AN INEXPENSIVE ^{15}O LABELLED MOLECULE DELIVERY SYSTEM FOR CLINICAL FLOW STUDIES

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ABSTRACT

A recent market study has shown that a small 3 MeV deuteron cyclotron dedicated to ^{15}O production could be an effective alternative to the expensive Strontium-Rubidium generators for clinical studies. The feasibility of the nitrogen target has now been demonstrated. Yield over 250 mCi at saturation are expected. The target technology, including critical window problems, is described.

INTRODUCTION

A number of today's P.E.T. centres operate without direct connection to a cyclotron. The recent development and implementation of positron emitters distribution centres are likely to increase the number of such "stand alone" cameras.

For those P.E.T. centres, a possible source of clinical flow measurement agents is $^{82}Sr \rightarrow {}^{82}Rb$ generators. However, the use of the ^{82}Rb suffers from several well-known disadvantages:

- the high positron energy decreases the imaging resolution
- the availability of the generators has been irregular and, considering the sources of ^{82}Sr, is unlikely to improve
- the cost is extremely high
- ^{82}Rb does not form endogenic compounds as oxygen does, thus questions in the interpretation of data arise
- ^{82}Rb does not allow metabolism studies, as the ^{15}O.

I.B.A. has designed what is probably the world's smallest commercial cyclotron. This cyclotron is essentially a one function/one button ^{15}O generator. It uses the $^{14}N(d,n) \rightarrow {}^{15}O$ reaction on natural nitrogen at 3.2 MeV deuteron energy.

Enclosed in the base of the cyclotron, a simple chemistry unit combining the ^{15}O into the classical forms: $^{15}O_2$, $C^{15}O$, $C^{15}O_2$, $H_2{}^{15}O$.

GENERAL DESIGN FEATURES

The relatively modest beam specifications of such a cyclotron : 3.2 MeV deuteron, up to 50 μA of extracted beam on target, allows an extremely simple cyclotron design.

The CYCLONE 3D is a classical, flat pole, weak focusing cyclotron using positive ion acceleration and classic electrostatic deflector extraction. However, due to the low deuteron beam energy and the careful choice of construction materials, practically no activity is generated in other elements than the target itself. The magnet is square (1m x 1m x 0.7m), with a vertical acceleration plane, allowing location of the target at ground level and self shielding using the cyclotron structure .

The CYCLONE 3D opens like a book allowing easy access to the interior. The 90° dees operate at the first harmonic to minimize beam phase shift during acceleration. For a dee voltage of 30 kV, the required R.F. power is 5 kW. This is supplied by a frequency controlled oscillator incorporating a rugged industrial triode tube.

Pumping is performed by a Diffstack 100/300 oil diffusion pump, with a speed of 500 L/sec. for hydrogen, backed by a rotary vane pump. This combination allows operating pressure to be reached in 15 minutes after venting to atmosphere.

The R.F. oscillator with the dee resonating inductance are located in the top of the magnet. Water cooling is supplied by a simple unit that can be located outside the building or on its roof.

The chemical synthesis unit, including three miniature ovens for the production of $C^{15}O_2$, $C^{15}O$, $H_2{}^{15}O$, is located in the base of the magnet, and is shielded by thick lead shields.

TARGET DESIGN AND TESTS

Two approaches could be considered for the production target using the reaction:

$$^{14}N(d,n) \rightarrow {}^{15}O$$

1) a "classical" gas target, using a thin window
2) a windowless, high temperature solid target using the internal beam of the cyclotron. The ^{15}O activity would then diffuse out of the target material and be pumped by the cyclotron vacuum pump.

For now, only the first solution has been pursued.

One of the most critical aspects of the design of such a gas target for low energy deuterons is the entrance foil. Materials with a high melting point are needed to allow cooling by radiation to complement convection cooling. Among possible refractory materials, molybdenum (melting point 2617 $^{\circ}C$) and titanium were considered and tested.

