THE USE OF ONE-SIDE ALUMINUM COATED THIN POLYCARBONATE FILM (2 - 10 μM) AS A HIGH PRECISION NEUTRON OR FISSION COUNTER

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In 1971 a research project was initiated jointly by the University of Toronto, Canada, and University of Sao Paulo, Brazil, to study "Photofission of Mg-24" using thin polycarbonate (PC) film. The project was conducted in the Linear Accelerator Laboratory of the University of Toronto. At the start of the project, the research team, lacking previous experience in the subject, sought help from the Department of Material Science about high purity target materials, from the Department of Chemical Engineering where there was a small group working on PC and from Dr. Maraghi who was the Manager of Bayer AG in Canada. In 1973 when I was a full time research associate for this project, I received a message from Bayer AG in Germany through Dr. Maraghi that they would be happy to show me how they made their thin PC film if anytime I visited Germany.

Three years later, with our joint efforts, we achieved the following results. Figure (1) gives the excitation function of $M^{24}(\gamma c)C^{12}$ reaction with very small cross sections ranging from 20 to 5 pb (10^{-36} cm^2)[1]. One of the main techniques adopted for distinguishing a few particles of C^{12} from the other particles was to determine the time for the etchant to penetrate through the PC film[2] as shown in Figure (2).

Near the end of this project, a new laboratory exercise was introduced to the University Fourth Year curriculum, the students could determine the spontaneous fission half life of U^{238} by covering a PC film on a polished depleted uranium plate for a few weeks and then etching out the fission tracks from the PC film. Also, fission barriers of nuclides in the region of Z ~ 82 and N ~ 126[3], the so called region of closed shell, could be determined using the same technique. In the Linear Accelerator Laboratory, we spent most of our time on operating the accelerator. The exposed detectors were processed, using the direct reading method as shown in Figure (3), at the same time when the accelerator was running. Before irradiation the PC detector was coated on one side with aluminum using a vacuum evaporator. After irradiation the exposed detector was floated on the surface of NaOH solution with the aluminum side facing upward. After a certain lapse of time depending primarily on the thickness of the PC film and the etching temperature, the etchant appeared on the upper surface along the trajectory of the damaged track and dissolved the aluminum around the track so that a bright spot could be observed with the naked eye. The etching process ended when there was no further increase in the number of the bright spots. The complete etching process did not require special care except taking pictures on the development of the bright spots with a camera if records were required. By the time when we shut down the accelerator, all the

irradiated PC films had already been etched out except the last piece. Figure (4) is a picture of the film after etching.

Although Bayer AG supplied us with PC samples of thickness down to 2 μM, the PC film adopted in the above experiments was rarely thinner than 6 μM. PC film thinner than 6 μM down to 2 μM is usually produced by a mechanical stretching process during production therefore its thickness is not as uniform as the film above 6 μM.

By thin detector we mean that its thickness is less than the range of the average fission fragments in the film (~18μM). The advantage of using thin film is that the method of read-out is much simpler and faster than with a thick detector. There are two read-out methods for thin detectors, the sparking method and the direct reading method, as mentioned above. Both methods had actually been tested during the progress of the project. Film thinner than 6 μM cannot be used satisfactorily for the sparking method, but it performs well for the direct reading method. That is, even if the thin film is slightly non-uniform it will not affect the direct-reading method. In other words the effect of the thinner parts of the film on the direct reading method is just that it will take a slightly shorter time for the etchant to penetrate through those parts of the film. For the sparking method, dielectric may completely break down through the thinner parts of the non-uniformed film.

Using the direct reading method, the etching curve[4] (the plot of the relative yield against etching time) can be schematically shown as in Figure (5). The curve corresponding to the heavy fission fragments is located to the farther left of the curve corresponding to Ne. For heavy fission fragments, it shows a single curve because the resolution of thin PC cannot differentiate the fission fragments. However, if a certain percentage of tetrachloro or tetrabromo polycarbonate is introduced in the pure resin, the detector thus fabricated will be less sensitive than that fabricated with pure resin (Biphenol A polycarbonate)[5]. Schematically the detector made with the mixture will give an etching curve for the heavy fission fragments as shown in Figure (6).

