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TRIP REPORT

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Trip Report No. 6524 *How*

Author: H. C. Woodsum

Date: October 2, 1970

Trip To: Oak Ridge
National
Laboratory,
Oak Ridge, TennDate of Trip: Sept. 28 & 29,
1970**MASTER**PURPOSE OF TRIP:

To attend Annual Neutron Physics Division Meeting.

PERSONS PRESENT:

See Attachment 1

SUMMARY:

NOTICE

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The Annual Neutron Physics Division Information Meeting held on Sept. 28 and 29th at the Oak Ridge National Laboratory was attended by the author for the purpose of becoming familiar with recent ORNL experimental and analytical work. Most of the presentations given on the first day of the meeting were of direct or indirect interest to the NRD Analytical and/or Experimental personnel. Most of the presentations given on the second day, however, were concerned with high energy particle interactions (with the exception of a discussion on measurements of U-238 capture cross sections) and hence would not be of immediate use to NRD. A copy of the meeting formal program agenda is shown in attachment 2.

Several points in this meeting stand out and thus are mentioned briefly here. First, based on some recent ORNL inelastic scattering cross section measurements for carbon, it has been determined that there exist discrepancies between these recent measurements and the ENDF/B data in certain portions of the high energy range (e.g., ~6 MeV) by as much as a factor of 2. Whether this has any serious implications to NERVA nuclear or shielding analysis is not known, but since C is such an important

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element to NERVA, the effect should be evaluated. Much new data on U-238 cross sections was presented, some of which appeared to be superior in energy resolution to previous U-238 data. The usefulness and significance of these new data to NERVA also should be investigated. A method of reducing the ray effects incurred by discrete transport methods was alluded to in the discussion on transport calculations of a point source in air. The ray effects were reduced by use of an analytic first-collision source. The latter results I'm sure will also be covered in a separate report by Martin Schneider, who also covered this meeting for the Reactor Physics & Math Group.

The SNAP Optimization and Coupled Neutron-Gamma Ray Transport Studies discussion outlined some shield optimization calculations performed for SNAP using the ASOP code. $TiH_{1.5}$ was investigated as a replacement for the current W-LiH shield and it was determined that if the inner layer of W-LiH was replaced with $TiH_{1.5}$ the shield weight remained about the same: if all the shield were replaced with $TiH_{1.5}$, the shield weight was significantly heavier.

The presentation on Neutron Transport in Metal Shields was concerned with experimental and analytical support to the LMFBR and FFTR program. Streaming of neutrons in the top plug and lower support plate shield regions was analyzed by ORNL and determined to be much higher than allowable. Significant problems were experienced by ORNL in getting agreement between analytical techniques, between analytical and experimental results, and between experimental techniques in the analysis and experimentation performed to resolve and evaluate the FFTR streaming problems. Most, but not all, of these discrepancies have been resolved (see Discussion). The experimental techniques made use of NE-213 and Bennett-Benjamin H_2 -recoil spectrometer systems and measurements were performed both at ORELA and at the Tower Shielding Facility.

The author toured the Oak Ridge Linear Accelerator (ORELA) facility and was much impressed by the facility and especially the extent of the automated data processing equipment which included 2 SEL 810Bs, one PDP-4 and one PDP-9 CPUs, 2 magnetic tape units, and 2 disk units, a multiverter to accept 4 simultaneous sets of input, and an interactive display terminal with light pen. The author also received a copy of the Neutron Physics Division Annual Progress Report for period ending May 31, 1970, ORNL-4592. Further discussion of this meeting follows:

DISCUSSION:

A short discussion of certain of the presentations which are of special interest to NRD personnel is given below.

