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ORNL SUMMER SHIELDING SESSION

Gale Young, Leader

SUMMARY REPORT ON SUMMER SHIELDING WORK

GALE YOUNG

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This report is one of a series on shielding and represents part of the work of a summer group working principally at Oak Ridge National Laboratory. Participants are drawn from Nuclear Development Associates (Navy contract), NEPA, Bureau of Ships and Bureau of Aeronautics (Navy Department), AEC, RAND, General Electric, Argonne and Oak Ridge National Laboratory.

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ORNL-437

SUMMARY REPORT ON SUMMER SHIELDING WORK

Gale Young

O U T L I N E

ACTIVITIES

- Nuclear Information
- Analytical Attenuation Studies
- Monte Carlo Attenuation
- Experimental Attenuation Studies
- Miscellaneous

CONCLUSIONS AND RECOMMENDATIONS

- Neutron Data
- Gamma Source Spectra
- Gamma Absorption Coefficients
- Gamma Ray Penetration
- Neutron Penetration
- Materials

[redacted]

SUMMARY REPORT ON SUMMER SHIELDING WORK

This report briefly summarizes the activities and findings of a shielding study conducted during the summer of 1949. This "Summer Shielding Session" was a single joint effort on the parts of several organizations sponsored by the AEC, Air Force, and Navy. Appendix I lists the individuals who took part in the work, and their organizations and sponsors. Appendix II indicates the travel and consulting done in connection with the summer's work. The study was largely done at ORNL, although it included work done on both coasts, and the reports were issued* through ORNL. These reports are listed in Appendix III.

While some new results were obtained, the summer work was largely devoted to reviewing fundamentals, and was more or less a continuation of the shielding review begun at Lexington last summer. We shall first summarize the activities of the summer session, and then briefly give the conclusions reached and the recommendations made.

ACTIVITIES

The summer session activities fall under four main headings, plus a miscellaneous section.

Nuclear Information: A preliminary survey of fast neutron data was made early in the summer by Friedman and Feshbach (1), after which Feshbach studied in more detail the data for water (2) and other substances (3)

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* See footnote in Appendix I.

[redacted]

such as B, Fe, W and Pb. This last report (3) gives a critical discussion of considerable portions of the fast data field. A memo by Ergen gives some recent Minnesota data on C, Si, S and Mg (4).

After a visit with Friedman to the Canadian project to obtain some advanced data on capture gamma rays, Blizard reviews the present information on gamma spectra from neutron capture (5). Young and Blizard summarize the information on fission and fission product gamma rays (6).

A critical review of theoretical and experimental work on gamma absorption coefficients was made by Powell and Snyder (7).

Analytical Attenuation Studies: Welton* devoted the summer to critical study of analytical methods, and his review report (8) covers a substantial fraction of this field. Butler (9) gives a presentation which includes several of the cases which have been worked out.

Murray (10)reports some recent considerations which supplement his earlier (33, 34, 35, 36) results. Welton and Goertzel (11) make a contribution to shielding theory, and Young (12, 13) indicates some applications of old results.

Monte Carlo Attenuation Studies: A general account of the use of Monte Carlo methods for shielding is given by Goertzel and Kahn (14), and Goertzel (15, 16) presents some detailed theoretical considerations.

Welton (8) includes a few numerical comparisons of analytic

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* See footnote in Appendix I.

[redacted]

calculations with Monte Carlo results obtained by Kahn, Goertzel (appendix in reference 16) gives the results of some hand computation studies, and Nelson (17) describes a problem which was set up on IBM machines.

Experimental Attenuation Studies: Experimental neutron attenuation work at ORNL to date is critically reviewed by Sleeper (18), and Blizard summarizes work on the Hanford (19) and Canadian (20) shields. Sleeper and Clifford discuss some recent ORNL experiments in more detail (21), and Ergen (22) similarly covers the experiments done at ORNL for NEPA.

Some discussion was held on the forthcoming "lid tank" experiments at ORNL (23), on possible future work at Brookhaven, and on the use of low power critical-assembly-type experiments for shielding measurements (37, 38).

Some references to gamma ray transmission measurements are given by Powell (24).

Miscellaneous: A little time was spent on discussion of materials. Blizard (25) obtained some opinions on the production of B^{10}; and Zirkind made some preliminary estimates on its shielding effectiveness.