There are other methods to make the fabricated detector less sensitive to heavy ions. If a PC film is irradiated by a heavy ion source (for instance, fission fragments from a bare Cf-252 source) under vacuum and under UV of a specific wave length (a different wave length for a different composition of the detector material, for instance, mylar is different from PC), it will require much longer etching time. The asymptotic condition is when the track etching rate V_T is virtually equal to that of the bulk etching rate V_B, the individual tracks could no longer be identified . On the other hand, there is also the method for shortening the etching time. The etching time can be shortened when using PC film which has been irradiated under the existence of oxygen and simultaneously under the UV of the same wave length as when the etching time is extended.

So far we have briefly described the etching performance of the thin PC film. Now we will turn to its practical use. There are two uses:

(1) The determination of the trace amount of fissile elements[6] - As an example, in 1983 it was a routine method for the Ontario Ministry of Labour to conduct analysis of uranium dust collected on the filter paper at the vicinity of the uranium mine tailings areas in Elliot Lake. The filter paper PC film assembly was irradiated with thermalized neutrons from a 500 μg Cf-252 neutron source for one week to compensate for its low neutron flux (~10^6/cm^2/sec.). Ten years later, the neutron source can still be used to-day to irradiate a testing sample for the direct reading method.

(2) The determination of stray neutrons from a container containing the fissile material, for instance, the used fuel element. It is believed that more practical uses can be developed in this direction. The basic assembly for the device is shown in Figure (7).

In monitoring neutrons over a large area (for instance, the storage canister for used fuel from the power reactor is usually a cylinder of 15 ft. long and 5½ ft. in diameter), we would want to replace the He^3 proportional counter by PC film. The advantage of the He^3 counter is that it can give an instant display. The merits of the PC assembly is that it is less expensive, more flexible to fit the geometry of the material to be monitored, no requirement for long time power supply, and absolutely no instrument drift under all conditions.

Although past experience reveals that thin PC film has the potential to be used as a low background detector for fission and neutron, further investigation is still required. Here are some suggestions.

(1) Basic considerations:

(a) PC was discovered by Bayer AG, Germany, and General Electric, United States, almost the same time. For further development of the thin film technique, contacts with both companies are required. The best quality thin PC film was made by Bayer AG, Germany. Since Bayer AG had stopped their production of thin PC film after July 1994, contact with General Electric through Professor R.L. Fleischer* is the only alternative especially in the U.S.

*Professor R.L. Fleischer, Department of Earth and Environmental Sciences, West Hall, Rensselear Polytechnic Institute, Troy, NY 12180-3590.

(b) One of the defects of thin PC film is its property of absorbing moisture when it is exposed to air. Thin PC film should be kept in a low temperature oven with temperature below the softening point of PC.

(c) Mylar can also be used as a fission or neutron detector and is more resistant to vapour absorption. However, thin Mylar film (for instance, film thinner than 10 μM) is not available in the market.

(d) The device for handling PC film of large areas should be specially designed.

(e) The primary records during etching are the pictures taken while etching is in progress. The use of a timer-controlled camera and the availability of a dark room would offer a special convenience.

(2) The sensitivity of the PC system is only limited by the uranium content in the PC film. Therefore the uranium content in the current PC film should be checked. So far the only rough record is from the sparking method[7].

(3) The use of the PC system for neutron detectors is only limited by the fact that how large an uniformly distributed U or Pu source can be prepared so that the total amount of uranium or Pu can be known. Although the quantitative painting of uranium or Pu on a large piece of aluminum sheet had previously been published[8], extension of the method to very large areas should still be studied.

(4) In order to provide the monitoring result as fast as possible, the method or high temperature etching of the 2 μM PC film should be developed.

(5) Final field testing be conducted to check the performance of the neutron detector method (for instance, the used fuel element canister of the Duke Power Company or Ontario Hydro).

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1. A.H. Chung (1973) Ph.D. Thesis, Department of Physics, University of Toronto.

2. W.T. Diamond (1973) paper presented at the 1973 Inter. Conf. on Photonuclear Reactions and Applications, Asilomar, California.