1. Development and Application of Transport Methods to Weapons Radiation Shielding Problems by E. A. Straker.

It was noted that the MORSE, generalized 3D geometry, time dependent Monte Carlo Program and 1 and 2D discrete ordinates code techniques were used for this analysis. Vic Cain has written a set of sub routines for analyzing source particle histories for MORSE. The problems analyzed consisted of an isotropic point source, 50' above ground with either of 2 fast neutron spectra (14 MeV or fission spectrum). Also, a very anisotropic

point source ($\cos = \pm 0.1$) was analyzed. The conclusion from this study were:

- a. That low energy neutron produced secondary gammas are important, especially > 500 m from the source.
- b. The anisotropic point source gives isometric doses ≥ 900 m and nearly isometric doses at ~ 500 m from the source.
- c. A method of eliminating ray effects was found necessary for the anisotropic source calculations. This method consisted of using an analytic first collision source and applying a delta function to direct uncollided source transport.

2. Experimental Results from ORELA Shield Test Facility by C. E. Burgart.

The Oak Ridge Linear Accelerator Shielding Test Facility consists of a 160 m flight path at 165° from the beam produced by 140 MeV electrons impinging on a water cooled Ta target. Measurements to date have consisted of comparisons of Time of Flight (TOF) with NE-213 and FERDOR infolded measured fast neutron spectra with certain shield materials in the beam. The materials tested include 3.5" U-238 + 8" H₂O and 3.5" U-238 + 5" Pb + 3/4" B. Generally good agreement between the two techniques were observed except at low (< 0.7 MeV) energies where the NE-213 system is known to be uncertain. A PDP-9 computer was used to sort the two parameter pulse height and time of flight data.

3. Neutron Transport in Metal Shields by F. Mynatt.

There are 5 separate radiation streaming problems associated with the FFTR reactor, which ORNL is attacking by a combined experimental/analytical program. These include:

- a. Streaming through 21" thick steel shield containing passages for coolant which protects the lower core support plate from radiation damage.
- b. Neutron streaming through the low density, $\sim 4'$ thick Na plenum on top of the reactor.
- c. Streaming through the fission product gas cavity.
- d. Streaming through the top fuel handling mechanism.
- e. Streaming through penetrations of Na pipes in the reactor shield.

ORNL used a P_γ 50 angle DOT with 11,000 space points to analyze the streaming through the fuel handling mechanism. This mechanism consists of a rotating stainless steel plug of SS-304 + iron surrounded by a 1/2 inch thick gap. This plug design presently has 2 offsets to reduce streaming, but even with the offsets the streaming is calculated to be 50x higher than tolerable. This presents some problems since the top head region of the FFTR is scheduled for initial machining in March, 1971 and will cost ~ 7 M\$.

A combined experimental/analytical program has been pursued for evaluating the streaming through the shield which protects the bottom core support plate. Some difficulties were experienced in both the experimental and analytical programs. For example, initial transport calculations through the bottom steel shield region showed a basic disagreement of a factor of 10 between Monte Carlo and transport code results. The M. C. Calculations used 296 fine groups while the transport code used 39 groups. By comparison with recent experiments of Cerbone at GGA, it was determined that the M.C. results are most nearly correct and the S_n 39 group calculation was considerably in error. From further analysis it was determined that the cause of the difficulty was due to the narrow window anti-resonance in the Fe cross section which was not evaluated properly with the broad 39 group scheme. This was further substantiated by comparison of ANISN calculations with LINAC measurements.

Experiments were also carried out at the TSF using the SNAP reactor above various thicknesses of Fe up to 18" thick. Spectral measurements below the iron were performed with NE-213 and Benjamin H₂ recoil spectrometers. DOT S100, P₁, 296 group calculations were also performed on these configurations. The initial NE-213 measurements did not overlap with the H₂ recoil measurements, Also the 3 different chamber H₂ recoil (with different pressures of H₂) spectrometer data did not overlap with each other. Refilling and redesign of the H₂ chambers plus recalibration at the ORELA finally resulted in agreement but the shapes of the measured and calculated spectra still do not agree although the total energy integrals agree within 9%. The agreement of DOT with the experiments above 0.2 MeV was fairly reasonable but was poor below 0.2 MeV.

