for Dr Farr

717673

Letter from Schott Bergen & Dr Farr

November 20, 1952

October 10, 1952

A. Schott
Neurology
Bergen, Norway

Dear Dr. Schott:

In Dr. Farr's absence, I am replying for him to your request for information regarding the use of neutron-capturing isotopes in the treatment of brain tumors.

The technic at the reactor consists simply of placing the patient's head in position over an opening through the shield of the reactor and of a size comparable to that of the area which it is desired to irradiate. A gamma shield is interposed in the opening to reduce the effects from gamma rays. No graphite in addition to that normally present in the reflector of the reactor is used; such use would give a better thermalized beam, but would also reduce the thermal neutron flux. The patients are sedated, but are conscious. The length of time of the irradiation varies with our estimate of the concentration of boron in the tumor and with the neutron flux available.

Since we are not sure just what features of the technic you wish to know about, this may not answer your question satisfactorily. However, we would be glad to answer more specific questions if we can. The details have not been published.

Sincerely yours,

BEST COPY AVAILABLE

James S. Robertson, M.D.
Head, Biophysics

JSR:mg

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BOX No.
FOLDER

4001907

I. The Patient Exposure Port. The patient exposure port and preparation room should use a vertical face of the reactor and remain essentially as now drawn. The more detailed design of the port should be modified as follows:

A. A shutter for the port should be provided.

1. The reasons are:

a. To allow access to the preparation room by persons preparing the patient, while the reactor is in operation.

b. To allow more accurate control of exposure time than would be possible if it were necessary to bring the reactor to power with the patient positioned for exposure.

c. To avoid interference with the independent operation of other facilities.

2. The shutter should consist of two parts, a neutron and a gamma shield.

a. The gamma shutter should be motor-driven, and require of the order of 60 seconds or less to open. While the gamma shutter is closed, continuous occupancy of the preparation room should be permissible (total radiation exposure less than 8 millirem/hour); while it is open, limited access to the region of the port should be permissible.

b. The neutron shutter should be of suitable materials for absorbing slow and epithermal neutrons and the total time for its opening or closing should not exceed two seconds. The shutter should be located between the patient headblock and the shielding interposed between the patient and the reactor core. It is anticipated that the patient headblock be rigidly fixed to a cart on which the patient can be completely prepared well-removed from the exposure port. When the patient is completely prepared, the cart can be wheeled to the exposure port. The headblock will be so designed and so positioned on the movable cart that it can be easily "plugged in" to the port opening, following which the neutron shutter can be opened for the exposure.

B. As presently indicated, the shielding and moderating materials between the patient and the reactor core are fixed. The entire assembly in the 20" diam tube leading from reactor core to treatment port, including the shutters, bismuth shield, deuterium tanks, and graphite stringers, should be removable. Graphite stringers should be removable essentially to the core of the reactor. Changing of the assembly should require no more than 2 or 3 days' work.

C. The center of the port should be 36 inches from the floor.

4001908

BROOKHAVEN NATIONAL LABORATORY

MEMORANDUM

REPOSITORY Brookhaven National Laboratory

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BOX No. _____

FOLDER _____

Date: December 7, 1959

To: Dr. J. S. Robertson

From: C. G. Amato CGA

Subject:

1.0 Recently, data have been analyzed which were taken, using various foils, with varying quantities of heavy water located between the BMRR core and the dose point (located at the center of the patient therapy portal). These data are presented in Table I. Table II contains a description of the shielding array. All measurements were taken at 1 megawatt. In addition, results of modifications in the liner of the cone are also reported.

2.0 Results of these measurements are summarized below.

2.1 No fast neutron flux, (energy greater than 2.9 MEV), was detected under any condition.

2.2 A fast neutron flux in the energy region 1.5 to 2.9 MEV is present. This flux is not a major component of the neutron spectrum. It is detected using boron-shielded fission foils (depleted U^{238}). Since the spectral distribution in this energy region is still unknown, I consider it unwise to convert a count rate to a number flux. However, relative intensity may be safely stated. As the amount of heavy water decreases, this component of the fast flux increases. When no heavy water is present, this component increases by a factor of 7.5 over the flux present with all D_2O tanks full.

