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ORNL SUMMER SHIELDING SESSION

Gale Young, Leader

PROGRAM FOR THE ORNL BULK SHIELD TESTING FACILITY

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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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OAK RIDGE NATIONAL LABORATORY

PROGRAM FOR THE ORNL BULK SHIELD TESTING FACILITY

Abstract

2×10^8 neutrons/cm^2 sec. emerging from a hole in the ORNL pile shield generate gammas and fast neutrons in a 28" x 32" source plate of natural uranium. The radiation enters a 7' x 11' x 7' water tank, in which the test sample can be located. After initial calibration, it will be possible to investigate one sample of fixed composition and geometry in two weeks, or one given set of components such as iron and water in representative geometries and relative concentrations in two months. Measurable attenuations are: with thermal neutron detectors 10^9, with ionization chambers for gammas 4×10^5, with G. M. tubes for gammas $10^6 - 10^7$, with devices measuring biological neutron dosage, or measuring neutron and gamma spectra $10^4 - 10^5$. Fundamental information pertinent to shield design will be sought, the desired accuracy being $\pm$ 5% of the thickness or g/cm^2 required for any given attenuation. Present one-shift operation of the facility requires about 10 people, not all of which are available at the time of writing. Expansion to two shifts, and to the use of the thermal column on the top of the ORNL pile, as a second facility are under consideration. The personnel requirements increase somewhat less than proportionally to the number of shifts.

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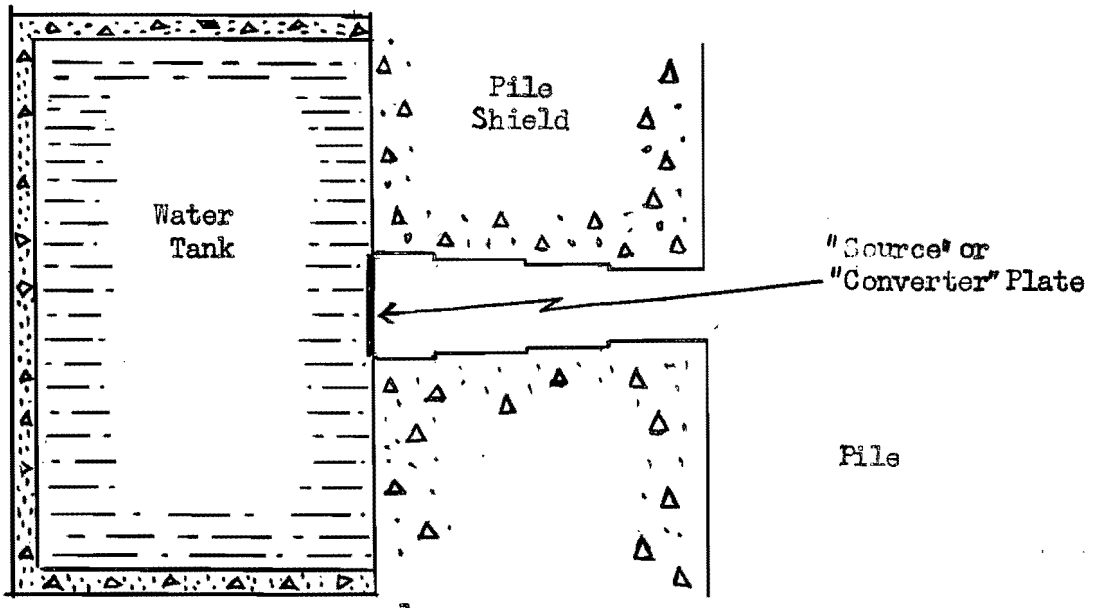
1. Description of the Facility

The ORNL Bulk Shield Testing Facility (see sketch) uses the neutrons which



emerge from the 28" x 32" hole[1] through the 7' shield of the ORNL pile. These neutrons, most of which are thermal, impinge on a "converter plate", made up of cylindrical slugs of natural uranium. Hence the converter plate becomes a source of neutrons and γ-rays, with a spectrum which is--except for degradation inside the plate -- a fission spectrum.

Outside the converter plate, there is a water tank, 11 feet wide, 7 feet high and 7 feet thick. The test samples are inserted into this tank and the radiation penetrating various thicknesses of the sample is measured. The purpose of the water is, mainly, to protect the operating personnel from radiation while allowing easy maneuvering of the test samples.

