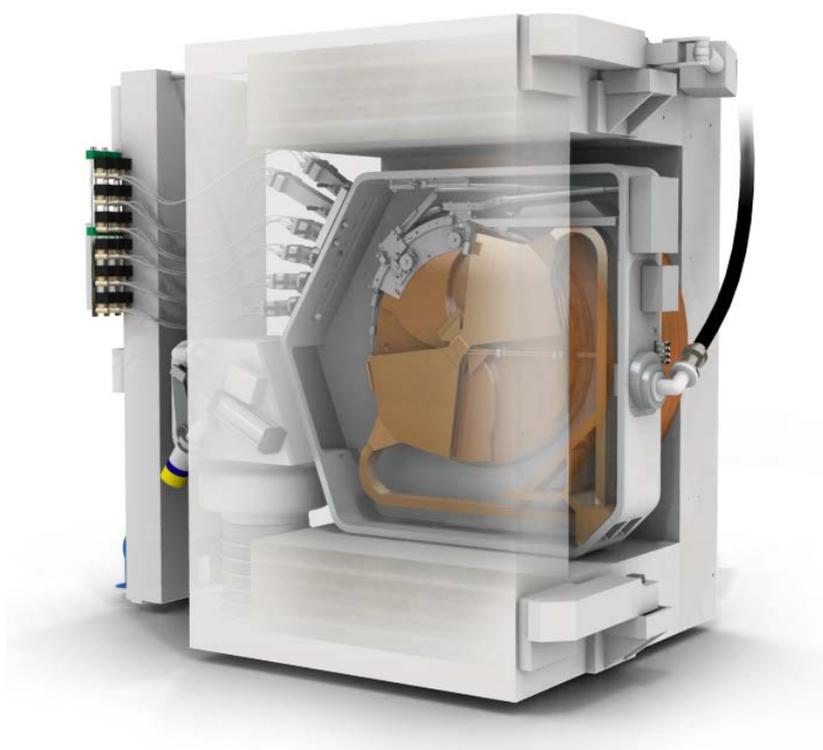


# PETtrace 800 series Site Planning Guide

Class A





## REVISION HISTORY

Revision	Date	Reason for change
18	May 2, 2017	Section 5-14: $^{13}\text{NH}_3$ target gas and liquid added. [PCR 17-106] Section 7-3-2: Note on water manifold 1 added. [PCR 16-183]
17	January 25, 2017	Table 2-12: ProCab specifications updated. [PCR 16-242] Section 2-3-1: Text updated. [PCR 16-242] Table 2-17: ProCab specifications updated. [PCR 16-242] Figure 2-27: Drawing updated. [PCR 16-242] Section 5-2: Directives updated. [PCR 16-136] Section 5-14-2: Note about gases added. [PCR 15-126] Section 8-2: Information about ProCab updated. [PCR 16-242] Figure 8-1: Figure updated. Table 8-1: ProCab dimensions updated. [PCR 16-242]
16	January 13, 2016	Table 5-11, 5-14: $^{18}\text{F}$ - Nb 27 self-shielded target added. [PCR 15-193] Section 5-6, 5-14, 7-3 : Gas tube specifications updated. [PCR 15-185]
15	August 7, 2015	Section 5-2: New section added with compliance with regulatory requirements. [PCR 15-094] Section 7-3-3 moved to new section 7-4. Chapter 9: Site readiness checklist updated (rev E). [PCR 15-087]
14	July 14, 2014	Chapter 9: Site readiness checklist updated (rev D). [PCR 13-032, PCR 13-236] Table 5-1: Note specifying humidity conditions for the compressor added. [PCR 13-194]
13	June 11, 2013	Section 1-4-12, 3-6: Compile LOTO procedures. [PCR 13-141] Section 3-6, 6-1-2: "Should" changed to "must". [PCR 13-141] Section 5-3: New section: altitude requirements. [PCR 13-141]
12	February 27, 2013	New section 1-4-13 with information on cleaning and waste added. Table 6-1: Maximum allowed THD added. [PCR 12-120] Chapter 9: Site readiness checklist updated.
11	September 12, 2012	Section 1-2, 1-4-12, Ch. 9: Requirement for washing facilities added. [PCR 12-207] Table 5-11: Helium pressures updated. [PCR 12-212] Chapter 9: Info added on Atlas Copco air compressor service. [PCR 11-065] Rigging/installation requirements updated. [PCR 12-207] Section 10-2: Rigging/installation equipment updated. [PCR 12-207]

Revision	Date	Reason for change
10	June 8, 2012	<p>Table 2-15: Responsibility for floor area smoothness for the integrated shield changed from GE to Customer. [PCR 11-292]                      Figure 2-7: updated. [PCR 10-188]                      Section 2-5-3-1: Heat dissipation capacity updated to 1 kW. Minimum flow rate updated to 10 l/s (36 m<sup>3</sup>/h). [PCR 10-188]                      Section 5-12-3: New section with gas consumption estimations added. [PCR 10-115]                      Section 5-12-2-2: Note added. [PCR 10-115]                      Table 6-1: updated. [PCR 12-050]                      Table 6-2: Radiation shield compressor information updated. [PCR 12-050]                      Sec. 6-3-1-1: To step up/down a 5-conductor site system text updated. [PCR 12-138]                      Sec. 6-3-2: Note added. [PCR 06-165]                      Table 6-3: Cyclotron power consumption updated and power factor added. [PCR 12-050]                      Figure 6-4 to 6-6: Radiation shield compressor information updated. [PCR 12-050]                      Figure 7-2: Updated to include a flow gauge and bypass on customer side. [PCR 12-141]                      Table 8-2: Radiation shield tanks added. [PCR 12-027]                      Chapter 9: updated. Site readiness checklist added. [PCR 12-105]</p>
9	October 21, 2011	<p>Ill. 2-21: Secondary WCU updated. [PCR 10-174]                      Ill. 2-28: CCU installation information added. [PCR 11-037]                      Sec. 2-4-2: Floor tolerances updated. [PCR 11-191]                      Table 5-4: Primary cooling requirements updated. [PCR 11-135]                      Ill. 5-1: Secondary WCU updated. [PCR 10-174]                      Sec. 5-12-2: H<sub>2</sub>/D<sub>2</sub> warning updated. [PCR 09-186]                      Table 6-1 and sec. 6-2: Variation of nominal line voltage changed from ± 5% to +10%, -5%. [PCR 10-179]                      Ill. 7-2: Cooling system schematics updated (previous ill. 7-3 removed). [PCR 10-174] (<i>Converted to Skribenta.</i>)</p>
8	March 25, 2011	<p>Sec. 1-4-8: updated. [PCR 08-084]                      Table 2-10: updated.                      Table 2-15: Secondary Water Cooling Unit measurements updated.                      Ill. 2-21: updated.                      Ill. 5-1: updated.                      Sec. 5-12-2: updated. [PCR 08-084]                      Sec. 5-12-4: updated. [PCR 08-084]                      Ill. 7-4: Drawing updated.                      Table 7-4: updated.                      Ill. 7-5: Gas purity specifications removed.</p>
7	June 3, 2010	<p>Rebranding                      Sec. 3-2-5: Dose rate contours updated.                      Sec. 1-4: Info added about printer supplied with the system. [PCR 10-062]                      Ill. 2-20: Flat screen added.                      Table 5-15: Gas tube dimension for ion source gases added.</p>

Revision	Date	Reason for change
6	December 7, 2009	<p>Ch. 1; Sec. 2-5-2: Access to Internet recommended. [PCR 09-226]            Sec. 1-1-1: Regulatory compliance information removed. Now only found in PETtrace Operator Guide (dir. 2131768). [PCR 09-236]            Sec. 1-4-8: Table modified.            Ch 2: Compressed air tank removed.            New water manifold 1, CCU Gen II added.            Sec. 2-2-4: Cooling system within controlled area. [PCR 09-060]            Sec. 5-7: Ventilation of high-radiation areas. [PCR 09-040]            Sec. 5-12-2: Ion source gas specs modified. [PCR 07-139]  <sup>11</sup>CO<sub>2</sub> HP, <sup>11</sup>CH<sub>4</sub>, <sup>18</sup>F- Gen II, Nb 25, <sup>18</sup>F<sub>2</sub> Proton target added. [PCR 04-254]            Sec. 5-12: Gas regulators recommendation modified.            Customer supplied gas tubes added. [PCR 07-139]            Ch 6: 208 VAC removed as mains voltage option. Info added on transformers. [PCR 05-010, DOC0438404SPN]            Sec. 7-2: Cable diagram modified (RJ-45 cables).            New cooling system drawings.            Sec. 7-3-3: Gas tubes modified.            Table 7-7: Customer supplied gas tubes added. [PCR 07-139]            Ch 8: Compressed air tank removed.            Crate tables modified.</p>
5	November 1, 2006	<p>New document layout, affect all pages.            Ch 1: Section 1-1 info about optional Target systems site planning            Ch 2: Illustration 2-7 and 2-22 updated.            Section 2-5-3-2 info about radiation shield updated.            Ch 3: Illustrations 3-1 and 3-2 replaced.            Section 3-2-5-4 info about radiation shield updated.            Section 3-4 info about decommissioning.            Ch 5: Section 5-12-2-2 updated <sup>11</sup>C target gas spec.            Illustration 5-3 updated.            Section 5-7 hot cell ventiation added.            Ch 7: Section 7-3 updated. Illustrations 7-3 and 7-4 replaced.            Section 7-3 updated water piping spec.</p>
4	Nov 15, 2004	<p>Ch 7 Interconnection Data:            Figure 7-5 System Gas Interconnections updated with respect to new options (<sup>11</sup>CH<sub>4</sub> Methane and <sup>18</sup>F<sub>2</sub> Proton).</p>
3	May 5, 2004	<p>Important Precautions page 5: German WARNUNG text revised ("KUNDENDIENST-HANDBUCH NICHT ZU RATE GEZOGEN" changed to "KUNDENDIENST-HANDBUCH ZU RATE GEZOGEN"). page 8: "CQA process" changed to "PQR process".            Ch 1: EMC test standards EN 50 081-2 and EN 50 082-2 replaced with EN 61326.            Ch 3 page 80-81: Figures 3-1, 3-2, 3-3 (Gamma Dose Contour Maps) replaced with 3-1 Neutron Dose Contour Map and 3-2 Gamma Dose Contour Map.            page 86: Section 5 LOTO (Lock-Out, Tag-Out) procedure added.            Ch 5 page 95: Data in Table 5-4 Primary Cooling System Requirements updated.            Ch 6 thoroughly revised (Power distribution info, LOTO, Emergency stops and lighting, UPS issues, RCCB specifications, Mains Distribution dwgs updated).</p>

Revision	Date	Reason for change
2	January 15, 2003	Legal Notes: The text "GE Exclusive..." removed. Important Precautions: The text revised Ch 1: Section 4.5 Item no.10 Added information about the filter. Ch 2: The text about plenum removed. Ch 3: Section 2.4.2 The condition values modified to appropriate levels in text and figures 3-1, 3-2, 3-3. Section 3.2 Ci changed to mCi. Ch 5: Section 4.2 Note about water specifications added. Section 10.0 Changed Gas Specification value in Table 12.2.1. Section 14.1 Text revised. Ch 6: Section 3.0 voltage 380 VAC changed to 400 VAC(This does not affect the drawings). Six drawings added, Protective Grounding Schematic and Mains Power Supply. Ch 7: Figure 7-5 Drawing Gas Interconnections updated.
1	February 15, 2002	Revision of text and figures throughout the guide.
0	April 10, 1995	Initial document release.

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# 1 GENERAL INFORMATION

## 1-1 Introduction

This manual applies to the following cyclotron systems:

- PETtrace 800 series (for example PETtrace 840, PETtrace 860, and PETtrace 880)
- PETtrace (sales discontinued in 2010)

The system is called *PETtrace 800* in this manual. Illustrations and drawings marked *PETtrace* also apply to *PETtrace 800 series*, unless stated otherwise.

The guide contains the physical-, electrical-, plumbing- and magnetic data necessary for planning and preparing a site for a PETtrace 800 tracer production system. Preinstallation work is done to prepare the customer's premises for the installation of the tracer production products.

This material is not intended to be a substitute for a qualified site planner, or Project Coordinator. Nevertheless, it does provide some of the guidelines that are needed to successfully plan the suite.

### **Note!**

*Site planning information for the Beam Line system will be found in PETtrace 800 series Beam Line System Manual (dir. 5137921-100), and for  $^{18}\text{F}_2$  Proton target system in PETtrace 800 series  $^{18}\text{F}_2$  Proton Target System Site Planning, Installation and Service Manual (dir. 2410009-100).*

### 1-1-1 Purpose

This manual is a site preparation document, and is intended for use as a guide and reference for site planning personnel. Found in this portion of the documentation, are data relating to the preparation of the site at which the cyclotron is to be installed.

The document is particularly intended for use by the Purchaser, the project architect or the Purchaser's contractor, in preparing the new site for installation.

The data found herein represents the accumulation of the detailed information that is necessary for the site planning process. The information will be useful to architectural and site planners, construction engineers, contractors trade personnel, and others.

Good site preparation is essential for a smooth and efficient installation. Poor site planning may result in compromising operator use and/or product quality. The results of good up front planning will only benefit the project.

It is important to finalize the design of the desired site configuration before construction is started. Once the site is completely prepared, it will be difficult and costly to make revisions.

Generally, workers with experience in this kind of project should be used. Contractors and other personnel with experience in “general” construction only, may fall short of the mark of a good project installation, if specific background in medical suite planning and construction is lacking. For this reason, it is recommended that time be invested in identifying and selecting experienced personnel that are right for this vital part of the project.

**Note!**

*Since this equipment involves the use of radioactive isotopes, compliance with Nuclear Regulatory Commission Regulations, or similar regulatory requirements, depending on the site location, must be demonstrated. Regulatory compliance should be arranged for as an early step in the site planning process.*

### 1-1-2 Project Coordinator

The Project Coordinator should be involved in every phase of development of the project, from concept of the facility to installation and start-up of the equipment. Ideally, this person should be thoroughly familiar with the construction process. The Project Coordinator should keep in close contact with all of the contractors, subcontractors, GE and administrative personnel, as well as planners and architects. Maintaining a schedule and adjusting that schedule as needed is the responsibility of the Project Coordinator.

GE can provide a site planning service to assist the Purchaser with site preparation. Please contact your local GE representative.

### 1-2 Purchaser responsibilities prior to installation

Unless otherwise agreed, the Purchaser is responsible for all site preparation, which may include, but is not limited to, the following work:

- Cost analysis, construction, renovation or alterations and modifications not specifically provided for in the contract.
- Construction permits, inspections, licensing, etc.
- Demolition, removal and clean-up of existing construction.
- Procurement of all materials required to carry out the work.
- Installation of structural reinforcements, as required.
- Installation of lighting.
- Installation of air and water cooling equipment to specification.
- Installation of adequate air conditioning and ventilation for the PET area.
- Installation of non-electrical lines, such as plumbing, compressed air and vacuum lines.

All lines must be clearly labelled.

- Installation of raised flooring, electrical conduit, junction boxes, ducts, surface raceways, outlets and line safety switches.
- Installation of radiation protection material.

- Installation of wires not supplied by GE, such as the facility input power line to the Mains Distribution Panel, the Power Distribution Unit, and any emergency power lines.

The electrical contractor shall test and tag both ends of all wires. Color-code the wires for easier identification. All wires must be continuous, without splices. Insulation on all equipment ground wires must be green with a yellow stripe.

**Note!**

*A connection for Internet access close to Cabinet 3 is recommended.*

- Procurement and installation of fire control devices, as required by local codes.
- Compliance with all applicable national and local building and safety codes.
- Permits and licenses to produce and handle radioisotopes.
- Installation of all gases and radiochemistry test equipment.
- Storage of the system equipment prior to installation.
- Washing facilities available for washing hands after working with lead plates or lead bricks.

## 1-3 Installation process

The complete project from the awarding of the contract to the final installed and accepted product involves many activities, which will result in the equipment listed in the quotation being rigged into place, assembled, tested and calibrated.

This document identifies the different responsibilities of the customer and GE in the project. For additional information regarding the time required for cyclotron installation, see [Section 1-5 Installation flow chart on page 23](#) of this chapter.

### 1-3-1 Facility planning

Initially, the facility planning will define the details in the building and facility specification and GE will supply all necessary information. The building design must be approved by GE prior to starting the construction/renovation of the facility.

### 1-3-2 Rigging/mechanical installation

The equipment is typically delivered to the site in two 20-foot containers (a shielded system in three 20-foot containers). A rigging company should be contracted to unload the equipment from the containers and transport the components into the cyclotron facility to their proper locations. The rigging should include uncrating and unpacking. The unloading and rigging will be supervised by GE personnel.

At the completion of the rigging, qualified GE technicians will unpack the equipment in preparation for assembly. The equipment assembly will entail:

- mechanical assembly
- alignment of critical components
- assembly documentation

Prior to all assembly work being completed, GE electrical technicians will begin installing cables between power supplies, electronic cabinets and loads. At the same time qualified electricians have to be contracted to connect the equipment to the electrical power distribution panels. All GE cables will be connected or terminated in an appropriate manner.

### 1-3-3 System start-up

At the completion of the mechanical installation, GE engineers will proceed to start up and test the cyclotron and the radiochemistry production equipment.

The equipment is tested to ensure proper performance throughout its specified operating range. All relevant parameters are calibrated and optimized. The engineers, at the completion of each subsystem start-up, will document their settings and calibrations in order to provide a record for future use and to ensure the reproducibility of the cyclotron performance.

Additional equipment and chemicals are needed in order to complete the installation and startup. Providing this equipment and these chemicals is the responsibility of the customer and will be specified by GE.

### 1-3-4 Performance tests

When all subsystems are individually functioning to their specifications, the start-up phase of the installation will be complete. At this point, GE engineers will optimize the efficiency of the cyclotron and produce beam on a test target.

The beam tests will ensure that the cyclotron produces its guaranteed output and operates within specifications. All settings and calibration will be documented.

#### 1-3-4-1 Radioisotope production and radiochemistry

When proper cyclotron performance has been demonstrated, the GE application specialist will begin the isotope production in order to optimize the target system performance. The yields of the different products will be brought to their specified levels.

Once the target yields have been verified, the application specialist will proceed stepwise to produce the precursors to their specified levels. All settings and procedures will be documented.

1-3-4-2 Performance tests

When all systems are in proper working order, the equipment will be ready for performance tests.

Typically, the cyclotron performance tests will be performed during the period in which the radioisotope production is being tested.

The radiochemistry system performance tests will then be performed and be shown to meet the rated specifications.

**1-4 Conditions and responsibilities for site planning, construction, installation and start-up**

1-4-1 General

Item no.	Item	Cust.	GE
1	GE shall elect one responsible project leader with whom the Purchaser will communicate.		X
2	The Purchaser is required to inform GE about project schedule and changes in project schedule.	X	
3	The Purchaser is responsible for applying for permits and licensing for producing and handling of radioisotopes.	X	

1-4-2 Building design and equipment layout

Item no.	Item	Cust.	GE
1	Provision of documents specifying: <ul style="list-style-type: none"> <li>• dimension and weight of major components</li> <li>• air temperature and humidity requirements</li> <li>• heat dissipation to air from the delivered equipment</li> <li>• access requirements</li> <li>• equipment layouts</li> <li>• needs for cable trays</li> <li>• water piping and lifting equipment</li> <li>• compressed air requirements</li> <li>• outlets, electrical and data</li> </ul>		X

Item no.	Item	Cust.	GE
2	Generation of architectural drawings of the facility, including the delivery path of the cyclotron.	X	
3	Drawings must be approved by GE before construction work begins and within four weeks of receipt of material mentioned in 2.		X

### 1-4-3 Media supply

Item no.	Item	Cust.	GE
1	Generation of construction drawings showing dimensions and routings of cable trays, water pipes and feedthroughs.		X

### 1-4-4 Electricity

Item no.	Item	Cust.	GE
1	Specification of main power distribution panel loads.		X
2	Provision and installation of main power distribution panel.	X	
3	Provision and installation of the power distribution panel in the cyclotron room.		X
4	Specification of loads for cables supplied by Purchaser.		X
5	Provision, installation and connection of electrical power cables between: <ul style="list-style-type: none"> <li>the main power distribution panel and the power distribution panel</li> <li>the main power distribution panel and the "mains" connection (ac power input) of all GE power supply cabinets</li> <li>the main power distribution panel and the closed deionized water cooling system</li> </ul>	X	
6	Provision, installation and connection of: <ul style="list-style-type: none"> <li>power cables between power supply cabinets and loads</li> <li>control cables</li> </ul>		X
7	Interconnection cables, supplied by GE, from power supplies and electronic control units are to be located in ducts, trenches, conduits and/or cable trays. The Purchaser must supply and install these ducts/cable trays and it is the Purchaser's responsibility to ensure that this cable routing system meets local electrical codes and requirements.	X	
8	A connection for Internet access close to Cabinet 3 is recommended.	X	

**1-4-5 Water cooling system**

Item no.	Item	Cust.	GE
1	Provision of closed deionized water cooling system.		X
2	Provision and installation of external chiller for cooling of closed deionized water cooling system.	X	
3	Provision and installation of control system to keep cooling water to cyclotron at specified temperature within $\pm 1^{\circ}\text{C}$ ( $\pm 2^{\circ}\text{F}$ ).	X	
4	Specification of heat load for external chiller.		X
5	Provision and installation of water manifolds with flow guards for equipment to be cooled.		X
6	Provision and installation of all piping from GE supplied water manifolds to heat loads.		X
7	Provision and installation of all water pipes from the closed deionized water cooling system, to manifolds in the cyclotron room and the power supply room.	X	
8	Provision and installation of all water pipes from the closed deionized water cooling system to the external chiller.	X	
9	All pipes in item no. 7 and 8 to be cleaned internally before connection to GE supplied equipment.	X	
10	Filter supplied on external chiller cooling loop to protect heat exchanger. A low water flow will damage the system.	X	
11	A connection for primary water to the closed deionized water cooling system and one-way valve on city water line to cooling unit in order to eliminate back-streaming shall be provided by the Purchaser.	X	

**1-4-6 Compressed air**

Item no.	Item	Cust.	GE
1	Provision and installation of compressed air system, including shut off valves and terminations to GE supplied manifolds.	X	
2	Provision and installation of compressed air manifolds and connections from manifolds to loads.		X

**1-4-7 Ventilation**

Item no.	Item	Cust.	GE
1	Provision and installation of air ventilation system.	X	

### 1-4-8 Gas and liquid distribution

Item no.	Item	Cust.	GE
1	Provision and installation of: <ul style="list-style-type: none"> <li>gas supply with gas bottles/tanks/generators</li> <li>regulators and fittings</li> <li>clean, high quality tubes to the cyclotron room/vault and the synthesis units/hot cells,</li> </ul> for ion source, target and optional process gases.	X	
2	Provision and installation of all connections <i>except those directly to the GE cyclotron system and GE synthesis unit(s).</i>	X	
3	Provision and installation of all connections directly to the GE cyclotron system and GE synthesis unit(s).		X
4	Provision and installation of piping from the target system in the cyclotron room to the chemistry processing systems in the radiochemistry laboratory. Maximum length of pipes 40 m.		X
5	All building preparations necessary for the gas and liquid distribution pipes with feedthroughs and radiation shielding. Including all hardware necessary for the pipe and tube installation with consoles, trays, etc.	X	

### 1-4-9 Off-loading and rigging

Item no.	Item	Cust.	GE
1	Provision of access roads for trucks with adequate capacity up to off-loading point.	X	
2	Access hatch or other entrance to the cyclotron vault ready to receive cyclotron.	X	
3	Rigging and tools for unloading and bringing equipment into final position in building.	X	
4	Supervision of rigging.		X

### 1-4-10 Installation of cyclotron

Item no.	Item	Cust.	GE
1	The customer is required to ensure that the site is properly prepared and ready (i.e. a dust-free, protected laboratory completed environment), allowing the installation to progress without delay or interruption.	X	

Item no.	Item	Cust.	GE
2	GE will inspect the site before the start of the installation. The installation of the equipment will not be started until the site is accepted by GE.		X
3	Assembly and commissioning of cyclotron and performance testing.		X

#### 1-4-11 Additional equipment and materials

Item no.	Item	Cust.	GE
1	<p>Provision of operating supplies like ion source gases, target and processing gases, dry nitrogen etc. This includes all chemicals, starting material, consumables and media needed in the production.</p> <p>Provision of a complete chemistry laboratory including necessary test equipment in order to perform the acceptance test protocol.</p> <p><b>Note!</b> <i>A printer is not supplied with the system.</i></p> <p>Recommended printers to connect to the Master System: Hewlett Packard™ printers (Laserjet™ or similar model)</p>	X	

#### 1-4-12 Safety

Item no.	Item	Cust.	GE
1	The complete radiochemical production facility where the equipment from GE will be installed is the responsibility of the Purchaser.	X	
2	The complete installation for radioactive isotope production has to be designed for a safe handling of activity with respect to personal safety of the staff and the surroundings.	X	
3	Calculations on all radiation shielding. The responsibility for adequate radiation protection, final decisions concerning the arrangement of shielding and handling of induced activities (air, water, targets, etc.) according to requirements from the local and national authorities.	X	
4	Provision and installation of safety devices like "beam on" signs, door interlocks, alarms, emergency switches according to customer needs and local codes.	X	
5	Provision of local codes and working regulations that apply to GE staff.	X	
6	Washing facilities available for washing hands after working with lead plates or lead bricks.	X	
7	Compile site-specific Lock-Out and Tag-Out (LOTO) procedures, in cooperation with GE, for the subsystems that are subject to LOTO.	X	

1-4-13 Cleaning and waste

Item no.	Item	Cust.	GE
1	General cleaning of cyclotron room.		X
2	Provision of state and/or local laws and regulations for sorting and packing waste. See Table 1-1.	X	
3	Sorting and packing of waste according to provided state and/or local laws and regulations.		X
4	Disposal of waste.	X	

Table 1-1: Waste – type and amount

Type of waste	Amount <sup>1</sup> [kg]
Wood (pallets, pallet collars, crates, etc.)	1 030 + 150 <sup>2</sup> + 150 <sup>3</sup>
Plastic (cans, packing material, styrofoam™, etc.)	76 + 72 <sup>4</sup> + 22 <sup>5</sup>
Iron (screws, nail plates, cans, etc.)	95 + 70 <sup>6</sup>
Aluminum (material used for securing load during shipping, etc.)	1.5
Lead (remainders from installation, etc.)	5–35
Paper (cardboard, packing material, etc.)	20

- 1 Approximate maximum amount.  
The weight might vary depending on what options etc. that are shipped with the cyclotron.
- 2 Self-shielded PETtrace 800 systems only. Might be contaminated with boric acid or borax pentahydrate.
- 3 Self-shielded PETtrace 800 systems only. Might be contaminated with lead.
- 4 Self-shielded PETtrace 800 systems only. Might be contaminated with boric acid or borax pentahydrate.
- 5 Self-shielded PETtrace 800 systems only. Might be contaminated with epoxy hardner.
- 6 Self-shielded PETtrace 800 systems only. Might be contaminated with epoxy resin and dye.

### 1-5 Installation flow chart

The typical installation cycle for the unshielded cyclotron is approximately seven weeks, and for the shielded cyclotron approximately nine weeks. [Table 1-2](#) and [Table 1-3](#) show the top level installation schedules for the systems.

**Table 1-2: Typical installation cycle – unshielded cyclotron**

Activities:	Week 1	W 2	W 3	W 4	W 5	W 6	W 7
Shipment to customer 1–5 weeks							
Rigging 5 days	X						
Mechanical installation 10 days		X	X				
Electrical installation 5 days			X				
Start-up, sub systems				X			
Beam test 2 days					X		
Target test 3 days					X		
Performance test procedure						X	(X)

**Table 1-3: Typical installation cycle – shielded cyclotron**

Activities:	W 1	W 2	W 3	W 4	W 5	W 6	W 7	W 8	W 9
Shipment to customer 1–5 weeks									
Rigging 5 days	X								
Mechanical installation 20 days		X	X	X	X				
Electrical installation 10 days				X	X				
Start-up, sub systems						X			
Beam test 2 days							X		
Target test 3 days							X		
Performance test procedure								X	(X)



## 2 SPACE PLANNING

### 2-1 Introduction

The cyclotron system produces radioactive pharmaceuticals. For this reason, special care must be taken when developing the floor plan.

The radioactive isotopes are produced in designated targets, then transported to the radiochemistry lab for additional processing. The final products are transported from the radiochemistry lab to the PET-suite or its vicinity. The facility floor design must accommodate the flow of isotopes, personnel and patients within the PET-suite.

The system is typically divided into three or four rooms:

- Cyclotron room: See [Section 2-2-1 Cyclotron room with an unshielded machine on page 28](#) (unshielded – needs a vault) and [Section 2-2-2 Cyclotron room with integrated shield on page 30](#) (integrated shield)
- Power supply room<sup>1</sup> for the electronics cabinets: See [Section 2-2-3 Power supply room \(shielded and unshielded\) on page 31](#)
- Water cooling room<sup>1</sup> for the secondary Water Cooling Unit: See [Section 2-2-4 Cooling system room on page 33](#)
- Radiochemistry lab: See [Section 2-2-5 Radiochemistry lab on page 33](#)

<sup>1</sup> For best results, place the electronics cabinets and the Water Cooling Unit in the same room (controlled area in regard to radioactivity), reducing the total number of rooms from four to three.

## 2-2 Room sizes

Table 2-1 and Table 2-2 contain the lists of recommended dimensions needed to accommodate operation, service access and traffic patterns within the PET cyclotron facility. Figure 2-1 shows a typical facility layout with a vault. Section 2-2-1 Cyclotron room with an unshielded machine on page 28 contains additional room information for the unshielded cyclotron. Figure 2-2 shows a layout with the integrated radiation shield. Section 2-2-2 Cyclotron room with integrated shield on page 30 contains additional room information for the cyclotron with an integrated radiation shield.

**Table 2-1: Recommended room dimensions – vault version**

Room	Recommended area in m <sup>2</sup> and (ft <sup>2</sup> )	Recommended room dimensions in meters and (feet)
Cyclotron room	20 (210)	5 × 4 (16 × 13)
Power supply room	20 (210)	5 × 4 (16 × 13)
Cooling room	10 (100)	3.5 × 3 (11 × 10)
Radiochemistry lab	30 (310)	6 × 5 (20 × 16)

**Table 2-2: Recommended room dimensions – shielded version**

Room	Recommended area in m <sup>2</sup> and (ft <sup>2</sup> )	Recommended dimensions in meters and (feet)
Cyclotron room/ power supply room	42 (460)	7 × 6 (23 × 20)

Figure 2-1: Typical facility with a vault

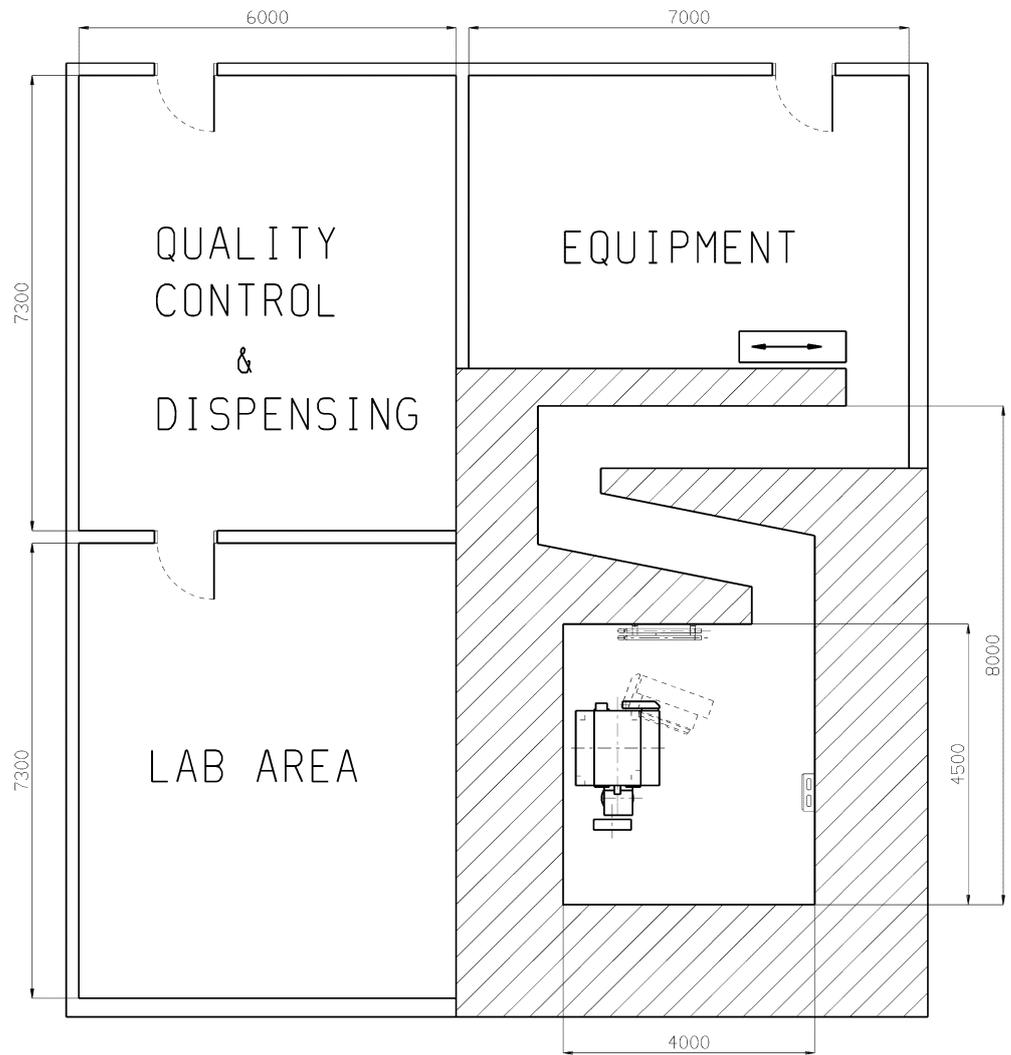
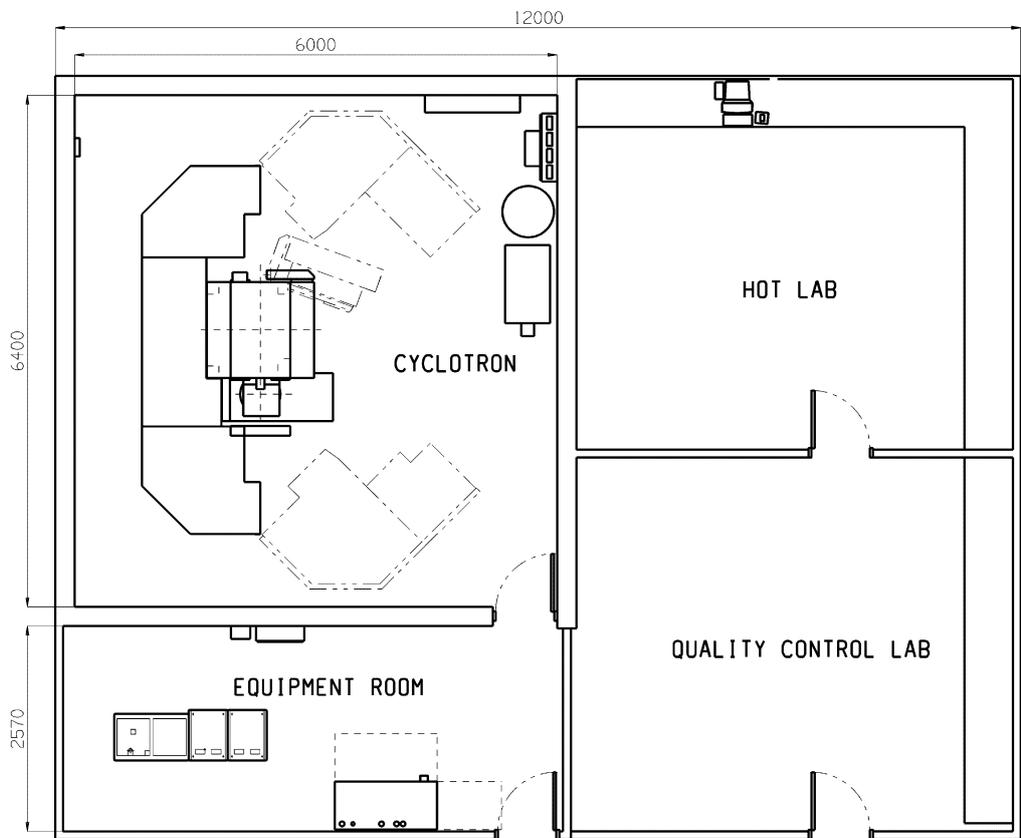


Figure 2-2: Typical facility with an integrated shield



2-2-1 Cyclotron room with an unshielded machine

2-2-1-1 Room size

Typically, the unshielded cyclotron shares a vault with the water manifold, ion gas manifold, PDU and tapping transformer, the optional waste gas system and other accelerator/target support systems.

Table 2-3: Unshielded cyclotron room dimensions

Recommended area	20 m <sup>2</sup> (210 ft <sup>2</sup> )
Length	5.0 m (16 ft)
Width	4.0 m (13 ft)
Height	2.4 m (8 ft) (free clearance)

### 2-2-1-2 Equipment dimensions

The cyclotron will be transported into the cyclotron vault as a single unit, with the following dimensions:

**Table 2-4: Unshielded cyclotron dimensions**

Weight	20 metric tons (44 000 lbs)
Length	1.9 m (6 ft)
Width	1.7 m (5 ft 6 in)
Height	2.1 m (6 ft 10 in)

### 2-2-1-3 Unshielded cyclotron floor load

The weight of the magnet is distributed on four 150×150 mm steel shim plates. [Section 2-4 Floor specifications on page 38](#) contains additional floor loading information and specifications.