3. H.L. Pai and C.R. Phillips (1978) *Nucl. Inst. and Methods,* 131, p. 81.

4. H.L. Pai and C.R. Phillips (1977) *Rev. Sci. Inst.,* 48, p. 1488.

5. H.L. Pai (1973) paper presented at the Annual Meeting of Canadian Association of Physicists, Montreal.

6. H.L. Pai et al (1979) *Nucl. Tracks,* 3, p. 223.

7. R.M. McCorkell and Y.F. Huang (1977) *Rev. Sci. Inst.*, 48, 8, p. 1005.

8. K.M. Glover and P. Borrell (1955) *Nucl. Energy,* 1, p. 214.

Figure (1)

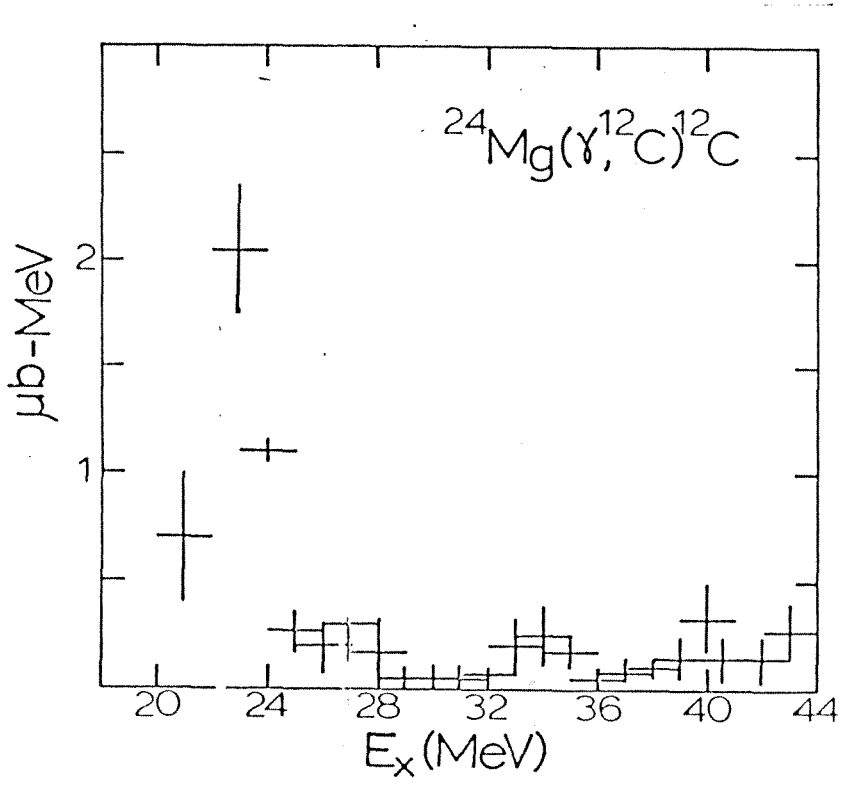


Fig. 7-15. *The equivalent photon-induced fission cross section as a function of excitation energy in ^{24}Mg. In terms of the incident electron beam the maximum in the curve corresponds to ~40 picobarns. The ^{12}C ions, of energy 4 to 15 MeV, were identified as described in Fig. 3-13.* (*After Chung, 1973.*)

Figure (2)