4. Shield Optimization Studies by Ward Engle

SNAP shield optimization studies were performed using the ASOP code (coupled with DOT and ANISN). Studies were first performed to determine whether 1, 2, 3, or more layers of W in the W-LiH laminated shield was optimum. From this study it was determined that two layers was the minimum weight configuration and hence no weight gains could be made by going to a larger number of layers. A study was also performed with TiH_{1.5} replacing all or part of the W-LiH shield. With TiH_{1.5} replacing the inner layer of W-LiH, it was found that the optimized shield weight was about the same as for the reference LiH-W shield; if all the LiH-W was replaced with TiH_{1.5}, the total weight was heavier.

An optimization was also carried out with dose constraints in three different directions. This required running three separate ANISN problems and ASOP calculations and then wedding the results to obtain the overall minimum configuration.

5. An Evaluation of Secondary Gamma-Ray Production Data for Various Shielding Materials by R. E. Maerker

This presentation was concerned with the measurements of secondary gamma-ray spectra from slabs of material placed in a collimated beam from the TSF water reactor.

The presentation was taken directly from ORNL-4475*, and thus will not be elaborated on to any great extent here. However, some of the quoted uncertainties in measurements and calculations may be of interest, as follows:

Spectral unfolding	+ 15%
Measured neutron field	+ 15%
Measured secondary γ background	+ 30%
Calculated Cd filtered response	+ 20%
Net overall uncertainty	+ 30%

Also, the conclusions from this work were that the secondary capture gamma spectra, as published by Troubetzkoy et al, were good for Fe, Ni, and Cr, but poor for K, Na, and Si.

6. $n, n'\gamma$ and n, xy Cross Section Measurements by Francis Perey

Cross section measurements of one or the other of the above noted types have been made at ORNL for Ca, Na, Mg, Al, Si, S, Ga, V, Fe, ^{60}Co , Ni, and Y. Of these, the C cross section work is probably of most interest to NERVA. The ORNL measured angular distribution data for C inelastic cross sections differ considerably from the ENDF/B data for some energies. As a result, the total C inelastic cross section may also differ considerably from ENDF/B values since the ENDF/B values generally used 90° cross sections and multiplied by 2π to obtain total inelastic cross section. It was also noted, in passing, that all C cross sections up to hundred of MeV have been measured quite carefully with the exception of the $n, n'\gamma$ cross section for which only one set of relatively poor cross sections existed prior to the ORNL work. The energy resolution of the ORNL data appears to be quite good, being of the order of 1.5-6 KeV at least up to 2 MeV. It was also noted that 24 papers and reports have been published on the ORNL cross section work in the past 12 months. Also, Keith Penney is doing an evaluation of the ORNL Fe cross sections vs other similar data.

7. Radiation Shielding Information Center by R. W. Roussin

Mr. Roussin first noted that there would be a seminar on the Monte Carlo codes ANTI-2 and MORSE during the week of October 5-9, 1970.

A computer-based reference retrieval system has been developed for RSIC in the last year.

RSIC also does state-of-the-art review, as requested. Typical of this, the gamma and neutron transmission in concrete review, was recently completed. This review is published in ORNL-RSIC-26.

It was noted that the NASA funding for RSIC would be discontinued at the end of this calendar year.

* "Gamma-Ray Spectra Arising from Thermal-Neutron Capture in Elements Found in Soils, Concretes, and Structural Materials by R. E. Maerker and F. J. Muckenthaler."

