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■技術論文■

Compositional Qualification of Radiation Protection in Neutron Radiotherapy Room with KCCH Cyclotron *

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ABSTRACT

Radiation exposure of the personnel in the neutron therapy facility of KCCH cyclotron neutron system is discussed. In neutron therapy room, medical personnel is exposed to photons of the remanent induced radioactivity from the isocentric gantry in which targets and collimators are mounted. The radiation level of the neutron therapy room of KCCH cyclotron was acceptable and it decreased immediately after beam off. Personal exposure measured by individual monitor was far less than permissible level.

INTRODUCTION

In the hospital, special attention is necessary for the radiation protection because there are plenty of people unlimited to enter the facility and they are unoriented and untrained in radiation protection. In neutron therapy facilities, radiation exposure of medical personnel and non-occupational person is due to remanent radioactivity from activation of components by the high energy particle beam. This remanent radioactivity is photons induced in the treatment gantry. In the gantry, there are neutron producing targets, beam collimantors and auxiliary equipments, and these materials are the major source of neutron activation.

The Korea Cancer Center Hospital (KCCH) started neutron therapy in October 1986. The authors analyzed radiation safety of the neutron treatment room and machine control area by the compositional consideration of the followings :

1) mapping of scattered radiation in the neutron gantry room,
2) measurement of radioactivity from neutron activation of equipments such as gantry, patients couch and floor,
3) measurement of T-1/2 and T-1/10 clearing of room radioactivity by means

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of gamma-survey, air sampling and background after beam off,
detection of surface radioactivity on the patient's skin and surface of lucite phantom immediately after neutron irradiation,

5) measurement of total accumulated exposure to the technologists and engineers for and appropriate time.

Finally, the compositional qualification of radiation safety of the treatement room area is discussed and conclusion for adequate arrangement to the personnel and patients follows.

PHYSICAL CHARACTERISTICS OF KCCH -CYCLOTRON

Beam characteristics

Physical characteristics of KCCH cyclotron neutron beam are as follows: The cyclotron accelerates protons up to the energy of 50.5 MeV. The protons hit the beryllium target to produce neutron beam of the reaction of p^{+} (50.5) Be. The beryllium target is 10.6 mm thick. Penetration depth of the neutron beam is 14.5 cm for 50% depth dose in water(Fig.1). Depth of maximum dose (Dmax) is 1.05 mm.

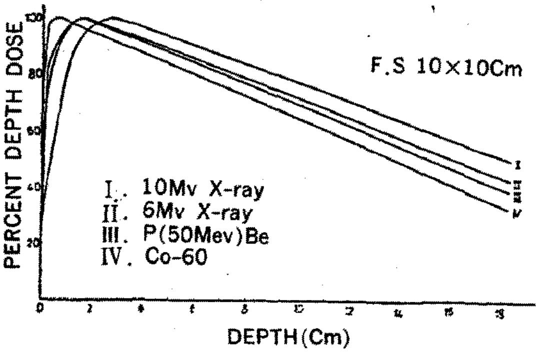


Fig.1. Central axis percent depth dose curves of neutron beams. Curves for photon beams currently used at Korea Cancer Center Hospital are shown for comparisn.

Penumbra size is 8 mm from 80 % to 20 % isodose levels. The maximum dose rate is 50 rad/min at the point of maximum depth dose when the beam current is 50 μA in maximum.

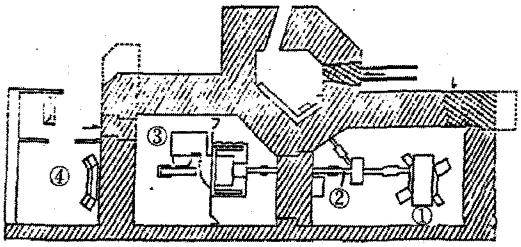
Layout of facility

Figure 2 shows the top view of layout of the cyclotron vault and neutron therapy room. Accelerated protons go through the beam transport system to reach the neutron gantry. The room is enclosed by the walls of thick concrete and limestone layers.

Thickness of the wall varies from 2.5 to 3 m and it consists of outer layers of heavy concrete and a limestone layer in the middle. The floor is made of concrete except for the region beneath the gantry. All doors move by motor power.

The treatment system

The gantry rotates isocentrically in 360 ° as the beam target is mounted in the gantry. The collimators are located in front of the target around the beam axis(Fig.3). The collimator housing is made of steel and Benelex.



1. Cyclotron
2. Beam transport system
3. Neutron therapy gantry
4. Control room

Fig.2. Layout of cyclotron vault and r therapy room.

