

SPECIAL TARGET PREPARATION TECHNIQUES
FOR CHALK RIVER NUCLEAR PHYSICS

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ABSTRACT

The techniques and apparatus described in this paper were developed to fulfill the needs of Nuclear Physics Research at Chalk River. They include: a safe apparatus for the preparation of adsorbed tritium targets, a technique for the fabrication of temperature resistant targets of isotopically enriched selenium, an apparatus for the preparation of reactive metal targets for scattering experiments, and a technique for the fabrication and mounting of ultra-thin, $2 \mu\text{g}/\text{cm}^2$ carbon stripper films.

In the field of Nuclear Physics Research, success often depends on the quality of the target material. It must meet the highest standard of purity, the thickness must often be measured with great accuracy, and the target must be chemically stable and heat resistant. Many techniques suitable for one type of nuclear reaction may not be appropriate to another. Some special preparation methods developed for MP tandem accelerator experiments have been published previously¹⁾. In this paper, other techniques used at Chalk River for the nuclear physics program will be discussed. They are:

1. A safe apparatus for the preparation of adsorbed tritium targets.
2. A technique for the fabrication of temperature resistant targets of isotopically enriched selenium.
3. An apparatus for the preparation of reactive metal targets.
4. A technique for the fabrication and mounting of ultra-thin $2 \mu\text{g}/\text{cm}^2$ carbon stripper foils.

1. A Safe Apparatus for the Preparation of Adsorbed Tritium Targets

Solid targets containing tritium are very valuable for the study of nuclear reactions using heavy ion beams, such as $\text{T}(^{12}\text{C},\text{p})^{14}\text{C}$ (ref. 2). The apparatus to be described has been used to produce titanium tritide targets on

thick backings and on thin copper foils. The latter targets were stretched to provide flat targets suitable for the measurement of nuclear lifetimes by the recoil distance technique.

The tritium target preparation apparatus is illustrated in Fig. 1. All the parts are stainless steel and consist of a reaction chamber, a Pirani type pressure gauge, a calibrated chamber, an 8 l/s ion pump, a cryopump and a small (10 cm^3) chamber containing about 25 grams of uranium turnings used to purify and store tritium. The reaction chamber and the uranium chamber have internal iron-constantan thermocouples to monitor temperatures. The volume of the pressure gauge and the associated chamber have been accurately measured so that the total volume of tritium used can be determined. This stainless steel system eliminates the dangers of tritium release from breakage of a glass system. Residual tritium is contained within the system by adsorption in the cellular anode of the ion pump.

Prior to use with tritium, the uranium oven must be activated with hydrogen. This hydrogen chemically reacts with the uranium to form hydrides. When the hydride is subsequently decomposed, the uranium becomes a finely divided powder which will readorb hydrogen readily³⁾. The procedure for this activation is as follows. Uranium turnings, normally stored in oil, are degreased in trichlorethylene and rinsed in acetone and distilled water. The turnings are then immersed in 8 N nitric acid to dissolve the surface oxides. The uranium now exhibits a silver metallic lustre. The turnings are rinsed several times in distilled water, in alcohol and then transferred rapidly to the oven.

The oven is evacuated and baked at approximately 600°C for ten minutes, then the temperature is reduced to approximately 120°C . Hydrogen is introduced steadily at a pressure of 13 kPa (100 mm). After the absorption has stopped, the temperature is raised above 300°C and the hydrogen is released. This procedure is repeated several times because the initial impregnation of hydrogen in uranium is slow. When the uranium has become sufficiently activated, the temperature is increased to 500°C to remove all hydrogen and the uranium oven is valved off.

To charge the uranium with tritium, the uranium is heated to 120°C and known quantities of tritium are repeatedly absorbed from the calibrated chamber. The absorption process will rapidly reduce the tritium pressure from 13 kPa (100 mm of Hg) to 133 mPa (1 micron) in the chamber. The target foil tritiation procedure is as follows. The foils to be tritiated are mounted between two stainless steel discs (Fig. 2) several foils are mounted between spacers on a stainless steel rack (Fig. 3) which is then inserted into the reaction chamber attached to the tritium apparatus and evacuated to 130 μPa (10^{-6} torr). The reaction chamber is then heated to 500°C until the contents have been outgassed

and then the temperature is dropped to 320°C. The pressure should now read about 13 μ Pa (10^{-7} torr). The uranium oven is heated to 220°C. The reaction chamber and ion pump are valved off and the uranium oven valve is opened. Tritium is introduced into the calibration chamber to a pressure of 27 kPa (200 mm of Hg), the valve is reclosed and the uranium oven temperature is reduced to 120°C. The valve is opened to the reaction chamber and the pressure drops steadily as tritium is absorbed into the titanium. When the pressure reaches 1.3 kPa (10 mm of Hg) the valve to the uranium oven is opened and the remaining tritium is reabsorbed by the uranium. The calibration and reaction chambers are again evacuated to 13 μ Pa (10^{-7} torr) and the tritiation cycle is repeated.

