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FROM THE EDITOR

Paul Bergstrom

This is the time of year when those of us in the Northern Hemisphere have seen the leaves change their colors and fall from the trees. Many prefer to look back to the warmth of a few short weeks ago instead of looking forward to the imminent chill. However, in this issue, we follow the thinking of our colleagues from the south and look forward.

Looking forward one sees that next year's agenda includes the election of officers for the Society. In this issue, we have a tentative slate of candidates along with instructions on how to join the slate.

We also have further details on the next Symposium.

Our technical contribution for this issue came across the "electronic transom" from Iran. It is an article on the Boron Neutron Capture Therapy (BNCT) research performed at the Tehran Research Reactor.

I close in asking again for your involvement in the Society. Whether it is by contributing an article, by running for office or by getting your colleagues to join, your contribution is needed and appreciated.

Paul Bergstrom

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PRESIDENT'S COLUMN

Malcolm Cooper

I am just about to send out the invitations to plenary lecturers for our Cape Town symposium, ISRP-9.

We plan to have a very rich variety of radiation physics presented by exciting speakers who are leaders in their fields. Perhaps I can remind you that there will also be space in the programme for some contributed papers to be presented orally, in addition to the usual lively poster sessions. If you are interested in radiation–based analytical techniques then attendance at the associated workshop is a must. I was able to visit the conference venue last month: with views of the Atlantic Ocean in one direction and Table Mountain in the other it may be difficult to concentrate on the science!

We are doing everything possible to keep attendees' costs low. I not only visited the President Hotel where the conference will be held but also the nearby, cheaper accommodation that we have reserved as well. It is also to a high standard and extremely good value for money. Please visit the meeting web site,

http://www.medrad.tlabs.ac.za/isrp9.html

which will be updated as information comes in about speakers, etc.

Recently I have been intrigued by correspondence in the journal Physics World about what might be the most beautiful experiment in Physics

(www.physweb.org/article/world/15/9/1).

The winner appears to be a multi-slit interference experiment with electrons (interference was demonstrated with up to five slits): it is of course utterly inexplicable classically. However, unlike other frontrunners, such as Young's double slit experiment, Millikan's oil drop experiment etc., the experimenter's name is not associated with it. I was astonished to find out that this classic experiment was performed as late as 1961, by Claus Jönsson (***Zeits f Physik vol. 161 p454, 1961***). I guess that this qualifies as a radiation physics experiment, but I wonder what other "beautiful" radiation physics experiments you would nominate?

My email inbox remains ever ready to receive your suggestions.

Malcolm Cooper

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Measurement and Calculation of Neutron and Gamma Absorbed Dose in a Head Phantom in Boron Neutron Caputure Theory

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ABSTRACT

In Boron Neutron Capture Therapy, neutron and gamma dose determination is of prime importance. The neutron and gamma absorbed doses were measured in a cylindrical head phantom, 18cm in diameter and 20cm in height. For this purpose gold foils (bare and cadmium covered) and TLD-700 were used for neutron flux and gamma dose measurements respectively. The contributions to absorbed dose were due to ^{10}B(n,a)^{7}Li, ^{1}H(n,g)^{2}D, ^{14}N(n,p)^{14}C and recoil proton reactions. The KERMA factors for different energy groups were used to convert the neutron flux to the relevant absorbed dose. There was good agreement between experimental values and the calculated dose.

Keywords: Boron Neutron Capture Therapy, Phantom, TLD, Dose components, Spectrum unfolding, Neutron Filter.