### 2-2-1-4 Construction and layout

The cyclotron requires a pit for the diffusion pump. [Section 2-5 Architectural reminders on page 41](#) contains additional floor pit information and specifications. All cabling and water lines in the vault may be routed from above or run in a floor trench. Floor drains in pit areas or drainage pump located in pit is recommended.

When designing the vault, leave wall space in the cyclotron room to mount the following components ([Section 2-6 System component illustrations on page 45](#) contains dimensional drawings of these components):

- 1 PDU
- 2 Tapping transformer (usually sits on floor, beneath PDU)
- 3 Cooling water manifold
- 4 Ion gas manifold

Design the vault to prevent radioactive leakage around the following penetrations:

- 1 Ventilation ducts
- 2 System cabling
- 3 Cyclotron system water cooling pipes
- 4 Compressed air pipes
- 5 Gas piping
- 6 Drains

### 2-2-2 Cyclotron room with integrated shield

Design the cyclotron room for the shielded as a single, dedicated room, or integrate it with the power supply room and/or water cooling room.

#### 2-2-2-1 Room size (single room option)

**Table 2-5: Cyclotron room size, integrated shield**

Recommended area	45 m <sup>2</sup> (500 ft <sup>2</sup> )
Length	7.0 m (23 ft)
Width	6.5 m (22 ft)
Height	3.5 m (11 ft 6 in)

#### 2-2-2-2 Equipment dimensions

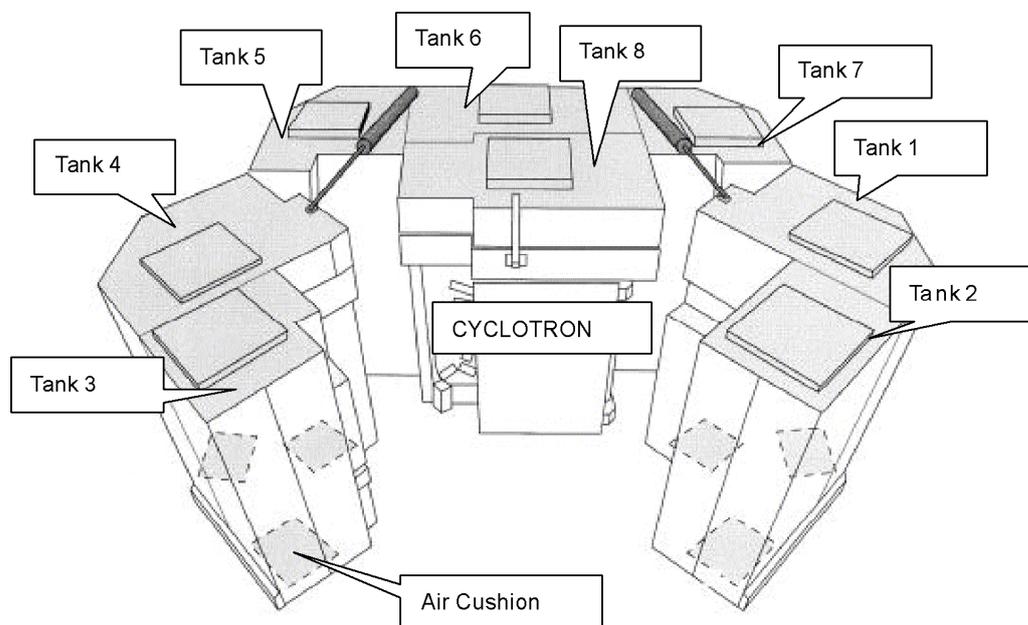
The cyclotron magnet will be transported into the cyclotron vault without its shields. The magnet has the following dimensions:

**Table 2-6: Unshielded cyclotron magnet dimensions**

Weight	20 metric tons (44 000 lbs)
Length	1.9 m (6 ft)
Width	1.7 m (5 ft 6 in)
Height	2.1 m (6 ft 10 in)

The radiation shield arrives as eight empty stainless steel tanks. Once inside the cyclotron room, the tanks are assembled and filled with boronated water and fitted with extra lead. The tanks are shipped on their sides.

Figure 2-3: Radiation shield tanks



Data for the assembled radiation shield:

Table 2-7: Shield dimensions

Weight	47 metric tons (103 400 lbs)
Length	4.8 m (15 ft 9 in) (when closed)
Width	3.1 m (10 ft 2 in) (when closed)
Height (also length during shipment)	2.8 m (9 ft 3 in)

### 2-2-2-3 Cyclotron and integrated shield floor load

The weight of the shield is not equally distributed over its area. Maximum floor loading occurs in the area occupied by the moveable shields on the target side of the machine. When closed, the load on this part of the floor is about 4.7 metric tons/m<sup>2</sup>. During activation of the air cushions, the load per square meter increases by 25%, to 5.9 metric tons/m<sup>2</sup>. [Section 2-4 Floor specifications on page 38](#) contains additional floor loading information and specifications.

### 2-2-3 Power supply room (shielded and unshielded)

The power supply room contains three power supply/electronics cabinets, the PSMC, RFGP and CAB 3. You can also place the secondary Water Cooling Unit in this room (recommended). If the accelerator has an integrated radiation shield, you may place the three cabinets and/or water cooling unit in the same room as the accelerator.

Table 2-8: Power supply room size

Recommended area	20 m <sup>2</sup> (215 ft <sup>2</sup> )
Height	3.0 m (10 ft)

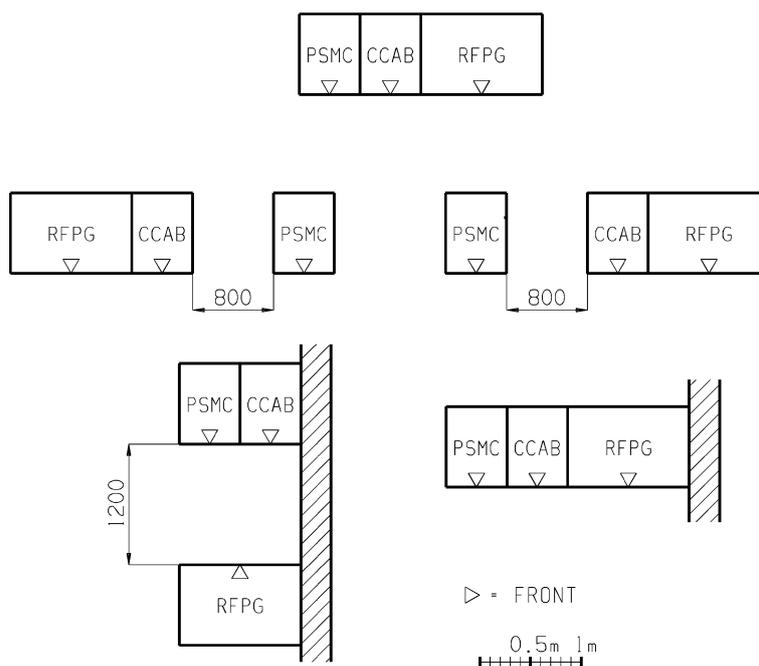
The power supply room cabinets have the following dimensions:

Table 2-9: Power supply room cabinet dimensions

Dimension	Cabinet 1 (PSMC)	Cabinet 2 (RFPG)	Cabinet 3 (CAB 3)
Weight	700 kg (1540 lbs)	750 kg (1650 lbs)	240 kg (530 lbs)
Length	0.8 m (32 in)	0.8 m (32 in)	0.8 m (32 in)
Width	0.6 m (24 in)	1.2 m (47 in)	0.6 m (24 in)
Height	1.8 m (71 in)	1.8 m (71 in)	1.8 m (71 in)

The three cabinets rest directly on the power supply room floor. Position the power supply room and the cyclotron room as close together as possible, to avoid timing problems caused by overlong power and signal cables. The PSMC and RFPG cabinets are water cooled, so install a floor drain in the power supply room. Position the PSMC cabinet, so it has service access to the front, rear and left sides. If possible, place the secondary Water Cooling Unit in the power supply room.

Figure 2-4: Power supply room configurations



SCALE 1:50

### 2-2-4 Cooling system room

Place the Water Cooling Unit as close to the cyclotron room as possible, and on the same floor level, to avoid high static pressure and flow resistance. Install a floor drain in the cooling system room.

The Water Cooling Unit can be placed in a separate cooling system room, or in the power supply room, with the three power supply/electronics cabinets (recommended).

We recommend that the room where the Water Cooling Unit is placed is a controlled area.

**Table 2-10: Cooling system room dimensions**

Recommended area	10 m <sup>2</sup> (110 ft <sup>2</sup> )
Length	3.5 m (11 ft)
Width	3.0 m (10 ft)
Height	2.4 m (8 ft)

**Table 2-11: Cooling system dimensions**

Weight	300 kg (660 lbs)
Length	1.2 m (3 ft 11 in)
Depth	0.6 m (2 in)
Height	1.55 m (5 ft 1 in)

### 2-2-5 Radiochemistry lab

The radiochemical production facility design should also include a radiochemical laboratory to accommodate the chemistry process systems. These systems should be mounted in a radiation protected area, such as a hot cell.

The process systems for <sup>11</sup>C and <sup>15</sup>O gas products will be installed in a shielded process cabinet supplied by GE. The radiochemistry lab should be designed to accommodate this cabinet, as well as the necessary analytical instruments, such as GC and HPLC.

Reserve a minimum 1 m × 1 m work surface dedicated to the cleaning of contaminated items. This area must be surrounded by adequate radiation shielding, such as lead bricks. The radiochemistry lab should also include additional working, rinsing and washing areas.

The optional process cabinet (ProCab) contains a lead shielded enclosure, for safe processing, that opens for access and maintenance. The Purchaser should provide a detector to measure the level of radioactivity inside the process cabinet when it is open.

The operator controls the radiochemical production with a dedicated (Master) workstation. The workstation has a keyboard and flat screen. The workstation can be placed on a desk in the radiochemistry lab or located elsewhere within the facility.

Design the air exchange system to exhaust in the direction of the hot cells, and ventilate outside the lab. All feed-throughs must be shielded against radiation leaks.

The radiochemistry lab equipment have the following dimensions:

**Table 2-12: Radiochemistry lab equipment dimensions**

Dimension	ProCab	NH <sub>3</sub> module	H <sub>2</sub> O module	Master
Weight	3570 kg (7870 lbs)	5 kg (11 lbs)	10 kg (22 lbs)	36 kg (80 lbs)
Length	560 mm (22 in)	200 mm (8 in)	200 mm (8 in)	540 mm (21 in)
Width	920 mm (36 in)	150 mm (6 in)	150 mm (6 in)	1200 mm (48 in)
Height	2200 mm (87 in)	200 mm (8 in)	350 mm (14 in)	509 mm (20 in)

### 2-3 Cabling considerations

When determining how to route the cables, consider the following:

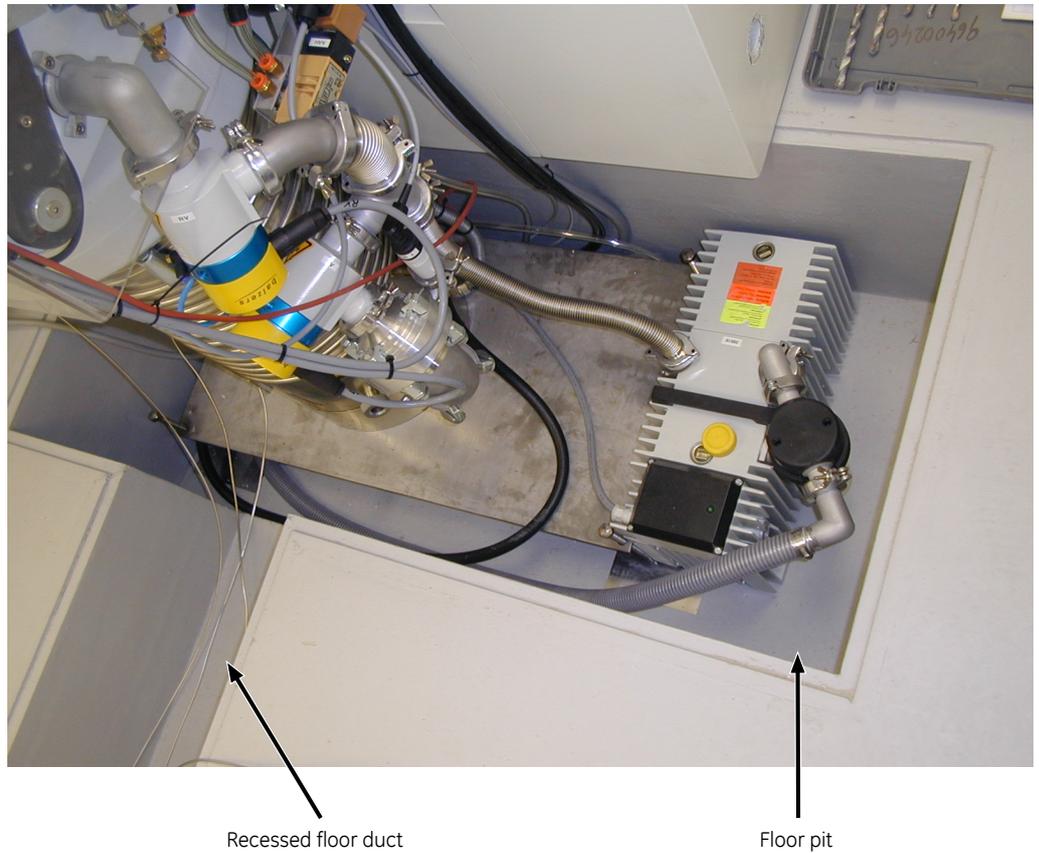
- All cords and cables must be protected from physical damage.
- All cable runs must comply with local and national codes.
- Cable runs should be accessible, for troubleshooting purposes.
- Cable ducts or raceways should be large enough to:
  - accommodate all cable connectors
  - pull a single cable when all the other cables are in place
  - accommodate future modifications or upgrades

#### 2-3-1 Recessed floor ducts

A recessed floor duct in a single room, or between two adjacent rooms, combines a neat, functional appearance with accessibility and room for modifications and upgrades. The disadvantage is the amount of work required to install it. Due to their construction, it may be impossible to retro-fit older buildings with recessed floor ducts.

Always consider placement of heavy components or if components need to be anchored to the floor when planning for recessed floor ducts, as one might interfere with the other.

The optional integrated radiation shield design uses a floor duct in the cyclotron room.

**Figure 2-5: Recessed floor duct**

### 2-3-2 Cable raceways

Surface-mounted overhead raceways and ladders, with a minimum width of 18 inches, offer a practical solution to the problem of retro-fitting an older structure. The entire raceway is accessible to check existing cables or add new ones. Divided raceways provide separate spaces for power and signal cables. Raceway systems are relatively easy to expand, when compared to other cable routing methods.

Figure 2-6: Overhead cable raceway



### 2-3-3 Raised flooring

If you decide to use a raised aluminum floor in the power supply room, choose one with a conductive vinyl covering. The raised floor must be able to support the load during the power supply installation ([Table 2-16](#) for PSMC and RFPG power supply cabinet weights).

### 2-3-4 Conduit

Conduit can be used only if the size is adapted to house the size of the cable connectors.

The conduit diameters usually cannot accommodate the cable connectors, especially after one or two cables have been pulled. The conduit size restriction also makes it difficult to add cables during modifications or upgrades. Once a few cables have been pulled, subsequent cables tend to catch on and tangle with the existing cables, even when using a fish line or wire to pull the cables. Of all the cable routing methods in use, conduit provides the least access to existing cables.

### 2-3-5 Wall/vault penetrations

The standard PETtrace 800 cyclotron vault requires about 1.7 meters of concrete shielding. (Cyclotron systems with the optional integrated radiation shield require significantly less concrete shielding.) When designing the cyclotron suite, take steps to protect all power, cable and media plumbing penetrations from radiation leakage.

[Table 2-13](#) lists subsystem penetration requirements, and [Table 2-14](#) lists the types of media and number of penetrations needed between rooms. Try to route the cables, pipes and hoses so a minimum number of penetrations accommodates as many pipes, cables and hoses as possible.

**Table 2-13: Feed-through types**

Subsystem	Compressed air	Cables	Cold gas	Radioactive gas	Water cooling
Accelerator	X	X	X	X	X
Electronics cabinets		X			X
Waste gas system				X	
Master system		X			
Gas storage			X	X	
Process cabinet	X	X	X	X	
Hot cells		X	X	X	X
Integrated radiation shield <sup>1</sup>	X	X			
Compressor <sup>1</sup>	X	X			

<sup>1</sup> Option

**Table 2-14: Penetrations**

Media type(s)	To room	From	Diameter in mm and (in)	Max # penetrations
<b>Concrete penetrations:</b>				
Power + signals <sup>1</sup>	Cyclotron vault	Power supply room	120 (4.8)	4
Cooling water <sup>2</sup>	Cyclotron vault	Water Cooling Unit	60 (2.4)	3
Cold gases <sup>3</sup>	Cyclotron vault	Gas storage	100 (4)	1
Compressed air	Cyclotron vault		25 (1)	1

Media type(s)	To room	From	Diameter in mm and (in)	Max # penetrations
<b>Other penetrations:</b>				
Cooling water	Power supply room	Water Cooling Unit	60 (2.4)	2
Cold gases <sup>3</sup>		Gas storage	100 (4)	1
Hot gases <sup>3</sup>	Radiochemistry lab	Cyclotron vault	100 (4)	1
Signals	Radiochemistry lab	Power supply room	100 (4)	1
Hot gases + waste	Scanner room		75 (3)	1
	Gas adm system			

- 1 Angle these large penetrations from ceiling to floor, to minimize radiation leakage.
- 2 Due to the use of PVC pipes, this penetration cannot be angled. Angle the penetration on a different axis, so the radiation from the cyclotron cannot pass straight through the opening.
- 3 Group the hot and cold gas lines together, and pass them through a single penetration.

## 2-4 Floor specifications

### 2-4-1 Weight tolerances

#### 2-4-1-1 Standard PETtrace 800 system

The unshielded cyclotron weighs about 20 000 kg, with the weight distributed over four 150×150 mm steel shimming plates. The floor pressure on the individual plates varies from 17 to 58 kp/cm<sup>2</sup>.

#### 2-4-1-2 Cyclotron with optional integrated radiation shield

When the cyclotron has an integrated radiation shield, the weight of the top tank increases the floor pressure by 4.5 kp/cm<sup>2</sup>, which increases the floor pressure on the individual plates to 21.5 to 62.5 kp/cm<sup>2</sup>.

The floor surface also requires special treatment to withstand loading and facilitate the motion of the moveable shield. The finished surface must withstand 800–900 kg/cm<sup>2</sup>.

### 2-4-2 Slope tolerances

In order to facilitate the motion of the integrated shield, the floor in the cyclotron room must be level, with ±1/8" slope from point to point.

Table 2-15 lists the current surface smoothness and floor slope tolerances of the magnet, integrated shield, polyshield and Beam Line.

**Table 2-15: Floor tolerances**

Floor area	Slope	Surface smoothness	Final treatment responsibility
Magnet (when there is no integrated shield)	1.00%	± 2.5 mm (entire magnet floor area)	Customer
Integrated shield	0.25%	± 2.5 mm (entire fixed integrated shield floor area) ± 0.9 mm/m (under the movable doors)	Customer
Polyshield	0.25%	± 0.9 mm/m (under the polyshield)	Customer
Beam Line	1.00%	± 2.5 mm (under the Beam Line)	Customer

**2-4-3 Floor loading**

Table 2-16 lists weights, floor loads and normal mounting methods for the cyclotron components.

**Table 2-16: Floor loads for standard PETtrace 800 components**

Component	Weight kg (lbs)	Overall area W×D×H mm (in)	Floor load (kp/m <sup>2</sup> )	Mounting method
Magnet	20 000 (44 000)	1330×1200×1900 (52.5×47×75)	12531	
PSMC	700 (1540)	600×800×1800 (23.5×31.5×71)		Set on floor
RFPG	750 (1650)	1175×800×1800 (46×31.5×71)		Set on floor
Control cabinet (CAB 3)	240 (530)	600×800×1800 (23.5×31.5×71)		Set on floor
Master system	36 (79.2)	475×540×510 (18.5×21.5×20)		Set on table
Roughing pump	27 (59.4)	450×190×250 (17.5×7.5×10)		Set on floor
Service laptop with PSS	5 (11)	300×310×230 (12×12.2×9)		Set on table
PDU (unshielded version)	30 (66)	600×210×800 (23.5×8.5×31.5)		Bolted to wall
Helium cooling system				Attached to target panel

Component	Weight kg (lbs)	Overall area WxDxH mm (in)	Floor load (kp/m <sup>2</sup> )	Mounting method
Secondary Water Cooling Unit	300 (660)	600×1200×1550 (23.5×47×61)		Set on floor
Water manifold 1	40 (88)	1300×200×1000 (52×8×39.5)		Bolted to wall or magnet
Customer Interface Box (CIB)	5 (11)	300×210×420 (12×8.5×17)		Bolted to wall
Ion source gas manifold	5 (11)	290×80×320 (11.5×3.2×12.5)		Bolted to wall
Compressed air manifold	5 (11)	580×190×720 (23×7.5×28.5)		Bolted to wall

**Table 2-17: Floor loads for options**

Component	Weight kg (lbs)	Overall area WxDxH mm (in)	Floor load (kp/m <sup>2</sup> )	Mounting method
Process Cabinet (ProCab)	3570 (7870)	920×560×2200 (36.2×22×86.6)		Bolted to wall (can also be bolted to floor) <sup>1</sup>
Chemistry Control Unit (CCU)	13 (29)	197×332×520 (8×13×20)		Set on floor
Chemistry Electronics Unit (CEU)				
Waste gas system	1500 (3300)	630×630×1150 (25×25×45.5)		Set on floor
<b>The following components are included with the integrated radiation shield option:</b>				
Integrated radiation shield	47000 (103400)	4750×3150×2800 (187×124×110.5)	3800	Set on floor
Integrated radiation shield, opened		5950×4300×2800 (234×169×110.5)		
PDUS (replaces PDU)	35 (77)	1080×400×640 (42.5×16×25.2)		Bolted to wall
Air compressor	250 (550)	700×1300×800 (27.5×51.2×32)		Set on floor

<sup>1</sup> If earthquake protection is required, follow federal, state and/or local rules and regulations.

## 2-5 Architectural reminders

### 2-5-1 General reminders

- 1 People with cardiac pacemakers, neurostimulators and biostimulation devices may not enter magnetic fields greater than 5 gauss. The suite design and scanner location must take this exclusion zone into consideration ([Figure 4-1](#), [Figure 4-2](#)).
- 2 Pay attention to isogauss limits, with respect to both indoor and outdoor environments.
- 3 Include space in the electronics room design for a lockable cabinet to store documentation and tools.

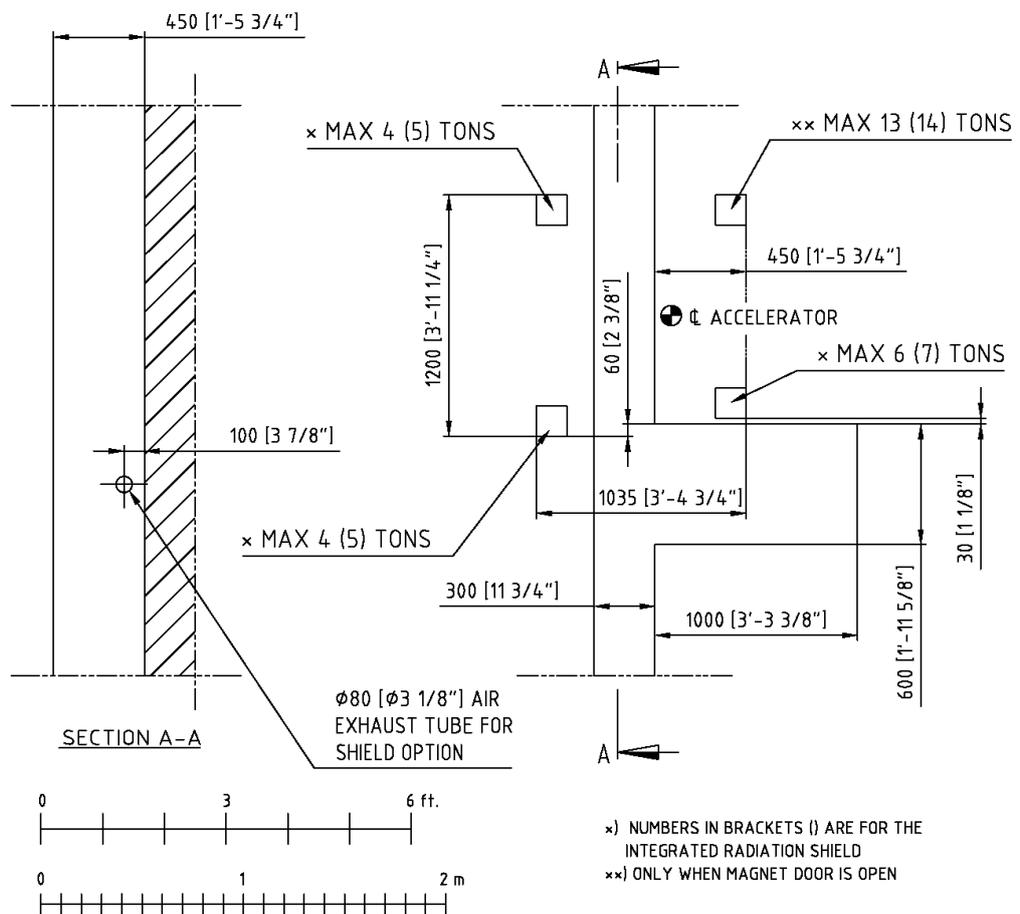
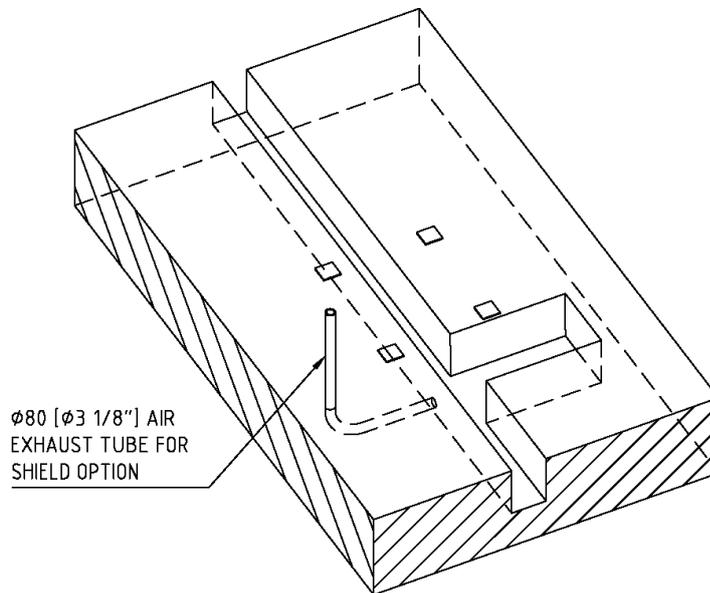
### 2-5-2 Tele and data communication

- 1 The suite requires two separate, dedicated telephone lines to the power supply room. One of the lines should be available for modem.
- 2 A connection for Internet access close to Cabinet 3 is recommended.

### 2-5-3 Cyclotron pit

The cyclotron vacuum pump extends 45 cm below the floor surface. [Figure 2-7](#) through [Figure 2-10](#) show the relative location and depth of the accommodating floor pit and give floor plate specifications for floor ducts. The pit also serves as a cable and gas pipe duct to the accelerator. The actual entry points of the cables and pipes into the pit vary, according to the design and layout of the cyclotron suite.

Figure 2-7: Floor pit/duct



### 2-5-3-1 Water drains

If the facility purchases the integrated radiation shield, the lowest part of the pit must have a drain, because the shields contain about 28 m<sup>3</sup> of water. The pit is large enough to hold the entire volume of the water cooling system (about 75 liters), so the drain is not required on an unshielded system.

- Minimum drain diameter: 50 mm (optional)

Also, in case of integrated radiation shield, the pit design includes an air exhaust that must be able to dissipate 1 kW of heat created by the vacuum pump system.

- Minimum exhaust tube diameter: 80 mm
- Minimum flow rate: 10 l/s (36 m<sup>3</sup>/h)

### 2-5-3-2 Radiation shielding

The cyclotron target systems produce radioactive gases. The pipes for radioactive gases run from the cyclotron pit to the hot lab, where they enter a hot cell or process cabinet. The pipes must be shielded in areas where personnel can be exposed to dosage from the radioactive gas:

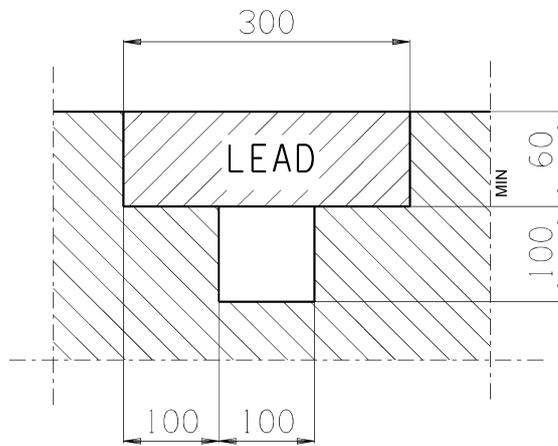
- Minimum pipe shielding: 60 mm of lead or corresponding concrete thickness (but check for typical values in accordance with local regulations).

On unshielded systems, the concrete vault provides adequate shielding to the gas pipes inside the vault. Systems with the integrated radiation shield require additional shielding for the pipes that run between the cyclotron and the hot cell or process cabinet. If the PET-suite has a gas administration system in the scanner room, the pipes must be shielded all the way to the administration system.

[Figure 2-8](#) shows a duct profile for a concrete floor under construction that provides an inexpensive and easy way to shield the contents. [Figure 2-10](#) gives additional floor shield specifications.

If the room has a finished floor, you can purchase a lead shielding system for the pipes from the following manufacturers: Von Gahlen and Lemer.

Figure 2-8: Duct profile



*Not according to scale*

Figure 2-9: Accelerator/pit position

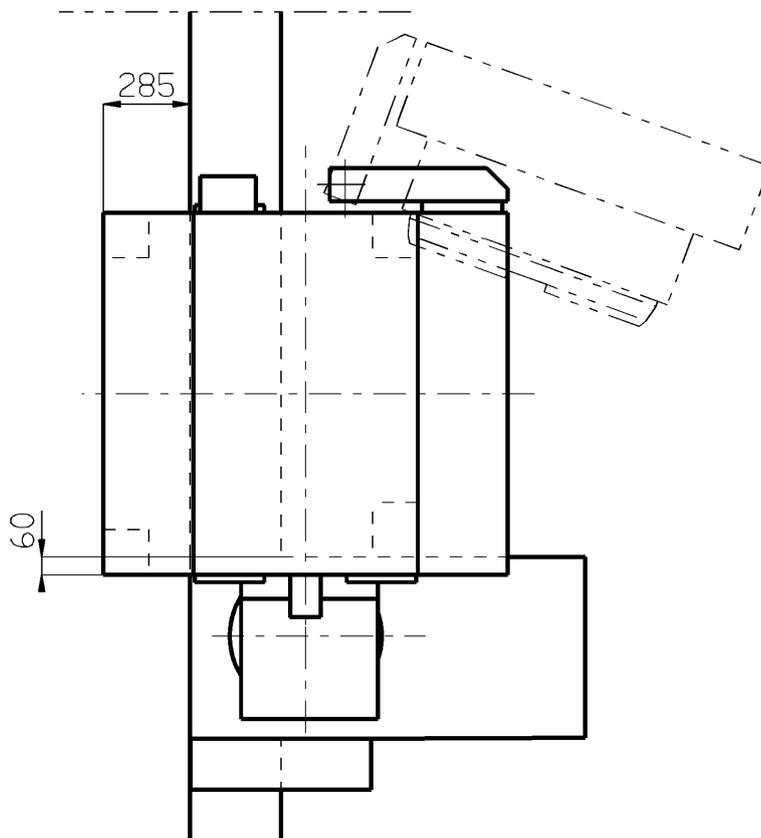
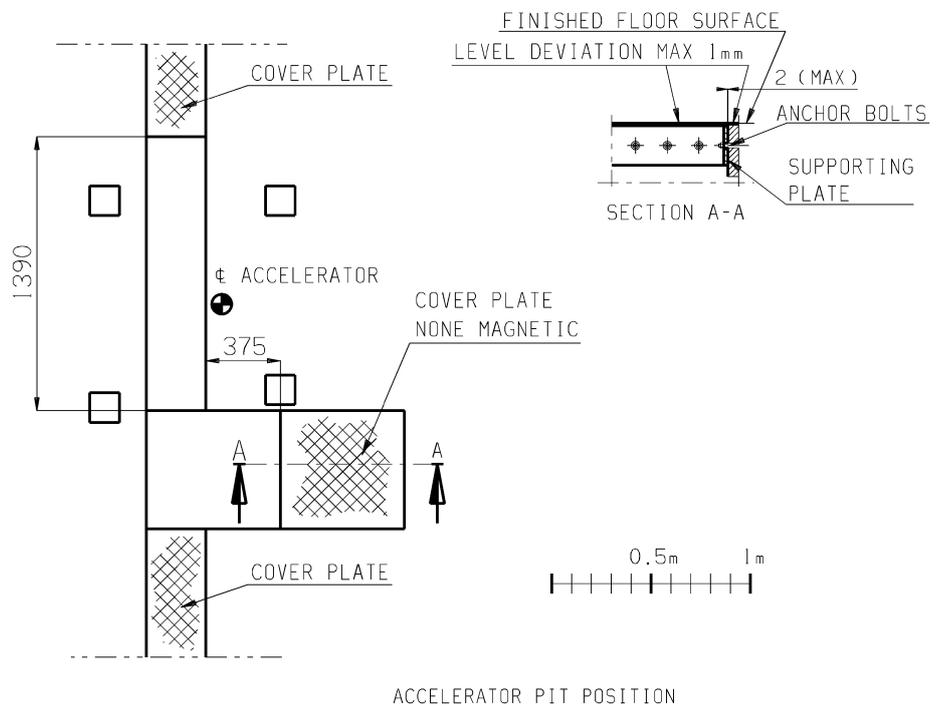


Figure 2-10: Floor cover plate



## 2-6 System component illustrations

PETtrace 800 produces the commonly used radioisotopes for positron emission tomography (PET),  $^{18}\text{F}$ ,  $^{11}\text{C}$ ,  $^{13}\text{N}$ , and  $^{15}\text{O}$ . The system design accommodates both research and clinical use.

The cyclotron system consists of the following major subsystems:

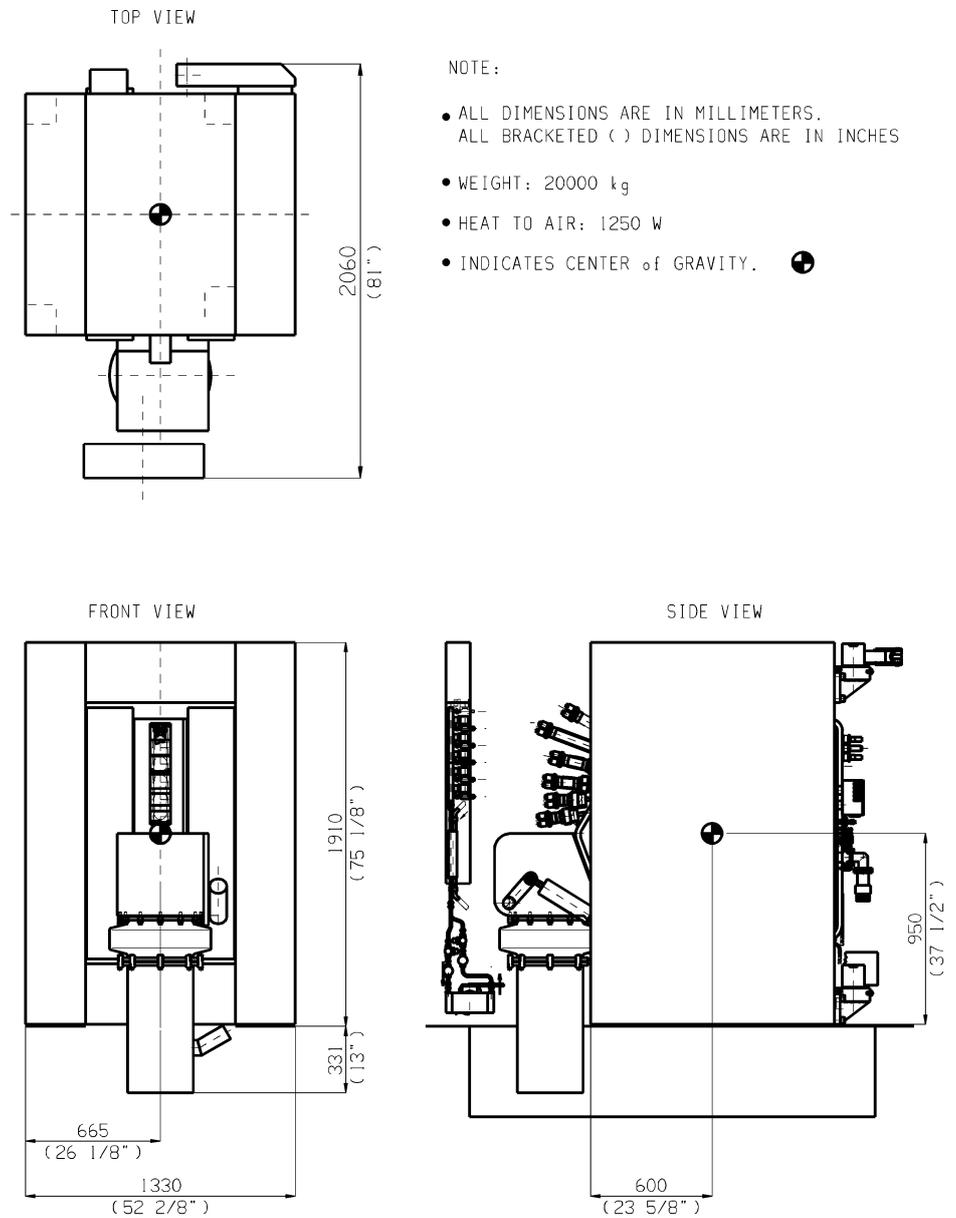
- Dual particle cyclotron
- Standard target system (up to six positions)
- Standard chemistry system, that automates the production of  $^{15}\text{O-O}_2$ ,  $^{15}\text{O-CO}_2$ ,  $^{15}\text{O-H}_2\text{O}$ ,  $^{11}\text{C-CO}$ ,  $^{11}\text{C-CO}_2$ ,  $^{11}\text{C-HCN}$  and  $^{13}\text{N-NH}_3$
- Standard target and chemistry support system.