2.3 The thermal neutron number flux and the gamma dose rate are inversely proportional to the amount of heavy water.

2.4 The average value for thermal flux with all heavy water tank full (as given by averaging data for six foils) is 5.1×10^{10} n/cm^2· sec. This increases to 6.5×10^{10} n/cm^2· sec when all D_2O tanks are empty.

4001909

4.5 A 1/4" thick aluminum sheet was placed over all surfaces of the liner.

$$\phi_{TH} = 6.12 \times 10^{10} \text{ n/cm}^2\text{-sec}$$

$$\phi_{\gamma} = 857 \text{ r/min}$$

4.6 The plastic liner and aluminum sheet were removed. The concrete cone surface was covered with a 2.5-inch layer of Bi.

$$\phi_{TH} = 5.24 \times 10^{10} \text{ n/cm}^2\text{-sec}$$

$$\phi_{\gamma} = 550 \text{ r/min}$$

4.7 A boron carbide epoxy resin plate was placed between the dose point and core with the arrangement noted in 4.5.

$$\phi_{TH} = \text{not measured}$$

$$\phi_{\gamma} = 670 \text{ r/min}$$

4.8 The core to dose point material sequence was altered and is described under "new configuration" in Table II. The Bi liner has been retained.

$$\phi_{TH} = 1.66 \times 10^{10} \text{ n/cm}^2\text{-sec}$$

$$\phi_{\gamma} = 54 \text{ r/min}$$

4.9 The preceding measurements were made at or scaled to 1 megawatt. All heavy water tanks were full at all times. Knowledge of core configuration by the reader of this memo is assumed.

5.0 An automatic wire scanner is under construction. A slow chopper will be received sometime in late January (sic). Gamma dose and spectral measurements will be soon begun. A subsequent memo will contain a critique of the foil technique.

C. G. Amato

cc: Dr. L.B. Farr
Dr. B.B. Stickley
Dr. Y.L. Yamamoto
Dr. S. Fine
Dr. V.P. Bond
Dr. S.H. Cohn
Dr. D.C. Borg
Dr. R. Sher
Dr. J.M. Hendrie
Dr. H.J.C. Kouts
Dr. G. Price
Mr. R.W. Powell
Mr. J. Gilmartin
Miss D. Driscoll
Mr. C. Meinhold
Mr. T. Konikowski
Mr. J.B. Godel
Mr. J. Floyd

4001910

TYPE OF MEASUREMENT

One D_2O Tank Pull				No D_2O Tank Pull			
$\phi_{TH + RES}$	ϕ_{RES}	ϕ_{TH}	CR	$\phi_{TH + RES}$	ϕ_{RES}	ϕ_{TH}	CR
5.25×10^{10}	4.43×10^{8}	5.48×10^{10}	6.5	5.95×10^{10}	5.79×10^{8}	5.89×10^{10}	5.5
6.8×10^{10}	5.6×10^{8}	6.7×10^{10}	6.5	7.5×10^{10}	6.8×10^{8}	7.5×10^{10}	6.0
6.5×10^{10}	3.18×10^{8}	6.43×10^{10}	11.	6.76×10^{10}	4×10^{8}	6.72×10^{10}	9.0
6.27×10^{10}	2.58×10^{8}	6.24×10^{10}	13.	6.53×10^{10}	3.1×10^{8}	6.5×10^{10}	11.
6.15×10^{10}	1.79×10^{8}	6.13×10^{10}	18.	5.9×10^{10}	2.38×10^{8}	5.87×10^{10}	14.
5.87×10^{10}	5.32×10^{8}	5.8×10^{10}	73.	6.55×10^{10}	7.38×10^{8}	6.48×10^{10}	58.
28,920 r/hr				32,500 r/hr			

1161004

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COLLECTION Cronkite Correspondence Files
BOX No.
FOLDER

MEDICAL RECORD COMMITTEE MINUTES

Members Present:

Dr. Dahl, Chairman
Miss Harrison, Secretary
Dr. Love
Mr. Finn

I. CORRECTION OF MINUTES OF 1-7-60

Under Item IV of the minutes of 1-7-60 the criteria for a patient on the Research Service was modified to read thus:

> "If the examination and/or medical care of an individual is not directly related to the investigator's research program per se, such examination and/or care should be considered as consultation to an Industrial Medicine case by a Research Staff member."