INTRODUCTION

Pioneering work of boron neutron capture therapy (BNCT) as a potential, clinical technique to destroy malignant tumors - especially glioblastoma- is usually attributed to two individuals: William H. Sweet and Hiroshi Hatanaka. Their work started in the early 1950s. In this technique, a neutron beam from a research reactor core passing through a proper moderator and a filter reduce the core neutron energy to epithermal range and a collimator converts them to an epithermal neutron beam. Prior to neutron bombardment, the patient is administered a boron-10 compound such as BSH ($Na_{12}B_{12}H_{11}$ SH). Then the epithermal neutron beam impinges on the patient head. The epithermal neutron beam is normally used for deep-seated brain tumors since the epithermal neutrons are more or less slowed down and turn to thermal neutrons before reaching the tumor. It is worth mentioning that, because of its anti-body properties, BSH overwhelms the tumor. BSH is a stable and non-toxic compound.[1] Therefore it can be applied without hesitation. The neutrons during passage through the brain undergo several reactions including ^{10}B(n,a)^{7}Li, ^{1}H(n,g)^{2}D, ^{14}N(n,p)^{14}C and elastic scattering from protons. Because the cross section for ^{10}B(n,a)^{7}Li reaction is rather high,3838 barns, Boron is very suitable for tumor therapy. In this reaction 2.79 MeV is released in the form of kinetic energy of two ions, ^{7}Li and ^{4}He, in a proportion reciprocal to their atomic masses. It should be pointed out that in 94% of reactions, a gamma ray with 478KeV is emitted. The energy of the alpha particles released in this reaction is enough to travel about 10mm in tissue. Therefore, each alpha particle because of its high LET can destroy a cancer cell. Because of the high Boron-10 concentration in the tumor, 40-50ppm, as compared to 10ppm in other parts of the brain, the absorbed dose due to this reaction in the tumor is several times higher than that in normal tissue. This is enhanced by the peak thermal neutron flux in the tumor.

Success in BNCT lends itself in precise dose determination and it plays a key role in this technique. Since direct dose measurement in a human head is not practical, a head phantom is normally used instead. Ordinary distilled water is a suitable material that has very similar properties to normal brain tissue with regard to neutron interaction and energy absorption. Different shaped head phantoms namely cylindrical, elliptical or cubic are used. We used a cylindrically-shaped phantom, 18cm in diameter and 20cm high filled with distilled water. The measurements were carried out in the head phantom containing a small tumor-shaped cylinder containing boric acid, 50ppm B-10. The phantom was placed in front of the neutron beam tube of the Tehran Research Reactor (TRR) in such a way as to receive the emerging epithermal neutrons from the collimator. The beam was directed at the small cylinder. The gamma ray absorbed dose component due to ^{10}B(n,a)^{7}Li, ^{1}H(n,g)^{2}D, and ^{14}N(n,p)^{14}C reactions and core gamma rays was measured using TLD-700 and the neutron flux was measured using gold foils. To convert neutron flux to absorbed dose the relevant KERMA factors were applied[2].

MATERIALS AND METHODS

In 1993 there was an attempt to investigate the possibility of using the BNCT technique at the Tehran Research Reactor[3]. A collimator and an Al-Fe filter were designed, constructed and installed in a beam tube of TRR, see Fig. 1. The filter was composed of 24 pieces of alternating aluminum and iron blocks, 5cm each. To stop core gamma rays from reaching the target, a 15cm bismuth block was placed behind the filter.

