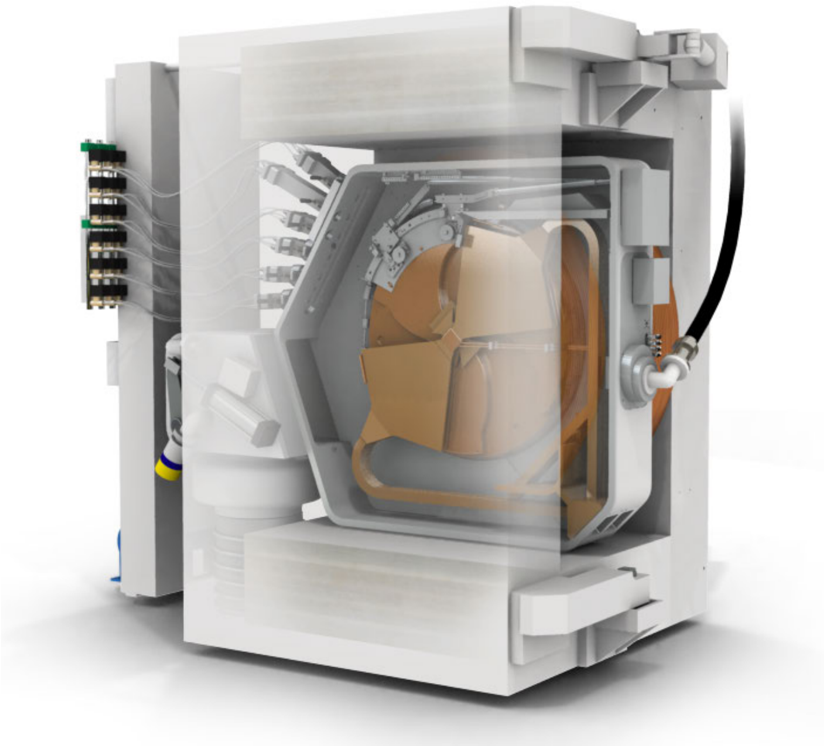
PETtrace 800 series
PETtrace Kunpeng
Site Planning Guide



2102960-100
Revision 29

Revision history

Revision	Date	Reason for change
29	February 3 , 2025	Sec. 8-2-1: Warning added for lifting eye bolts. [ECR2389458]
28	December 20, 2023	Updated to include PETtrace Kunpeng [PCR 23-195]: Title of manual updated on front page and header. Product name PETtrace 800 replaced or removed throughout the manual. Sec. 1-1: Cyclotron systems in this manual updated. Sec. 5-2: Compliance with regulatory requirements updated.
27	September 29, 2023	Branded to GE HealthCare. New layout. Sec. 2-2-5: Added information on bench radiation shield. [PCR 21-304] Sec. 2-6: Added information on bench radiation shield. [PCR 21-304] Sec. 10-2: Added information on mobile mini lift. [PCR 21-304] (Corrected typos below for revision 25: The drawing numbers and related PCR number shall be CAA209-56003 (729178), CAA209-56004 (729179) and CAA209-56005 (729180). [PCR 20-083])
26	May 26, 2023	Sec. 7-2: Ethernet communication network overview added. [SPR HCS-DM00711337] Sec. A-2: Compatible cyclotron ports added [SPR HCSDM00719228, HCS-DM00699041] Sec. A-2: Information on CIB added. [SPR HCSDM00709370] App. A-7: Information and specification for LAN cables added. [SPR HCS-DM00728417, HCSDM00687102] App. A-7: Specifications for mains power cables added. [SPR HCSDM00702730] App. A-7: Ethernet communication network overview added. [SPR HCS-DM00711337] App. A-9: Added LOTO requirement for CHS air supply. App. A-13: PETtrace 800 Solid target platform connections overview added.
25	May 31, 2022	CAA209-54003 (729178), CAA209-54004 (729179) and CAA209-54005 (729180) added as reference document to manual. [PCR 20-082] Sec. 1-2: Added internet access to customer responsibilities. [PCR 20-377] Sec. 1-4-4: Removed Internet access. [PCR 20-377] Sec. 1-4-5: New section concerning Internet access. [PCR 20-377] Sec. 2-5-2: Removed modem requirement. Internet access via Ethernet. [PCR 20-377] Sec. 5-6-2: Updated text. [PCR 22-014] Sec. 5-6-3: Updated specifications. Added table 5-3. [PCR 22-014] Sec. 7-3: Added requirements/recommendations. [PCR 22-014] Sec. 7-3-1: Updated figure 7-3 (added filter). [PCR 22-014] Sec. 7-5: Updated Safety interlocks in table 7-5. [PCR 21-357] Sec. 8-2: Updated text about loading. Added warning. [PCR 19-379] Sec. 9: Added network to M5 #1. [PCR 20-377] App. A: Site planning info added on PETtrace 800 Solid target platform. [PCR 22-130]

Revision	Date	Reason for change
24	November 18, 2021	Sec. 5-9: Added warning concerning risk for release of ^{13}N gas. [PCR 21-178] Table 5-6: Added $[^{13}N]N_2/NO_x$ (^{68}Ga by-product). [PCR 21-178] Table 5-7: Added ^{13}N, ^{66}Ga and ^{67}Ga. [PCR 21-178] Table 5-9: Changed text 1st cell/last row. [PCR 21-178] Sec. 11-4: Removed Diethyl ether. [PCR 20-198]
23	May 5, 2021	Section 2-2: Note regarding recommended minimum room dimensions added. [PCR 15-131] Section 2-2: Table 2-2 and 2-5, and fig 2-2 updated (changed dimensions to 8 × 6 m). [PCR 15-131] Section 8-2-1: New section added with information on lifting straps and eye bolts. [PCR 20-230] Section 10-2: Removed specification of crane capacity and added requirement of cordless screwdriver.
22	December 12, 2019	Information about Customer Documentation Portal added. Chapter 1: PETtrace 890 added. Section 3-2-5: Gamma isodose curves added to right side of cyclotron in figs. 3-1, 3-3, 3-5, and 3-7. [PCR 19-250]
21	April 15, 2019	Section 2-5-3-1: Warning added (California proposition 65). [PCR 19-106] Section 5-14: Table 5-15 (Target liquid specifications) moved from section 5-14-4 to 5-14-2-4 (new). Section 6-1-1: Table 6-1 updated. [PCR 19-069] Section 6-2: Table 6-2 updated, Table 6-3 added. [PCR 19-069] Section 6-2: Table 6-2 updated (overload relay spec.). [PCR 18-396]
20	November 26, 2018	Chapter 5: Table 5-9 updated, value for He cooling gas to 0.38 ± 0.03 MPa (changed in gas spec doc). [PCR 18-354] Chapter 6: Fig. 6-4, 6-5 and 6-6 updated. Section 5-14-1: Compressed air pressure updated. [PCR 18-354] Section 5-14-2-1: Ion source gas pressures updated. [PCR 18-403]
19	March 5, 2018	Chapter 2: Table 2-3, sec. 2-2-5, figure 2-7, 2-8, 2-27 updated. [PCR 14-188, 15-211] Section 3-2-5: Isodose curves for 160 µA added. [PCR 17-210] Section 5.6: Air and water cooling tables updated (simplified). Section 5-16-2: Comment about safety inputs added. [PCR 17-273] Chapter 5: Tables updated to accommodate for ^{68}Ga. [PCR 17-179] Chapter 6: Power requirements values updated. [PCR 17-179]
18	May 2, 2017	Section 5-14: $^{13}NH_3$ 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]

Revision	Date	Reason for change
16	January 13, 2016	Table 5-11, 5-14: $^{18}F^{-}$ 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 require-ments. [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]
10	June 8, 2012	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^3/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]

Revision	Date	Reason for change
9	October 21, 2011	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_2/D_2 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] *(Converted to Skribenta.)*
8	March 25, 2011	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.
7	June 3, 2010	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.
6	December 7, 2009	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] $^{11}CO_2$ HP, $^{11}CH_4$, $^{18}F^-$ Gen II, Nb 25, $^{18}F_2$ 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.

Revision	Date	Reason for change
5	November 1, 2006	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 11C target gas spec. Illustration 5-3 updated. Section 5-7 hot cell ventilation added. Ch 7: Section 7-3 updated. Illustrations 7-3 and 7-4 replaced. Section 7-3 updated water piping spec.
4	Nov 15, 2004	Ch 7 Interconnection Data: Figure 7-5 System Gas Interconnections updated with respect to new options ($^{11}CH_4$ Methane and $^{18}F_2$ Proton).
3	May 5, 2004	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).
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: Section2.4.2 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.

Customer Documentation Portal

Manuals can be downloaded from the Customer Documentation Portal (CDP).

Enter the Customer Documentation Portal through
https://www.gehealthcare.com/documentationlibrary.

1. In the **Modality** drop-down menu, select **Radiopharmacy Cyclotrons**.
2. Select product.
3. Select document type and language, if desired.
4. Click **Search**.

Please check CDP regularly for updates.

Table of Contents

1 General information

1-1 Introduction

This manual applies to the following cyclotron systems:

- PETtrace 800 series (PETtrace 840, PETtrace 860, PETtrace 880, and PETtrace 890; manufactured for the global market)
- PETtrace Kunpeng (manufactured in China for the Chinese market)

If content is applicable only to the PETtrace 800 series, the system is referred to as PETtrace 800. If content is applicable only to the PETtrace Kunpeng system, the system is referred to as PETtrace Kunpeng.

The guide contains the physical, electrical, plumbing and magnetic data necessary for planning and preparing a site for the tracer production system. Preinstallation work is done to prepare the customers 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 site.

Note!
Site planning information for the PETtrace Solid target platform is found in *Appendix A Site planning – PETtrace Solid target platform**.*

Note!
Site planning information for the Beam Line system is found in PETtrace 800 series Beam Line System Manual (dir. 5137921-100), and for $^{18}F_2$ Proton target system in PETtrace 800 series $^{18}F_2$ 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. The manual includes 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 customer, the project architect or the customer’s contractor, in preparing a new site for installation.

The manual contains detailed information necessary for the site planning process. The information is 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 compromise operator use, safety, and/or product quality. The results of good up-front planning will 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 is difficult and costly to make revisions.

Generally, workers with experience in this kind of projects should be used. Contractors and other personnel with experience only in “general” construction, may not meet the requirements for a good project installation. A specific background in medical suite planning and construction is highly recommended. For this reason, it is recommended that time be invested in identifying and selecting experienced personnel suited 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 the project, from concept of the facility, to installation and start-up of the equipment. Ideally, the Project Coordinator should be thoroughly familiar with the construction process. The Project Coordinator should keep in close contact with all of the contractors, subcontractors, GE HealthCare and administrative personnel, as well as planners and architects. Maintaining a dynamic schedule is the responsibility of the Project Coordinator.

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

1-2 Customer responsibilities before installation

Unless otherwise agreed, the customer 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 clearly labelled non-electrical lines, such as plumbing, compressed air and vacuum lines.
- Installation of raised flooring, electrical conduits, junction boxes, ducts, surface raceways, outlets and line safety switches.
- Installation of radiation protection material.

- Installation of wires not supplied by GE HealthCare, 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. All ground wires must be green with a yellow stripe.
- Installation of Ethernet (RJ45) connections for Internet access:
  - Close to Cabinet 3
  - In the cyclotron vault (unshielded cyclotron)
- Procurement and installation of fire control devices, as required by local regulations.
- 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 before installation.
- Facilities 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 HealthCare in the project. For additional information regarding the time required for cyclotron installation, see Section 1-5 Installation flow chart on page 26 of this chapter.

1-3-1 Facility planning

Initially, the facility planning defines the details in the building and facility specification, with GE HealthCare supplying all necessary information. The building design must be approved by GE HealthCare before starting the construction/renovation of the facility.

1-3-2 Rigging/mechanical installation

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

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

- mechanical assembly
- alignment of critical components
- assembly documentation

Before all assembly work being completed, GE HealthCare electrical technicians begin installing cables between power supplies, electronic cabinets and loads. Qualified electricians are contracted by the customer to connect the equipment to the electrical power distribution panels. All GE HealthCare cables should be connected or terminated in an appropriate manner.

1-3-3 System start-up

At the completion of the mechanical installation, GE HealthCare 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. At the completion of each subsystem start-up, the engineers 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, specified by GE HealthCare, are needed to complete the installation and start-up. Providing this equipment and these chemicals is the responsibility of the customer.

1-3-4 Performance tests

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

The beam tests ensure that the cyclotron produces its guaranteed output and operates within specifications. All settings and calibrations are documented.

1-3-4-1 Radionuclide production and radiochemistry

When proper cyclotron performance has been demonstrated, the GE HealthCare application specialist will begin the radionuclide production 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	Customer	GE HealthCare
1	GE HealthCare shall elect one responsible project leader with whom the customer will communicate.		X
2	The customer is required to inform GE HealthCare about project schedule and changes in project schedule.	X	
3	The customer 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	Customer	GE HealthCare
1	Provision of documents specifying: • dimension and weight of major components • air temperature and humidity requirements • heat dissipation to air from the delivered equipment • access requirements • equipment layouts • needs for cable trays • water piping and lifting equipment • compressed air requirements • outlets, electrical and data		X
2	Generation of architectural drawings of the facility, including the delivery path of the cyclotron.	X	
3	Drawings must be approved by GE HealthCare before construction work begins and within four weeks of receipt of material mentioned in 2.		X

1-4-3 Media supply

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

1-4-4 Electricity

Item no.	Item	Customer	GE HealthCare
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 customer.		X
5	Provision, installation and connection of electrical power cables between: • the main power distribution panel and the power distribution panel • the main power distribution panel and the “mains” connection (ac power input) of all GE HealthCare power supply cabinets • the main power distribution panel and the closed deionized water cooling system	X	
6	Provision, installation and connection of: • power cables between power supply cabinets and loads • control cables		X
7	Interconnection cables, supplied by GE HealthCare, from power supplies and electronic control units are to be located in ducts, trenches, conduits and/or cable trays. The customer must supply and install these ducts/cable trays and it is the customer’s responsibility to ensure that this cable routing system meets local electrical codes and requirements.	X	

1-4-5 Network

Item no.	Item	Customer	GE HealthCare
1	Provision of Internet access via Ethernet connection (RJ45) close to Cabinet 3.	X	

Item no.	Item	Customer	GE HealthCare
2	Provision of Internet access via Ethernet connection (RJ45) inside vault (unshielded cyclotrons).	X	

1-4-6 Water cooling system

Item no.	Item	Customer	GE HealthCare
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 ±1°C (±2°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 HealthCare 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 HealthCare 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 to eliminate back-streaming shall be provided by the customer.	X	

1-4-7 Compressed air

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

1-4-8 Ventilation

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

1-4-9 Gas and liquid distribution

Item no.	Item	Customer	GE HealthCare
1	Provision and installation of: • gas supply with gas bottles/tanks/generators • regulators and fittings • clean, high quality tubes to the cyclotron room/vault and the synthesis units/hot cells, for ion source, target and optional process gases.	X	
2	Provision and installation of all connections *except those directly to the GE HealthCare cyclotron system and GE HealthCare synthesis unit(s)*.	X	
3	Provision and installation of all connections directly to the GE HealthCare cyclotron system and GE HealthCare 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 radio-chemistry 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	

1-4-10 Off-loading and rigging

Item no.	Item	Customer	GE HealthCare
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

1-4-11 Installation of cyclotron

Item no.	Item	Customer	GE HealthCare
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	
2	GE HealthCare 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 HealthCare.		X
3	Assembly and commissioning of cyclotron and performance testing.		X

1-4-12 Additional equipment and materials

Item no.	Item	Customer	GE HealthCare
1	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. Provision of a complete chemistry laboratory including necessary test equipment in order to perform the acceptance test protocol. ***Note!*** *Printer is not supplied with the system.* Recommended printers to connect to the Master System: Hewlett Packard™ printers (Laserjet™ or similar model)	X	

1-4-13 Safety

Item no.	Item	Customer	GE HealthCare
1	The complete radiochemical production facility where the equipment from GE HealthCare will be installed is the responsibility of the customer.	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	

Item no.	Item	Customer	GE HealthCare
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 HealthCare 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 HealthCare, for the subsystems that are subject to LOTO.	X	

1-4-14 Cleaning and waste

Item no.	Item	Customer	GE HealthCare
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[1] [kg]
Wood (pallets, pallet collars, crates, etc.)	1 030 + 150[2] + 150[3]
Plastic (cans, packing material, styrofoam™, etc.)	76 + 72[4] + 22[5]
Iron (screws, nail plates, cans, etc.)	95 + 70[6]
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 cyclotrons only. Might be contaminated with boric acid or borax pentahydrate.

3 Self-shielded cyclotrons only. Might be contaminated with lead.

4 Self-shielded cyclotrons only. Might be contaminated with boric acid or borax pentahydrate.

5 Self-shielded cyclotrons only. Might be contaminated with epoxy hardner.

6 Self-shielded cyclotrons 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, subsystems				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, subsystems						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 30 (unshielded – needs a vault) and Section 2-2-2 Cyclotron room with integrated shield on page 32 (integrated shield)
- Power supply room [1] for the electronics cabinets: See Section 2-2-3 Power supply room (shielded and unshielded) on page 33
- Water cooling room[1] for the secondary Water Cooling Unit: See Section 2-2-4 Cooling system room on page 35
- Radiochemistry lab: See Section 2-2-5 Radiochemistry production facility on page 35

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 30 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 32 contains additional room information for the cyclotron with an integrated radiation shield.

Note!
The dimensions in tables Table 2-1 and Table 2-2 are recommended minimum dimensions. From a safety perspective, it is good if the cyclotron room is larger than the minimum. A larger room will also facilitate the installation work.

[1] 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.

Table 2-1: Recommended room dimensions – vault version

Room	Recommended area in m^2 and (ft^2)	Recommended minimum 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^2 and (ft^2)	Recommended minimum dimensions in meters and (feet)
Cyclotron room/ power supply room	48 (517)	8 × 6 (26 × 20)

Figure 2-1: Typical facility with a vault

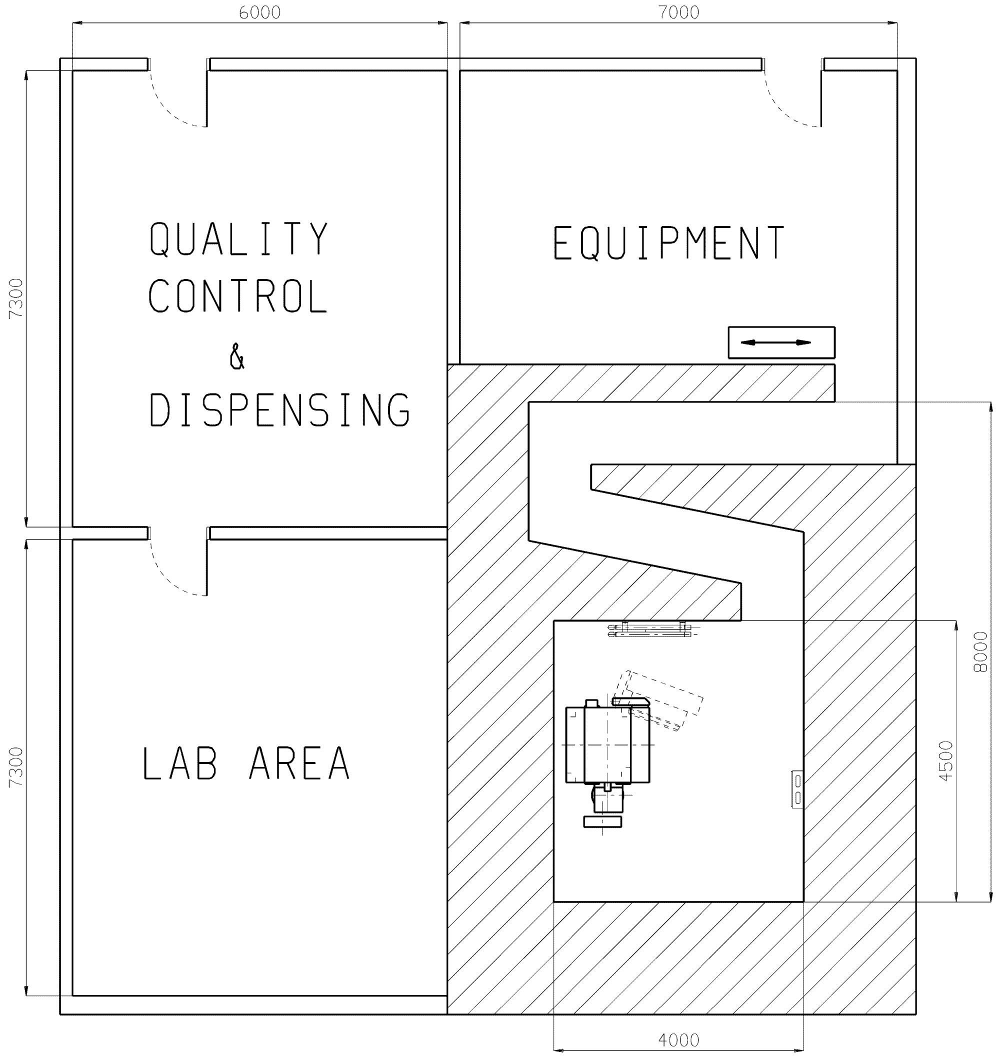
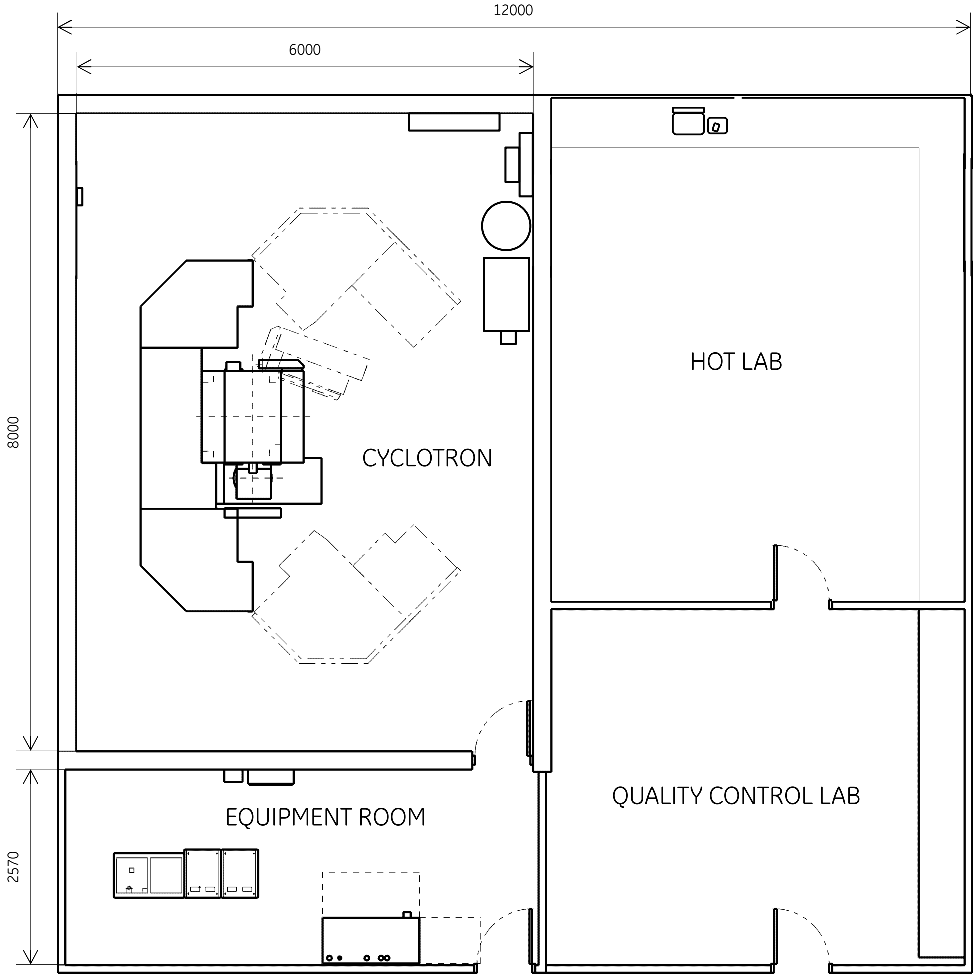


Figure 2-2: Typical facility with an integrated shield



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^2 (210 ft^2)
Length	5.0 m (16 ft)
Width	4.0 m (13 ft)
Height	2.6 m (9 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 40 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 43 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 47 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	48 m^2 (517 ft^2)
Length	8.0 m (26 ft)
Width	6.0 m (20 ft)
Height	3.5 m (11 ft 6 in)

2-2-2-2 Equipment dimensions

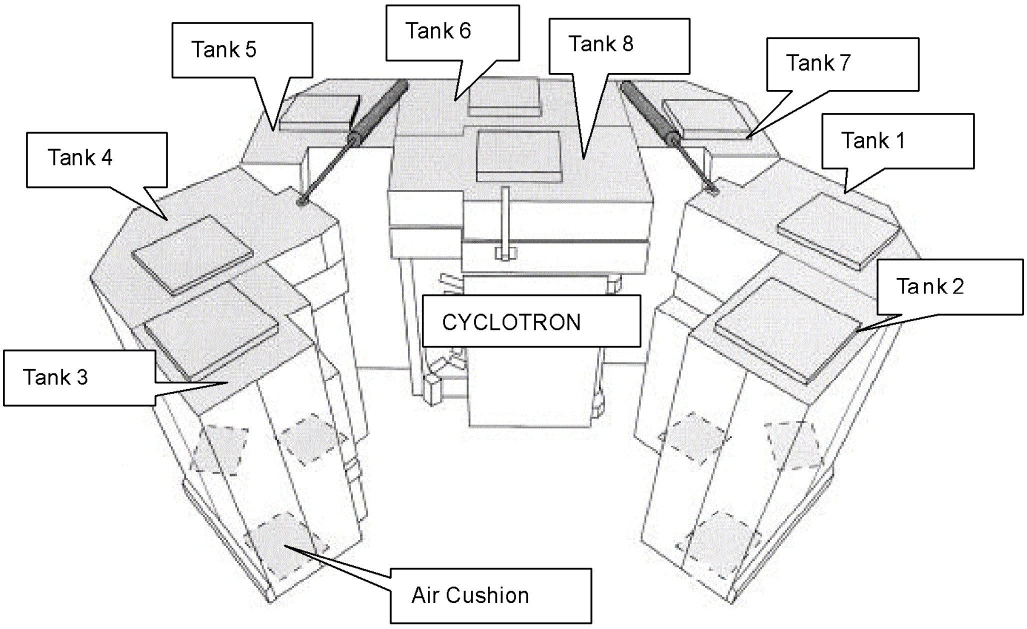
The cyclotron magnet will be transported into the cyclotron vault without its shields. The magnet has the following dimensions:

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^2. During activation of the air cushions, the load per square meter increases by 25%, to 5.9 metric tons/m^2. Section 2-4 Floor specifications on page 40 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, RFPG and CAB 3 cabinets. 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^2 (215 ft^2)
Height	3.0 m (10 ft)

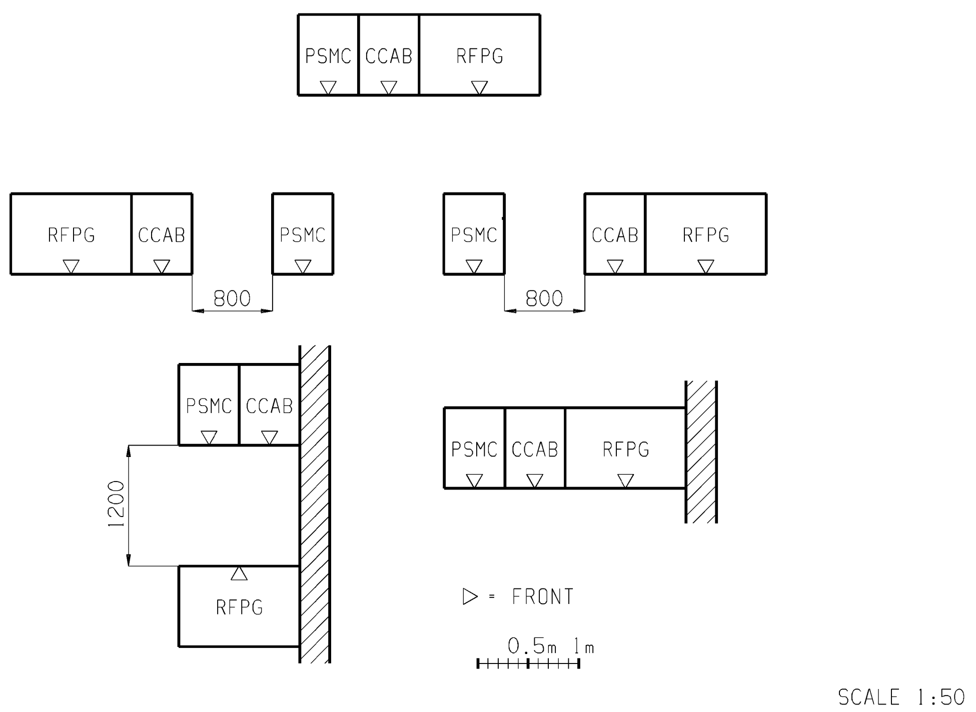
The power supply room cabinets have the following dimensions:

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



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^2 (110 ft^2)
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	320 kg (710 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 production facility

The radiochemistry production facility design should include a radiochemistry laboratory to accommodate the chemistry process systems, which are normally installed in radiation protected areas such as hot cells.