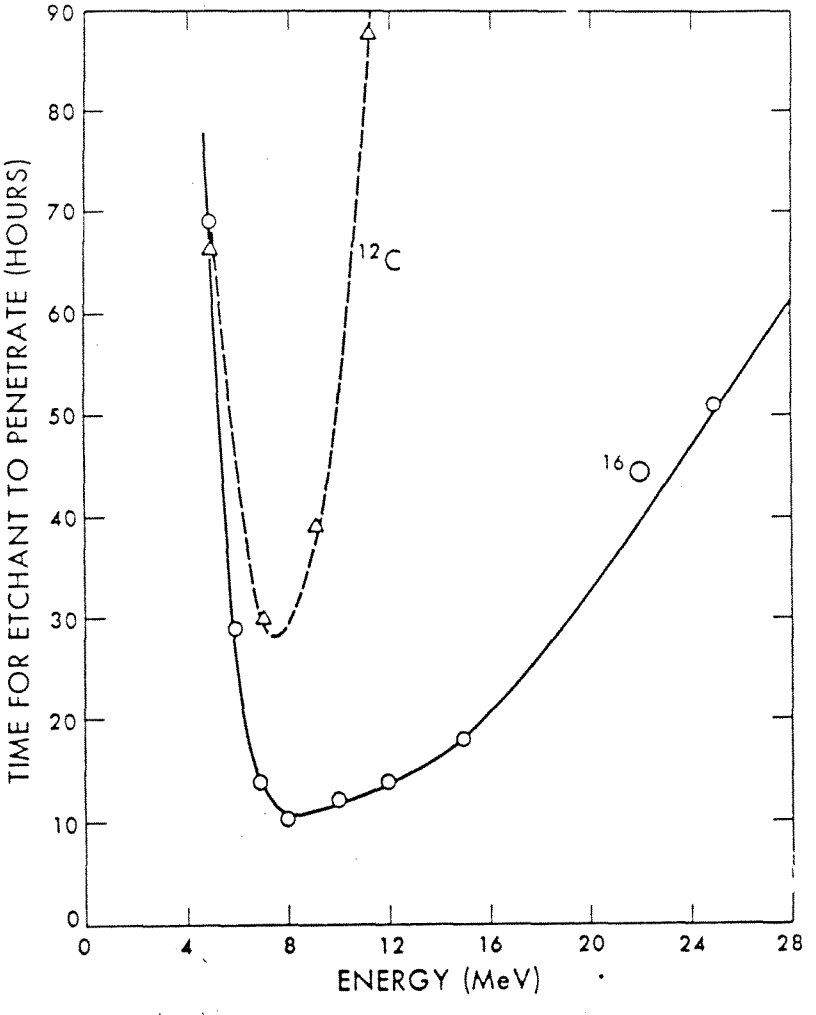


Fig. 3-13. *The time, t = (thickness) ÷ v_T, for etchant to penetrate a thin, aluminized Makrofol sheet from one side can be monitored by placing a movie camera on one side and a light source on the other side of the sheet, which floats on the surface of NaOH solution. The ionization maximum shows up as an etch time minimum. (After Diamond et al., 1973.)*

Figure (3)

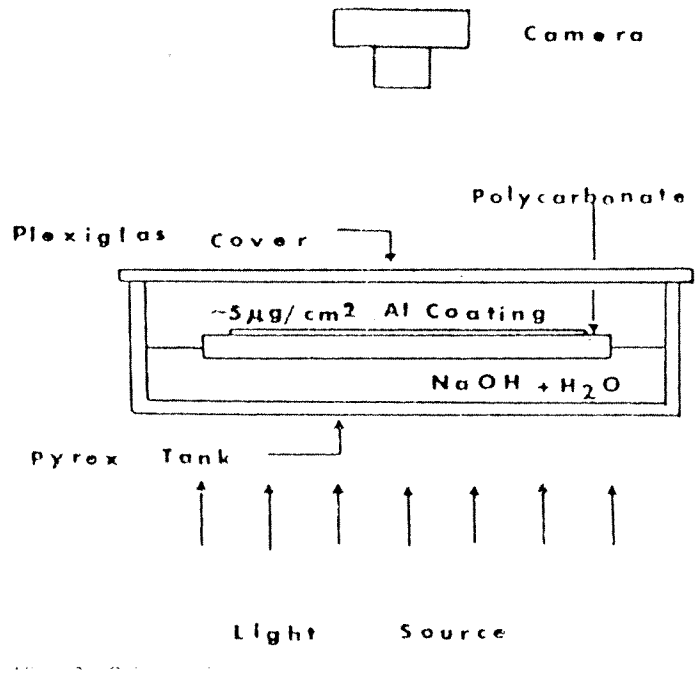

Camera
Polycarbonate
Plexiglas Cover
~5µg/cm2 Al Coating
NaOH + H2O
Pyrex Tank
Light Source

Figure (4)