Fig. 1 Collimator and Al-Fe filter detailed design

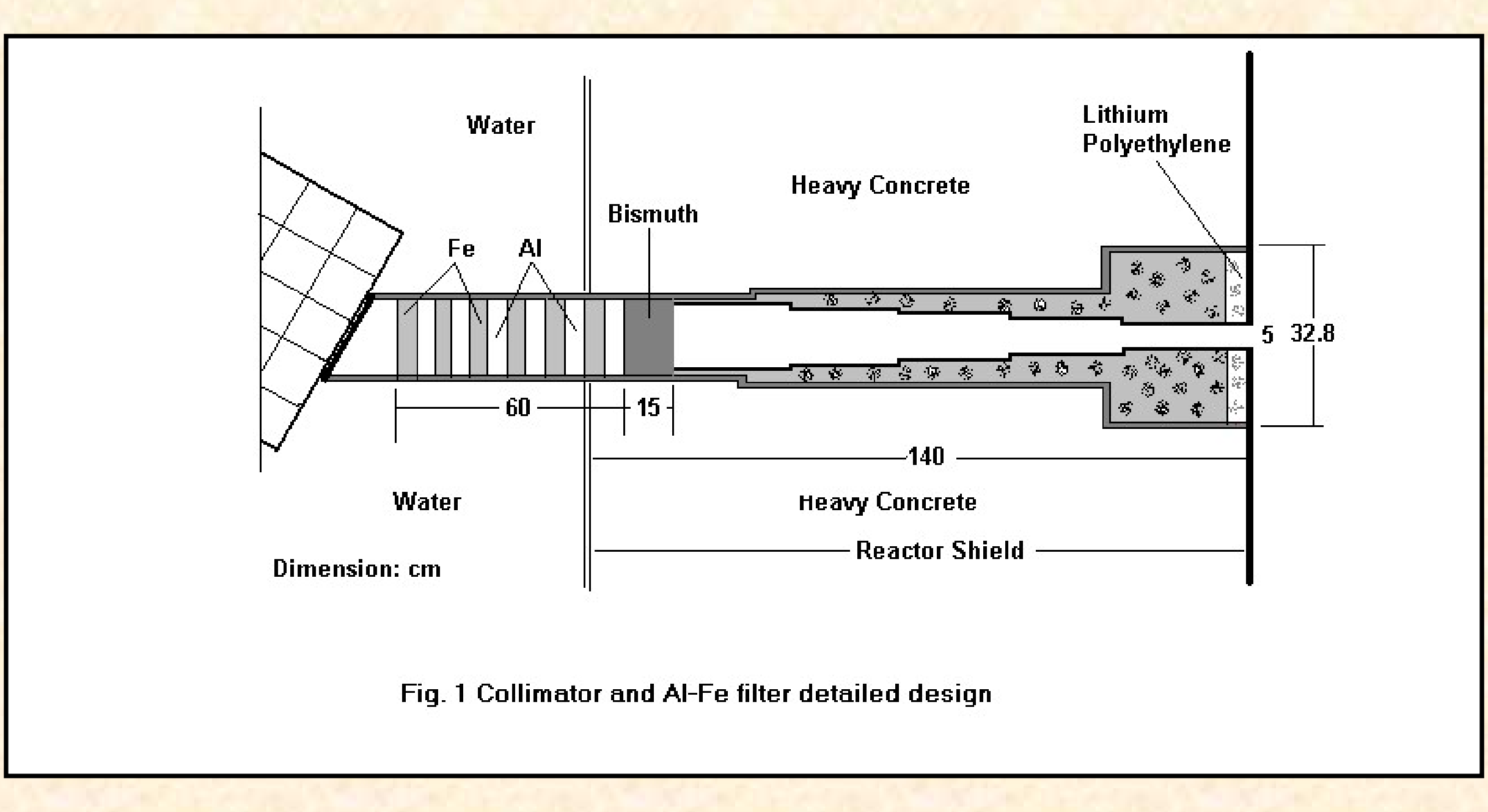

Fig. 1 Collimator and Al-Fe filter detailed design

To determine the central beam hole axis, a radiographic cassette containing an x-ray film was placed in front of the beam hole, once with a gadolinium converter and second time without a converter. The irradiation period extended 24 hours. The x-ray film was scanned by a laser-scanner to determine the center of the neutron beam.

The leakage neutron spectrum was measured at the beam outlet using an He-3 counter and the unfolding technique[3,4]. The spectrum from a bare Cf-252 neutron source, a distribution of well thermalized neutrons and the BNCT beam port neutron spectrum are shown in ***Fig. 2***.

