TECHNICAL CONCEPT—OPERATION HENRE

F. F. Haywood
J. A. Auxier

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CIVIL EFFECTS TEST OPERATIONS
U.S. ATOMIC ENERGY COMMISSION
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TECHNICAL CONCEPT - OPERATION
HENRE

By

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Oak Ridge National Laboratory
Oak Ridge, Tennessee
February 1965
NOTICE

This report is published in the interest of providing information which may prove of value to the reader in his study of effects data derived principally from nuclear weapons tests and from experiments designed to duplicate various characteristics of nuclear weapons.

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ABSTRACT

A small but intense source of 14 Mev neutrons is to be mounted in the hoisting mechanism of the 1500-ft BREN tower at the Nevada Test Site. The experimental program, designated Operation HENRE, will be conducted during the spring and summer of 1965 and will be sufficiently comprehensive to characterize the radiation fields. In addition, a series of applied shielding experiments will include configurations of interest to both military and civilian laboratories. It is important that data be accumulated which will assist in understanding the apparent uncertainties in existing transport calculations, especially data which will give approximate values for effective neutron cross sections for air-over-ground transport.

The neutron source will be operated at heights from about 25 ft to 1500 ft above the air-ground interface. The average neutron yield during operational periods of about 4 hours is expected to be equal to or greater than $10^{13}$ n/sec.
ACKNOWLEDGEMENTS

This report includes contributions from the Program Directors listed in the organizational chart given in Chapter 5. The authors are also indebted to the Scientific Advisory Committee for helpful suggestions, to the Technical Director's staff for Operation BREN, and to the Civil Effects Test Operations staff.
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Chapter 1

INTRODUCTION

As a result of research accomplished during Operation BREN in 1962, it has been proposed that a monoenergetic point neutron source be constructed and operated on the same tower. The field experiment which would be conducted at this time has been designated as Operation HENRE (High Energy Neutron Reactions Experiment). In order to obtain a significant particle fluence at distances to 1500 meters, the most feasible method (because of weight and size limitations) is a positive ion accelerator employing the T(d,n)^4He reaction. The accelerating energy of the D^+ ions would be approximately 150 kv.

In January 1964, a group was formed at ORNL to undertake a detailed feasibility study concerning the design, construction, and operation of such a neutron source. This study group was made up of employees of the ORNL Health Physics and Thermonuclear Divisions, members of the U. S. Army, and employees of Edgerton, Germeshausen and Grier, Inc. Specifically, the feasibility study was to determine if an accelerator could be constructed so that it would: (1) meet the weight and volume restrictions compatible with the present hoisting mechanism on the 1500-ft tower, and (2) be capable of producing an average of 10^{13} n/sec for a period of 4 hrs. By May 1964, the study had resulted in the conclusion that it was feasible to build such an accelerator and have it perform satisfactorily.¹

Technology in the fields of target and ion source development has advanced markedly. Titanium-tritide targets have been tested with a resulting neutron yield of 9.5 \times 10^{10} neutrons per second per milliamp of unanalyzed beam with a target half-life of 2 to 4 hrs. A highly reliable duoplasmatron ion source has been developed by the Thermonuclear Division for the injection of high-beam currents into the DCX-1 and DCX-2 machines.² This type ion source has been chosen for use in the HENRE neutron source because it has been demonstrated to be reliable and stable and has been operated at a beam current of 300 ma for 4 hrs. Thus, a target yield of 9.5 \times 10^{10} n/sec-ma with a 2-hr half-life and an ion source operating at 300 to 500 ma would produce 2.8 to 4.8 \times 10^{13} n/sec so that the average neutron yield for 4 hrs would be >10^{13} n/sec. Neutrons produced in this machine would be emitted from a tritium target of approximately 1000 cm² in area. The ion beam is allowed to "blow up" (see Fig. 1.1) so that the heat produced in the target may be dissipated easily.

