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BROOKHAVEN NATIONAL LABORATORY

MEMORANDUM

DATE: March 8, 1960

TO: Dr. J. S. Robertson

FROM: C. G. Amato CGA

SUBJECT: Summary of BMRR Patient Therapy Portal Geometries.

1.0 Since last spring over 20 geometries have been experimentally evaluated when built into the BMRR in order to arrive at one which will produce a maximum thermal neutron flux and an accompanying minimum gamma intensity. In addition, the spectral destribution of the flux should be that of a soft spectrum, i.e., no fast neutrons.

2.0 Neutron spectrum determinations have been made using radioactivants, a technique based upon threshold energy for various reactions. Gamma intensity has been measured using a Li-shielded Victoreen condensor-r-meter having a wall thickness designed to insure secondary electronic equilibrium when the chamber is exposed to Co^{60} gamma radiation. In addition, radiophotoluminescent glass needles have been recently introduced. These needles are relatively neutron-insensitive and apparently energy-independent without metallic shielding from 1 MeV to 22 MeV. No gamma spectral distribution has as yet been obtained.

3.0 The data in the first of the two enclosures report, in the first two columns, the measured rates. The third through tenth columns of data translate the rates into what I hope will be figures of significance for the doctors, and that is, exposure and exposure time. These eight columns are broken up into four categories determined by either the total gamma exposure or thermal neutron NVT. Depending upon the criterion, the corresponding exposure time and NVT are reported in the third through eighth columns. The ninth and tenth columns reflect the effect of holding thermal neutron NVT at 10^{13} and show the accompanying gamma dose and exposure time. The geometries have been ranked according to gamma dose delivered per 10^{13} NVT. Exposure time, which cannot be neglected in practice, has been overlooked in this rating. The lower the gamma exposure in r, the higher the rating (there are two minor exceptions to this).

4.0 These enclosures are essentially the same as those prepared for an inter-departmental meeting in January attended by Dr. Haworth, Dr. Farr, Mr. Powell and others. During this meeting, Dr. Farr stated his specifications for neutron capture therapy. They are:

a. 5×10^{12} to 10^{13} NVT of thermals
b. 100 r or less of gammas
c. 100 ms to 100 sec exposure time
d. no fast neutrons
e. an undefined, as yet, resonance spectrum

If these requirements are strictly applied, no geometry is suitable. If the maximum gamma exposure requirement is relaxed to permit 300 r and exposure times of 100 to 200 seconds, then five configurations are acceptable. On one of which, in theory, is usable, and that is geometry E due to the absence of a "fast" neutron flux.

5.0 As of this writing, the patient therapy portal configuration denoted as geometry E has been installed and measurements taken. While the data obtained and an analysis of it will be published shortly in another memo, the following comments, subject to future modification, are made:

a. There are no neutrons above 1.5 MeV present.
b. Neutron number flux fell below the design goal by slightly more than 50%.
c. Gamma intensity is lower than anticipated.
d. More work will be done this week to place gamma measurements on a firmer footing.

6.0 The techniques of neutron spectroscopy and gamma dosimetry, per agreement, will be outlined in detail in a "cook-book" type of report which should be issued in June.

cc: Dr. L.E. Farr
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Measured Radiation Rate		Integrated Ra			
Gamma	Thermal Neutron	Gamma Dose Limited to 500 r		Gamma Dose Limited to 300 r	
(r/hr)	(n/cm^2-sec)	Thermal NVT (n/cm^2)	Exposure Time (seconds)	Thermal NVT (n/cm^2)	Exposure Time (seconds)
240	2.4×10^{9}	1.79×10^{13}	7460	1.08×10^{13}	4476
7,200	5.0×10^{10}	1.25×10^{13}	250	7.5×10^{12}	150
9,600	6.2×10^{10}	1.17×10^{13}	188	7.0×10^{12}	144
3,600	2.3×10^{10}	1.16×10^{13}	499	6.9×10^{12}	300
3,240	1.7×10^{10}	8.9×10^{12}	555	5.4×10^{12}	333
6,600	3.1×10^{10}	8.4×10^{12}	272	5.0×10^{12}	165
7,500	3.2×10^{10}	7.7×10^{12}	240	4.59×10^{12}	144
3,600	1.3×10^{10}	6.5×10^{12}	500	3.9×10^{12}	300
24,000	7.5×10^{10}	5.6×10^{12}	75	3.4×10^{12}	45
7,500	2.3×10^{10}	5.4×10^{12}	240	3.24×10^{12}	144
25,680	6.6×10^{10}	4.6×10^{12}	70	2.77×10^{12}	42
28,900	6.7×10^{10}	4.12×10^{12}	63	2.61×10^{12}	39
16,200	3.7×10^{10}	3.89×10^{12}	111	2.34×10^{12}	66
24,000	5.1×10^{10}	3.83×10^{12}	75	2.28×10^{12}	45
32,400	6.7×10^{10}	3.58×10^{12}	55	2.15×10^{12}	33
8,400	1.89×10^{10}	3.16×10^{12}	167	1.9×10^{12}	102
33,000	5.24×10^{10}	2.88×10^{12}	55	1.73×10^{12}	33
48,000	6.4×10^{10}	2.4×10^{12}	38	1.34×10^{12}	24
51,400	6.12×10^{10}	2.14×10^{12}	35	1.28×10^{12}	21
45,000	3.8×10^{10}	1.53×10^{12}	40	9.18×10^{11}	24

