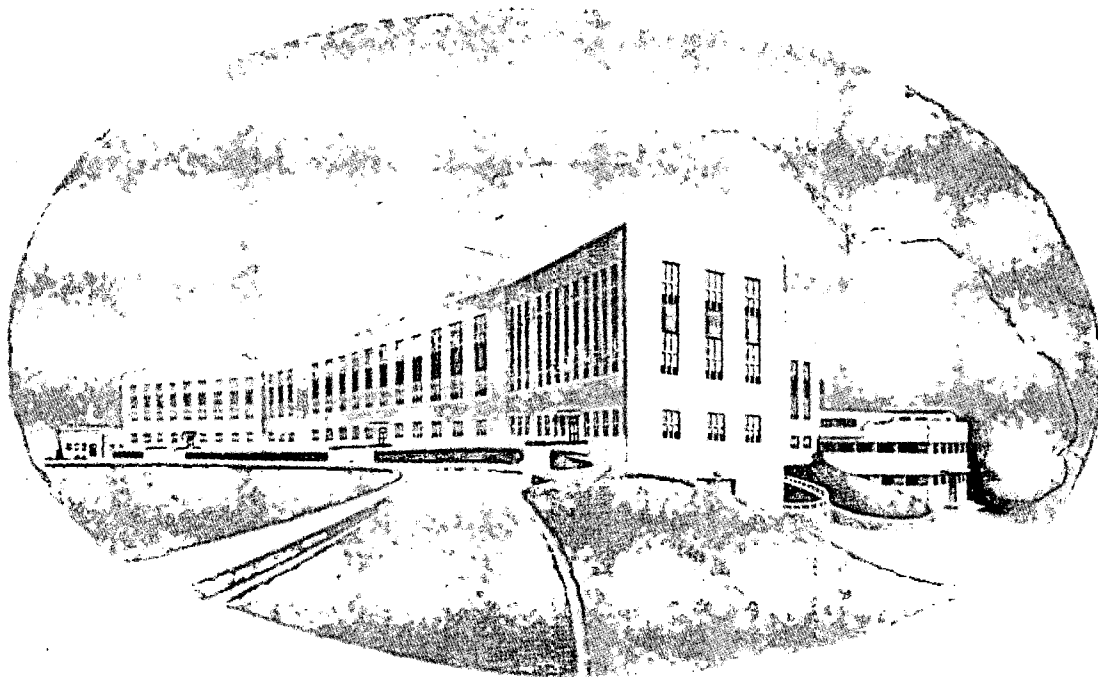


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# NAVAL MEDICAL RESEARCH INSTITUTE



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BIBLIOGRAPHY ON SAFE HUMAN THRESHOLDS TO  
EXTRA-LOW-FREQUENCY ELECTRIC CURRENT

Research Report

MR005.08-0030B

Report No. 2

BIBLIOGRAPHY ON SAFE HUMAN THRESHOLDS TO  
EXTRA-LOW-FREQUENCY ELECTRIC CURRENT

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Research Report  
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## ABSTRACT

Over one thousand references on electric shock hazards and electrical safety are included from three computer retrievals, a sixty-hour Library of Congress search and contributions from over 50 organizations and individuals. The citations are divided into sections according to subject matter and arranged alphabetically by author within each section.

Emphasis is upon published original experimental work concerning physiological thresholds to electric current at power transmission frequencies. Experimental work on biological impedances and on the pathophysiology of electric shock is also represented extensively. Clinical reports of pathological sequelae of electric shock are categorized, as are electrical safety standards in industry, agriculture and medicine. A few biological references obtained on peripherally-related subjects such as electroanesthesia, electroconvulsive therapy and legal execution are included. Finally, selected general reviews are presented.

Bibliography  
Electrical safety standards  
Electrical shock  
Physiological thresholds

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## I. INTRODUCTION

### 1. Previous Bibliographies:

Several bibliographies on electric shock hazards and electrical safety standards have been compiled since 1954 when the American Institute of Electrical Engineers printed as Publication S-69 the thirty-four page "Bibliography on Electrical Safety -- 1930-1953" by AIEE members J. A. Gienger and R. L. Lloyd. This bibliography is organized chronologically within five sections: 1) electrical accidents, 2) accident prevention methods, 3) effects of electric shock, 4) resuscitation, and 5) safety codes and standards.

In 1956 Wills Maclachlan, a pioneer in industrial electrical safety, collected and compiled in 98 typewritten pages a "List of articles, books, and reports on electrical shock and correlated subjects." This alphabetical list is no longer available as the CIS "Electrical Accident Bibliography" from the International Labour Organization, but both of these early bibliographies can be found in the Engineering Societies Library, 345 East 47th Street, New York, N. Y. 10017.

Interest in the literature of electric shock hazards and electrical safety has been renewed recently, mainly because of the potentially lethal effects of extremely small alternating electrical currents which can be introduced into the human body inadvertently during some of the new and increasingly prevalent biomedical engineering techniques such as angiography, cardiac catheterization, and cardiac pacing. The two bibliographies mentioned below, which have recently been received through the generosity of their authors, emphasize potential electrical hazards of biomedical engineering.