Dietrich (26) applied some Lexington results to an estimate of

[redacted]

shield weights for the Navy pile.

A considerable fraction (about 2/3) of the summer session reports (see Appendix III) are expected to be unclassified. Appendix V gives a list of older shielding reports suggested for declassification.

Zirkind has begun a more detailed technical summary of the summer's work, but this report is not yet finished. It includes an account by Nelson of a matrix computing method (47) not discussed elsewhere in the summer reports.

CONCLUSIONS AND RECOMMENDATIONS

Shielding has attained infancy. It has begun to exist as a recognizable technical subject, and has started to grow the requisite experimental and theoretical legs on which to walk. The following suggestions are aimed at encouraging a healthy and orderly development.

Neutron Data: It is a familiar statement that our knowledge of microscopic nuclear data is inadequate. Shielding, with its emphasis on neutrons of high energy (say around 1 to 10 mev), is rather poorly off in this respect.

Some specific recommendations which can be acted on directly are

(a) Make a competent, careful and critical study of the existing fast neutron data, employing the best available theoretical methods to estimate and extrapolate further (e.g. 3, 2, 48, 28).

[redacted]

(b) See what further measurements valuable for shielding can be made soon on existing apparatus (e.g. 4, 29).

(c) Develop analytical and numerical methods for attenuation calculations so that sensitiveness of the results to variations in the data can be made visible. Such parametric studies provide indications as to the type and accuracy of data needed for shielding.

In a more uncertain, or less immediate, category one may add

(d) Encourage additional measurements (scattering, inelastic energy loss, etc.) when feasible, and give reasonable support to further development of experimental methods and facilities. Such theoretical programs as (a) and (c) should offer considerable guidance in this.

(e) Investigate macroscopic approaches, such as the old so-called "Borst experiments" (30), to see if backward inferences about the microscopic data can be made from spectral degradation or attenuation in slabs of material (31, 32, 23, 42, 41).

Gamma Source Spectra: With their better pile and advanced apparatus, the Canadians appear to be well in the forefront here (5). They find detailed line structure in the capture spectrum; however the apparatus is uncalibrated,

[redacted]

and may be limited to the higher photon energies.

(f) Follow the Canadian work closely, encourage them in it, and see if we can be of any assistance.

(g) See if the present methods can be supplemented at the lower photon energies (say below 3 or 4 Mev).

(h) Ensure that the capture gamma studies cover the elements of interest in shielding (5).

(i) Encourage investigation of the fission and early fission product spectrum (6).

(j) Encourage work on gamma rays from inelastic scattering. These are of interest directly as a reactor gamma source requiring shielding, and indirectly for the information they may provide on neutron energy loss (48).

(k) Develop analytic and numerical methods for attenuation calculations to display sensitiveness to source spectra.

(l) Investigate macroscopic experiments (46, 23) for measuring the attenuation of relevant spectra in media (e.g. heavily borated) in which further gamma production is depressed.

[redacted]

Gamma Absorption Coefficients: Uncertainty here reflects quite strongly in shield weight. At present it appears (7) that the significant quantities are known to about $\pm$ 5%. Experimental data are missing in the important neighborhood about the minimum of heavy elements.

(m) With higher energy radioactive sources, and lower energy detectors for betatron sources, try to get experimental points nearer the minimum in heavy elements.

(n) Support theoretical studies, to say the equivalent of a few PhD theses, aimed at improving the calculations.

Gamma Ray Penetration: Besides the uncertainty in the primary coefficients just referred to, there is uncertainty about the secondary "buildup factors." Analytical approaches to this problem, such as the Greuling "straight ahead" approximation and the Wheeler-Wick angular treatment, are reviewed by Welton (8); Monte Carlo and other numerical studies are cited by Welton (8) and Plesset and Cohen (43); and Powell (24) gives a bibliography of experimental work. The experiments are mostly small attenuation and as yet largely unanalyzed; the analytical results do not agree with the few Monte Carlo calculations which have been made, and the numerical results of Peebles (43) are inaccessible.

(o) Make good experiments in various dense materials, using source energies ranging up to several Mev if possible.

[redacted]

(p) Interpret these experiments carefully.

(q) Develop numerical and analytical computations to adequately cover the attenuation problem.

(r) Anticipate later needs to be able to deal with variable density media, multiple regions, ducts, odd geometries, etc.