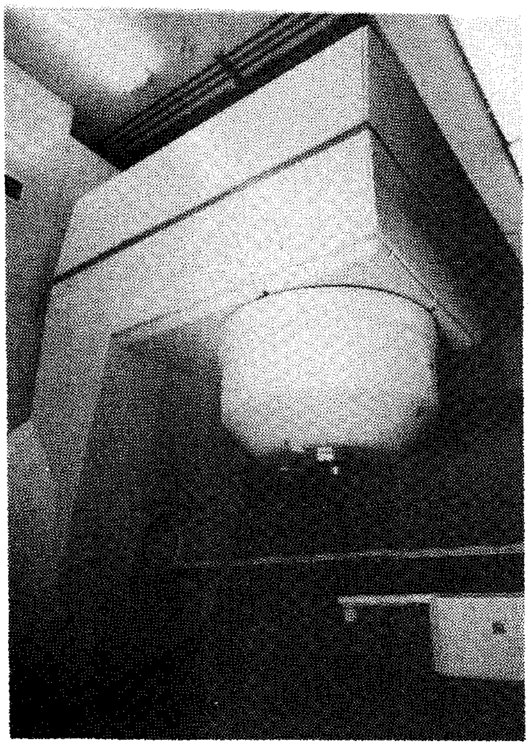


Fig.3. Isocentric gantry and treatment table.

Collimator itself is made of mild steel. When the radiation field should be adjusted, the motor driven collimator is controlled remotely by a switch on the control console. There is a beam flattening filter in front of the target which is made of pure iron, but no beam hardening filter. Gantry mounted wedges are made of tungsten with wedge angles of 30°, 45° and 60°.

The floor of the treatment room beneath the gantry is specially designed moving floor, so that, when the gantry rotates to opposite side of the patient couch, moving part of the floor goes down below the floor level. That part of the moving floor is made of wood and steel frame. The treatment table where the patient lies down is made of wood.

Measurements

Measuremnts of the primry neutron beam for radiation therapy was carried out by 0.1 and 1.0 cc ion chamber (IC-17 and IC-18, Far West Tech.) with TE (tissue equivalent) plastic build-up cap under the flow of TE gas. Measurements of scattered radiation around the gantry during neutron irradiation were done by 80 cc ion chamber(IC-80) in many points from the isocenter to make mapping of scattered radiation. Intensities of photons from the activation of materials and surface of phantom and patient's skin were measured by Victoreen survey meter(491). Room air was sampled and analysed by air sampler (SAAM-1 air monitor, Tech. Assoc.) and multichannel analyzer (Ortec). Room radiation level was monitored by the wall mounted Victoreen dosemeter (ion chamber 847-1-5). Finally, personnel doses were determined using thermoluminescent dosimeter badges with three months of interval.

Treatment method

The method of patient treatment is very similar to the conventional photon therapy in terms of patient set up, beam alignment and field adjustment. The Korea Cancer Center Hospital has more than 70 new patients needs neutron therapy every year.

During the first year period, treatment was done for 4 to 5 days a week, 10 patients per day in average until late 1987, and then, treatment was done for three days a week. Two technologists (RTT) are in full time job. There are five engineers with three assistants to control and operate cyclotron.

RESULTS

The map of scattered radiation in the treatment room at the isocenter level during exposure is shown in Fig. 4. High radiation

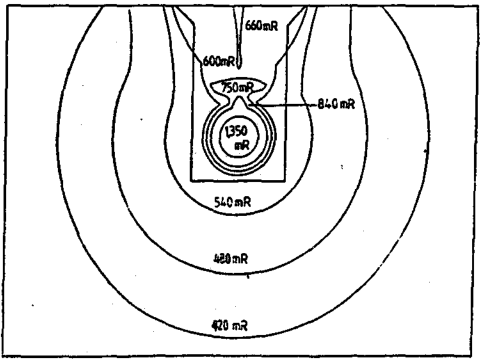


Fig.4. Map of scattered radiation of the neutron therapy room.
Dimension of the room is 773 x 535 cm.

level is seen around the beam transport system at the gantry arm.

Measured dose rate in the room after turn-off are shown in Table 1. Near the collimator, dose rate was 26 mR/h just after exposure, but it dropped to 5.6 mR/h in two minutes. On the treatment table, it dropped from 15 mR/h to 5.6 mR/h. On the wooden floor, it dropped from 12 mR/h to 5.2 mR/h. Variability of decay rate may come from different materials exposed to neutron.

The results of measurements of air activation are shown in Fig. 5 as a function of time. And the changes of radiation level at around the treatment couch at isocenter high is shown in Fig.6 as a function of time.

Table 1. Dose rate at some positions after 90 rad neutron irradiation.

Position	Dose rate (mR/h in average) just after	 2 min after
Collimator (gantry)	26	5.6
Treatment table	15	5.6
Floor	12	5.2

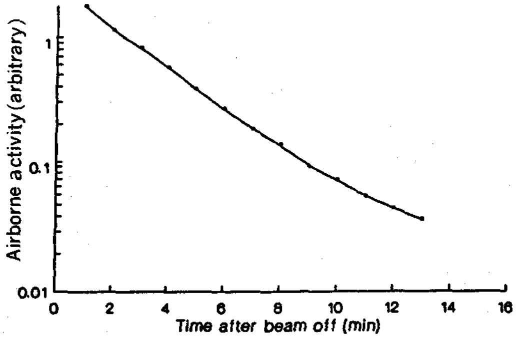


Fig.5. Radioactivity in room air samples as a function of time.