The process systems for ^{11}C and ^{15}O gas products can be installed in a lead-shielded process cabinet (ProCab) supplied by GE HealthCare. If the ProCab option is chosen, the radiochemistry lab should be designed to accommodate this cabinet, and the customer should provide a detector for measuring the level of radioactivity inside the cabinet when open.

Apart from the shielded area, the radiochemistry lab should include sufficient space for working, rinsing and washing, as well as areas for the necessary analytical instruments.

The operator controls the radiochemical production via dedicated (Master) workstation. The workstation can be located in the radiochemistry lab or elsewhere within the facility. A separate laptop can be used as a mobile client to the workstation.

The air exchange system for the radiochemistry lab should be designed 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_3 module	H_2O module
Weight	3570 kg (7870 lbs)	5 kg (11 lbs)	10 kg (22 lbs)
Length	560 mm (22 in)	200 mm (8 in)	200 mm (8 in)
Width	920 mm (36 in)	150 mm (6 in)	150 mm (6 in)
Height	2200 mm (87 in)	200 mm (8 in)	350 mm (14 in)

The radiochemistry production facility should also include a minimum 1 × 1 m work surface in a controlled area dedicated to cleaning of radioactive items, for example, targets. This surface should be on a bench or a stable table capable of handling the large weights of the supplied bench radiation shield and the ten lead bricks to be placed there. The bench radiation shield weighs 160 kg and the ten lead bricks nearly 12 kg each. The shield must NOT be placed on, for example, a roller table. Lifting and moving the shield requires a mobile mini lift.

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

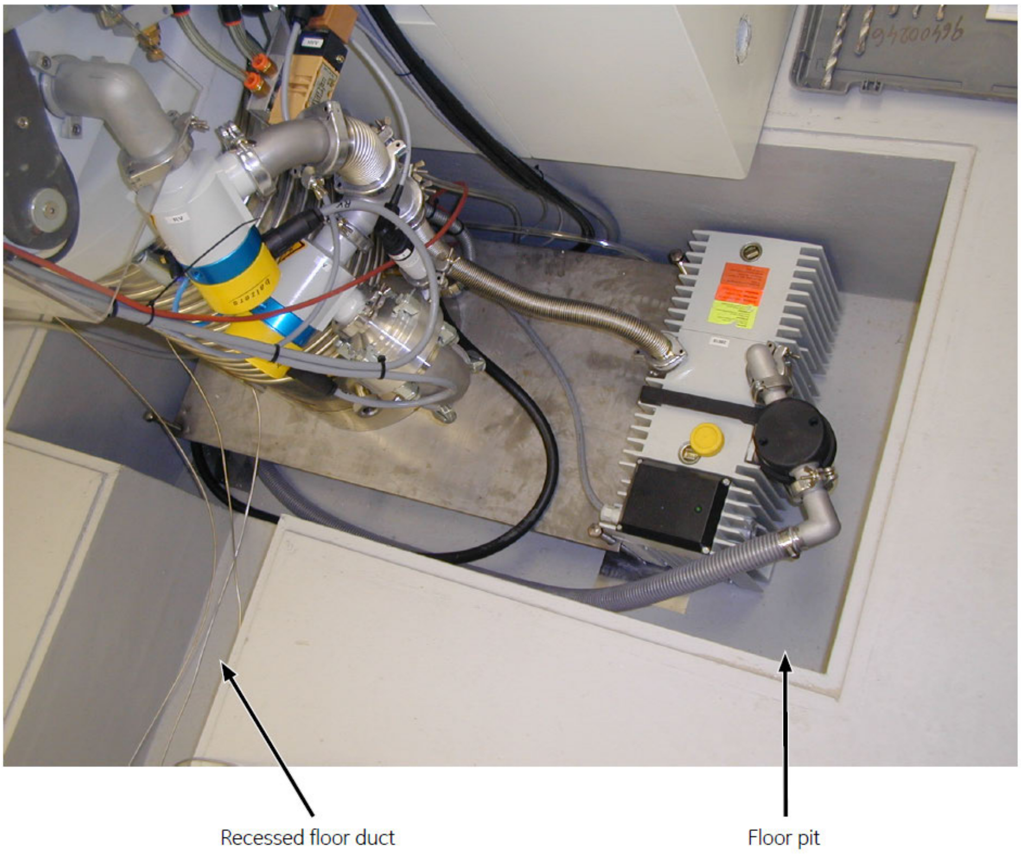
2-3-1 Recessed floor ducts

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 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[1]	X	X			
Compressor[1]	X	X			

1 Option

Table 2-14: Penetrations

Media type(s)	To room	From	Diameter in mm and (in)	Max # penetrations
Concrete penetrations:				
Power + signals[1]	Cyclotron vault	Power supply room	120 (4.8)	4
Cooling water[2]	Cyclotron vault	Water Cooling Unit	60 (2.4)	3
Cold gases[3]	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
Other penetrations:				
Cooling water	Power supply room	Water Cooling Unit	60 (2.4)	2
Cold gases[3]		Gas storage	100 (4)	1
Hot gases[3]	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 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^2.

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^2, which increases the floor pressure on the individual plates to 21.5 to 62.5 kp/cm^2.

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^2.

2-4-2 Slope tolerances

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 cyclotron components

Component	Weight kg (lbs)	Overall area W×D×H mm (in)	Floor load (kp/m2)	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
Secondary Water Cooling Unit	320 (710)	600×1200×1550 (23.5×47×61)		Set on floor

Component	Weight kg (lbs)	Overall area W×D×H mm (in)	Floor load (kp/m2)	Mounting method
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 W×D×H mm (in)	Floor load (kp/m2)	Mounting method
Process Cabinet (ProCab)	3570 (7870)	920×560×2200 (36.2×22×86.6)		Bolted to wall (can also be bolted to floor)[1]
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
The following components are included with the integrated radiation shield option:				
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

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

2-5 Architectural reminders

2-5-1 General reminders

- 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).
- Pay attention to isogauss limits, with respect to both indoor and outdoor environments.
- Include space in the electronics room design for a lockable cabinet to store documentation and tools.

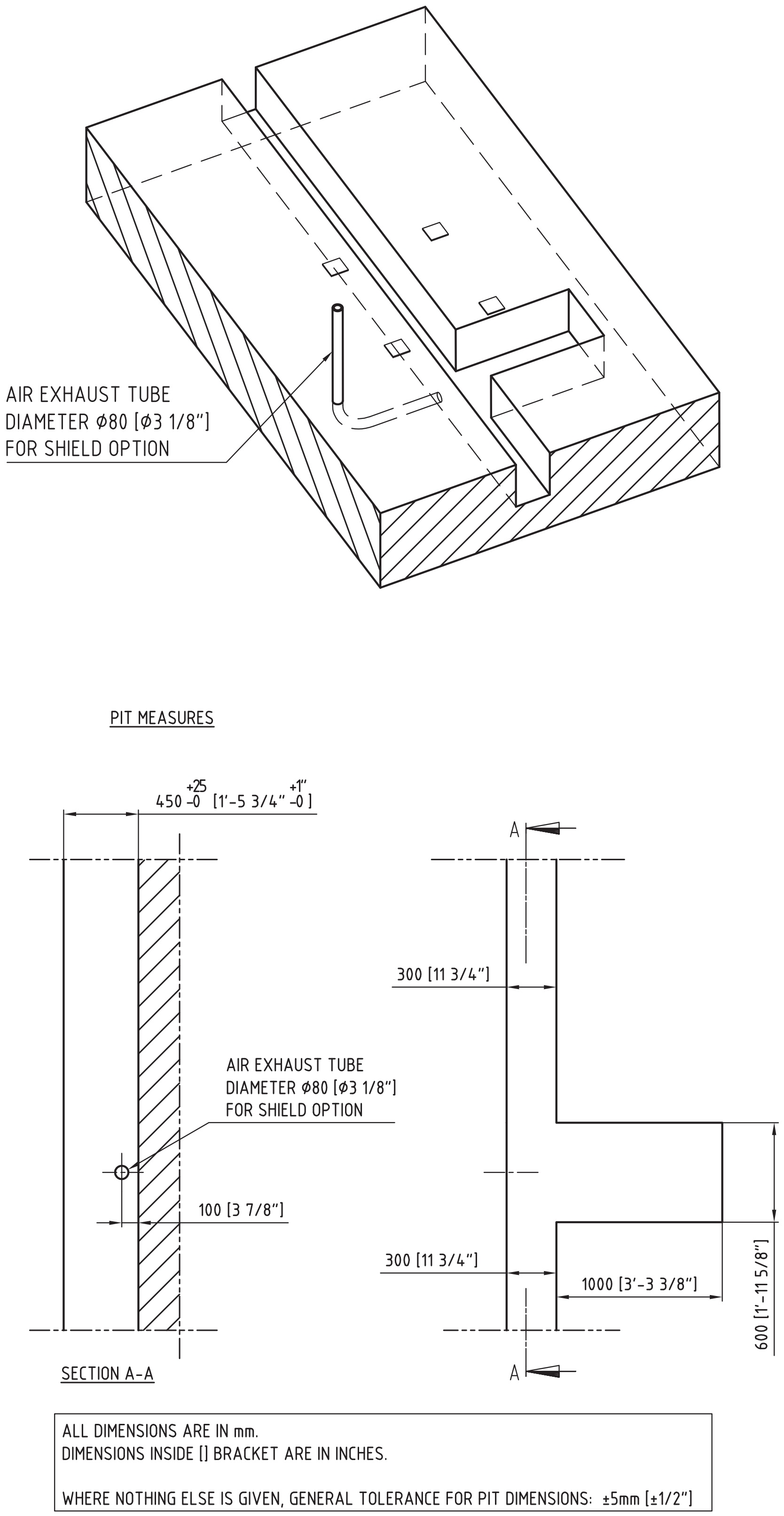
2-5-2 Connectivity and data communication

- An Ethernet connection for Internet access close to Cabinet 3.
- An Ethernet connection for Internet access inside the vault (unshielded cyclotron).

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, as the shields contain about 28 m^3 of water. (Depending on local regulations, special waste water treatment may be required.)

> **CAUTION!**
>
> *Sites in California (US) and other sites that follow California proposition 65.*
>
> The radiation shield tanks contain boron water which includes lead bricks. Long term exposure results in a lead concentration above 5 µg/l upper limit concentration according to the state law California proposition 65.
>
> Make sure that any boron water spillage is kept isolated and does not enter the drain.
>
> Use protective clothing, gloves, and goggles when handling the spillage.

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^3/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

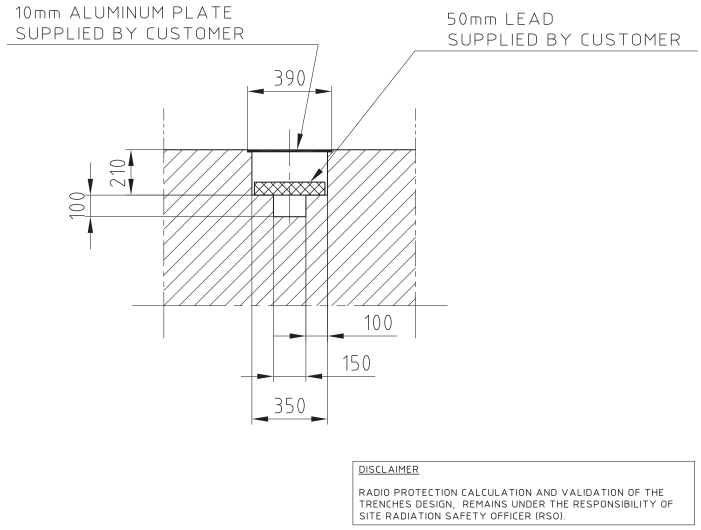


Figure 2-9: Accelerator/pit position

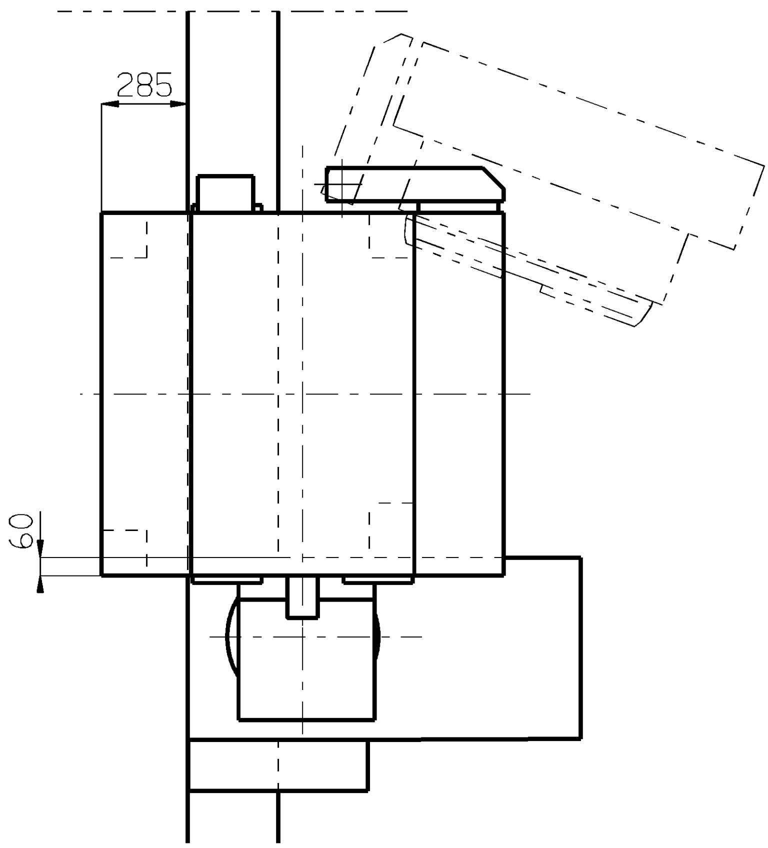
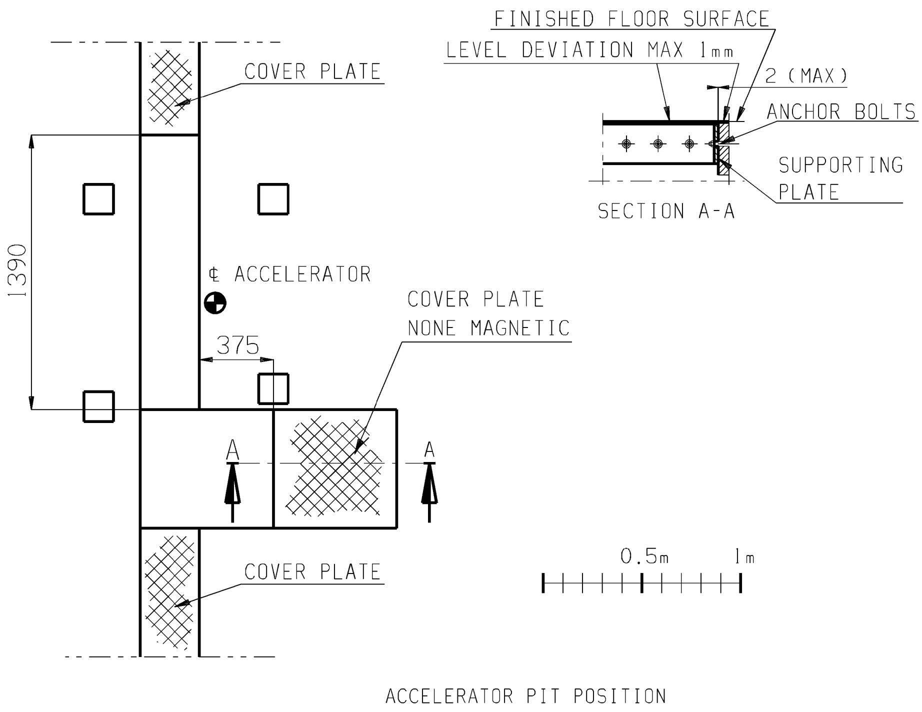


Figure 2-10: Floor cover plate



2-6 System component illustrations

The system produces the commonly used radioisotopes for positron emission tomography (PET), ^{18}F, ^{11}C, ^{13}N, ^{15}O and ^{68}Ga. 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 $[^{15}O]O_2$, $[^{15}O]CO_2$, $[^{15}O]H_2O$, $[^{11}C]CO$, $[^{11}C]CO_2$, $[^{11}C]HCN$, and $[^{13}N]NH_3$.
- 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
Standard system components	
Unshielded cyclotron	Figure 2-11
Minimum unshielded cyclotron service area	Figure 2-12
Cabinet 1, Magnet Power Supply (PSMC)	Figure 2-13
Cabinet 2, RF Power Generator (RFPG)	Figure 2-14
Cabinet 3, Control Cabinet (CAB 3)	Figure 2-15
Power Distribution Unit (PDU)	Figure 2-16
Ion source gas manifold	Figure 2-18
Roughing vacuum pump	Figure 2-19
Master System	Figure 2-20
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Customer Interface Box (CIB)	Figure 2-23
Bench radiation shield	Figure 2-24
Options	
Integrated radiation shield (IRS)	Figure 2-25
PDU shielded system (PDUS) – with IRS	Figure 2-17
Compressor – with IRS	Figure 2-26
Compressed air manifold – with IRS	Figure 2-27
Process Cabinet (ProCab)	Figure 2-28
Chemistry Control Unit (CCU) – with ProCab or as a separate option purchase	Figure 2-29
Chemistry Electronics Unit (CEU) – with CCU	
Waste gas unit	Figure 2-30

Figure 2-11: Unshielded cyclotron

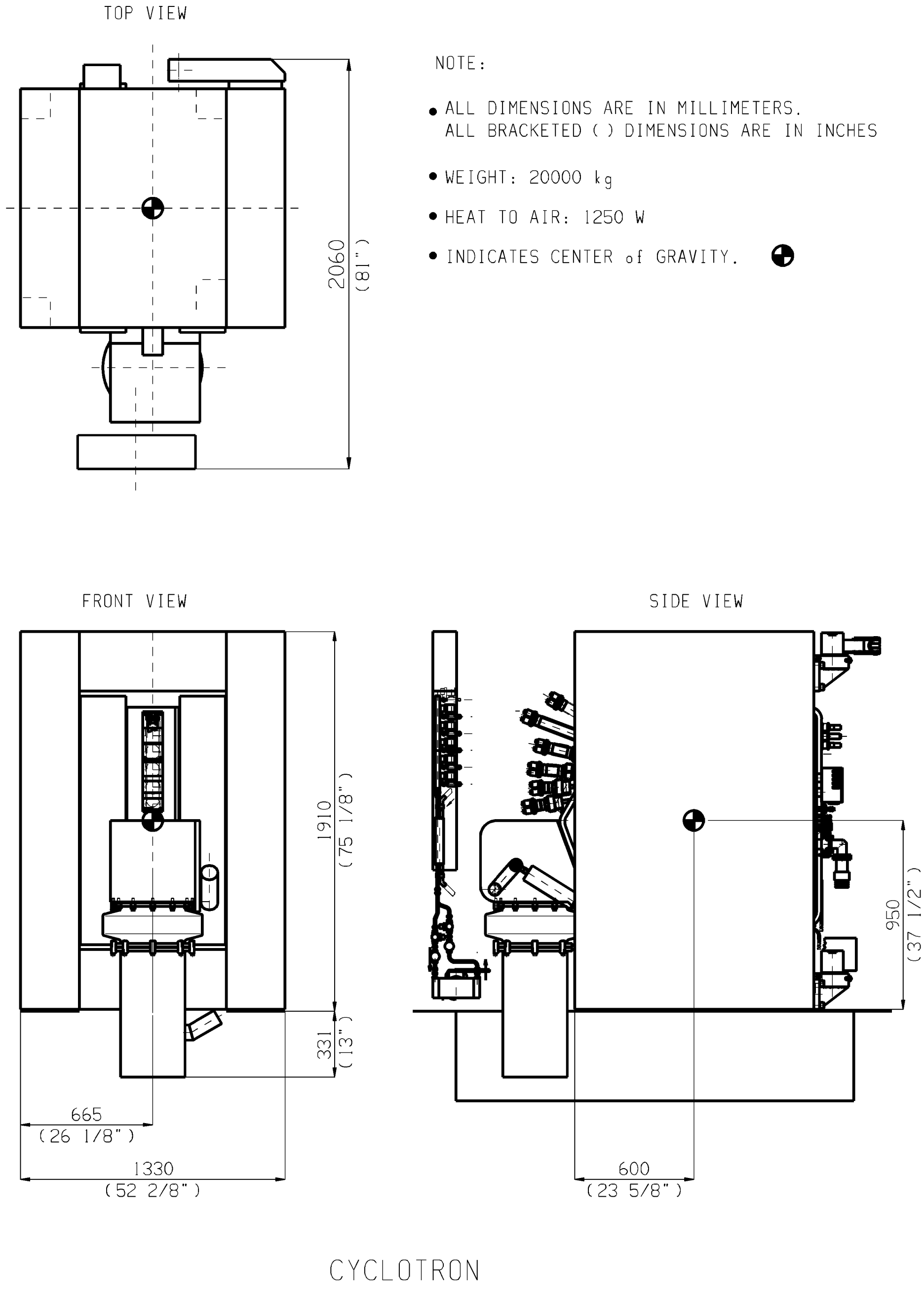


Figure 2-12: Minimum unshielded cyclotron service area

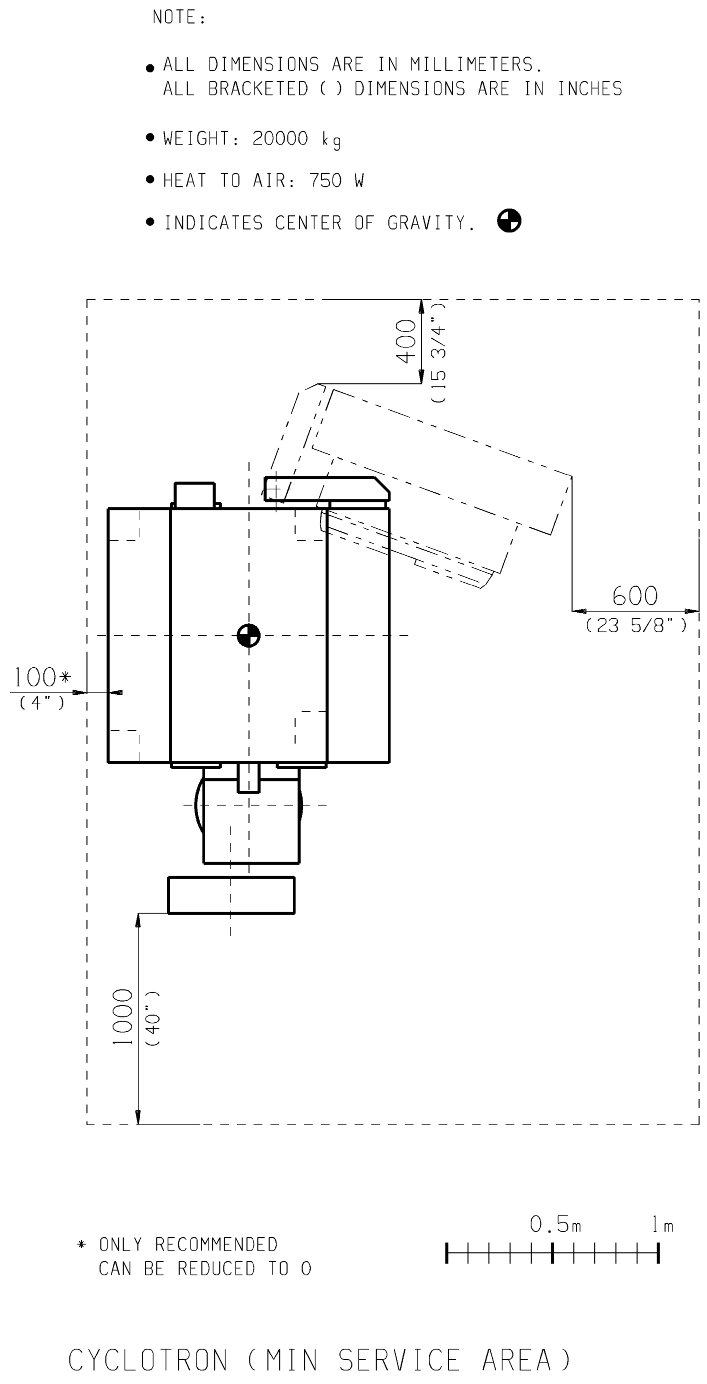


Figure 2-13: Cabinet 1 – Magnet Power Supply (PSMC)