The thermal flux at the pile end of the core hole is 5×10^9 n/cm^2 sec., but this flux is attenuated by a factor of about 25 before it reaches the converter plate. This attenuation is merely a geometrical effect, due to the absorption of some of the neutrons by the walls of the core hole, and it results in a colli-

[1] E. P. Blizard, C. E. Clifford, J. Cassidy, ORNL 32, p.3, and fig. 9

[redacted]

mation of the neutrons. The remaining 2×10^8 neutrons create fast neutrons in the converter plate and considering the competing reactions and the loss of the neutrons traveling in the direction back to the pile, a source current of the order of 10^8 n/cm^2 sec is expected from the converter plate. The fissions in the converter plate correspond to a power of the order of 10 watts.

There will be some fast neutrons and γ-rays from the pile which penetrate the source plate, and enter the water tank. The neutron background is estimated to be about 10% of the total flux entering the tank. For γ's the background is not known at present. A movable boron shutter is provided which when closed absorbs most of the thermal neutrons before they hit the source plate and consequently prevents most of the fissions in the plate. This arrangement makes it possible to measure the background effects alone. Subtraction of the background from the measurements with the shutter open reveals the effects of the fission spectrum of both neutrons and gammas.

Unfortunately, the source plate and some material in its neighborhood sends some neutrons back into the core hole where they cause capture γ's in such components as the iron lining of the hole. These neutrons, and hence the secondary γ's which they create, are influenced by the shutter position, and this makes the background measurements less clear-cut than outlined above.

Furthermore, the background radiation is collimated; that is, the neutrons or γ-rays proceed all in about the same direction. On the other hand, radiation from the source plate is isotropic; that is, the radiation is emitted in all directions. There is some difference in the penetration of collimated and isotropic radiation. This complicates matters further, but offers, on the other hand, some hope of investigating these two types of radiation separately.

It is also necessary to place a boron shutter on the outside of the source plate (between source plate and tank) to prevent the shielding sample from reflecting thermal neutrons into the source plate. This would cause variation in the source strength, every time the sample is changed, and it also would prevent complete shut-off of the source, because fast background neutrons would be slowed down and reflected by the sample and cause fissions in the source.

A third shutter can be inserted on the pile side of the source plate. This shutter has a circular aperture and confines the fissions to a circle in the center of the source plate, making a symmetrical source available, the size of which can be controlled by using shutters with various apertures.

The time required for the investigation of one sample of fixed composition and geometry is estimated to be two weeks. A given set of components such as iron and water should be investigated in various relative concentrations, so that one such set of components will take about two months. These time estimates refer to one shift operation.

These long measuring times become necessary because several types of measurements must be made and long counting times are essential at low fluxes. An additional time consuming factor is also the necessity of taking, in some cases, numerous measurements off the center line.

The measurements off the center line are sometimes necessary for the following reason. The source is 28" x 32", and the samples are about twice as large. The measurements have to be reduced to some definite geometry, such as an infinite plane source, or a point source, in an infinite sample. In some cases, the Hurwitz[1] equation is applicable which makes this reduction on the basis of measurements along the centerline only. In the other cases, the measurements

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[1] See ORNL-436, p. 8.

off the centerline are essential, and they can be tedious in spite of the use of automatically recording instruments, and careful choice of the measuring time at each point, designed to obtain a given statistical accuracy in a minimum of time.

For the measurements close to the walls and surface of the water tank-- such as measurements behind thick samples or measurements far off the centerline-- one must consider the background of radiation generally prevailing in the pile building. A one-foot concrete wall has been built around the tank, and this wall attenuates the neutron background to the point where the sensitivity of the instruments, rather than the background limits the detectable radiation. This is not true at the upper surface of the tank and hence the measuring instruments must be kept somewhat below the surface where the background is sufficiently low. This limits the useful excursion of the instruments to about 75 cms above the center line. For gamma rays the background is not detectable with the ionization chambers. However, with the more sensitive G. M. tubes the background can be reached and it amounts to about five times the background of cosmic rays and spurious pulses.

With thermal detectors a total neutron attenuation of 10^9 seems to be measurable. For this attenuation the lowest reading, taken with a BF_3 tube of 50 square inches effective area, would be about 10 counts/min and this is still above the background at the center line of the sample. For γ's the ionization chambers measure to an attenuation of 4×10^5, the instrument being the limiting factor. G. M. tube can measure into the background which is about 10^{-6} to 10^{-7} of the intensity at the source. Regarding attenuations through which the energy spectra can be followed, see Section 4.