II. SUPPLEMENTARY RADIATION THERAPY FORM

Mr. Finn presented a draft of such a form from Dr. Cronkite whose patients frequently receive deep x-ray therapy in outside hospitals while on the BNL census. Miss Harrison suggested that this report was actually a detailed description of special radiation therapy, the main entry of which is included in the perpetual Isotope-Radiation Summary Form No. 1107-A. This newly proposed form, therefore, is similar to the mimeographed I^{131} tracer form, Neutron Capture Therapy measurements, and several other special forms designed principrily for the use of the scientific staff members. Hence, the question is whether or not these reports are bona fide medical record forms per se. Mr. Finn noted that these special reports are, nevertheless, frequently filed in the medical records and therefore, this Committee should reserve the right of review and evaluation. All members were in accordance with this concept, summarized thus:

> "The Medical Record Committee will be the responsible organ for the review, evaluation, and final decision regarding the development and use of all special clinical research forms that are to become an integral part of the medical record."

Dr. Dahl took the draft submitted by Dr. Cronkite and will study and appraise it with other appropriate staff members (e.g. Supervisor

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BOX No.
FOLDER

January 22, 1960

Dr. L. B. Farr

C. G. Amato CGA

Project status review

1.0 Purpose:

To present an end-of-year project review.

2.0 Project Status:

2.1 Neutron spectroscopy.

The major effort has been directed toward developing techniques, using activation analysis which will yield the spectral and spatial distribution of the patient neutron therapy beam in air, in vivo and in phantoms during steady-state reactor operation. These methods will also be applicable to pulsed neutron beams. The objectives of this program have been achieved. Eight isotopes are being used, and two more may be added in 26 geometries. Three counting techniques have been developed. Cadmium and boron shielding is used to obtain information in the resonance region. Results of this program indicate that, depending upon moderator, reflector and collimator geometry and pile-power level, a maximum thermal flux of 7.5×10^{10} may be attained accompanied by a very intense gamma beam. The gold resonance flux lying between 0.4 ev and 4.95 ev is two orders of magnitude less than the thermal flux. Neutron number flux falls off rapidly with energy vanishing at 2.9 MeV. An essentially uncollided neutron flux is present in the energy region of 1.5 to 2.9 MeV. The value of this value is approximately 9×10^{2} n/cm^2-sec. Film emulsion techniques, very recently used, confirm foil measurement. Greater use of emulsions will be made in the future. If possible, a slow chopper will also be used.

4001913

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BOX No.
FOLDER

February 24, 1960

Dr. C. E. Falk, Directors Office

Dr. E. E. Stickley

MRR mag

MEDICAL RESEARCH REACTOR: February 1960

The structural changes have now been completed in operating and preparation rooms attached to the MRR. These modifications serve to separate this suite from the air-lock entry system, where both the traffic pattern and the air supply had been unsatisfactory. The rooms can now function entirely independently of the reactor building, allowing their more effective utilization. The principal changes were the installation of two self-contained air-lock passageways and revision of the air supply and its associated equipment.

Certain experimental work of a physical nature was continued during this construction period. That noted previously dealt with assessment of the best selection and placement of materials in the therapeutic neutron stream, for control and direction of the neutrons and other radiations. Further tests have now been run to evaluate flux and energy distribution of the delivered neutrons, as well as to attempt spectroscopy of the gamma-ray contamination. At this time the foil activation measurements are still not completed. Approximate calculations of the slow neutron flux and the gamma-ray field (with no tissue present) gave 2.0×10^{10} n/cm^2 sec and 21 r/min, respectively at nominal one-megawatt power level. Back-scatter effects present in the actual exposure procedure will raise both these figures.

cc: Dr. L.B. Farr

4001944

BROOKHAVEN NATIONAL LABORATORY

MEMORANDUM

REPOSITORY Brookhaven National Laboratory

COLLECTION Robertson Correspondence Files

BOX No.