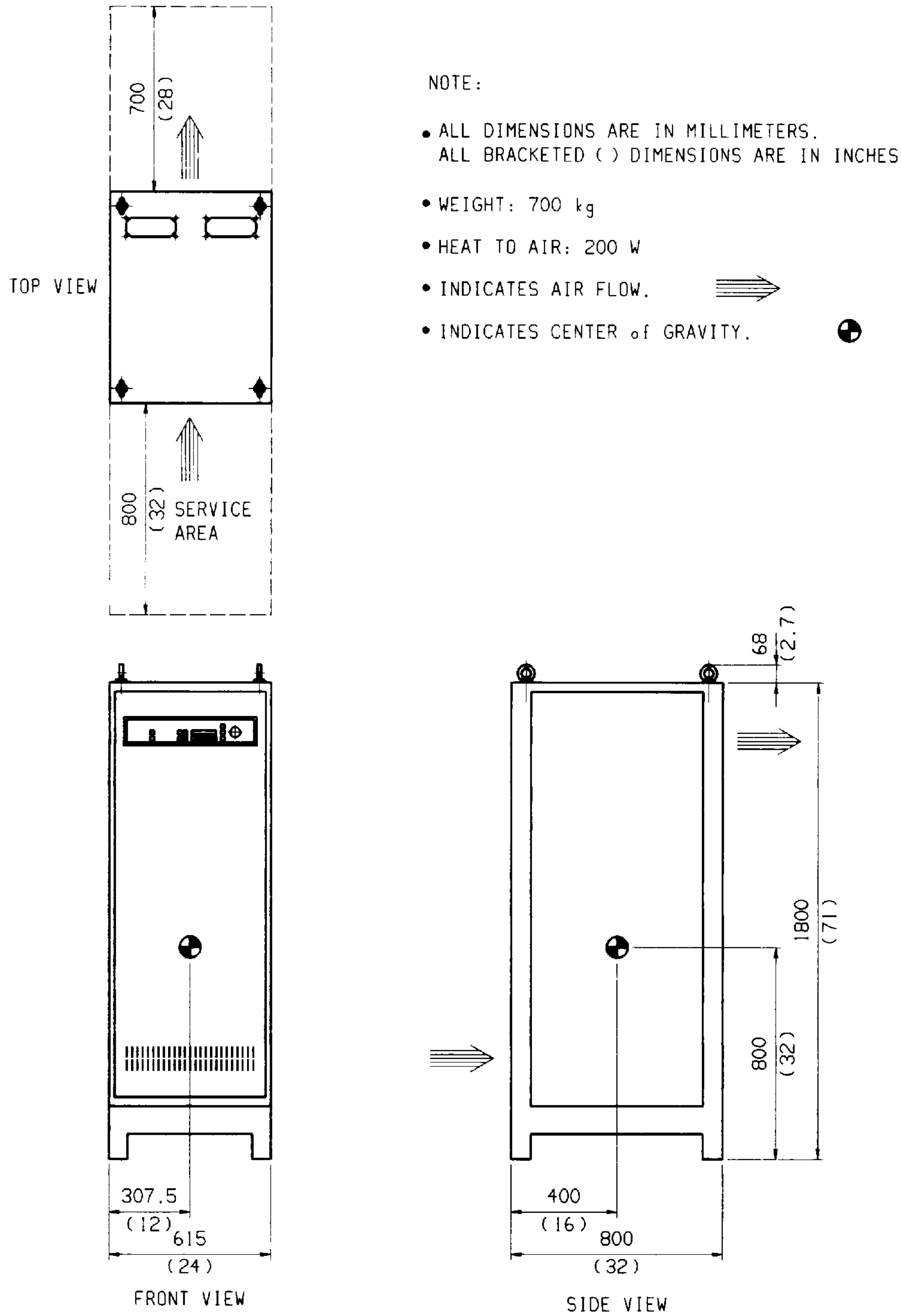


Figure 2-14: Cabinet 2 – RF Power Generator (RFPG)

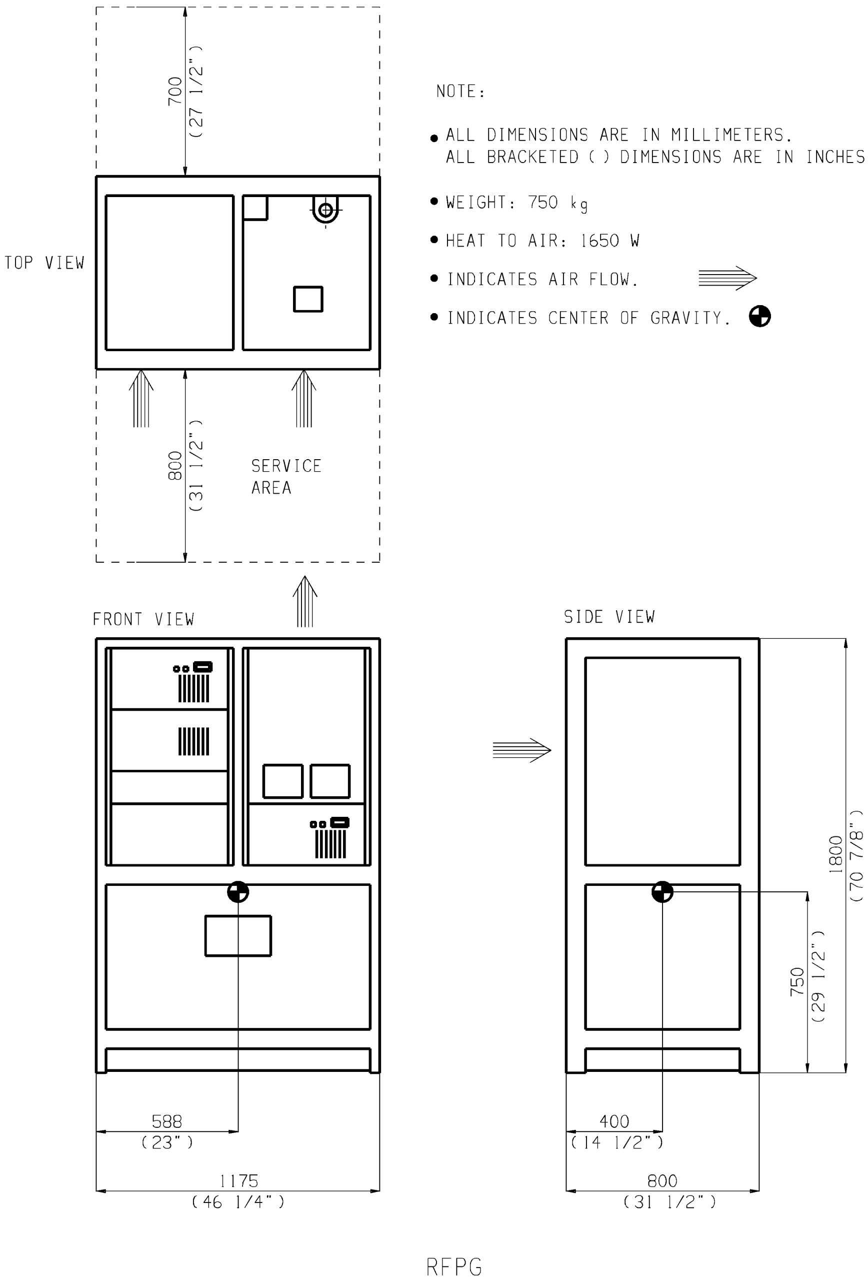


Figure 2-15: Cabinet 3 – Control Cabinet (CAB 3)

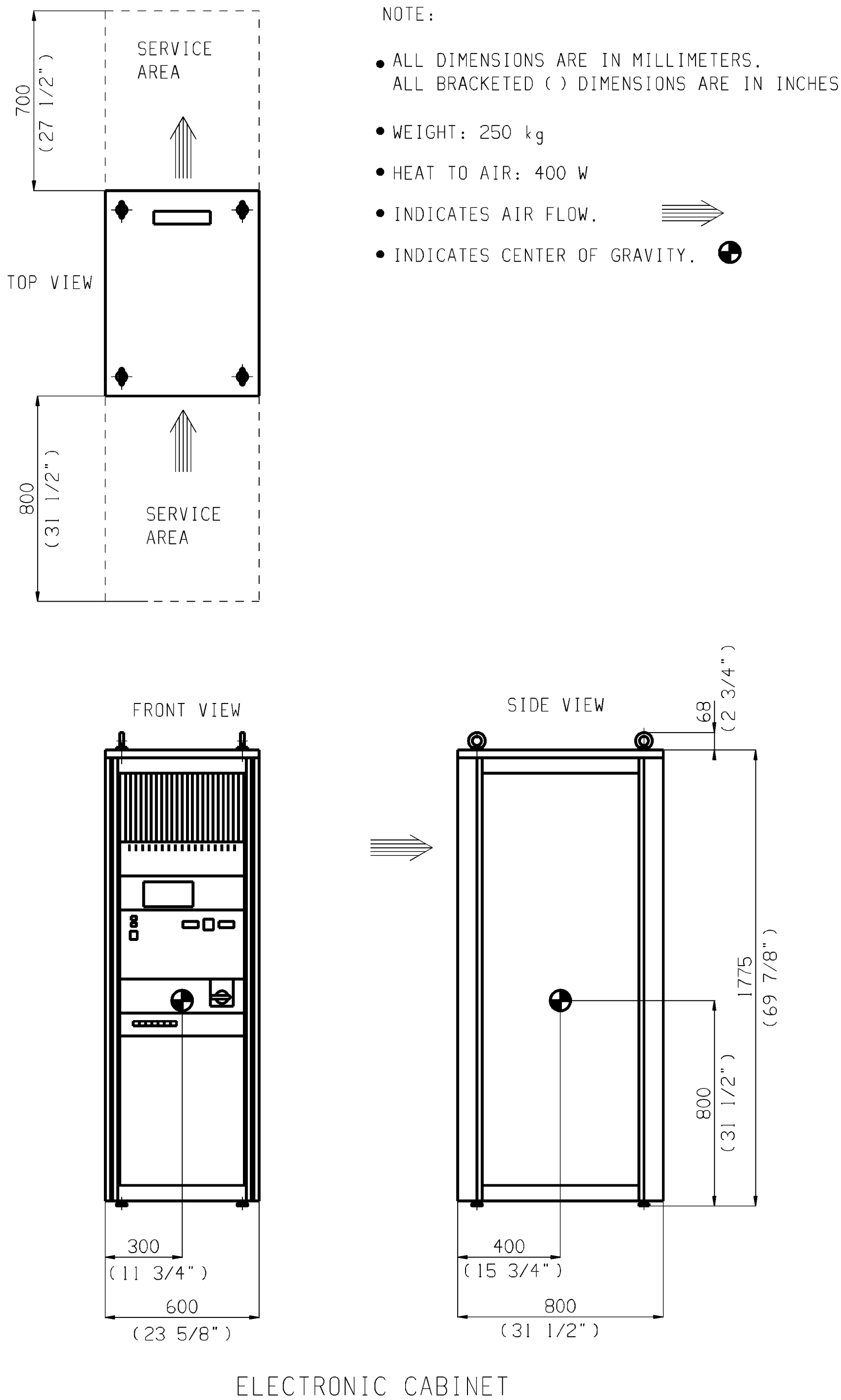


Figure 2-16: Power Distribution Unit (PDU)

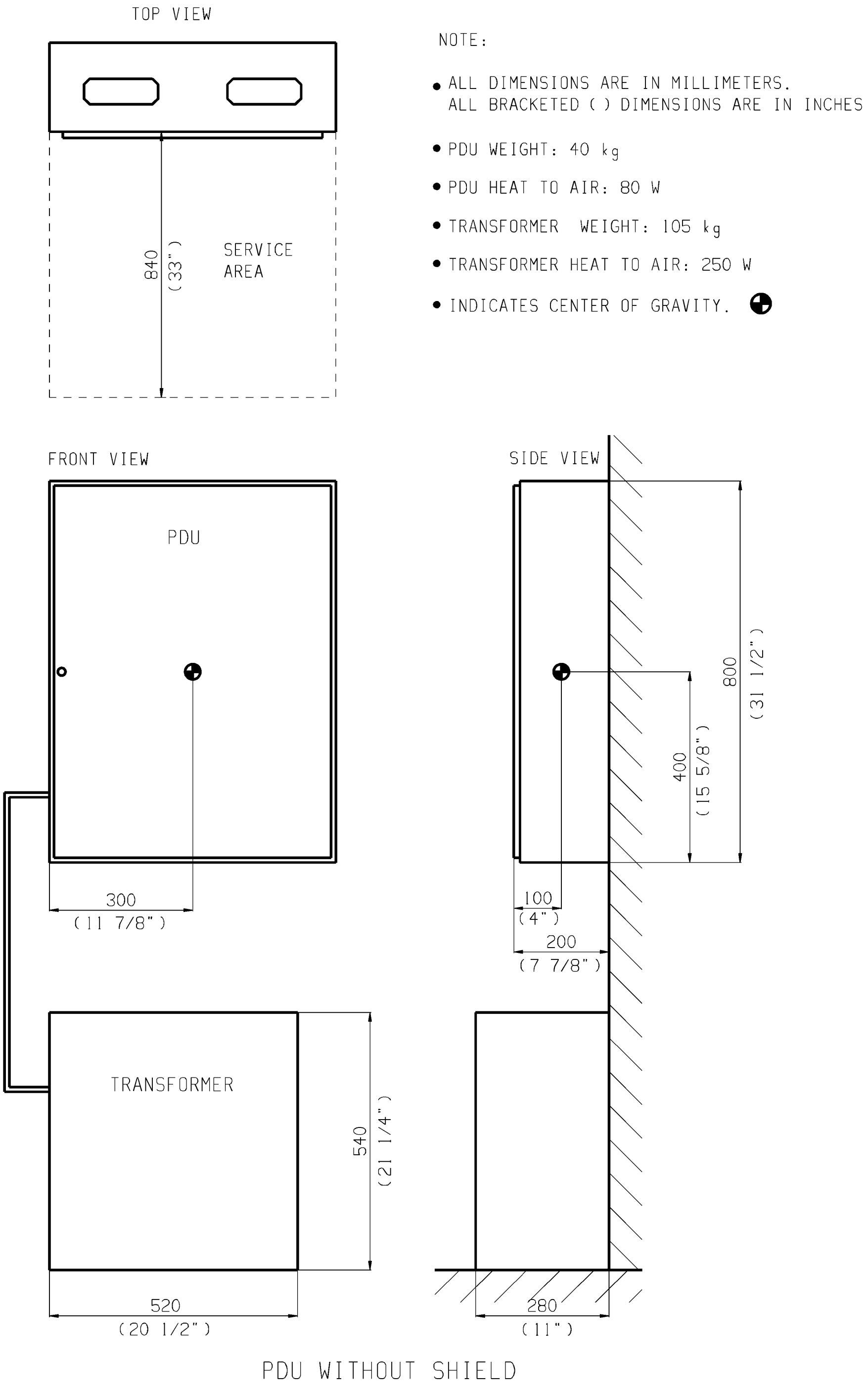


Figure 2-17: PDU Shielded System (PDUS) – part of IRS option – replaces standard PDU