Considering the target pressure (one to two atmospheres) a foil thickness of 4 μm was necessary. This thickness corresponds to an energy loss of 310 KeV for molybdenum and 190 KeV for titanium.

A test target was built and tested using a 3.2 MeV deuteron beam from a Van de Graaf accelerator. The beam was defocused so as to be uniformly spread on a 0.8 cm diameter (0.5 cm^2) circular spot defined by a beam collimator. In this case, foil failure was observed quite consistently at currents of 4-6 μA for titanium and 10-12 μA for molybdenum. Based on those measurements, a 4 μm thick molybdenum window was selected. The maximum current density used on the target will be less than 7 $\mu A/cm^2$, ensuring a large safety margin.

The target used on the CYCLONE 3D makes use of the large axial focusing and radial defocusing effects encountered in the crossing of the magnet fringing field to spread the beam in the radial direction to 8 cm and an axial direction to 1 cm. With such beam dimensions a beam current of 50 μA can be used without overheating the target entrance foil.

The same test with the Van de Graaff accelerator was repeated to verify the experimental yield of the target. The saturation yield found was 6.2 $\pm$ 0.5 mCi/μA, at 3.2 MeV.

CONCLUSION

A small classical cyclotron like the CYCLONE 3D, accelerating deuterons to an energy of 3.2 MeV can produce useful amounts of ^{15}O and become an inexpensive replacement for ^{82}Sr - ^{82}Rb generators for PET studies. A simple and classical thin foil gas target has been designed and successfully tested.

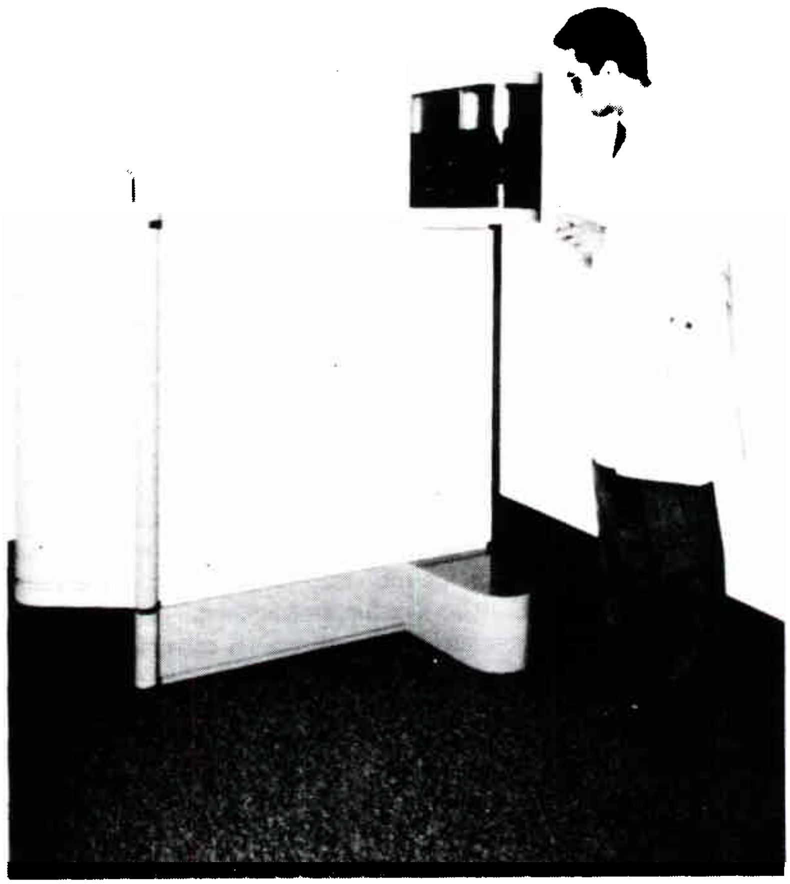

Figure 1 - The CYCLONE 3D

Figure 2 - The Cyclone 3-D ^{15}O dispensing unit.