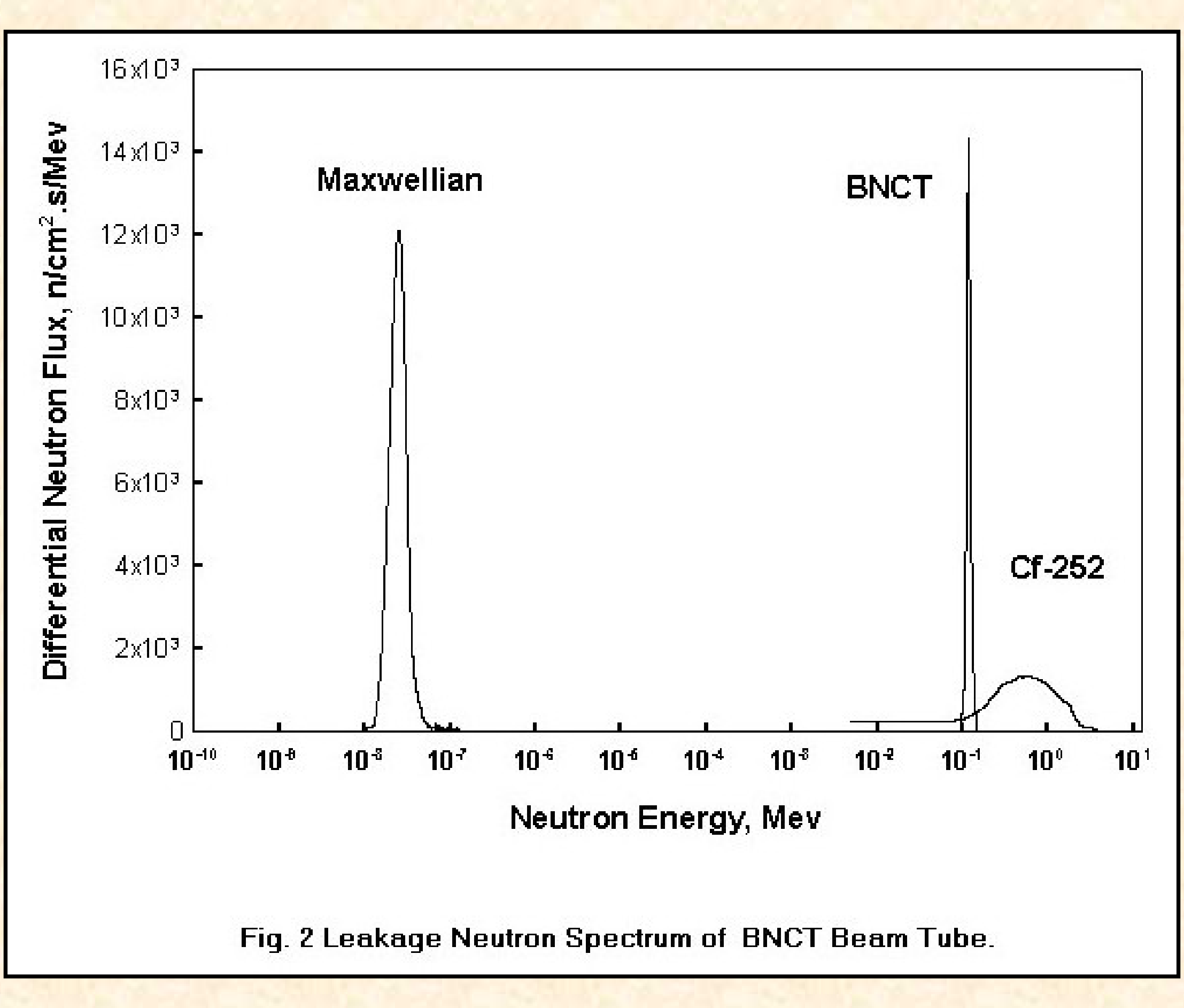

Fig. 2 Leakage Neutron Spectrum of BNCT Beam Tube.

The dose measurements were carried out in a cylindrical head phantom made of Plexiglas, filled with distilled water. Bare and cadmium covered gold foils, 1cm diameter and 5mm, were used in three radial rows to measure thermal and epicadmium fluxes. The irradiated gold foils were counted on a HPGe detector. The absolute net area under the prominent Au-198 photo-peak, 412Kev was determined utilizing a detector efficiency factor. Using the following relations, thermal and epithermal neutron fluxes were determined.[5]

$$\phi_{th} = \frac{M}{Na\,\sigma_{th}}\left[\left(\frac{A_S}{m}\right)_{bare} - F_{Cd}\left(\frac{A_C}{m}\right)_{Cd}\right] \qquad (1)$$

$$\phi_{epi} = \frac{F_{Cd}\,(A_S/m)_{Cd}\,M}{Na.RI.\,F_{res}} \int_{0.4}^{E} \frac{dE}{E} \qquad (2)$$

where

M = molecular weight of Au, u,
Na = Avogadro Number,
As = saturated activity, dps,
m = gold foil weight, g,
F_{Cd} = cadmium self-absorption coefficient[6],

Ac = cadmium covered gold foil activity, dps,
s_{th} = thermal neutron capture cross section, 99b,
RI = integral resonance of Au-197, 1550 b,
F_{res} = resonance self-absorption coefficient[6],
e = Detector efficiency.