Table 2-18 contains the list of Illustration names and corresponding figure numbers that conclude this section.

**Table 2-18: System component illustration list**

Illustration name	Figure number
<b>Standard system components</b>	
Unshielded cyclotron	<a href="#">Figure 2-11</a>
Minimum unshielded cyclotron service area	<a href="#">Figure 2-12</a>
Cabinet 1, Magnet Power Supply (PSMC)	<a href="#">Figure 2-13</a>
Cabinet 2, RF Power Generator (RFPG)	<a href="#">Figure 2-14</a>
Cabinet 3, Control Cabinet (CAB 3)	<a href="#">Figure 2-15</a>
Power Distribution Unit (PDU)	<a href="#">Figure 2-16</a>
Ion source gas manifold	<a href="#">Figure 2-18</a>
Roughing vacuum pump	<a href="#">Figure 2-19</a>
Master System	<a href="#">Figure 2-20</a>
Secondary Water Cooling Unit	<a href="#">Figure 2-21</a>
Water manifold 1	<a href="#">Figure 2-22</a>
Customer Interface Box (CIB)	<a href="#">Figure 2-23</a>
<b>Options</b>	
Integrated radiation shield (IRS)	<a href="#">Figure 2-24</a>
PDU shielded system (PDUS) – with IRS	<a href="#">Figure 2-17</a>
Compressor – with IRS	<a href="#">Figure 2-25</a>
Compressed air manifold – with IRS	<a href="#">Figure 2-26</a>
Process Cabinet (ProCab)	<a href="#">Figure 2-27</a>
Chemistry Control Unit (CCU) – with ProCab or as a separate option purchase	<a href="#">Figure 2-28</a>
Chemistry Electronics Unit (CEU) – with CCU	
Waste gas unit	<a href="#">Figure 2-29</a>

Figure 2-11: Unshielded cyclotron

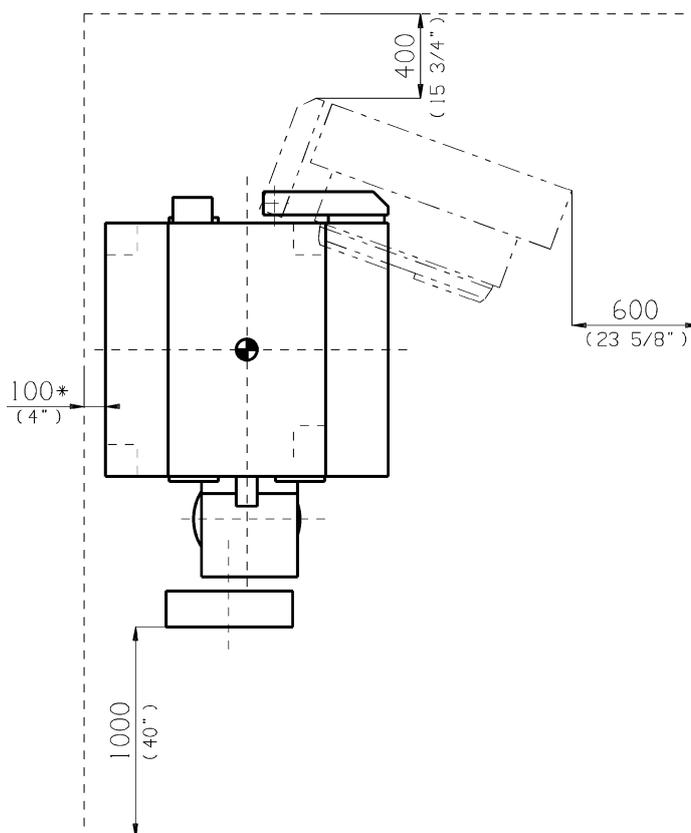


CYCLOTRON

Figure 2-12: Minimum unshielded cyclotron service area

NOTE:

- ALL DIMENSIONS ARE IN MILLIMETERS.  
ALL BRACKETED ( ) DIMENSIONS ARE IN INCHES
- WEIGHT: 20000 kg
- HEAT TO AIR: 750 W
- INDICATES CENTER OF GRAVITY. ⊕

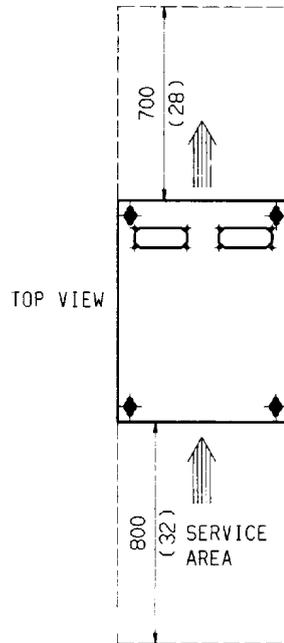


\* ONLY RECOMMENDED  
CAN BE REDUCED TO 0



CYCLOTRON (MIN SERVICE AREA)

Figure 2-13: Cabinet 1, Magnet Power Supply (PSMC)



NOTE:

- ALL DIMENSIONS ARE IN MILLIMETERS.  
ALL BRACKETED ( ) DIMENSIONS ARE IN INCHES
- WEIGHT: 700 kg
- HEAT TO AIR: 200 W
- INDICATES AIR FLOW. 
- INDICATES CENTER OF GRAVITY. 

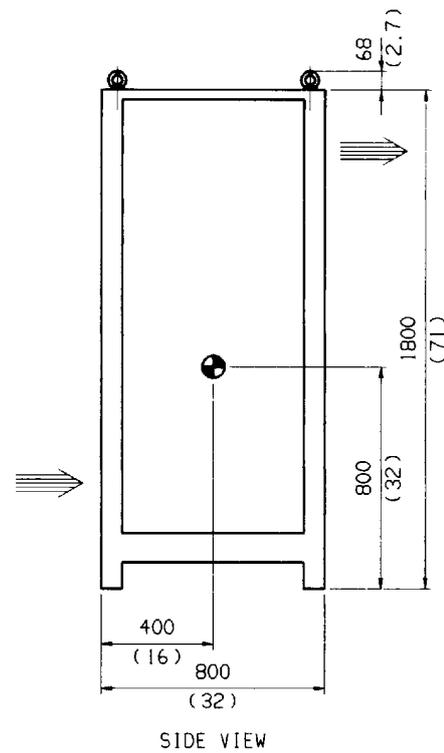
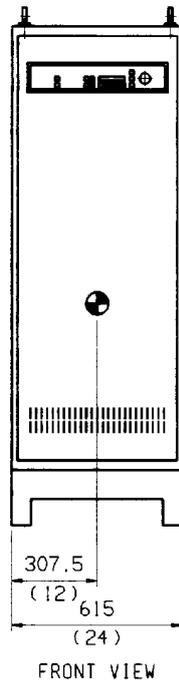
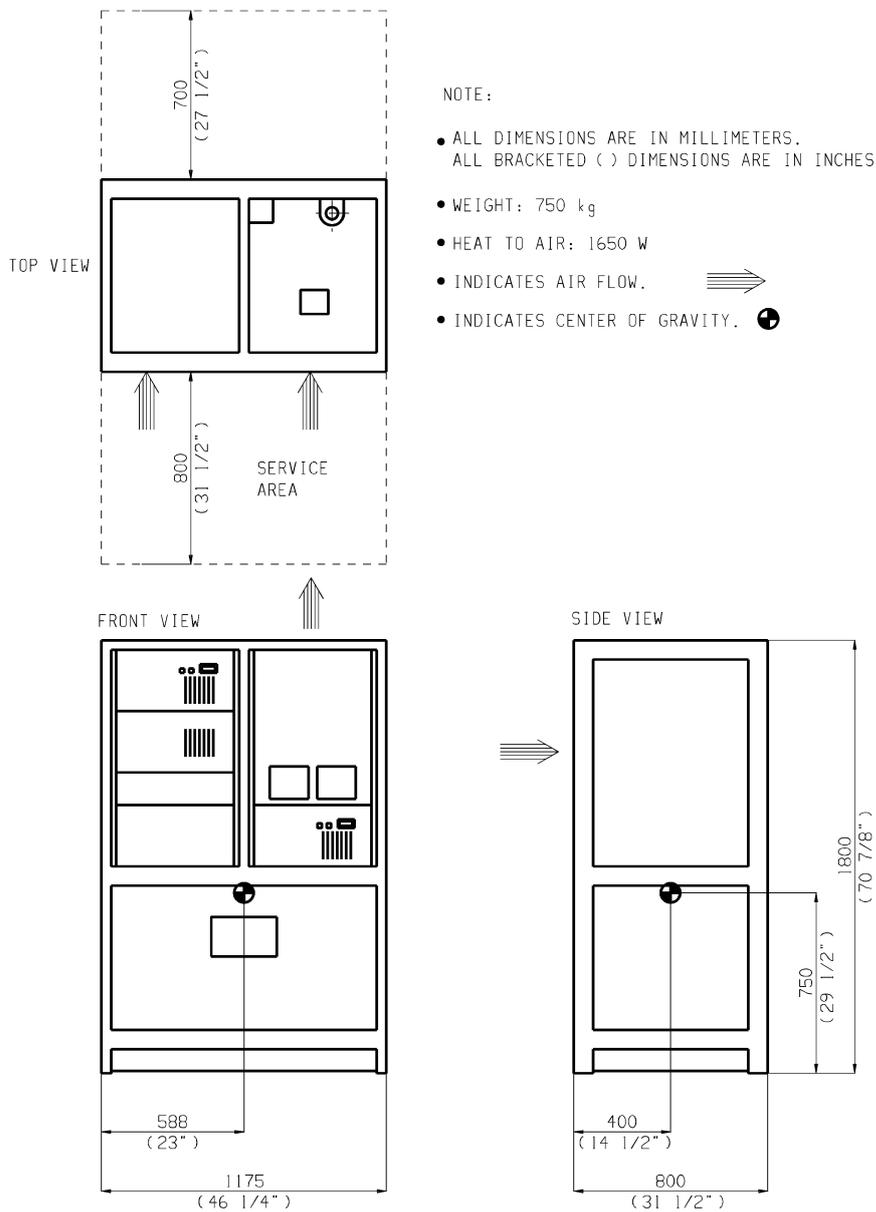
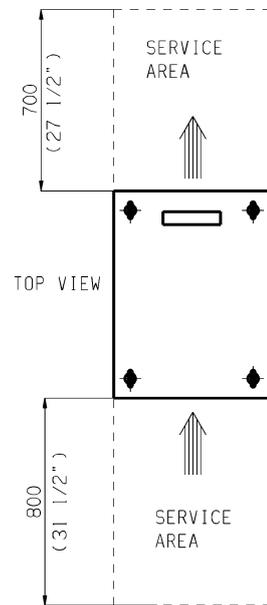


Figure 2-14: Cabinet 2, RF Power Generator (RFPG)



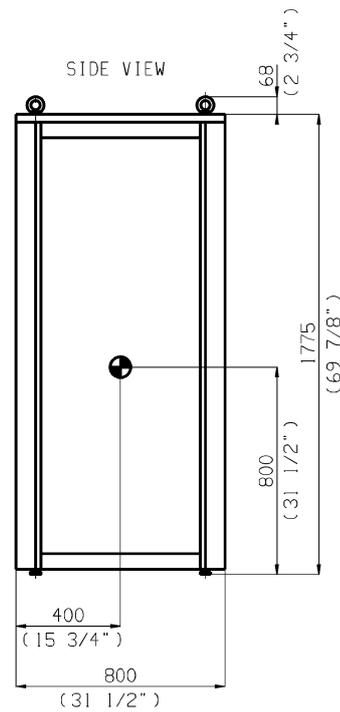
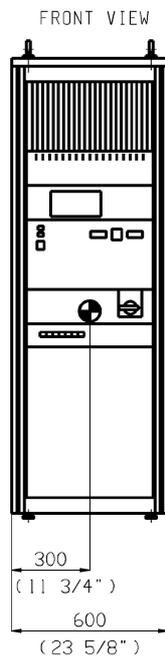
RFPG

Figure 2-15: Cabinet 3, Control Cabinet (CAB 3)



NOTE:

- ALL DIMENSIONS ARE IN MILLIMETERS. ALL BRACKETED ( ) DIMENSIONS ARE IN INCHES
- WEIGHT: 250 kg
- HEAT TO AIR: 400 W
- INDICATES AIR FLOW. 
- INDICATES CENTER OF GRAVITY. 



ELECTRONIC CABINET

Figure 2-16: Power Distribution Unit (PDU)

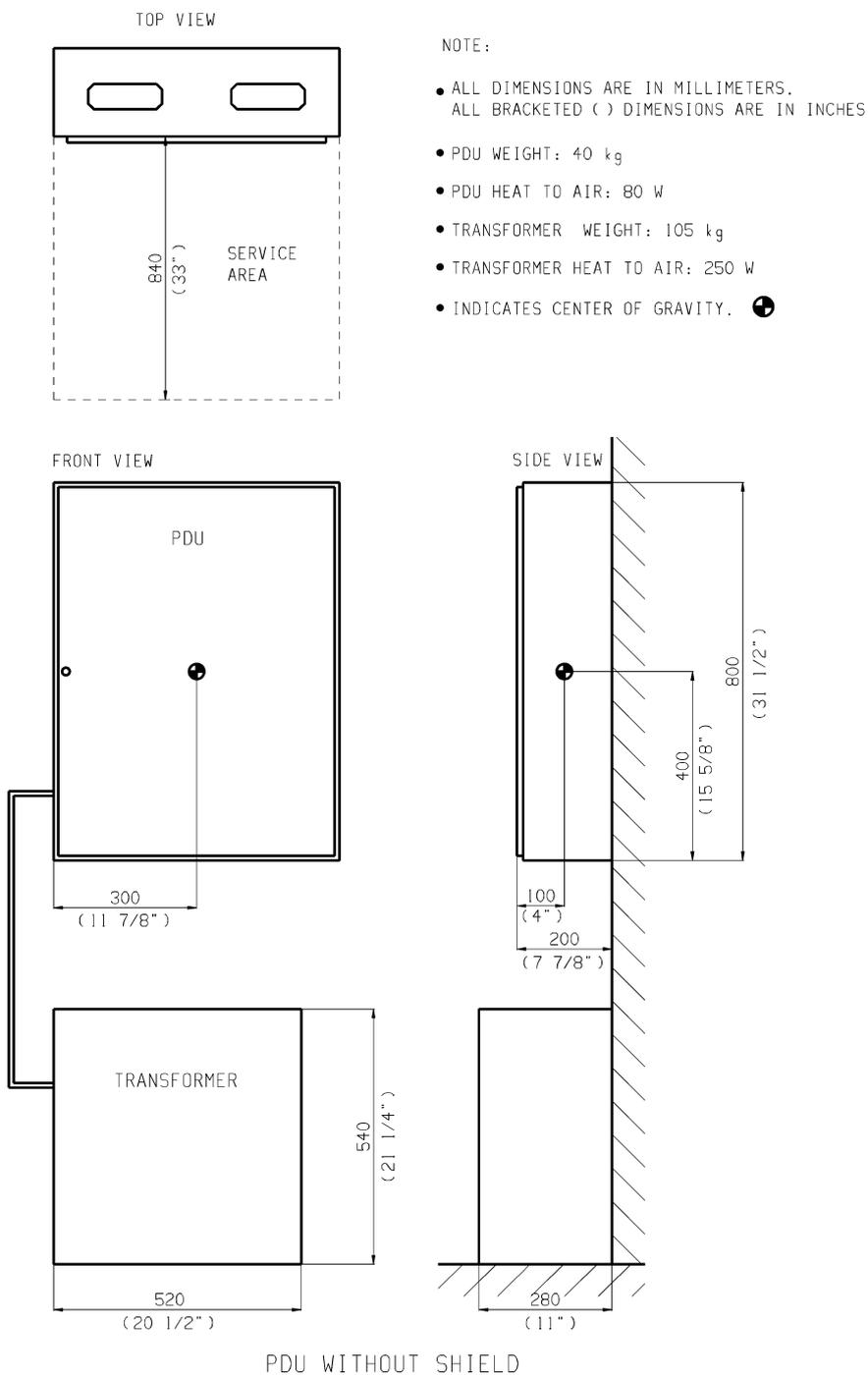
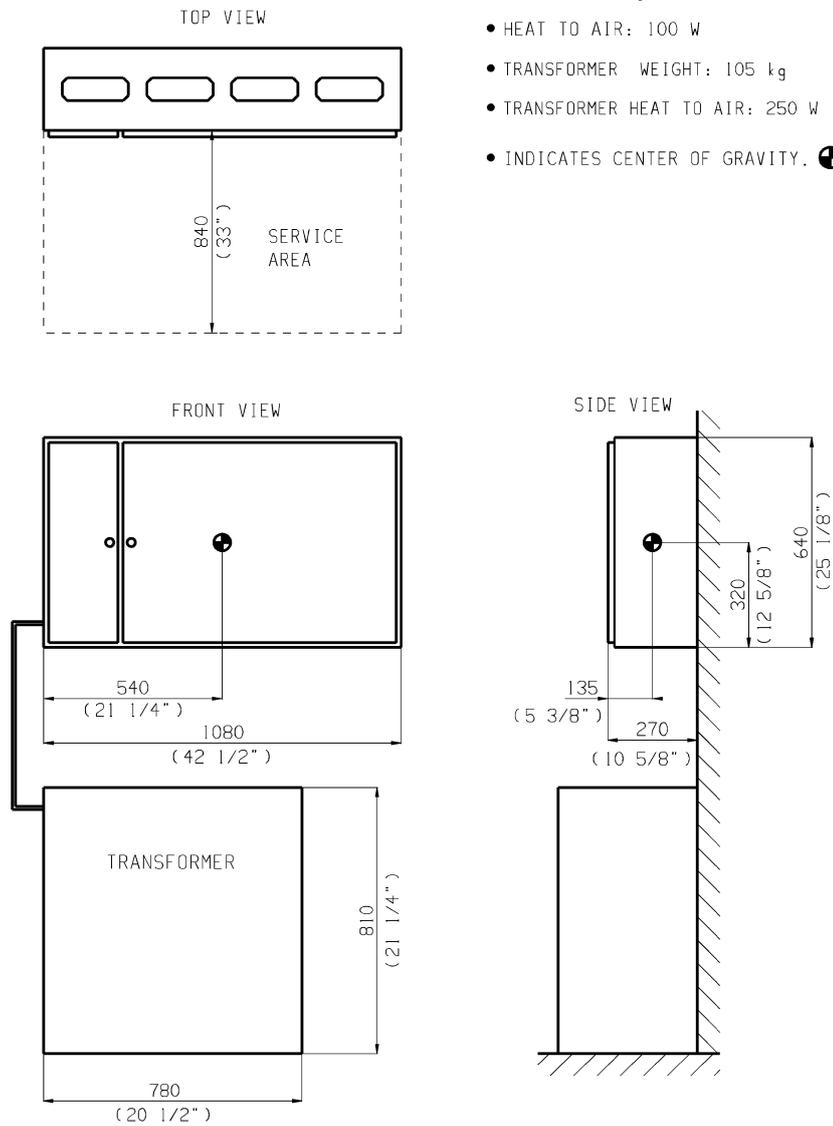


Figure 2-17: PDU Shielded System (PDUS) – part of IRS option – replaces standard PDU

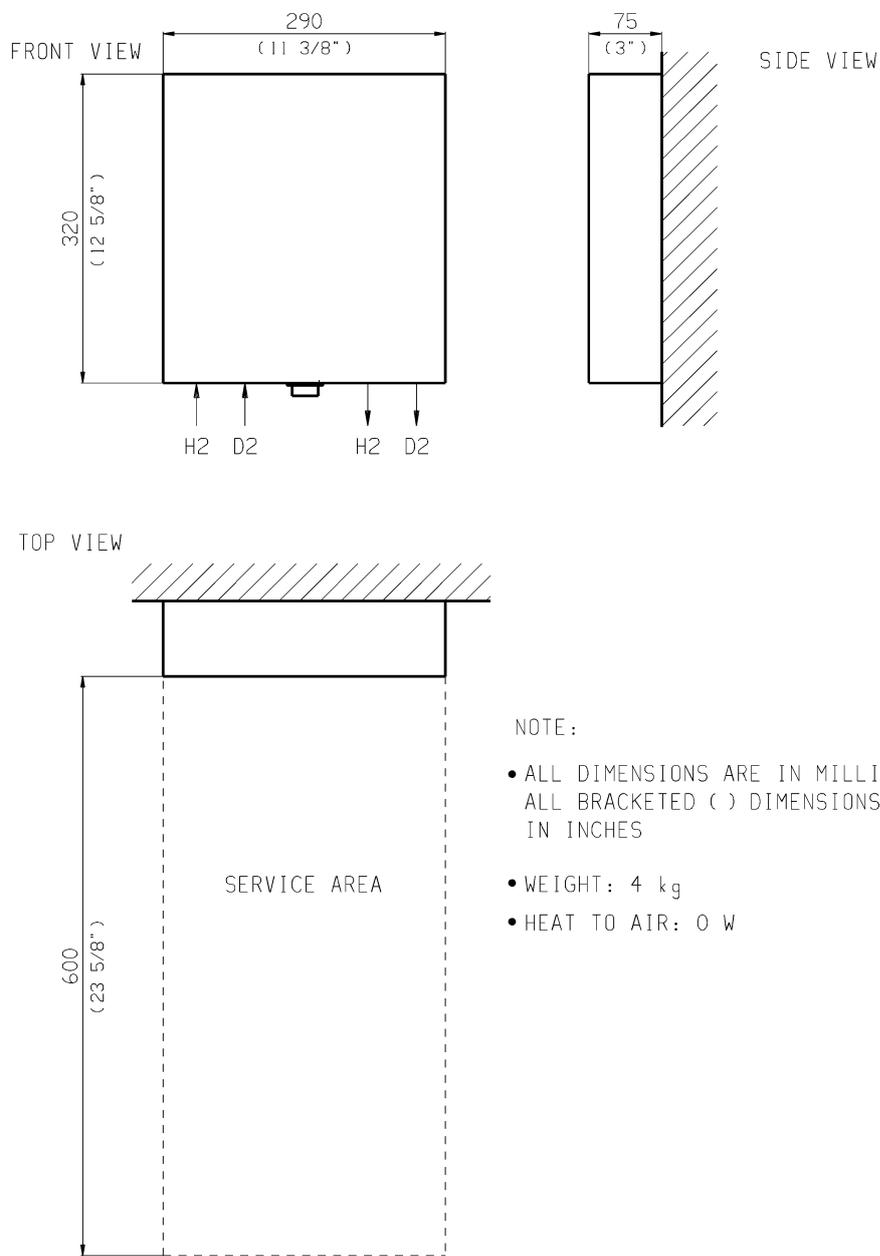
NOTE:

- ALL DIMENSIONS ARE IN MILLIMETERS.  
ALL BRACKETED ( ) DIMENSIONS ARE IN INCHES
- WEIGHT: 50 kg
- HEAT TO AIR: 100 W
- TRANSFORMER WEIGHT: 105 kg
- TRANSFORMER HEAT TO AIR: 250 W
- INDICATES CENTER OF GRAVITY. 



PDU WITH SHIELD

Figure 2-18: Ion gas manifold

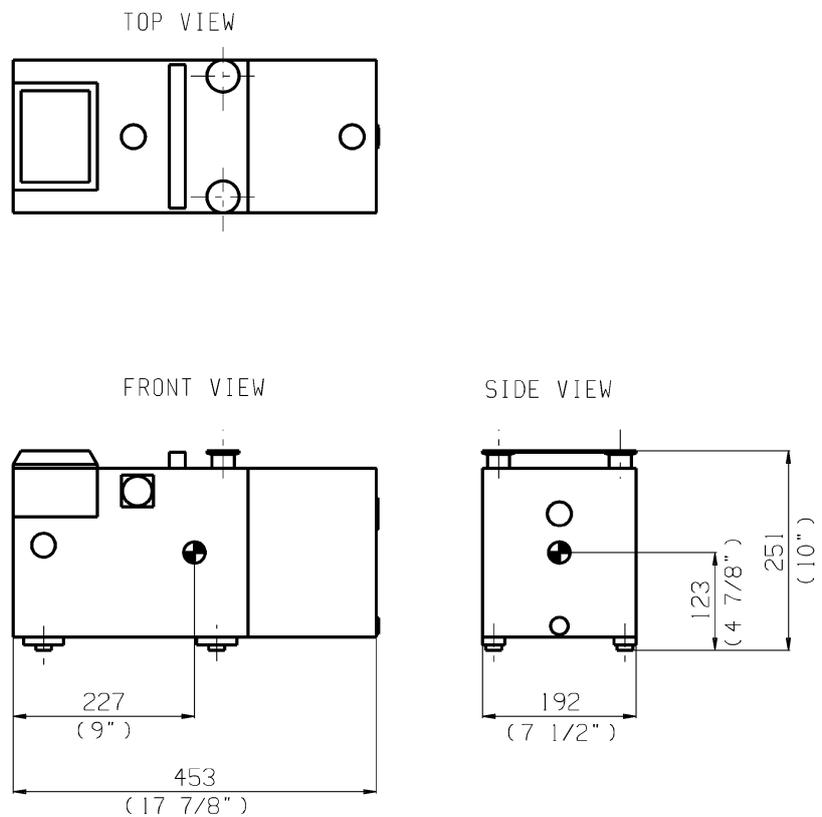


ION SOURCE GAS MANIFOLD

Figure 2-19: Roughing vacuum pump

NOTE:

- ALL DIMENSIONS ARE IN MILLIMETERS.  
ALL BRACKETED ( ) DIMENSIONS ARE IN INCHES
- WEIGHT: 27 kg
- HEAT TO AIR: 100 W
- INDICATES CENTER OF GRAVITY. 

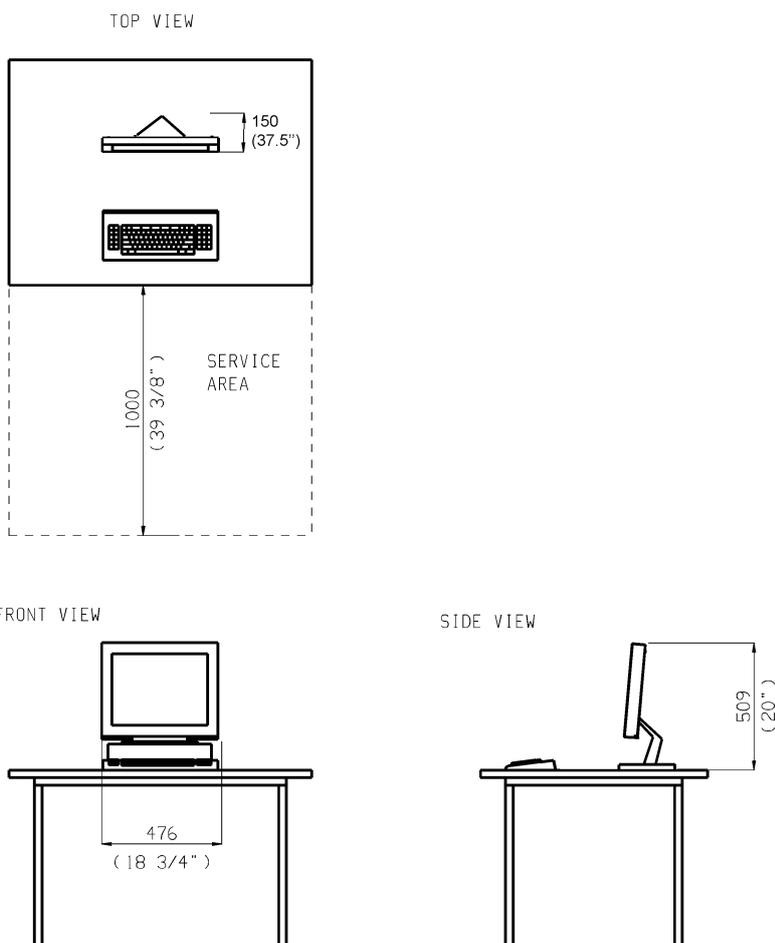


MECHANICAL VACUUM PUMP

Figure 2-20: Master System

NOTE:

- ALL DIMENSIONS ARE IN MILLIMETERS.  
ALL BRACKETED ( ) DIMENSIONS ARE IN INCHES
- WEIGHT: 16 kg
- HEAT TO AIR: 300 W



MASTER SYSTEM

**Note!**  
Customer provides desk or table, and chair.

Figure 2-21: Secondary Water Cooling Unit (WCU)

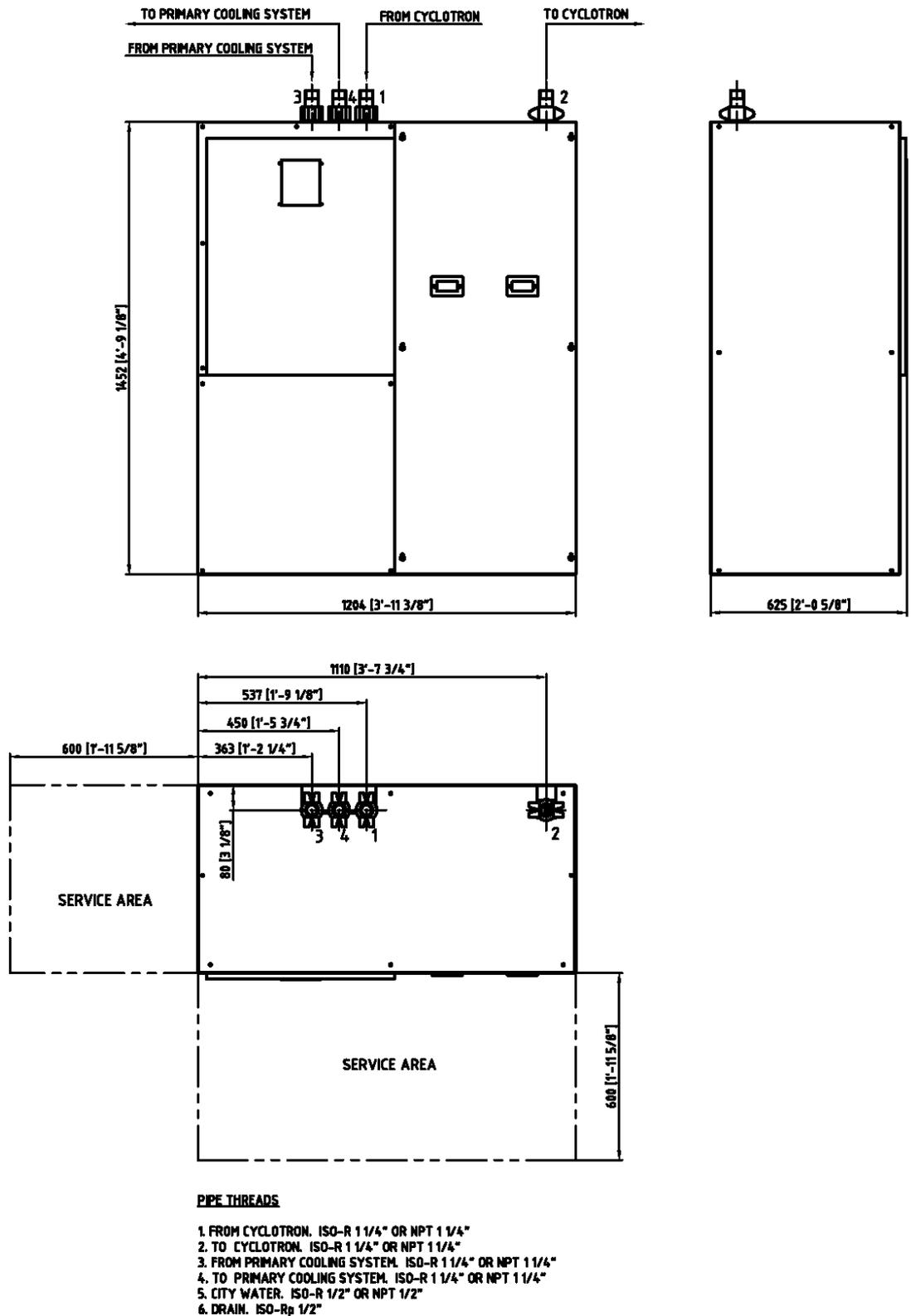


Figure 2-22: Water manifold 1

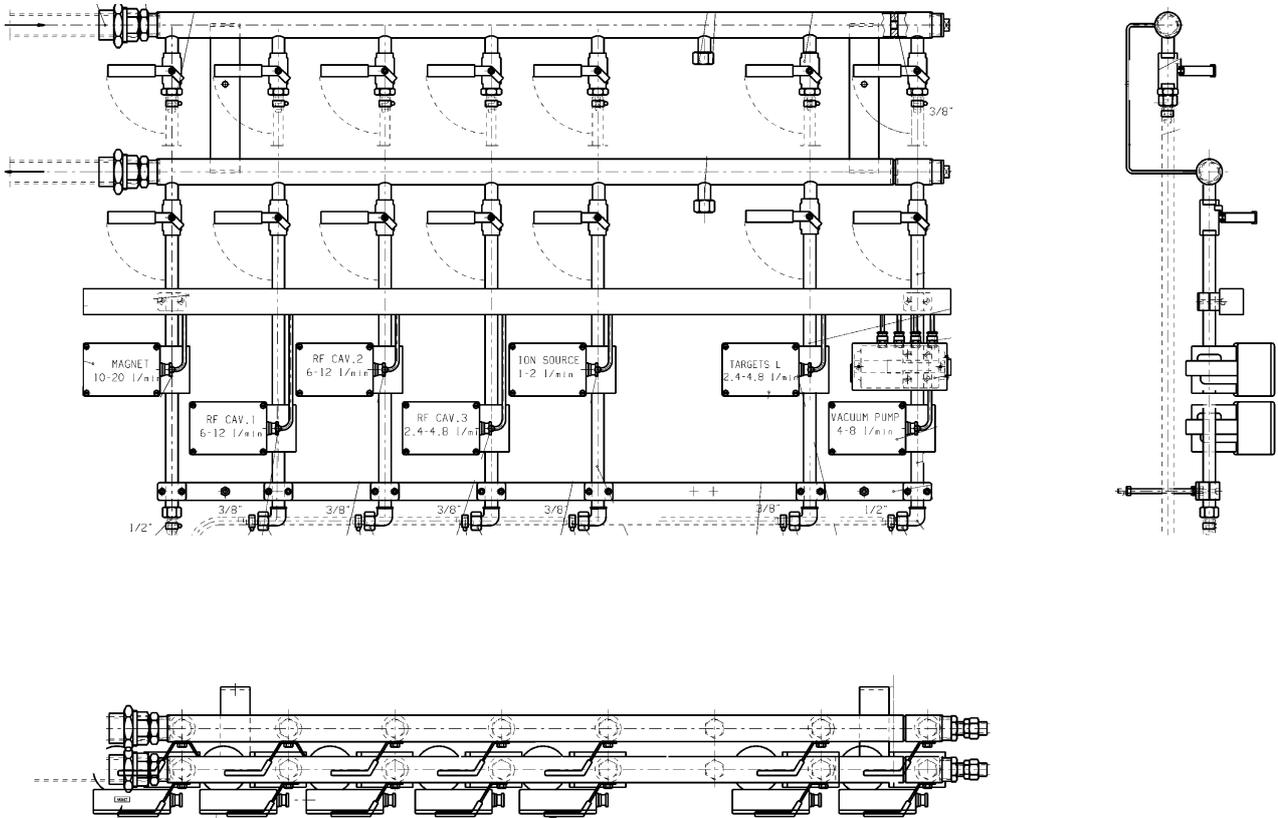
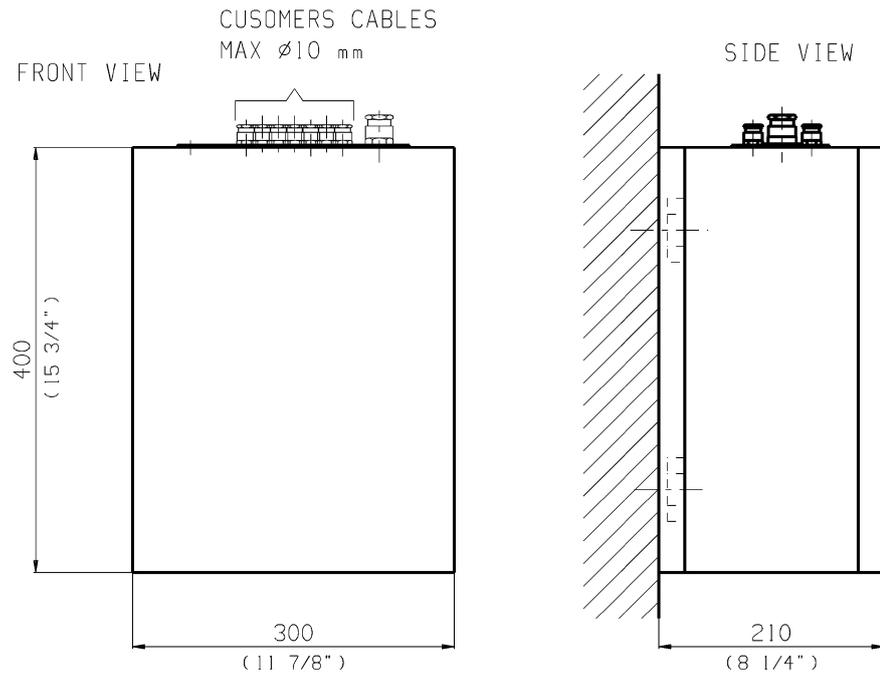


