Elaboración de un manual genérico para la instalación de un ciclotrón y salas técnicas anexas para la producción de radiofármacos
Contents

Cyclotron
PETtrace
Target Data
Cyclotrons

...accelerate charged particles, such as protons and deuterons, so that collisions with target materials produce radionuclides

$^{11}$C, $^{13}$N, $^{15}$O, $^{18}$F are radionuclides that decay by position emission and are used in imaging by PET
GE Cyclotrons

PETtrace Cyclotron
Gold standard
Highest Output

MINItrace Cyclotron
Clinical and Research Compact Siting
Global Leadership
…Over 100 GE Cyclotron Customers
Contents

Cyclotron Overview
PETtrace
Target Data
GE’s PETtrace Cyclotron…

…for flexible, low-cost isotope production that provides…

Performance
to meet regional distribution demands

Efficiency
to match clinical schedules

Flexibility
for research protocols
Performance… for FDG Distribution

Capacity
Highest in the market

Scalable
Tiered offering of 4, 6, 8 Ci in 2 hours

Reliable

Dual beam capability
Possible to increase production output, or produce 2 isotopes at the same time
Efficiency …for Clinical Schedules

Short production runs
Significantly shorter than 11 MeV machines

Long lasting components
Ion source and targets last up to 2X longer than other cyclotrons

Vertical orientation
for easy siting, maintenance, and service

On Line Center
& Local Service Support
Flexibility …for Research

**Capacity**
High for all tracers

**Speed**
Fast switch between different nuclides and tracers

**Flexibility**
Enables research

**Dual beam capability**
possible to make different tracers simultaneously
GE Cyclotrons…when time counts

The high production capacity of GE PETtrace Cyclotrons

<table>
<thead>
<tr>
<th>Radio nuclide</th>
<th>Form</th>
<th>Yield (mCi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$^{18}$F (120 min.)</td>
<td>HF</td>
<td>8000 EOB (PETtrace 8 - Dual beam)</td>
</tr>
<tr>
<td>(60 min.)</td>
<td>$F_2$</td>
<td>300 EOB</td>
</tr>
<tr>
<td>$^{11}$C (30 min.)</td>
<td>$CO_2$</td>
<td>3000 EOB</td>
</tr>
<tr>
<td></td>
<td>CO</td>
<td>1500 EOS</td>
</tr>
<tr>
<td></td>
<td>HCN</td>
<td>1300 EOS</td>
</tr>
<tr>
<td></td>
<td>CH$_3$I</td>
<td>1000 EOS</td>
</tr>
<tr>
<td>$^{13}$N (30 min.)</td>
<td>NH$_3$</td>
<td>450 EOS</td>
</tr>
<tr>
<td>$^{15}$O (6 min.)</td>
<td>O$_2$</td>
<td>2000 EOB</td>
</tr>
<tr>
<td></td>
<td>CO</td>
<td>700 EOS</td>
</tr>
<tr>
<td></td>
<td>CO$_2$</td>
<td>700 EOS</td>
</tr>
<tr>
<td></td>
<td>H$_2$O</td>
<td>1200 EOS</td>
</tr>
</tbody>
</table>
PETtrace Cyclotron Specifications

**Type**
Negative Ion Cyclotron
Dual Particle

**Energy**
16.5 MeV H-
8.4 MeV D-

**Beam Current**
80 µamp H-
60 µamp D-

**Targets**
6 Ports
Dual Irradiation

**Vertical Orientation**
High Energy, 16.5 MeV
...provides high output of many isotopes

Large quantities in a very short time

Higher yields of radionuclides
Higher specific activity

Up to 2X faster than other cyclotron types

Enables research
High Energy, 16.5 MeV
…uniquely provides

Less Maintenance and parts replacement
Better Saturation Yield

More specific activity
More profitability
More time for other activities
High Energy, 16.5 MeV
…uniquely provides
Dual Particle Capability

...Deuterons enable inexpensive target gases

$^{15}$O produced from inexpensive $^{14}$N gas

Versus $^{15}$N gas at ~ $400 / liter for protons

$^{18}$F-F$_2$ produced from inexpensive $^{20}$Ne gas

Versus $^{18}$O gas at ~ $800 / liter for protons

Deuteron reactions available for other positron emitters
Dual Beam Capability

Allows increased production of same isotope

Production of two different isotopes at the same time

Make C-11 for research while 18F production is ongoing

Asynchronous operation
Upright Design
…for convenient operation and service

Advantages
- Small footprint - small room
- Cyclotron can be placed against wall
- Excellent service access
- Eliminates need for hydraulic system
- Minimizes room height requirement