On 1 July, 1969, Beckman Corporate Research Activities (2500 Harbor Blvd., Fullerton, California 92634) issued as Report MRR20 a "Bibliography on Hazards, Safety and Standards in Biomedical Engineering," which Allan F. Pacela of Beckman Instruments Inc. has been collecting for the Safety Standards Committee of the Group on Engineering in Medicine and Biology of the Institute of Electrical and Electronics Engineers (IEEE). This twenty-page bibliography is divided into ten subject categories: 1) anesthetic explosion hazards, 2) clinical and research shock hazards, 3) deaths and accidents due to electrical shock, 4) design of instruments and apparatus, 5) electrical burns and injuries, 6) government training pamphlets, 7) physiological effects of electrical shock, 8) resuscitation, 9) standards, codes, guides, and regulations, and 10) miscellaneous references.

Another pertinent bibliography, dated September 1969, has been compiled by Professor Paul E. Stanley of the School of Aeronautics, Astronautics and Engineering Sciences, Purdue University, Lafayette, Indiana 47907. This is called a "Chronological Bibliography on Electric Shock Hazards in Medicine" and includes nine pages of references from 1905 to 1969.

## 2. Present Sources:

The present bibliography was collected to help in preparing NMRI Research Report No. 1, MR005.08-0030B, entitled, "Minimum thresholds for physiological responses to flow of alternating electric current through the human body at power-transmission frequencies".

Three computer-assisted literature searches were specially conducted. A Medlars search of medical citations from January 1964 to May 1969 was performed at the National Library of Medicine, Bethesda, Maryland. A NASA Literature Search on "Electric Shock to Humans" and a Defense Documentation Center (DDC) Search on "Standards for Electrical Safety" were also performed by computers, and each yielded unique pertinent citations. The National Bureau of Standards Clearinghouse for Federal Scientific and Technical Information (CFSTI) and the Science Information Exchange of the Smithsonian Institution made contributions from their regular information retrieval services.

The staff of the Library of Congress Reference Department performed a sixty-hour search of Electrical Engineering Abstracts, Applied Science and Technological Index, Engineering Index and Library of Congress catalogues from 1945 to June 1969 for citations in the non-medical literature. They also conducted a "pre-Medlars" search of Medical Abstracts and Cumulated Index Medicus from 1944 to 1964.

The Canadian Standards Association, the Washington Branch of the International Labour Office, the National Safety Council, and the U. S. Public Health Service Environmental Control Administration responded to our inquiries with many useful citations. The Industrial Hygiene Foundation of America Inc. of Pittsburgh, Pa., contributed 161 abstracted references from its files.

Mr. C. A. Bentel and Mr. A. W. Smoot of the Electrical Department of Underwriters' Laboratories Inc. were particularly helpful by providing a list of articles on body impedance and by directing attention to the earlier bibliographies. Dr. Dietrich Beischer of the Naval School of Aviation Medicine, Professor C. F. Dalziel of the University of California, Mr. L. H. Isaacson of the Veterans Administration, Dr. W. R. Lee of the University of Manchester, Mr. David Lubin of Sinai Hospital of Baltimore, Mr. John Maccioli of the Naval Safety Center, Mr. R. T. Mallard of General Electric Company, and Mr. B. M. Savaiko of the Army Electronics Command kindly contributed pertinent references from their personal files.

Most of the citations in this bibliography have been verified from the original articles or reproductions of them. The staff of the Technical Reference Library of NMRI -- in particular, T. P. Robinson, E. Gendleman, E. S. Capps, and H. Z. Levy -- have been characteristically diligent and resourceful in obtaining the requested references. A. M. Woke of NMRI kindly translated articles written in German, and Dr. F. S. Letcher of NMRI read and reported upon those written in Russian. Where

the citation of an article has not been checked against the original, the words "not verified" appear in parentheses at the end of the citation. All verified articles were read for the NMRI Report No. 1 mentioned above.

### 3. Present Emphasis:

The purpose of this literature search was to aid in determining generally acceptable safe minimum human thresholds for extra-low-frequency electric current. Thus the emphasis has been upon published original experimental data on physiological thresholds to electric current at power transmission frequencies. It is hoped that the citations are comprehensive of all readily available literature in these categories. Experimental work on biological impedances and on the pathophysiology of electric shock, if not completely cited, is at least well represented. Considerable effort was also made to obtain codes and standards of electrical safety established in the construction and electrical industries and within the military. In the process of collecting these above subjects, numerous references to possible electropathological sequelae and fatal case reports were also obtained, which are categorized without any pretense to completeness. The few citations on peripherally related subjects which were received are offered as potential leads to a more complete literature on the subject.

### 4. Acknowledgements:

In addition to the kind cooperation and assistance of the people and organizations mentioned above and in the companion NMRI report, in particular the extensive help of H. Z. Levy in bibliographic editing and of F. M. Epstein in assembling the final report is gratefully acknowledged.

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