Figure 2-23: Customer Interface Box (CIB)

NOTE :

- WEIGHT: 5 kg



NOTE :

- ALL DIMENSIONS ARE IN MILLIMETERS.  
ALL BRACKETED ( ) DIMENSIONS ARE IN INCHES
- WEIGHT: 10 kg
- HEAT TO AIR: 0 W

CUSOMERS INTERFACE BOX

Figure 2-24: Optional Integrated Radiation Shield (IRS)

NOTE:

- ALL DIMENSIONS ARE IN MILLIMETERS.  
ALL BRACKETED ( ) DIMENSIONS ARE IN INCHES
- WEIGHT: 47000 kg
- INDICATES GEOMETRIC CENTER ●

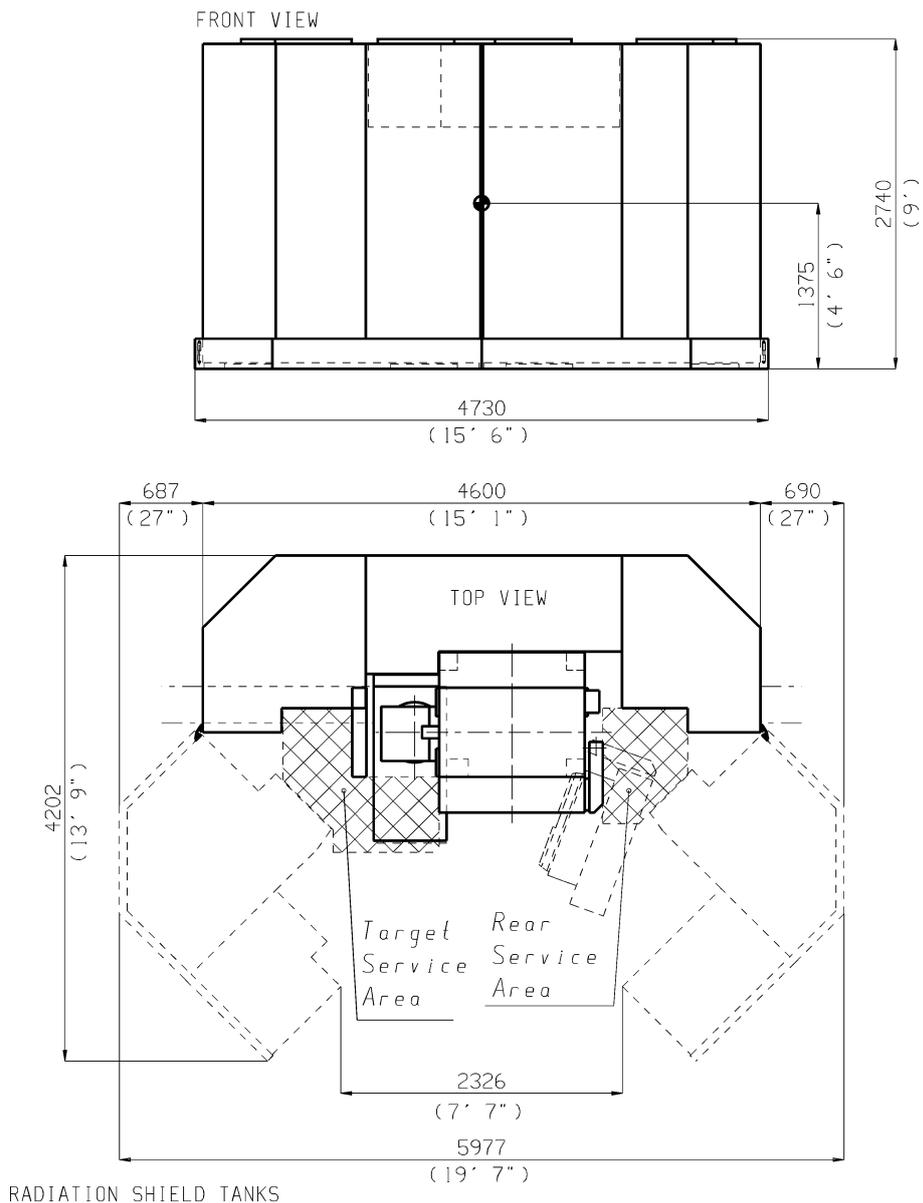
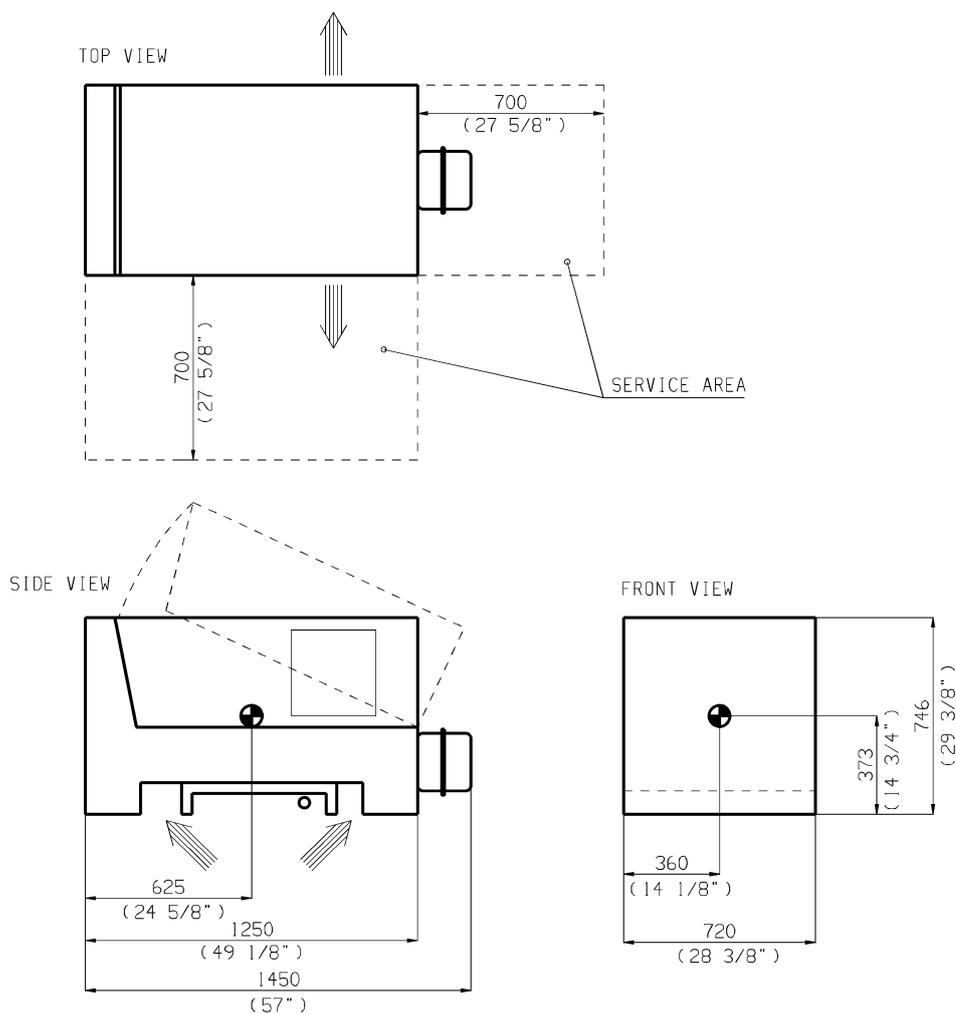


Figure 2-25: Compressor – part of IRS option

NOTE:

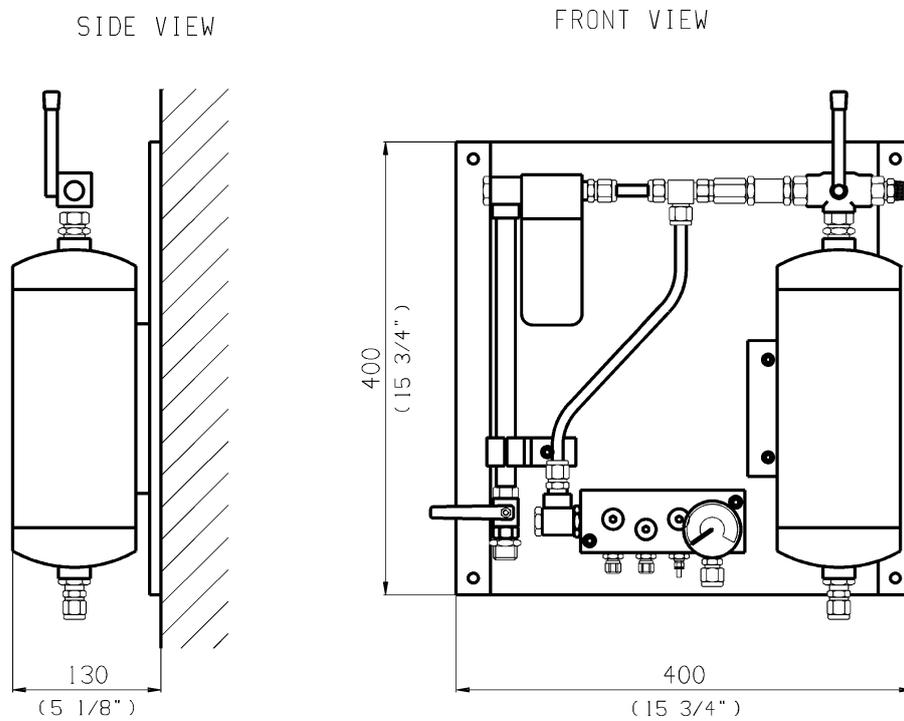
- ALL DIMENSIONS ARE IN MILLIMETERS.  
ALL BRACKETED ( ) DIMENSIONS ARE IN INCHES
- WEIGHT: 173 kg
- INDICATES AIR FLOW. 
- INDICATES CENTER OF GRAVITY. 



( ONLY FOR RADIATION SHIELD OPTION )

COMPRESSOR

Figure 2-26: Compressed air manifold



NOTE:

- ALL DIMENSIONS ARE IN MILLIMETERS.  
ALL BRACKETED ( ) DIMENSIONS ARE IN INCHES
- WEIGHT: 6 kg
- HEAT TO AIR: 0 W

AIR MANIFOLD

Figure 2-27: Process Cabinet (ProCab)

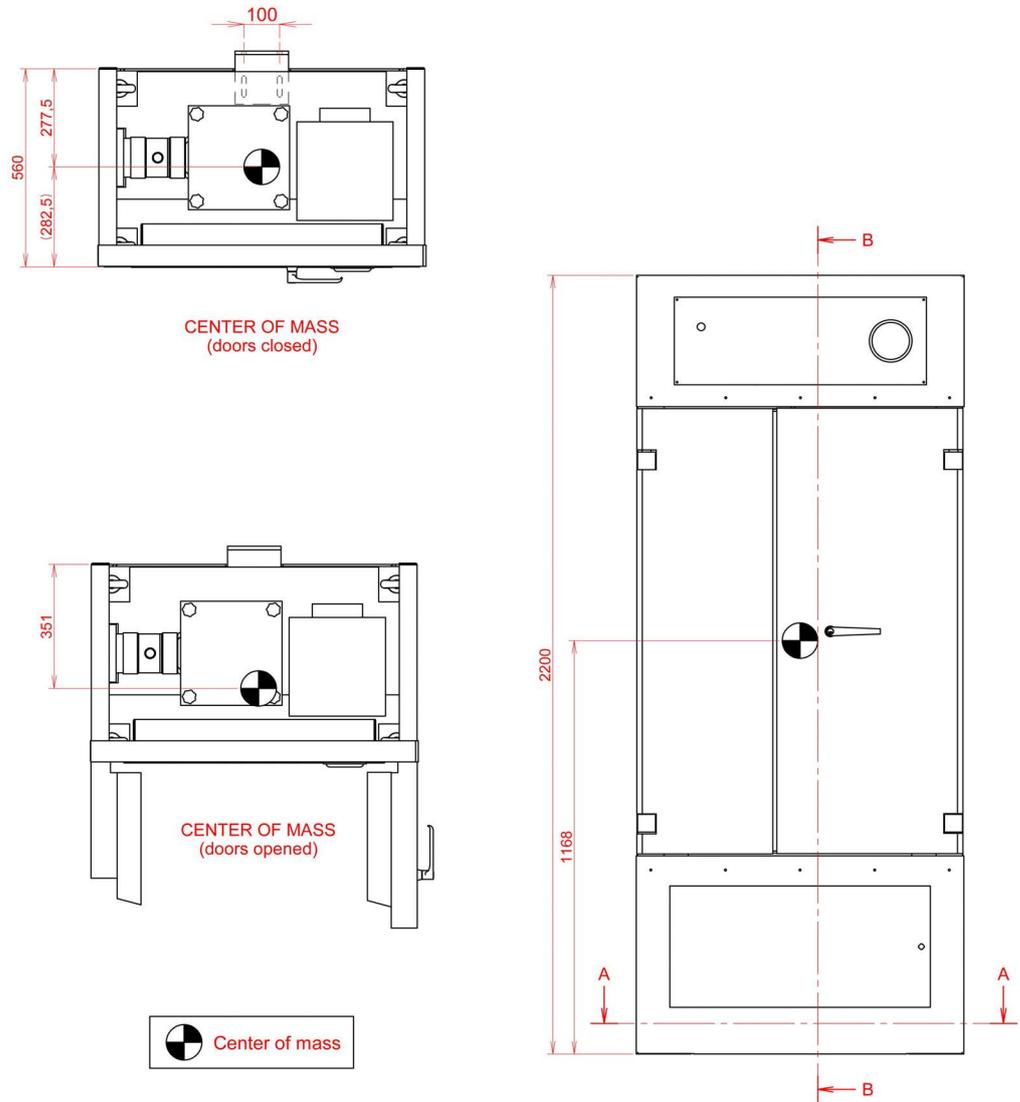
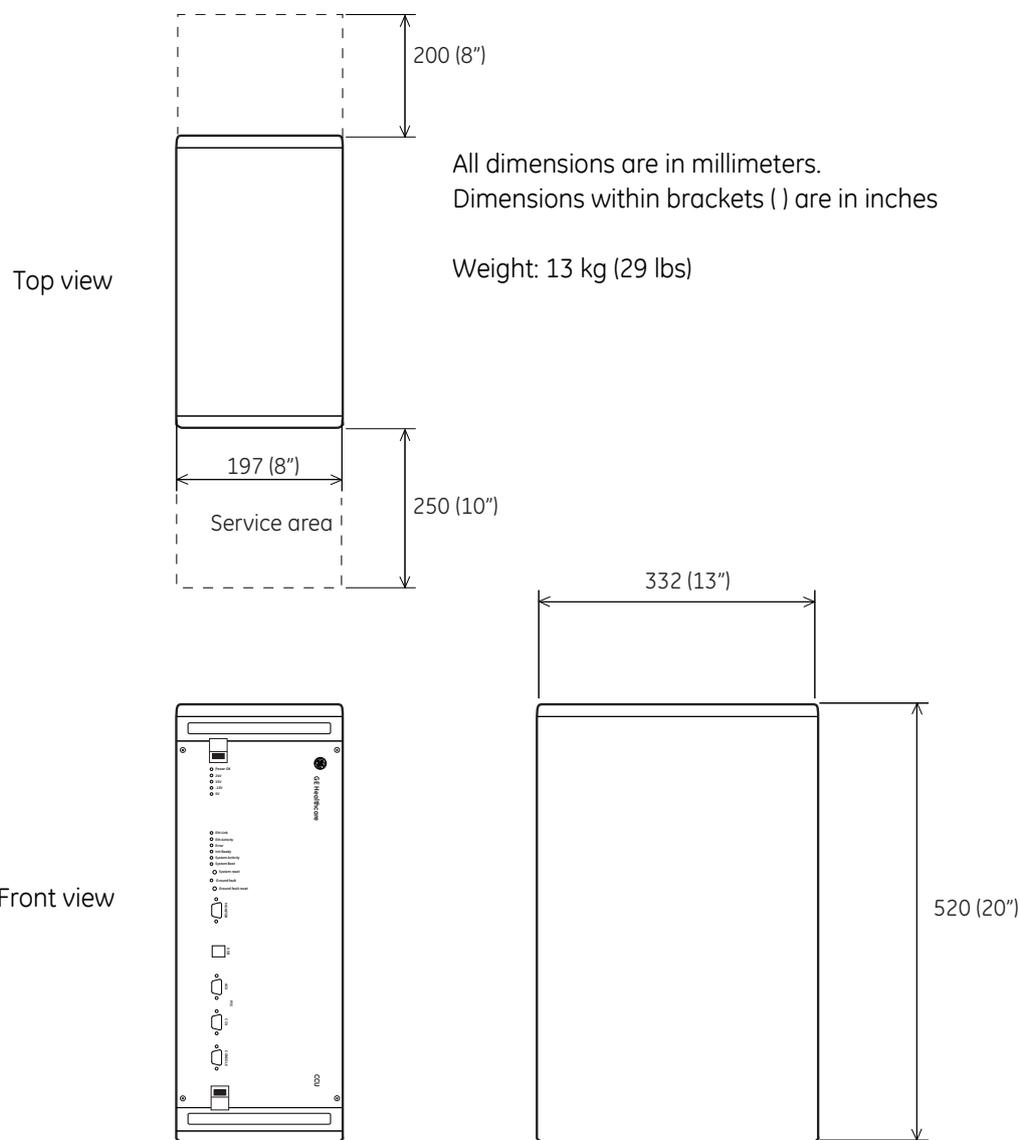


Figure 2-28: Chemistry Control Unit (CCU) – part of ProCab option -or- separate option



- Provide sufficient free space around the CCU in order to maintain the ambient temperature requirements (see [Table 5-1](#)).

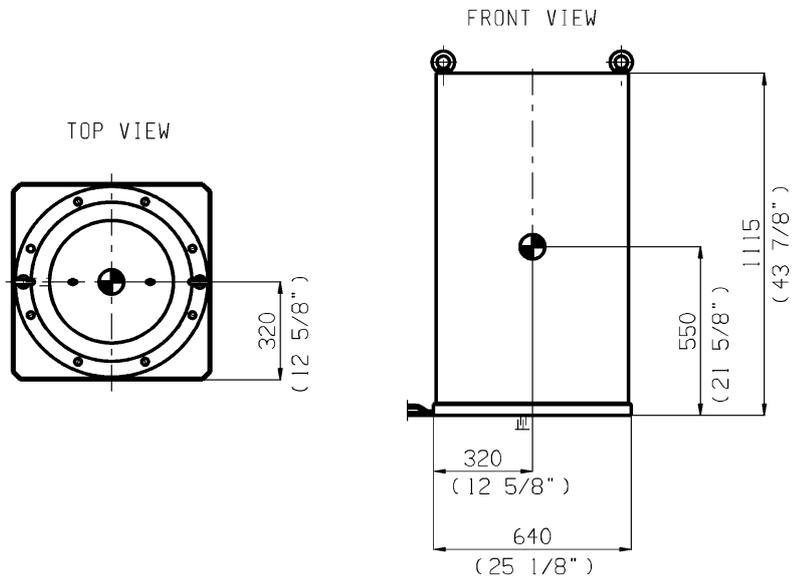
Do not block the air inlets or outlets on the CCU!

- The CCU should be placed on the floor in either vertical or horizontal position.

Figure 2-29: Optional waste gas unit

NOTE:

- ALL DIMENSIONS ARE IN MILLIMETERS.  
ALL BRACKETED ( ) DIMENSIONS ARE IN INCHES
- WEIGHT: 1400 kg
- INDICATES CENTER OF GRAVITY. 



WASTE GAS SYSTEM



## 3 RADIATION SHIELDING AND SAFETY REQUIREMENTS

### 3-1 Introduction

This chapter presents an overview of the radiation shielding and safety requirements to observe during the planning, design and construction of the cyclotron facility.

Hire a facility designer with a working knowledge of the available publications concerning radiation safety and radiation shielding. Hire experts in shielding design and the handling of radioactive materials, who can implement a PET facility radiation safety program.

At the minimum the designer must read and understand the following publications:

- [NCRP Report No. 51](#) – Radiation Protection Design Guideline for 0.1 to 100 MeV Particle Accelerator Facilities
- [NCRP Report No. 38](#) – Protection Against Neutron Radiation
- [NCRP Report No. 39](#) – Basic Radiation Protection Criteria
- [American National Standard N43-4](#) – Safety in the Design and Operation of Particle Accelerators
- [OSHA Standards](#) – Part 1920.96 (Ionizing Radiation) of Chapter XVII of title 29 of the code of Federal Regulations

The information in this chapter was gathered to assist the Purchaser in determining the resource requirements for the architectural and radiation shielding design, and radiation safety program implementation of a PET facility. The Purchaser (and the GE site planning group) still must approve the final design.

The radiation sources discussed herein may be subject to regulations by federal, state, or local governmental agencies. Such regulations may involve registration, licensing, and compliance with specific radiation handling procedures. The Purchaser has the responsibility to determine what the requirements are and to see to their compliance.

### 3-2 Materials and methods

#### 3-2-1 General

The cyclotron produces two kinds of charged particles, protons with an energy of 16.5 MeV and deuterons with an energy of 8.4 MeV. The beam current can for example be 75  $\mu\text{A}$  for protons and 60  $\mu\text{A}$  for deuterons, depending on the performance option installed.

The primary beam is stopped very quickly when it interacts with matter and it does not in itself produce any radiation protection problems. In the process of being stopped, the proton or deuteron beam produce secondary particles, neutrons, which create the primary radiation shielding problem.

The neutrons have a considerable penetrating power and their energy define the thickness of the biological protection around the accelerator, i.e. how thick the concrete wall and the roof have to be. In addition, the charged particle beam and the primary and secondary neutrons produce induced radioactivity in the material being hit. This induced radioactivity is a primary problem of concern within the cyclotron vault but does not influence the building design except for the requirement for some shielded space for the storage of radioactive components.

The system is available in two configurations:

- 1 Unshielded, requires a concrete vault
- 2 With integrated radiation shield (optional)

### 3-2-2 Protection against neutrons

The charged particle beam has a well defined direction. When the beam interacts with matter neutrons are produced, which basically will have the same direction as the charged particle beam. These forward directed neutrons have the highest energy and are referred to as the primary neutron burst.

However, neutrons will be emitted in other directions as well, but their intensity and energy will be significantly lower. Therefore, for these types of calculations we assume that the neutron flux perpendicular to the charged particle beam will be less than 30% of the neutrons in the forward directions and that the neutron flux in the backward direction is at least 10 times lower than in the forward direction. These assumptions are conservative and provides certain safety margin. See [Table 3-1](#) for typical neutron production rates.

When the primary neutrons hit walls and other material in the room more than 90% will be absorbed but about 10% will be reflected back into the room but with much lower energy. After a few such reflections the neutrons have almost totally been thermalized and one has a neutron "gas" in the room without any specific component of direction.

The primary neutron burst in the forward direction is an important component for the radiation shielding calculations as this burst contains the highest neutron density. It is important that this burst is primarily directed towards areas having a natural radiation protection, e.g. outer walls with soil on the other side and away from areas where personnel will stay for a longer period of time. The primary source of neutron burst is the target area where 100% of the extracted beam is interacting with matter.

The neutron burst from the target area should thus be directed away from the laboratory areas as much as possible.

A common principle is that the closer the radiation shield is positioned around a concentrated radiation source the lower mass of protection material is required. Half of all neutrons produced are in the forward direction (within a cone with the top angle of about 30°).

It may therefore be convenient to equip the target positions with dumps, i.e. tubes in the walls of a few meters length or movable concrete blocks with corresponding holes. Such a shield is not only convenient to reduce the total mass of concrete in the radiation shield but it also protects other equipment in the vault against high neutron doses.

The iron yoke of the accelerator has a thickness of 27.5 cm. This corresponds to about 65 cm of concrete with a density of 2.3 g/cm<sup>3</sup>. As this shield is situated close the radiation sources the accelerator should be positioned such that it provides a maximum contribution to the total shielding.

### 3-2-3 Worst case

For an accelerator with these particle energies it is the neutron flux alone which determines the thickness of the concrete, that means that the neutron energies contribute only to a small amount. The reason is that after penetration of a few decimeter of concrete the neutron energies have mainly been degenerated such they have the same neutron spectrum.

The National Council for Radiation Protection and Measurement, NCRP, has published a book titled "Radiation Protection Design Guidelines for 0.1-100 MeV Particle Accelerator Facilities" (NCRP Report No. 51). Approximate estimations of the neutron flux and wall thickness can be derived from this handbook.

**Table 3-1: Neutron flux**

Particle	Energy (MeV)	Beam current (μA)	Target material	Neutron flux (neutrons/cm <sup>2</sup> /s) forward	Neutron flux at 90 degrees
p+	16.4	100	Al	3 × 10 <sup>7</sup>	9 × 10 <sup>6</sup>
d+	8.5	100	C	5 × 10 <sup>7</sup>	15 × 10 <sup>6</sup>
d+	8.5	100	Cu	5 × 10 <sup>6</sup>	15 × 10 <sup>6</sup>

There is no significant difference of the neutron flux produced during the acceleration of protons or deuterons. As the proton case gives higher neutron energies and a larger buildup factor in the radiation shield this case has been considered the worst case.

### 3-2-4 Vault apertures and penetrations

The radiation calculations must take personnel passages and penetrations for cables and piping into consideration. Use one of the following methods to provide personnel access to the cyclotron:

- Shielded door in the form of a plug door or a movable block
- Maze

### 3-2-4-1 Shielded door

Such a door can be arranged in many different ways, either as a plug in the wall or as a movable block to protect the hole in the concrete wall. A plug in the wall often has the same equivalent thickness as the surrounding radiation shielding wall and is often made of the same material, e.g. concrete.

In order to make a movable block thinner another material, such as steel, can be used. Radiation door shielding effectiveness is relatively easy to calculate. The disadvantages are that they can be relatively expensive, mechanically complex and do not allow fast access to the vault.

Advantages:

- Easy to calculate shielding effectiveness, especially when using the same material and thickness as the surrounding walls
- Requires less floor space than a maze; door can swing on hinges or slide to one side

Disadvantages:

- Relatively expensive
- Mechanically complex
- Impedes fast access to the vault

### 3-2-4-2 Maze

By making the maze to the vault long, with multiple legs and angled it is possible to achieve a large reduction of the neutron flux. The entrance door may therefore be a light structure, occasionally reinforced with a layer of thermal neutron shielding protection such as boron loaded polyethylene. More careful computations using a Monte-Carlo simulation program can be performed after the selection of the principle layout.

Advantages:

- Access door easier to open; no mechanical assistance required
- Provides faster access to the vault

Disadvantages:

- More difficult to calculate shielding effectiveness
- Occupies more floor space than a vault hatch

### 3-2-5 Radiation area descriptions

#### 3-2-5-1 High radiation areas

The space housing the cyclotron, is the “cyclotron room” and as such is considered a HIGH RADIATION AREA. The following features should be included in the design of this area.

- Appropriate cyclotron operation state signs should be placed at the control console and at the entrance to the cyclotron room.
- Doors or barriers should be provided and interlocked in such a way that ion beam operation is impossible with an open door and is stopped if the door is opened.
- Provision should be made for an available indication (signal indication available) that the beam is about to be turned on.
- At least one clearly marked emergency beam off switch should be conveniently located in the cyclotron room to make ion beam operation impossible.
- It must be possible to open access doors from the inside of the cyclotron room.
- Motor or hydraulic driven doors must have manual operated override options.

The most commonly produced short-lived positron emitters include Carbon-11, Nitrogen-13, Oxygen-15 and Fluorine-18. The cyclotron produces and transfers batches containing up to 5 Ci between the target station and the hot cells. These radioisotopes are transported in small diameter tubes, which are typically covered with 3–5 cm of lead for protection. Capacity of shielding has to follow local regulations.

**Note!**

*Patient doses are ranging from 5–20 mCi.*

#### 3-2-5-2 Radiation areas

Any area where radioisotopes are prepared or used is designated a RADIATION AREA. These areas are restricted to protect individuals from exposure to radiation. In addition to the radiochemical laboratory, RADIATION AREAS include the PET scanner room, the blood lab, any related quality control area(s) and the area adjacent to the integrated radiation shield.

**Note!**

*The optional integrated radiation shield for the cyclotron has two pneumatically operated front sections, which open the shield to provide access to the cyclotron and target area. The movable sections are electrically interlocked to prevent ion beam operation (beam on) when the shield is open.*

#### 3-2-5-3 Unrestricted areas

Areas contiguous to the PET facility considered to be unrestricted do not require radiation monitoring unless the regulations call for other requirements.

#### 3-2-5-4 Optional integrated radiation shield performance

The optional integrated radiation shield provides an alternative to the cost of retro-fitting an existing building with about 2 meters of concrete to shield the cyclotron.

The integrated shield is comprised of eight water filled stainless steel tanks, designed to attenuate neutron and gamma radiation through the use of a sandwich construction. The inner layer of lead, close to the targets, reduces gamma flux from the targets and the layer of boron loaded polyethylene (PE) moderates the neutron. Additional layers of lead captures the gammas created by slow neutrons in the cyclotron components. The boronated water filled tanks stops the remaining neutrons.

Enclosing the cyclotron in the integrated radiation shield, reduces the radiation in the area surrounding of the shield to low dose rates. A concrete wall, with a suitable thickness around the cyclotron room, might be necessary to meet lower dose rates in the vicinity of the cyclotron.

In order to estimate the wall dimensions (concrete) for the cyclotron room the following approximate 1/2-value thickness can be applied (according to Monte Carlo simulations specifically made for this cyclotron):

- For gamma attenuation: **12 cm**
- For neutron attenuation: **8 cm**

Figure 3-1 to Figure 3-6 illustrate the gamma and neutron dose rate contours (radiation levels) for the integrated radiation shield during the following operating conditions:

- $^{18}\text{F}$ - production with enriched oxygen-18 water (> 95%)
- Total beam currents of 60  $\mu\text{A}$ , 100  $\mu\text{A}$ , and 130  $\mu\text{A}$ , respectively.

**Note!**

*The radiation level increase in proportion to a higher beam current.*

#### 3-2-5-5 Accuracy of neutron and gamma dose rate contours

The given dose rate contours have tolerances.

Variations can be related to:

- Variations in mechanical set-up.
- Interactions with adjacent concrete walls (reflected neutrons).
- Accuracy of measurement grid.
- Instrument tolerances (see note below).

A reasonable estimation of the tolerances of the given dose rates is in the order of  $\pm 20\%$  excluding the tolerances of the instruments.