With this technique the amount of tritium absorbed by the titanium can be monitored. It has been possible to produce targets containing one atom of tritium per atom of titanium. After the tritiation is complete, the temperature of the reaction chamber is allowed to drop slowly to room temperature.

2. A Technique for the Fabrication of Temperature Resistant Targets of Isotopically Enriched Selenium

Selenium metal has a melting point of 217°C and vapour pressure of 13 μ Pa at 125°C. Targets of metallic selenium deteriorate rapidly under bombardment. Two procedures were used at Chalk River to prepare isotopically enriched selenium targets for the following nuclear physics experiments:

1. $^{74}\text{Se}(\text{}^3\text{He}, \text{}^3\text{He})\text{}^{74}\text{Se}$
2. $^{74}\text{Se}(\text{}^3\text{He}, \text{t})\text{}^{74}\text{Br}$
3. $^{74}\text{Se}(\text{p}, \text{n})\text{}^{74}\text{Br}$

Method 1

Films of aluminium ($\sim 70 \mu\text{g}/\text{cm}^2$) are mounted on suitable frames and placed in a vacuum system. Molybdenum and tungsten boats contain respectively ^{74}Se and pure aluminium for evaporation. The selenium is sublimed onto the aluminium to the required thickness and a film of aluminium ($\sim 70 \mu\text{g}/\text{cm}^2$) evaporated over the selenium.

Method 2

Lead selenide has a melting point of 1065°C. This easily evaporated chemical can be used to fabricate targets of isotopically enriched selenium.

Preparation of Selenide

Lead selenide is prepared by melting stoichiometric quantities of isotopic selenium and lead⁴⁾. The melting is carried out in an evacuated quartz chamber at 1200°C. The grey metallic lead selenide is evaporated from a molybdenum boat on a suitable substrate, such as a thin film of carbon or

11.000000.

The targets produced by these two methods were exposed to a 33 MeV He beam with intensity 1.2 μ A for many hours with no sign of deterioration.

3. A Method for the Preparation of Reactive Metal Targets

Targets of reactive metals such as lithium and calcium are needed for experiments such as the recent studies of ^7Li breakup⁵⁾. These metals will react with air and deteriorate rapidly. As several targets are needed for one experiment, the chamber described below is used. The apparatus consists of a 19 inch pyrex cross with the following attachments:

1. A 9 inch adapter plate, with an O-ring to fit over a conventional 7 inch pumping system (Fig. 4).
2. One horizontal outlet with an adaptor flange to fit an 8 inch flange on the Ortec scattering chamber (Fig. 5).
3. Another horizontal outlet equipped with a flange containing two high current electrical feedthroughs (Fig. 6).
4. The remaining vertical outlet has a rotatable feedthrough for a thickness monitor sensor head (Fig. 7).

This apparatus permits lithium or calcium targets to be produced by evaporation on thin carbon films premounted on target frames. The auxiliary target chamber allows up to eight targets to be produced and transferred under vacuum or in an atmosphere of inert gas to the Ortec 19 inch diameter scattering chamber.

The apparatus is easily installed on a conventional pumping system and permits on accurate monitoring of target thickness.

4. A Technique for the Fabrication and Mounting of Ultra-Thin $2 \mu\text{g}/\text{cm}^2$ Carbon Stripper Foils

Thin carbon-foil strippers provide significantly higher average states than gas strippers for heavy ion beams. However, for stripping in the terminals of tandem accelerators they suffer from two disadvantages compared to gas strippers. They have a finite lifetime and they produce larger multiple scattering since self-supporting foil thicknesses are generally much thicker than necessary to produce an equilibrium charge state distribution at tandem energies. Therefore it is very desirable to produce the thinnest possible carbon films, providing that the reduction in thickness does not decrease their lifetime under bombardment.