Minimum maintenance exposure
- Shielded targetry panel
- Fast target removal
- Upright design for easy access
Design Simplicity
…for operation confidence and safety

Reliability by simple design
Few cabinets / components
Few moving parts in vacuum
Simple, fixed internal ion source

Ease of Use
Automatic preparation of cyclotron
Automatic preparation of target
Automatic function validation
Automatic beam regulation
Cyclotrons Components

PETtrace Cyclotron
Weight  20 metric tons
Dimension 1.2 x 1.3 x 1.9 (m)

Magnet
Ion Source
Beam Extraction
Beam Diagnostics
Vacuum
Radio Frequency System
Control System
Targets
Target Support Systems
Cyclotron Components

**PETtrace**

- Magnet Open
- Ion Source
- Beam Extraction
PETtrace Cyclotron Target Configurations, Dual Beam

Simultaneous Bombardment

Allows twice the production of same isotope

Production of two different isotopes at the same time

Make C-11 for research while 18F production is ongoing
PETtrace Cyclotron Targetry
… Flexibility and Ease of use

**Targetry Design**
Removal in 10 seconds
Modular design
High yield
Easy disassembly
PETtrace Cyclotron Configuration Options

...Shielded and Unshielded

Decision based on space availability and cost

Vault

Self shield
PETtrace Cyclotron Generation II Target

Over 3.5 Ci/hr
…over 5.5 Ci/2hr, Single Target 18F- Yield

*Improved Cooling*

*Depth Optimization*

*Higher beam capacity…60uA*
PETtrace Cyclotron Line of Scalable Production

4, 6 and 8 Ci/2hr production capacity
Field upgradeable
Add capacity as the market grows
Double digit capacity built into the platform
…not limited by beam energy
Active R & D for further yield improvement
## PETtrace Cyclotron Benefits

<table>
<thead>
<tr>
<th>Features</th>
<th>Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dual Particle</td>
<td>Widest range of tracers production options</td>
</tr>
<tr>
<td>High Energy = 16.5 MeV / 8.4 MeV</td>
<td>Highest production capacity due to efficient beam use.</td>
</tr>
<tr>
<td>Beam Current = 80µamp / 60 µamp</td>
<td>Scaleable for users needs: high production output with more efficient targets</td>
</tr>
<tr>
<td>Target Ports = 6</td>
<td>More output or more variety in one run with concurrent production of multiple isotopes</td>
</tr>
<tr>
<td>Dual Irradiation</td>
<td>Vertical orientation for easy siting, maintenance, and service</td>
</tr>
<tr>
<td>Upright Design</td>
<td>Fixed, simple design, high reliability</td>
</tr>
<tr>
<td>Ion Source</td>
<td>Experienced industry and product experts for on site training and remote support</td>
</tr>
</tbody>
</table>
PETtrace Cyclotron Proactive Service
Planned Maintenance
Two planned maintenance (PM) visits per year
Periodic Operator Maintenance

Consumables
Ion source cathodes  about every 6 months
Target maintenance kits depending on activity
Extraction stripper foils about every 6 months

User Supplies
Gases for ion source & target foil cooling
Gases for targets & chemistry processing
Compressed air
Electric power consumption 70 kVA, 3-phase
Primary cooling system 75 kW
Contents

Cyclotron Overview
PETtrace
Target Data
**PETtrace $^{18}$F High Yield Target Data**

<table>
<thead>
<tr>
<th>Nuclear Reaction</th>
<th>$^{18}$O($p,n$)$^{18}$F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Target medium</td>
<td>$H_2^{18}$O</td>
</tr>
<tr>
<td>Beam Energy</td>
<td>16.5 MeV protons</td>
</tr>
<tr>
<td>Water container mtrl</td>
<td>Silver</td>
</tr>
<tr>
<td>Target volume</td>
<td>0.8 ml</td>
</tr>
<tr>
<td>Fill volume</td>
<td>1.1 ml</td>
</tr>
<tr>
<td>Target pressure</td>
<td>30 bar (3MPa)</td>
</tr>
<tr>
<td>Target foils</td>
<td>Havar 25 and 50 $\mu$m</td>
</tr>
<tr>
<td>Foil cooling</td>
<td>Re-circulating helium</td>
</tr>
<tr>
<td>Target cooling</td>
<td>De-ionized water</td>
</tr>
</tbody>
</table>
PETtrace $^{18}$F-F2 Target Data