**Note!**

*Typical instrument tolerances: Gamma monitor  $\pm 15\text{--}20\%$ , Neutron monitor  $\pm 40\%$ .*

Figure 3-1: Gamma dose rate contours on the radiation shield. Total beam current: 60  $\mu$ A

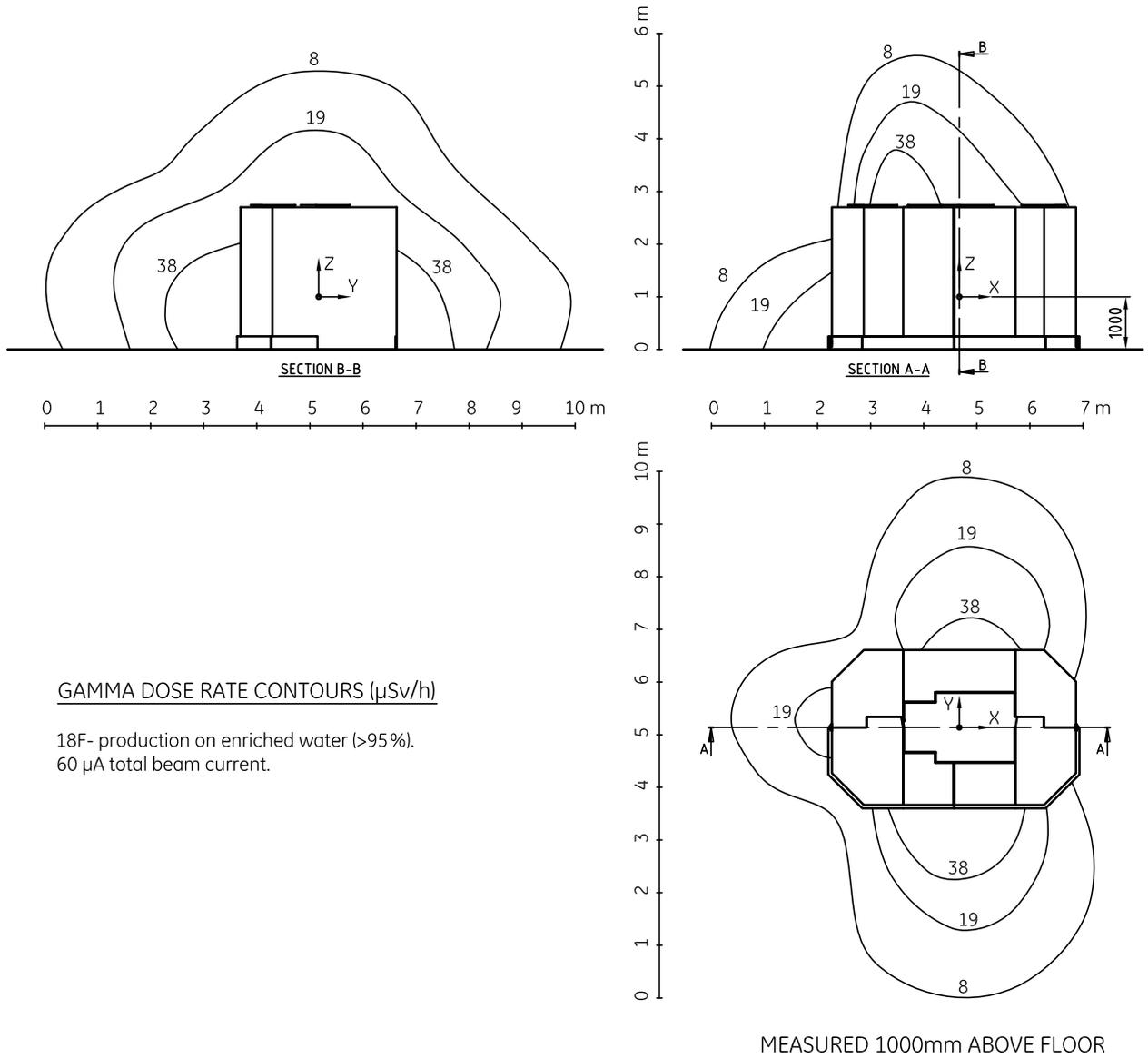


Figure 3-2: Neutron dose rate contours on the radiation shield. Total beam current: 60  $\mu$ A

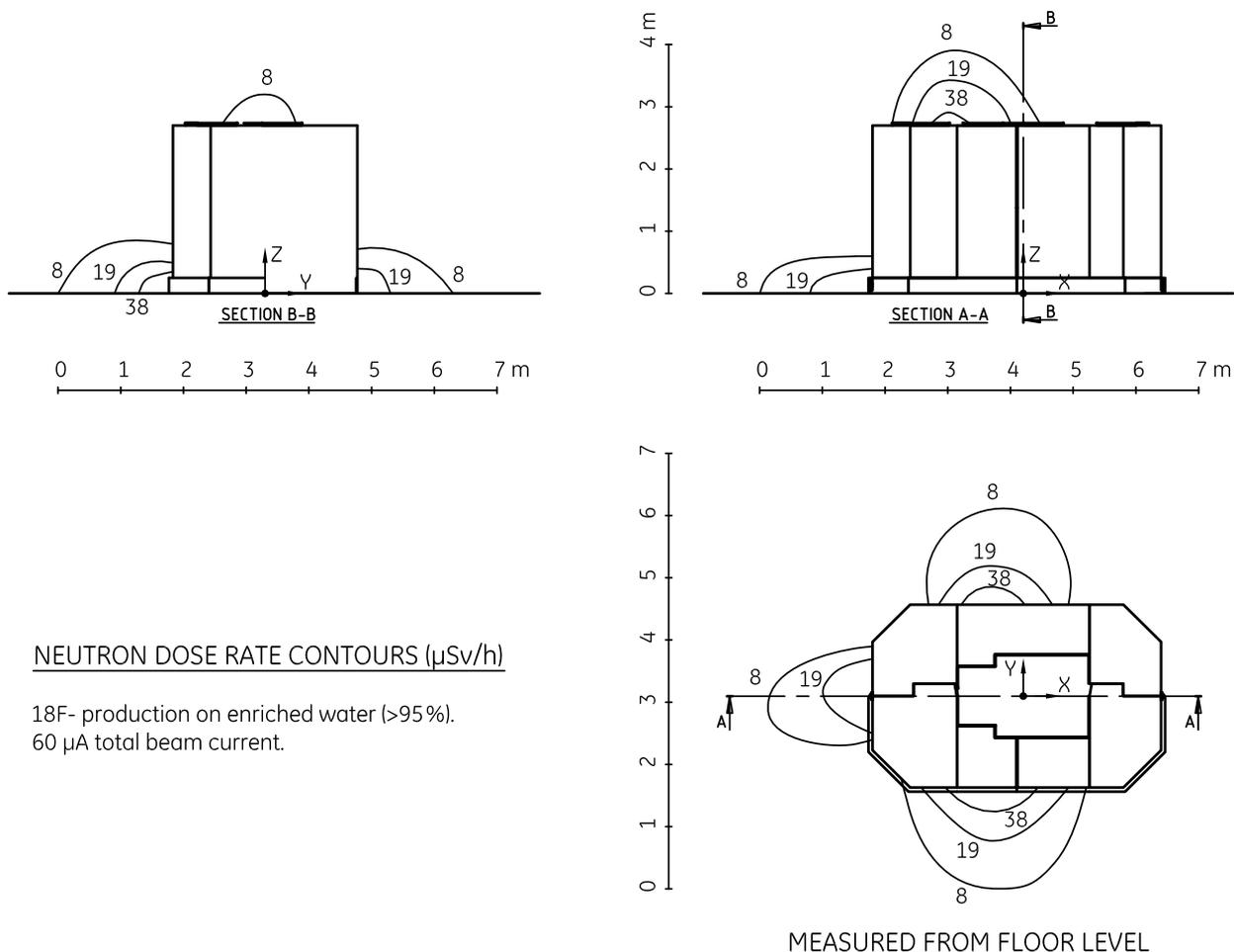


Figure 3-3: Gamma dose rate contours on the radiation shield. Total beam current: 100  $\mu$ A

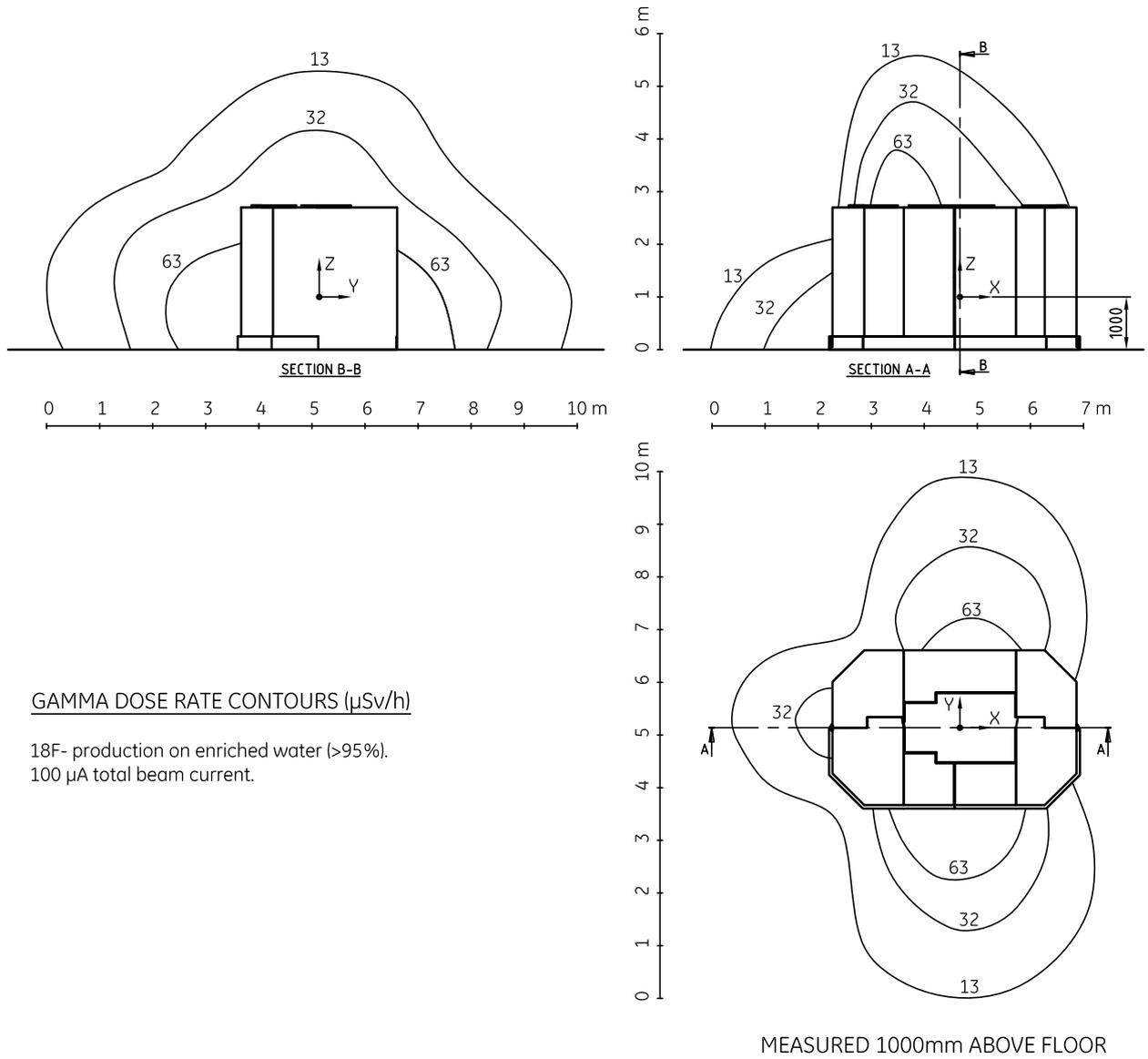


Figure 3-4: Neutron dose rate contours on the radiation shield. Total beam current: 100  $\mu$ A

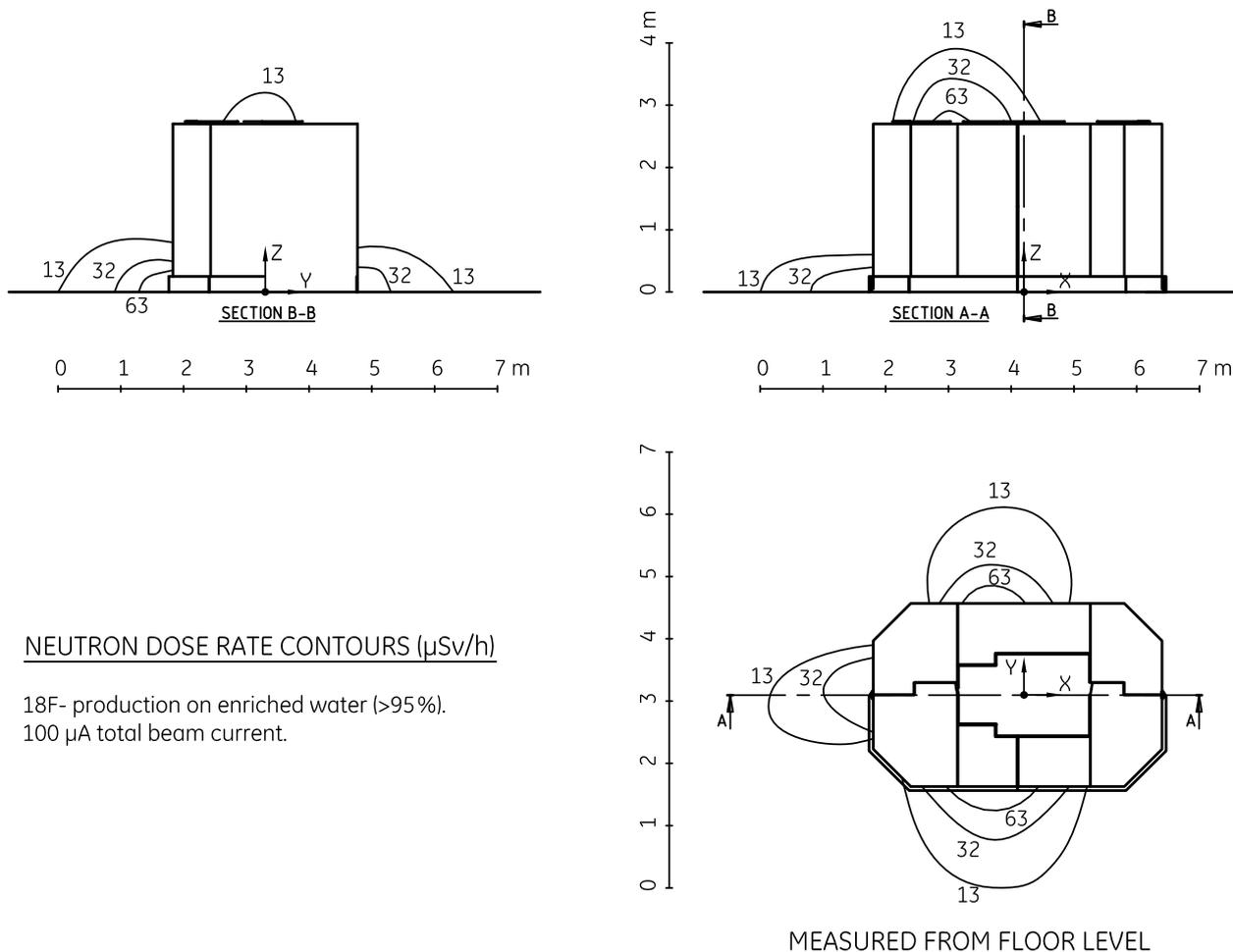


Figure 3-5: Gamma dose rate contours on the radiation shield. Total beam current: 130  $\mu$ A

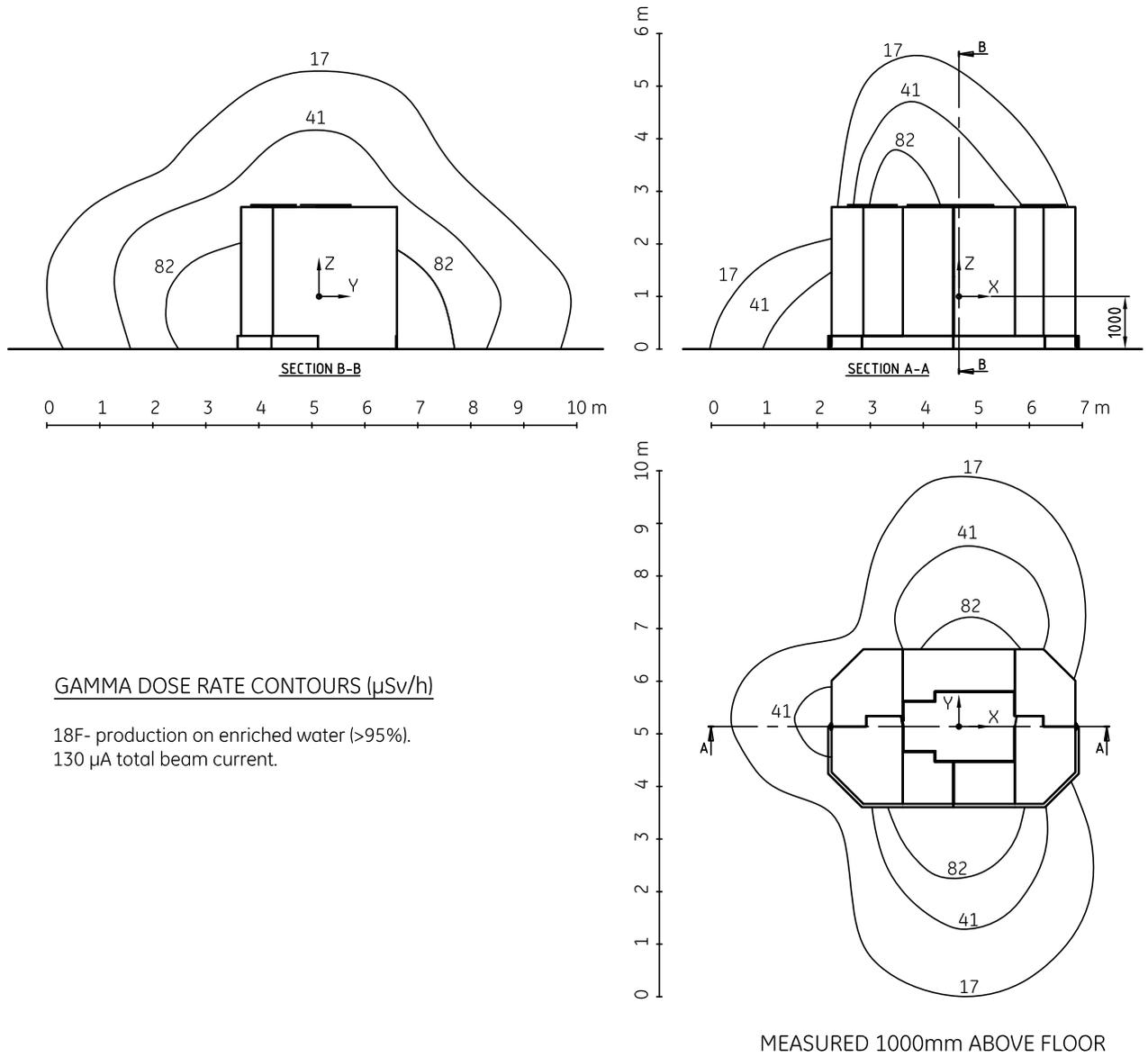
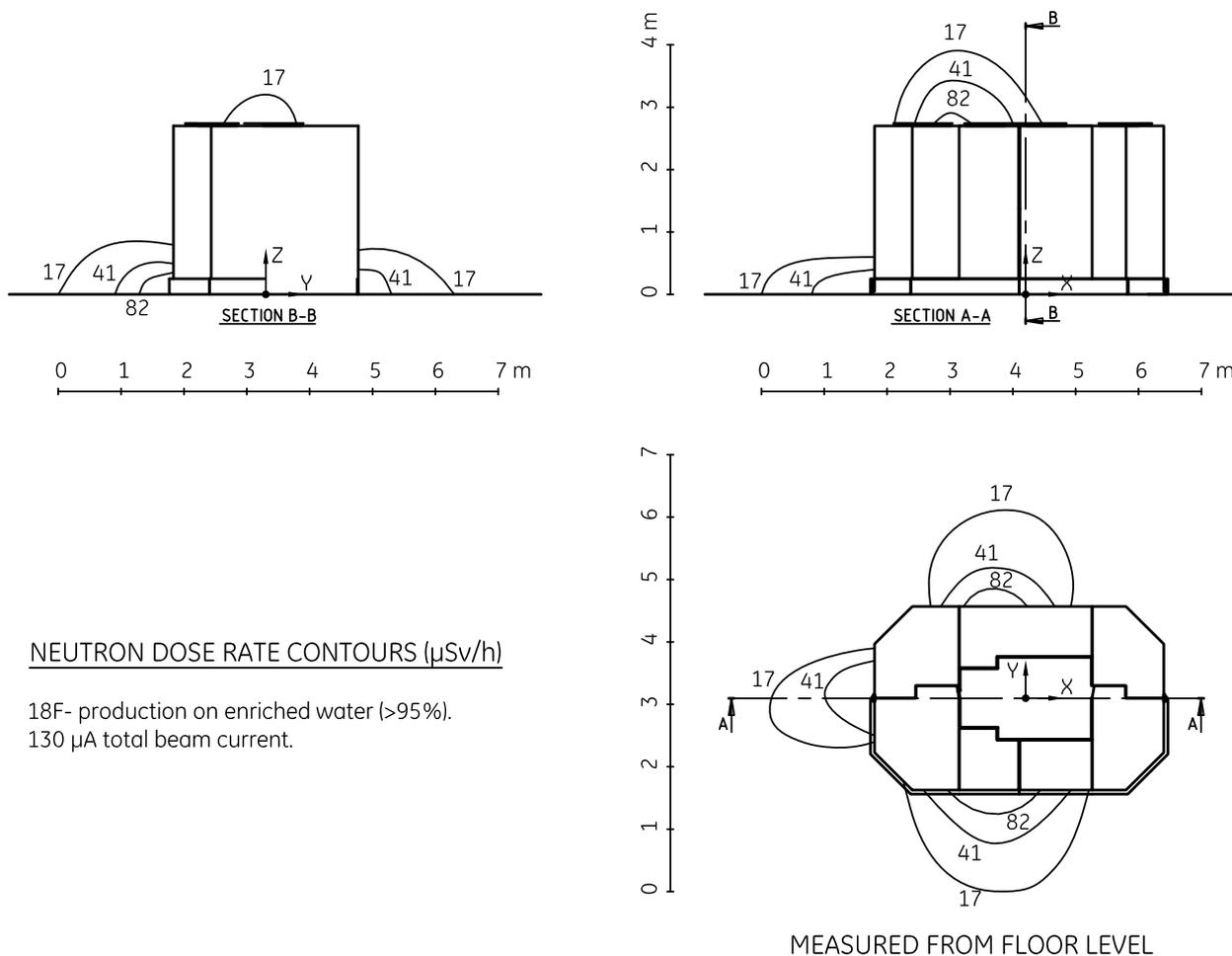


Figure 3-6: Neutron dose rate contours on the radiation shield. Total beam current: 130  $\mu$ A



### 3-2-6 Waste gas production

Radioactive gases from hot cells and process cabinets must decay before they can be released into the normal exhaust or ventilation system. The cyclotron produces relatively short lived radioactive gases (2 to 20 minutes) at the relatively slow rate of 1 l/min, so it requires a fairly small waste gas system for decay storage.

The waste gas unit is a separate option. It provides a cost effective way to store radioactive gases until they decay to acceptable levels. When customers buy the ProCab option, they usually purchase the waste gas unit, as well.

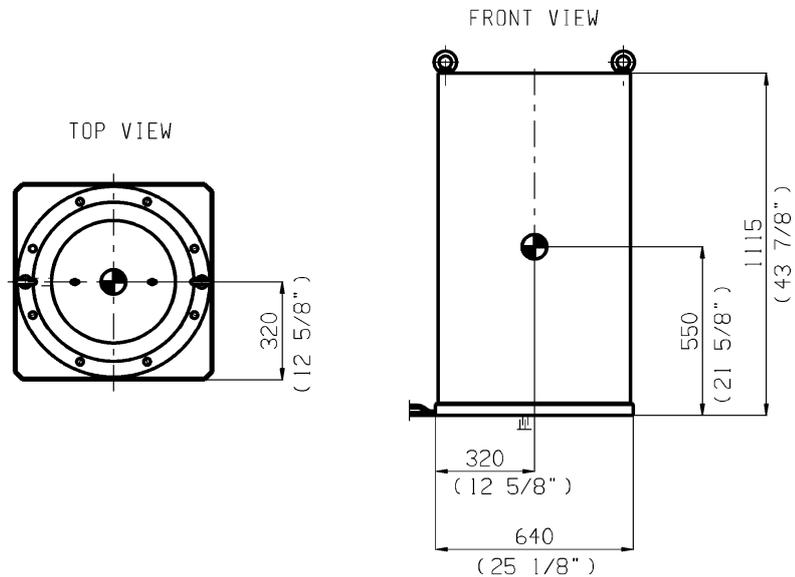
The waste gas unit has a lead shielded delay line with an effective volume of 60 liters. The effective volume equals the amount of radioactive gas that can constantly flow into the waste gas system before any radioactive gas flows out the exhaust. With a flow rate of 1 l/min, the 60 liter waste gas delay has the capacity to accept radioactive gas for one hour.

Position the waste gas unit close to the duct for gas pipes in the cyclotron room.

Figure 3-7: Waste gas unit

NOTE:

- ALL DIMENSIONS ARE IN MILLIMETERS.  
ALL BRACKETED ( ) DIMENSIONS ARE IN INCHES
- WEIGHT: 1400 kg
- INDICATES CENTER OF GRAVITY. 



WASTE GAS SYSTEM

**CAUTION!**

This low volume waste gas storage unit cannot accommodate a patient gas administration system, where the gas flow rate can exceed 30 l/min. If the facility requires a decay line for the patient gas administration system, select another solution.

## 3-3 Calculations

### 3-3-1 Radiation level calculations

Use the following calculations as a guideline to determine the radiation dose rates adjacent to the cyclotron vault, which in turn determine the required thickness of the concrete shielding wall surrounding the cyclotron.

The following sample calculations do not encompass all of the necessary calculations required for the successful design and construction of the cyclotron facility concrete vault or maze. The assumptions upon which these calculations are based, such as a concrete density of 2300 kg/m<sup>3</sup>, concrete water content, beam particle, beam energy, and target material may not apply to your project site.

Always consult an expert with experience in the design of cyclotron radiation shielding during the planning, design and construction phases of the cyclotron vault, shielding doors and mazes.

**Note!**

*The accuracy of the neutron transmission data (examples 1, 2 and 3) may be no better than a factor of 2, and a half-value layer of shielding material should be added to the calculated thickness for conservative design.*

- Reference for all calculations: NCRP Report No. 51
- Equation used during the following examples:

$$H = \frac{Q_0 \times B_n \times T}{k \times d^2}$$

Where:

- **H** = radiation level at reference point (mrem/h)
- **Q<sub>0</sub>** = the fluence rate at a standard reference distance of one meter (M.<sup>2</sup>/am<sup>2</sup> S.)
- **B<sub>n</sub>** = shielding transmission ratio (rem cm<sup>2</sup>)
- **k** = 2.8 × 10<sup>-7</sup> (h rem/s mrem)
- **d** = distance from source to reference point (meters)
- **T** = occupancy factor

### 3-3-1-1 Calculation of the radiation level outside the cyclotron room in an unrestricted and unoccupied area, such as a ventilation room

The neutron fluence rate for 75  $\mu\text{A}$  of protons is  $1.5 \times 10^7$  (ENTRAP report No 51, page 111).

A concrete thickness of 190 cm provides a shielding transmission value of  $4 \times 10^{-14}$  (NCRP report No 51, page 121).

The occupancy factor for the room equals 0.25 (ENTRAP report No 51, page 90).

The distance from the source to the reference point equals 5.3 M.

$$H = \frac{1.5 \times 10^7 \times 4 \times 10^{-14} \times 0.25}{2.8 \times 10^{-7} \times (5.3)^2} = 0.019 \frac{mrem}{h}$$

### 3-3-1-2 Calculation of radiation level outside the cyclotron room in a restricted and fully occupied area such as a laboratory, located perpendicular to the forward beam direction

The neutron fluence rate in the 90° direction for 75  $\mu\text{A}$  of protons equals  $4.5 \times 10^6$ . (NCRP report No 51, page 111).

A concrete thickness of 160 cm provides a shielding transmission value of  $3.5 \times 10^{-13}$  (NCRP report No 51, page 121).

The occupancy factor for the room equals 1.0 (NCRP report No 51, page 90).

The distance from the source to the reference point equals 4.2 m.

$$H = \frac{4.5 \times 10^6 \times 3.5 \times 10^{-13} \times 1}{2.8 \times 10^{-7} \times (4.2)^2} = 0.32 \frac{mrem}{h}$$

**Note!**

*Measurements made at a cyclotron indicate that the fluence rate in a direction perpendicular to the forward beam direction equals about 30% of the fluence rate in the forward direction.*

### 3-3-1-3 Calculation of radiation level outside the cyclotron room in a restricted and fully occupied area such as a laboratory, located perpendicular to the forward beam direction

The neutron fluence rate in the 90° direction for 75  $\mu\text{A}$  of protons equals  $4.5 \times 10^6$  (NCRP report no 51, page 111).

A concrete thickness of 195 cm provides a shielding transmission value of  $4 \times 10^{-14}$  (NCRP report no 51, page 121).

The occupancy factor for the room equals 1.0 (NCRP report no 51, page 90).

The distance from the source to the reference point equals 3.5 m.

$$H = \frac{4.5 \times 10^6 \times 4 \times 10^{-14} \times 1}{2.8 \times 10^{-7} \times (3.5)^2} = 0.052 \frac{mrem}{h}$$

### 3-3-2 Radiation intensity calculations

Use the following intensity calculations for any area/room in a PET facility.

Intensity (mrem/h) as function of:

- Activity in mCi
- Distance in meters
- Shielding half-value thickness in centimeters
- Shielding thickness in centimeters

for 511 keV gamma annihilation from beta positron-emission.

Use the following formula to calculate the level of intensity at a specific distance:

$$I = \text{constant} \times A/d^2$$

Where:

- **I** = intensity, mrem/h
- **A** = activity, mCi
- **d** = distance in meters
- **constant** = 0.592 (m<sup>2</sup> × mrem/h)/mCi

for 511 keV gamma annihilation from beta positron-emission.

*Example:* To calculate the intensity 1 Ci from a distance of 0.5 m: What is the level of intensity at the distance of 0.5 m for an activity of 1 Ci:

$$\frac{0.592 \times 1}{0.5 \times 0.5} = 2.368 \frac{\text{mrem}}{\text{h}}$$

The shielding decreases the intensity value by the following formula:

$$I_{\text{shield}} = I / (2^{(t/t_{1/2})})$$

Where:

- **I** = Intensity without shielding
- **I<sub>shield</sub>** = Intensity with shielding, in mrem/h
- **t** = thickness of shielding material, in centimeters
- **t<sub>1/2</sub>** = half-value thickness, in centimeters
- **t<sub>1/2</sub> lead** = 0.42 cm (lead at 511 keV gamma)
- **t<sub>1/2</sub> concrete** = 5 cm

*Example:* To calculate the level of intensity behind 6 cm of lead shielding:

$$I_{shield} = (2.368) / 2^{(6/0.42)} = 0.119 \frac{mrem}{h}$$

### 3-4 Decommissioning aspects of the cyclotron

Cyclotrons can in theory run forever, if the consumable components and parts that require maintenance are taken care of. The cyclotron technology is mature since its invention in the 1930's. Compact cyclotrons installed in the 1970's are still operational today and produce isotopes on a routine basis. The GE cyclotrons are by design intended to run for a long period of time. Thus, the need for decommissioning for new GE cyclotrons based on end-of-life is not the primary reason for decommissioning. With the rapid commercialization of PET tracer distribution industry and interest in novel research isotopes, there are other reasons why decommissioning may be required. These reasons are general and apply to overall cyclotron industry:

- The specific commercial entity housing cyclotron either loses interest in production of isotopes or goes out of business
- As cyclotrons are getting part of a commercial operation – the commercial terms on financing/loan may require asset repossession and redeployment
- Upgrade of hardware platform either for age or capability

The objective of this section is to outline key steps and issues involved in decommissioning of the GE cyclotrons. The basis of this section is published literature, personal communication with the experts in the field, consultations with experts within GE Healthcare.

There are some key aspects one needs to be aware of in decommissioning a cyclotron:

- Stopping the use and estimating a cool-down period
- Dismantling a cyclotron with the goal of redeployment
- Dose measurement and segregation of parts requiring special handling
- Disposal or storage of radioactive materials
- Decommissioning aspects of the vault
- Reassembly in the case of redeployment

Each of the above six steps requires in depth project management and comes with a cost and requires time. For further details and documentation regarding this matter, contact GE Healthcare. It should be noted that this section is considered to be guidelines and should be used as a reference. The specifics of time and cost depends on the specifics of the actual situation and must therefore be evaluated on case-by-case basis.

### **3-5 Interlocks and monitor systems**

The complete installation for radioactive isotope production must be designed for the safe handling of radioactivity with respect to personal safety of the staff and the surroundings. Regulations are set for such facilities by local and national authorities.

This safety consideration might include the building safety interlock system, surveillance equipment and radiation monitoring systems.

The building interlock system can be integrated into the cyclotron safety system to provide fail-safe operation.

Closed-circuit television and an intercom network are recommended for surveillance and communications. Radiation monitoring stations should be integrated into the facility plans.

### **3-6 Lock-Out and Tag-Out procedure**

The facility must be designed to help service personnel perform proper Lock-Out and Tag-Out (LOTO) procedure before service and maintenance. LOTO must be performed to avoid electrical shocks, exposure to hazardous gases, mechanical hazards and other personal injuries while performing maintenance and service on the cyclotron system.

It is the responsibility of the Purchaser to compile site-specific Lock-Out and Tag-Out (LOTO) procedures, in cooperation with GE, for the subsystems that are subject to LOTO.

## 4 MAGNETIC FIELD CONSIDERATIONS

### 4-1 Introduction

The three-dimensional static magnetic field extends into space above and below the magnet, as well as the surrounding space on the same level.

Objects within this three-dimensional space, such as PET scanners, nuclear cameras, MRIs, pacemakers, neurostimulators, structural steel and elevators can have an effect, and be effected by the magnetic field.

Examine all areas within this three-dimensional field, and identify any ferro-magnetic material that may interfere with or redirect the magnetic field. Remember to include any floors above and below the cyclotron room.

### 4-2 Exclusion zone

The recommended five gauss exclusion zones for cardiac pacemakers, neurostimulators and other biostimulation devices are shown in [Figure 4-1](#), [Figure 4-2](#) and [Figure 4-3](#).

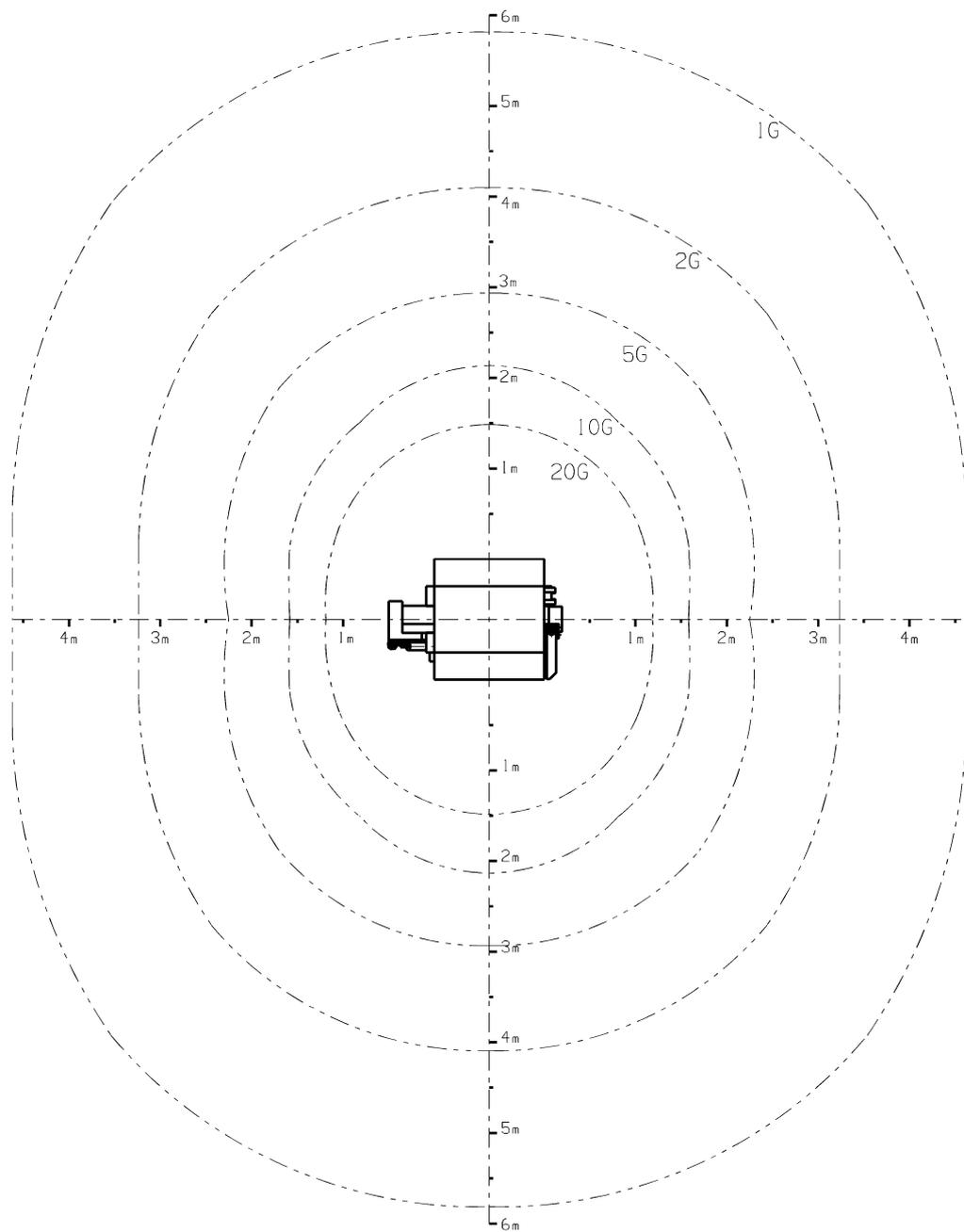
### 4-3 Magnetic shielding

When designing the site location, try to position the cyclotron room as far from any known source of magnetic interference as possible. If necessary, use magnetic shielding to reduce the fringe fields surrounding the cyclotron magnet to minimize the effects on the external environment. The shields usually consist of thick iron plates, built into the floor, walls and/or ceiling during construction of the PET suite.

The design of a magnetic shield requires a comprehensive computer analysis, which predicts the effect of the shield on the magnetic field. The structural capacity of the site, and available space, also impact the shield design.

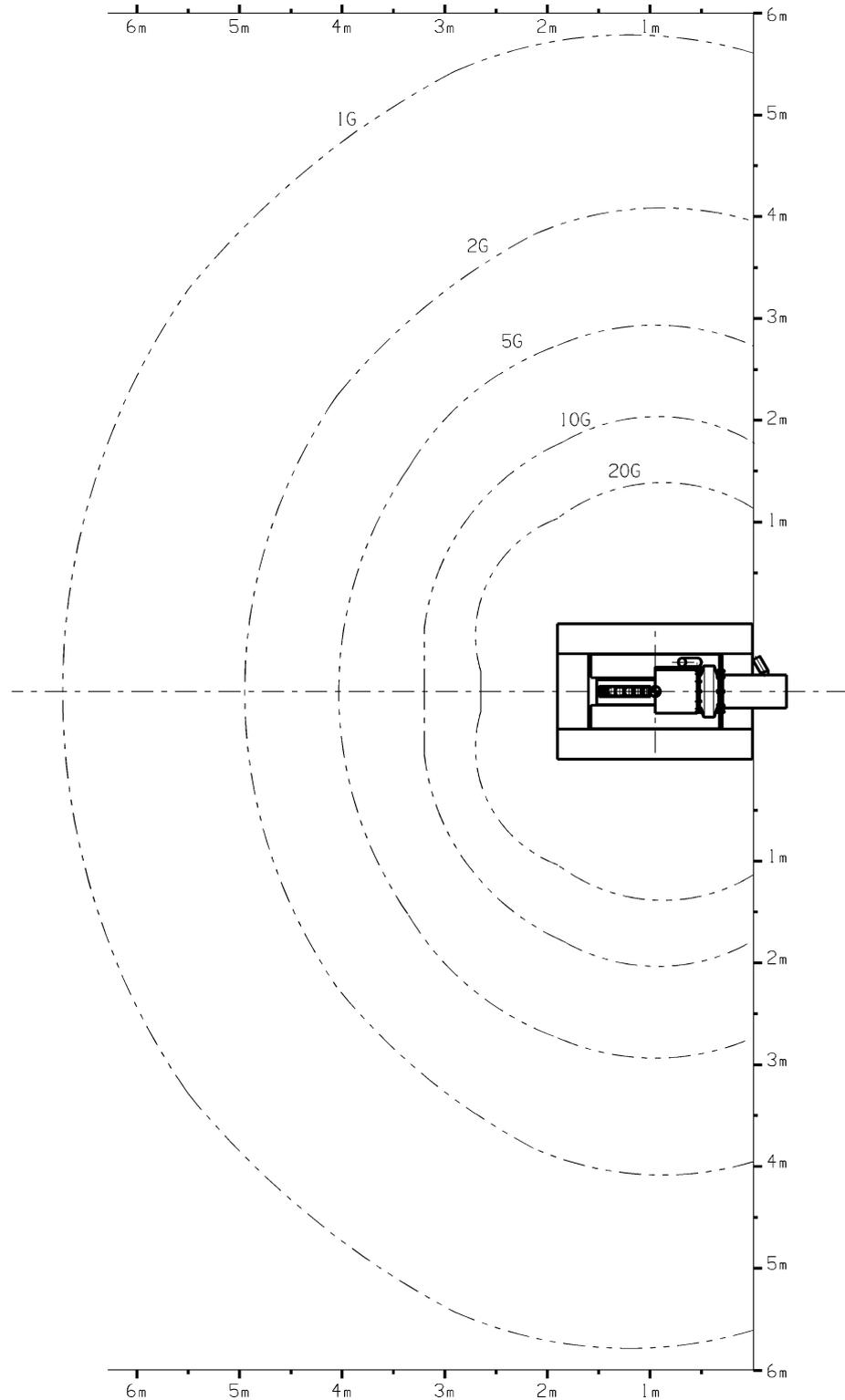
Contact the GE site planning group for more information, and assistance with your magnetic shield design.