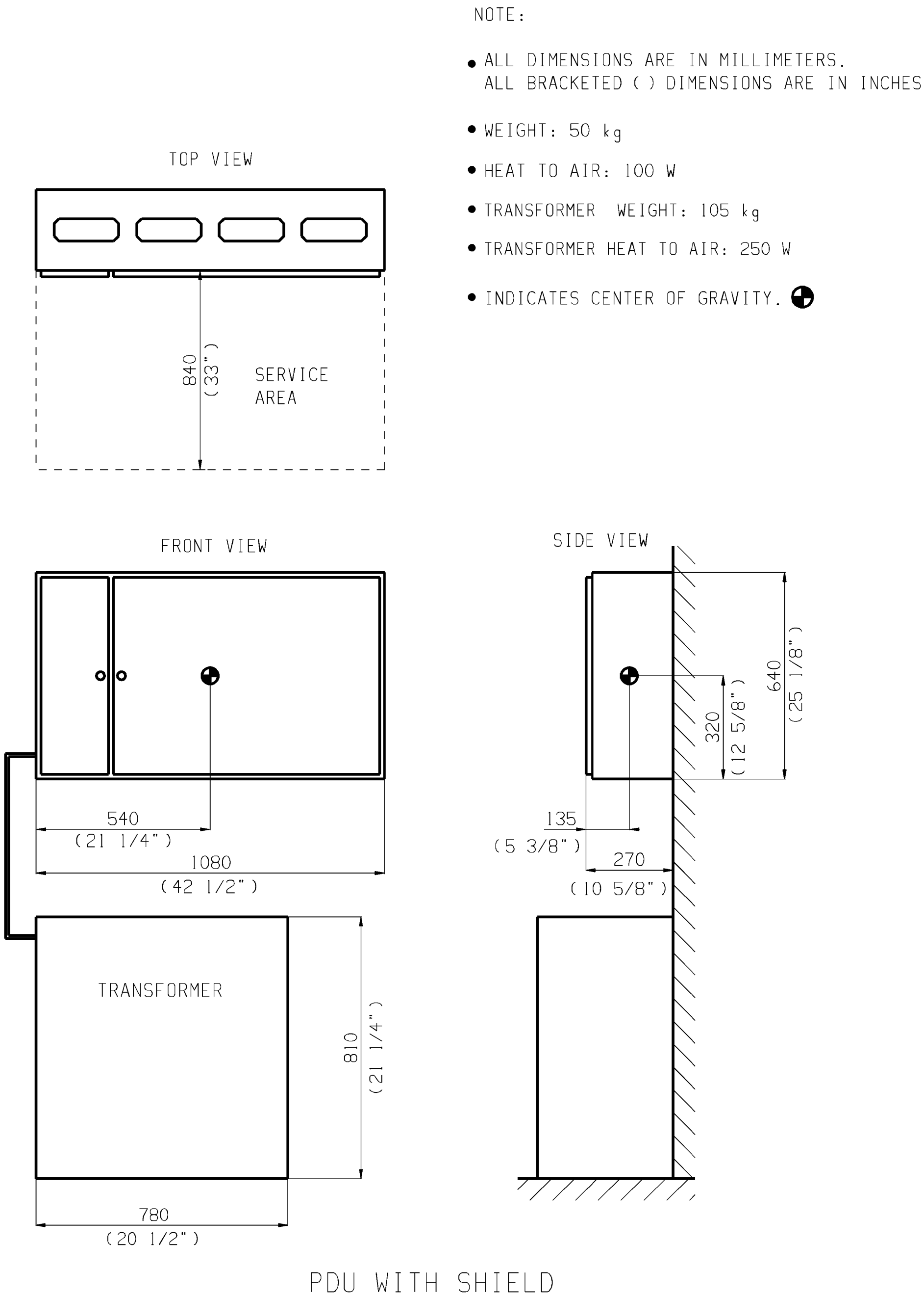


Figure 2-18: Ion gas manifold

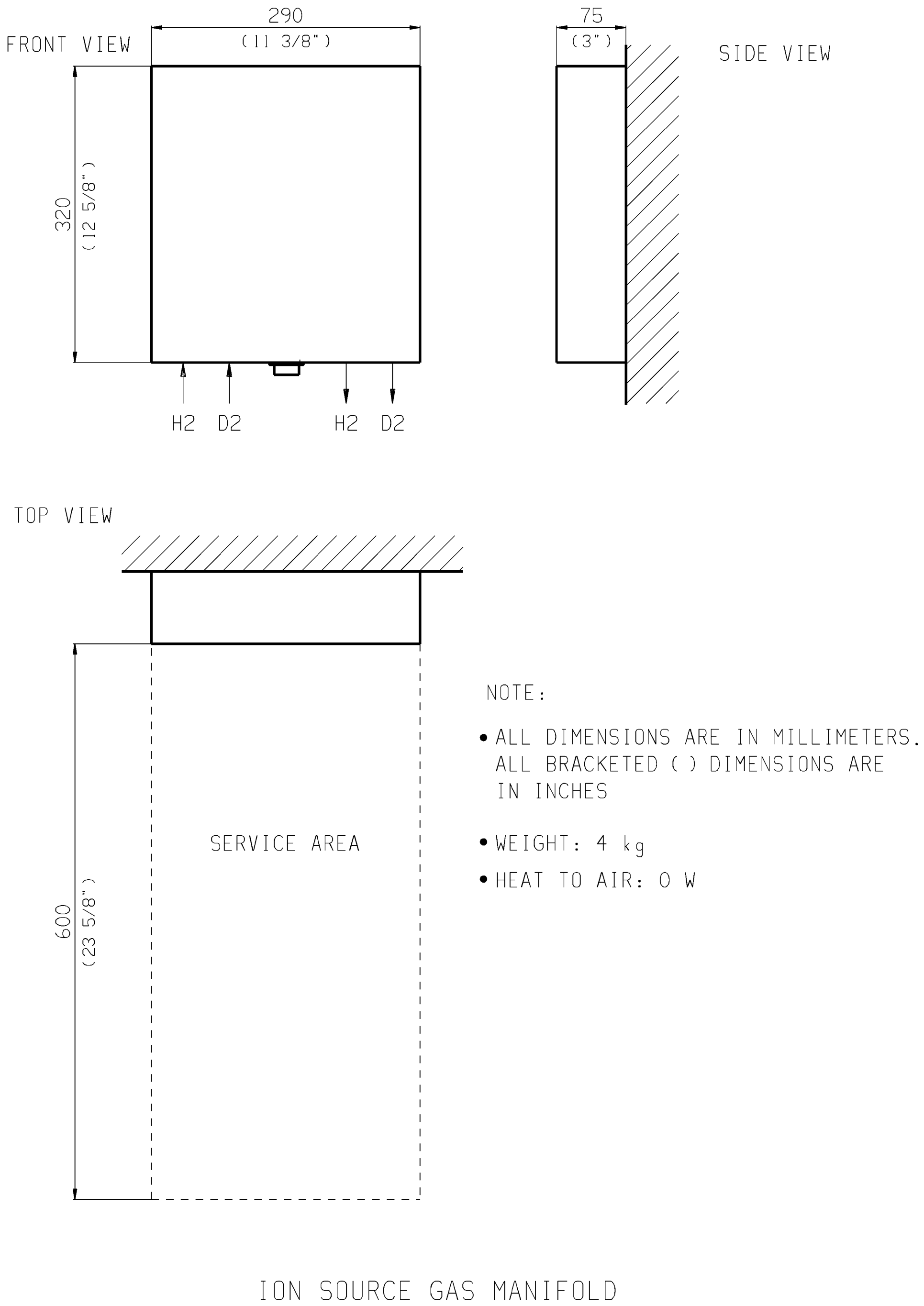


Figure 2-19: Roughing vacuum pump

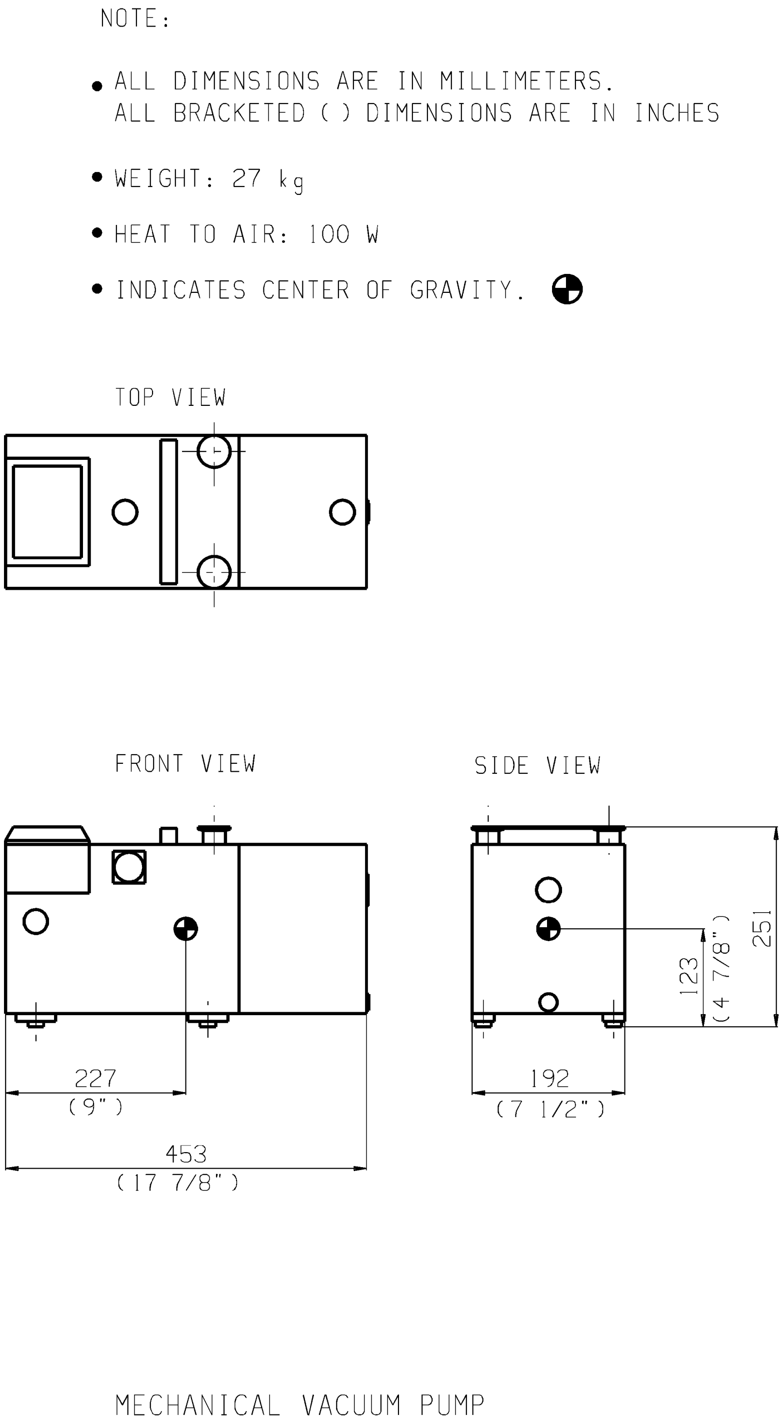
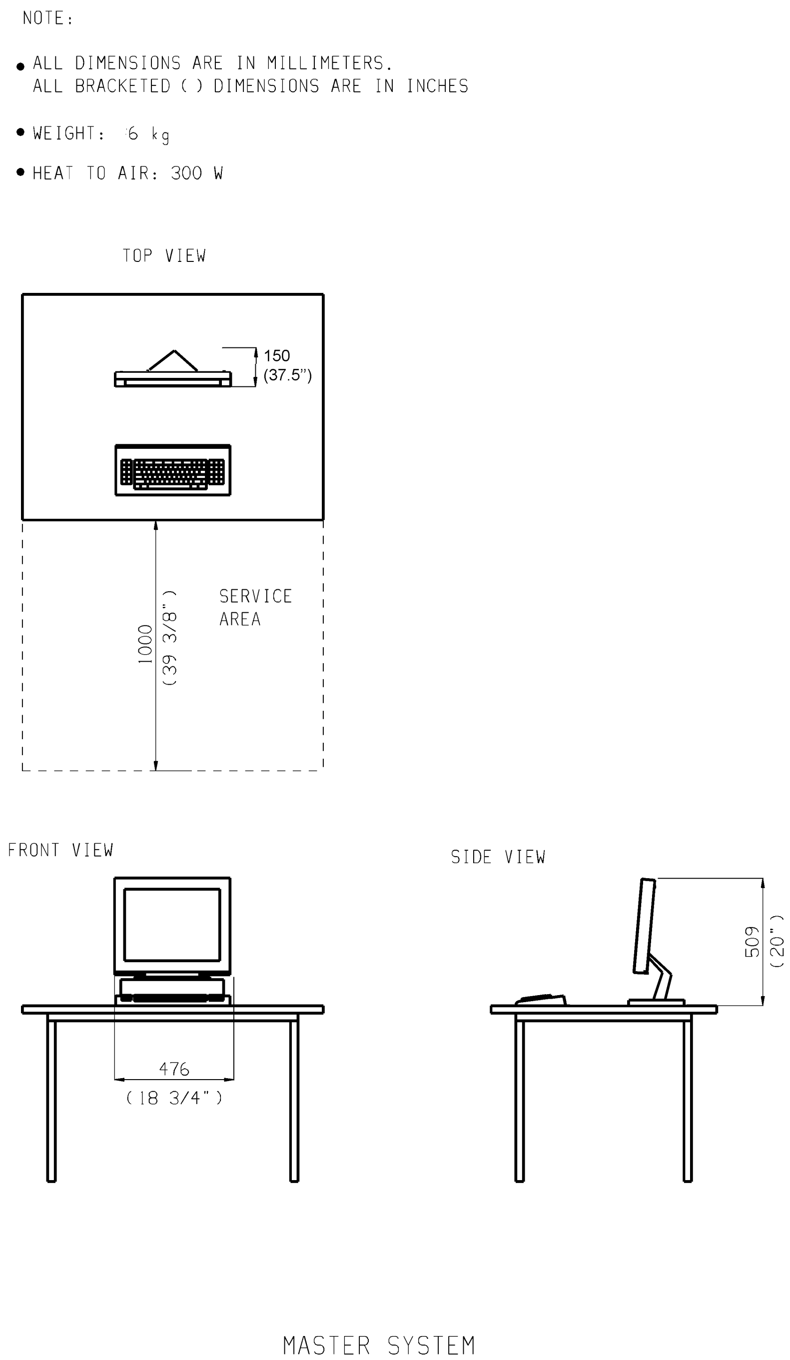
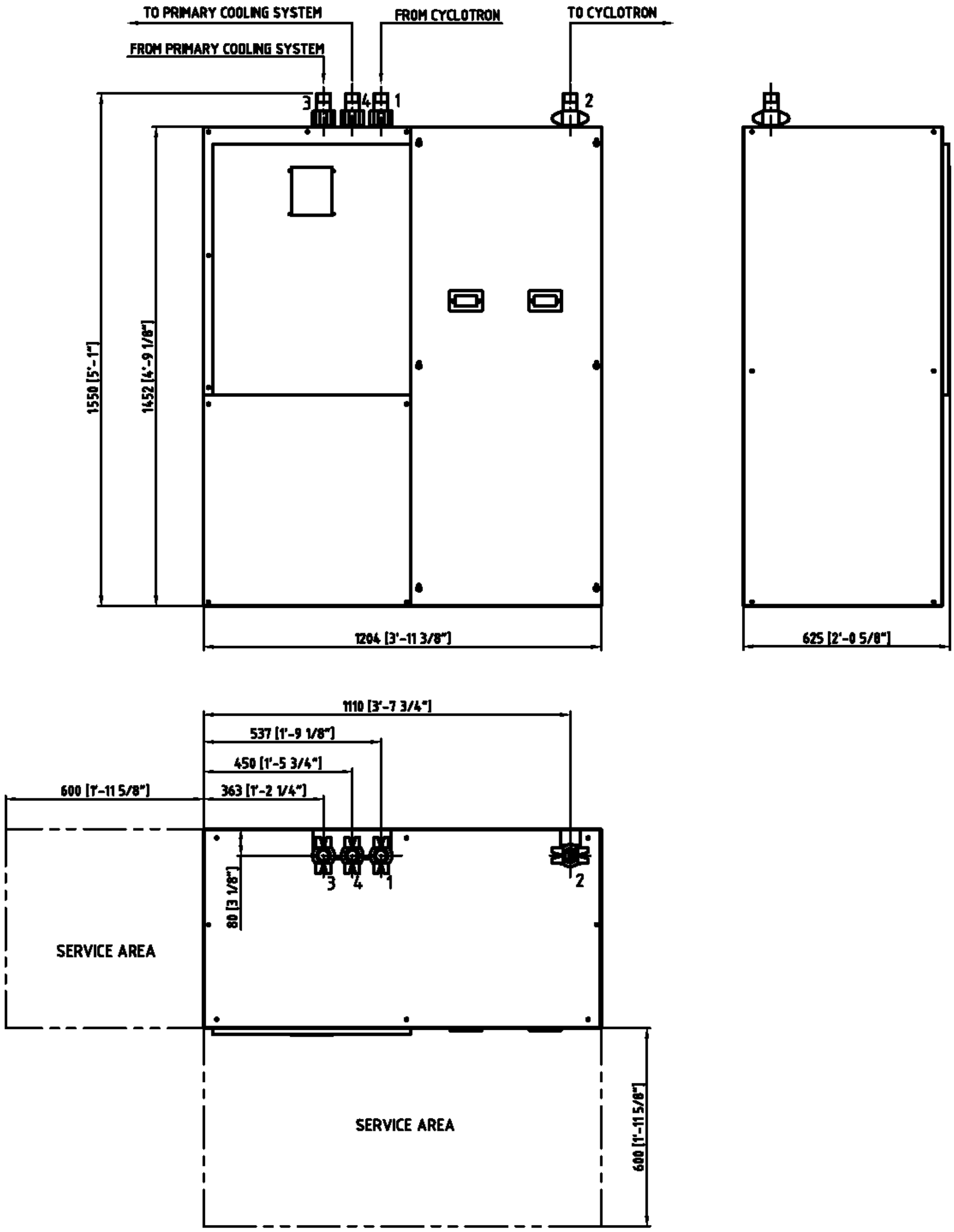


Figure 2-20: Master System



Note!
Customer provides desk or table, and chair.

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



PIPE THREADS

1. FROM CYCLOTRON. ISO-R 1 1/4" OR NPT 1 1/4"
2. TO CYCLOTRON. ISO-R 1 1/4" OR NPT 1 1/4"
3. FROM PRIMARY COOLING SYSTEM. ISO-R 1 1/4" OR NPT 1 1/4"
4. TO PRIMARY COOLING SYSTEM. ISO-R 1 1/4" OR NPT 1 1/4"
5. CITY WATER. ISO-R 1/2" OR NPT 1/2"
6. DRAIN. ISO-Rp 1/2"

Figure 2-22: Water manifold 1

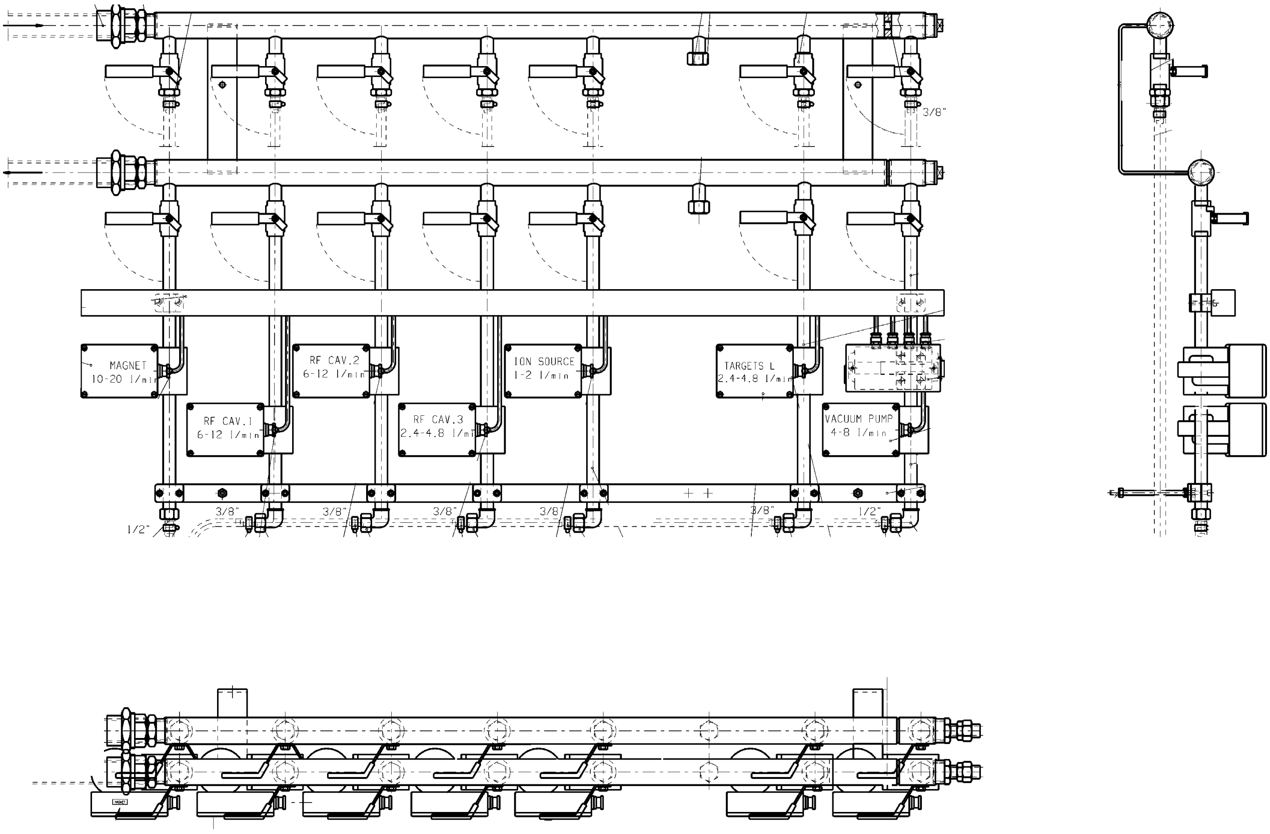


Figure 2-23: Customer Interface Box (CIB)

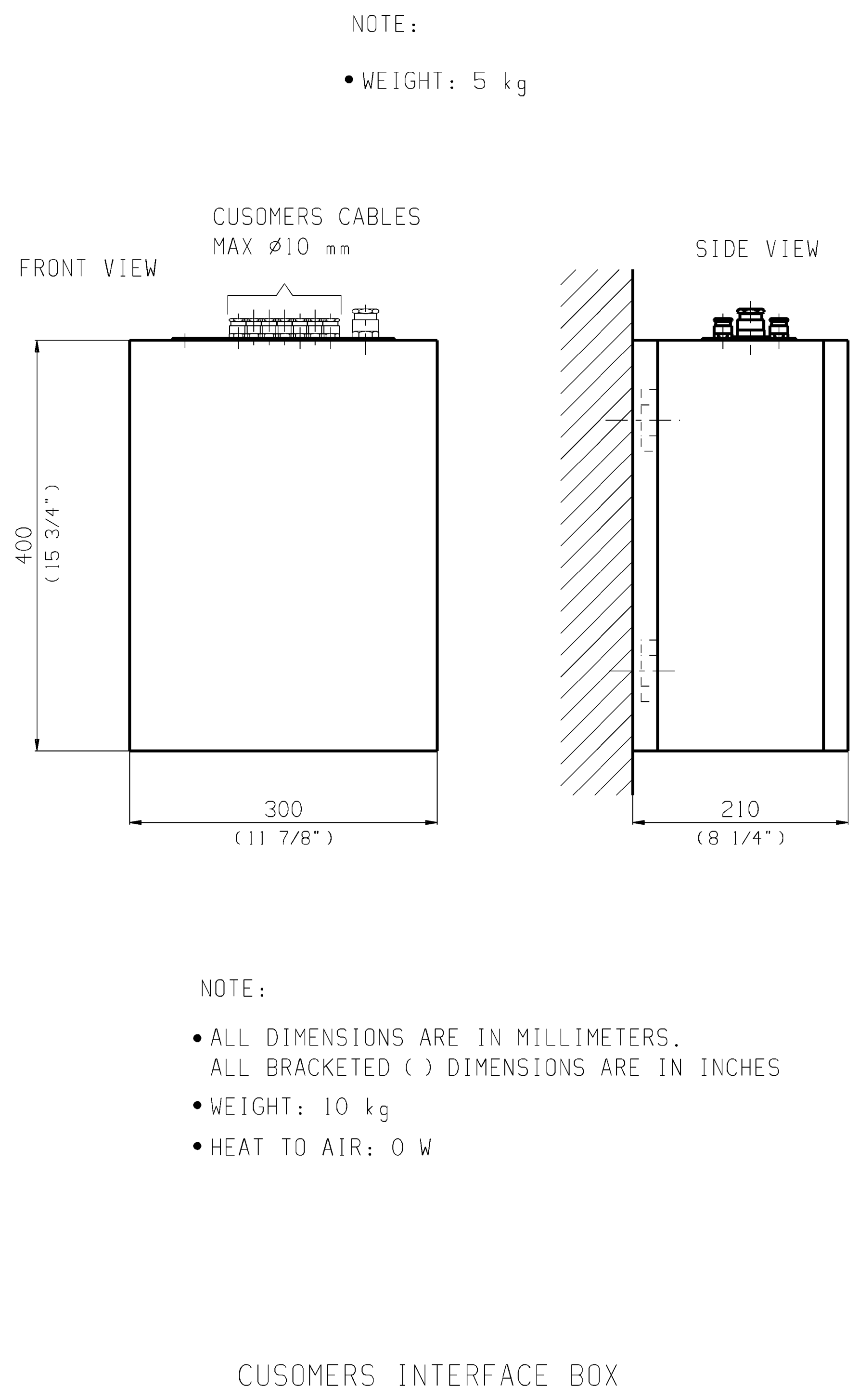
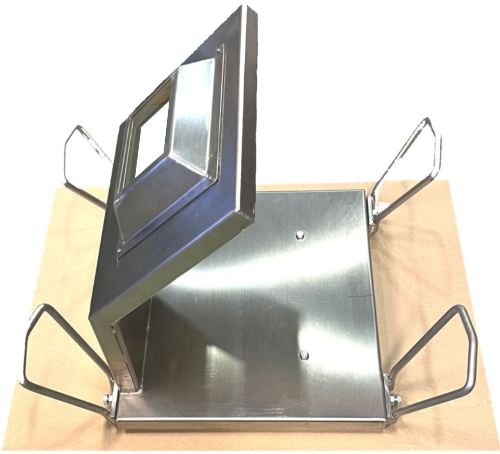
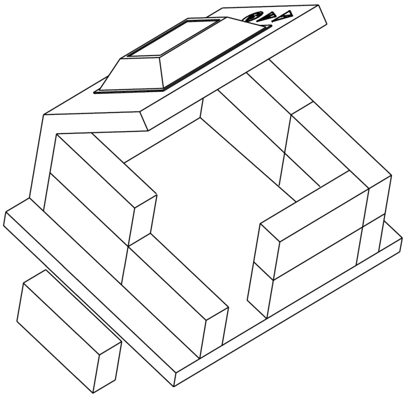


Figure 2-24: Bench radiation shield

Bench radiation shield



Bench radiation shield with lead bricks



- Bench radiation shield
  Weight: 160 kg
  Dimensions: 50 × 45 × 50 cm (W × D × H)
- Lead bricks (ten pcs .)
  Weight: 11.3 kg
  Dimensions: 20 × 5 × 10 cm (W × D × H)

Note!
The customer shall provide a bench or stable table (minimum 1 × 1 m surface) capable of handling the total weight of the shield (280 kg). Lifting and moving the shield requires a mobile mini lift.

Figure 2-25: Optional Integrated Radiation Shield (IRS)

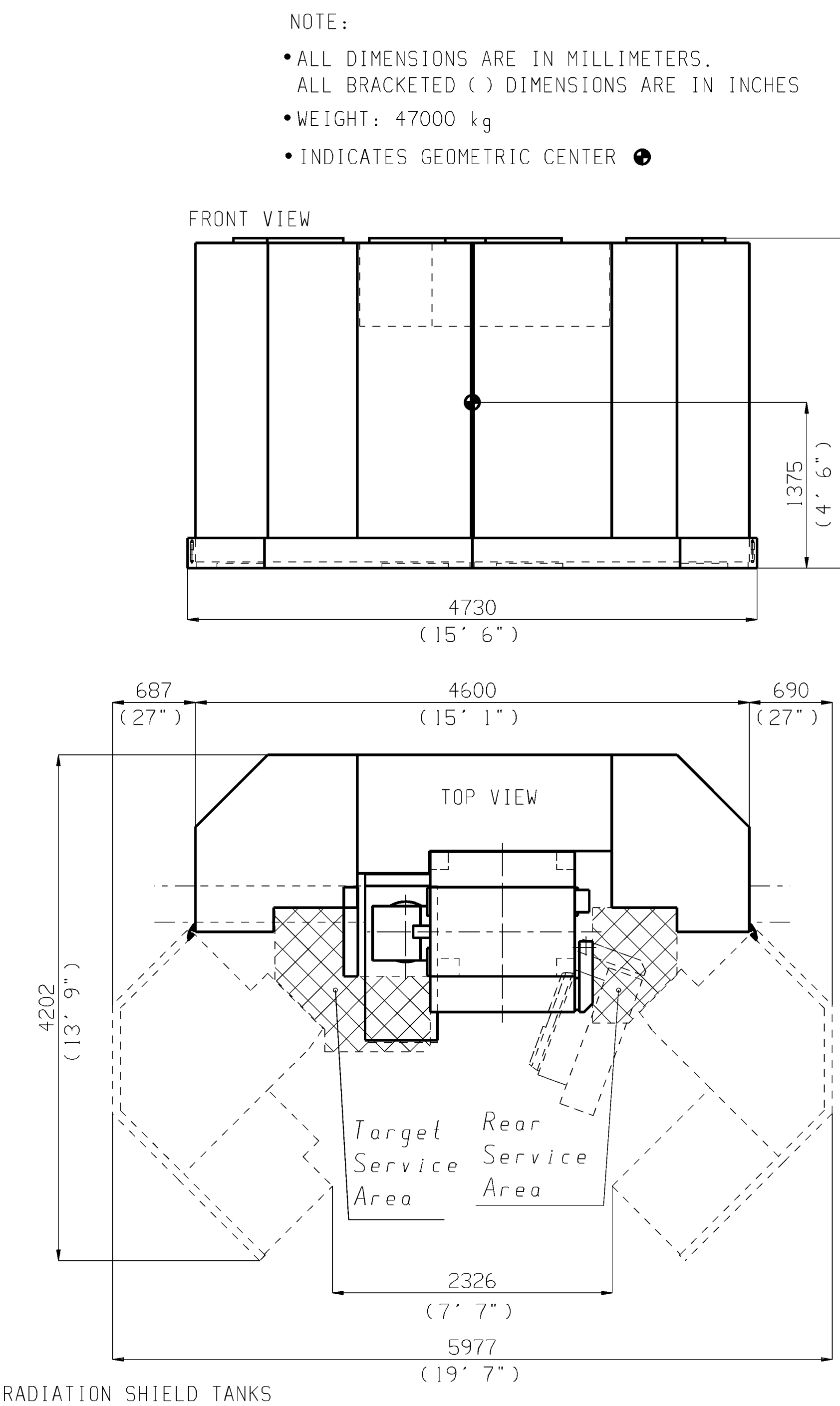


Figure 2-26: Compressor – part of IRS option

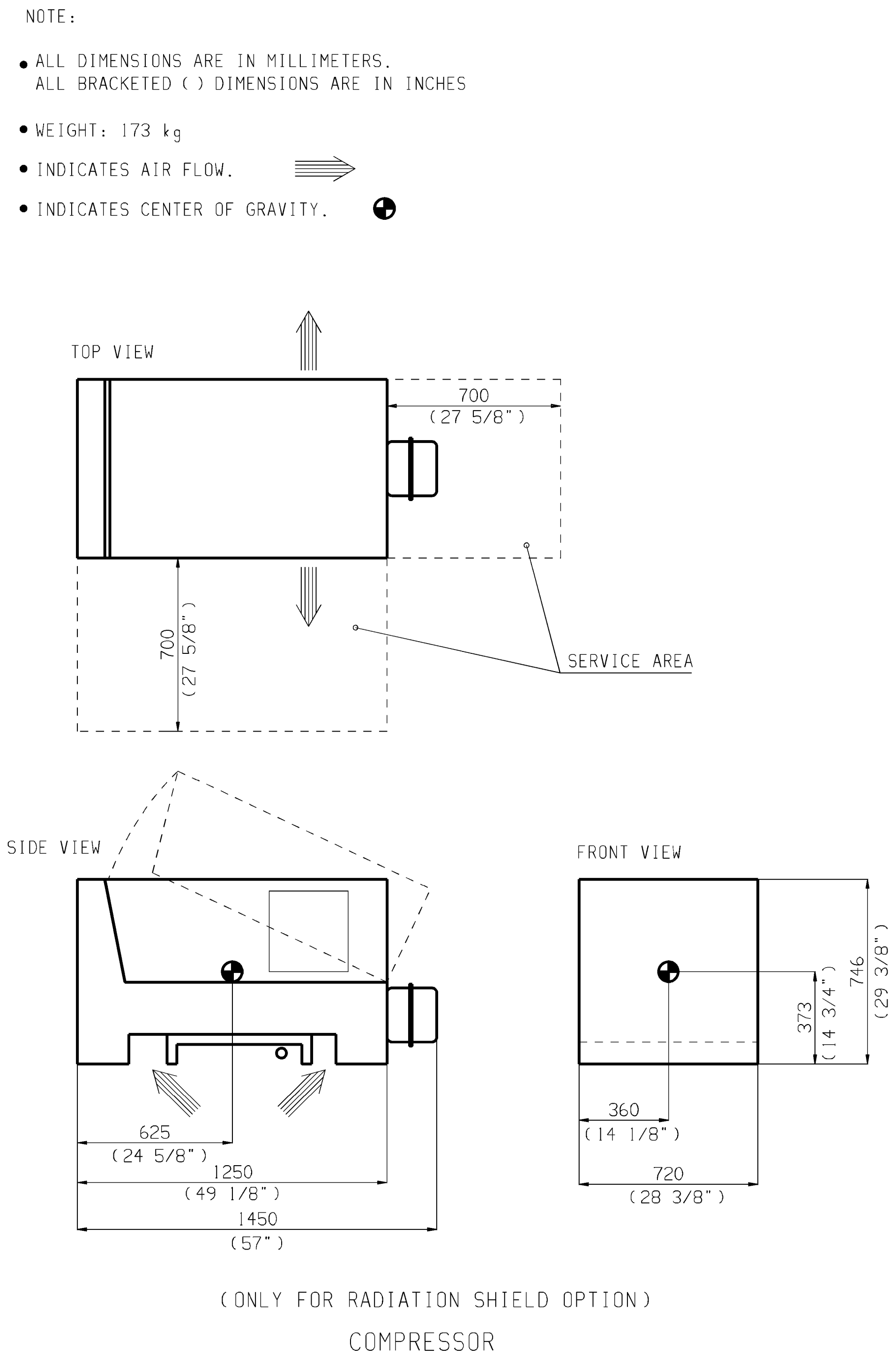


Figure 2-27: Compressed air manifold

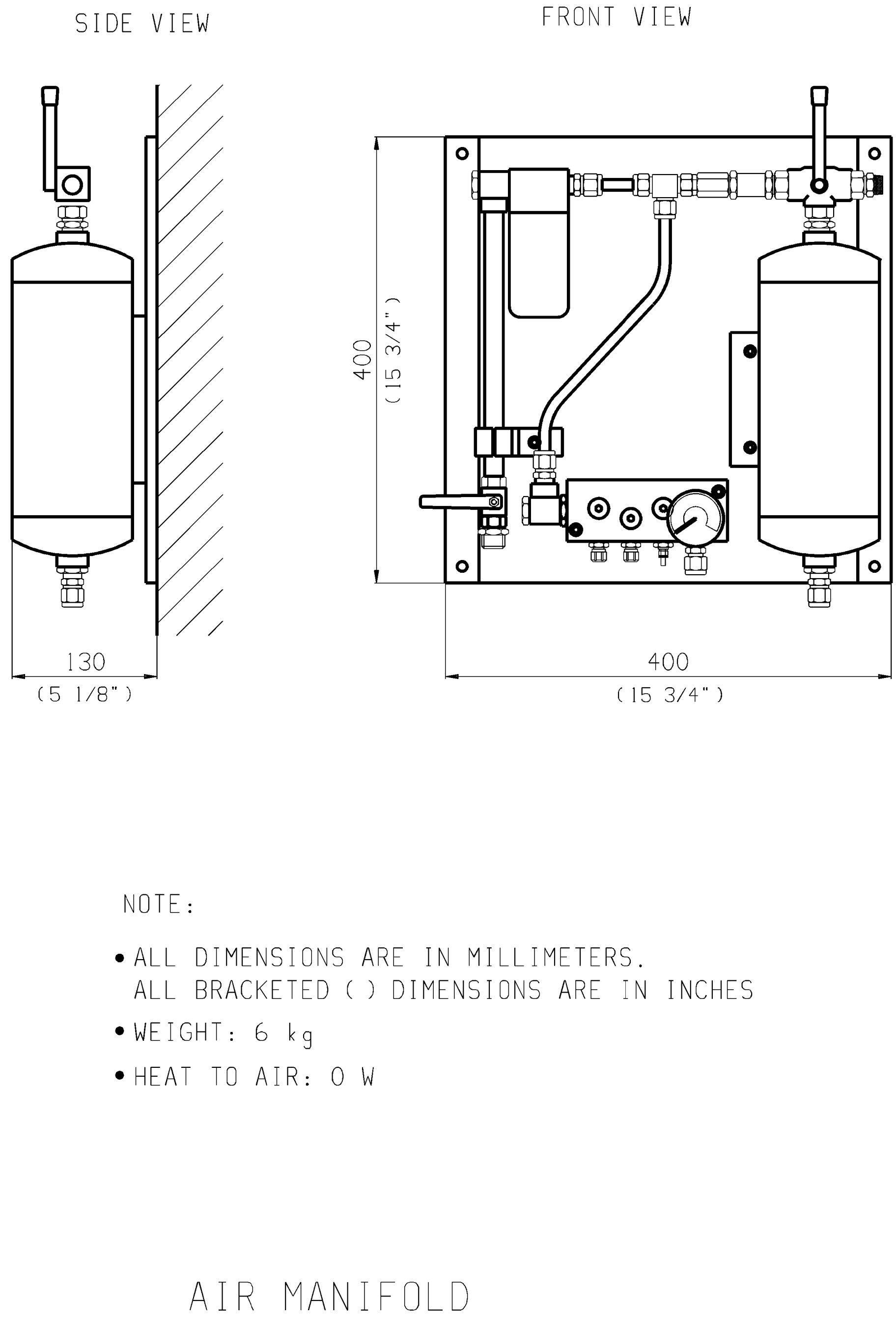


Figure 2-28: Process Cabinet (ProCab)