On the following day (September 29) the only paper of direct interest to NRD personnel was the paper on ^{238}U cross section measurements. The following measurements were performed at the ORELA:

σ γ ($\pm 10\%$)	1-100 KeV
σ n, n' ($\pm 15\%$)	0.1-1 Mev
σ n, n' ($\pm 15\%$)	> 1 MeV

Measurements were made at one of the 40 m stations of the LINAC using an 800-gal liquid scintillator tank with 16 photomultipliers in an underground chamber. The first measurements made with this sensitive device showed such a high background, the measurements were almost meaningless. It was henceforth found that the background was due to the natural activity of K^{40} in the concrete, which is quite high in the soil around the ORNL area. Hence, the cheapest and most expeditious method of reducing this background was to buy marble 1' x 1' x 1" blocks intended for patio stone, and build an underground shelter between the concrete and the detector tank. This reduced the background about a factor of 10. Another factor of 10 reduction in background was achieved by accepting only coincidence measurements from the two symmetrical halves of the scintillator tank. The ORNL ^{238}U data is still being evaluated but some differences with previous work have been noted. ORNL is also trying to fit the experimental data with an analytical model.

The sixth paper of the second day, "Induced Activity in the Moon from Solar and Galactic Cosmic Ray Bombardment," was of general interest. This paper noted that an effort is being expended to help determine the age of moon rock and soil samples by analyzing the intrinsic radioactive species. Typical is the ^{26}Al activity of ~ 200 dpm/kg at the moon surface. H. Bertini's code for calculating penetration of high energy particle fluxes in various materials has been extended from 3 GeV up to several hundred GeV for purposes of this analysis. Typical results from this analysis give ranges of values from $200-3500 \times 10^6$ years vs 700×10^6 years (based on ^{81}Kr dating) for soil and from $390-6900 \times 10^6$ years vs 510×10^6 years (based on ^{81}Kr dating) for rock No. 17-32. The author saw some of the moon samples which were being counted at the lab.

This summarizes the extent of the ORNL presentations. However, some "after-the-meeting" discussions and impressions may also be of interest. First D. K. Trubey asked E. A. Warman if he thought RSIC could get some NASA funding through the NERVA program. Ed referred Trubey to several SNPO-W types.

Ed Warman was campaigning for papers to be presented at the symposium in Las Vegas next spring, and asked everyone he met if he was giving a paper. Some invited papers will also be given and some astronaut will give an invited paper, according to Ed. He seemed most interested in getting an astronaut who had been on one of the lunar explorations to discuss the apparent scintillations induced in the eyes of the astronauts. Ed claimed that on the last lunar landing these scintillations had been counted and determined to be about 100 per minute. There is some speculation that these scintillations are

neutron or heavy particle-induced. Thus, one of the biophysicists associated with the space program is supposed to have exposed himself purposely to a neutron field similar to that known to be present on the moon in order to see if he could observe this phenomena.

Several times in the program presented by ORNL it was noted that part of the current government funding was being terminated at the end of the year. Also, it was determined by a conversation with Leo Holland that the Tower Shielding Facility work is being continued but at a much lower manpower level than last year's effort. Leo says that current operations involve only himself, one engineer, and one technician but that a two-shift operation is being maintained. Of the remainder of the 12 or more people who used to work at the TSF, 1 died (T. V. Blosser), and the remainder have been transferred to the new Neutron Physics Division building at the ORELA.

The author took a tour of the ORELA facilities on the afternoon of the first day and was much impressed by the facility and especially the data acquisition system. Two SEL-810Bs, 1 PDP-4, and a PDP-9 CPUs are presently available for use although only 1 SEL-810B was in use at the time of the visit; the other was broken down. The author was given a detailed description of the data acquisition system. It was noted that the two SELs were about 9 months later than originally planned in receiving the lab's acceptance. Repair and maintenance of the data acquisition system is entirely the lab's I&C group responsibility except for components which cannot be repaired by the ORNL I&C group and thus require supplier maintenance. Thus, as much redundancy is built into the system as is felt practical (e.g., 2 SELs, 2 tape units, 2 disk units, 4 channels of multiplexer).

Although the present system seemed quite elaborate and extensive to the author (the estimated cost was \$0.5 M), this system is only Phase I of a II-Phase system and thus probably represents less than half of the total planned. Future plans for Phase II include adding 2 more PDP-15s, a PDP-10, another remote display terminal, etc., as described on p. 26 of ORNL-4592.