FOLDER

DATE: March 8, 1960

TO: Dr. J. S. Robertson

FROM: C. G. Amato CGA

SUBJECT: Summary of BMRR Patient Therapy Port: 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).

400144

Measured Radiation Rate		Integrated Ra			
		Gamma Dose Limited to 500 r		Gamma Dose Limited to 300 r	
Gamma (r/hr)	Thermal Neutron (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

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.

4001917

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COLLECTION Lewis Strauss Correspondence Files
BOX No.
FOLDER

May 24, 1960

C. E. Falk, Directors Office

Dr. B.E. Stickley, Medical Dept.

Material for May Letter to AEC

Medical Research Reactor.

Studies have been resumed on the effect of heavy particle radiation on tumors implanted in mouse thigh muscle. The purpose is to evaluate the influence of injection-to-irradiation time and of boron concentration on tumor regression. In the new series to date, animals have been exposed for four conditions, each such point of the data requiring a half-day of reactor schedule.

Analysis of the neutron energy spectrum also continues, utilizing resonance activation foils, with the recent emphasis being on measurement of induced short-lived gamma activities.

Experimental neutron capture therapy of human brain tumors has been resumed for selected cases. In preparation for continuance of this program, the validity of linear relationships between slow neutron and gamma ray output, as well as between output and reactor power, has been explored over the range of MRR power useful for therapeutic purposes. No important deviations from direct linear dependence were found from 0.1 to 3.0 megawatts.

Enriched lithium-6 metal is now used for local shielding of the patient's eyes and other regions lying close to the irradiated area. In excluding neutrons from ionization chambers, this material also makes possible a more effective approach to gamma ray dosimetry in phantom studies related to the therapeutic program.

cc: Dr. L.E. Farr

REPOSITORY Brookhaven National Laboratory

COLLECTION Robertsons Correspondence Files

BOX No.

FOLDER

21 June 1960

Dr. L.E. Farr

Dr. J.S. Robertson

Patient

Iodine activation in [redacted] during NCT

1. From the gold foil determination, the neutron flux at the thyroid was 1.43×10^8 n/cm^2-sec. The exposure time was 100 sec.

2. The formula for calculating activation is

$$R = \frac{1.64\ \sigma}{10^5\ A}\left[1 - e^{-\lambda t}\right] \mu c/\text{gram}$$

3. For iodine, I^{127} is 100% abundant, the activation σ for producing the 25-minute I^{128} is 3.6 barns (BNL 325), and about 17% of the I^{128} disintegrations yield an 0.46 MeV gamma ray. Thus in this case we have, in terms of γ μc:

$$R = \frac{(1.64)(1.43 \times 10^8)(3.6)(0.17)}{10^5\ (128)}(0.0493) = 0.788\ \gamma\ \mu c/\text{gram of iodine}$$

4. The table for the standard man gives the body iodine content as 0.03 gram. Assuming that the body content is roughly proportional to the body weight and that 1/2 the iodine is in the thyroid, this patient would have

$$(0.03)(0.5)\left(\frac{40}{70}\right) = 0.00857 \text{ gram of iodine in her thyroid.}$$

Thus we might expect of the order of (0.00857)(0.788) = 0.00675 γ μc of I^{128} in this patient's thyroid.

While detectable in the whole-body counter in the absence of other activities, this amount of activity is sub-marginal in the presence of much competition. Actually a small peak is seen which could be the 0.46 MeV gamma ray, but further study is needed to prove whether or not it is attributable to I^{128} and, if so, to quantify it.

cc: Dr. S.H. Cohn
Dr. H.S. Stickley

4001919

REPOSITORY Brookhaven National Laboratory
COLLECTION Robertson's Correspondence Files
BOX No.
FOLDER

October 26, 1960

L. B. Parr

C. B. Meinhold

Interlock System Lockout

As you may realize, the interlock system now being installed on the treatment room doors in the Medical Research Reactor includes a device for "locking out" this safety system. This device is on interval timer which can render the interlock system inoperable for periods up to one hour. This creates, of course, an extremely dangerous situation in that personnel will come to rely on an interlock system which may, in effect, not be there. It was for this reason that Dr. S. Pine of the Medical Department, G. Pitcher of the Reactor Division, and I were opposed to the inclusion of such a device when we were doing the original design.