The neutron source for Operation HENRE will be placed on the BREN tower at the Nevada Test Site (Fig. 1.2). A preliminary layout of the components of the neutron source is shown in Fig. 1.3.
ACCELERATOR VACUUM MANIFOLD

TRITIUM TARGET (~145kV)

ION SOURCE AT GROUND POTENTIAL

EXTRACTOR ELECTRODE AT -150 kV

INSULATOR

D\textsubscript{2} GAS LEAK

D\textsuperscript{+} BEAM

VACUUM ~3\times10^{-6} \text{ mmHg}

CORONA DOME

INSULATOR GUARD RINGS

Fig. 1.1—Simplified diagram of HENRE neutron source
Fig. 1.2—Area Four Nevada Test Site
Fig. 1.3—Layout of components for HENRE neutron source
REFERENCES


Chapter 2

GENERAL OPERATING AND EXPERIMENTAL PROCEDURES

2.1 OPERATION PROCEDURE

The primary experimental program of Operation HENRE requires that the neutron source be operated for 130 to 150 hrs at intensities $\geq 1 \times 10^{13}$ n/sec. The operating cycle will be set tentatively for three 4-hr operations each week; i.e., a 4-hr operation one day, with the following day reserved for routine machine maintenance and data analysis. Any deviations from the general operating schedule will be at the discretion of the Technical Director. Requests for non-routine operation of the neutron source would be granted providing the following conditions were met:

1. The time required for neutron source operation fell during the regular scheduled workweek.
2. The consumption of tritium targets at that time is within the programmed use rate.
3. There is no serious conflict with the routine duties of the operation crew.

There will be limited access to the area near the tower during operation. The exact location of barricades or signs, which indicate how close personnel will be allowed to approach the tower, will depend on the results of radiation surveys. The basis for such barricades or signs will be an exposure level of 100 mrem/wk. A sweep of the experimental area will be done before startup by persons appointed by the Technical Director or by the NTS guard force. Barricades and flashing lights will be utilized on roads leading into Area 4, and a guard will be on duty during operational periods. Those persons participating in Operation HENRE at NTS will be monitored according to current practices of NTS Rad-Safe. Red and blue beacons will be utilized. The red beacon will represent "high voltage on" and the blue beacon will indicate that the ion beam is being accelerated, i.e., the neutron source is on.

2.2 EXPERIMENTAL PROCEDURE

The neutron source will be operated for periods ordinarily 4 hrs in length at heights ranging from about 25 ft to 1500 ft above the ground. Specific heights and corresponding times at each height were determined after reviewing the proposed experimental programs. There will be periods of scheduled non-operation for purposes of reviewing data and programming subsequent operations. Because of a relatively heavy operational schedule requested by the DASA-supported laboratories, the programs designed to characterize the radiation fields will be conducted first. For this reason, the neutron source will be operated first at a height of 1500 ft, then at successively lower levels down the length of the tower. The requirements for source operation are given in Table 2.1.
Table 2.1—PROJECTED OPERATIONAL PERIODS

<table>
<thead>
<tr>
<th>Source Height</th>
<th>Minimum No. 4-hr runs</th>
<th>Optimum No. 4-hr runs</th>
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<tr>
<td>1500 ft</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>1125 ft</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>500 ft</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>300 ft</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>108 ft</td>
<td>18</td>
<td>25</td>
</tr>
<tr>
<td>54 ft</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>27 ft</td>
<td>4</td>
<td>8</td>
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</tbody>
</table>
Chapter 3

EXPERIMENTAL PROGRAM

3.1 GENERAL OBJECTIVES

The complement of experimental programs which are listed in this chapter do not represent necessarily the final design of the field experiment. This information is representative of the programs proposed by the individual organizations which will participate in Operation HENRE.

Operating time for the initial main body of experiments must be limited because of the costs associated with target fabrication. Operation HENRE is budgeted for 130 to 150 hrs of operation at an average yield of $10^{13}$ n/sec. Additional time will be available utilizing the same tritium targets, but the yield will be less than $10^{13}$ for most of this time.

The following sections represent the experimental programs as they were submitted to the office of the Technical Director. More detailed program descriptions have been submitted and are now under review by the Operation HENRE Scientific Advisory Committee; these descriptions will appear in the Operations Plan.