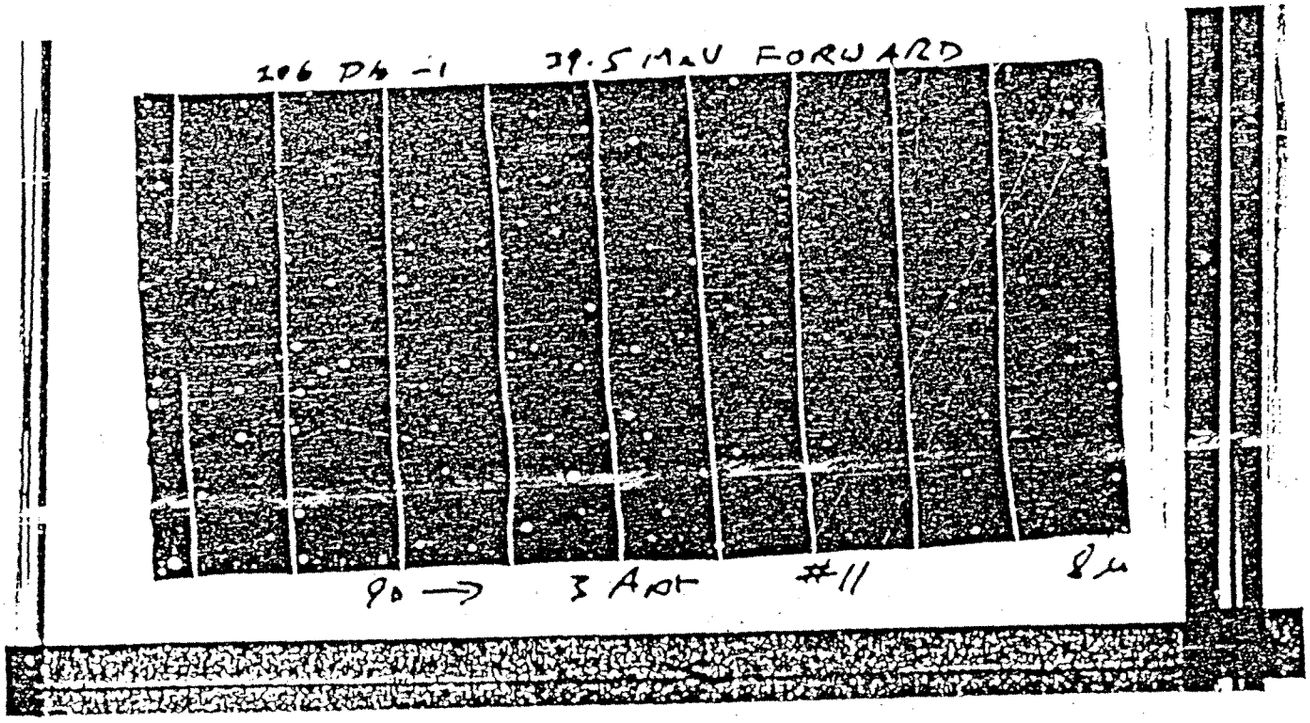


Figure (5)

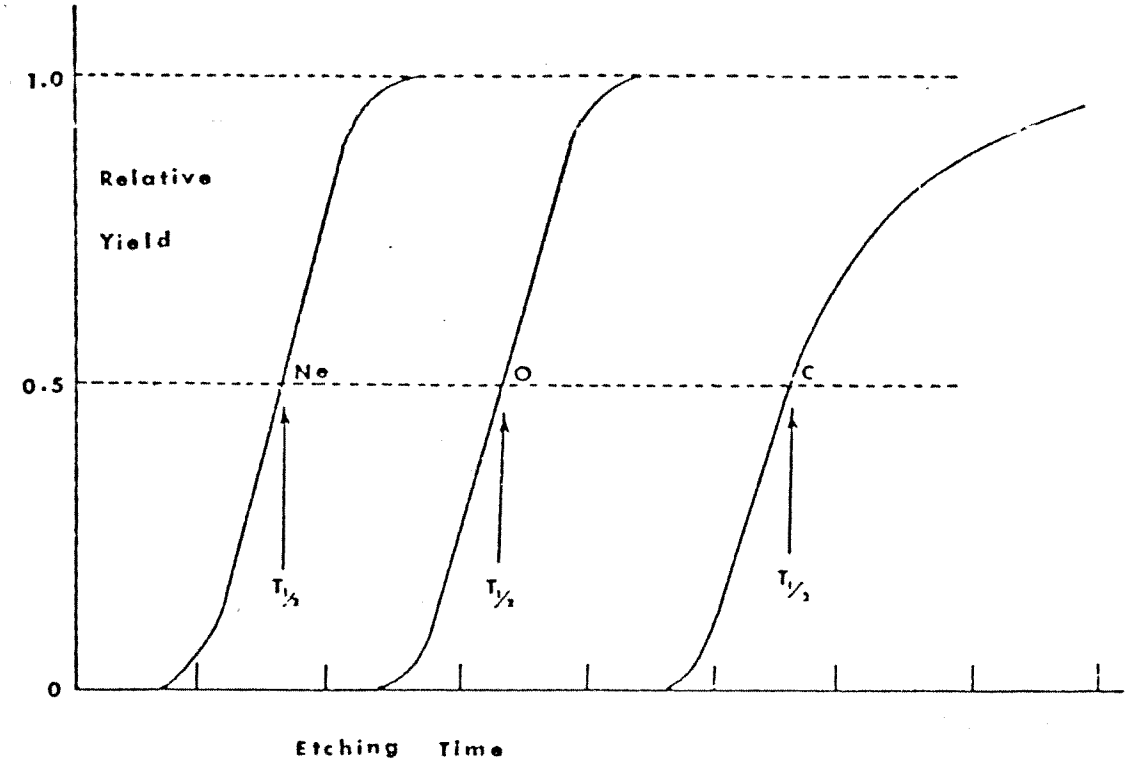


Figure (6)

