(*Table* 2 *contd.*)

Subject	Clock hours
Environmental monitoring	9
Transportation of radioactivity	7
Criticality for technicians	3½
Emergency action	8
Spectrometer use	28½
In-plant training and familiarization	269
Special problems, all plants	42
Air monitor chart analyses	8
Ra–Th problems	6
Laboratory and plant tours	35
Seminars	76
Study time	191
Visiting lecturers	12
First aid	20
Laser safety	3
Fire and radiation safety	8
Ventilation and radiation safety	8
Other safety considerations	7
Meteorology and health physics	2
Maintenance problems	2
Training personnel in radiation safety	4
Review	12
Course critique and termination	8
TOTAL	953

Problems encountered have been few. Adequate facilities at the NRTS are gradually becoming available. Bolstering of the summer NRTS staff has been accomplished by hiring qualified personnel now in the teaching profession or in graduate school.

Very few students who enter the course drop out. On the other hand, it appears that few of the graduates will be available as technicians; most of them become so interested that they pursue BS degrees in some aspect of nuclear science. The Committee does not regard this as a loss, however, but as success in aiding the supply of better educated nuclear personnel.

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Thorium Fission Cross Section for Neutrons Between 12.5 and 18 MeV Using Fission Fragment Damage Tracks in Lexan

(*Received* 22 *November* 1966)

A class of materials (mica, plastics and glass) known as solid state nuclear track detectors may be used as neutron detectors by placing them next to a fission foil.(1) Such a detection system is useful for measuring 14 MeV neutron fluence around low voltage generators where competing reactions can make analysis of activation foil data difficult. Any fissionable material including U and Th can be used to produce fragments. Thorium has an advantage over other materials in that it is free of elements or isotopes that have fission cross sections for thermal neutrons. However, unlike ^{238}U, limited experimental data are available for Th fission cross section above 10 MeV.(2) The following note describes the fission foil-detector method for determining neutron fluence and its application to the measurement of thorium fission cross section for neutrons between 12.5 and 18.0 MeV.

Fission fragments that penetrate the detector produce radiation damage along their path. Chemical etching of the detector will create hollow channels or tracks that can be observed with an optical microscope.(3,4) For a Lexan polycarbonate resin detector placed in contact with a thick fission foil, Prêtre *et al.*,(5) have found a constant sensitivity factor of

$$1.16 \times 10^{-5}\ \text{tracks/neutron-barn.}^{(5)}$$

Although the cross section of ^{232}Th could be determined directly from the sensitivity factor, a more direct approach was applied by utilizing available cross section data for ^{238}U and exposing thorium–Lexan and uranium–Lexan pairs simultaneously to monoenergetic neutrons. The measured thorium fission cross section is then the ratio of the ^{232}Th and ^{238}U fission fragment tracks per unit area multiplied by the ^{238}U cross section.

The fission foil–Lexan pairs were exposed to monoenergetic neutrons at a Van de Graaff generator. Monoenergetic neutrons were produced by bombarding a tritium target with 0.6 and 2.0 MeV deuterons. Neutrons between energies of 12.5 and 18.0 MeV were obtained from the reaction $T(d, n)^4$He by placing the detectors at appropriate angles to the incident deuteron.(6) The exposed Lexan detectors were etched in a potassium hydroxide solution as described by Prêtre *et al.*(5) and enough tracks

Table 1. *The fission cross section of* ^{232}Th

E_n (MeV)	^{232}Th Tracks/cm^2	^{238}U Tracks/cm^2	σ ^{238}U (n,f) (*barns*)	Track ratio ^{232}Th/^{238}U	σ ^{232}Th (n,f) (*barns*)
12.5	1.12×10^4	4.20×10^4	1.04	0.27	0.28
13.0	1.34×10^4	4.48×10^4	1.07	0.30	0.32
13.0	1.01×10^5	3.01×10^5	1.07	0.34	0.36
13.5	1.53×10^4	4.67×10^4	1.09	0.33	0.36
14.0	1.37×10^5	4.05×10^5	1.13	0.34	0.38
14.5	1.89×10^4	5.50×10^4	1.23	0.34	0.42
14.5	1.22×10^5	3.81×10^5	1.23	0.32	0.39
15.0	1.47×10^5	4.29×10^5	1.29	0.34	0.44
15.5	1.54×10^5	4.56×10^5	1.33	0.34	0.45
16.0	2.68×10^4	7.21×10^4	1.36	0.37	0.50
16.0	1.36×10^5	4.12×10^5	1.36	0.33	0.45
16.5	2.44×10^4	6.51×10^4	1.37	0.37	0.51
17.0	3.46×10^4	8.82×10^4	1.38	0.39	0.54
17.5	3.00×10^4	7.75×10^4	1.38	0.39	0.54
18.0	2.81×10^4	7.89×10^4	1.38	0.36	0.50
18.0	3.51×10^4	9.40×10^4	1.38	0.37	0.51