We have developed a technique for producing ultra-thin ($2 \mu\text{g}/\text{cm}^2$) carbon foils by supporting them on a $5 \mu\text{g}/\text{cm}^2$ film of cellulose nitrate. The cellulose nitrate makes them easy to mount on frames and transport to the accelerator without breakage, and it quickly evaporates under bombardment. These foils are

found to have average lifetimes similar to 5 or 10 $\mu\text{g}/\text{cm}^2$ foils, with improved beam transmission because of the lower multiple scattering.

The method of preparation is straightforward. 2 $\mu\text{g}/\text{cm}^2$ of carbon is evaporated onto a microscope slide which has been coated with a suitable parting agent. The carbon coated glass is dipped in a dilute solution of cellulose nitrate (70 ml of collodion in one litre of iso-amyl acetate) and allowed to dry while held in a vertical position. The film is scribed and individual foils are floated on warm distilled water and mounted on metal frames with an opening of 12 mm diameter (Fig. 8). The 2 $\mu\text{g}/\text{cm}^2$ foils with cellulose nitrate layer could be mounted on these frames with a success rate greater than 80%.

The 12 mm diameter of the self supporting foil is somewhat larger than the original (8 mm) size provided for the National Electrostatics Corp. foil changer in order to prevent the beam striking the frame, (Fig. 9). In this way it is hoped to avoid activation of the frames and foil breakage at the frame edge. The large opening size is useful in compensating for the difficulty in reproducibly positioning the foil holders behind the beam-defining aperture. The uniform darkening and eventual cracking in the bombarded region which is evident in Fig. 8 is typical of the failures observed in stripper foils.

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References

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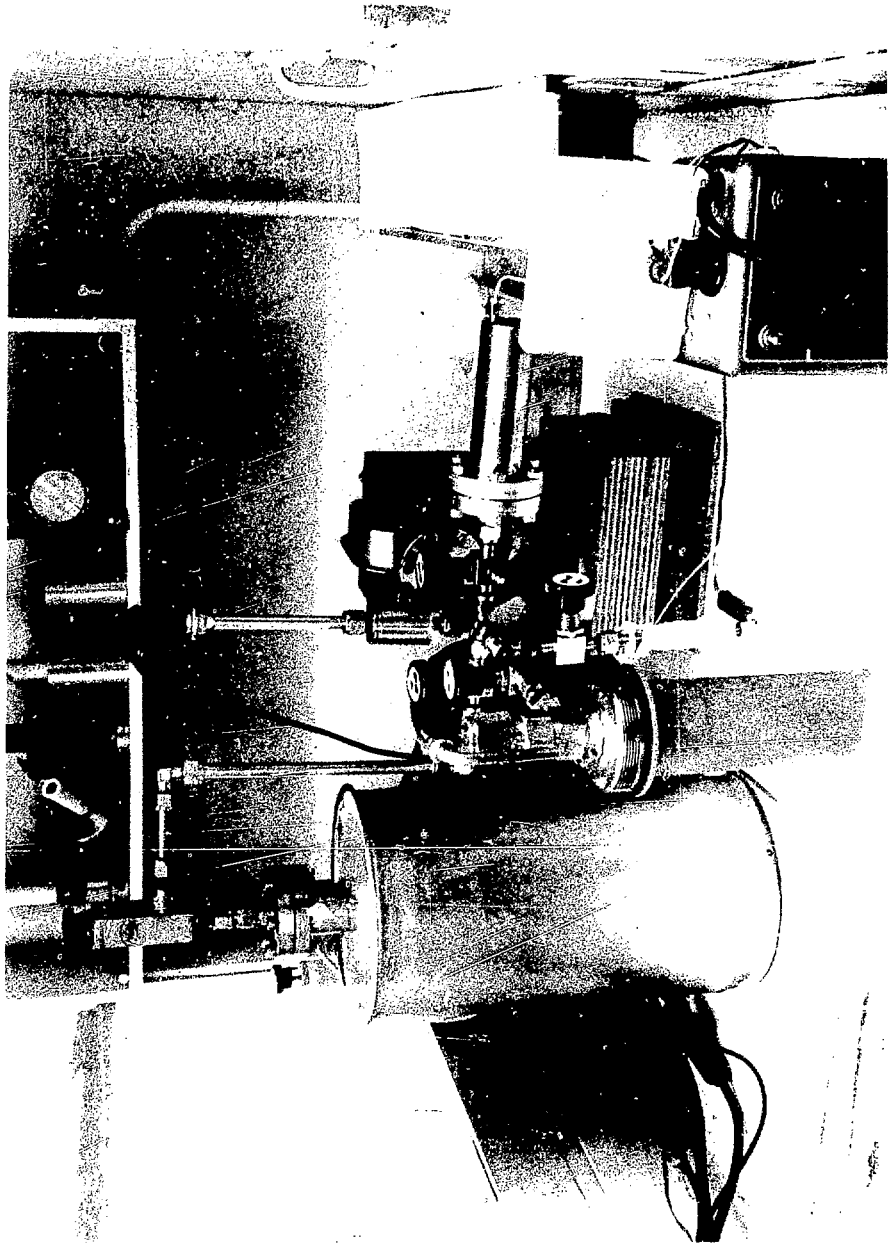


Figure 1. Illustration of apparatus for the preparation of tritium targets.