1 i a t i o n D o s e

Gamma Dose Limited to 100 r		Thermal Neutron NVT of 10^{13}		Remarks
Thermal NVT (n/cm^2)	Exposure Time (seconds)	Gamma Dose (r)	Exposure Time (seconds)	
3.6×10^{12}	1492	248	4170	BNL Graphite Pile, Medical Facility
2.5×10^{12}	50	400	200	BMRR Proposed Revision Geometry B
2.34×10^{12}	38	425	161	Geometry A with 4"x4" Li F head bloc and 2" additional Bi shielding
2.32×10^{12}	100	431	431	Geometry A, 4" additional Bi shieldi
1.8×10^{12}	111	542	602	Geometry D
1.68×10^{12}	55	668	323	Geometry A, 2" additional Bi
1.53×10^{12}	48	650	313	Geometry A, 2" additional Bi shielding and 3"x3" head block
1.3×10^{12}	100	770	770	Geometry C, outer 4" Bi removed, all D_2O tanks full and 1.0 ft. graphite added
1.12×10^{12}	15	892	134	Geometry B with outer 8" Bi plate removed
1.08×10^{12}	48	927	445	Geometry B with D_2O thickness extrapolated to 15 inches
9.24×10^{11}	14	1084	152	Geometry B, 3.7 in. of D_2O
8.71×10^{11}	13	1196	149	Geometry B, 1.8 in. of D_2O
7.8×10^{11}	22	1215	270	Geometry B with D_2O thickness extrapolated to 10 inches
7.6×10^{11}	15	1305	196	Geometry B
7.2×10^{11}	11	1355	151	Geometry B, all D_2O tanks empty
6.3×10^{11}	34	1235	529	Geometry B with plastic reflector an outer 8" Bi glock removed
5.8×10^{11}	11	1750	191	Geometry B with outer 8" Bi plate removed and a 2.5 in.thick Bi reflecto
4.8×10^{11}	8	2090	157	Geometry B with 8.0 in. removed from inner Bi block and no outer Bi plate
4.3×10^{11}	7	2570	164	Geometry B with a 0.25-in. thick Al sheet placed over the reflector
3.1×10^{11}	8	3290	263	Geometry B with the plastic reflecto removed and 8" from the inner Bi

BMRR Patient Therapy Portal Geometries

Core

0.25 in. C
0.25 in. Al
0.25 in. air gap
6.0 in. C
12.0 in. Bi

A	B	C	D	E
5.5 in. C	5.5 in. D_2O	5.5 in. D_2O	5.5 in. D_2O	5.75 in. air gap
0.12 in. Mg	0.25 in. Al	0.25 in. Al	0.25 in. Al	0.12 in. Mg
4.0 in. C	0.12 in. Mg	0.12 in. Mg	0.12 in. Mg	2.0 in. Bi
8.0 in. Bi	4.0 in. C	4.0 in. air gap	12.5 in. C	8.0 in. D_2O
17 in. air gap	8.0 in. Bi	8.0 in. Bi	16.5 in. air gap	3.0 in. Bi
Dose point	17 in. air gap	17 in. air gap	2.0 in. Bi	16 in. air gap
	Dose point	2.0 in. Bi	Dose point	1.0 in. Bi
		Dose point		Dose point

All geometries describe the shutter open position. In geometry E, the 2" Bi, 8" D_2O and 3" Bi are located within the movable shutter. In geometries A, B, C, and D, the D_2O is surrounded by Bi. Unless noted to the contrary under remarks and excluding the graphite pile from consideration, the outer air gap, which is conically-shaped, is lined with a polyethylene reflector.