Figure 4-1: Cyclotron magnet isogauss line plot center level



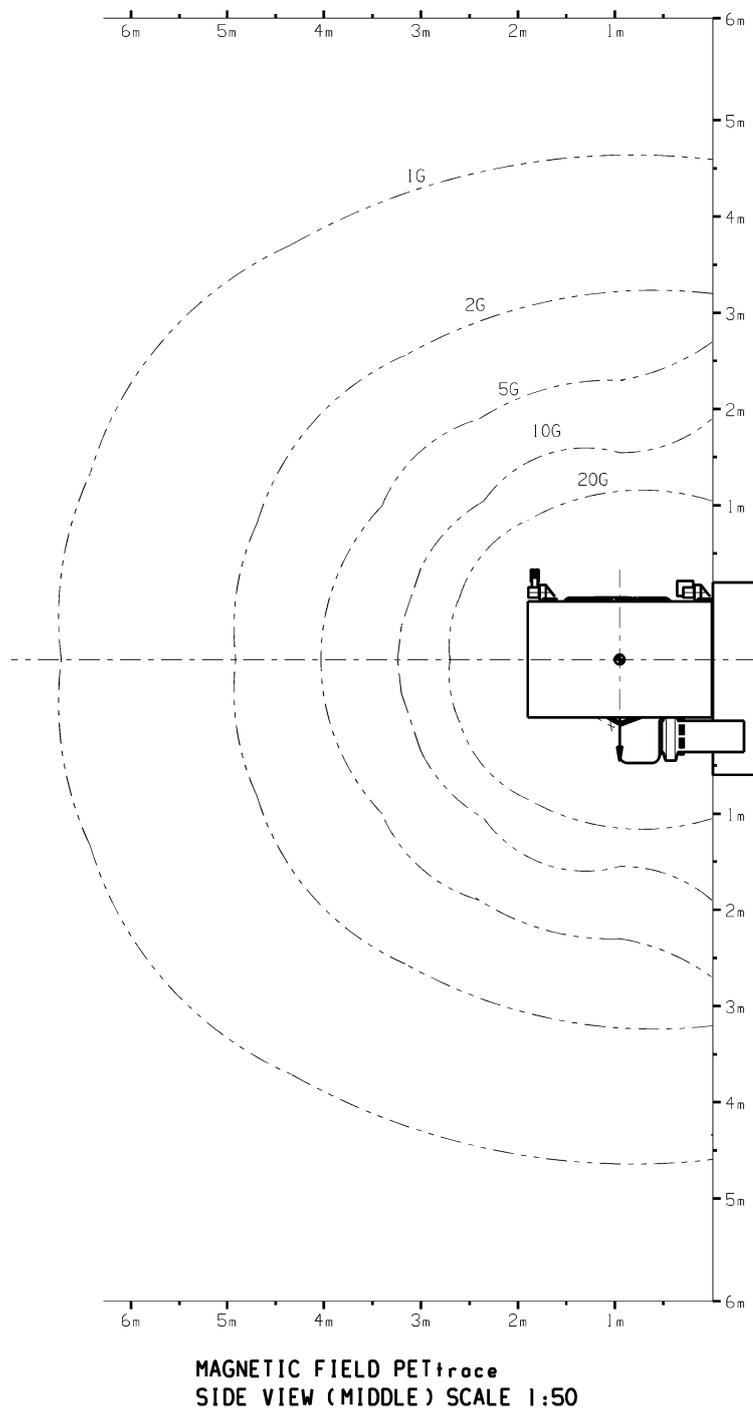
MAGNETIC FIELD PETtrace  
TOP VIEW (HEIGHT 0.95m) SCALE 1:50

Figure 4-2: Cyclotron magnet isogauss line plot vertical view



**MAGNETIC FIELD PETtrace  
FRONT VIEW (MIDDLE) SCALE 1:50**

Figure 4-3: Cyclotron magnet isogauss line plot vertical view



## 5 SITE ENVIRONMENT

### 5-1 Introduction

The rating and duty cycles of all subsystems apply only when the room environment is maintained as specified in the following sections.

### 5-2 Compliance with regulatory requirements

**PETtrace 800 is marked with the  symbol in accordance with the following directives:**

- European directive 2014/30/EU concerning electromagnetic compatibility (EMC).
- European directive 2014/35/EU concerning low voltage devices.

**CE marking:**

The CE marking is only valid for PETtrace 800 when it is:

- connected as described in the user documentation, and
- used in the same state as it was delivered from GE Healthcare, except for alterations described in the user documentation.

**PETtrace 800 is marked with the  and  symbols**

The product meets all applicable requirements and technical regulations in the Customs Union member countries (Russia, Belarus, Kazakhstan, Armenia, and Kyrgyzstan).

The  symbol is only applicable for Russia.

**PETtrace 800 has been tested for safety according to the following standard:**

- EN 61010-1 ed. 3:2010, concerning safety requirements for electrical equipment for measurement, control and laboratory use.

**PETtrace 800 has been tested for EMC according to the following standard:**

- EN 61326-1:2013 concerning electromagnetic emission and immunity.

Electromagnetic emission compliance:

Class A	PETtrace 800 is intended for use in an industrial environment. PETtrace 800 is not suitable for use in domestic establishments or those directly connected to a low voltage power supply network which supplies buildings used for domestic purposes.
Group 1	PETtrace 800 uses RF energy only for its internal function.

### 5-3 Facility safety

The facility must be furnished with different safety systems and have strictly organized rules that exactly describe what actions to be taken in different emergency situations. The organization around the cyclotron system shall at least provide the following:

- Radiation level monitoring system with alarms<sup>1</sup>
- Personnel radiation dose monitoring system
- Fire extinguishing system<sup>2, 3</sup>
- Equipment for handling and storage of radioactive parts and components
- Procedures and equipment for disposal of radioactive material
- Procedures for the event of radioactive leakage
- Rules for alerting ambulance, fire brigade, maintenance staff for the facility services etc.

**Note!**

**1.** *The Accelerator Control System allows for external interlock which will turn off the accelerator beam operation in case of exceeded radiation limits.*

**Note!**

**2.** *Fire extinguishing media should be adequate for electric fires. Do not use water.*

**Note!**

**3.** *Due to the magnetic environment, non-ferrous fire extinguisher should be used in the cyclotron room.*

### 5-4 Altitude

The system is designed to be placed at an altitude of up to 2000 m (6562 ft) above sea level.

## 5-5 Temperature and humidity specifications

Use the specifications listed in [Table 5-1](#) to design your heating, ventilation and air conditioning systems (HVAC systems).

**Table 5-1: Temperature and humidity specifications**

Location	Temperature range °C	Temperature regulation °C	Temperature change °C/h	Relative humidity (%)	Humidity change (%h)	Maximum room gradient
Cyclotron room <sup>1, 2</sup>	18–25	± 3	3	30–60	5	3
Power supply room <sup>1</sup>	18–25	± 3	3	30–60	5	3
Water cooling room	15–30	± 5	5	20–80	5	5
Radiochemistry lab <sup>3</sup>	18–25	± 3	3	30–60	5	3
Other laboratories <sup>3</sup>	18–25	± 3	3	30–60	5	3

- 1 Cyclotron room and power supply room not expected to be regular working area.
- 2 If not in the cyclotron room, the same specifications apply to the room where the compressor (self-shielded systems) is located.
- 3 Customer specifies environment conditions for working personnel.

## 5-6 Cooling requirements

### 5-6-1 Air cooling requirements

The cyclotron system requires about 5 kW total air cooling. These values do not include personnel, lights, water cooling equipment and other equipment not included in the cyclotron delivery.

Take care to locate the air conditioning supply and return ducts in accordance with all applicable, federal, state and local rules and regulations for radiation areas.

**Table 5-2: Cyclotron air cooling requirements**

Component	Cyclotron room		Power supply room		Radiochemistry lab	
	Watts	BTU/h	Watts	BTU/h	Watts	BTU/h
Magnet	-	-				
Shield 1	-	-				
Shield 2	-	-				
Shield 3	-	-				

Component	Cyclotron room		Power supply room		Radiochemistry lab	
	Watts	BTU/h	Watts	BTU/h	Watts	BTU/h
Shield 4	-	-				
Cabinet 1, PSMC			200	680		
Cabinet 2, RFPG			1650	5610		
Cabinet 3, CAB 3			400	1360		
RF cavity	250	850				
Master System					300	1020
Process Cabinet (ProCab)					1000	3400
Roughing vacuum pump	100	340				
Diffusion pump	550	1870				
Helium cooling system	350	1190				
Chemistry Control Unit (CCU)					300	1020
PETtrace 800 Service System (PSS)			100 <sup>1</sup>	340 <sup>1</sup>		
Power Distribution Unit (PDU)	100	340				
Cables	500	1700	500	1700		
Secondary cooling unit			200	680		

<sup>1</sup> Intermittent use

### 5-6-2 Water cooling requirements

**Note!**

All specifications below are based on the use of a water only system, that is no antifreeze additives.

An external chiller should be supplied and connected, by the Purchaser, to the closed deionized water cooling system. The external chiller; a cooling tower or a refrigeration system, must supply an inlet water temperature of not more than 15°C and provide temperature regulation of the closed deionized water cooling system within 20 ±1°C.

The Purchaser supplies and installs all the piping and connections between the cyclotron cooling system and the external chiller, and between the cyclotron cooling system and the supply/return manifolds on GE equipment. The Purchaser also supplies a connection for makeup water to the cyclotron cooling system.

If local codes and health physics regulations permit it, install floor drains in the cyclotron room, power supply room, water cooling room and the radiochemistry laboratory. Install floor drains in all water and cable trenches in the building.

**Table 5-3: Cyclotron water cooling requirements**

Component	Cyclotron room		Power supply room	
	Watts	BTU/h	Watts	BTU/h
Magnet coils	41 000	139 400		
RF cavity	12 000	40 800		
Ion source	500	1700		
Diffusion pump	345	1175		
Targets	800	2720		
PSMC			7400	25 160
RFPG			8000	27 200
Helium cooling system	350	1190		
Secondary cooling unit	2000	6800		

### 5-6-3 Secondary cooling unit

The secondary cooling unit provides a complete water cooling recirculation system for the cyclotron. The unit has two separate water systems, divided by a water-to-water heat exchanger, as well as the pumps and interlocks.

The secondary water system is a closed loop system for deionized water. In this water circuit, a deionizer and filter system guarantees the conductivity level of the water, and keeps particles out of the cooling circuit.

**Note!**

*The highest point in the secondary water system needs bleeders.*

The primary water system circuit connects to the customer water system (primary cooling system).

Table 5-4: Primary cooling system requirements

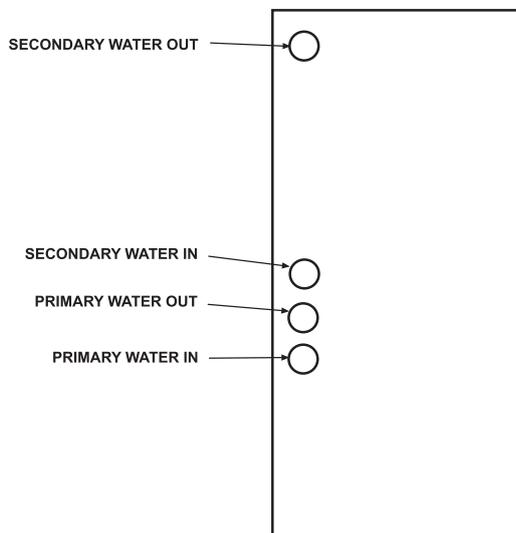
Flow	120-160 l/min (32-42 US Gallon/min)
Inlet temperature to secondary cooling system	10-15 °C (50-59 °F)
Max system pressure	1 MPa
Differential pressure (heat exchanger)	Approx. 0.13 MPa
Connection	DN32
Capacity	Minimum 80 kW

5-6-4 Water connections

All water cooling circuit connections are located on the top of the secondary cooling unit. A connection for makeup water is located behind the front cover on the right side of the unit.

To eliminate all problems with different flange standards in different countries, the cooling unit delivers with a complete set of flanges for all the connections. The customer only need to supply GE with a pipe in the specified size.

Figure 5-1: Top view of secondary cooling unit



**Table 5-5: Water cooling connections**

	Connection
Primary water	DN32
Secondary water main circuit	DN32
Secondary water vacuum circuit	DN15
Makeup water	o.d. 1/2"

### 5-6-5 Heat load to water

The cyclotron system can be operated in several different modes with various heat loads to the water cooling system. The normal heat load to the water cooling system when running is approx. 70 kW.

When the machine is turned off the vacuum system is normally still running and the heat load to water is approx. 4 kW.

Sometimes this wide range in heat load creates a problem to the customer’s primary water cooling system. If the difficulty is to dissipate the low load of 4 kW, a solution can be to cool the vacuum pump with primary water. The cyclotron system has this flexibility if needed.

### 5-7 Lighting

The Purchaser prepares and arranges for lighting to the PET suite. Recommended illumination:

- 500 lux in each room
- Emergency lighting in the cyclotron vault
- Emergency lighting in other areas as required by local and national codes

### 5-8 Noise reduction

Recommended: Install acoustical ceilings, walls and floors to reduce background noise from operating equipment.

**Table 5-6: Typical noise level readings**

Cyclotron room	70 dB
Power supply room	70 dB
Radiochemistry lab	65 dB
Water cooling room	70 dB

## 5-9 Room ventilation

Divide the entire PET-facility into the following radiation activity zones, and ventilate accordingly:

- High radiation areas (cyclotron vault, hot cells, integrated radiation shield)
- Radiation areas
- Unrestricted areas



### WARNING!

The air ventilated from the cyclotron vault, hot cells or integrated radiation shield might unintentionally be radioactive. Follow the guidelines below when designing the ventilation system.

Design the ventilation to transport the facility air from lower level to higher level areas. Consequently, the air exiting the cyclotron vault, hot cells, and integrated radiation shield should NOT be transferred to other rooms. It should instead be exhausted through the ventilation stack. Provide air exhaust system filters and radiation monitoring systems, as required by federal, state and local regulations.

Keep a negative air pressure in the cyclotron vault, hot cells, and integrated radiation shield, relative to the adjacent areas.

Provide air exhaust at the following locations in the cyclotron system:

- Cyclotron floor pit: cyclotrons with the integrated radiation shield require an air vent for the roughing vacuum pump, see [Section 2-5-3-1 Water drains on page 43](#).
- Radiochemistry lab: The 125 mm hose connector at the top of the Process Cabinet requires an air flow of 150 m<sup>3</sup>/h. Valves on the inlet and outlet set the underpressure to 150 Pa.
- Hot cell: Required air flow at least 72 m<sup>3</sup>/h (20 l/s) @ 30–80 Pa underpressure.

## 5-10 Ambient radio frequency interference

The cyclotron system uses high power radio frequency to produce the potential voltages to accelerate the beam. The RF power generator produces 12 kW at 27.2 and 27.8 MHz, contained within a grounded metal structure. Maximum RF noise leakage in the vicinity of the cyclotron:

- Field strength: <100 mV/m
- Frequency: 1–1000 MHz

### 5-11 Pollution

- Clean the site prior to equipment delivery, to keep dust to a minimum. Excess dirt can clog the component air filtration systems
- Install antistatic carpets, or use an antistatic solution to treat the carpets, to prevent static discharges, which can effect operation or cause system failures
- Never use steel wool to clean tile floors. The steel fibers can enter cabinet enclosures and cause internal shorts
- If possible, provide a passage-way air lock, with a sink to wash hands and a dressing area to change clothes and shoes

### 5-12 Hazardous gases and liquids

**Table 5-7: Hazardous gases involved in the chemistry and target processes**

Hydrogen (H <sub>2</sub> )	<ul style="list-style-type: none"> <li>• Explosion risk in different mixing proportions with air.</li> <li>• Always provide good ventilation.</li> <li>• Avoid open flames in the Process Cabinet.</li> <li>• Close the H<sub>2</sub>-main valve by hand after processing, for double security.</li> </ul>
Ammonia (NH <sub>3</sub> )	<ul style="list-style-type: none"> <li>• Breathing NH<sub>3</sub> can cause lung damage; always provide good ventilation.</li> <li>• Always provide faceguard equipment</li> <li>• Close the NH<sub>3</sub> main valve by hand after processing, for double security</li> </ul>
Fluorine (F <sub>2</sub> )	<ul style="list-style-type: none"> <li>• Toxic, very reactive, and may have special storage requirements</li> <li>• Always provide adequate ventilation</li> </ul>

**Table 5-8: Radioactive gases present at the product outlets**

$^{11}\text{C}-\text{CO}_2$	Radioactive. Do not inhale.
$^{11}\text{C}-\text{CO}$	Radioactive. Do not inhale.
$^{11}\text{C}-\text{HCN}$	Radioactive. Do not inhale.
$^{15}\text{O}-\text{O}_2$	Radioactive. Do not inhale.
$^{15}\text{O}-\text{CO}_2$	Radioactive. Do not inhale.
$^{15}\text{O}-\text{CO}$	Radioactive. Do not inhale.
$\text{Ne}+^{18}\text{F}_2$	Radioactive. Do not inhale.
$\text{H}_2+^{15}\text{O}-\text{O}_2$	Radioactive. Do not inhale.

**Table 5-9: Radioactive liquids present at product outlets or at the outputs of dedicated process units**

$^{18}\text{F}-\text{F}^-$ (aq)	<ul style="list-style-type: none"> <li>• Handle liquid containing <math>^{18}\text{F}^-</math> with special care.</li> <li>• Store the liquid in a sealed bottle in a lead box</li> <li>• Contact with skin is dangerous.</li> </ul>
$^{13}\text{N}-\text{NH}_3$ (aq)	
$^{11}\text{C}-\text{HCN}$ (aq)	

### 5-13 Construction materials

Strong magnetic fields exist adjacent to the cyclotron magnet. Care should be taken to maintain adequate distances between ferromagnetic materials and the cyclotron magnet.

- Use non-magnetic (aluminum) cover plates for the pit.

### 5-14 Utility requirements

#### 5-14-1 Compressed air supply

The cyclotron requires dry, compressed air with a pressure of 0.6 MPa (6 bar) to actuate the pneumatic valves. Each valve activation requires about 2 liters of air for 1 second, at 0.6 MPa. Provide contingencies to maintain compressed air service to the cyclotron in the event of power failure.

Include compressed air outlets in the design of the cyclotron room, power supply room, water cooling room and radiochemistry laboratory, with a maximum flow rate of 10 liters/minute at 0.6 MPa.

### 5-14-2 Customer supplied gases

**Note!**

The Purchaser supplies all gas cylinders, tubes and regulators specified or recommended by GE.

During normal operation, the cyclotron system requires an operating supply of:

- ion source gases
- target gases
- process gases

Some options share gases. For example, because the  $^{11}\text{C}$ ,  $^{15}\text{O}$  gas, and  $^{15}\text{O}$  water processing systems all require hydrogen gas, with a purity of 5.7, at a pressure of 0.25 MPa, they may share a cylinder of  $\text{H}_2$  gas.

Some cylinders have more than one regulator: For example, the  $^{11}\text{CO}_2$  HP target system require  $\text{N}_2 + 1\% \text{O}_2$ -gas at a pressure of 1.3 MPa and the  $^{15}\text{O}$  target system uses the same gas mixture but at a lower gas pressure, 1 MPa. The two targets can then share the same bottle but need to have separate gas regulators. *However, the  $^{15}\text{O}$  target system can be ran with a lower quality of gas than the  $^{11}\text{CO}_2$  HP target system. If you decide to share gas bottle between the systems, the highest gas quality must be used for both systems.*

In addition to the supply lines to the cyclotron, the suite design must accommodate the shielded transport of products from the cyclotron target to the radiochemistry laboratory for further processing. GE provides and installs the piping between the cyclotron target and the radiochemistry lab.

- The gas supply (bottles) should be positioned as close as possible to the point of use (regulator).
- All gases with regulators must be installed and available for use by the time of cyclotron start-up.

**WARNING!**

Hydrogen ( $\text{H}_2$ ) and deuterium ( $\text{D}_2$ ) gas is explosive at certain mixing proportions with air. Provide adequate ventilation.

**WARNING!**

Fluorine gas ( $\text{F}_2$ ) is toxic and caustic. If inhaled, it can cause severe damage to lungs and mucous membranes. Provide adequate ventilation.

**WARNING!**

Ammonia gas ( $\text{NH}_3$ ) is toxic. If inhaled, it can cause damage to lungs. Provide adequate ventilation.

The customer is responsible to ensure, early in the design process and in collaboration with local regulatory agencies, that all gases are stored properly.

The customer is also responsible for providing adequate gas detection equipment and ventilation to follow applicable laws or regulations.

The following gas specification tables list the *minimum required* gas purity, regulator pressure range and the recommended gas cylinder size.

**Note!**

*Note the use-by date on the gas cylinders. Old gas cylinders might impair the gas quality and thereby the cyclotron performance.*

The quality numbers are explained in the table below. This concept has been adopted to eliminate the ambiguity often associated with gas purity levels.

Purity	Minimum purity [%]	Total impurities [ppm]
2.0	99.0	10 000 (1%)
2.5	99.5	5000
3.0	99.9	1000
3.5	99.95	500
4.0	99.99	100
4.5	99.995	50
5.0	99.999	10
5.5	99.9995	5
6.0	99.9999	1

5-14-2-1 Ion source gases

**Table 5-10: Ion source gas specifications**

Particle	Gas specification	Operating pressure [MPa (psi)]	Regulator pressure range [MPa (psi)]	Recommended cylinder size	Tube connection o.d.
Protons	H <sub>2</sub> (6.0)	0.2 ± 0.01 (29 ± 1.5)	0.02–0.5 (2.9–72.5)	50 l	1/8"
Deuterons	D <sub>2</sub> (2.7)	0.2 ± 0.01 (29 ± 1.5)	0.02–0.5 (2.9–72.5)	20 l	1/8"

5-14-2-2 Target gases

Table 5-11: Target gas specifications

Target	Gas specification	Operating pressure [MPa (psi)]	Regulator pressure range [MPa (psi)]	Recommended cylinder size	Tube connection o.d.
<sup>11</sup> CO <sub>2</sub> standard	N <sub>2</sub> (6.0) + 1% O <sub>2</sub> (5.0) (C <sub>n</sub> H <sub>m</sub> < 0.1 ppmv, CO+CO <sub>2</sub> < 0.1 ppmv)	1.2 ± 0.03 (175 ± 5)	0.04–2.1 (5.8–305)	50 l	1/8"
<sup>11</sup> CO <sub>2</sub> HP	N <sub>2</sub> (6.0) + 1% O <sub>2</sub> (5.0) (C <sub>n</sub> H <sub>m</sub> < 0.1 ppmv, CO+CO <sub>2</sub> < 0.1 ppmv)	1.3 ± 0.03 (190 ± 5)	0.04–2.1 (5.8–305)	50 l	1/8"
<sup>11</sup> CH <sub>4</sub>	N <sub>2</sub> (6.0) + 10% H <sub>2</sub> (6.0)	1.0 ± 0.1 (145 ± 15)	0.04–2.1 (5.8–305)	50 l	1/8"
<sup>15</sup> O	N <sub>2</sub> (5.0) + 1% O <sub>2</sub> (4.5)	1.0 ± 0.1 (145 ± 15)	0.04–2.1 (5.8–305)	50 l	1/8"
<sup>13</sup> N	He (5.5)	0.45 ± 0.03 (65 ± 5)	0.04–1.0 (5.8–145)	50 l	1/8"
<sup>13</sup> NH <sub>3</sub>	He (5.5)	LP: 0.45 ± 0.03 (65 ± 5) HP: 1.3 ± 0.03 (190 ± 15)	0.04–1.0 (5.8–145) 0.04–2.1 (5.8–305)	50 l	1/8"
<sup>18</sup> F- Nb 27 self-shielded target <sup>18</sup> F- Nb 25 <sup>18</sup> F- HYT <sup>18</sup> F- Gen II	He (5.5)	LP: 0.45 ± 0.03 (65 ± 5) HP: 3 ± 0.05 (435 ± 7)	0.04–1.0 (5.8–145) > 4.0 (> 580)	50 l	1/8"
<sup>18</sup> F <sub>2</sub> Deuteron	Ne (4.5), low carbon, oxygen contents	1.05 ± 0.03 (145 ± 5)	0.04–2.1 (5.8–305)	20 l	1/8"
	Ne (4.5) + 1% F <sub>2</sub> (1.8) F <sub>2</sub> : HF < 0.5%	0.35 ± 0.03 (45 ± 5)	0.04–0.65 (5.8–94)	20 l	1/8"

Target	Gas specification	Operating pressure [MPa (psi)]	Regulator pressure range [MPa (psi)]	Recommended cylinder size	Tube connection o.d.
<sup>18</sup> F <sub>2</sub> Proton	3% F <sub>2</sub> (3.0) + He (5.0)	0.1–1.0 (14.5–145)	0–1.0 (0–145)	20 l	1/16"
	Ar (5.0)	1.05 ± 0.05 (152.5 ± 7)	0.04–2.1 (5.8–305)	50 l	1/8"
	<sup>18</sup> O <sub>2</sub> (1.8)	0.1 ± 0.05 (14.5 ± 7)	0–0.5 (0–72.5)	0.45 l (45 bar, stainless steel)	1/16"
All except <sup>18</sup> F- Nb 27 self-shielded (cooling)	He (5.5)	0.35 ± 0.03 (50 ± 5)	0.04–1.0 (5.8–145)	50 l	1/8"

**Note!**

It is recommended to have spare bottles of helium for target cooling and target gas for <sup>18</sup>F, <sup>13</sup>N and <sup>13</sup>NH<sub>3</sub>.

5-14-2-3 Process gases

Table 5-12: Process gas specification

Chemistry system	Gas specification	Operating pressure [MPa (psi)]	Regulator pressure range [MPa (psi)]	Recommended cylinder size	Tube connection o.d.
<sup>11</sup> C, <sup>15</sup> O	N <sub>2</sub> (6.0), carbon content < 0.1 ppmv (C <sub>n</sub> H <sub>m</sub> < 0,1 ppmv, CO+CO <sub>2</sub> < 0.1 ppmv)	0.25 ± 0.1 (36 ± 14)	0.02–0.5	50 l	1/8"
<sup>11</sup> C, <sup>15</sup> O	H <sub>2</sub> (5.7), carbon content < 0.1 ppmv (C <sub>n</sub> H <sub>m</sub> < 0,1 ppmv, CO+CO <sub>2</sub> < 0.1 ppmv)	0.25 ± 0.1 (36 ± 14)	0.02–0.5	50 l	1/8"
<sup>11</sup> C	NH <sub>3</sub> (4.5), H <sub>2</sub> O < 50 ppmv	0.27 ± 0.1 (39 ± 14)	0.04–0.65	20 l	1/8"

5-14-3 Gas consumption estimation

For operating pressures and recommended cylinder sizes, see Table 5-10, Table 5-11 and Table 5-12.

The typical gas cylinder pressures that have been used when estimating number of productions per bottle are given in the table below. If other cylinder sizes or pressures than listed in the tables above are used, the values must be adjusted accordingly.

Effects of leaks are not included the estimations. Effects of gas consumption due to pre- and post-synthesis are included.

Generally, a more precise estimation of the consumption should be done by monitoring pressure decrease in the bottles. The tables below cannot replace such monitoring.

**Table 5-13: Estimated usage – ion source gases**

Particle	Gas	Nominal cylinder pressure (MPa)	Approx. no. of operating hours before replacing cylinder <sup>1</sup>
Protons	H <sub>2</sub>	20	> 2000
Deuterons	D <sub>2</sub>	20	> 1000

<sup>1</sup> Estimations are based on cylinder sizes in Table 5-10.

**Table 5-14: Estimated usage – target gases**

Target	Gas	Nominal cylinder pressure (MPa)	Approx. no. of productions before replacing cylinder <sup>1</sup>
<sup>11</sup> CO <sub>2</sub> standard	N <sub>2</sub> + 1% O <sub>2</sub>	20	> 500
<sup>11</sup> CO <sub>2</sub> HP	N <sub>2</sub> + 1% O <sub>2</sub>	20	> 500
<sup>11</sup> CH <sub>4</sub>	N <sub>2</sub> + 10% H <sub>2</sub>	20	> 500
<sup>15</sup> O	N <sub>2</sub> + 1% O <sub>2</sub>	20	Batch mode: > 1000
			Cont. mode: > 800 (10 min.)
<sup>13</sup> N	He	15	> 1200
<sup>13</sup> NH <sub>3</sub>	He	15	> 1000
<sup>18</sup> F- Nb 27 self-shielded	He	15	> 1000
<sup>18</sup> F- Nb 25	He	15	> 1000
<sup>18</sup> F- HYT	He	15	> 1000
<sup>18</sup> F- Gen II	He	15	> 1000
<sup>18</sup> F <sub>2</sub> Deuteron	Ne	20	> 500
<sup>18</sup> F <sub>2</sub> Deuteron	Ne + 1% F <sub>2</sub>	20	> 1000

Target	Gas	Nominal cylinder pressure (MPa)	Approx. no. of productions before replacing cylinder <sup>1</sup>
<sup>18</sup> F <sub>2</sub> Proton	3% F <sub>2</sub> + He	15	> 300
	Ar	20	> 1000
	<sup>18</sup> O <sub>2</sub>	4.5	> 200
All except <sup>18</sup> F- Nb 27 self-shielded (cooling)	He	15	> 2000

<sup>1</sup> Estimations are based on cylinder sizes in [Table 5-11](#).

**Table 5-15: Estimated usage – process gases**

Chemistry system	Gas	Nominal cylinder pressure (MPa)	Approx. no. of productions before replacing cylinder <sup>1</sup>
<sup>11</sup> C, <sup>15</sup> O	N <sub>2</sub>	15	> 500
<sup>11</sup> C, <sup>15</sup> O	H <sub>2</sub>	15	> 500
<sup>11</sup> C	NH <sub>3</sub>	0.7	> 200

<sup>1</sup> Estimations are based on cylinder sizes in [Table 5-12](#).

**5-14-4 Customer supplied gas regulators**

The customer is responsible for the installation of gas bottles and regulators. Federal, state or local laws or regulations might apply. [Table 5-16](#) lists the gas regulator recommendations.

**Table 5-16: Gas regulator recommendations**

Parameter	Value/description
Type/Material	Should match the gas type and quality
Maximum primary pressure	200 bar
Secondary pressure range	As required by the application (see <a href="#">Table 5-10</a> to <a href="#">Table 5-12</a> )
Max. flow	155 l/min, Cv = 0.02
Stability	+0.04 bar sec. @ -7 bar prim.

**Table 5-17: Target liquid specifications**

Target	Liquid specification
<sup>18</sup> F-	<sup>18</sup> O-H <sub>2</sub> O, [ <sup>18</sup> O]-enrichment > 95%, deionized, sterile filtered
<sup>13</sup> N	<sup>16</sup> O-H <sub>2</sub> O, deionized, sterile filtered 18 Mohm
<sup>13</sup> NH <sub>3</sub>	5 mM ethanol (> 99.5%) in deionized, sterile filtered water (18MΩ)

**5-14-5 Customer supplied gas tubes**

The customer is responsible for providing and installing the gas tubes that are not included in the cyclotron delivery. [Table 5-18](#) lists gas tube recommendations.

**Table 5-18: Gas tube recommendations**

Parameter	Value
Material	Chromatography grade, 0.085" i.d., 316 stainless steel
Quality/grade	Thermocouple cleaned and capped
Dimension	Max. o.d. 1/4" o.d. 1/8" for ion source gases

- Tubes should be seamless with welded connections, when possible.
- No mechanical connections in conduits or inaccessible location.
- Each tube is to be capped, taped or folded and crimped to prevent interior contamination.
- Each line is to be clearly marked on each end to uniquely distinguish it (permanent marker, crimps).
- No tube bends should be less than a 50 mm radius. If a tube is kinked, it must be replaced.

**5-15 Vibration**

Vibration in the building is normally not a problem. The weight and size of the equipment require a rigid facility, which by definition reduces the vibration to a satisfactory level.

## 5-16 Safety systems

The cyclotron system design includes a number of interlock systems, to guarantee safe operation. These interlocks only protect the cyclotron; the Purchaser must provide additional safety systems, such as ventilation and fire protection.

### 5-16-1 Mains Distribution Panel (MDP)

The Purchaser-supplied Mains Distribution Panel (MDP) can accommodate a number of emergency off switches. Provide at least one emergency off switch in the cyclotron area and in the hot lab installed in accordance with all applicable federal, state and local electrical code requirements. Design this safety system so the activated push button must be manually reset in order to restore power to the system.

Service personnel must be able to Lock-Out and Tag-Out (LOTO) all individual outgoing mains distribution lines, to prevent accidental electrocution.

For additional information regarding the MDP, see [Chapter 6 Power requirements](#) of this manual.

### 5-16-2 Customer Interface Box (CIB)

The cyclotron system can provide some hard-wired status information, through three galvanically insulated relay contacts in the Customer Interface Box (CIB). The CIB is normally attached to a wall in the power supply room. The designer may use these contacts to power warning lights, signs or other safety devices. The relays accept a maximum of 220 V and 10 A.

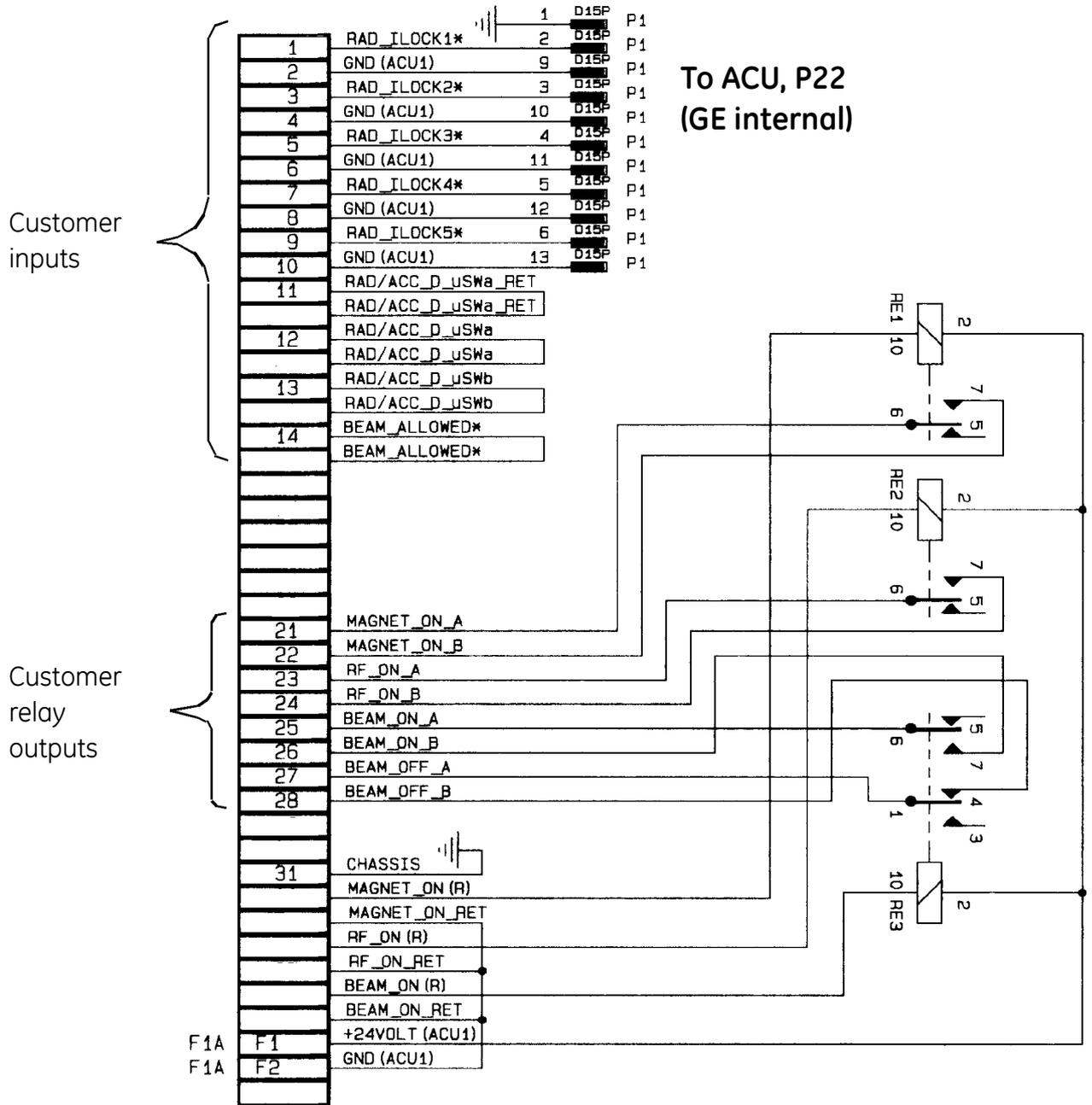
The relay contacts provide the following status information:

- **Magnet ON** – The contact between terminal 21 and 22 closed when main coil power supply (PSMC) is on.
- **RF ON** – The contact between terminal 23 and 24 closes when RF-generator (RFPG) is on.
- **Radiation ON** – The contact between terminal 25 and 26 closes when ion source power supply (PSARC) is on.

