.
Chuck Peltier	International Association of Chiefs of Police
Peter Polson	Ausa Research
Elliot Poston	National Institute of Health, Division of Research Grants
Tim Powers	Burson-Marsteller
Thomas G. Raslear	Walter Reed Army Institute of Research, Department of Microwave Research
James Repace	U.S. EPA
Allen Rose	National Institute of Standards and Technology
Lee Rosen	National Institute of Health, Division of Research Grants
William Ruppert	Kustom Signals
Robert Schell	State of Maine, Radiation Control Program
Robert Schneider	--
Richard B. Shepard	University of Alabama at Birmingham, Department of Surgery
Riaz A. Siddiqui	GE American Communications
Louis Slesin	Microwave News
David H. Sliney	U.S. Army Environmental Hygiene Agency, Laser Microwave Division
Jeff Snyder	U.S. Department of Labor, Occupational Safety and Health Administration
Marilyn Sommer	BEMS
Robert A. Stark	Naval Surface Warfare Center, White Oak Detachment
Richard R. Strickland	Loral Microwave Narda

Attendee (cont'd)	Organization (cont'd)
Paul Strudler	National Institute of Health, Radiation Study Section, Division of Research Grants
Carl H. Sutton	Medical College of Wisconsin (Neurosurgery), VA Medical Center
John Thompson	U.S. Coast Guard
Larry Toburen	National Academy of Sciences
Tynes Tore	Cancer Registry of Norway
Paul D. Tveten	Navy Environmental Health Center
Barry Umansky	National Association of Broadcasters
Steven Vipavetz	Naval Sea Systems Command
Pamela Vossenes-Fernandez	American Public Health Association
Paul Wagner	U.S. EPA, Region 4
Donald L. Walker	Motorola
Edward Washburn	U.S. Department of Energy, Office of Epidemiology and Health Surveillance, Environmental Safety and Health
Dorothy Wellington	--
Kelly Williams	National Association of Broadcasters
Bary Wilson	Battelle-Pacific Northwest Laboratory
John Wykoff	MBH Industries
Robert Yacovissi	Department of the Navy, Bureau of Medicine and Surgery
Gary Zeman	AT&T Bell Labs
B.C. Zook	George Washington University

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15. SUPPLEMENTARY NOTES

16. ABSTRACT

On April 26 and 27, 1993, the U.S. Environmental Protection Agency (EPA) Office of Air and Radiation and Office of Research and Development held a conference to assess the current knowledge of biological and human health effects of radiofrequency (RF) radiation and to address the need for and potential impact of finalization of federal guidance on human exposure to RF radiation. More than 200 people attended the conference. Attendees represented the federal government, academia, the private sector, trade associations, the media, and the public. Plenary papers presented at the meeting focused on current research findings on a variety of topics, including exposure assessment, dosimetry, biological effects, epidemiology, the basis for exposure limits, and emerging health issues. Panel discussions focused on identifying key scientific information needs for and the policy implications of the development of further EPA guidance on human exposure to RF radiation. This document, Volume 1, provides a record of much of the information presented at the conference, outlines key recommendations provided to EPA by conference participants, and presents the EPA strategy for addressing RF radiation. Volume 2, under separate cover, provides the plenary papers presented by invited speakers.

Two key conclusions emerged from the conference: (1) there is sufficient information on thermal exposure/effects on which to base an RF radiation exposure standard; and (2) EPA should develop some type of RF radiation exposure guidelines. These conclusions were considered by EPA in its decision to proceed with the development of guidelines on human exposure to RF radiation and to develop a longer term strategy to address remaining issues. Part of this strategy has involved creating an inter-agency work group and requesting the National Council on Radiation Protection (NCRP) to assess several remaining issues. Information provided at the conference also was used as a basis for EPA comments to the Federal Communications Commission (FCC) 1993 proposal to adopt the RF radiation exposure guidelines developed in 1992 by the American National Standards Institute (ANSI) and the Institute for Electrical and Electronics Engineers (IEEE).

17. KEY WORDS AND DOCUMENT ANALYSIS

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