3.2 SPECIFIC OBJECTIVES AND TECHNIQUES

3.2.1 Program 1 - Directed by John A. Auxier, Oak Ridge National Laboratory

The purpose of this program is to describe, through the techniques of dosimetry and spectrometry, the "free-field" characteristics of the radiation field associated with a point source of 14 Mev neutrons positioned as high as 1500 ft above the air-ground interface. Interactions of radiation with matter will be studied by utilizing the same techniques but applied to measurements in phantoms and lightweight frame dwellings.

Measurements of dose and spectrum will be made as a function of source height, detector height, and angle of incidence for several horizontal positions. The probable source heights are 25, 100, 300, 500, 1125, and 1500 ft. The respective optimum times at these heights are 12, 12, 8, 8, 12, and 12 hrs.

Electronic particle counters to monitor neutron dose and spectrum from thermal energies to 14 Mev and nuclear emulsions for neutron energy spectrum will be used. For measurements of gamma exposure, the Halogen-quenched geiger counter with energy filter according to the principle set forth by E. B. Wagner, et al., 1 will be used. Scintillation techniques will be used for measuring gamma-ray spectra.

3.2.2 Program 2 - Directed by Thomas R. Jeter, Ballistic Research Laboratories

Incident and transmitted neutron spectra will be measured for several selected shield enclosures using lithium-6 and helium-3 sandwich-type solid-
state spectrometers, and incident and transmitted gamma spectra will be measured using stilbene scintillator and pulse-shape discriminator. Hurst-type proportional counters will be used for measuring fast neutron dose; gamma dose will be measured with gamma dosimeters and inferred from gamma spectra.

Using each shield (4 total), neutron spectra will be accumulated at 27, 54, and 108 ft from the tower at source heights of 27, 54, and 108 ft. Spectra will be accumulated for three configurations for each shield. This will be accomplished by varying the amount of water in voids of each shield. Using a pulse-shape discriminator, similar runs will be made at slant ranges to 2000 ft from the source. It is planned to run gamma and neutron measurements simultaneously but on different shields. Operating time for neutron spectrometers will be 4 to 6 hrs; operating time for gamma spectrometers will be 1/4 to 1 hr.

3.2.3 Program 3 - Directed by F. M. Tomnovec, U. S. Naval Radiological Defense Laboratory

To determine the neutron distribution in air, ground, and field fortifications, a variety of thermal and fast neutron detectors will be used. Thermal neutron detectors will be inserted into the ground and field fortification interior walls and then removed for counting after each run. It is estimated that the program will need 16 hrs at a source height of 27 ft and 12 hrs at a source height of 300 ft. The bulk of the measurements will be made within 30 yds of the base of the tower, but some measurements will be made at greater distances. It is proposed to place a series of neutron threshold detectors along one of the support wires of the tower to record the energy distribution of the neutrons from the source as a function of distance in the air. The neutrons would be from operations at heights greater than 300 ft on the basis of availability.

3.2.4 Program 4 - Directed by H. Wade Patterson, Lawrence Radiation Laboratory, Berkeley

The objective of this project is to measure the attenuation of fast neutrons from a monoenergetic source at several distances and at several source heights. The use of BF₃ proportional counters and foil activation techniques is planned.

The first operation would be the simultaneous measurement of neutron flux at several distances from the tower using activation techniques. These measurements would be accomplished at several source heights. Based upon the information gained, proportional counter measurements will then be taken at the same detector stations and source heights.

3.2.5 Program 5 - Directed by Ralph E. Rexroad, Nuclear Defense Laboratory

The objective of this project is to determine the distribution of 14 Mev neutrons and secondary gamma photons in open and covered cylindrical holes in the ground. Additionally, basic information on the propagation of 14 Mev neutrons and secondary gamma photons at the air-ground interface will be obtained.

Neutron spectrum and dose and gamma dose inside open and covered cylindrical holes in the ground will be measured as a function of depth into the holes and functions of slant range, height of neutron source, and angle of incidence from the source. Free-field neutron spectrum and dose and gamma dose measurements will be made as a function of slant range, height of neutron source, and angle of incidence from the source.
Four sets of three circular foxholes each will be located at horizontal distances of 0 (as close to the base of the tower as feasible), 27, 54, and 108 ft from the neutron source. In addition, at each distance, studies will be made with the source at heights of 27, 54, and 108 ft above the ground. At each of the four distances and three heights, measurements will be made at several depths (maximum of 3) to determine attenuation by: (1) an open foxhole, (2) a concrete-covered hole, and (3) a foxhole with a lightweight cover.