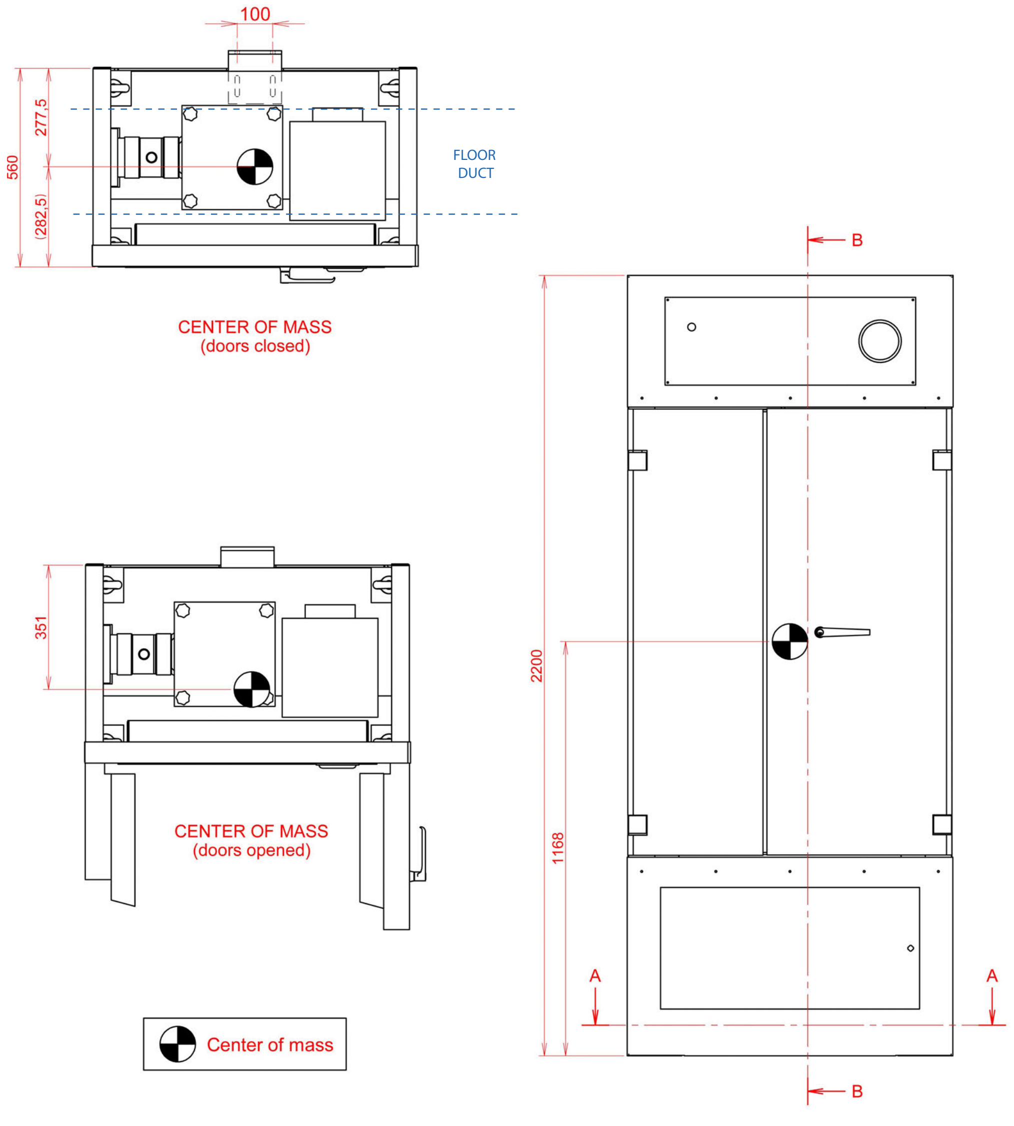
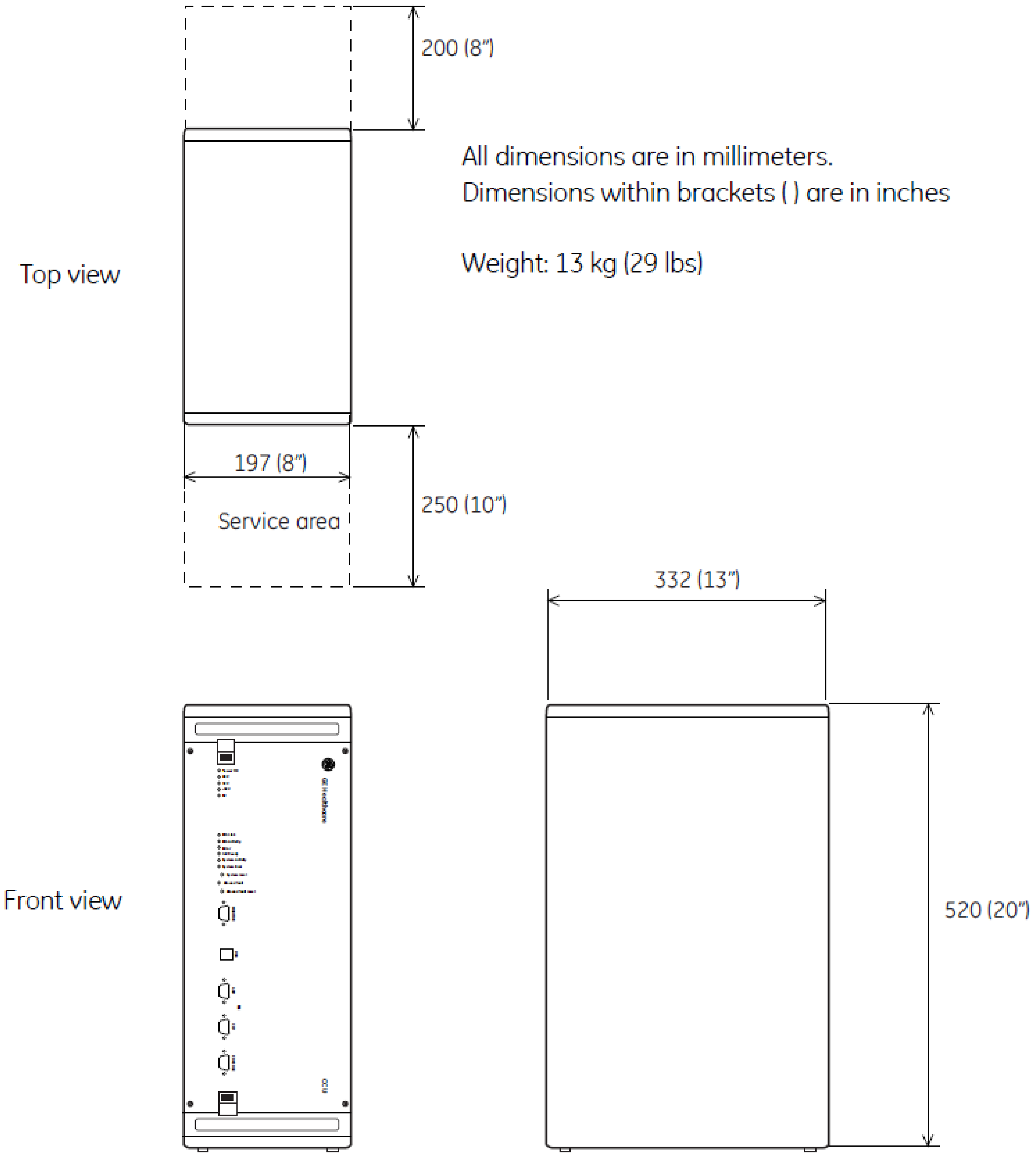


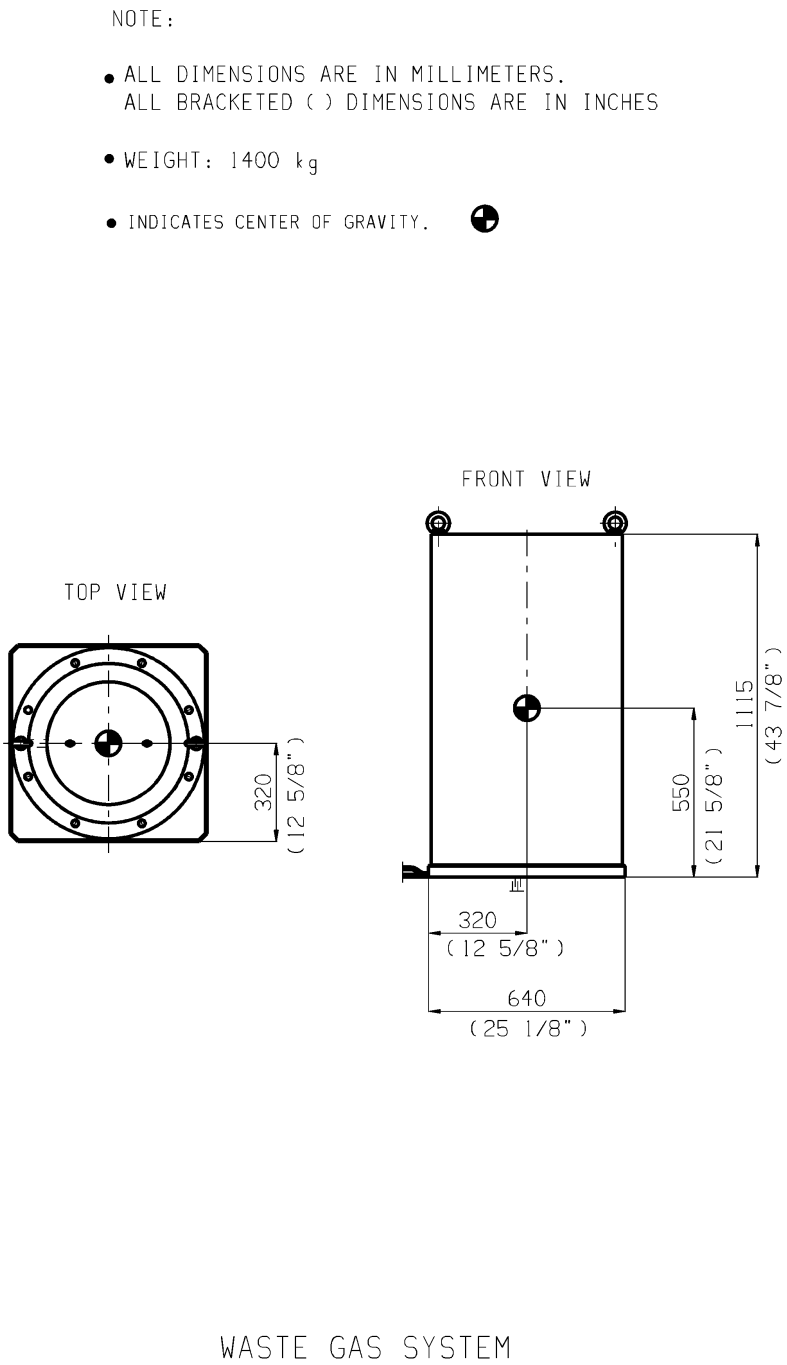
Figure 2-29: Chemistry Control Unit (CCU) – part of ProCab option -or- separate option



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

  Do not block the air inlets or outlets on the CCU!
- The CCU should placed on the floor in either vertical or horizontal position.

Figure 2-30: Optional waste gas unit



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 customer in determining the resource requirements for the architectural and radiation shielding design, and radiation safety program implementation of a PET facility. The customer (and the GE HealthCare 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 µA for protons and 60 µA 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^3. 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^2/s) forward	Neutron flux at 90 degrees
p+	16.4	100	Al	3×10^7	9×10^6
d+	8.5	100	C	5×10^7	15×10^6
d+	8.5	100	Cu	5×10^6	15×10^6

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.

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.

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 3-8 illustrate the gamma and neutron dose rate contours (radiation levels) for the integrated radiation shield during the following operating conditions:

- $^{18}F^{-}$ production with enriched oxygen-18 water (> 95%)
- Total beam currents of 60 µA, 100 µA, 130 µA, and 160 µA, 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 ±20% excluding the tolerances of the instruments.

Note!
Typical instrument tolerances: Gamma monitor ±15–20%, Neutron monitor ±40%.

Figure 3-1: Gamma dose rate contours on the radiation shield. Total beam current: 60 µA.

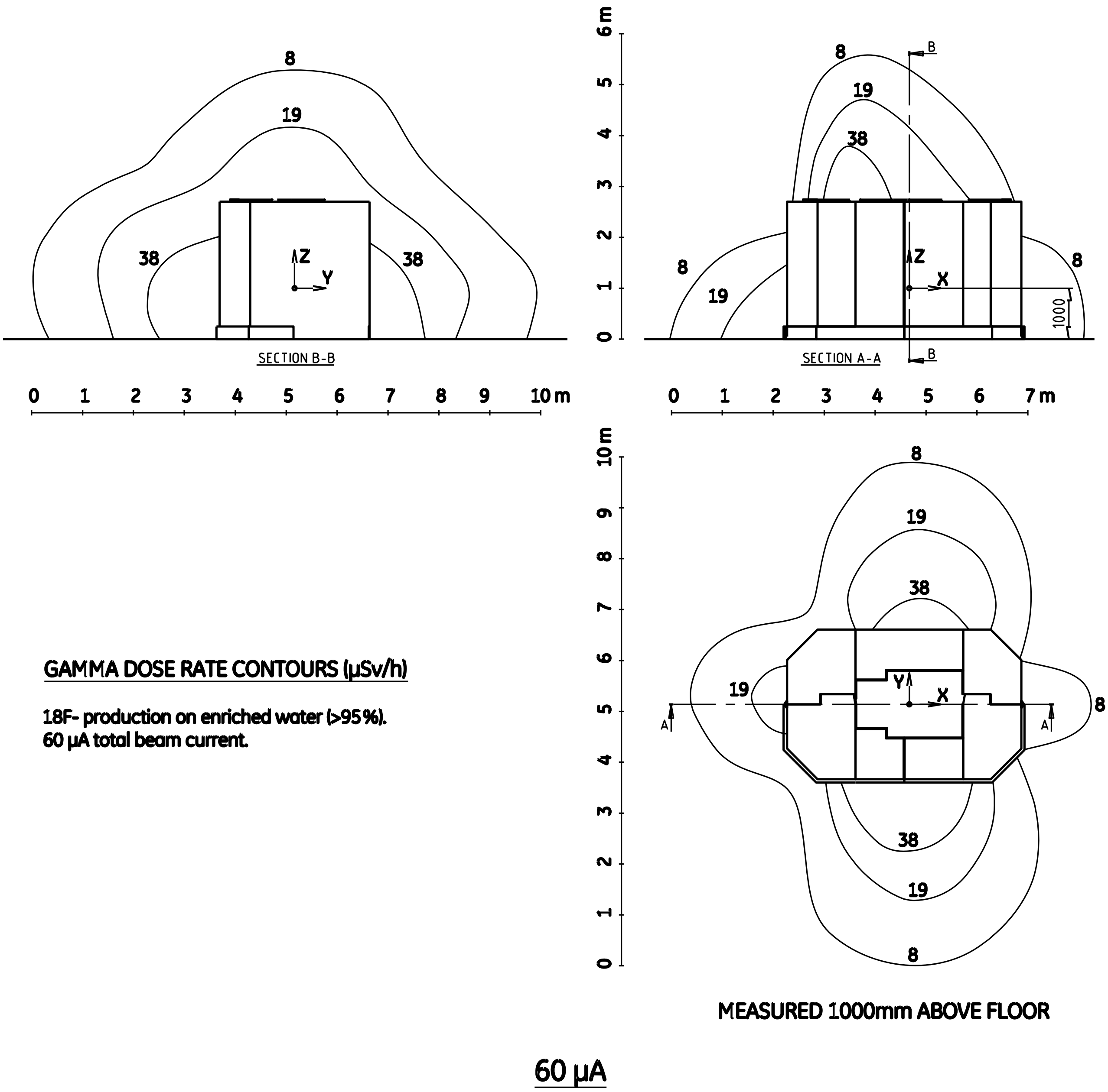


Figure 3-2: Neutron dose rate contours on the radiation shield. Total beam current: 60 µA.

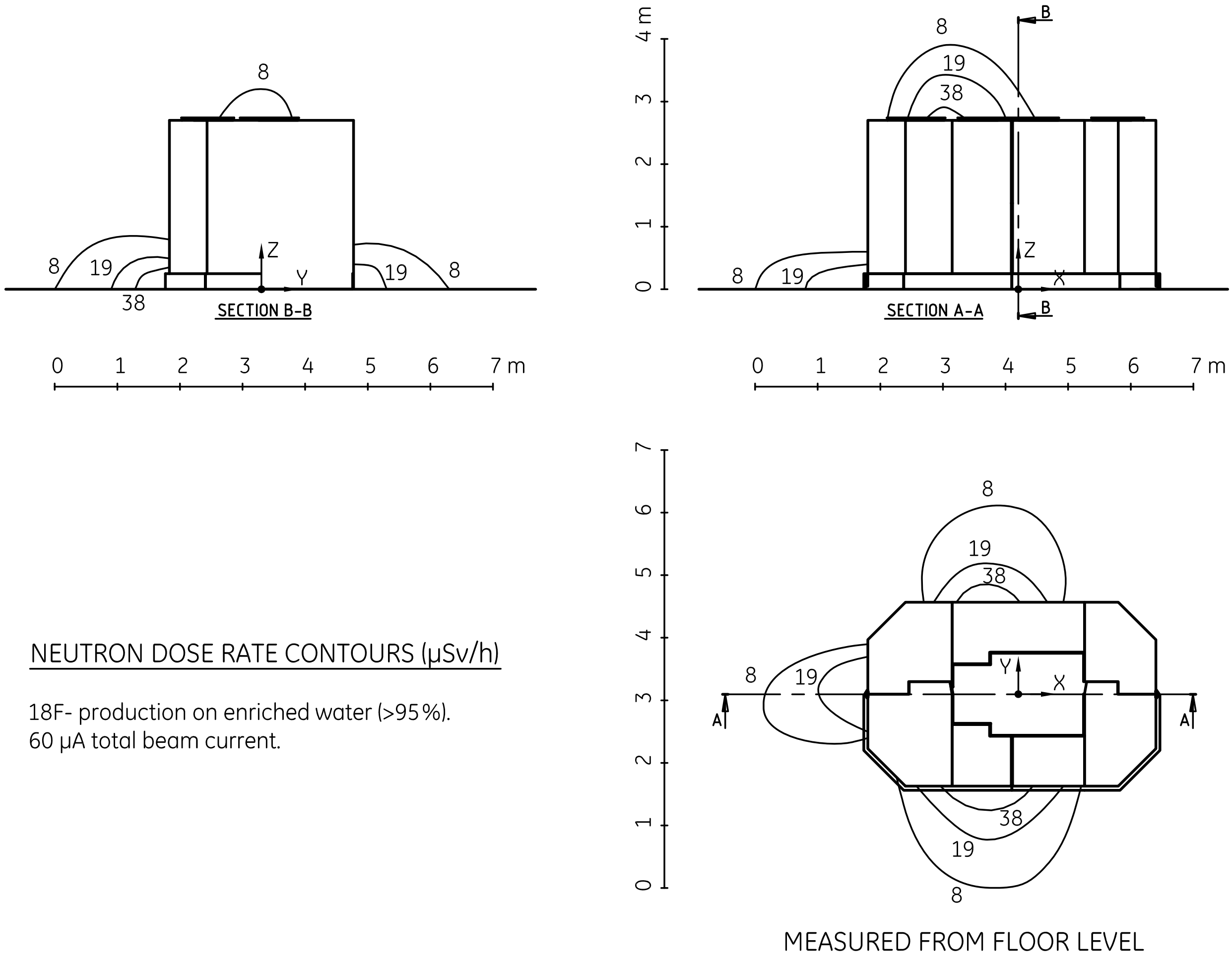


Figure 3-3: Gamma dose rate contours on the radiation shield. Total beam current: 100 µA.

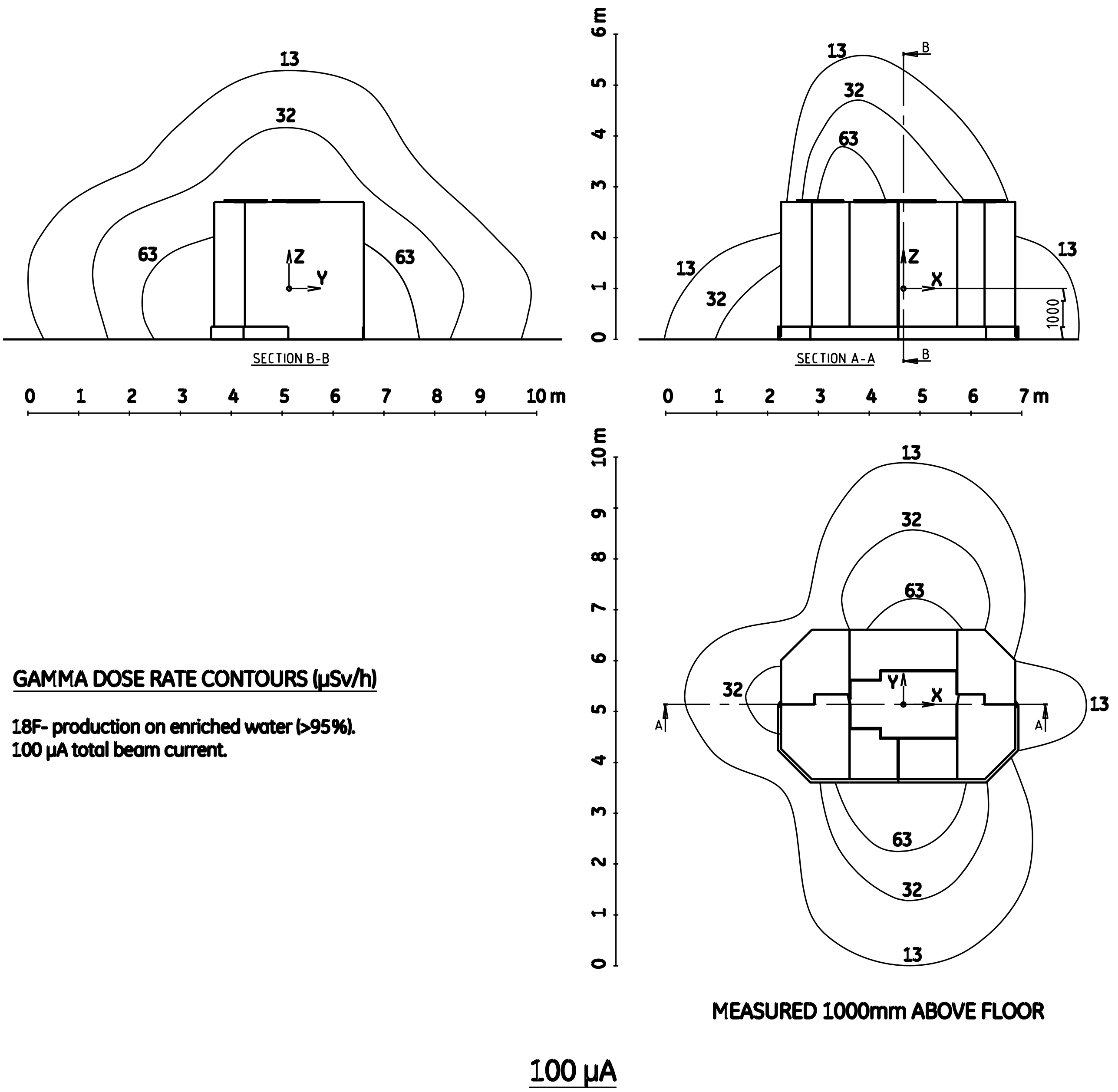


Figure 3-4: Neutron dose rate contours on the radiation shield. Total beam current: 100 µA.