Various members of the Medical Department indicated, however, that the "lockout" would be required during use of these facilities for patient treatment. This was a decision presumably based on medical considerations, so the above group acquiesced to this demand. In view of the hazard involved, it is advised that the following administrative rules be adopted.

1. Any person wishing to use these facilities with the interlock system "locked out" must:

   a. Receive written permission from a designated member of the Medical Department.

   b. Notify, in writing, the reactor operator or his supervision.

   c. Notify, in writing, a member of the Medical Health Physics Group.

This written notification should be made 24 hours prior to the experimental run.

It is further suggested that mechanical means be installed to prevent the use of this "lockout" device by persons unauthorized to do so.

CBM/eb
cc: P. Cowan
H. Kuper
R. Powell
J. Robertson ← THIS COPY FOR

4001920

Mr. Walter S. Snyder -2- 6 December 1960

For the gamma emitters (almost entirely H^1 and Cl^{35}) the usual formula for a uniformly distributed source, a la Hine and Brownell, eq 72, page 873, was used, with the necessary substitution of (nγ) reaction frequency rate for C in microcuries per gram, as indicated in the formula at the end of the table. A thermal neutron flux of 10^{12} n/cm² sec is assumed, and since is adjusted to 10^{11} disintegrations, the constant comes out:

$$(6.025 \times 10^{23})(10^{-24})(10^{12})(10^{-11}) = 6.025.$$

atoms/mole cm²/barn

The geometry factor used was 90, which seemed reasonable at the time. This part of the calculation is explained, even though the basic assumption of uniform flux is outrageous because it seems that division of the doses listed by the g factor used gives a number which does have validity when a corresponding factor which does take into account the non-uniform flux is used. I would especially like to have your opinion on this step of the reasoning.

The big job, of course, was calculation of the proper "g" value, with "g" as

$$\text{"g"} = \int_V \frac{f(x)\, e^{-\mu\rho}}{\rho^2}\, dV$$

where f (x) is the relative (nγ) reaction rate throughout the volume.

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BOX No.
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Measurements made by gold wire activation in a tissue-equivalent phantom head exposed to an 8x8 cm thermal neutron "beam" from the MRR were available as the input data for f (x), and are shown as isodose contours in an enclosed diagram. Based on this, the "g" factor for each of 90 points within a 10 cm diameter x 10 cm long cylinder was calculated by numerical integration of the Δg's from some 30,000 elements of volume, using the IBM 704 computer. Whereas the g factor for a uniform flux in this size cylinder comes out about 65 (using the formula in Siri) for the mid point and about 38 at the center of either end, the "g" values for the non-uniform flux come out 20.4 at the center of the presenting end, goes through a maximum of 23.1 at about 6 mm depth, falls to 19.9 at 2.16 cm, 15.9 at 3.16 cm, 12.2 at 4.16 cm, etc. to 1.95 at 10 cm, for the points along the axis.

The relative doses shown in the diagram sent you previously include the heavy-particle contribution to the dose. Thus at the maximum we have

$$\left(\frac{160}{90}\right)(23) = 40.8 \text{ gamma rad}/10^{12} \text{ nvt/cm}^2$$

$$+ \underline{23.5}\ N^{14}\ (n\alpha) \text{ and } O^{17}\ (n\alpha) \text{ rad}/10^{12} \text{ nvt/cm}^2$$

$$\text{Total } 64.3 \times 10^{-12} \text{ rad/n/cm}^2$$

4001921

For the gamma emitters (almost entirely H^1 and Cl^{35}) the usual formula for a uniformly distributed source, a la Hine and Brownell, eq 72, page 873, was used, with the necessary substitution of (nv) reaction frequency rate for C in microcuries per atom [illegible] in the formula at the end of the table. A thermal neutron flux of 10^{-7} n/cm^2 sec is assumed, and since is adjusted to 10^{11} disintegrations, the constant comes out:

6 December 1960

$(6.025 \times 10^{23})(10^{-24})(10^{12})(10^{-11}) = 6.025$.