Fig.3 shows thermal and epicadmium fluxes along three lines inside the head phantom.

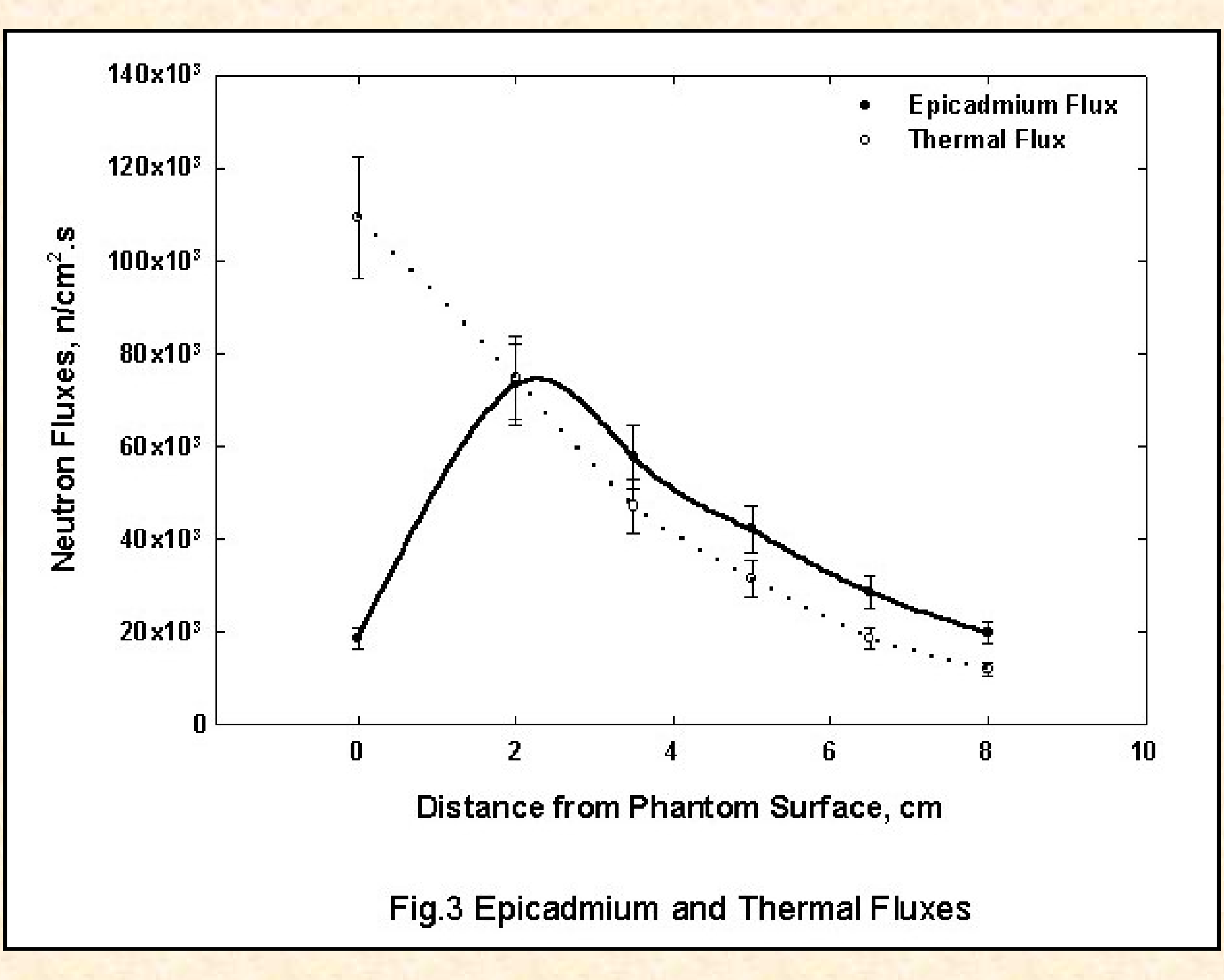

Fig.3 Epicadmium and Thermal Fluxes

For gamma ray dose measurements the TLD-700s, 4mm in diameter and 1.5mm thick were used. The TLDs were calibrated prior to irradiation.