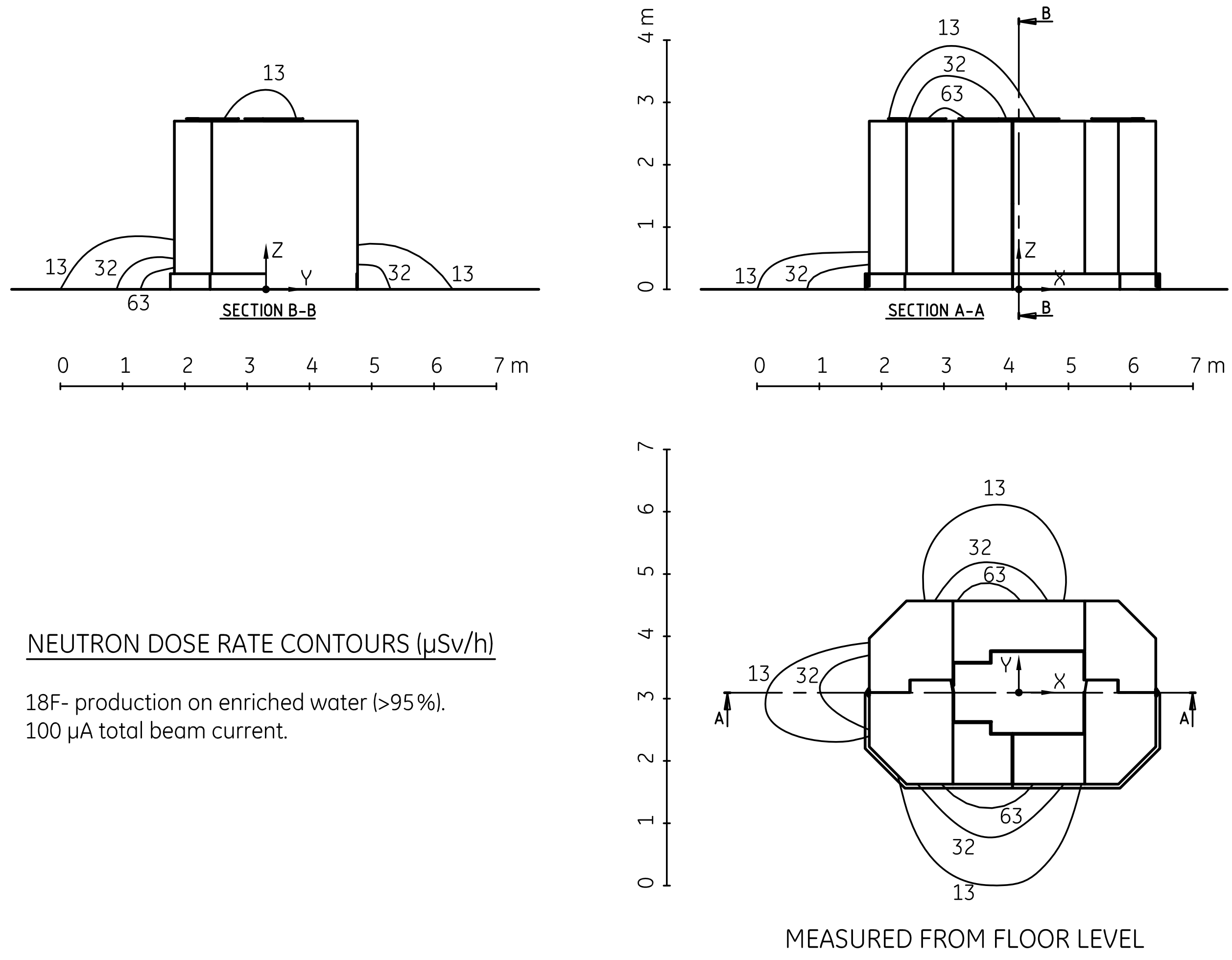


Figure 3-5: Gamma dose rate contours on the radiation shield. Total beam current: 130 µA.

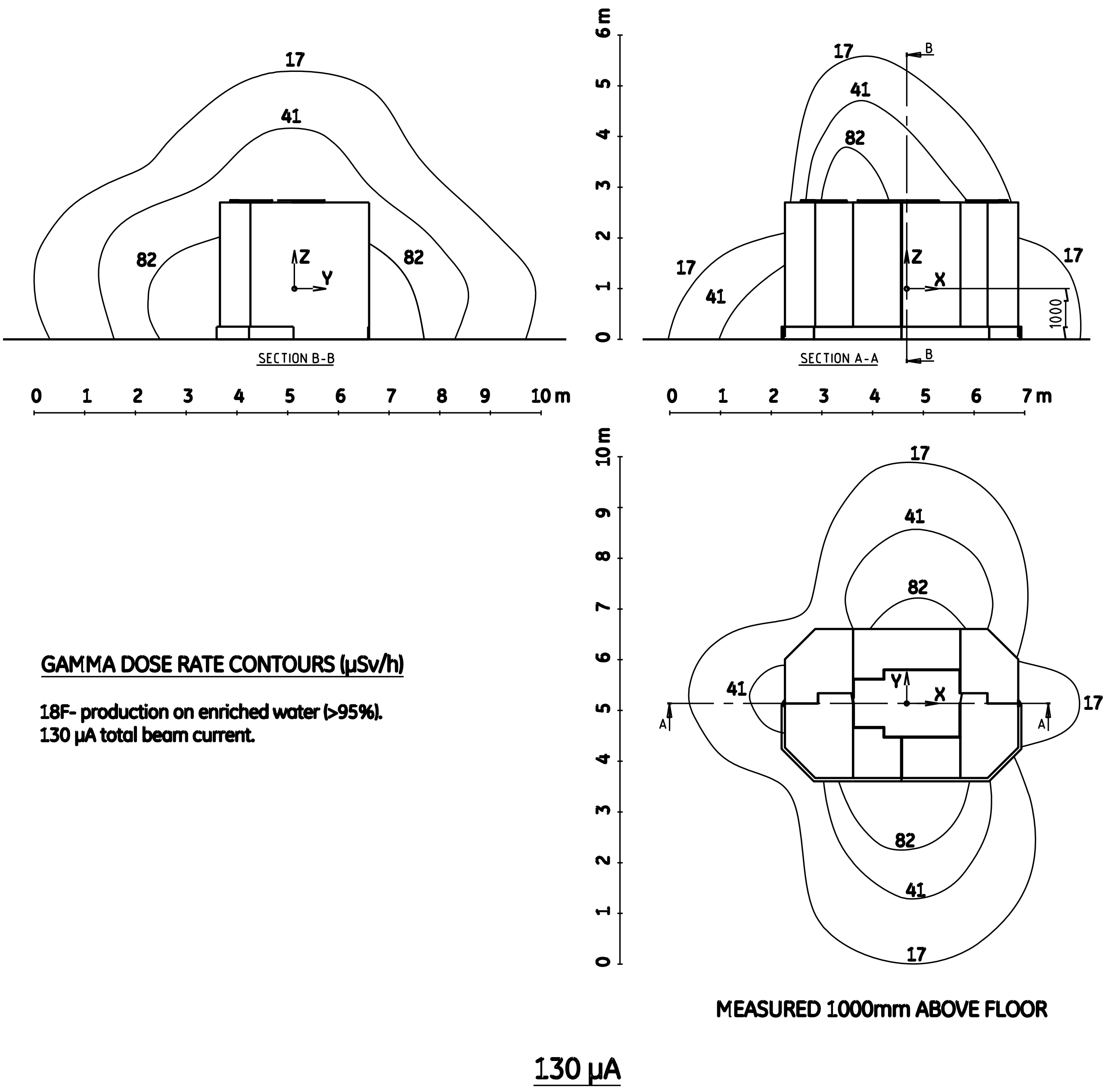


Figure 3-6: Neutron dose rate contours on the radiation shield. Total beam current: 130 µA.

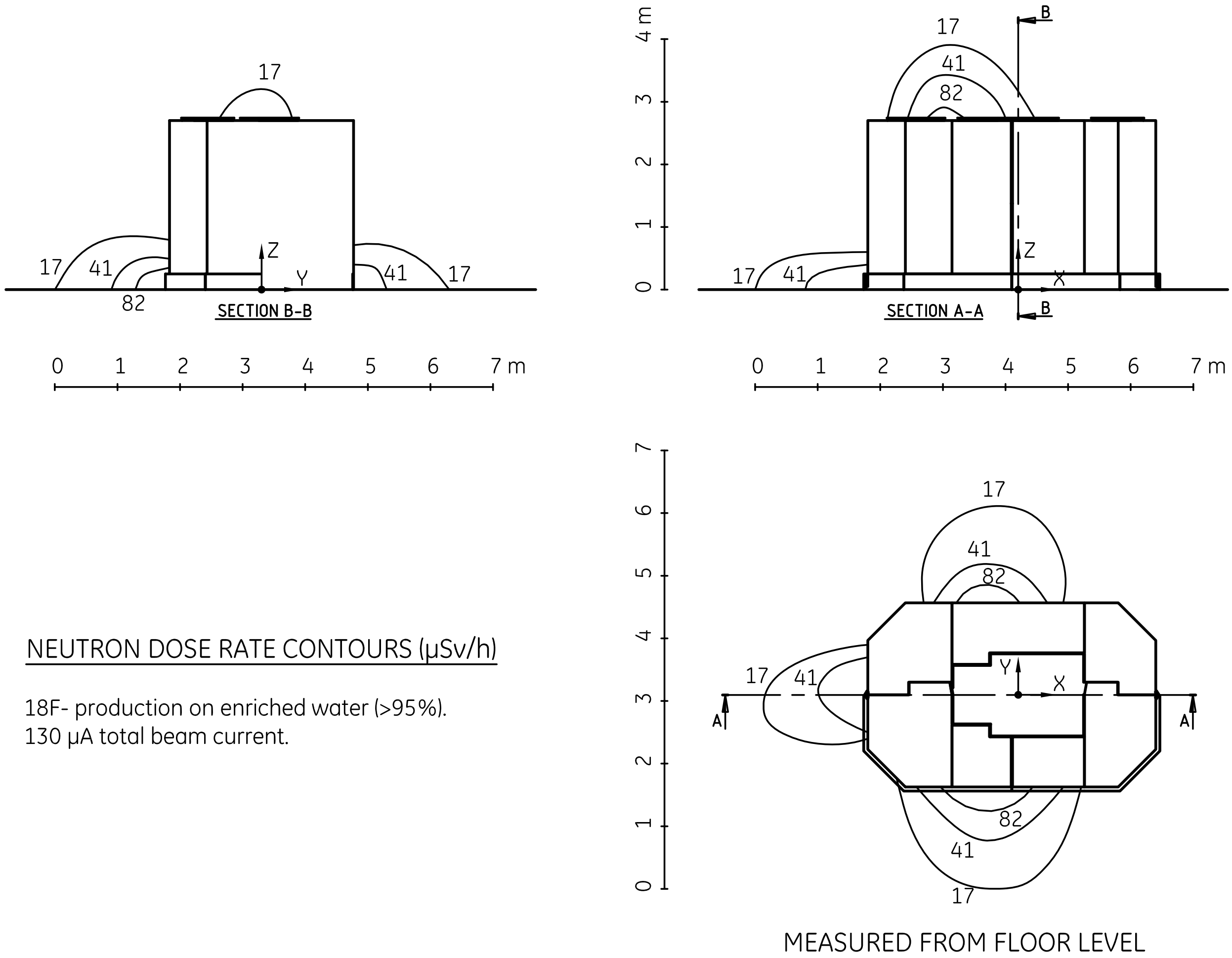


Figure 3-7: Gamma dose rate contours on the radiation shield. Total beam current: 160 µA.

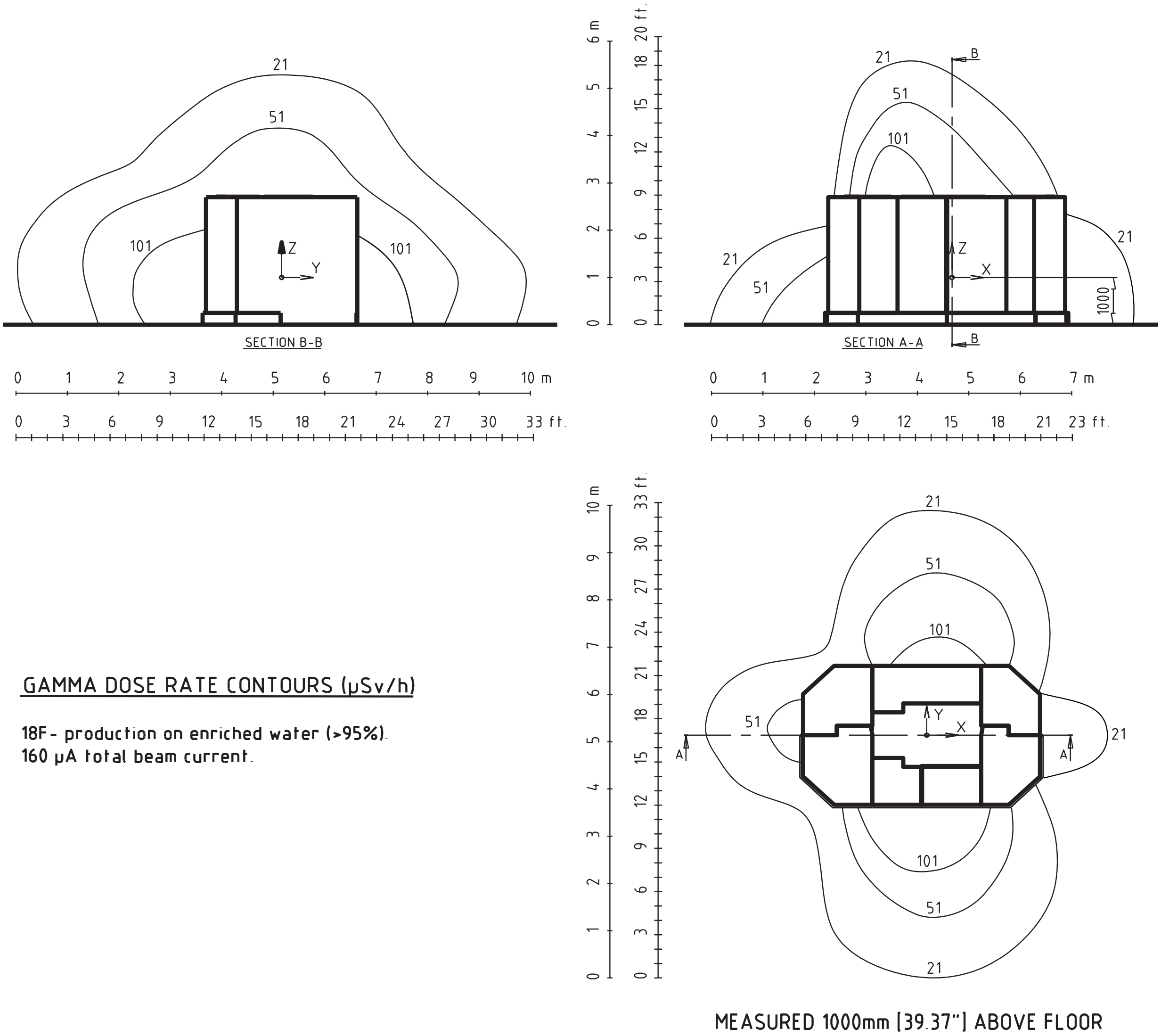
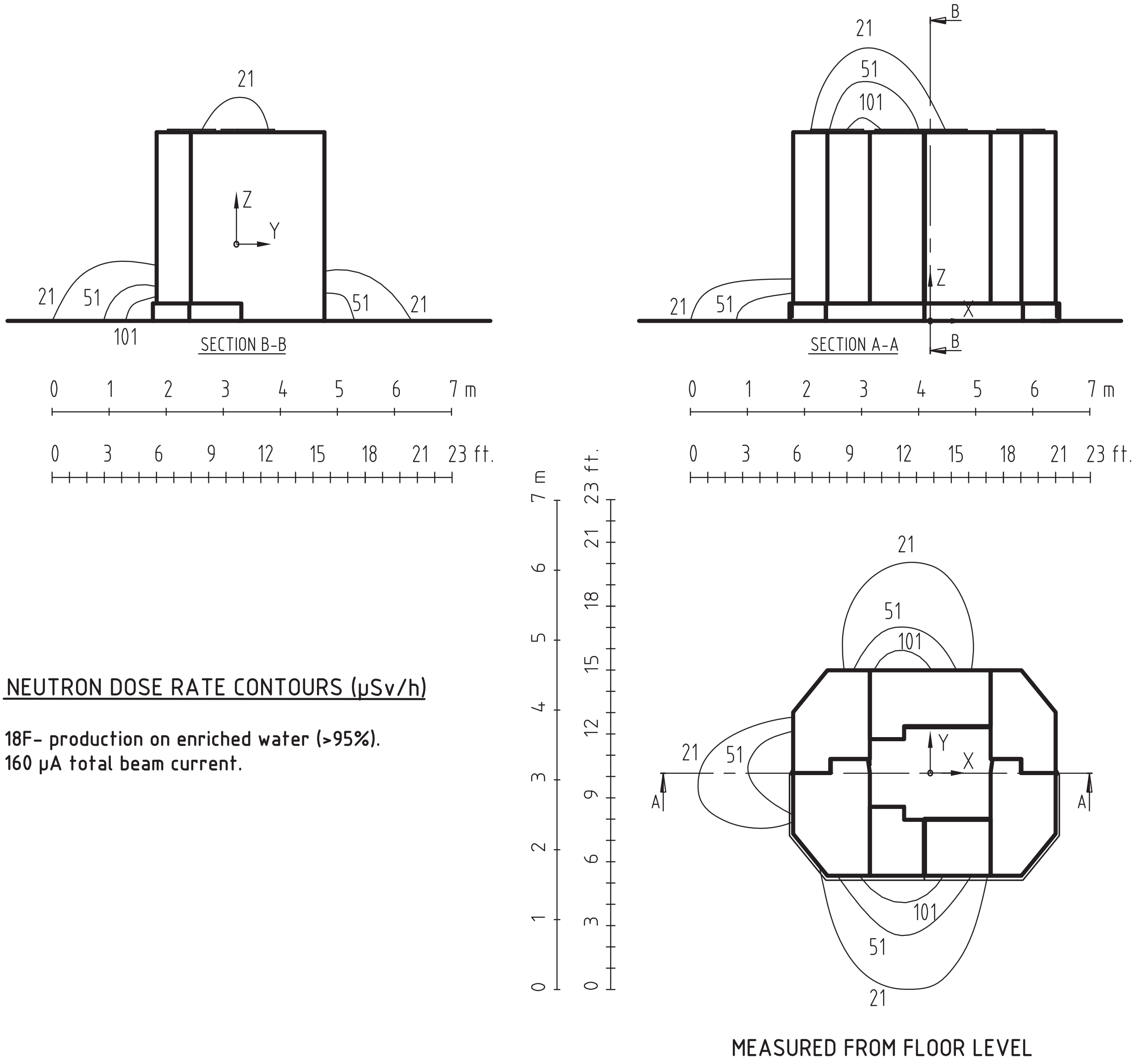


Figure 3-8: Neutron dose rate contours on the radiation shield. Total beam current: 160 µA.



3-2-6 Waste gas production

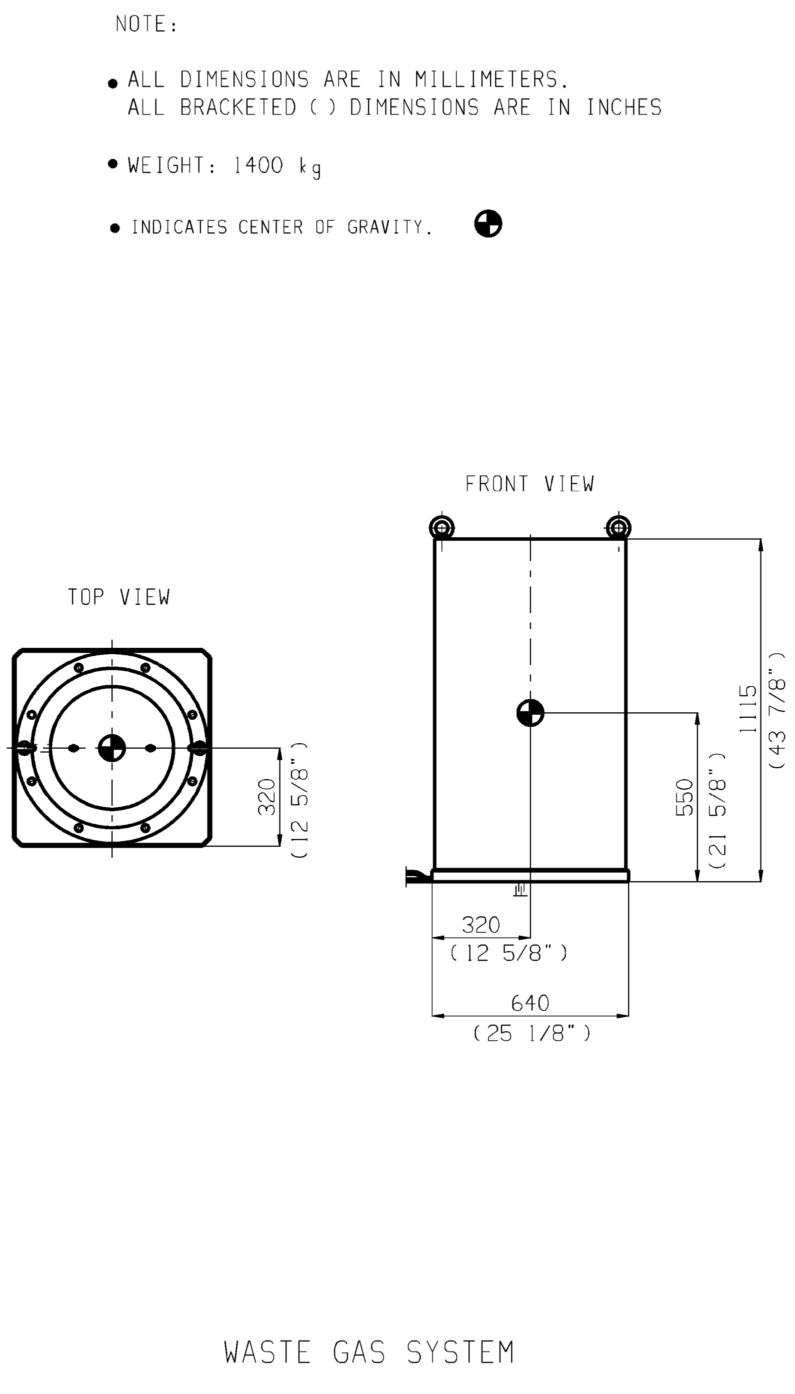
Radioactive gases from hot cells and process cabinets must decay before they can be released into the normal exhaust or ventilation system. The cyclotron produces relatively short lived radioactive gases (2 to 20 minutes) at the relatively slow rate of 1 l/min, so it requires a fairly small waste gas 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 3-9: Waste gas unit



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^3, 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)
  - $\mathbf{Q_0}$ = the fluence rate at a standard reference distance of one meter ($M.^2/am^2$ S.)
  - **Bn** = shielding transmission ratio (rem cm^2)
  - **k** = 2.8×10^{-7} (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 µA of protons is 1.5×10^7 (ENTRAP report No 51, page 111).

A concrete thickness of 190 cm provides a shielding transmission value of 4×10^{-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.

$$H = \frac{1.5\times10^7\times4\times10^{-14}\times0.25}{2.8\times10^{-7}\times(5.3)^2} = 0.019 \ \frac{mrem}{h}$$

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 µA of protons equals 4.5×10^6. (NCRP report No 51, page 111).

A concrete thickness of 160 cm provides a shielding transmission value of 3.5×10^{-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.

$$H = \frac{4.5\times10^6\times3.5\times10^{-13}\times1}{2.8\times10^{-7}\times(4.2)^2} = 0.32 \ \frac{mrem}{h}$$

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 µA of protons equals 4.5×10^6 (NCRP report no 51, page 111).

A concrete thickness of 195 cm provides a shielding transmission value of 4×10^{-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.

$$H = \frac{4.5\times10^6\times4\times10^{-14}\times1}{2.8\times10^{-7}\times(3.5)^2} = 0.052 \ \frac{mrem}{h}$$

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:

$$I = constant \times A/d^2$$

Where:

- **I** = intensity, mrem/h
- **A** = activity, mCi
- **d** = distance in meters
- **constant** = 0.592 (m^2 × 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:

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

The shielding decreases the intensity value by the following formula:

$$I_{shield} = I/(2^{(t/t1/2)})$$

Where:

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

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

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

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 HealthCare cyclotrons are by design intended to run for a long period of time. Thus, the need for decommissioning for new GE HealthCare 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 HealthCare 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 monitoring 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 customer to compile site-specific Lock-Out and Tag-Out (LOTO) procedures, in cooperation with GE HealthCare, 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 affected by, the magnetic field.

Examine all areas within this three-dimensional field, and identify any ferromagnetic material that might 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 HealthCare site planning group for more information, and assistance with your magnetic shield design.

