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RESULTS OF MEASUREMENTS OF AN ISOCENTRIC FAST NEUTRON THERAPY UNIT WITH A 42 MEV PROTON CYCLOTRON SYSTEM

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Abstract. - Depth dose and dose rate characteristics of fast neutron beams produced by the bombardment of 42 MeV protons on a beryllium target is presented along with the measured dose rate with and without a polyetheylene hardening filter. Also presented are the measured effectiveness of collimating the fast neutron beam for radiotherapy use and the measured residual radioactivity of the treatment head shielding used to attenuate radiation outside of the desired field of the neutron beam.

Introduction. - Three isocentric neutron radiotherapy units have been built by The Cyclotron Corporation which were designed to be used with existing cyclotrons capable of accelerating four different charged particles. Among the particles which these cyclotrons could accelerate were 26 MeV protons and 15 MeV deuterons. The characteristics of the neutron beam produced by these units have been presented. [1,2,3] Although these units overcame the disadvantage of fixed position neutron therapy units, the depth dose characteristics of these units did not meet the criteria for a clinically useful neutron therapy apparatus.[4] The design and fabrication of a 42 MeV proton cyclotron and isocentric neutron therapy unit was started in 1978 with the goal of producing neutron beam depth dose charactistics comparable to 4 MV teletherapy units and dose rates capable of delivering a 100 cGy neutron treatment fraction within a few minutes. Measurements of the completed 42 MeV proton cyclotron and isocentric unit were made in 1980 and the results are presented below.

Neutron Beam Characteristics - The depth dose characteristic of the neutron beam was measured in a tissue equivalent liquid phantom with a density of 1.08 and shown on figure 1. This measurement was made with 42 MeV protons bombarding on a sintered beryllium target, 0.6 cm thick, which would remove 15.3 MeV from a 42 MeV proton beam. The beryllium target was brazed onto a copper backing plate, 0.2 cm thick. The face of the phantom was 125 cm from the target with a 10 cm x 10 cm field as defined by AAPM Report No. 7. [5] As shown on Figure 1, the depth for 50% of the maximum dose occurs at 13.2 cm when a 3 cm thick (2.7 g cm^{-2}) polyethylene hardening filter was placed upstream of the collimator near the beryllium target. Without a hardening filter, the depth for 50% of maximum dose occurs at 12.1 cm. The measured dose rate at these points were 0.8 cGy/min-μA with a filter and 1.1 cGy/min-μA without a filter. The depth dose and dose rate characteristics are influenced by the target thickness and the backstop material. The measurement of the effects from using different target thicknesses was made and previously published. [6]

Collimation of the Neutron Beam - The neutron beam produced by the proton on beryllium reaction is forward directional with an angular distribution and spectra measured by several groups.[7,8] For neutron radiotherapy, the criterion is to have a collimator which will attenuate the total radiation dose, 5 cm outside of the treatment field, to less than 2% of the central axis dose at the isocenter, measured in air. More desirable is to have the leakage radiation dose to be 1% rather than 2%. One of the difficulties of achieving such a criterion is that the scattered and residual radiation of the treatment room walls could be a significant portion of the radiation outside of the treatment field. Figure 2 is a measurement of the dose profile in air measured across a 10 cm x 10 cm collimated field at 125 cm from the target. This measurement was made with and without the collimator opening plugged and compared with two types of collimator materials. One was Benelex which is a compressed wood (density = 1.35) and the other was a water extended polyethylene loaded with approximately 30% of iron filings. Figure 3 shows another measurement (with a different thickness target) comparing the effectiveness of a Benelex collimator versus a steel collimator. All the collimators were 63.5 cm long and the face of the collimator to the isocenter was 33 cm.

Residual radioactivity - The materials used in the treatment head shield are subject to activation by both fast and thermal neutrons. Measurements were made to determine the radioactive build-up by simulating the activation which a treatment unit will experience in radiotherapy use. Figure 4 shows the residual radiation build-up measured around the treatment head as it is exposed to 100 cGy of irradiation every 15 minutes. This measurement will give an indication of what radioactivity staff personnel may be exposed to at the end of a day of treatments.