Mr. Walter S. Snyder
Assistant Director
Health Physics Division
Oak Ridge National Laboratory
P.O. Box X
Oak Ridge, Tennessee

Dear Mr. Snyder:

Thanks very much for your reprint, the rem dose memo, and especially for the interest you expressed in our problems of the proper "g" value, with "g" as

We haven't written up a complete explanation of how our calculations were achieved but essentially they go as follows: [illegible] (nv) reaction rate

The calculations were directed to determining the radiation dose attributable to thermal neutrons when the head is exposed at the MRR.

throughout the volume.

The tissue composition for the standard man was tentatively assumed, realizing that corrections may be needed for the head. The values used are listed in the enclosed table, and do differ a bit from those you used. The value for hydrogen, which is, of course, the most important, is about the same, although perhaps my value should be raised a little. The nitrogen value varies among tissues and your value seems quite high if applied to the brain. Javid et al. J. Clin. Investigation 31 (1952) p. 604-610, in the table on p. 607 list 1.74% for gray matter, 1.70% for white matter and a maximum of 2.20% for brain tumor nitrogen (cula in Siri) for the mid point and about 38 at the center of either end, the "g" values for the non-

The absorption cross sections were taken principally from BNL 325. Since our plan was to work with measured neutron fluxes, the scattering cross sections were not needed. 4.10 cm, etc. to 1.95 at 10 cm, for the points along the axis.

References for the numbers used for the energies and for the gamma constant are listed in the table. It should be noted that the gamma constants listed are for 10^{11} disintegrations, whereas the values usually given are in terms of millicurie hours, or 1.332×10^{11} disintegrations.

$(\frac{\text{[illegible]}}{\text{[illegible]}})(\text{[illegible]}) = 45.8$ gamma rad/10^{12} nvt/cm^2

The calculations which take the actual neutron flux distribution into account had not been achieved when this table was prepared, and the figures in the last column were arrived at by assuming a uniform neutron flux throughout the tissue. 10^{-12} rad/n/cm^2

4001922

These results show that the difference in aperture or exposed area did not modify the delivered neutron numbers more than the estimate allowed for. Therefore, another experiment was carried out to investigate the possibility that movement of the patient, with consequent interposition of 4 mm of lithium-6 into the field, might have caused the low values which were found.

A series of exposures was made at low power, using the 10 cm circular field and the plastic cylinder phantom, approximating the treatment conditions. A layer of lithium-6, 4 mm thick, was positioned at the edge of the field (as intended in the patient experiment), and was moved toward the center of the field in centimeter steps. No appreciable diminution of flux was noted.

TABLE IV

Lithium-6 (4 mm) shading experiment
Reactor power: 10 kW
Aperture: 10 cm circular
Exposures: 100 seconds

lithium position	aperture n/cm².sec	phantom surface n/cm².sec
0 - at edge of field	2.09×10^8	2.20×10^8
1 cm into field	2.03	3.09
2 " " "	1.85	1.98
3 " " "	2.07	2.15
4 " " "	1.91	2.15

There must remain some interfering factor not reached by the discussion above. Beyond this urgent point, the variations of 7% or more noted between calibrations demonstrates a continuing need for a more comprehensive approach to the neutron measurement problem.

cc: Dr. J.S. Robertson
Dr. Y.L. Yamamoto

2 June 1961

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Dr. Ira Zartman
Reactor Division
Atomic Energy Commission
Washington 25, D. C.

Dear Dr. Zartman:

Enclosed is an abstract for a proposed paper for the October Vienna meeting.

This is the contribution on medical and biological applications requested by your committee.

We sincerely regret the delay in submission of this abstract and hope that it does reach you in time for consideration.