It is expected that this project will require interruption of each source run at approximately 10 min after the start of the run for a maximum of 15 min in order to retrieve specific detectors.

Instrumentation will consist of the following: (1) coated solid-state detectors and threshold detector systems for neutron spectrum measurements, (2) proportional counter for neutron dose measurements, and (3) film and thermoluminescent dosimeters for gamma dose measurements. This project will require access to either bunker 4-300 or bunker 4-480 in order to house associated electronic components (scaler, etc.) and test personnel during source exposures.

3.2.6 Program 6 - Directed by James E. McLaughlin, Health and Safety Laboratory, U. S. Atomic Energy Commission

The measurement of neutron spectra at various distances from the source, and with the source at various distances above ground, will be made with Ilford G-5 and K-2 emulsions. Results will be compared with theory.2

Seven emulsion exposures are contemplated. The emulsions would be located 500 to 700 yds from the tower base with source heights between 27 ft and 300 ft.

3.2.7 Program 7 - Directed by J. K. Morrow, Air Force Weapons Laboratory

The specific objectives of this program are:

1. High-energy neutron cross sections will be validated for a large number of nuclear reactions which have been selected because of characteristics which make them useful in measuring neutron flux and spectra.

2. Foil measurements will be made with a source height of 27 ft and horizontal distance of 27 ft to investigate the neutron spectrum near the air-ground interface.

3. The application of the iterative method of foil data reduction to this type of neutron spectrum will be analyzed and subjected to error analysis.

4. The angular dependence of the source emission will be determined from 0° to about 120° using the $^{32}$S(n,p)$^{32}$P reaction.

3.2.8 Program 8 - Directed by James H. Dowling, Armed Forces Radiobiology Research Institute

The experimental objective of this program will be to obtain the total depth dose distribution in tissue equivalent phantoms, approximating the torso dimensions of a "standard man", resulting from field geometry exposures using a high-energy neutron source. In addition, the source components of the absorbed dose will be studied as a function of source-phantom distance and angle. These data will be used to clarify details of depth dose distributions and to obtain insight to BREN results.
3.2.9 Program 9 - Directed by Rodney M. French, U. S. Main Battle Tank

(a) Project 9.1 - Rodney M. French, Project Officer, U. S. Main Battle Tank. The objective of this project is to evaluate experimentally the United States/Federal Republic of Germany Radiological Armor Design methods, techniques, and mockups.

This experiment will provide data in a realistic shield geometry which is directly applicable to the evaluation of the Slab Penetration and Reflection Calculation Procedure (SPARC Code) and the shield geometry integration procedure (Combine Code).

A source height of 108 ft will be required. Operating time at this height should not be less than about 72 hrs.

The Radiological Armor Pod (RAP) will be positioned at a slant distance of about 500 ft from the source. Fast neutron and gamma-ray dose rates will be obtained at various locations inside the RAP as a function of inner polyethylene shielding thickness and as a function of the RAP angle of orientation relative to the source.

(b) Project 9.2 - Robert L. French, Project Officer, Radiation Research Associates, Inc. The objective of this project is to make differential measurements of fast neutron air-ground-interface effects to substantiate theoretical calculations. Fast neutron data will be obtained by positioning detectors above and below a 2π shield located at several heights above the ground. Non-shielded detector measurements will be made at identical heights. The concept for the experiment is described elsewhere.

For a source height of 500 ft, the horizontal range of detector and shield positioning will be from 1000 to 1500 ft from the tower. A total of 4 hrs source operating time is estimated at this source height. This gives approximately 1 hr of operation time for each of four detector-shield altitudes. To determine the air-ground-interface effects produced by varying the source height, two additional source heights (one less than and one greater than 500 ft) are to be used for approximately 2 hrs each.

Instrumentation will consist of six channels of applicable fast neutron dosimeters with supporting electronics and cable. Measurements are to be made at locations above and below the 2π shield and repeated with no shield at the same altitudes. A separate detector at a fixed position will be required for monitoring changes in source intensity.