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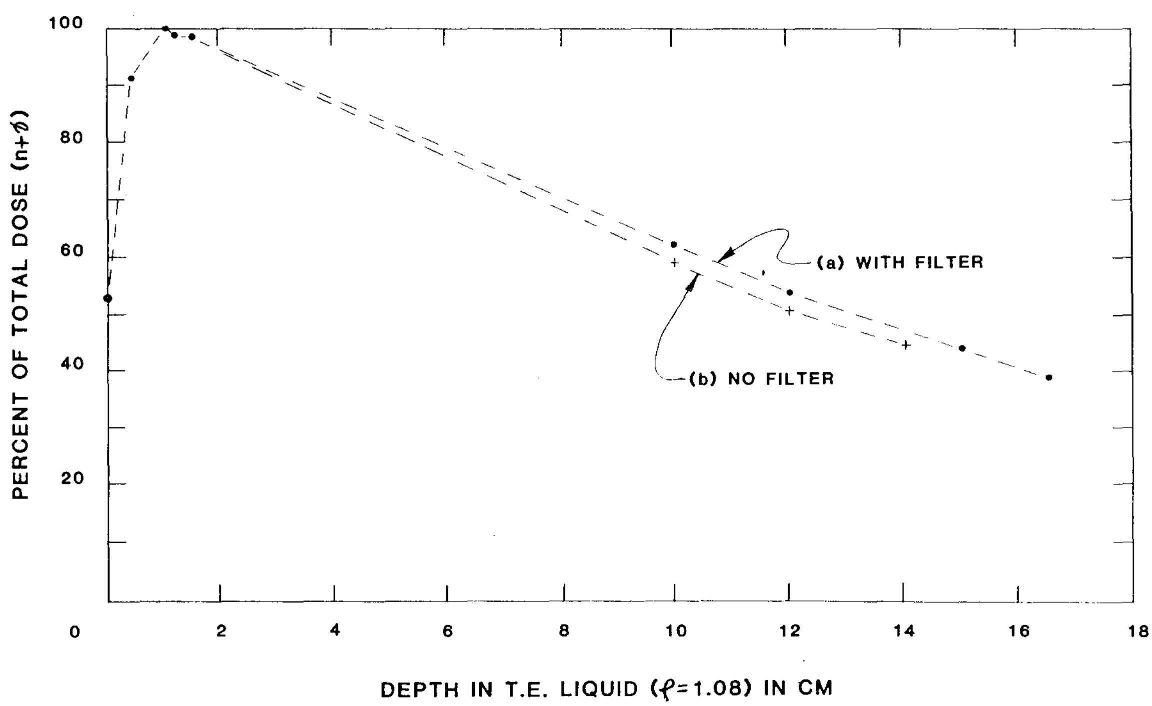

Fig.1 Central Axis depth dose curve for P(42) Be(15.3) Neutron Beams with (a) 3 cm thick polyethylene hardening filter and (b) no hardening filter

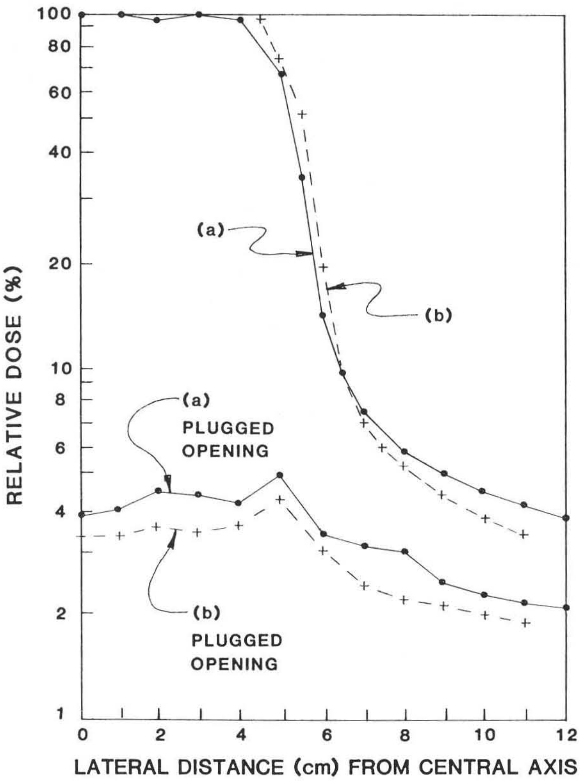

Fig.2 Dose profile measured in air, 125 cm from 0.60cm thick beryllium target, 10 cm x 10 cm field,no hardening filter with collimator material made of (a) Benelex and (b) Water extended polyethylene +30% Fe filings. Lower curves show same profile measurement with collimator opening plugged with borated polyethylene.