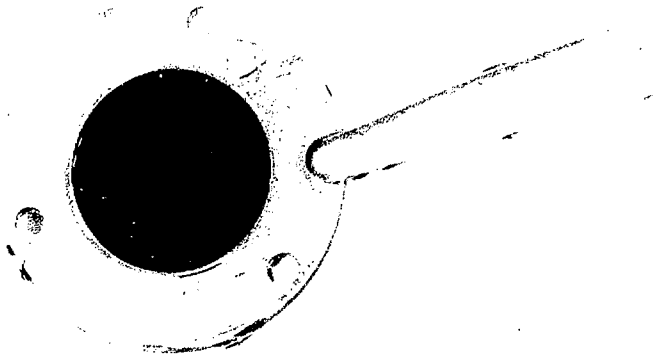


Figure 2: Tritiated foil mounted between two stainless steel discs.



Figure 3: Stainless steel rack supporting several tritiated foils.

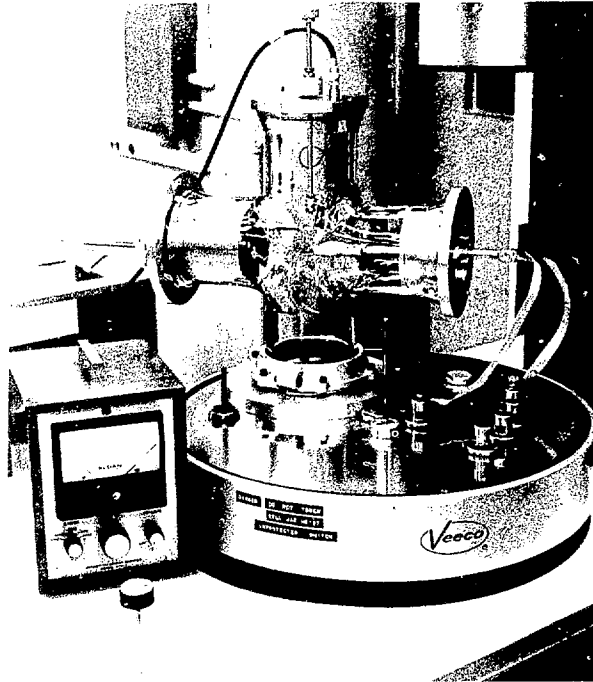


Figure 4: Apparatus for the preparation of reactive metal targets.

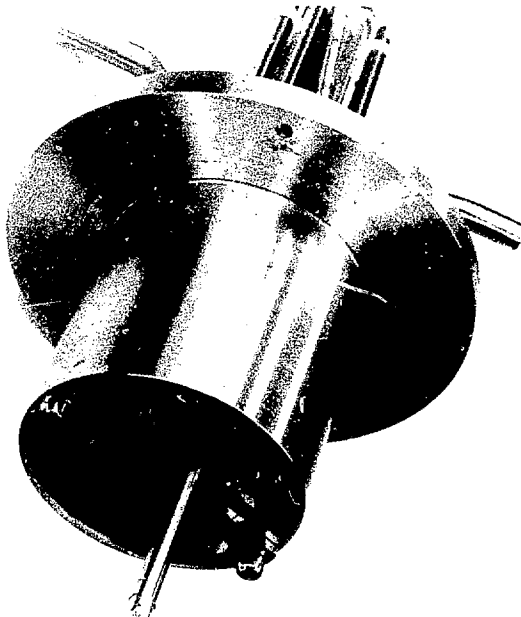


Figure 5: Flange containing the Ortec scattering chamber.