DOSE DETERMINATION

Major reactions in BNCT treatment are due to ^{10}B(n,a)^{7}Li, ^{14}N(n,p)^{14}C , ^{1}H(n,g)^{2}D, recoil protons and (n,n') reactions. The absorbed dose in brain is as a result of thermal and epithermal neutron reactions as follows:

1. ^{10}B(n,a)^{7}Li reaction

^{10}B + n à a + ^{7}Li +2.79Mev 6%

^{10}B + n à a + ^{7}Li +2.31Mev 94%

^{7}Li à g + 0.478 Mev

2. ^{14}N(n,p)^{14}C reaction

^{14}N + n à p + ^{14}C + 0.62Mev

In this reaction 0.580 Mev energy is given off as kinetic energy of the proton and the remaining 40Kev, is taken away by ^{14}C as kinetic energy.

3. ^{1}H(n,g)^{2}D reaction.

Following neutron capture by a hydrogen nucleus, a 2.25 Mev gamma ray is emitted. Due to the high proportion of hydrogen in the brain, absorbed dose of this reaction is rather high. TLD-700 chips measured the absorbed dose of gamma rays of these reactions and core gamma rays. Ten TLD-700 chips were used in two radial rows. They were irradiated for 24 hours in the head phantom. Table 1 shows measured dose along the path to the small cylinder in the phantom.

4. Recoil proton and (n,n') reactions.

The determination of absorbed dose of epithermal neutrons is rather complicated. Scattering of epithermal neutrons from hydrogen nuclei resulted in proton recoil or elastic scattering. To estimate the absorbed dose due to these two reactions, the slowing down neutron spectrum was determined pointwise using the transport equation with anisotropic scattering.

We employed the ANISN/PC code along with a 17-group cross section library [IRAN. LIB[7]]. We calculated from the computational output the space dependant spectrum along the neutron trajectory towards the tumor. At each point inside the head phantom, the absorbed dose of ***ith*** energy group was calculated from equations (3) and (4) using calculated fluxes by ANISN/PC.

$$D_i = \sum_{i=1}^{N} \phi(Ei) * F_N(Ei) \qquad (3)$$

where

F_n(Ei) = KERMA (Kinetic Energy Released in Medium) factor for ***ith*** group
f(Ei) = Group neutron flux, n/cm^{2}.s

The KERMA factor for ***ith*** group, Fn (Ei) was calculated using the following relation[8]:

$$F_n(Ei) = 1.602*10^{-8}\ sN\ m^{-1}E_{tr} \qquad (4)$$

where

F_n (Ei) = KERMA factor as a function of neutron energy, in J/kg or Grey
s = neutron-isotope cross section reaction for specified neutron energy,b
N = Number of atoms in the sample
m = mass of sample, g
E_{tr} = total kinetic energy transferred to medium.

The incident epithermal neutrons on the human head phantom, undergo elastic scattering from hydrogen nuclei which may lead to recoil protons. As a result, the neutron spectrum extends to the thermal region as they travel towards the small cylinder tumor inside the phantom.

RESULTS AND DISCUSSIONS

Table 2 and ***Fig. 4*** give the total and the contribution of each component in building up RBE absorbed dose rate in the tumor along its central line. The result is in good agreement with those of Raaijimakers ***et.al.***[9]. In spite of the fact that the neutron flux level is too low to be feasible in the clinical application. However, this facility can be utilized for ***in-vitro*** and ***in-vivo*** experiments. The results of the project, especially the neutron beam energy and dose distribution in tumor and surrounding tissues encourages us for future planning. The data obtained from this project has provided enough information to extend the project to practical application.