REFERENCES

Chapter 4

OPERATING PROCEDURES AND RESPONSIBILITIES

4.1 TECHNICAL DIRECTOR

The Technical Director (TD) shall be responsible to the Director of CETO for the performance of all operational and technical phases of Operation HENRE. Operation of the 14 Mev neutron source will be under his direct control. A complete, detailed operating log will be maintained for the TD by the source operator and will document starting and stopping times, high voltage and beam current, and source height for each operating period together with other pertinent information as directed by the TD.

Use of relatively small calibration sources will not be under direct control of the TD.

The Deputy Technical Director (DTD) shall represent the TD in operational and technical matters as required.

4.2 OPERATIONS OFFICER

The Operations Officer will maintain contact with Office of Programs and Plans (OPP-NVOO) through CETO and will adjust HENRE operating schedules to avoid conflict with other activities at NTS. He will inform OPP-NVOO of scheduled source operation a minimum of 24 hrs in advance and will report start-up and shut-down times for each operating day.

4.3 RADIOLOGICAL AND OPERATIONAL CRITERIA OFFICER

The Radiological and Operational Criteria Officer shall assist the TD in formulating and carrying out the Rad-Safe plan to prevent radiation injury to participants in Operation HENRE or to others at NTS. He shall be responsible for area surveys before, during, and after periods of operation, as required, and shall keep the TD informed of radiation hazards. He shall maintain liaison with the Rad-Safe Officer-NTS and CETO to insure compliance with applicable NTS procedures. He shall maintain a log that will document all radiation surveys, instructions issued, and important decisions concerning radiation safety.

4.4 OTHER OPERATIONAL OFFICERS

The Radiation Source Operations Officer shall be responsible for actuation of the mechanisms for providing the radiation to meet the programmatic needs within the limitations of his facilities and consonant with safe operation of those facilities.
C-1, C-4, and C-6 shall be responsible to the TD for administrative services, material and support services, and engineering and construction services, respectively, under normal CETO arrangement.

4.5 PROGRAM DIRECTORS

The Program Director (PD) shall be responsible to the TD for the conduct of the respective programs and the personnel involved therein.

The PD's shall keep the TD informed as to the progress, needs, safety, and preferred schedule of their respective programs.

4.6 PROJECT OFFICERS

Project Officers (PO) shall be responsible to their PD for obtaining the data required by the objectives of their respective projects.

The PO's shall be responsible for the procurement, placement, maintenance, and operation of instrumentation required by their respective projects.

The PO's shall keep their respective PD's informed of progress, safety, scheduling, special needs, disposition of personnel, and other matters pertinent to their respective projects.

All reports, including day-to-day liaison, to OPP-NVOO from the TD or subordinates shall be channeled through the TD and CETO.

Written progress reports shall be submitted through the TD to CETO on a mutually agreeable schedule.

Written interim reports shall be submitted by all projects and programs to the TD at the completion of experimentation and before departing from NTS.

Each PD will submit a final report by project to the Director, CETO, through the TD, for publication as a CEX report. A draft of each report must be submitted within 6 months of the conclusion of Operation HENRE.

4.7 RAD-SAFE PLAN

This Rad-Safe plan pertains to the operation and use of the 14 Mev neutron source in conjunction with Operation HENRE.

This plan covers the operations under all programs of Operation HENRE, and each user group participating in Operation HENRE will use NTS personnel monitoring as required in NTSO-0524.

Initial steps to be taken relative to personnel safety are:

1. Bio-assay techniques will be required in determining the body background of personnel prior to participation in Operation HENRE.
2. All parent organizations of personnel participating in Operation HENRE are required to submit records showing the amount of radiation their personnel have received through occupational exposure.

Control of radiation exposure will be followed as described in NTSO-0524.

The exposure limit for Operation HENRE will be 3 rem/quarter (gamma plus neutron). However, in no case will the accumulated exposure at NTS, combined
with previous occupational exposure, exceed the maximum permissible dose (MPD) = 5 (age - 18) for any individual.

Each PD will be issued information indicating the expected radiation hazard in his area at all times when the neutron source is in use.

A routine monitoring program will be established compatible with the neutron source operating schedule and will be under the direction of the Rad-Safe Officer.

In the event of a radiation emergency, proper reports will be channeled to OPP-NVOO through the TD and CETO.

