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SUBJECT: SUMMARY OF LID TANK NEUTRON DOSIMETER MEASUREMENTS IN PURE WATER

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The instrument used to detect the fast-neutron dose consists of a proportional counter, designed by G. S. Hurst¹, an integrator (pulse sorter) designed by F. Glass.² Hurst and Glass give a rather detailed discussion of the operational characteristics as well as adjustments that must be made to insure accurate dosage measurements. Since measurements in the Lid Tank must be carried out in a field of varying gamma radiation to which the counter is sensitive the gain and pulse size discrimination must be set so that the gamma-induced pulses account for only a very small percent of the total count rate. It was determined experimentally that the counter operated satisfactorily in a gamma flux of 10 R/hr.

If a polonium-beryllium source is used and the pulses are taken from the discriminator circuit of an A-1 amplifier, a determination of the high voltage setting for the tube can be obtained. A typical count per minute vs high voltage curve is shown in Fig. 1. However, with some of the tubes the straight portion of the curve is not so extensive as the curve shown.

The gamma-ray cut-off was determined by placing a radium source at a distance from the counter which would produce a gamma dosage of 10 R/hr. By varying the gain of the A-1 amplifier, the gamma-ray count rate can be controlled since its pulse, without pile up is much smaller in amplitude than the proton pulse. In Fig. 2

a plot of counts per minute vs gain illustrates the effect of the change of gain on the response to gamma radiation or fast neutrons produced by a polonium-beryllium source.

To determine the counter's sensitivity to fast neutrons a polonium-beryllium source in air was used. The dosage per count was calculated by the use of the inverse square law. The conversion factor from neutrons/cm²/sec to mrep/sec (4.0×10^{-6}) for a polonium-beryllium source was computed by G. S. Hurst of the Health Physics Division. By substitution in the following equation, dosage per count per minute is obtained:

$$\frac{\frac{\text{neutrons/sec}}{4\pi(Z^2)} \times 4.0 \times 10^{-6} \times 3.600 \times 10^3}{\text{count/min}} = \frac{(\text{mrep/hr})}{(\text{count/min})}$$

(Z = distance from source to center of detection of the counter).

Fast-Neutron Dosimeter Measurements in Water

Over a period of approximately 1 1/2 years a series of fast-neutron dosage measurements were made in the Lid Tank. Table 1 shows the results of these experiments by date and by experiment numbers. Experiment 11-0 (0.6% Boron-water) included in this summary indicates the effect of the Boron on fast neutron dose is practically negligible. Dosage measurements entitled by PHS were

obtained from a graphical integration of the integral pulse height curves from the A-1 amplifier for comparison with the dose observed by the pulse integrator. These dosage measurements of both methods appear to be in good agreement.

The gamma discrimination for Lid Tank measurements was increased so that the counts from gamma rays are biased out for a dose of 17 R/hr, which is the radiation at about 37 cm from the source plate. To insure that gamma radiation was not being detected, measurements were taken with the pile power lowered from 3600 to 2100 kw. The effect of lowering the pile power on gamma radiation is shown in the inset of Fig. 3. In the overlapping region from 30 to 70 cm from the source the agreement was within a few percent, which indicates that gamma radiation was not detected at the higher pile power level since the gamma counting rate would vary as the square of the gamma intensity (due to pile up). The counting rate was also shown to not be so high as to cause a serious loss of counts at the higher power.

To determine whether the pulse integrator was measuring the proper dosage, a comparison by graphical integration of the pulses was made. G. S. Hurst and R. H. Ritchie³ show that the area under the PHS curve from a source of fast neutrons is proportional to the dose received. Pulse height curves were taken using a polonium-beryllium source to determine the fast neutron dosage per unit of area under the curve. PHS curves were then made in the Lid Tank as shown in Table 1.

The dosage obtained by graphical integration of the PHS curves is in close agreement with the dose which was given by the pulse integrator. Had there been a difference between the two methods of obtaining dosage, this would have indicated that the pulse integrator was not operating properly. Since the slope of the pulse height curves taken in the Lid Tank does not change appreciably as the pulse height approaches zero, this is an indication that no gamma radiation was detected.

Comparison of Bulk Shielding Facility and Lid Tank Shielding Facility Dosimetry

In comparing the BSF and Lid Tank fast-neutron dosimeter data, the measurements of the Lid Tank were reduced by a factor of 6, since the Lid Tank source is about 6 watts. The BSF data is approximately a factor of 2 higher than the Lid Tank data at small source distances, these blending together in the vicinity of 110 cm from the source.

Blizard and Welton⁴ have compared the fast neutron dose in water as measured at the two ORNL shielding facilities, making detailed corrections for the differences in power and geometry. Their calculations show a discrepancy between the two of a factor of about two.