The gamma measurements in pile bulk-shielding tests have not as yet been generally understandable.

(s) See if the new "lid tank" experiments (23) give more nearly interpretable results.

The gamma measurements in a lead reflector around a critical assembly (42, 37) may possibly illustrate a cleaner experimental situation. See (x) below.

<u>Neutron Penetration</u>: This is expected to be a more persistent and troublesome problem than that of gamma penetration. Measurements on the shields of the Hanford (19) and Canadian (20) piles leave something to be desired. Only one shield measurement can be said to exist and to have been analyzed and calibrated (44); the other measurements are uncalibrated and all but a few are more-or-less voided by composition or neutron leakage uncertainty (18).

[redacted]

(t) Proceed with the fundamental ORNL lid tank program on B, water, and mixtures of these with heavy elements (23).

(u) Develop theoretical studies to keep abreast of and understand the experimental findings.

(v) Encourage further Hanford measurements, further Canadian measurements if feasible, and measurements of the Brookhaven shield as soon as possible.

(w) Develop, on basis of the above experience, a program for the Brookhaven pile.

(x) Investigate small low-power critical-experiment type measurements which may have advantages of low background, isolation convenience, precision atmosphere, and relatively prompt availability. (37, 38).

On the theoretical side, there is some beginning in the way of analytical methods (8, 9, 10, 11, 33, 35), and considerable recent progress toward Monte Carlo (14, 15, 16, 17) methods. The Wigner "straight ahead" approximation appears useful for neutrons in hydrogen, and is being extended to include isotropic scattering (9, 11, 33, 35). Analytical attack on boron shields is not yet really mounted, but the subject is being approached (10, 45).

[redacted]

(y) Continue the integrated development and interplay of these analytical and numerical methods, and their progress toward shield understanding.

(z) Again anticipate future needs involving non-uniform media, ducts, etc.

Materials: The summer session did not really get into materials, or close to actual engineering design questions; such matters are beyond the scope of the present work. However, a few impressions may be noted.

Apparently there is little solid information on heavy hydrides other than those of U, Zr, and Ti. There are some preliminary favorable opinions regarding the possibility of producing enriched B for 10^5 dollars per ton (25); perhaps serious theoretical study of the shielding gain from B enrichment will be called for. The strategic scarcity of certain materials (e.g. tungsten) for shielding may need further evaluation in light of the fact that shielding need not demand materials of highest purity. Recent memos by Rockwell cover some aspects of the materials situation (39, 40).

In addition to composition, the density of a shield material is an important parameter. If an ample amount of hydrogen would go "free" into the spaces between the atoms of a dense gamma shield (and if such a material were available and stable and conducted heat well and so on), an optimum

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shield design would be more or less apparent. Thus, in one sense, there is a "shielding problem" primarily because of the constraints introduced by ordinary (i.e. non-nuclear) properties of materials; and one can hardly hope to deal satisfactorily with the problem without adequate information about these constraints.

Since one can not expect to develop all possible combinations or run all materials in attenuation tests, it is clearly necessary to exercise judgment based on a core of shield understanding. Materials work that is not well guided can become very expensive; hence we would suggest

(A) A careful critical review of relevant materials, properties, costs, strategic availability, etc.

(B) Development of analytical and numerical methods for calculating attenuations and extrapolating measurements.

(C) Further selected materials development based on and in close touch with the best integrated shielding knowledge.

[redacted]

APPENDIX I

PERSONNEL OF SUMMER SESSION

Organization	Individuals	Sponsor
AEC	T. A. Welton *	AEC
ANL	J. Butler J. R. Dietrich	AEC
Bureau of Aeronautics	R. Zirkind	Navy
Bureau of Ships	E. P. Blizard	Navy
KAPL	H. P. Sleeper	AEC
NEPA	W. K. Ergen J. L. Powell	Air Force
NDA	F. L. Friedman G. Goertzel H. Feshbach G. Young	Navy
ORNL	C. E. Clifford F. H. Murray M. L. Nelson W. S. Snyder	AEC
RAND	H. Kahn	Air Force

Computing was done at NDA, ORNL, and RAND

* For simplicity, Welton and his work are discussed here with the summers activities generally. Actually he was on a special contract with the AEC (Dr. George Weil), and his major report was issued by the AEC.