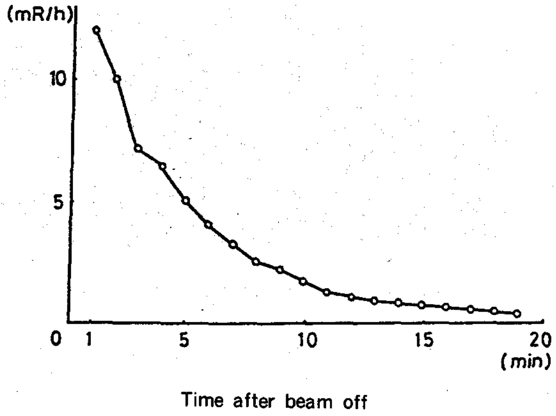


Fig.6. Radoatopm level at around the treatment couch.

Consequently, the clearance patterns of airborne activities and gamma dose rates in the therapy room can be summairzed as shown in Table 2. Variability of clearance time may be from the difference of activated materials according to the individual method of measurement.

Materials irradiated by high energy neutron beam may also be activated by nuclear reaction. The measured external ; dose rates of phantom and human skin are given in Table

Table 2. Clearance of room radioactivity

Time	air sampling (count)	survey meter (mR/h)	wall monitor (mR/h)
T-1/2	4.5 min	2.6 min	1.9 min
T-1/10	9.2 min	10.2 min	3.2 min

3 as a function of time after neutron irradiation. It appears that dose rate at lucite phantom surface is as 12 mR/h just after beam off and it drops to 5.4 mR/h two minutes later. Dose rate at skin of the patient drops from 26 mR/h to 4.5 mR/h.

Exposure to persons working in the neutron therapy section was monitored with TLD badges. Dose per fraction (one session of treatment) for RTT was 0.08 mrem in average. Quarterly average dose was 37 mrem for RTT and 30 mrem for engineer. Yearly average dose per person was 126 mrem for RTT and 90 mrem for engineer (see Table 4).

Table 3. External dose rates after 90 rad neutron irradiation.

Irradiated substance	dose rates (mR/h in average)	
	just after	2 min later
Lucite phantom	12	5.4
Patient skin	26	4.5

Table 4. Average exposure dose to neutron therapy staff.

	RTTs	engineers
Dose/fraction	0.08 mrem	-
Quarterly average dose	37 mrem	30 mrem
Yearly average dose	126 mrem	90 mrem

DISCUSSIONS

External neutron therapy systems generally used in the institutes are d-T generators and cyclotrons. In these neutron therapy facility, the major sources of remantent radioactivity are target, field defining collimators and beam flattening filters. They have wall mounted fixed neutron gantry where the collimators are interchangeable for each treatments. Therefore, working for the change of collimator is the major source of exposure for that persons. In TAMVEC facility (M.D. Anderson hospital, Texas, USA)[1] radiation levels at 46 cm off the central axis was around 100 mR/h from twice a week treatment schedule. In Fermilab (Batavia, Illinois, USA) [2] it was 25 mR/h one minute after 1 Gy exposure. In Hammersmith hospital (London, England)[3] radiation level at 15 cm from the neutrom port was around 10 mR/h just after 15 minute exposure of neutron with 55 μA deutron. This activity decayed out 10 minutes later.

In KCCH cyclotron neutron system[4], field defining is done by motor driven collimators mounted in the gantry. Beam flattening filter and wedge filters are also mounted within the gantry. Therefore, it is not necessary for the staffs to touch any accessory equipments for neutron production and irradiation. This type of gantry mounted target and collimator system reduced the occasion of personal exposure during work time. Remanent radioactivity produced by neutron activation in the materials is mostly short-lived and does not accumulate signficantly during the treatment day. Technologists were advised to enter the room in five minutes after beam off. In Clatterbridge hospital[5], their standard treatment prescribed a 1 Gy irradiation followed by a 10 minutes waiting period.

For the past two years, the accumulted radiation dose to staff in KCCH cyclotron neutron facility was very low in comparison with persons working in institutions of other countries. The main source of radiation exposure for the engineers is remanent radioactivity in the cyclotron vault if they enter that room for maintenance. Weekly maintenance of cyclotron is done on Monday. This gives two days of decay time after use of done on during previous week. This schedule reduces exposure to the engineers.

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原子力病院 싸이클로트론 中性子線 治療室의 放射線 防禦에 관한 總合的 評價

韓國에너지연구소부설 原子力病院 治療放射線科

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要 約

원자력병원 싸이클로트론 中性子線 치료실의 방사선 準位를 측정함으로써 방사선 안전도를 검토하여 보았다. 중성자선 치료실내 방사선 노출은 주로 isocentric gantry에 내장된 중성자선 標的과 照射野를 결정하는 collimator의 放射化로 인한 殘留放射能 (remanent radioactivity)에 의해 결정 된다. 측정결과 線量率은 과다하지 않았고 개인 集積線量도 허용치 이내였다.

방사선 작업종사자로서의 의료기사는 환자치료 시 매 照射 완료 직후부터 5분간 減殺시간을 갖도록 조치하였다.