The sample sizes used at present are believed to be adequate to minimize spurious effects at the sample boundary. As long as inexpensive materials like iron and lead are used, it appears unnecessary to determine the required sample size very accurately. However, with tungsten it becomes important to consider the sample size carefully, since a reduction in size by one foot corresponds to several tons saving in expensive material. It may be necessary to investigate such tricks as surrounding the test sample by another material of similar nuclear properties but greater availability.

2. Purpose of the Program

The purpose of the ORNL bulk shielding program is to obtain fundamental information pertinent to the design of shields. The emphasis on fundamental information contrasts the program with cut-and-try tests which would be applicable only to specific cases. However, the information is not intended to be as fundamental as cross sections, etc., which require Monte Carlo or complicated analytical calculations to be converted into actual shield design.

Specifically, the investigations to be done will fall into the following categories, listed approximately in the order in which they will be attacked.

a. Calibrated measurements of the attenuation of fission neutrons and associated gammas in uniform shields[1].

b. Calibrated measurements, as under a, but with the difference that pile structure materials such as Fe, Be, and H_2O are inserted between the source and the sample.

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[1] Uniform shields are shields with a composition which is constant over the sample, except for inhomogeneities of the order of a relaxation length or less. Shields made up of laminations may be uniform according to this definition.

[redacted]

c. Investigation of graded shields, that is, shields the average composition of which varies throughout the sample.

d. Investigation of the effect on gamma rays of the addition of small amounts of boron in strategic locations.

e. Investigation of ducts and voids[1].

f. Test of specific arrangements of shield components suggested by contemplated applications.

3. Accuracy of Experiments

It is intended to aim for an accuracy of $\pm$ 5% in the thickness or g/cm^2 required for any given attenuation.

Connected herewith is a requirement for calibration of the measurements to within a factor of 2 or better. This means that the wattage in the fission source plate of specified design will be measured and that the neutron and gamma flux will be expressed in absolute units (e.g. neutrons/cm^2 sec., biological dosage). In a shield with an attenuation of e^{20} an error by a factor of 2 in the absolute calibration corresponds to 3.5% in the shield thickness.

4. Measuring Techniques

At present the gamma flux is measured by ionization chambers and G. M. tubes. The neutron flux is measured by BF_3 counters; natural U, 25 and 28 fission chambers; and gold and indium foils.

An important quantity will be the biological dosage. For gammas this is being measured by suitable ionization chambers. An integrating proton recoil counter for measuring the biological dose due to neutrons above thermal energies is being developed by the ORNL Health Physics Division and will be adopted for

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[1] It may very well be that ducts and voids will have been tested to a large extent in connection with critical assemblies, by the time the ORNL Bulk Shield Testing Facility gets to this phase of the program.

[redacted]

shielding measurements. This instrument requires considerably higher fluxes than thermal neutron detectors.

None of the above neutron instruments distinguish in themselves between neutrons of different energies except that the 28 fission chamber is sensitive only to neutrons above about 1 Mev.

It is contemplated to use instruments specifically designed for spectroscopy, such as fluorescent crystal counters and deuterium loaded films for gammas, and proton recoil counters and films for neutrons. This is also discussed under "Expansion of Facilities". Some ideas regarding the spectrum could perhaps be obtained with the present instruments by following the attenuation through the water -- or any other "analyzer" substance -- behind the sample. The shape of the attenuation curve in the analyzer should be indicative of the spectrum.

It should be emphasized that any type of spectroscopy --whether by means of the "analyzer" discussed above, or by a specifically designed spectroscopic instrument,-- requires higher fluxes than the mere measurement of thermal neutrons. Hence, the spectroscopy will be limited to attenuations of the order $10^4 - 10^5$, and even so, long counting times will be required.

5. <u>Priority and Limitations</u>

Priority shall be given in the following order:

a. Calibration of the facility, such as measurements of the background, measurement of the power in the source plate and so on.

b. Tests on materials of interest primarily to mobile reactors such as Pb, W, Fe, B and hydrogenous material. U offers a somewhat more complicated problem because of the neutron multiplication and national policy and, according to present plans, it will not be attacked in the near future. The first tests will involve water and combinations of water with Fe and Pb.

c. Tests on materials of interest primarily to stationary reactors, such as MO; anhydrous MO; Hanford type shields; and such materials and configurations as suggested by the MTR, Hanford and Schenectady projects. These tests are to be interleaved with the mobile reactor tests, and they are to be carried out at such times that they do not interfere seriously with the mobile reactor projects. Many of the tests contemplated primarily for mobile reactor applications are of direct interest to stationary reactors.