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APPENDIX II

LISTS OF TRIPS AND VISITS

Summer Session Personnel

Blizard	1	trip	to	Chalk River
	1	"	"	Brookhaven
	1	"	"	Washington
Butler	1	"	"	ANL
Dietrich	2	"	"	ORNL
Ergen	1	"	"	University of Minnesota
Feshbach	1	"	"	ORNL
Friedman	2	"	"	ORNL
"	1	"	"	Chalk River
"	1	"	"	NDA
Goertzel	4	"	"	ORNL
Kahn	3	"	"	ORNL
"	1	"	"	NDA
Welton	1	"	"	KAPL
	1	"	"	Washington (Fano)
	1	"	"	Los Alamos (Bethe)

Visitors and Consultants

Hurwitz	1	"	"	ORNL
Marshak	1	"	"	ORNL
Tonks	1	"	"	ORNL
Von Neumann	1	"	"	ORNL

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APPENDIX III

SUMMER SESSION REPORTS

(1) F. Friedman and H. Feshbach, Collection of Data for Shielding, ORNL-418, Secret

(2) H. Feshbach, Neutron Data for Water Shielding, ORNL-417, believed not secret

(3) H. Feshbach, Fast Neutron Data, ORNL-433, believed not secret

(4) W. K. Ergen, Total Cross Sections of Light Elements as Obtained From the University of Minnesota, ORNL-426, believed not secret

(5) E. P. Blizard, Capture Gamma Rays, ORNL-419, believed not secret

(6) G. Young and E. P. Blizard, Summary of Gamma Rays From Fission and Fission Products, ORNL-420, believed not secret

(7) J. L. Powell and W. S. Snyder, Absorption of Gamma Rays, ORNL-421, believed not secret

(8) T. A. Welton,--review of analytical methods for shielding calculations, believed not secret

(9) J. W. Butler, Asymptotic Neutron Distribution in a 3 Component Mixture With Forward Hydrogen Scattering, ORNL-431, believed not secret

(10) F. H. Murray, Approximate Analysis of the Penetration of Neutrons Through a Thick Shield Composed of Non-Hydrogenous Materials, ORNL-424, believed not secret

(11) T. A. Welton and G. Goertzel, Asymptotic Distribution of Neutrons From a Point Source in a Medium Containing Hydrogen and an Isotropic Scatterer, ORNL-425, believed not secret

(12) G. Young, Piece-Wise Greuling Solutions for Hydrogen, ORNL-415, not secret

(13) G. Young, On Straight-Ahead Gamma Transmission With a Minimum in the Cross-Section, ORNL-416, not secret

[redacted]

(14) G. Goertzel and H. Kahn, Monte Carlo Methods for Shield Computations, ORNL-429, believed not secret

(15) G. Goertzel, Quota Sampling and Importance Functions in Stochastic Solution of Particle Problems, ORNL-434, believed not secret

(16) G. Goertzel, A Proposed Particle Attenuation Problem, ORNL-423, believed not secret

(17) M. L. Nelson, A Monte Carlo Computation Being Made for Neutron Attenuation in Water, ORNL-439, believed not secret

(18) H. P. Sleeper, A Critical Review of ORNL Shield Measurements: Neutron Attenuation, ORNL-436, Secret

(19) E. P. Blizard, Measurements on Hanford Type Shields, ORNL-430, Secret

(20) E. P. Blizard, Canadian Measurements of an Iron-Water Shield, ORNL-428, Secret

(21) H. P. Sleeper and C. E. Clifford, Attenuation Measurements in Heavy Aggregate MI Concrete, ORNL-438, Secret

(22) W. K. Ergen and C. E. Clifford, Neutron and Gamma Attenuation Through Tungsten Carbide and Boron Carbide, ORNL-435, Secret

(23) W. K. Ergen, E. P. Blizard, C. E. Clifford and G. Young, Program for the ORNL Bulk Shield Testing Facility, ORNL-427, Secret

(24) J. L. Powell, Gamma Ray Attenuation Experiment References, ORNL-422, believed not secret

(25) E. P. Blizard, Notes on the Cost of Enriched Boron in Ton Lots, ORNL-432, Secret

(26) J. R. Dietrich, Preliminary Estimate of an Iron-Water Shield for the Naval Reactor, ORNL-440, Secret

(27) G. Young, Summary Report on Summer Shielding Work, ORNL-437, Secret

These reports fill a solid block of ORNL numbers from 415 to 440 inclusive, plus the report (8) by Welton issued through the AEC.