Based on these plans, I came away feeling that the WANEF data acquisition system plans are, if anything, too minimal and conservative.

This summarizes the extent of the 2-day ORNL visit.

H. C. Woodsum

NEUTRON PHYSICS DIVISION INFORMATION MEETING

September 28-29, 1970

List of Attendees by Installation

Argonne National Laboratory

David Meneghetti

Atomics International

Harry Rood

Defense Atomic Support Agency (DASA)

Capt. Dean Kaul

Federal Aviation Administration

Wallace Friedberg

Gulf Radiation Technology

M. P. Fricke

L. Harris, Jr.

Lawrence Radiation Laboratory,
Livermore

Eugene Goldberg

Los Alamos Scientific Laboratory

Wendell A. Biggers

Michael R. Cates

Darrell M. Drake

Ralph R. Fullwood

M. S. Moore

Henry T. Motz

Leona Stewart

George C. Marshall Space Flight Center

~~Henry E. Stern~~

Massachusetts Institute of Technology

Herman Feshbach

NASA, Lewis Research Center

Donald Connolley

Irving Karp

Norman Pentz

North American Rockwell Corp.

E. Richard Cohen

ORTEC

Robert Bardorf

Leif Johannessen

John H. Neiler

Radiation Research Associates, Inc.

~~N. M. Schaeffer~~

Sandia Laboratories

Clarence R. Mehl

Savannah River Laboratory

R. A. Benjamin

H. E. Hootman

R. M. Satterfield

Science Applications, Inc.

J. A. Lonergan

U. S. Atomic Energy Commission

P. B. Hemmig

Keran O'Brien

Robert Sanna

University of Florida

A. J. Mockel

University of Maryland

Philip G. Roos

George Harrison

Westinghouse Electric Corp.

Paul F. Fox

J. L. Rathbun

Westinghouse Astronuclear Laboratory

H. C. Woodsum

M. J. Schneider

ANSC

E. A. Warman (1st day only)

September 25, 1970

OAK RIDGE NATIONAL LABORATORY

NEUTRON PHYSICS DIVISION INFORMATION MEETING

September 28-29, 1970

Central Auditorium, Building 4500N

Monday, September 28 – C. E. Clifford, Chairman

- 9:00 Introductory Remarks – F. C. Maienschein
- 9:10 Development and Application of Transport Methods to Weapons Radiation Shielding Problems – E. A. Straker
- 9:35 Experimental Results from the ORELA Shield Test Facility – C. E. Burgart
- 9:55 Neutron Transport in Metal Shields – F. R. Mynatt
- 10:20 SNAP Shield Optimization and Coupled Neutron Gamma-Ray Transport Studies – W. W. Engle
- 10:40 Intermission
- 10:55 An Evaluation of Secondary Gamma-Ray Production Data for Various Shielding Materials – R. E. Maerker
- 11:15 n, n' and $n, x\gamma$ Measurements – F. C. Perey
- 11:35 Radiation Shielding Information Center – R. W. Roussin
- 12:00 Lunch

Tuesday, September 29 – R. W. Peelle, Chairman

- 9:00 Capture Cross Section and Related Measurements for ^{238}U – G. de Saussure
- 9:30 $\bar{\nu}(E)$ for ^{239}Pu – L. W. Weston
- 9:50 An Application of Invariant Imbedding to Nuclear Reaction Theory – R. B. Perez
- 10:10 Intermission
- 10:30 Space and High-Energy Accelerator Shielding – R. G. Alsmiller, Jr.
- 10:55 Calculation of Nuclear Reactions for Incident Nucleons and π -Mesons in the Energy Range 30 to 2700 MeV – H. Bertini
- 11:15 The Induced Activity in the Moon from Solar Cosmic-Ray and Galactic Cosmic-Ray Bombardment – T. W. Armstrong
- 11:35 Energy Spectra of Nuclear Secondaries from Proton and Alpha Particles on Nuclei – R. W. Peelle
- 12:00 Lunch