<table>
<thead>
<tr>
<th>Nuclear Reaction</th>
<th>$^{20}$Ne(d,$\alpha$)$^{18}$F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Target medium</td>
<td>Neon gas + 0.3% $F_2$</td>
</tr>
<tr>
<td>Beam Energy</td>
<td>16.5 MeV protons</td>
</tr>
<tr>
<td>Target chamber mtrl</td>
<td>Aluminium</td>
</tr>
<tr>
<td>Target volume</td>
<td>60 ml</td>
</tr>
<tr>
<td>Target length</td>
<td>130 mm</td>
</tr>
<tr>
<td>Target fill pressure</td>
<td>10 bar (1 MPa)</td>
</tr>
<tr>
<td>Target foils</td>
<td>Havar 25 $\mu$m (2)</td>
</tr>
<tr>
<td>Foil cooling</td>
<td>Re-circulating helium</td>
</tr>
<tr>
<td>Target cooling</td>
<td>De-ionized water</td>
</tr>
</tbody>
</table>
**PETtrace $^{11}$C Target Data**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
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</thead>
<tbody>
<tr>
<td>Nuclear reaction</td>
<td>$^{14}$N(p, $\alpha$)$^{11}$C</td>
</tr>
<tr>
<td>Target medium</td>
<td>N$_2$ (99.9999+ 0.5% O$_2$)</td>
</tr>
<tr>
<td>Beam energy</td>
<td>16.5 MeV protons</td>
</tr>
<tr>
<td>Target chamber mtrl</td>
<td>Aluminium</td>
</tr>
<tr>
<td>Target length</td>
<td>250 mm</td>
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<tr>
<td>Target volume</td>
<td>78 ml</td>
</tr>
<tr>
<td>Target fill pressure</td>
<td>10 bar (1MPa)</td>
</tr>
<tr>
<td>Target cooling</td>
<td>De-ionized water</td>
</tr>
<tr>
<td>Target foils</td>
<td>Havar 25 $\mu$m (2)</td>
</tr>
<tr>
<td>Foil cooling</td>
<td>Re-circulating helium</td>
</tr>
</tbody>
</table>
PETtrace $^{13}\text{N}$ Target Data

<table>
<thead>
<tr>
<th>Nuclear reaction</th>
<th>$^{16}\text{O}(p,\alpha)^{13}\text{N}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Target medium</td>
<td>Destilled water</td>
</tr>
<tr>
<td>Beam energy</td>
<td>16.5 MeV protons</td>
</tr>
<tr>
<td>Target chamber material</td>
<td>Silver</td>
</tr>
<tr>
<td>Target volume</td>
<td>0.8 ml</td>
</tr>
<tr>
<td>Target pressure</td>
<td>6 bar (0.6 MPa)</td>
</tr>
<tr>
<td>Target cooling</td>
<td>De-ionized water</td>
</tr>
<tr>
<td>Target foils</td>
<td>Titanium/Havar 25 µm (2)</td>
</tr>
<tr>
<td>Foil cooling</td>
<td>Re-circulating helium</td>
</tr>
</tbody>
</table>
**PETtrace $^{15}$O Target Data**

<table>
<thead>
<tr>
<th>Property</th>
<th>Specification</th>
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<tbody>
<tr>
<td>Nuclear reaction</td>
<td>$^{14}$N(d,n) $^{15}$O</td>
</tr>
<tr>
<td>Target medium</td>
<td>N$_2$ (99.995+1% O$_2$)</td>
</tr>
<tr>
<td>Beam energy</td>
<td>8.4 MeV deuterons</td>
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<tr>
<td>Target chamber mtrl</td>
<td>Aluminium</td>
</tr>
<tr>
<td>Target length</td>
<td>110 mm</td>
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<tr>
<td>Target volume</td>
<td>35 ml</td>
</tr>
<tr>
<td>Target fill pressure</td>
<td>10 bar (1MPa)</td>
</tr>
<tr>
<td>Target cooling</td>
<td>De-ionized water</td>
</tr>
<tr>
<td>Target foils</td>
<td>Havar 25 $\mu$m (2)</td>
</tr>
<tr>
<td>Foil cooling</td>
<td>Re-circulating helium</td>
</tr>
</tbody>
</table>