To investigate the possibility that this discrepancy could be laid to differences in measuring technique, the fast neutron and gamma

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sources and the method of calibration used at the BSF were applied at the Lid Tank. It was found the polonium-beryllium source used at the BSF produced approximately 8% higher counting rate per unit dose than the source used at the Lid Tank. This is understandable since the source strengths are only known to $\pm 7\%$. However, in an effort to eliminate both calibration and instrumentation differences between the measurements taken at the two facilities, the Lid Tank equipment was taken to the BSF and each dosimeter was calibrated by its own sources. Before making dosage measurements at the BSF 11.4 cm of lead was placed 10 cm from the north face of the reactor so as to reduce the gamma radiation. The gamma dose is shown in the inset of Fig. 4. The neutron dosage measurements in water were made successively. The dosage measurements taken with the Lid Tank equipment appeared to be about 3% higher than the BSF measurements. Note that due to a change in the BSF reactor fuel element configuration, the dosage measurements shown in Fig. 4 are a few percent higher than in the previously observed water data.⁵ It therefore appears that there is no appreciable error in either the Lid Tank or BSF measurements.

Acknowledgement is given to H. E. Hungerford for the BSF Neutron dosage measurements and to R. G. Cochran for his assistance in this project.

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 2. F. M. Glass and G. S. Hurst, Method of Pulse Integration Using the Binary Scaling Unit, Rev. Sci. Instr. 23, 67 (1952)
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 4. E. P. Blizard and T. A. Welton, Shielding of Mobile Reactors, ORNL-1130, Part 2 (1952)
 5. R. G. Cochran and H. E. Hungerford, Fast Neutron Dosimeter Measurements, C.F. 51-5-61 (1951)
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Encl. Tables 1, 2.
Figures 1 - 5.

Table 1

NEUTRON DOSIMETER MEASUREMENTS IN PURE WATER

Distance From Source Z(cm)	Gamma Dosage ¹⁾		Fast Neutron Distribution in Pure Water Measured at Various Dates (mrep/hr)			
	3600 kw	2100 kw	10/26/51	5/3/52	10/19/50	5/7/52
16.1	-	-	-	-	-	2.047×10^3
20.0	-	1.57×10^3	-	-	-	-
25.0	-	-	-	-	-	-
26.1	-	-	-	6.33×10^2	-	6.18×10^2
30.0	-	4.26×10^2	-	-	-	-
36.1	-	-	-	1.79×10^2	-	1.776×10^2
40.0	1.07×10^2	1.08×10^2	-	-	1.066×10^2	-
45.0	5.49×10^1	-	-	-	-	-
46.1	-	-	-	$6.01 \times 10^{1*}$	-	4.973×10^1
50.0	2.86×10^1	2.87×10^1	-	-	2.86×10^1	-
55.0	1.51×10^1	-	-	-	-	-
56.1	-	-	-	1.36×10^1	-	1.36×10^1
57.3	-	-	1.05×10^1	-	-	-
60.0	8.11×10^0	7.94×10^0	-	-	8.11×10^0	-
65.0	4.12×10^0	-	-	-	-	-
66.1	-	-	-	3.78×10^0	-	-
67.3	-	-	3.12×10^0	-	-	-
70.0	2.35×10^0	2.38×10^0	-	-	2.35×10^0	-
76.1	-	-	-	1.09×10^0	-	-
77.3	-	-	8.69×10^{-1}	-	-	-
80.0	7.0×10^{-1}	-	-	-	-	-
86.1	-	-	-	3.39×10^{-1}	-	-
87.3	-	-	2.59×10^{-1}	-	-	-
90.0	2.5×10^{-1}	-	-	-	-	-
96.1	-	-	-	1.07×10^{-1}	-	-
97.3	-	-	8.00×10^{-2}	-	-	-
106.1	-	-	-	3.37×10^{-2}	-	-
107.3	-	-	3.20×10^{-2}	-	-	-
116.1	-	-	-	1.35×10^{-2}	-	-
117.3	-	-	1.5×10^{-2}	-	-	-

1) Experiment 11-0

* not reliable

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COMPARISON OF BSF AND LID TANK NEUTRON DOSIMETERS IN WATER

Distance From Source* Z(cm)	Neutron Dosage (mrep/hr)	
	BSF	Lid Tank
47.8	1.48×10^1	1.53×10^1
57.8	3.29×10^0	3.31×10^0
67.8	7.55×10^{-1}	7.72×10^{-1}
77.8	2.16×10^{-1}	2.08×10^{-1}

*BSF Reactor

Fig. 1 NEUTRON DOSIMETER COUNT RATE
VS. HIGH VOLTAGE

COUNTS/MINUTE

10⁴
10³
10²

1900 2000 2100 2200 2300 2400 2500 2600

HIGH VOLTAGE

NO. 340-L210 DIETZGEN GRAPH PAPER
SEMI-LOGARITHMIC
2 CYCLES X 10 DIVISIONS PER INCH

EUGENE DIETZGEN CO.
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Fig. 2 NEUTRON DOSIMETER COUNT RATE VS. AMPLIFIER
GAIN FOR NEUTRON AND GAMMA RAYS

Fig. 3 FAST NEUTRON DISTRIBUTION IN PURE WATER

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Fig. 4. COMPARISON OF LID TANK AND BULK SHIELDING FACILITY
NEUTRON DOSIMETERS BY MEASUREMENTS IN PURE WATER AT THE BSF

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