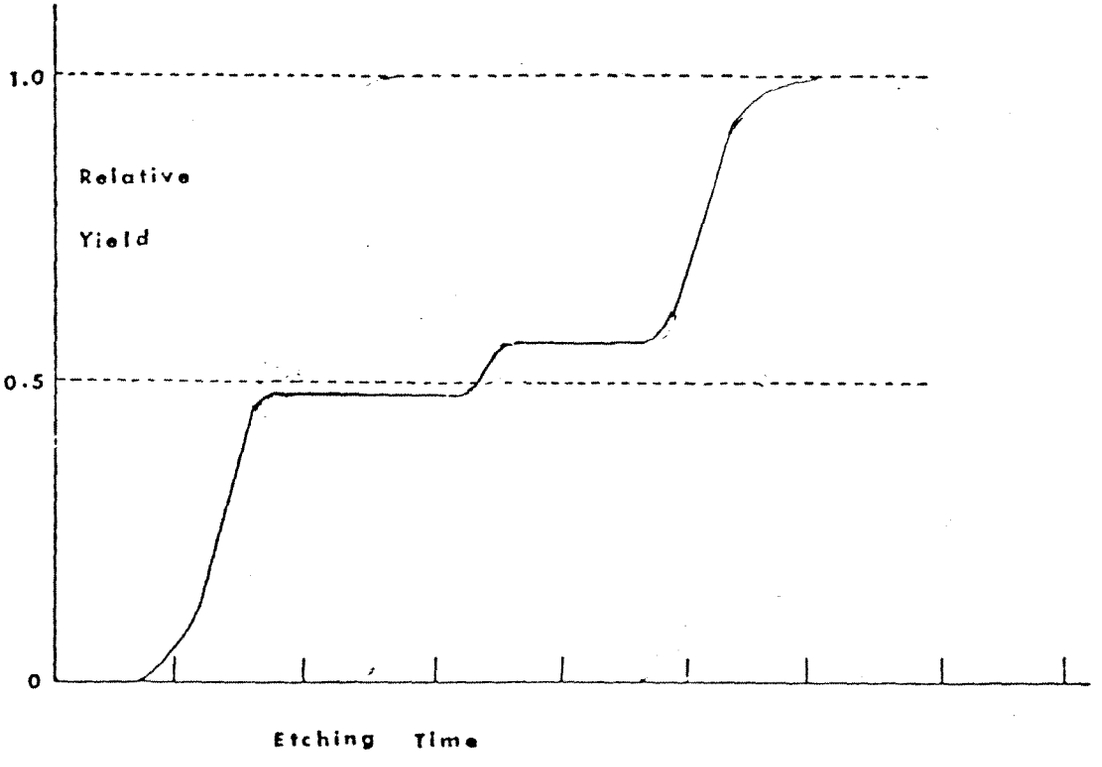
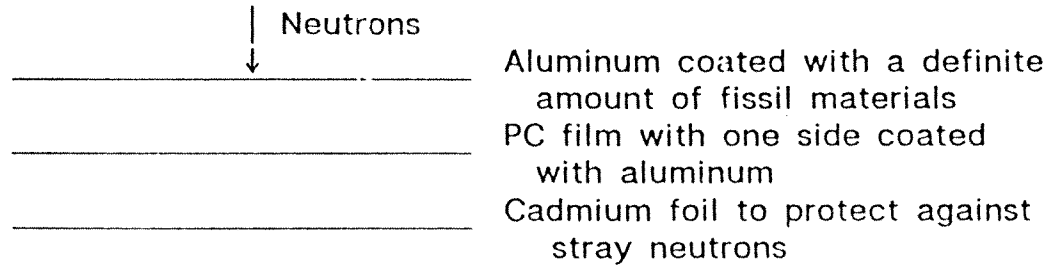


Figure (7)


Neutrons
Aluminum coated with a definite amount of fissil materials
PC film with one side coated with aluminum
Cadmium foil to protect against stray neutrons