In the event of widespread contamination, normal NTS procedures would be followed. During cleanup, exposure provisions of NBS Handbooks 591 and 692 would apply. Emergency services of the NTS support contractor would be requested as necessary.

PD's will register with the TD all radioactive materials used in relation to their programs. The neutron source will be shipped to NTS in accordance with AEC regulations.

REFERENCES

Chapter 5

ORGANIZATION AND RESPONSIBILITIES

The organization chart for Operation HENRE, showing responsibilities, is given on page 24.
**CETO-DBM**

Continuing Program at NTS

**Civil Effects Test Operation**

**Consultants**

Operation HENRE

Technical Director - F. F. Haywood
Deputy Technical Director - T. G. Provenzano

**Scientific Advisory Committee**

J. A. Auxier, Secretary
W. A. Biggers
R. E. Carter
C. D. Daniel
L. J. Deal, Co-chairman
O. de Lalla
R. D. Evans
C. L. Hansen, Jr., Co-chairman
H. O. Wyckoff

---

**Staff and Support Functions**

- **Administrative Services**
  - J. B. Williamson - CETO

- **Plans and Operations**
  - Z. Burson - EG&G

- **Materials and Support**
  - J. B. Williamson - CETO

- **Engineering and Construction**
  - Harry Rose - H&N

- **Radiological and Operation Criteria**
  - R. L. Clark - ORNL

- **Technical Reports and Classification**
  - F. F. Haywood - ORNL

- **Radiation Source Operation**
  - EG&G

---

**Scientific and Technical Programs**

- **Program 1** - Description of the Radiation Free-Field Characteristics from a Monoenergetic 14 Mev Source of Neutrons
  - J. A. Auxier - ORNL

- **Program 2** - Evaluation of Radiation Shields and Air-Ground Interface Effects
  - T. R. Jeter - BRL

- **Program 3** - Neutron Field and Induced Activity Studies
  - F. M. Tomnovec - USNRDL

- **Program 4** - Neutron Fields, Attenuation Measurements at Large Distances from a Monoenergetic Neutron Source
  - H. W. Patterson - LRL

- **Program 5** - Neutron and Gamma Shielding by Field Fortifications
  - R. E. Rexroad - NDL

- **Program 6** - Emulsion Neutron Spectrometry
  - J. E. McLaughlin - HASL

- **Program 7** - Validation of Neutron (14 Mev) Cross Sections by Foil Activation
  - J. K. Morrow - AFWL

- **Program 8** - Depth Dose Distributions in Human Tissue Equivalent Phantoms
  - J. H. Dowling - AFRRI

- **Program 9** - Experimental Confirmation of Radiological Armor Design Theory, Phase III
  - R. M. French - USMBT
CIVIL EFFECTS TEST OPERATIONS REPORT SERIES (CEX)

Through its Division of Biology and Medicine and Civil Effects Test Operations Office, the Atomic Energy Commission conducts certain technical tests, exercises, surveys, and research directed primarily toward practical applications of nuclear effects information and toward encouraging better technical, professional, and public understanding and utilization of the vast body of facts useful in the design of countermeasures against weapons effects. The activities carried out in these studies do not require nuclear detonations.

A complete listing of all the studies now underway is impossible in the space available here. However, the following is a list of all reports available from studies that have been completed. All reports listed are available from the Clearinghouse for Federal Scientific and Technical Information, National Bureau of Standards, U. S. Department of Commerce, Springfield, Virginia.

CEX-57.1 The Radiological Assessment and Recovery of Contaminated Areas, Carl F. Miller, September 1960.


CEX-58.8 Comparative Nuclear Effects of Biomedical Interest, Clayton S. White, I. Gerald Bowen, Donald R. Richmond, and Robert L. Combie, January 1961.

CEX-58.9 A Model Designed to Predict the Motion of Objects Translated by Classical Blast Waves, I. Gerald Bowen, Ray W. Albright, E. Royce Fletcher, and Clayton S. White, June 1961.


CEX-60.1 Evaluation of the Fallout Protection Afforded by Brookhaven National Laboratory Medical Research Center, H. Borella, Z. Bunon, and J. Jacovitch, February 1961.