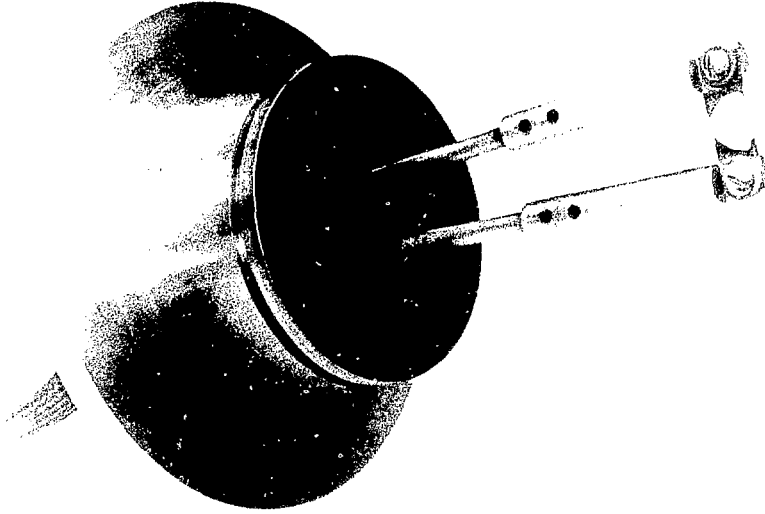


Figure 6: Flange containing two high current electrical feedthrough.

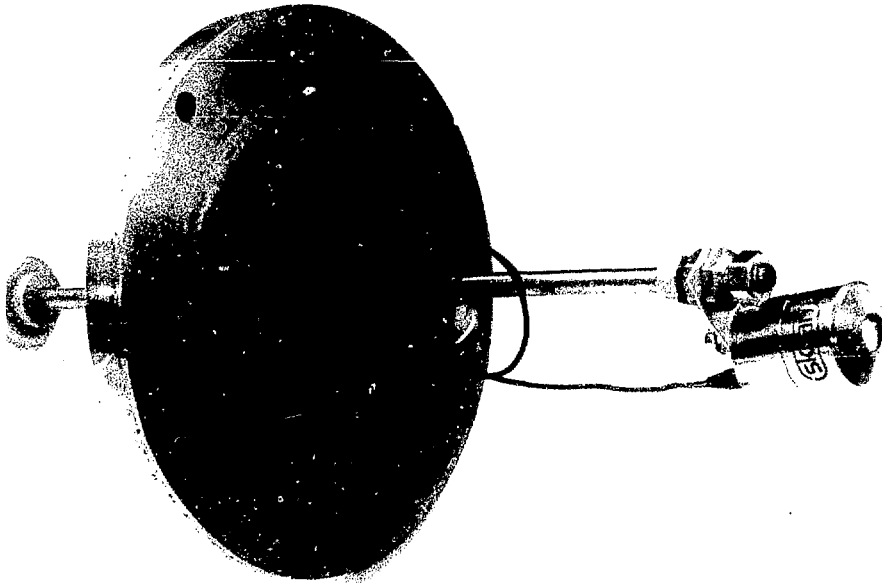


Figure 7: Flange containing thickness monitor sensor head.



Figure 8: Stripper foil ($2 \mu\text{g}/\text{cm}^2$) mounted over a 12 mm opening.

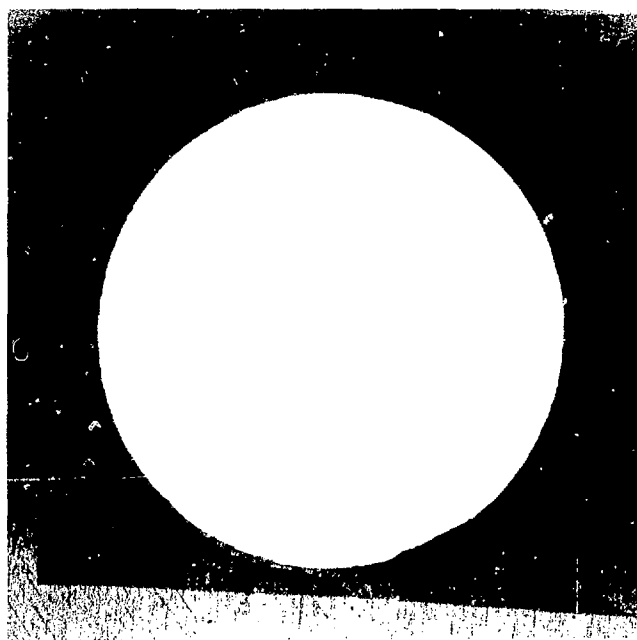


Figure 9: Stripper foil ($2 \mu\text{g}/\text{cm}^2$) mounted over a 8 mm opening.