The site designer also has access to two hard-wired cyclotron system input interlock loops. These two loops should be *independent* of each other and *potential free*. The first loop connects between terminal 11 and 12, the second between 13 and 14 on the CIB terminal strip. The interlock inputs are normally connected to vault door switches and radiation detector systems. Breaking one of these loops immediately stops the beam.

The site designer also has access to five safety status inputs. The operator consoles displays the safety status information, but will not stop the beam. Use these safety status inputs to monitor radiation. Keep all five inputs *separate* and *potential free*. These status loops connect to terminals 1 and 2, 3 and 4, 5 and 6, 7 and 8, 9 and 10 in the CIB.

Figure 5-2: Customer Interface Box connections



Use numbered terminals only

### 5-16-3 Safety systems not included with the cyclotron system

Due to regulatory differences throughout the world, GE cannot recommend universal safety systems. The following safety systems have been installed on most PET sites.

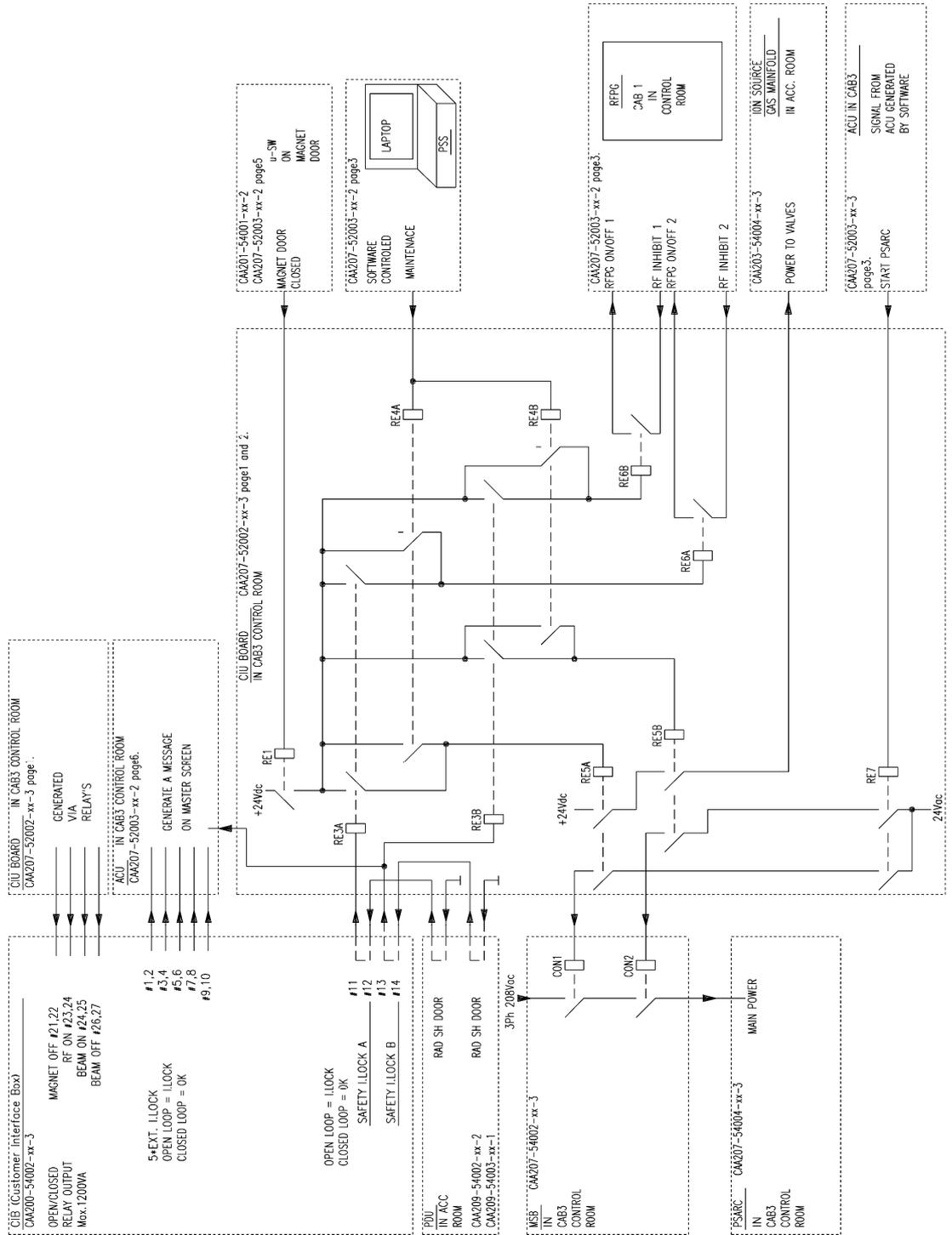
#### 5-16-3-1 Clearance system

The clearance system normally consists of a relay configured system with push buttons, located in the cyclotron vault. Anytime the vault door is opened, this system requires the operator to enter the vault and push two buttons, then leave the vault and close the door within a preset period of time. The object of the clearance system is to make the operator enter the vault and make sure no people are in the vault before starting the cyclotron. The operator cannot start the cyclotron until he or she presses the correct sequence of buttons within the designated time frame.

#### 5-16-3-2 Radiation monitoring system

The radiation monitoring system normally consists of a number of distributed sensors which monitor radiation. An alarm sounds and/or warning lights flash when a monitor detects radiation in excess of the predetermined safe levels. The sensors can be placed in chemistry areas, the cyclotron vault and in ventilation systems connected to the cyclotron vault and chemistry area.

Figure 5-3: Safety interlock and other CIB signals





## 6 POWER REQUIREMENTS

### 6-1 Introduction

#### 6-1-1 General power distribution

The cyclotron system requires a customer supplied Mains Distribution Panel (MDP) that meets GE specifications to provide the power feeds to the following system cabinets:

- 1 Radio Frequency Power Generator (RFPG)
- 2 Magnet Power Supply (PSMC)
- 3 Accelerator Control System (CAB 3)
- 4 GE supplied Power Distribution Unit (PDU)
- 5 Secondary Water Cooling Unit
- 6 Radiation Shield Compressor (RSC) (option)

The Radio Frequency Power Generator (RFPG) supplies power to the following subsystems:

- 1 Tube Amplifier Unit (TAU)
- 2 Grid Screen Power Unit (GSPU)
- 3 Driver Power Amplifier (DPA)
- 4 Driver Power Supply Unit (DPSU)
- 5 Source and Control Unit (SCU)

The Accelerator Control System (CAB 3) supplies power to the following subsystems:

- 1 Accelerator Control Unit (ACU)
- 2 Vacuum Control Unit (VCU)
- 3 Ion Source Power supply (PSARC)
- 4 Control Interface Unit (CIU)

The PDU supplies power to the following subsystems:

- 1 Chemistry Control Unit (CCU)
- 2 Chemistry Electronic Unit (CEU)
- 3 Vacuum system
- 4 Helium cooling system
- 5 Magnet yoke
- 6 Radiation shield drive system

All power cables to the ac power inputs of all GE cabinets shall be provided and installed in accordance with all applicable federal, state and local electrical code requirements.

During the PET suite design process, carefully consider the advantages and disadvantages of raised flooring, conduits, floor ducts and surface raceways for routing cables, as well as the federal, state and local electrical code requirements. If the site uses conduits, choose one with a large enough diameter to accommodate the passage of any cable with its connector, with all other cables in the conduit. (For more detailed information, return to [Chapter 2 Space planning](#).)

Position the Mains Distribution Panel (MDP) in the vicinity of the power supplies. To reduce voltage regulation and wiring costs, minimize the cable length between the primary power source and the system transformer. When routing cables, keep all phase conductors and circuit grounds in the same feed-through. Whenever possible, keep power cables away from signal and data cables.

**Table 6-1: Power Distribution**

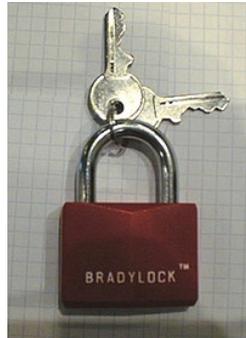
Total power consumption (with optional integrated radiation shield)	72 kW (83 kW)
Installed power (with optional integrated radiation shield)	105 kVA (119 kVA)
Wire system	3 phase 5 wire
Variation of nominal line voltage	+10%, -5%
Maximum allowed THD (Total Harmonic Distorsion)	5%

### 6-1-2 LOTO (Lock-Out and Tag-Out)

**Note!**

All mains distribution circuit breakers must be of the Lock-Out and Tag-Out (LOTO) type.

This means that the circuit breaker (CB1–CB6 in [Figure 6-4](#) to [Figure 6-6](#)) in the MDP must be lockable in the Off position with a padlock or a Lock-Out (see [Figure 6-1](#) below).

**Figure 6-1: LOTO Padlock and LockOut hasps**

### 6-1-3 Single-phase outlets

There should be at least four single-phase electrical utility outlets for powering the Master Station and accessories (service PC, etc.).

It is recommended that single-phase electrical utility outlets be provided along walls of the cyclotron room and power supply room to power service and test equipment.

### 6-1-4 Emergency facility lighting power

Emergency power is recommended for emergency facility lighting.

## 6-2 Power requirements

The cyclotron operates on the line voltages 380 VAC, 415 VAC and 480 VAC (with a variation of the nominal line voltage of +10%, -5%), 3-phase, 5-conductor, 50/60 Hz.

The customer provides the input power to the Mains Distribution Panel (MDP). In order to meet that country's regulation, GE individually specifies the size requirements of the power cables for each PET site. The maximum acceptable voltage drop from the MDP to the cyclotron subsystems is 1%.

Use the data in the Installed Power column in [Table 6-2](#) to determine the input power cable size.

Table 6-2: Mains input power

Subsystem	Installed power in kVA	kW during subsystem operation
PSMC	60	42
RFPG	25	21
CAB 3	7	1
PDU	9	5.5
Cooling system	3	2
Master Station	1	0.5
Radiation shield compressor (option)	(14)	(11)
Total	<b>105 (119)</b>	<b>72 (83)</b>

### 6-3 Recommended power distribution system

#### 6-3-1 Input voltage

The input transformers to the main cyclotron subsystems can be set to accept a number of different input voltages. Select the Mains Distribution Drawing that matches your facility power, from the following list. The drawings also identify the customer and GE responsibilities for mains power supply to the cyclotron system and crucial information concerning cyclotron PSMC (Cabinet 1) Residual Current Circuit Breaker (RCCB) setting.

- CAA209 56003: 380 VAC, see [Figure 6-4](#).
- CAA209 56004: 415 VAC, see [Figure 6-5](#).
- CAA209 56005: 480 VAC, see [Figure 6-6](#).

**Note!**

*Some minor system components are unique, and must be manufactured to meet the local voltage and frequency conditions. These components are specified during the ordering process.*

**Note!**

*For Japanese market with 415 VAC/60 Hz, an auto transformer must be installed to support the Water cooling system. The transformer shall be constructed for a load power of 2.0 kW.*

### 6-3-1-1 Transforming other site voltages

The site power distribution system might have to be modified with transformers:

- At some sites, the facility power must be stepped up/down to fulfill any of the specified input voltages.
- Sites that have a 4-conductor system (L1, L2, L3 and PE) must be transformed to a 5-conductor system (L1, L2, L3, N and PE).

**Note!**

*It is important to use the correct type of transformer. See instruction below.*

#### To step up/down a 5-conductor site system

Use a Y-autotransformer to feed all subsystems, except the PSMC. Feed the PSMC with a separate autotransformer.

#### To step up/down a 4-conductor site system

Use a Delta-Y full transformer to generate a 5-conductor that feeds all subsystems, except the PSMC. Feed the PSMC from the 4-conductor system through a separate autotransformer.

#### To only generate a 5-conductor system

Use a Delta-Y full transformer to generate a 5-conductor that feeds all subsystems, except the PSMC. Feed the PSMC directly from the 4-conductor system.

### 6-3-2 Emergency stops

The customer shall provide and install, in accordance with all applicable federal, state and local electrical code requirements, a Low Voltage Low Energy protective disconnect device with local and multi-point (at least one in cyclotron room and one in power supply room) remote control capability to disable all power to the cyclotron Mains Distribution Panel, see drawings in [Figure 6-4](#) to [Figure 6-6](#).

The drawings in [Figure 6-4](#) to [Figure 6-6](#) also identifies the customer and GE responsibilities for mains power supply to the cyclotron system.

**Note!**

*The drawings might not be representational for all sites. The customer is responsible for ensuring that the voltage for the emergency circuits match all applicable federal, state and local electrical code requirements.*

### 6-4 UPS (Uninterruptible Power Supply)

It is possible to connect the cyclotron system to an Uninterruptible Power Supply (UPS). If this alternative is chosen it should be an online UPS, where continuous production can be performed. The purpose of a UPS installation is not only protection against "power off" situations, but it is also a recommendation to sites that have voltage and/or frequency fluctuations in the main power distribution net. If the site area has experience voltage dips or other voltage/frequency variations on the main electrical distribution net it is an advantageous solution to install an UPS to maintain a stable line voltage for the cyclotron system. The UPS manufacturers recommend that the continuous load should be 0.8-0.9 (80-90%) of the UPS maximum capacity.

**Note!**

To be able to continue production in a power off situation, all peripheral subsystems that are connected to the cyclotron system must work according to specification. This includes but is not limited to the Master Station, external chiller for water cooling, compressed air supply and air condition.

It is highly recommended to install a small UPS to handle the Master Station and other computer equipment.

**Note!**

The data in [Table 6-3](#) is based on the data in [Table 6-2](#) and **does NOT** include all periphery subsystems that are connected to the cyclotron system, such as external chiller etc. The data for the Master Station **does NOT** include printers or other periphery computer equipment.

**Table 6-3: Recommended sizes of the UPS**

System	Power consumption, kVA	Recommended size on the UPS, kVA <sup>1</sup>
Cyclotron (with optional integrated radiation shield)	105 (119)	120 (150)
Master Station	0.5	1

<sup>1</sup> The cyclotron has a power factor of 0.8–0.85.

GE recommends and offer power survey prior to the installation of the cyclotron system.

### 6-5 Residual Current Circuit Breaker (RCCB)

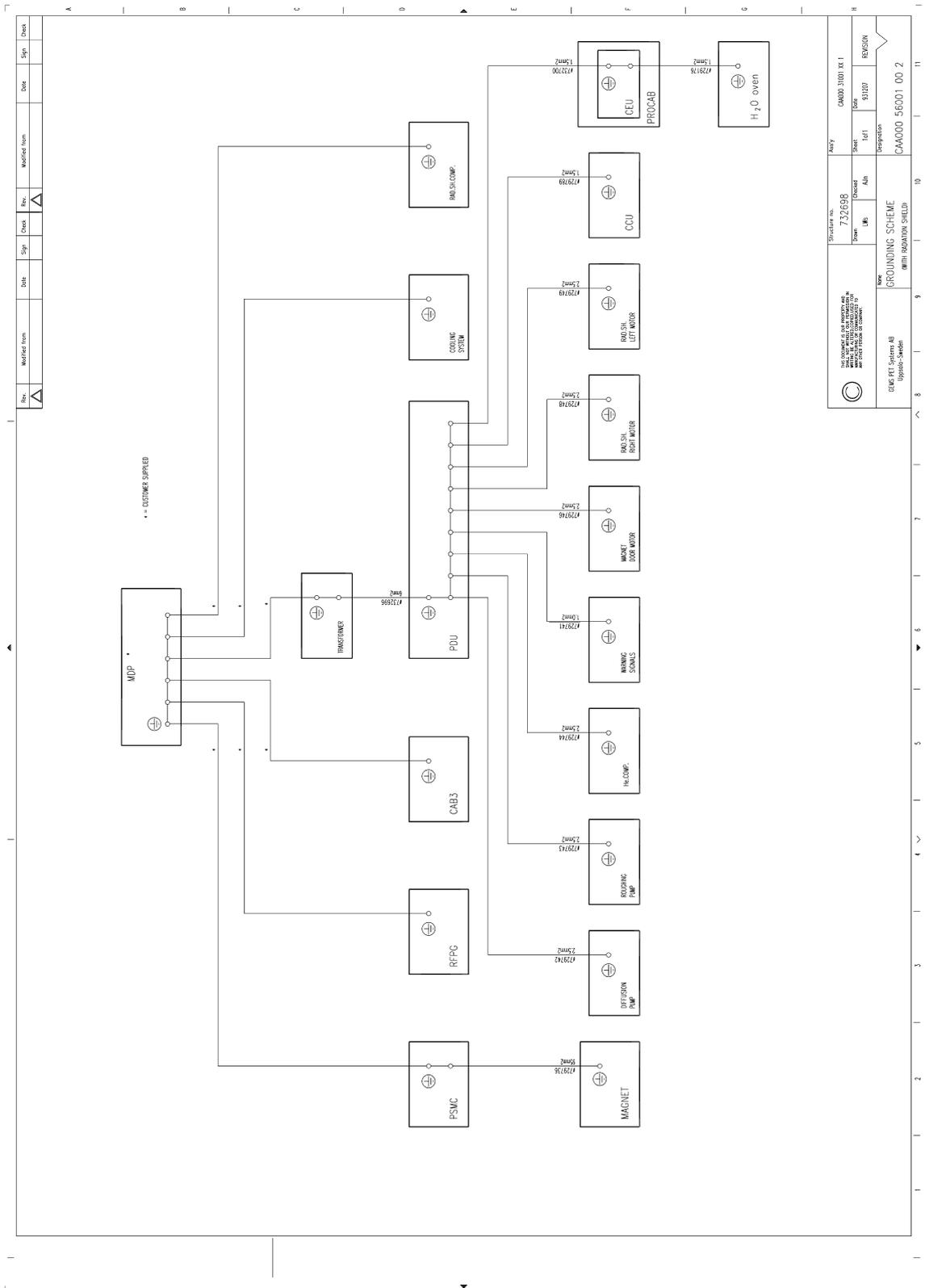
If a Residual Current Circuit Breaker (RCCB) is used, it should handle a minimum of 100 mA leakages current for CB2–CB6 (see [Figure 6-4](#) to [Figure 6-6](#)) and greater than 300 mA leakage current for CB1 (see [Figure 6-4](#) to [Figure 6-6](#)).

### 6-6 System ground

Drawing CAA000-56001 shows the protective grounding schematic for the cyclotron system with the integrated radiation shield and drawings CAA000-56002 shows the protective grounding schematic for the unshielded cyclotron. The grounding scheme is designed to minimize ground loops and prevent noise from interfering with low-level signals.

The Purchaser-provided ground interconnections must meet all applicable federal, state and local electrical codes. Any modifications to the ground scheme may impact cyclotron system performance and safety.

Figure 6-2: Grounding scheme with radiation shield, CAA000-56001



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Project 732698	Sheet 1 of 1	Date 9/1/07
Title GROUNDING SCHEME WITH RADATION SHIELD	Author JAH	Revision CAMD00 56001 00 2
Name DEMO PET System A1 Uppsala Sweden	Description CAMD00 56001 00 2	











## 7 INTERCONNECTION DATA

### 7-1 Introduction

This chapter addresses the cyclotron system cable, gas piping and water cooling interconnections. This chapter is divided into the following sections:

- Introduction: Lists component designators used to identify the cyclotron equipment
- Cable interconnections
- Water piping interconnections
- Gas piping interconnections

#### 7-1-1 Component designators

GE uses a Component Designator System to identify all cyclotron system components. All subsystem cabinets and components are referred to by their component designators in the interconnect diagrams and tables of this section. [Table 7-1](#) lists the cyclotron component designators.

#### 7-1-2 Group interconnects

[Figure 7-1](#) shows the group cable interconnect diagram for a standard cyclotron system. Each group contains one or more cables. See this diagram when using the cable interconnect tables in this chapter.

[Figure 7-2](#) shows the group water cooling interconnect diagram for a standard cyclotron system. Each group contains one or more water cooling pipes or hoses. See this diagram using the water piping interconnect tables in this chapter.

[Figure 7-4](#) shows the group gas piping interconnect diagram for a standard cyclotron system. Each group contains one or more gas pipes. See this diagram when using the gas piping tables in this chapter.

**Table 7-1: Component designators**

Basic system or option	Component designator	Component description
<b>Cyclotron system</b>		
	ACC	Accelerator (cyclotron incl. vacuum system and target system)
	PSMC	Cabinet 1, Magnet (main coil) Power Supply
	RFPG	Cabinet 2, Radiofrequency Power Generator
	CAB3	Cabinet 3, Accelerator Control System

Basic system or option	Component designator	Component description
	MCS	Master (Control) System
	CCU	Chemistry Control Unit
	CEU	Chemistry Electronics Unit
	CWU	Secondary cooling unit ( Water Cooling Unit)
	CWM	Cooling Water Manifold
	PDU	Power Distribution Unit
	ISGM	Ion Source Gas Manifold
	CIB	Customer Interface Box
	WLAA	Warning Lamp and Audible Alarm (for Magnet and Radiation Shield Doors)
	OWPS	H <sub>2</sub> O process unit ( <sup>15</sup> O water process system)
	NAPS	Ammonia process system ( <sup>13</sup> N-NH <sub>3</sub> )
	NAEU	Ammonia terminal box (Ammonia Electronic Unit)
	PDUT	PDU transformer
	PCAB	Process Cabinet ( <sup>11</sup> C and <sup>15</sup> O process panels)
<b>Gas piping connections only</b>		
	CPP	Carbon-11 product panel
	OPP	Oxygen-15 product panel
	LPP	Liquid product panel
	WGU	Waste gas unit
	WGP	Waste gas panel
<b>GE service equipment</b>		
	PSS	PETtrace 800 Service System (service laptop)

Basic system or option	Component designation	Component description
<b>Cyclotron system options</b>		
	PRS	Cyclotron Radiation Shield
	RSC	Radiation shield compressor (with receiver)
	RSM	Radiation shield compressed air manifold
	PDUS	Power Distribution Unit (for shielded cyclotron system – replaces PDU)

### 7-2 Cable interconnections

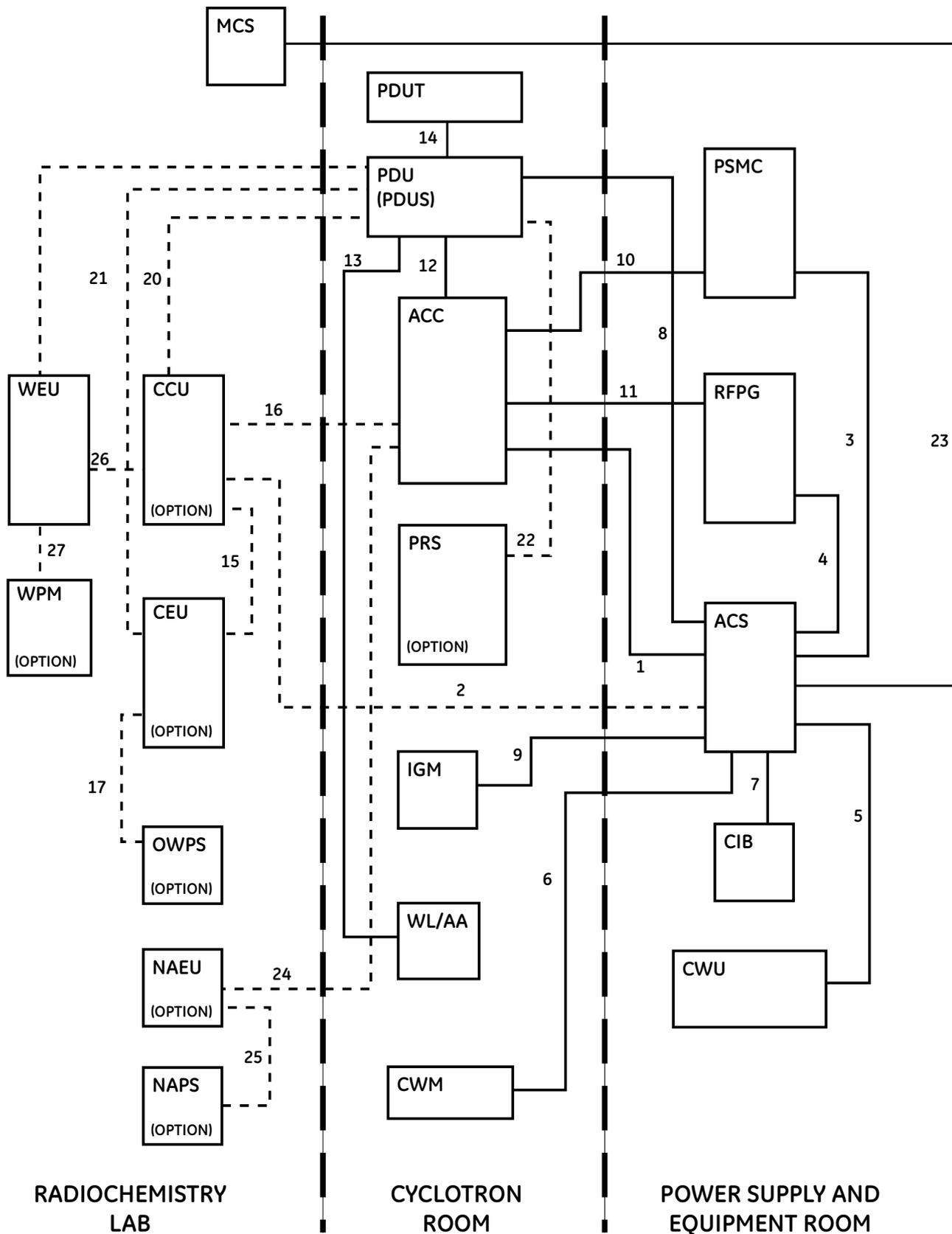
The three electronics and power supply cabinets in the power supply room are connected to the cyclotron by power and signal cables. The water cooling system is connected to the Accelerator Control System (ACS) by signal cables.

[Figure 7-1](#) shows the Group cable interconnect diagram for a standard cyclotron system. Each group contains one or more cables.

For information on mains power connections and emergency off circuit wiring, see [Chapter 6 Power requirements](#).

During the site construction process, the Purchaser installs the piping and floor ducts, cable troughs, cable raceways and/or raised floors according to the suite design specifications. During the cyclotron installation, the GE service representatives will route the GE supplied cables through the designated cable-ways and make the connections to the equipment and media supplies.

Figure 7-1: Group cable interconnect diagram



For information regarding the cabling interconnects between all cyclotron system components, refer to *PETtrace 800 series Installation Manual (dir. 2131771-100)*.

### 7-3 Water piping interconnects

The water cooling system removes a majority of the heat dissipated by the cyclotron system. This system uses deionized water in a closed circuit as the cooling media for the cyclotron and associated power supplies.

The site design must accommodate two main water cooling system units:

- 1 The secondary cooling unit with pump and heat exchanger.
- 2 Two water manifolds to distribute the water circuits to the subsystems.

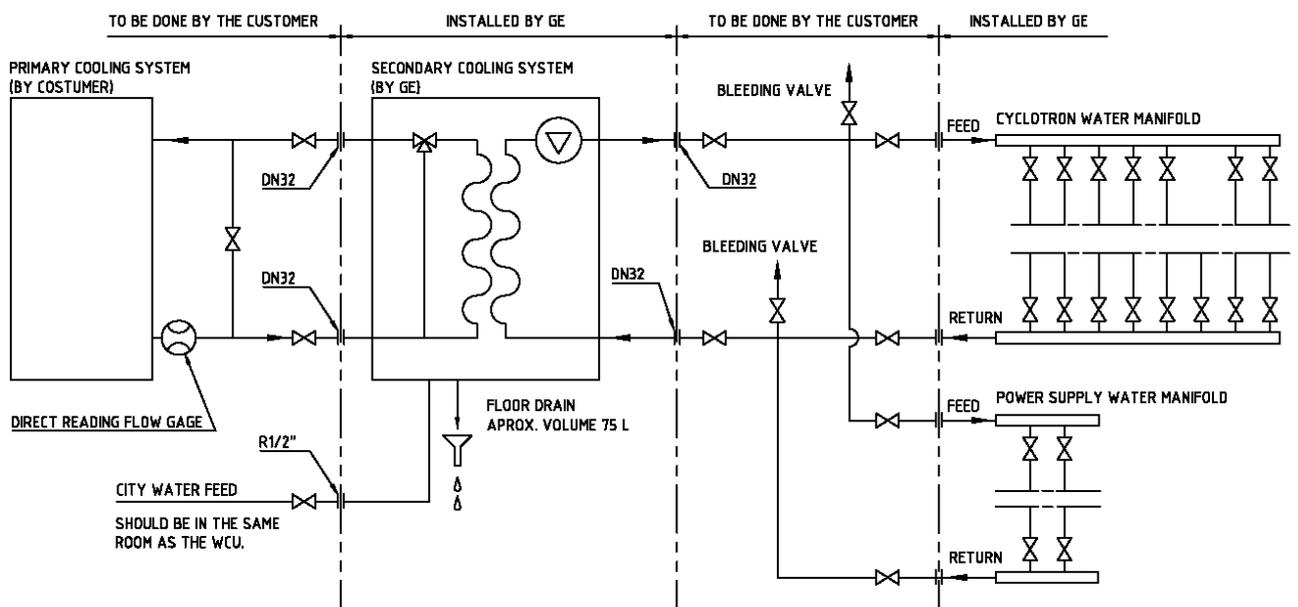
A sketch of the water cooling system is shown in [Figure 7-2](#).

The complete water cooling system including secondary cooling unit and water manifolds (parts of the GE delivery). Piping between these units and water hoses to accelerator subsystems are customers responsibility.

The customer is responsible for the supply of primary water at a correct temperature and flow, to the secondary cooling unit:

- Flow: > 120 l/min
- Temperature: 10–15°C (50–59°F)
- Pressure drop over pipe connections to the water system at normal operation (120 l/min): < 130 kPa

Figure 7-2: Cyclotron water cooling system schematics



### 7-3-1 Secondary cooling unit

The secondary cooling unit may be placed in a separate room, or in the power supply room. If absolutely necessary, you may place the secondary cooling unit in the cyclotron vault, but the radiation levels makes service more complicated.

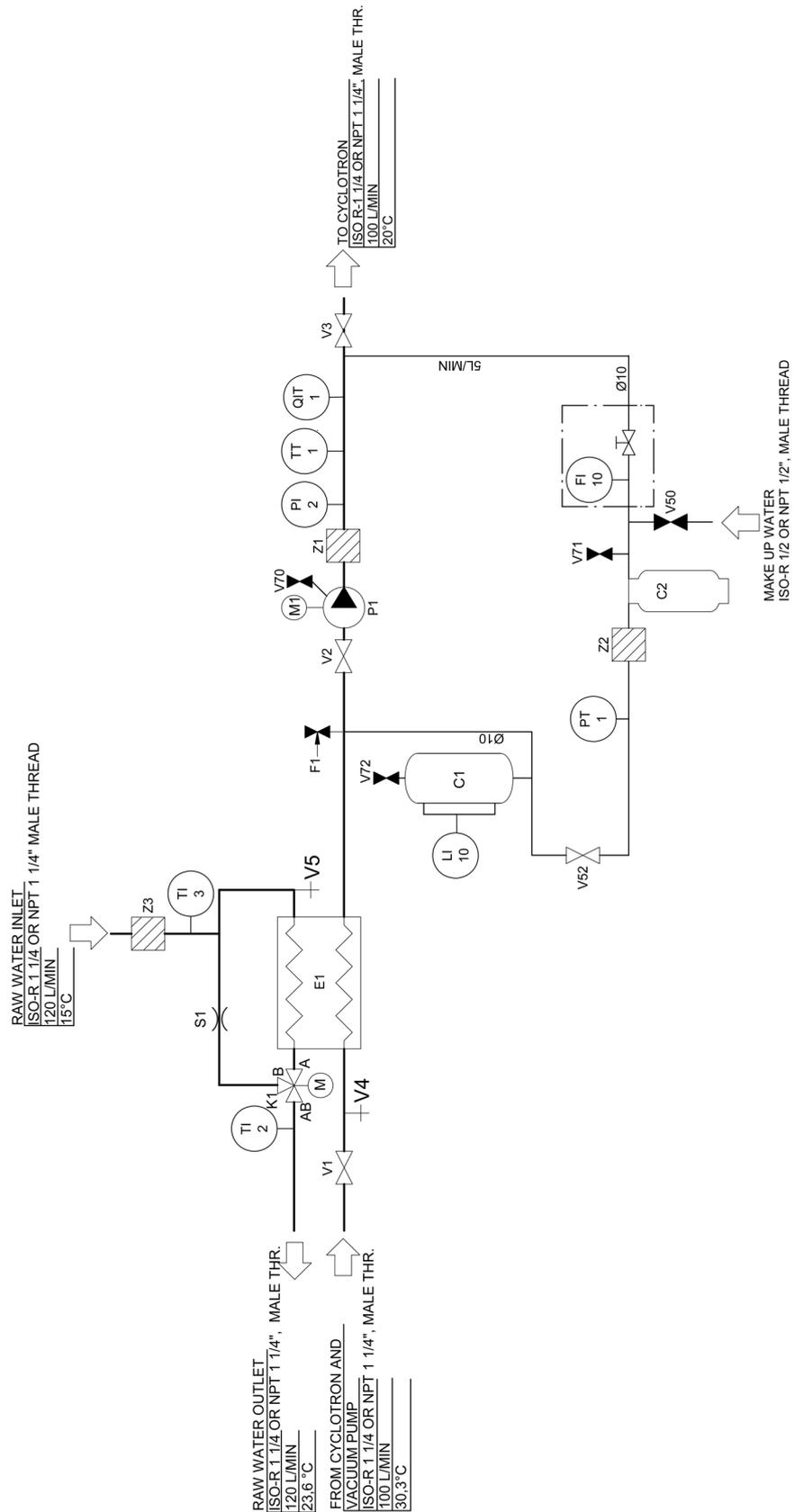
**Note!**

*Avoid sharp bends on the pipes/hoses and minimize the number of bends between the secondary cooling unit and water manifold 1.*

A block diagram of the secondary cooling unit is shown in [Figure 7-3](#).

Physical dimensions of the secondary cooling unit are available in [Section 2-2-4 Cooling system room on page 33](#).

Figure 7-3: Secondary cooling unit, block diagram



### 7-3-2 Water manifolds

Two water manifolds are parts of the cyclotron system. Both manifolds are indicated in [Figure 7-2](#).

Water manifold 1 is wall mounted. The unit distributes cooling water to the accelerator through rubber hoses. Incoming PVC, supply and return, water pipes are DN32 for the main water loop.

**Note!**

*To minimize the risk of insufficient water cooling flow to the cyclotron, make sure to place water manifold 1 so that no water hose exceeds a length of 7 meters.*

*Avoid sharp bends on the hoses and minimize the number of bends between the manifold and the cyclotron, and between the manifold and the secondary cooling unit.*

**Table 7-2: Rubber hoses, Water manifold 1**

Equipment	Number of hoses	Dimension o.d.
Main coil	2	1/2"
RF Cav 1	2	3/8"
RF Cav 2	2	3/8"
RF Cav 3	2	3/8"
Ion source	2	3/8"
Targets Pr.	1	3/8"
Targets upper	1	3/8"
Targets lower	1	3/8"
Vacuum system	1	1/2"
Vacuum system	1	3/8"

The water manifold can be oriented with outputs facing up or down. This gives a flexibility for rubber hose routing.

From the manifold the hoses can be routed on an overhead ladder or in a floor duct. The ladder or floor duct should be connected to the standard cyclotron pit shown in [Section 2-5-3 Cyclotron pit on page 41](#).

The standard cyclotron pit is designed to be large enough to accommodate all necessary water hoses, gas pipes and cables.

The water pipes and hoses should normally be routed separately from all kinds of cables.

Water manifold 2 does not have to be wall mounted. It can be placed on the ladder or below a raised computer floor close to the PSMC and RFPG. This water manifold is divided in two, one for water supply and one for the return water circuit.

**Note!**

Water manifolds should not be located above sensitive electronic or electrical components.

Water manifold 2 is glued onto the DN32 PVC pipes. It can be mounted as a terminator to the PVC pipes or it can be applied to pipes as a T-connector.

**Table 7-3: Rubber hoses, water manifold 2**

Equipment	Number of hoses	Dimension o.d.
RFPG	2	1/2"
PSMC	2	1/2"

The primary water supplied by the customer is connected to the cyclotron system at the top of the secondary cooling unit. The DN32 standard is used for all PVC pipes for primary water as well as for secondary water. In addition, one DN15 pipe is connected from the secondary cooling unit to water manifold 1. Return water from the vacuum system is connected in common with the main fine water return (DN32). All connections, male and female, are included in the delivery.

**Table 7-4: Dimensions of PVC pipes**

Water circuit	Connection type	Corresponding pipe diameter (mm)
Primary/Secondary water	DN32	40

### 7-4 Gas piping interconnects

Proper piping will be provided and installed:

- 1 Between the customers' gas regulators and the cyclotron
- 2 Between the cyclotron and the chemistry process units

In order to meet the specification of high radiochemical purity, the high quality tubing has been purged according to a special washing procedure. It is important to avoid contamination by other medias than those recommended by GE.

The piping system uses Swagelok connections of standard dimensions.

Federal, state or local regulations and laws might apply to the installation of gas bottles and regulators, and gas tubes in-between. The customer must take responsibility for this part of the system design and installation.

In order not to delay the start-up of the machine it is important that all necessary gases are available at the time for cyclotron installation start.

Figure 7-4 shows all interconnections included in the GE delivery. All pipes for gas and liquids and all connectors indicated on the illustration are a part of the GE delivery.