Very truly yours,

James S. Robertson, M.D., Ph.D.
Medical Physics Division
Medical Department

JSR:gfb

cc: Dr. L.H. Parr
Dr. G.F. Tape

4001924

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August 25, 1961

Dr. C. H. Falk

Dr. E. E. Stickley

AEC letter - July 1961

MEDICAL RESEARCH REACTOR

A neutron capture therapy procedure was carried out early this month. In conjunction with this experiment and to evaluate certain previous treatments, an extensive series of calibrations has been undertaken. The principal purpose of this work is to establish the influence of factors such as field size, local shielding, positioning of subject and the operating history of the reactor itself on the radiation dose delivered. Earlier calibrations are being reviewed completely. From these comparisons a standardized protocol will be devised to insure uniformly predictable dosimetry.

Other continuing experiments include the neutron irradiation of carcinoma tissue cultures and a repeat of the canine osteogenic sarcoma treatment. A complete procedure in the neutron capture treatment of tumor implants in mice was carried out by the medical students participating in the summer research proctorship program. Also under way at the moment is an extension of the study on neutron effects on optic response in the rabbit to measure directly the contribution of reactor gamma radiation during the lengthier exposures. Another investigation of great interest is the further trial of lithium-loaded gel-film chemical dosimeters.

A new series of experiments has been started, applying the method of instantaneous or neutron capture radioautography. This study is to establish, from the plant physiologist's point of view, the location and mode of utilization of boron and boron compounds in tubes of germinated pollen, a system which is of special interest with regard to boron metabolism.

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22 December 1961

Dr. C.E. Falk

Dr. J.S. Robertson

Medical Reactor Report - December

Investigations of the effects of neutron irradiation on tissues and tumors in small experimental animals and of the response of solid state detectors and fission chambers in operational situations were continued. Five dogs were injected with boron-10 pentaborate and exposed to high doses of neutrons in geometries simulating those used for neutron capture therapy in patients in studies of the physiological and histological thresholds for various effects on the central nervous system.

The activation analysis pneumatic tube is being repaired and remodeled because of mechanical difficulties which were encountered in its operation.

It is anticipated that during January the accumulated operation of the MRR will cross the 1000-megawatt-hour mark.

cc: Dr. L.E. Farr

4001926

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DATE August 24, 1962

Dr. C. Falk

Ralph Fairchild

HRR report - July 24 to Aug. 24

The HRR was operated for about 62% of the available time for a total of 22.3 MW hours.

In an effort to evaluate the neutron and γ doses delivered during previous neutron capture therapy experiments, a plastic "standard man" filled with tissue-equivalent fluid is being irradiated at the patient treatment port. Neutron and γ dose rates are being obtained as a function of position inside the phantom.

Previous experiments involving the irradiations of dogs, swine and HeLa cells at the patient port were continued. Health Physics instructional surveys of the animal and patient facilities with the AEC Health Physics fellowship students continued.

The Reactor Operations group finished annealing the core graphite. Maintenance work was done on the heat exchangers, and routine reactor safety circuit tests were carried out. The reactor power level indicator was recalibrated; heat balances and Au foil irradiations show that the power level is now 5% higher than before the recalibration on July 30, 1962.

cc: Dr. Bond
Dr. Robertson
R. Fairchild

4001927

UNITED STATES
ATOMIC ENERGY COMMISSION
WASHINGTON 25, D.C.

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IN REPLY REFER TO:

October 5, 1962

Dr. J. S. Robertson
Brookhaven National Laboratory
Associated Universities, Inc.
Upton, Long Island, New York

Dear Dr. Robertson:

On behalf of Dr. Dunham and members of the Division of Biology and Medicine staff, may I thank you for participating in the Neutron Capture Therapy Conference in Washington, September 24 and 25. Our impression is that valuable realistic consideration was given to many perplexing aspects of the general problem. We would be most pleased to receive a letter from you giving thoughts or ideas about points you feel may have been omitted or passed over too lightly, and particularly any conclusions which emerged from the meeting.