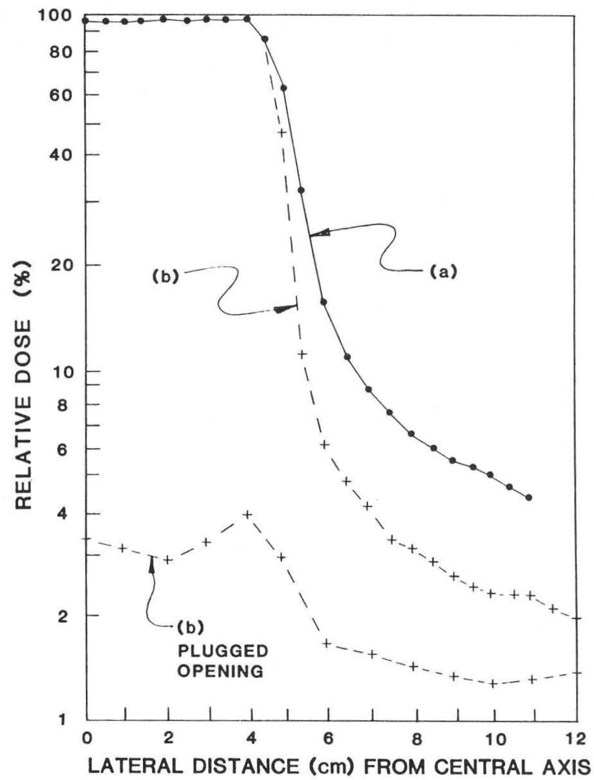

Fig.3 Dose profile measured in air, 125 cm from 0.35cm thick beryllium target, 10 cm x 10 cm field, 3 cm thick hardening filter with collimator material made of (a) Benelex and (b) low carbon steel.

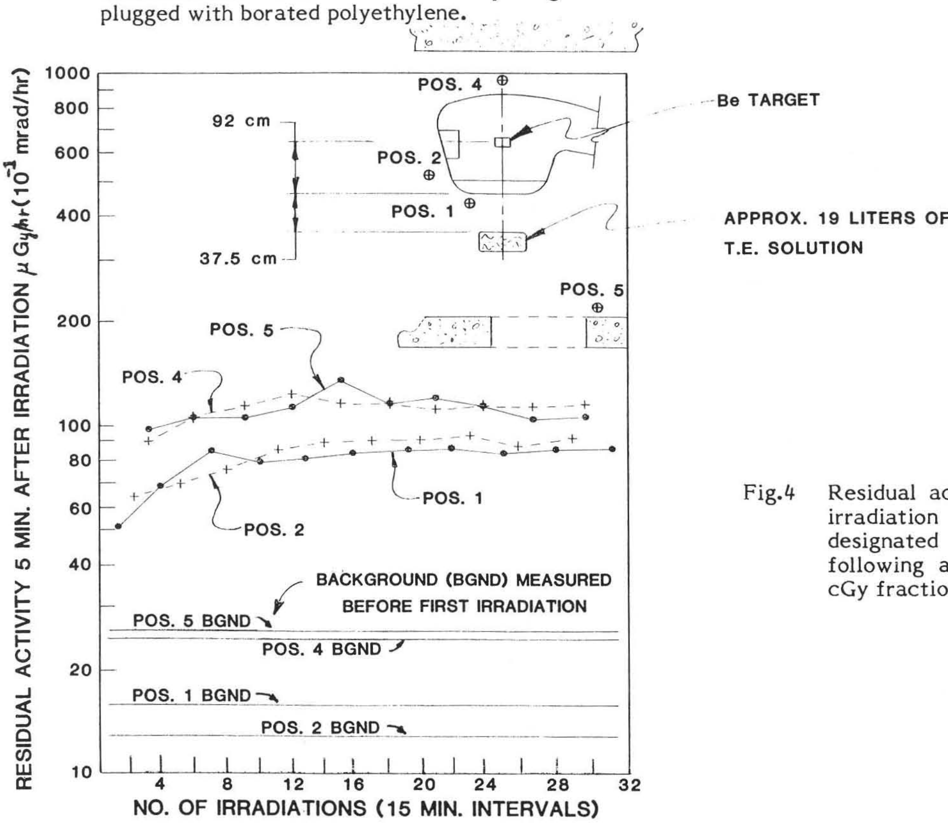

Fig.4 Residual activities measured 5 minutes after irradiation and 20 cm from the surface at designated areas. Build up was simulated following a treatment schedule of four 100 cGy fractions per hour.