**Note!**

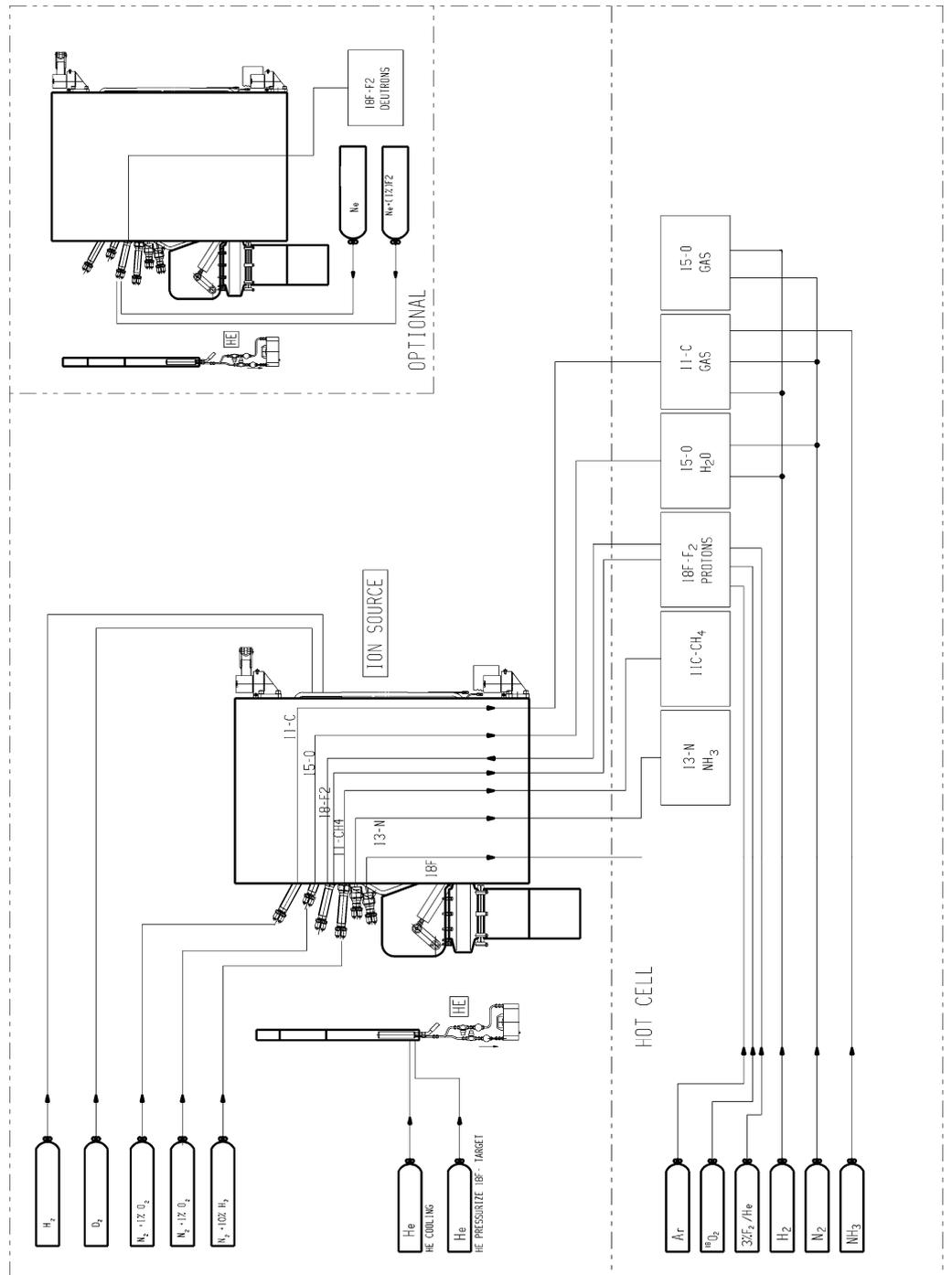
*Irrespective of what the illustration shows, the customer should provide the tubes between the gas bottles and the customer's regulators. See [Section 1-4-8 Gas and liquid distribution on page 20](#).*

Dotted lines indicate optional gas pipes, which are necessary only if a gas administration system is installed in the scanner room.

The maximum length for pipes between targets and hot cell/process cabinet is 40 meters.

For information about duct dimensions needed for gas and liquid tubes, see [Section 2-5-3 Cyclotron pit on page 41](#).

Figure 7-4: System gas interconnections



### 7-5 Customer furnished components

This section lists the customer furnished components, and details for connections to the cyclotron system.

**Table 7-5: Customer furnished electrical components and wiring**

Associated equipment	Material and labor provided by customer
Mains Distribution Panel	Provide and install mains distribution panel (MDP) with lockable circuit breakers. Provide mains power cables between MDP and cyclotron subsystems.
Emergency Off buttons	Provide and install wall switch box for flush mounted single push button stations. Provide red Emergency Off push button switch, with a guard to prevent inadvertent actuation and a SYSTEM EMERGENCY OFF nameplate. Locate near each exit in the cyclotron room and the and the power supply room. See <a href="#">Chapter 6 Power requirements</a> .
Protective disconnect device	Provide and install protective disconnect device with Low Voltage Low Energy local and multi-point remote control capability. (Three-pole, 600 VAC circuit breaker trip rated appropriately). See <a href="#">Chapter 6 Power requirements</a> .
Power for Master System	Provide and install power outlets for Master System and printer (if any). <b>Note!</b> A printer is not supplied with the system.
Safety Interlocks	Provide safety interlock components and wiring. Door switches, audible and visual alarms facility system interlocks, etc. as required by federal, state and local regulations.

**Table 7-6: Customer furnished water cooling components and piping**

Associated equipment	Material and labor provided by customer
Water cooling piping	Provide all primary (facility) water cooling piping to the secondary cooling unit. Provide secondary (de-ionized) water cooling piping between the secondary cooling unit and the water manifolds. Provide piping for make-up city water supply to the secondary cooling unit .
Radiation shield water supply	Provide water supply and drains in close proximity to radiation shield location. Water supply capacity 200 l/min (50 gpm). Standard 4" floor drain.

**Table 7-7: Customer furnished gas piping components**

Associated equipment	Material & labor provided by customer
Gas regulators	Provide gas regulators for all gases required for cyclotron operation. See <a href="#">Section 5-14-4 Customer supplied gas regulators on page 104</a> .
Gas tubes	Provide gas tubes between the gas bottles and the regulators. See <a href="#">Section 5-14-5 Customer supplied gas tubes on page 105</a> .
Compressed air supply	Clean, dry air, 0.6 MPa, 10 l/min.



## 8 SHIPPING AND DELIVERY DATA

### 8-1 Storage requirements

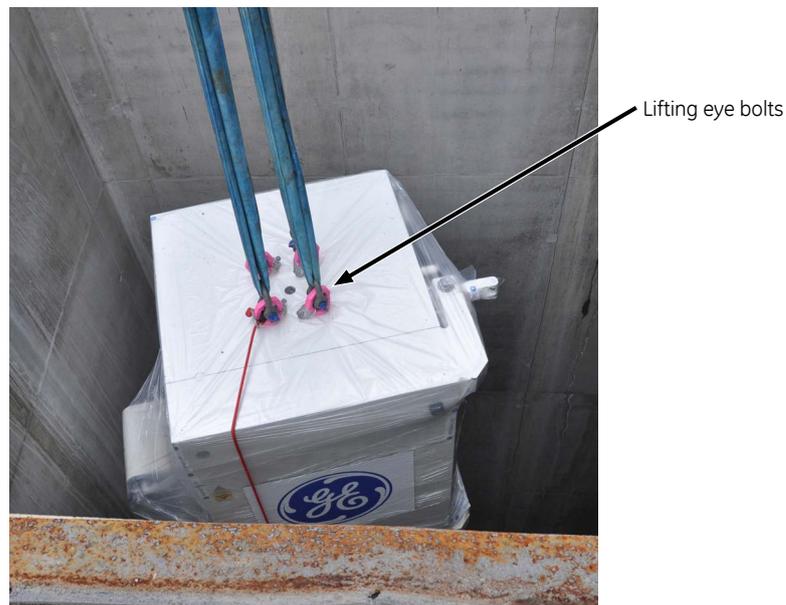
If the system must go into storage, keep it in a warehouse. Protect it from the weather. Maintain a storage temperature between 5°C and 40°C (41°F and 104 °F) with a relative humidity between 30% and 60% (non-condensing).

The unshielded system requires a storage area of 25 square meters. If the shipment includes the integrated radiation shield, double the storage area to 50 square meters.

### 8-2 Rigging requirements

With the exception of the vacuum system, radiation shield and target panel, the cyclotron and its subsystem cabinets arrive completely assembled. Hire an experienced rigger to plan and supervise the unloading of the system. The easiest way to unload the cyclotron is by heavy mobile crane. The accelerator magnet ships in the upright position, and arrives with four lifting eye bolts attached to the yoke. Use the crane, a forklift truck or skid loader to unload the remaining crates.

**Figure 8-1: Accelerator magnet with lifting eye bolts**



Choose the most direct delivery route from the entrance to the PET suite, as corners can be difficult to negotiate. Also take both the weight of the magnet and the weight of the rigging equipment into consideration when you plan the route. Hire a structural engineer to analyze the cyclotron room and magnet delivery route, to determine the load bearing capacity. Structural reinforcement may be required along the magnet delivery route. When mounted, the lifting fixture increases the height of the cyclotron by about 300 mm.

The top-heavy process cabinet (ProCab option) is the second heaviest subsystem, at 3570 kg. The cabinet is equipped with lifting eye bolts for rigging by crane (lifting straps ≥2 m required) or it can also be moved around on the supplied pallet using a forklift truck (load capacity ≥3600 kg/8000 lbs required).

**CAUTION! Tip hazard**

The ProCab safety support feet **must not** be removed until the ProCab has been finally positioned and is properly anchored to the wall, other than very temporarily during rigging, for example, to enable access through doorways.

The illustrations at the end of [Chapter 2 Space planning](#) show the center of gravity of the system components.

The optional waste gas unit weighs about 1500 kg.

### 8-3 Minimum access requirements

#### 8-3-1 Crated system dimensions

All equipment arrives packed in wooden crates. The crates are usually loaded into 20-ft containers for shipment. To facilitate rigging, the magnet ships in a container that opens from one end. [Table 8-1](#) lists the crate dimensions of the unshielded cyclotron system.

**Table 8-1: Unshielded cyclotron crate dimensions**

Contents	Dimensions (cm) W × D × H	Dimensions (in) W × D × H	Weight (kg)	Weight (lbs)
Water manifold, target panel	109 × 180 × 108	43 × 71 × 42.5	400	880
Vacuum pump, Master station	109 × 180 × 108	43 × 71 × 42.5	510	1122
Front frame target panel (1)	200 × 80 × 40	79 × 32 × 16	725	1595
Cabinet 1, PSMC	97 × 72 × 205	38 × 28.5 × 81	755	1661
Cabinet 3, ACS	90 × 98 × 210	35.5 × 38.5 × 83	350	770
Water system	150 × 86 × 186	59 × 34 × 73	495	1089
Cabinet 2, RFPG	95 × 135 × 207	37.5 × 53 × 81.5	612	1346
RF cable	170 × 30 × 170	67 × 12 × 67	40	88
Cable	120 × 80 × 60	47.5 × 32 × 24	385	847
Magnet	200 × 135 × 225	79 × 53 × 88.5	20300	44660
Cable duct, plastic shim	250 × 20 × 20	98.5 × 8 × 8	40	88
Rad. shield target VG-TTB/30-GE	70 × 40 × 70	27.6 × 16 × 27.6	250	550

Contents	Dimensions (cm) W × D × H	Dimensions (in) W × D × H	Weight (kg)	Weight (lbs)
Installation box (Gang box)	160 × 85 × 90	63 × 33.5 × 35.5	400	880
Process panel 150, C11 ProCab with panels	60 × 80 × 73 100 × 110 × 225	24 × 32 × 28.7 39.4 × 43.3 × 88.5	3570	7870
Waste gas storage	120 × 80 × 110	47.5 × 32 × 43.3	1500	3300

When the shipment includes the integrated radiation shield, container space doubles.

Table 8-2 lists the crate dimensions for the radiation shield.

**Table 8-2: Radiation shield crate dimensions**

Contents	Dimension (cm) W × D × H	Dimension (in) W × D × H	Weight (kg)	Weight (lbs)
Air compressor	145 × 80 × 97	57.2 × 32 × 38.2	215	473
Rear frame (pos. 2)	210 × 80 × 34	83 × 32 × 13.4	1295	2849
Door frame (pos. 3)	200 × 80 × 47	79 × 32 × 18.5	1385	3047
Frame hinge side (pos. 6)	170 × 80 × 45	67 × 32 × 17.7	1090	2398
Shield frame (pos 7)	170 × 87 × 27	67 × 34.3 × 10.6	1670	3674
Misc. rad. shield material	60 × 80 × 130	24 × 32 × 51.2	250	550
Misc. rad. shield material	60 × 80 × 170	24 × 32 × 67	570	1254
Sand, air manifold rad. shield	60 × 80 × 98	24 × 32 × 38.6	460	1012
Cable ladder	600 × 40 × 5	236 × 16 × 2	18	40
Lead plate N, O, P, X, Y	120 × 80 × 32	48 × 32 × 12.6	780	1716
Lead plate Q	120 × 80 × 38	48 × 32 × 15	1160	2552
Lead plate M, Z	120 × 80 × 30	48 × 32 × 12	760	1672
Lead bricks ~69 pcs. (4 pallets)	120 × 80 × 29	48 × 32 × 11.4	800	1760
Lead bricks 66 pcs, lead shims	120 × 80 × 28	48 × 32 × 11	800	1760
Installation material	120 × 80 × 113	48 × 32 × 44.5	220	484
Mixing tank	150 × 315 × 220	59 × 124 × 86.6	500	1100
Borax pentahydrate (4 pallets)	122 × 80 × 135	48 × 32 × 53.2	1000	2200

Contents	Dimension (cm) W × D × H	Dimension (in) W × D × H	Weight (kg)	Weight (lbs)
Boric acid (4 pallets)	126 × 80 × 135	49.6 × 32 × 53.2	1000	2200
Shield Tank 1	270 × 170 × 114	106.5 × 67 × 45	477	1050
Shield Tank 2	270 × 115 × 80	106.5 × 45.5 × 32	333	735
Shield Tank 3	270 × 100 × 95	106.5 × 39.5 × 37.5	360	800
Shield Tank 4	270 × 167 × 135	106.5 × 66 × 53	555	1225
Shield Tank 5	270 × 147 × 135	106.5 × 58 × 53	514	1135
Shield Tank 6	270 × 211 × 99	106.5 × 83 × 39	585	1290
Shield Tank 7	270 × 147 × 114	106.5 × 58 × 45	441	975
Shield Tank 8	209 × 131 × 70	82.5 × 51.5 × 27.5	261	575
Bottom Plate right	228 × 166 × 5	90 × 65.5 × 2	800	1760
Bottom Plate left	228 × 166 × 5	90 × 65.5 × 2	800	1760
Protecting border	170 × 80 × 50	67 × 32 × 20	140	310

Figure 8-2: Shield delivery



### 8-3-2 Uncrated system access requirements

Table 8-3 lists the minimum clearance requirements for doors and hallways. Table 8-4 specifies the minimum ceiling opening needed to deliver the accelerator and radiation shields by crane.

**Table 8-3: Minimum hallway and door dimensions**

Component	Minimum hallway/door width, mm (in)	Minimum hallway/door height, mm (in)
Magnet	2000 (79)	2300 (91)
RFPG	900 (36)	1900 (75)
PSMC	700 (28)	1900 (75)
Control cabinet	700 (28)	1900 (75)
Process cabinet (ProCab)	700 (28)	2100 (83)
Integrated radiation shield	1800 (71)	2300 (91)
Water cooling system	900 (36)	1900 (75)

**Table 8-4: Minimum ceiling openings**

Component	Minimum hole dimensions, mm × mm (in × in)
Cyclotron	2200 × 1600 (87 × 63)
Radiation shield	2300 × 1800 (91 × 71)

Table 8-5 lists the weight and dimensions of selected replacement components. If you plan to lower the cyclotron through the ceiling, make sure the doorways and hallways can accommodate these replacement components.

**Table 8-5: Replacement component dimensions**

Component	Approximate weight kg (lbs)	Overall dimensions W × D × H (mm)	Overall dimensions W × D × H (in)
Main coils	900 (1980)	230 × 1300 × 1300	9 × 51 × 51
Vacuum pump components	60 (132)	600 × 600 × 1000	24 × 24 × 39.5
Vacuum chamber	400 (880)	1150 × 1700 × 300	45.5 × 67 × 12



## 9 SITE READINESS

**All work must be performed in compliance with all applicable federal, state and local safety codes.**

Site readiness for each phase of the installation process must be confirmed by an on-site inspection conducted by GE personnel. The GE inspector is to complete the *Cyclotron delivery & installation request checklist* (see following pages in this section) and send it together with supporting documents, digital pictures and written communications to assigned TCM **and** RP installation leader.

 indicates that pictures should be provided. The size of each picture should be reduced to less than 0.5 MB.

Equipment delivery and manpower scheduling will occur once site readiness has been approved.

Cyclotron delivery & installation request <small>rev E</small>	
<b>Site information</b>	<b>Local GE project manager contact information</b>
<b>Site name:</b>	<b>Name:</b>
<b>City:</b>	<b>Cell phone:</b>
<b>Address:</b>	<b>E-mail:</b>
<b>Order/invoice information</b>	<b>Site representative contact information (FE, distributor)</b>
<b>GON:</b>	<b>Name:</b>
<b>Invoice account/PO:</b>	<b>Cell phone:</b>
<b>Finance contact:</b>	<b>E-mail:</b>
<b>Travel information</b>	<b>TC manager contact information</b>
<b>Closest airport:</b>	<b>Name:</b>
<b>Recommended hotels (GE-rate):</b>	<b>Cell phone:</b>
<b>Transport to the customer site:</b> <small>Taxi / Public transportation / Rental car</small>	<b>E-mail:</b>
<b>General comments</b>	<b>EHS representative contact information</b>
	<b>Name:</b>
	<b>Cell phone:</b>
	<b>E-mail:</b>

Production readiness (P)		
	#	Verified by/date
<b>Site forward production readiness</b> 1. Verify that site representatives (FE or customer) are fully clear on <i>how to order parts and accessories</i> for forward production. 2. Verify that site representatives (FE or customer) are fully clear on <i>how to contact the service organization and open complaints</i> , when needed.  <b>Note:</b> For service and spare parts for the Atlas Copco air compressor (self-shielded PETtrace 800 systems only), contact the local Atlas Copco representative directly.	P1	1.
		2.

Epoxy flooring (self-shielded PETtrace 800 systems only) (E)		
	#	Verified by/date
<b>Flooring ready for epoxy-coating</b> 1. The concrete floor is dry and clean. 2. All floor tolerances are within specifications. Provide survey report with this document. 3. Site conditions fulfilled: 20–27°C (degree Celsius) for 72 hours prior to the pour. Full lighting, power and adequate air exchange available.	E1	1.
		2.
		3.

PHASE ONE: Shipment and delivery (D)		#	Verified by/date	Comments
<b>D1: Facility provides security from theft or damage to the delivered equipment, GE tools and test equipment</b> 1. A lockable, secure room (15+ m <sup>2</sup> , is suggested) as temporary storage for uncrated, uninstalled items and tools available.	D1	1.	1.	
	<b>D2: Pre-delivery construction requirements in the cyclotron magnet-room/vault and the electronics room are met</b> 1. Ceiling tiles and grids are not installed. Access to cable trays and ladders is required during the mechanical installation phase of the project. 2. All dust generating work must be completed before system delivery. This is a warranty as well as an EHS concern. 3. Temperature and humidity is controlled: 30-60%RH / 18-25°C (degree Celsius). 4. All concrete surfaces, including floors, trenches, pits and walls, are finished (sealed), clean, dry and within specifications.  <b>Note:</b> Dimensions of cyclotron pit are extremely important for self-shielded systems. Once the equipment arrives at the owner's site, the owner is responsible for ensuring the equipment is protected from theft or damage. It is recommended that the equipment is covered and labeled as "fragile, not to be used as a work surface" until construction is 100% complete.	1.	1.	
		2.	2.	
		3.	3.	Humidity [%]: _____ Temp. [Celsius]: _____
		4.	4.	
5.	5.			
<b>D3: Design criteria for the building has been met by the owner's team</b> 1. Review the GE drawing set and the owner supplied construction drawings to confirm that each detail depicted on the GE drawing set has been incorporated into the construction. This includes but is not limited to pit and trenches dimensions, clear ceiling heights, conduit locations, etc. 2. A copy of the as-built drawings should be provided with this document.	D3	1.	1.	Flow meter gauge on primary side: <input type="checkbox"/> yes <input type="checkbox"/> no
	2.	2.		

PHASE ONE: Shipment and delivery (D)		#	Verified by/date	Comments
<b>D4: Designated space for staging and sorting equipment during the delivery and mechanical installation process</b>		<b>D4</b>	1.	1.
1. A self-shielded PETtrace 800 (SSPT) system requires 100+ m <sup>2</sup> (square meters) of space for an efficient delivery.  The space can be located inside or outside of the building provided all security and safety concerns are addressed.			2.	2.
2. The equipment <i>delivery route</i>  is defined and approved by the owner's engineers. The route must meet all clearance and weight bearing requirements. See the <i>Minimum access requirements</i> section in this manual.			3.	3.
3. During the mechanical installation phase, the self-shielded PETtrace 800 requires a <i>designated space for storing</i>  and mixing of borated water solution. The mixing tank requires <i>adequate clearances</i> to be delivered/removed from site and the mixing process requires <i>adequate power</i> and a <i>high-volume, heated water source</i> . <i>Ramps</i>  are required for passage over the filling hose. <i>Trays</i>  are required to collect any spill from hose connections when filling the tanks from a tanker truck.			4.	4.
4. Designated space for storing waste (app. 15-20 m <sup>2</sup> (square meters)) available. Instructions for waste sorting and packing according to state and/or local laws and regulations available. See the <i>Cleaning and waste</i> section in this manual.				
<b>D5: Delivery EHS aspects</b>		<b>D5</b>	1.	1.
1. The appropriate personal protective equipment (PPE), and tools for equipment delivery and rigging are available. (Minimum requirements for PPE and tools are specified in <i>PETtrace 800 series Installation Manual (dir. 2131771-100)</i> .)			2.	2.
2. Personnel involved in equipment delivery and rigging have received work instructions and information about safety procedures in accordance with <i>PETtrace 800 series Installation Manual (dir. 2131771-100)</i> .				
<b>D6: Copy of owner's licenses in hand</b>		<b>D6</b>		
License and permit requirements vary by location. A license or permit may be required for delivery of equipment, installation of equipment, production of radiation in the cyclotron, delivery of isotopes to a hot cell, etc.			1.	1.
1. The local GE team must have a detailed, thorough understanding of licensing requirements for the specific project.		2.	2.	
2. A copy of the required license(s) and/or permits for each phase of this project must be provided with his document before a new phase can begin.				

PHASE TWO: Mechanical installation (M)		#	Verified by/date	Comments
<p><b>M1: Facility is EHS compliant (provides a safe and clean working environment)</b></p> <ol style="list-style-type: none"> <li>Dry floors ; adequate lighting  for detailed work; dust free air; no exposed electrical wires; controlled temperature and humidity; limited construction personnel in all GE equipment/work areas; bunker ; interiors of conduits and trenches  are clean and dry; toilets  available; facilities for washing hands  available, for example, after working with lead for self-shielded PETtrace 800, etc.</li> <li>Self-shielded PETtrace 800 systems only: Day labor and equipment (lift capacity at least 200 kg; lift height at least 3 m) to move lead plates and lead bricks into position available. Refer to <i>PETtrace 800 series Radiation Shield Installation Manual</i> (dir. 2169053-100).</li> <li>All concerns must be resolved prior to GE personnel arriving at site.</li> <li>In the comments section on this row, provide name and cell phone number for responsible EHS inspector.</li> </ol>		M1	<ol style="list-style-type: none"> <li></li> <li></li> <li></li> <li></li> </ol>	<ol style="list-style-type: none"> <li></li> <li></li> <li>Name: _____</li> <li>Cell phone: _____</li> </ol>
<p><b>M2: Post-delivery construction in the cyclotron magnet-room/vault and the electronics room are 100% completed as per the GE drawings and owner supplied construction drawings</b></p> <ol style="list-style-type: none"> <li><u>Except for</u>: Ceiling tiles; mains power connections to electronics cabinets and PDUT; final plumbing connections to WCU (SwedeWater) and GE water manifolds.</li> <li>Equipment <i>delivery routes</i> and access points are closed up and finished.</li> <li><i>Water cooling chiller</i>  for the cyclotron is on-line, flushed and pressure tested.</li> <li><i>Make-up water outlet</i>  is operational and located next to WCU.</li> <li>HVAC system is fully operational including properly phased and permanent mains power connected to MDP. </li> </ol>		M2	<ol style="list-style-type: none"> <li></li> <li></li> <li></li> <li></li> <li></li> </ol>	<ol style="list-style-type: none"> <li></li> <li></li> <li></li> <li></li> <li></li> </ol>
<p><b>M3: Required gas cylinders and compressed air system + regulators are installed as per regulatory requirements for explosive and hazardous gases</b></p> <ol style="list-style-type: none"> <li>Owner supplied compressed air system (stand-alone)  is installed and operational for clean/dry/oil free air (6-8 bar).</li> <li>Gas storage space  is finished (exact storage requirements will vary by area and type of gases being used at the specific facility), gas piping  is installed and flushed with inert gas; all required gas bottles  and regulators  are on site and installed (see the <i>Utility requirements</i> section in this manual).</li> </ol>		M3	<ol style="list-style-type: none"> <li></li> <li></li> </ol>	<ol style="list-style-type: none"> <li></li> <li></li> </ol>

PHASE TWO: Mechanical installation (M)		
#	Verified by/date	Comments
<b>M4</b>	1. 2. 3.	1. 2. 3.
<b>M5</b>	1.	1.

PHASE THREE: Start-up and calibration (S)		
#	Verified by/date	Comments
<b>S1</b>	1. 2. 3. 4. 5.	1. 2. Test pressure [bar]: _____ Test time [h]: _____ 3. 4. 5. Attach completed test instructions to this checklist.
<b>S2</b>	1. 2. 3. 4. 5.	1. 2. 3. 4. 5.

**PHASE TWO: Mechanical installation (M)**

**M4: Owner supplied cyclotron support equipment is mechanically installed and validated on site (fully functional)**

1. Radioactive exhaust system, including all filters, is installed and fully functional.
2. All hot cells, including hot exhaust and options, are installed and fully functional.
3. Safety-interlock systems for cyclotron, hot cells, doors, etc., are installed and fully functional.

**M5: items S1 to be completed prior to/during the mechanical phase of the project**

1. Owner's plumber and electrician must finalize all connections and checks of the electrical, plumbing and compressed air within the first 5 days that the GE mechanical team is on site. GE will provide recommendations and guidance regarding connection points.

**PHASE THREE: Start-up and calibration (S)**

**S1: Construction 100% complete including "punch lists"**

1. Ceiling tiles and permanent lighting are installed throughout the cyclotron suite.
2. Cyclotron water cooling pipe work (WCU - GE Manifolds) is finished, pressure tested (12 bar) and all leaks repaired.
3. Compressed air supply is connected to GE supplied compressed air manifold.
4. Permanent mains power is connected to PDUT and all GE supplied electronic cabinets.
5. Grounding of all equipment is verified according to Ground test continuity instructions (DOC1653524). (The resistance must not exceed 0.2 Ω.)

**S2: Confirm all licensing requirements for owner and GE have been met**

1. Permission for production of radioisotopes and delivery to hot cell confirmed.
2. Controlled radiation area is established, monitored and enforced by owner. Radiation monitoring system and exhaust are installed, calibrated and fully operational.
3. Safety interlock system is commissioned and connected to CIB.
4. All radiation shielding is installed (product lines, trenches, transitions to hot cells, exhaust filters, etc.).
5. Hot cells are fully commissioned.

PHASE THREE: Start-up and calibration (S)		#	Verified by/date	Comments
<b>S3: Calibrated dose calibrator  installed in a suitable hot cell or shielded environment</b> 1. Supplier: _____ 2. Activity measurement range: _____ (Ci/GBq) 3. Calibration date: _____		S3	1. 2. 3.	1. ← Write supplier name 2. ← Write activity range 3. ← Write calibration date
<b>S4: Basic lab equipment and supplies available</b> 1. Balance  to weigh target deliveries is available. 2. O <sup>16</sup> target water and ethanol are available.		S4	1. 2.	1. 2.
<b>S5: Master control station</b> 1. RJ45 contact is available for remote connectivity to internet (InSite). 2. Printer for Master System installed. (A printer is not included in the delivery.) <b>Note:</b> Recommended printers are: Hewlett Packard™ (LaserJet™ or similar model).		S5	1. 2.	1. Printer model: _____ 2.
<b>S6: Radiation safety officer assigned and survey meter available</b> 1. In the comments section on this row, provide name and cell phone number to the responsible radiation safety officer who will instruct/oversee the installation team to adhere to local radiation safety regulations and follow the radioactive testing made by the installation team. 2. Portable radiation survey meter available.		S6	1. 2.	1. Name: _____ Cell phone: _____ 2. Portable radiation survey meter available: <input type="checkbox"/> yes <input type="checkbox"/> no

## 10 TOOLS AND TEST EQUIPMENT

### 10-1 Introduction

The following section lists the tools and test equipment needed to install and calibrate the cyclotron system.

### 10-2 Rigger/customer supplied equipment

- 1 50-80 ton crane for lifting magnet from delivery truck. Based upon the "Pick" of the cyclotron which is the distance from the initial pick point to the final staging point.
- 2 Steel floor plates to cover floors while transporting the magnet, 36 × 12 × 0.25 in.
- 3 Wood blocks, assorted sizes.
- 4 Jacks and accessories for lifting the magnet, 20 ton (45 000 lbs) capacity.
- 5 Equipment to unload and move crates, (e.g. fork lift, hand trucks etc.).
- 6 Panel lifters for computer flooring.
- 7 Ramps for passage over the hose when filling the radiation shield tanks.
- 8 Tray for collecting any spill from hose connections when filling the radiation shield tanks from a tanker truck.

### 10-3 Installation equipment

For information on installation equipment, refer to *PETtrace 800 series Installation Manual* (dir. 2131771-100).



## 11 ANALYSIS AND TEST EQUIPMENT

### 11-1 Introduction

The site must be equipped with a chemistry laboratory to analyze the yield, radionuclidic purity and chemical purity of the radioisotopes. The laboratory must have all analytical equipment installed in a hot cell and calibrated prior to the completion of the cyclotron system, because the chemistry analysis is included in the acceptance test for the site. The facility should also hire or assign qualified personnel to run the chemistry laboratory. The lab personnel should be present during the chemistry analysis portion of the acceptance test.

All chemicals for cyclotron system must be provided by the customer. Suppliers and formulations may differ between countries.

### 11-2 Test chemicals

For information on chemicals that should be available when testing the cyclotron system processes, please contact GEMS PET Systems AB in Uppsala, Sweden.

### 11-3 Process chemicals

For information on chemicals which are needed to support tracer production with the cyclotron system, please contact GEMS PET System AB in Uppsala, Sweden.

### 11-4 Other chemicals

The following chemicals should be available for cleaning purposes:

- Acetone
- Diethylether
- Distilled, deionized or nanopure water (for cleaning of the Ammonia Process System)
- Ethanol or methanol
- 2-Propanol

### 11-5 Analysis equipment

Table 11-1 lists a typical analysis equipment. Refer to detailed description for each separate project.

**Table 11-1: Analysis equipment**

Item
Thin Layer Chromatography (TLC) equipment including:
TLC scanner (BIOSCAN AC Scan Beta is recommended)
Supply of TLC plates on plastic or glass
Chamber for plates development
Micropipette or micro syringes or capillaries
Plate cutting table
Glassware for solvent preparation
Fume hood or well ventilated area
Gas Chromatography (GC) equipment including:
GC chromatograph
Heated injector
Thermoconductivity detector
Flame ionisation detector (not required but may be useful)
Radioactivity detector
Columns: Molecular sieves, Carbosphere 80/100, Porapak Q 80/100 (all columns must be filled columns, not capillary columns)
Supply of gases (helium, nitrogen) and solvents
Gas tight microsyringes, 1–10 microliters
Fittings, stainless steel tubing, accessories
Dose calibrator, capable of measurement of activity from 10 µCi to 5 Ci (Capintec dose calibrator is recommended)
HPLC system (not required, but may be useful) including:
UV detector
Radioactivity detector

Item
High pressure injection valve
Amino-derivatised silica column and reversed phase column
Pre-column filters
Solvent gradient programmable pump
Solvent preparation station
HPLC injection syringes
Accessories: extra tubing, fittings, tools
Computer with printer for data storage and report generation



## APPENDIX A GLOSSARY

### Glossary of Terms, Abbreviations and Acronyms

Appendix A lists the common terms, abbreviations and acronyms that are used throughout the cyclotron manuals. In general, acronyms are explained also at their first appearance in the text of each chapter.

#### A

AC	Alternating current
ACC	Accelerator
ACS	Accelerator Control System
ACU	Accelerator Control Unit
AI	Analog Input board
AO	Analog Output board
ACSIP	Accelerator Control System-Isotope Production
ATCP	Accelerator Test and Configuration Program

#### B

B	Check Valve/Backing Valve in product outlet
BCA	Beam Current Analyzer board
BEV	Beam Exit Valve
BV	Backing Valve

#### C

C	Column
Cabinet 1	PSMC
Cabinet 2	RF system
Cabinet 3	ACU, PSARC, VCU
CB	Circuit Breaker
CC	Column in $^{11}\text{C}$ chemistry system
CCS	Chemistry Control System
CCU	Chemistry Control Unit

CEU	Chemistry Electronic Unit
CIB	Customer Interface Box
CIU	Control Interface Unit
CO	Column in <sup>15</sup> O chemistry system
CPU	Central Processing Unit
CWM	Cooling Water Manifold
<b>D</b>	
DC	Direct current
DCM	DC Motor Servo board
DIO	Digital Input/output board
DP	Diffusion Pump (High Vacuum)
DPA	Driver Power Amplifier (RFPG)
DPC	Door Pendant Control
DPSU	Driver Power Supply Unit (RFPG)
<b>E</b>	
EOB	End of bombardment
EOP	End of process
EOS	End of synthesis
<b>F</b>	
F	Flow regulator
FWD, FWD PWR	Forward power (RF)
<b>G</b>	
GSPU	Grid Screen Power Unit (RFPG)
<b>H</b>	
HVAC	Heating, Ventilation and Air Conditioning systems
HVV	High Vacuum Valve

**I**

IRS Integrated Radiation Shield

IS Ion Source

ISGM Ion Source Gas Manifold

**L**

L1-L3 Line voltage, phase 1 to 3

LPP Liquid Product Panel

LTF Liquid Target Filler

**M**

M Fine Metering Valve

MCS Master (Control) System

MDP Mains Distribution Panel

MSB Main Switch Box

**N**

N Line voltage, neutral conductor

NAEU Ammonia Terminal Box (Ammonia Electronic Unit)

NAPS Ammonia Process System ( $^{13}\text{N-NH}_3$ )

**O**

O Oven

OC Oven,  $^{11}\text{C}$  chemistry system

OO Oven,  $^{15}\text{O}$  chemistry system

OPP Oxygen-15 Product Panel

OWPS  $\text{H}_2\text{O}$  Process Unit ( $^{15}\text{O}$ -Water Process System)

**P**

PCB Printed circuit board

PDU Power Distribution Unit

PDUS Power Distribution Unit (for shielded cyclotron system – replaces PDU)

PDUT	PDU Transformer
PE	Protective Earth
PEN	Penning Gauge
PET	Positron Emission Tomography
PIR	Pirani Gauge
PROCAB	Process Cabinet <sup>11</sup> C, <sup>15</sup> O
PRS	PETtrace Radiation Shield
PSARC	Power Supply for the Ion Source (arc power supply)
PSMC	Magnet (Main Coil) Power Supply
PSS	PETtrace 800 Service System
PWR	Power
<b>R</b>	
RCAV	RF Cavity
REFL, REFL PWR	Reflected power (RF)
RF	Radio Frequency
RFPG	RF Power Generator
RP	Rotary Pump (Fore-vacuum)
RSC	Radiation Shield Compressor (with receiver)
RSM	Radiation Shield Compressed Air Manifold
RV	Roughing Valve
<b>S</b>	
SCS	Standard Chemistry System
SCU	Source and Control Unit (RFPG)
SK	Socket (RFPG)
SM	Stepper Motor board
SSS	Standard Support System
STS	Standard Target System

**T**

TAU	Tube Amplifier Unit (RFPG)
TB	Terminal Box
TP	Test Point
TPSU	Tube Power Supply Unit (RFPG)
TS	Terminal Strip

**U**

ULSI	Ultra Low Standard Impurities
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**V**

V	Valve
VC	Valve in <sup>11</sup> C chemistry system
VCU	Vacuum Control Unit
VMEbus	Backplane bus for use in microcomputer systems
VO	Valve in <sup>15</sup> O chemistry system

**W**

WCU	Secondary Water Cooling Unit
WGU	Waste Gas Unit
WGP	Waste Gas Panel
WLAA	Warning Lamp and Audible Alarm (for Magnet and Radiation Shield Doors)

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For local office contact information, visit  
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