While the first attempts at brain-tumor therapy have proved disappointing, the diversity of conditions with respect to differential distribution of target materials of different kinds and the application of neutrons with differing energies are so vast that investigation of potentialities for therapy leaves open many avenues of investigation. We would especially ask whether benefit would come from a scientific meeting of the work-shop type convened perhaps shortly after the first of the year.

Please feel free to comment frankly and in detail.

Sincerely yours,

Dave

H. D. Bruner, M. D.
Assistant Director for
Medical and Health Research
Division of Biology and Medicine

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this need. It seems clear that a large fraction of the time at such a confab should be available for unscheduled presentations and discussions.

With best regards.

Sincerely yours,

James S. Robertson, M.D., Ph.D.
Medical Physics Division
Medical Department

JSR:gfb

cc: Dr. V.P. Bond

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March 25, 1963

File

R. Fairchild

Modification of MRR Animal Port

The Animal Port has been modified to give a beam of epithermal neutrons with a penetration curve (Ø vs distance) in a tissue-equivalent phant head (TEPH) suitable for N.C.T. The modification was made in the Animal Port rather than the Patient Port, since it is anticipated that experimental animal irradiations will be carried out. Also, expected irradiations of tissue-equivalent chambers and threshold detectors in the epithermal beam at various D_2O thicknesses would give a needless exposure to the reactor operators if carried out at the Patient Port.

The thermal flux, Cd ratios, γ contamination and neutron penetrations in a Cd-wrapped TEPH were evaluated at the Animal Port for the case of 7.075" D_2O and 0" D_2O in the reflector. These results agreed within 4% with the corresponding results at the Animal Port. Therefore, the two facilities can be considered identical. A 60-mil Cd filter was installed in the Animal Port, since satisfactory neutron penetrations in a Cd-wrapped TEPH have been obtained at the Patient Port (BNM 6824). However, a 4'x4' filter was installed between the 3.375" D_2O tank and the 3" Bi filter in the reflector (Fig. 1) rather than at the point of irradiation for two reasons: 1) Cd cannot be used at the point of irradiation since it is a significant source of capture γ's, and 2) it is desirable to remove the thermal neutron component as close to the core as possible since the γ contamination resulting from the capture of thermal neutrons

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The γ contamination at the bare port face with the two-filter arrangement that gave the curve in Fig. 4 is 8 r/min at 1 MW as measured with a Carbon-CO_2 current flow chamber. Gamma measurements were also made with a Victoree, Landsverk and Baldwin Farmer B.D. 11 and B.D. 2/15 chambers. These chambers gave γ dose rates of 18, 15.6, 16 and 19.5 r/min, respectively. They all, however, suffer from a neutron sensitivity due to the H_2 and N_2 in their air filling. Therefore, it is assumed that the 8 r/min given by the C-CO_2 chamber represents the most accurate estimate of the γ contamination. A condenser C-CO_2 chamber is being made so that an independent check can be made.

Assuming the γ contamination is 8 r/min at 1 MW and using the peak flux from Fig. 4, an integrated neutron flux of 5×10^{12} n/cm^2 could be delivered in 6 min (reactor power 5 MW) with an associated γ dose of 240 r (the 240 r does not include the γ dose from neutron capture in tissue). This is less of a γ dose than would have been delivered by the reactor γ contamination in a 120-sec run with a thermal beam at 5 MW. An additional advantage will obviously be gained from the removal of the thermal neutrons which were previously incident on the surface tissue. It should be remembered that the use of any beam-defining devices will reduce the neutron flux and lengthen the irradiation time. The γ dose rate does not increase with time during a 6-min run at 5 MW. Residual activity at the bare port face after a 6-min run at 5 min is 75 mr/hr.

The absorbed dose from fast neutrons remains to be determined. Preliminary data indicate a significant dose in rads at D_2O thicknesses less than 7.075". Therefore, the above data were taken with all the D_2O (7.075") in the shutter. Dog irradiations, etc. could be carried out while the fast neutron flux is being evaluated in order to gain experience with any beam-defining devices used, and to evaluate the biological effect of the epithermal beam.

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