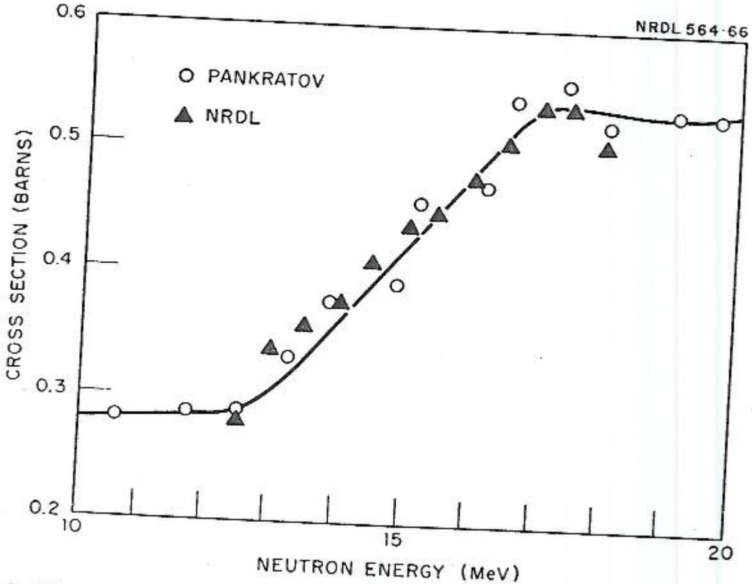

FIG. 1. The fission cross section of ^{232}Th for neutron energies between 10–20 MeV.

counted under the microscope to obtain a 5 per cent counting accuracy. Fission cross section values for ^{238}U are from Barrall and McElroy.(2)

Table 1 lists the neutron energy, the tracks per unit area counted in the ^{232}Th and ^{238}U detectors, the ^{238}U cross section used, the ratio of cross sections for the two detectors as determined from the track count, and the evaluated thorium cross section. Within the experimental error the values agree with recent values determined by Pankratov.(7) The NRDL values are plotted in Fig. 1 on Pankratov's curve.

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A Constant-Power Circuit for Heating Thermoluminescent Dosimeters*

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Thermoluminescent dosimeters fall into two general classes: (a) Those heated for thermoluminescence readout by a separate device, e.g. a hot-plate or planchet upon which the dosimeter is placed after exposure to radiation, and (b) those which include a heating element as an integral part of the dosimeter. The latter type usually has been heated ohmically by passing an alternating or direct current through electrical leads which penetrate the dosimeter envelope.(1–4)

One of the problems in the manufacture of internally-heated dosimeters is to produce heating elements which do not vary in resistance from one dosimeter to another. Assuming other dosimeter characteristics to be identical, differences in resistance will give rise to differences in heating rate, resulting in "squeezing" or "stretching" of the glow curve vs. time, if the heating current is delivered under typical constant-current or constant-voltage conditions. For example, if an individual dosimeter has a heating element 10 per cent lower in resistance than the average of a group of dosimeters, then a constant-current source will deliver 10 per cent less power, and a constant-voltage source 10 per cent more power, to that dosimeter than to a "normal" one.

Thermoluminescence readers which measure glow-peak height, and those which measure the light sum, are both sensitive to heating-rate variations. In the latter case the dependence stems from the fact that the light-summing is usually terminated at a fixed time after the beginning of the heating cycle, but the influence of thermal quenching of the luminescence can also give rise to a variation of glow-peak area with heating rate.(5)

A greater degree of heating-rate uniformity amongst a given group of dosimeters can be obtained through the use of a circuit which delivers approximately constant power, such as that shown in Fig. 1.

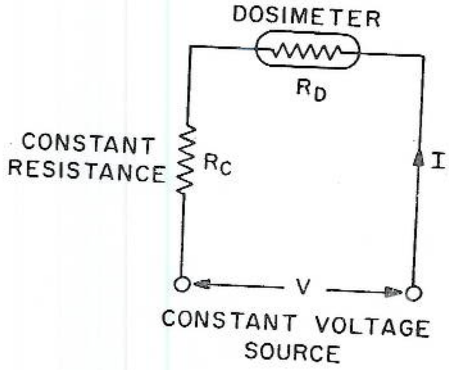

Fig. 1. Constant-power source. Constant voltage V is applied across the dosimeter in series with the constant resistance R_C. The value of R_C is chosen equal to the average value $\bar{R}_D$ of the dosimeter population.

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