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

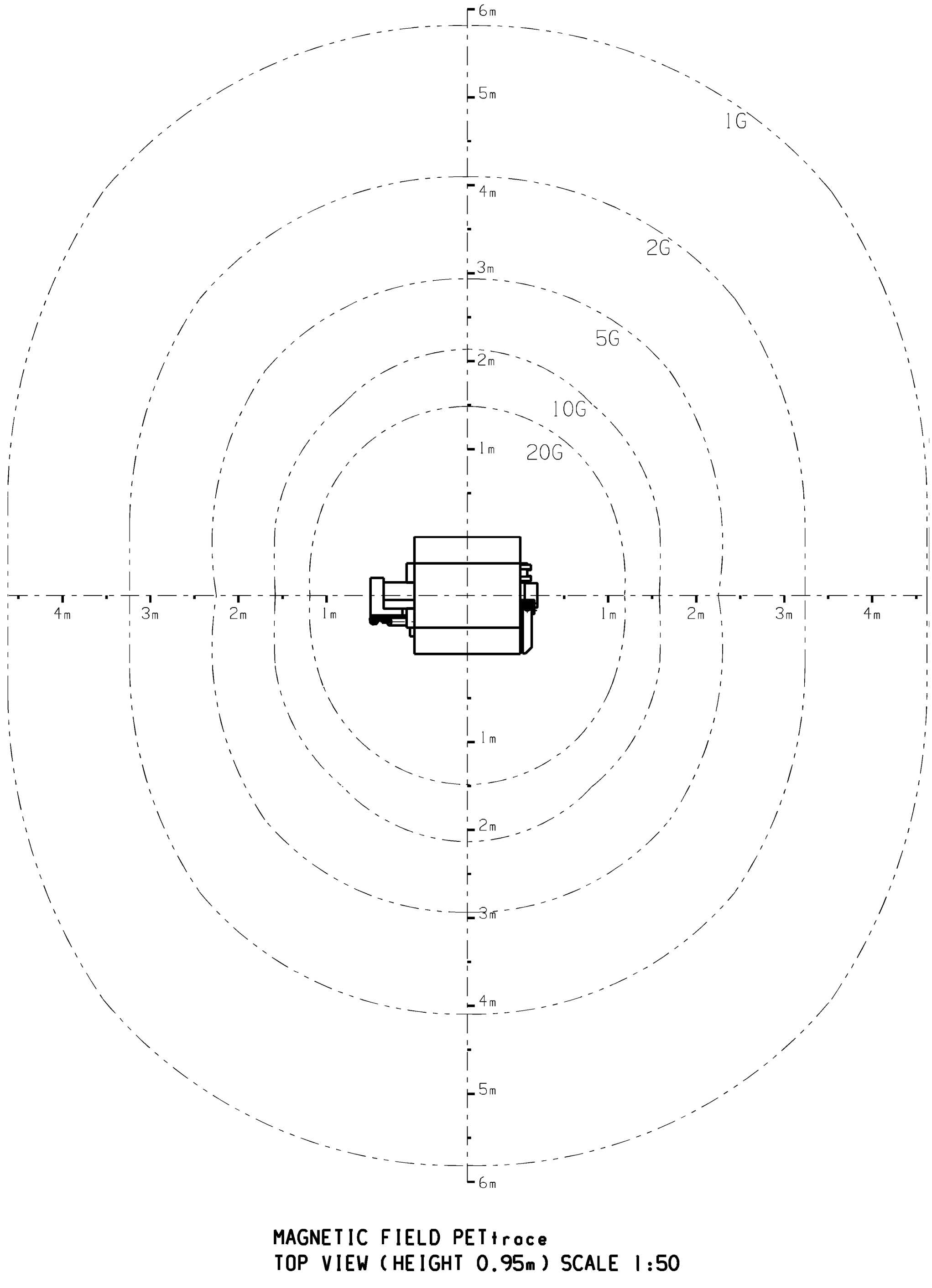


Figure 4-2: Cyclotron magnet isogauss line plot vertical view

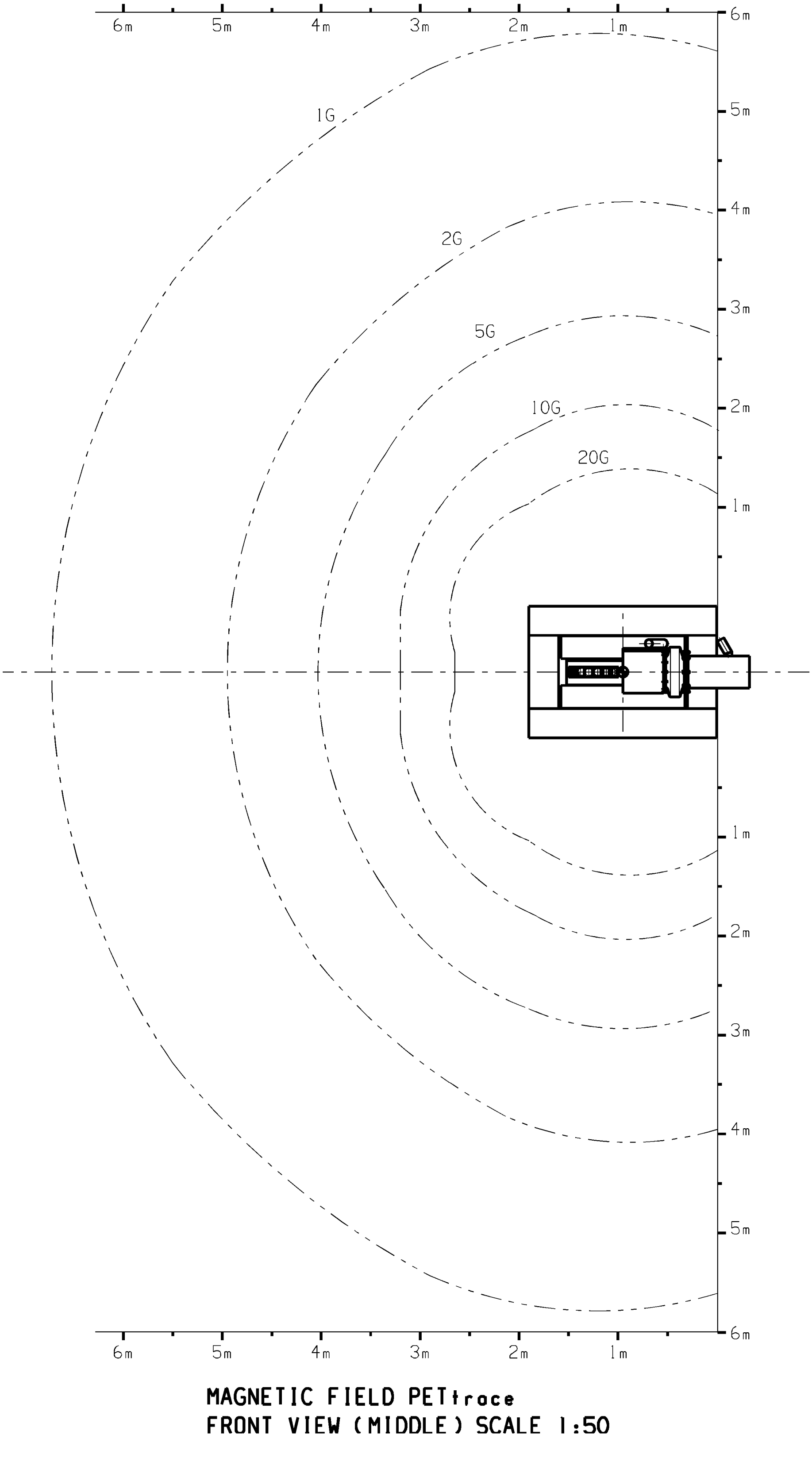
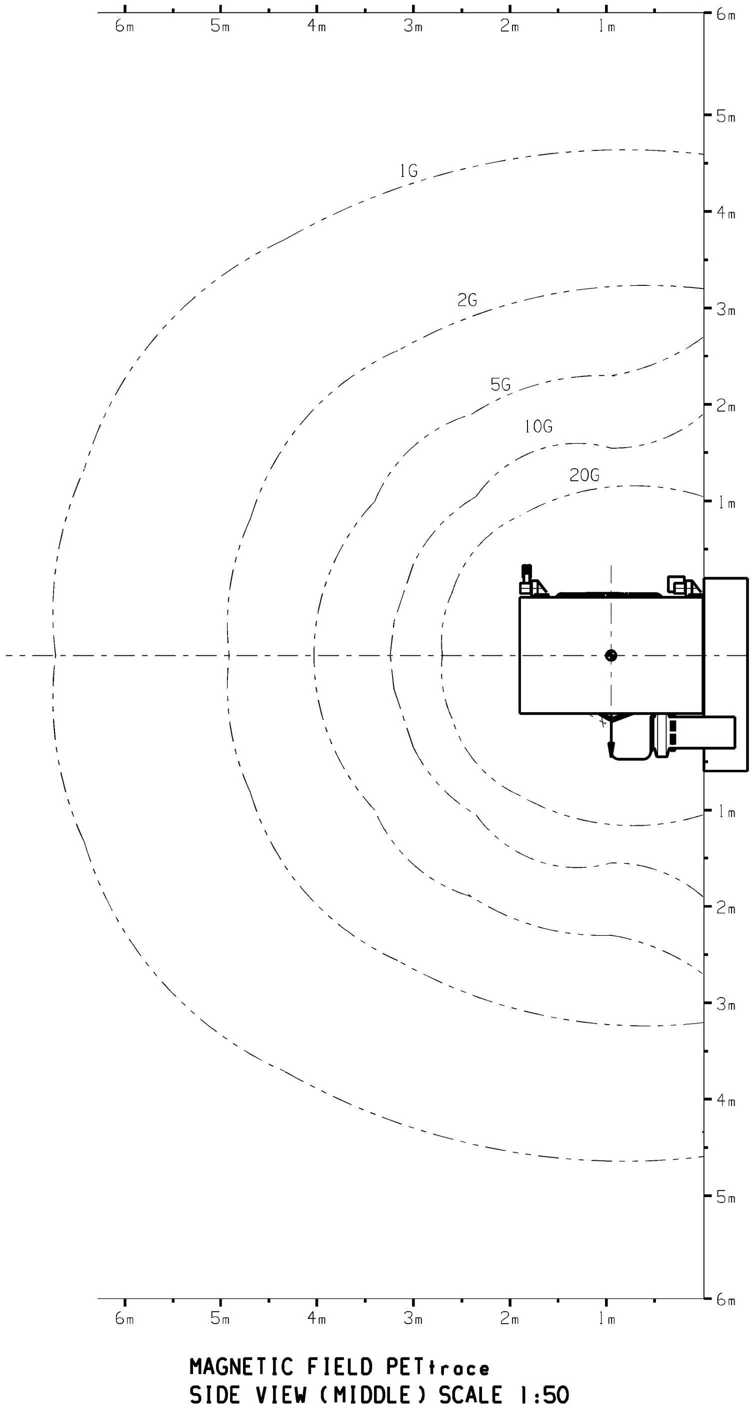


Figure 4-3: Cyclotron magnet isogauss line plot vertical view



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

5-2-1 PETtrace 800

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

- EN 61010-1 ed. 3:2010 + A1:2019, concerning safety requirements for electrical equipment for measurement, control and laboratory use.

  Pollution degree 2
  Installation category 2

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 (radio frequency) energy only for its internal function.

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

- EMCD 2014/30/EU concerning electromagnetic compatibility.
- LVD 2014/35/EU concerning low voltage devices.

CE marking:

The CE marking is valid for PETtrace 800 (including associated options) only when:

- the equipment is connected as described in the user documentation,
- the equipment is used in the same state as it was delivered from GE HealthCare (except for alterations described in the user documentation).

5-2-2 PETtrace Kunpeng

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

- IEC 61010-1:2010 + A1:2016, concerning safety requirements for electrical equipment for measurement, control and laboratory use.

  Pollution degree 2
  Installation category 2

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

- IEC 61326-1:2012 concerning electromagnetic emission and immunity.
- Electromagnetic emission compliance:

Class A	PETtrace Kunpeng is intended for use in an industrial environment. PETtrace Kunpeng 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 Kunpeng uses RF (radio frequency) 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[1]
- Personnel radiation dose monitoring system
- Fire extinguishing system[2, 3]
- 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 can turn off the accelerated proton beam in the event of exceeding pre-set radiation limits.*

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

Note!
3. *Due to the magnetic environment, a 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[1, 2]	18–25	± 3	3	30–60	5	3
Power supply room[1]	18–25	± 3	3	30–60	5	3
Water cooling room	15–30	± 5	5	20–80	5	5
Radiochemistry lab[3]	18–25	± 3	3	30–60	5	3
Other laboratories[3]	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. This does not account for heat generated by 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 local rules and regulations for radiation areas.

Assuming a standard distribution of equipment, the heat load to air for the different areas are:

Cyclotron room	2 kW
Cabinet room (with RFPG, PSMC, CAB3 and secondary cooling water unit)	3 kW
Radiochemistry lab (with CCU, Procab and master station)	2 kW

5-6-2 Water cooling requirements

An external chiller should be supplied and connected, by the customer, to the closed deionized water cooling system. The external chiller; a cooling tower or a refrigeration system, must supply an inlet water temperature in the range 10–15°C.

The customer 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 HealthCare equipment. The customer 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.

The total heat load to water is 65–70 kW, distributed as follows:

Cyclotron room	50 kW
Cabinet room	20 kW
Radiochemistry lab	0 kW

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 5-2: Primary cooling system requirements

Availability	Continuous	
Flow	120–160 l/min (32–42 US Gallon/min)	(No antifreeze added)
Inlet temperature to secondary cooling system	10–15°C (50–59°F)[1]	
Antifreeze	0–40% polypropylene glycol or ethylene glycol	20% requires ~13% higher flow rate 40% requires ~20% higher flow rate (compared to 0% antifreeze flow)[2]
Max system pressure	10 bar (145 psi)	
Differential pressure at 120 l/min (heat exchanger)	1.3 bar 1.4 bar with 20% antifreeze 1.5 bar with 40% antifreeze	(Antifreeze increases viscosity)
Capacity	Minimum 80 kW	
Connection	DN32	

1 Be aware that using cooling water inlet temperatures in the lower range can result in severe condensation and require additional insulation of piping and connections on the primary cooling water side.

2 Higher flow rates are required to maintain cooling capacity as antifreeze reduces thermal conductivity.

Table 5-3: Facility water quality requirements

pH	6–9
Specific conductivity	< 1000 µS/cm
Hardness	< 10 dH
Chloride (Cl)	< 300 ppm
Total M-alkalinity (TAC)	< 0–300 ppm $CaCO_3$
Particle size[1]	< 600 µm

1 The cooling unit has an inside 600 µm filter strainer to prevent large particles from entering the heat exchanger and other components. It is, however, recommended to add a 300 µm high flow capacity filter/strainer on the facility cooling water supply line before entering the cyclotron cooling unit, see Figure 7-4.

The water shall be free from oil, grease and organic material as this can form a sticky layer on the heat exchanger plates and cause accumulation of debris, with reduced cooling capacity as a result.

If the hardness exceeds the value in Table 5-3, an anti-scaling agent should be added to the cooling water.

Corrosion inhibitors are not required in the cooling water but can be accepted if used for other reasons in the external cooling water circuit.

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 HealthCare with a pipe in the specified size.

Figure 5-1: Top view of secondary cooling unit

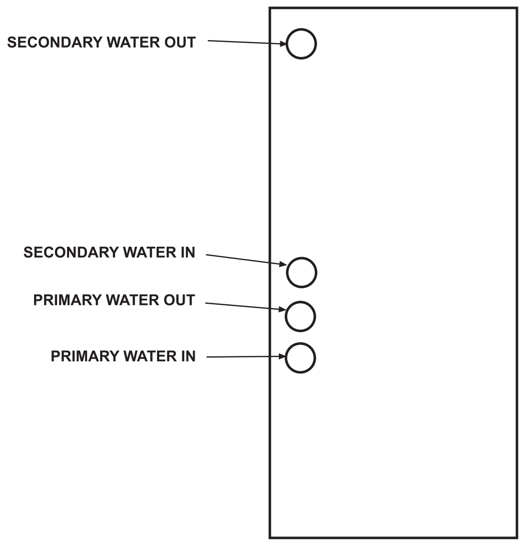


Table 5-4: Water cooling connections

	Connection
Primary water	DN32
Secondary water main circuit	DN32
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 customer 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 5-5: 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.

WARNING! Adequate ventilation for radioactive gas

Make sure the working environment is well ventilated. As both liquid and gaseous ^{13}N is produced during regular production of ^{68}Ga, there is a significant risk for release of ^{13}N gas in the hot cell.

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 45.
- ProCab: The 125 mm hose connector at the top of the Process Cabinet requires an air flow of 150 m^3/h. Valves on the inlet and outlet set the underpressure to 150 Pa.

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 before 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 5-6: Hazardous gases involved in the chemistry and target processes

Hydrogen (H_2)	• Explosion risk in different mixing proportions with air. • Always provide good ventilation. • Avoid open flames in the Process Cabinet. • Close the H_2-main valve by hand after processing, for double security.
Ammonia (NH_3)	• Breathing NH_3 can cause lung damage; always provide good ventilation. • Always provide faceguard equipment • Close the NH_3 main valve by hand after processing, for double security
Fluorine (F_2)	• Toxic, very reactive, and may have special storage requirements • Always provide adequate ventilation

Table 5-7: Radioactive gases present at the product outlets

$[^{11}C]CO_2$	Radioactive. Do not inhale.
$[^{11}C]CO$	Radioactive. Do not inhale.
$[^{11}C]HCN$	Radioactive. Do not inhale.
$[^{15}O]O_2$	Radioactive. Do not inhale.
$[^{15}O]CO_2$	Radioactive. Do not inhale.
$[^{15}O]CO$	Radioactive. Do not inhale.
$Ne+[^{18}F]F_2$	Radioactive. Do not inhale.
$H_2+[^{15}O]O_2$	Radioactive. Do not inhale.
$[^{13}N]N_2/NO_x$	Radioactive. Do not inhale. (Significant amounts co-produced in the ^{68}Ga process.)

Table 5-8: Radioactive liquids present at product outlets or at the outputs of dedicated process units

$[^{18}F]F^-$ (aq)	• Handle liquid containing $^{18}F^-$ with special care. • Store the liquid in a sealed bottle in a lead box • Contact with skin is dangerous.
$[^{13}N]NH_3$ (aq)	
$[^{11}C]HCN$ (aq)	
$[^{68}Ga]Ga^{3+}$ (aq)	Apart from ^{68}Ga, there is normally: • significant amounts of coproduced ^{13}N in liquid and volatile form, and • small amounts of coproduced ^{66}Ga and ^{67}Ga following the ^{68}Ga chemistry purification/labelling processes.

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 0.65 ± 0.05 MPa (6.5 ± 0.5 bar) to actuate the pneumatic valves. Each valve activation requires about 2 liters of air for 1 second, at 0.65 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 0.65 MPa.

5-14-2 Customer supplied media

Note!
The customer supplies all gas cylinders, tubes and regulators specified or recommended by GE HealthCare.

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}C, ^{15}O gas, and ^{15}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 H_2 gas.

Some cylinders have more than one regulator: For example, the $^{11}CO_2$ HP target system require N_2 + 1% O_2-gas at a pressure of 1.3 MPa and the ^{15}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}O target system can be run with a lower quality of gas than the $^{11}CO_2$ HP target system. If you decide to share gas cylinder 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 HealthCare provides and installs the piping between the cyclotron target and the radiochemistry lab.

- The gas supply (cylinders) 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 (H_2) and deuterium (D_2) gas is explosive at certain mixing proportions with air. Provide adequate ventilation.

WARNING!

Fluorine gas (F_2) is toxic and caustic. If inhaled, it can cause severe damage to lungs and mucous membranes. Provide adequate ventilation.

WARNING!

Ammonia gas (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 expiry date on the gas cylinders. Old gas cylinders might deteriorate 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 5-9: Ion source gas specifications

Particle	Gas specification	Operating pressure [MPa (psi)]	Regulator pressure range [MPa (psi)]	Recom-mended cylinder size	Tube con-nection o.d.
Protons	H_2 (6.0)	0.1 ± 0.05 (15 ± 7)	0.02–0.5 (2.9–72.5)	50 l	1/8"
Deuterons	D_2 (2.7)	0.1 ± 0.05 (15 ± 7)	0.02–0.5 (2.9–72.5)	20 l	1/8"

5-14-2-2 Target gases

Table 5-10: Target gas specifications

Target	Gas specification	Operating pressure [MPa (psi)]	Regulator pressure range [MPa (psi)]	Recom-mended cylinder size	Tube con-nection o.d.
$^{11}CO_2$ standard	N_2 (6.0) + 1% O_2 (5.0) (C_nH_m < 0.1 ppmv, CO+CO_2 < 0.1 ppmv)	1.2 ± 0.03 (175 ± 5)	0.04–2.1 (5.8–305)	50 l	1/8"
$^{11}CO_2$ HP	N_2 (6.0) + 1% O_2 (5.0) (C_nH_m < 0.1 ppmv, CO+CO_2 < 0.1 ppmv)	1.3 ± 0.03 (190 ± 5)	0.04–2.1 (5.8–305)	50 l	1/8"
$^{11}CH_4$	N_2 (6.0) + 10% H_2 (6.0)	1.0 ± 0.1 (145 ± 15)	0.04–2.1 (5.8–305)	50 l	1/8"
^{15}O	N_2 (5.0) + 1% O_2 (4.5)	1.0 ± 0.1 (145 ± 15)	0.04–2.1 (5.8–305)	50 l	1/8"
^{13}N	He (5.5)	0.45 ± 0.03 (65 ± 5)	0.04–1.0 (5.8–145)	50 l	1/8"
$^{13}NH_3$	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"
$^{18}F^-$ Nb 27 self-shielded target $^{18}F^-$ Nb 25 $^{18}F^-$ HYT $^{18}F^-$ 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"

Target	Gas specification	Operating pressure [MPa (psi)]	Regulator pressure range [MPa (psi)]	Recom-mended cylinder size	Tube con-nection o.d.
$^{18}F_2$ 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_2 (1.8) F_2: HF < 0.5%	0.35 ± 0.03 (45 ± 5)	0.04–0.65 (5.8–94)	20 l	1/8"
$^{18}F_2$ Proton	3% F_2 (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"
	$^{18}O_2$ (1.8)	0.1 ± 0.05 (14.5 ± 7)	0–0.5 (0–72.5)	0.45 l (45 bar, stainless steel)	1/16"
^{68}Ga	He (5.5)	LP: 0.45 ± 0.03 (65 ± 5)	0.04–1.0 (5.8–145)	50 l	1/8"
Cooling in all tar-gets except ^{68}Ga liquid target and $^{18}F^-$ Nb 27 self-shielded target	He (5.5)	0.38 ± 0.03 (55 ± 5)	0.04–1.0 (5.8–145)	50 l	1/8"

Note!
It is recommended to have spare cylinders of helium for target cooling and target gas for ^{18}F, ^{13}N and $^{13}NH_3$.

5-14-2-3 Process gases

Table 5-11: Process gas specification

Chemistry system	Gas specification	Operating pressure [MPa (psi)]	Regulator pressure range [MPa (psi)]	Recom-mended cylinder size	Tube con-nection o.d.
^{11}C, ^{15}O	N_2 (6.0), carbon content < 0.1 ppmv (C_nH_m < 0,1 ppmv, CO+CO_2 < 0.1 ppmv)	0.25 ± 0.1 (36 ± 14)	0.02–0.5	50 l	1/8"
^{11}C, ^{15}O	H_2 (5.7), carbon content < 0.1 ppmv (C_nH_m < 0,1 ppmv, CO+CO_2 < 0.1 ppmv)	0.25 ± 0.1 (36 ± 14)	0.02–0.5	50 l	1/8"
^{11}C	NH_3 (4.5), H_2O < 50 ppmv	0.27 ± 0.1 (39 ± 14)	0.04–0.65	20 l	1/8"

5-14-2-4 Target liquids

Table 5-12: Target liquid specifications

Target	Liquid specification
$^{18}F^-$	^{18}O-H_2O, [^{18}O]-enrichment > 95%, deionized, sterile filtered
^{13}N	^{16}O-H_2O, deionized, sterile filtered 18 Mohm
$^{13}NH_3$	5 mM ethanol (> 99.5%) in deionized, sterile filtered water (18MΩ)
^{68}Ga	1 M [^{68}Zn]$Zn(NO_3)_2$ in dilute nitric acid (HNO_3)

5-14-3 Gas consumption estimation

For operating pressures and recommended cylinder sizes, see Table 5-9, Table 5-10 and Table 5-11.

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[1]
Protons	H_2	20	> 2000
Deuterons	D_2	20	> 1000

1 Estimations are based on cylinder sizes in Table 5-9.

Table 5-14: Estimated usage – target gases

Target	Gas	Nominal cylinder pressure (MPa)	Approx. no. of productions before replacing cylinder[1]
$^{11}CO_2$ standard	N_2 + 1% O_2	20	> 500
$^{11}CO_2$ HP	N_2 + 1% O_2	20	> 500
$^{11}CH_4$	N_2 + 10% H_2	20	> 500

Target	Gas	Nominal cylinder pressure (MPa)	Approx. no. of productions before replacing cylinder[1]
^{15}O	N_2 + 1% O_2	20	Batch mode: > 1000
			Cont. mode: > 800 (10 min.)
^{13}N	He	15	> 1200
$^{13}NH_3$	He	15	> 1000
$^{18}F^-$ Nb 27 self-shielded	He	15	> 1000
$^{18}F^-$ Nb 25	He	15	> 1000
$^{18}F^-$ HYT	He	15	> 1000
$^{18}F^-$ Gen II	He	15	> 1000
$^{18}F_2$ Deuteron	Ne	20	> 500
$^{18}F_2$ Deuteron	Ne + 1% F_2	20	> 1000
$^{18}F_2$ Proton	3% F_2 + He	15	> 300
	Ar	20	> 1000
	$^{18}O_2$	4.5	> 200
All except $^{18}F^-$ Nb 27 self-shielded (cooling)	He	15	> 2000
^{68}Ga	He	15	> 1000

1 Estimations are based on cylinder sizes in Table 5-10.

Table 5-15: Estimated usage – process gases

Chemistry system	Gas	Nominal cylinder pressure (MPa)	Approx. no. of productions before replacing cylinder[1]
^{11}C, ^{15}O	N_2	15	> 500
^{11}C, ^{15}O	H_2	15	> 500
^{11}C	NH_3	0.7	> 200

1 Estimations are based on cylinder sizes in Table 5-11.

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 Table 5-9 to Table 5-11)
Max. flow	155 l/min, Cv = 0.02
Stability	+0.04 bar sec. @ -7 bar prim.