[redacted]

APPENDIX IV

OTHER REFERENCES

(28) B. T. Feld, Analysis of Inelastic Scattering in U, LP-105a

(29) Barshall, et al, Evidence for Broad Nuclear Energy Levels in Lead, Phy. Rev. 76, 463(A) (1949)

(30) See page 2 and reference 11 in G. Young, Rough Draft of a Bibliography on Shielding, ORNL-47.

(31) F. L. Friedman, Pile Technology Lectures 12 and 13 on shielding, M-3998 or CF 47-8-136, page 26.

(32) See "front slab" experiments in reference 18

(33) F. H. Murray, Approximate Calculation of the Neutron Flux From a Plane Source in an Infinite Medium Where the Nuclear Cross-sections Vary With the Energy and With the Distance From the Source, for Energies Above 5 Mev; ORNL-218, declassified

(34) F. H. Murray, The Energy Loss of Particles Traversing a Slab of Finite Thickness, CL-FHM-1.

(35) F. H. Murray, Approximate Formulas For the Slowing Down of Neutrons in Mixtures of Water and Aluminum, ORNL-272

(36) F. H. Murray, Quarterly Reports MonP-368, p. 100; CNL-35, p. 76; ORNL-51, p. 53; ORNL-159, p. 123; ORNL-228, p. 82; ORNL-365, p. 24.

(37) M. M. Mann, The Use of Critical Assembly in Shielding Experiments, CF-49-9-83

(38) J. Bair and R. Echols, Proposal for Low Power Critical Experiments to Determine the Properties of Shielding Materials and Shields, NEPA-1130-STR-12

(39) T. Rockwell, Shielding Materials, CF-49-8-218

(40) T. Rockwell, Compositions of Several Shielding Samples; Sept. 2, 1949

(41) Goodman et al;-- MIT work in spherical geometry; e.g. NP-875 and related reports

[redacted]

(42) M. M. Mann et al;--experiments in a Pb slab; ORNL-228, p. 59 and ORNL-325, p. 79

(43) M. S. Plesset and S. T. Cohen, Scattering and Absorption of Gamma-rays and Neutrons, R-132

(44) T. A. Welton, LP-141, A Heavy Iron-Aggregate Concrete Called MO

(45) H. A. Bethe, Neutron Diffusion at Large Distances From the Source, AECD-2105

(46) Clifford et al, Preliminary Capture Gamma Measurements, ORNL-51, p. 21

(47) Nelson and DeMarcus, Methods of Probabilities in Chains Applied to Particle Transmission Through Matter, NEPA-1135-STR-13

(48) B. T. Feld, Analysis of Inelastic Scattering, Phys. Rev. 75, 1115 (1949)

[redacted]

APPENDIX V

SUGGESTED REPORTS FOR DECLASSIFICATION

The following lists some older shielding reports which it is thought might with some censoring, be usefully declassified. In some cases a few notes are given about some of the items that might need to be deleted.

Friedman, the report cited in reference (31) above.

Wende, TNX-7 or N-609 or M-1324; may need to delete or revise section 2.

Wigner and Young, MonP-283; revise to avoid saying the fission spectrum is exponential, and delete reference to high flux pile.

Young, MonP-293

Soodak, LP-126; section 2 (p. 11 through 15), and maybe section 1 (p. 7 to 11), might be declassifiable.

Welton, LP-141; delete p. 4 through 9 and from p. 13 on, and delete mention of experimental result on p. 10.

Friedman, LP-154

Goertzel, LP-159; delete mention of experimental result on p. 3.

Wigner, C-137

[redacted]

Greuling; MonP-172, p. 23-28; MonP-130, p. 7-9.

Friedman, LP-178

Chicago Handbook, CL-697, Chapter V, section F.

1948 Summer Symposium Notes on Shielding, Supplement No. 1, Blaw-Knox article, Part III, p. 109-118.

Coveyou, CH-1629

Murray, references (34) and (36) and (35) above delete experimental results in the last of these.

Borst and Wollan, CP-378

Libbey, M-3551

Plesset and Cohen, reference (43) above

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