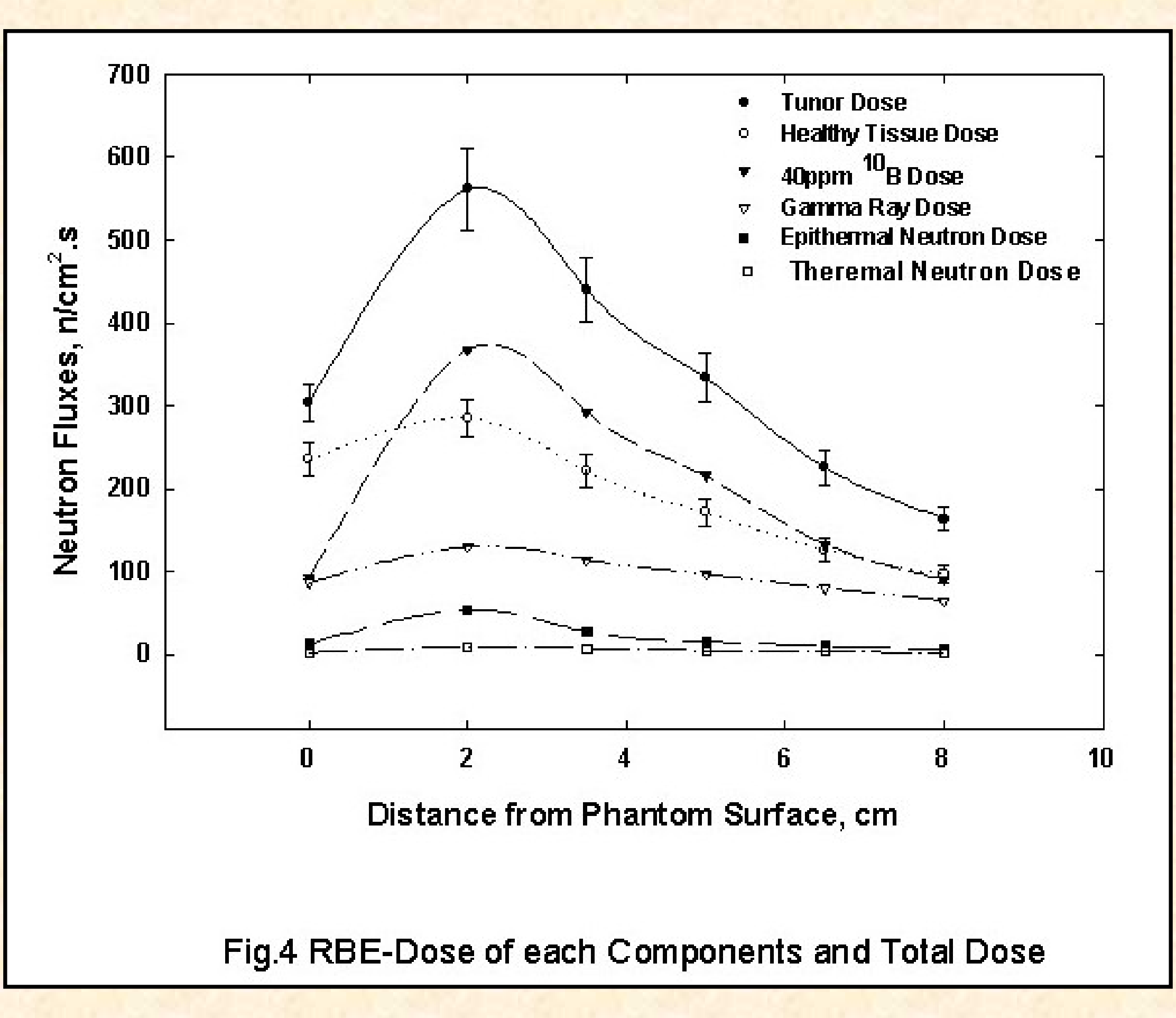

Fig.4 RBE-Dose of each Components and Total Dose

ACKNOWLEDGEMENT

Thanks are due to Tehran Research Reactor (TRR) operating staff in cooperating during implementation of the project and thanks to Neutron Physics Group, specially H.Ghods and H. Zandi, for assisting radiography and foil activation analysis measurements.