Limitations of the present bulk shielding facility include:

a. The fact that the attenuation factor through which neutron biological dosage, and neutron and gamma spectra can be measured is not as great as the attenuation factors anticipated for future reactor shields. Hence, extrapolation with inherent uncertainty is required. This is particularly true with respect to fast neutrons.

b. The large amounts of material required. Even if it is possible to use the trick of surrounding the test sample with cheaper material of similar properties, it still will be difficult to test such substances as B^{10} and Li^{6}, although these substances very likely could be obtained in sufficient quantities for actual shields, once their value was established. Cross section measurements by means of high voltage machines and subsequent theoretical calculation seem to be a better method of investigating the value of such expensive substances.

c. The difficulty of testing whole shields (shadow effects, etc.). Critical experiments, used as shield testing facilities, might be more suitable for tests of this kind.

6. <u>Expansions under Consideration</u>

a. Two-shift operation at the present facility, instead of the present one-shift operation. The introduction of more than two shifts would not help much

because the time not occupied by the two shifts could be used for operation of automatic devices.

b. The conversion of the thermal column on top of the ORNL pile into another bulk shield testing facility. This would not interfere with the thermal column work of the Biology Division.

c. The above mentioned use of neutron and gamma spectrometers, such as proton recoil counters, fluorescent crystal counters, and D-loaded film. A fluorescent crystal counter is available, but at present unused.

7. Personnel Requirements

a. One-shift operation of the present facility; no spectroscopy

1 Engineer to direct operations and to assist in planning of future operations and to make preliminary reports on data.

3 Technicians to take the readings at the test facility and in the counter room.

1 Instrument Man to check the instruments according to established checking procedure, and to replace and repair faulty ones. Possibly part-time service of the instrument man would do, provided the bulk shielding would have priority before other work.

1 Computer to bring the data into standard form, plot them, etc.

3 Physicists, to analyze and report the data; to plan future operations; to compare the results with existing theories.

1 part-time Secretary to type reports as well as to be responsible for files and the shielding library, and to assist the computer if possible.

b. Additional Personnel for Two-Shift Operations of the Present Facility; No Spectroscopy:

1 Engineer to direct operations

1 Technician to take readings

1 Instrument Man (as under a). One full-time instrument man would not do for both shifts, because of the possibility of failure of instruments during the second shift.

1 Computer (as under a)

1 Physicist

1 Secretary full-time would suffice for both shifts.

c. Second Facility - Initial Phase:

This would require the full-time services for at least a month of a mechanical engineer and of a physicist familiar with the shielding problem. These two men should come up with a report recommending or discouraging the use of the thermal column as a shield testing facility, and if they recommend its use, they should point out what is required in the way of preparation for this application. The time required for these preparations should be estimated in the report, and if possible, earlier.

d. Further Additional Personnel for Two-Shift Operation of Two Facilities, With Spectroscopy:

3 Technicians, one for normal operation of each extra shift, and one for spectroscopy measurements.

1 Engineer to direct operations (the type of work during at least one shift would be such that it could be done by a technician).

1 Senior Physicist or Electronic Engineer to design the spectroscopic instruments and to assume responsibility for spectroscopy.

1 Computer

1 Physicist

1 part-time Secretary

2 Instrument Men, full-time, one for each shift, should be sufficient for both facilities, but their qualifications should be rather high because of the complex spectroscopic instruments.

The following table summarizes the personnel requirements:

	Core Hole 1 Shift	Core Hole 2 Shift	Core Hole and Thermal Column (2 Shifts Each)
Engineers to direct operations	1	2	3
Technicians	3	4	7
Instrument Men	1/2-1	2x1/2 or 1-1/2	2
Physicist or Electronics Engineer for n-and gamma spectroscopy			1
Computer	1	2	3
Physicists	3	4	5
Secretary	1/2	1	1-1/2

Note: The operation of the thermal column, as included in the last column, of the table would have to be preceded by a study, requiring one mechanical engineer and one physicist, for one month.

8. Procedure in Expanding the Facility:

At present, we do not have quite sufficient personnel for the one-shift operation of the present facility. The instrument man, one physicist and two technicians are lacking. It is recommended that the full staff for one-shift operation be assembled, before two shifts are attempted, and that the second facility be investigated but not designed until the two shifts are running. The investigation of the second facility shall have lower priority than the operation of the present set-up.