Table 1

Absorbed Dose of Gamma-rays, mrad/hr

Distance from surface of phantom, cm	Central axis	Left side	Right side
0	174 ± 26	160 ± 24	150 ± 22.5
2	260 ± 39	235 ± 35	220 ± 33
4	220 ± 33	210 ± 31	205 ± 31
6	165 ± 25	160 ± 24	150 ± 22.5
8	130 ± 20	125 ± 19	120 ± 18

Table 2

Absorbed dose due to different reactions along central axis (RBE-mrad/hr)

Distance in Phantom, cm	**Absorbed Dose of Healthy Tissues**	Absorbed Dose of Tumor	**Absorbed Dose due to 40ppm ^{10}B**	Gamma-ray Absorbed Dose	Epithermal Neutron Absorbed Dose	Thermal Neutron Absorbed Dose
0.0	235 ± 19.9	304 ± 22.6	92 ± 11.2	87 ± 13	123 ± 14.8	2.3 ± 0.27
2.0	285 ± 23.3	561 ± 48.5	368 ± 44	130 ± 19.5	54 ± 6.4	9 ± 1.1
3.5	221 ± 19.4	440 ± 39.2	292 ± 35.2	114 ± 17	27 ± 3.2	7 ± 0.84
5.0	171 ± 15.6	334 ± 29.6	216 ± 26	97 ± 14	15.4 ± 1.8	5 ± 0.6
6.5	126.4 ± 13.2	225 ± 20.4	132 ± 16	80 ± 12.5	9.9 ± 1.6	3.5 ± 0.42
8.0	96 ± 10.47	163.5 ± 14	90 ± 10.4	65 ± 10	6.2 ± 1.7	2.3 ± 0.27

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Corporations and organizations are welcome to apply for membership of the
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Membership is open to organizations whose activities and aims are directed
towards the furtherance of the aims and directions of the Society
(i.e. those organizations which are actively involved in practising or
promoting radiation physics and its applications).

The rates are (in US dollars) :

Not-for-Profit Organisations :

Developed Countries :	$600
Developing Countries :	$150

Commercial Organisations :

Developed Countries :	$1200
Developing Countries :	$300

For further information contact the Membership Secretary :

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NEW MEMBERS, ADDRESS CHANGES

Welcome to New Members :

Professor Margarida Costa, ***Portugal***

Professor Isabel Lopes, ***Portugal***

Assoc. Professor William L. Dunn, ***U.S.A.***

New Members' addresses are listed in the Contact Members' Details
(click on country next to name)

Changes to Members' Addresses and Contact Information

Address change :

Dr Mala Das, ***Japan*** ***(from India)***

Email updates :

Dr Ikuo Kanno, ***Japan***

Members' new addresses and contact information are listed in the Contact Members' Details
(click on country next to name)

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Elections - 2003

According to the IRPS Constitution, election of Officers of the Society, including the President, the Secretary, the Treasurer and the Vice Presidents, will take place once every three years. The terms of office for each of the eight Executive Councillors correspond to six years, the terms being so arranged that the terms of half of the councillors expire each three years.

A Nominations/Elections Committee, consisting of M.J. Farquharson (UK), L. Gerward (Denmark), R.T. Mainardi (Argentina) and D. McLean (Australia), hereby proposes the following list of candidates:

President: Richard H. Pratt (USA)

Secretary: David A. Bradley (UK)

Treasurer: Ante Ljubicic (Croatia)

Regional Vice Presidents:

Western Europe: Michael J. Farquharson (UK)

Eastern Europe: Ladislav Musílek (Czech Republic)

F.S.U.: Andrei V. Korol (Russia)

North America: John H. Hubbell (USA)

South & Central America: Anselmo S. Paschoa (Brazil)

South East Asia: Suprakash C. Roy (India)

North East Asia: Luo Zhengming (P.R. China)

Africa & Middle East: Dan T.L. Jones (South Africa)

Australasia: Dudley C. Creagh (Australia)

Councillors:

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T. Nakamura (Japan)

William L. Dunn (USA)

Jorge Fernandez (Italy)

Joanne O’Meara (Canada)*

Councillors continuing:

D. McLean (Australia)

Leif Gerward (Denmark)

Raul T. Mainardi (Argentina)

* ***Filling the vacancy of M.J. Farquharson. Thus, the term is for three years.***

Additional candidates may be proposed with their consent for any position if a nomination petition, signed by ten full members of the Society in good standing, is received by the Nomination Committee by February 28, 2003.

Nominations should be sent to the Nomination Committee, care of:

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