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 5-17 lists gas tube recommendations.

Table 5-17: Gas tube recommmendations

Parameter	Value
Material	Chromatography grade, i.d. 0.085" 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 customer must provide additional safety systems, such as ventilation and fire protection.

5-16-1 Mains Distribution Panel (MDP)

The customer-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 that the activated push button must be manually reset 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.

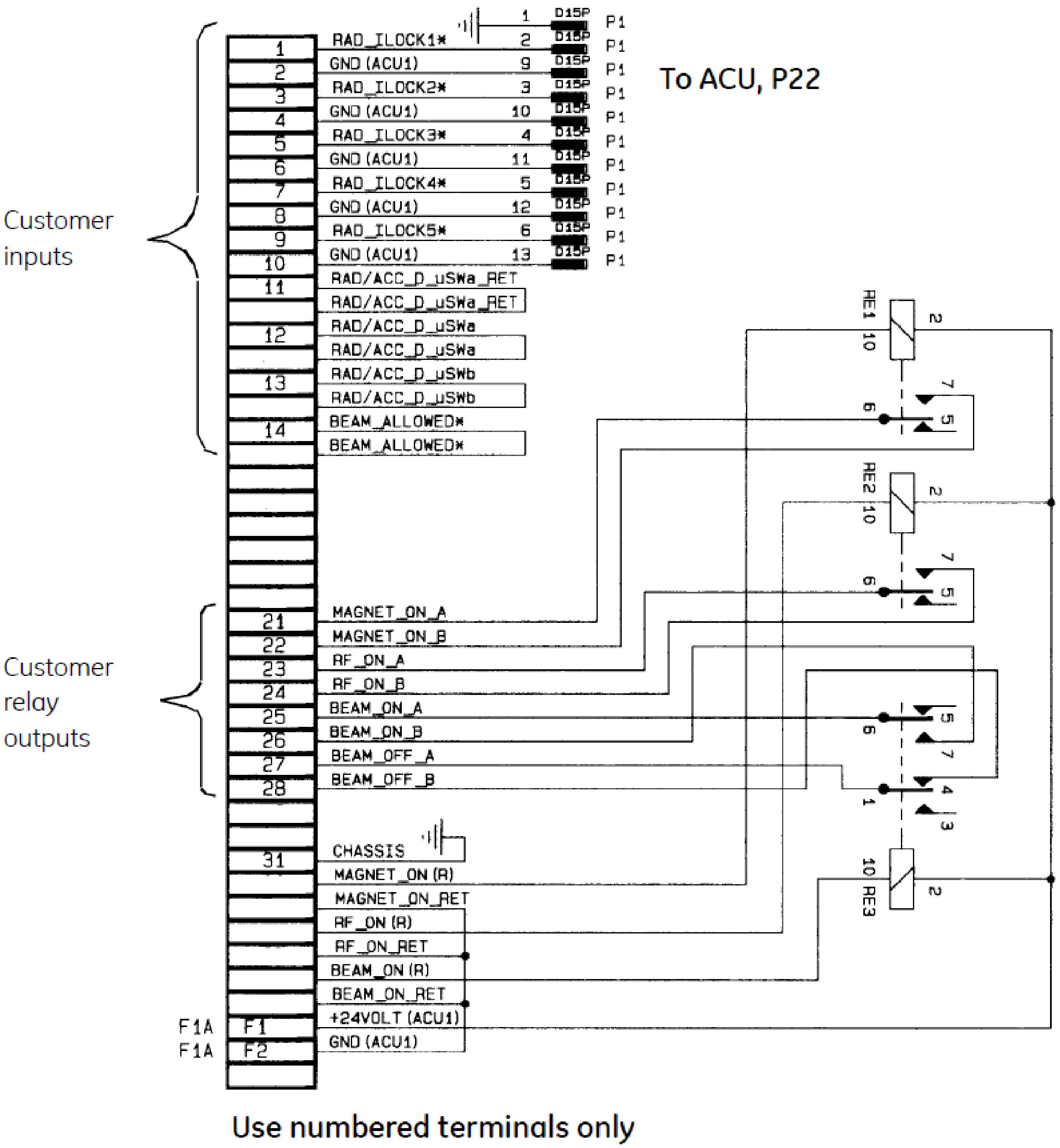
The relay contacts provide the following status information:

- **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 status information. The inputs will not stop the beam or interrupt an ongoing target delivery, but they will prevent start of delivery. Use these safety status inputs to monitor radiation. Keep all five inputs *separate* and *potential free*. The inputs 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



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

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

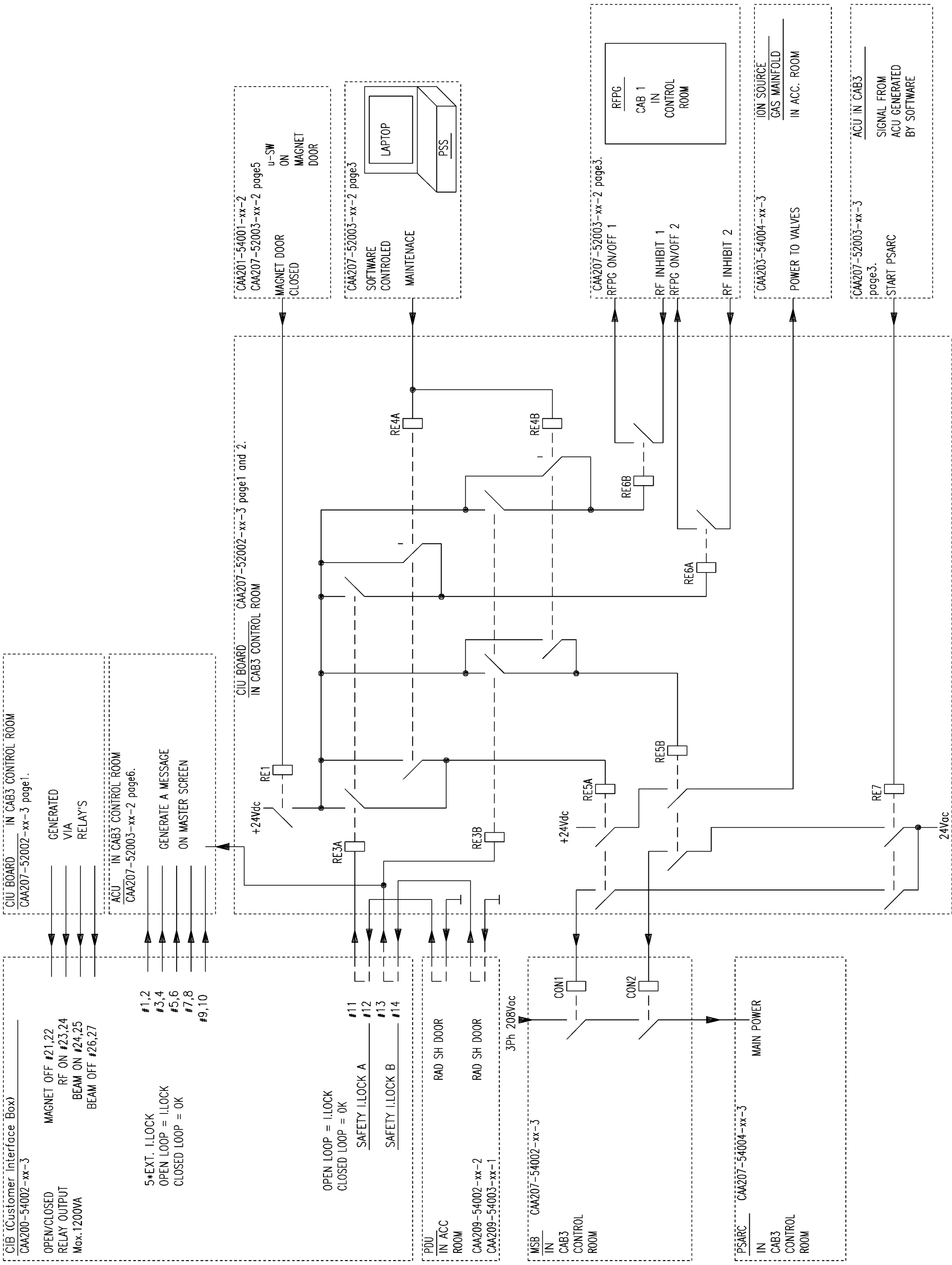
5-16-3-1 Clearance system

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 the correct sequence of buttons is pressed 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 HealthCare 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 HealthCare 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 Electronics 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 HealthCare 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 a type with a large enough diameter to accommodate the passage of any cable with its connector, with all other cables in position 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

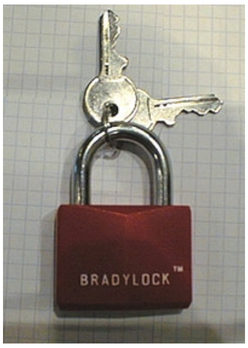
Total power consumption	75 kW
Installed power	109 kVA
Wire system	3 phase 5 wire
Variation of nominal line voltage	+10%, -5%
Maximum allowed THD (Total Harmonic Distorsion)	5%

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). To meet the regulations in a country, GE HealthCare 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 for a standard system. Table 6-3 shows the contribution from different optional systems.

Table 6-2: Mains input power (standard system)

Subsystem	Installed power [kVA]	Total consumed power during operation [kW]
PSMC	61	75
RFPG	28	
CAB 3	7	
PDU transformer	10	
Cooling system	2.5	
Master station	0.4	
Service laptop	0.2	

Table 6-3: Mains input power (optional systems)

Option	Installed power [kVA]	Consumed power during operation [kW]
Radiation shield compressor[1] (only when opening the shield doors)	14	11
Beam Line system	19	15
Gas processing systems	2.5	< 2
$^{18}F_2$ Proton target system	0.2	< 0.2
Client station	0.2	< 0.2

1 The 32 A overload relay (motor circuit breaker) for power to the radiation shield compressor GA11 must have thermomagnetic release characteristic D.

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 HealthCare responsibilities for mains power supply to the cyclotron system and crucial information concerning cyclotron PSMC (Cabinet 1) Residual Current Circuit Breaker (RCCB) setting (see Section 6-5 Residual Current Circuit Breaker (RCCB) on page 123).

- 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 HealthCare 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.

GE HealthCare recommends and offer power survey before the installation of the cyclotron system.

Note!
The data in Table 6-4 is based on the data for a standard system in Table 6-2. Any options from Table 6-3 needs to be added. The data ***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 6-4: Recommended sizes of the UPS

System	Consumed power during operation [kW]	Recommended size on the UPS [kVA][1]
Cyclotron	75	120
Master Station	0.4	1

1 The cyclotron has a power factor of 0.8–0.85.

6-5 Residual Current Circuit Breaker (RCCB)

If a Residual Current Circuit Breaker (RCCB) is used, it should handle the following leakage currents (see Figure 6-4 to Figure 6-6):

- CB1: more than 300 mA leakage current
- CB2–CB6: a minimum of 100 mA leakage current

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 customer-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

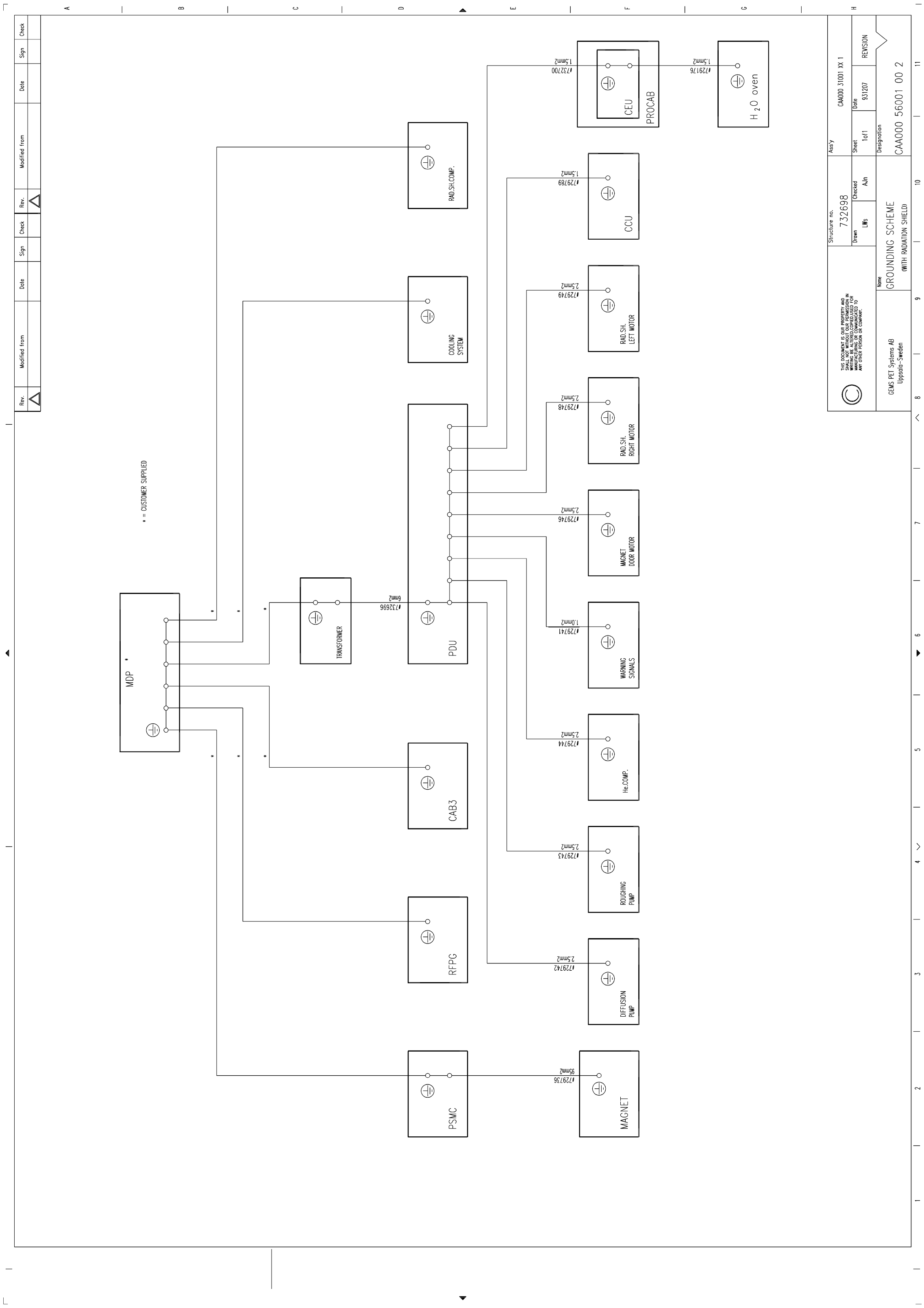


Figure 6-3: Grounding scheme without radiation shield – CAA000-56002

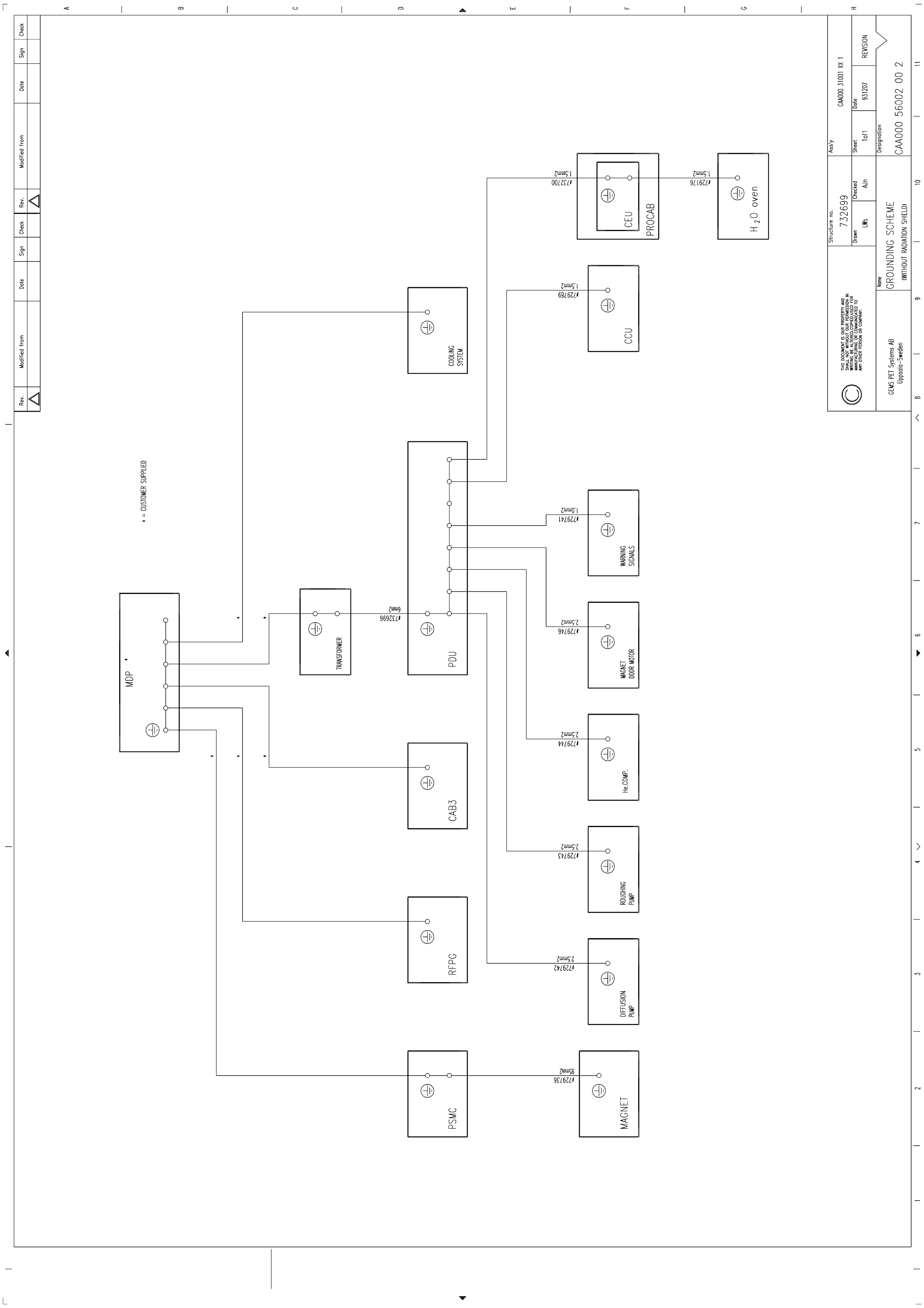


Figure 6-4: Mains Distribution 380 VAC, CAA209 – 56003

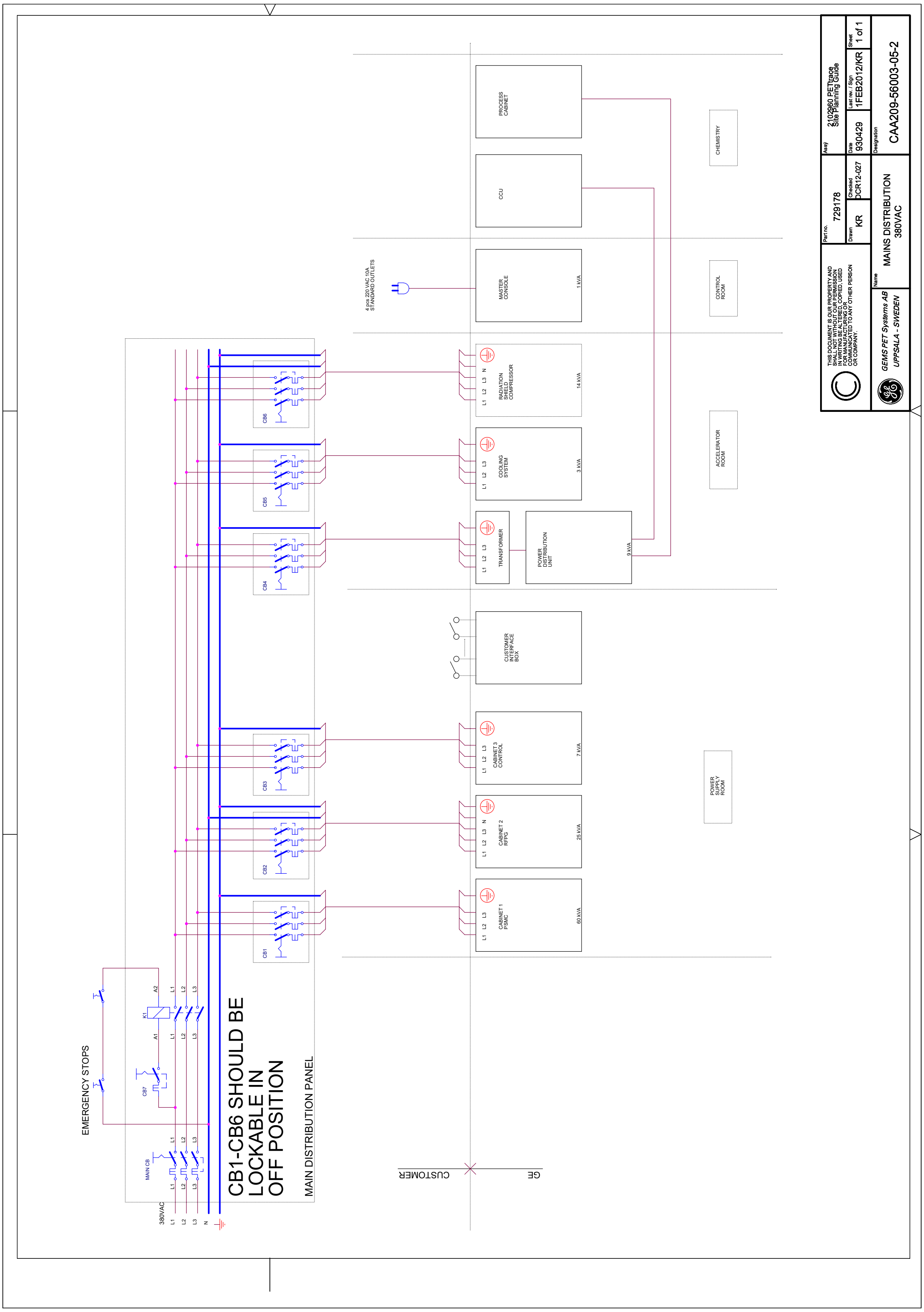


Figure 6-5: Mains Distribution 415 VAC, CAA209 – 56004

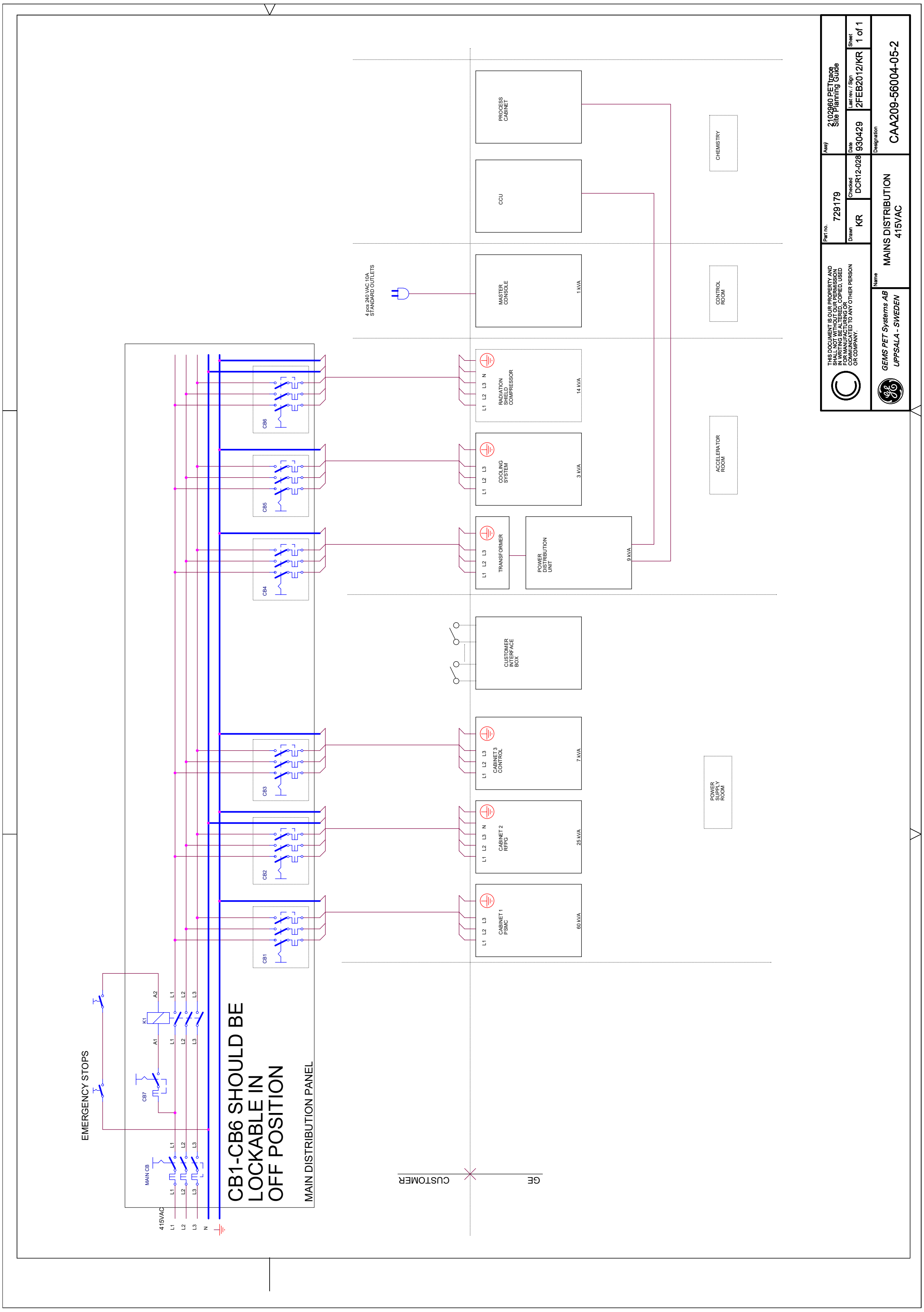
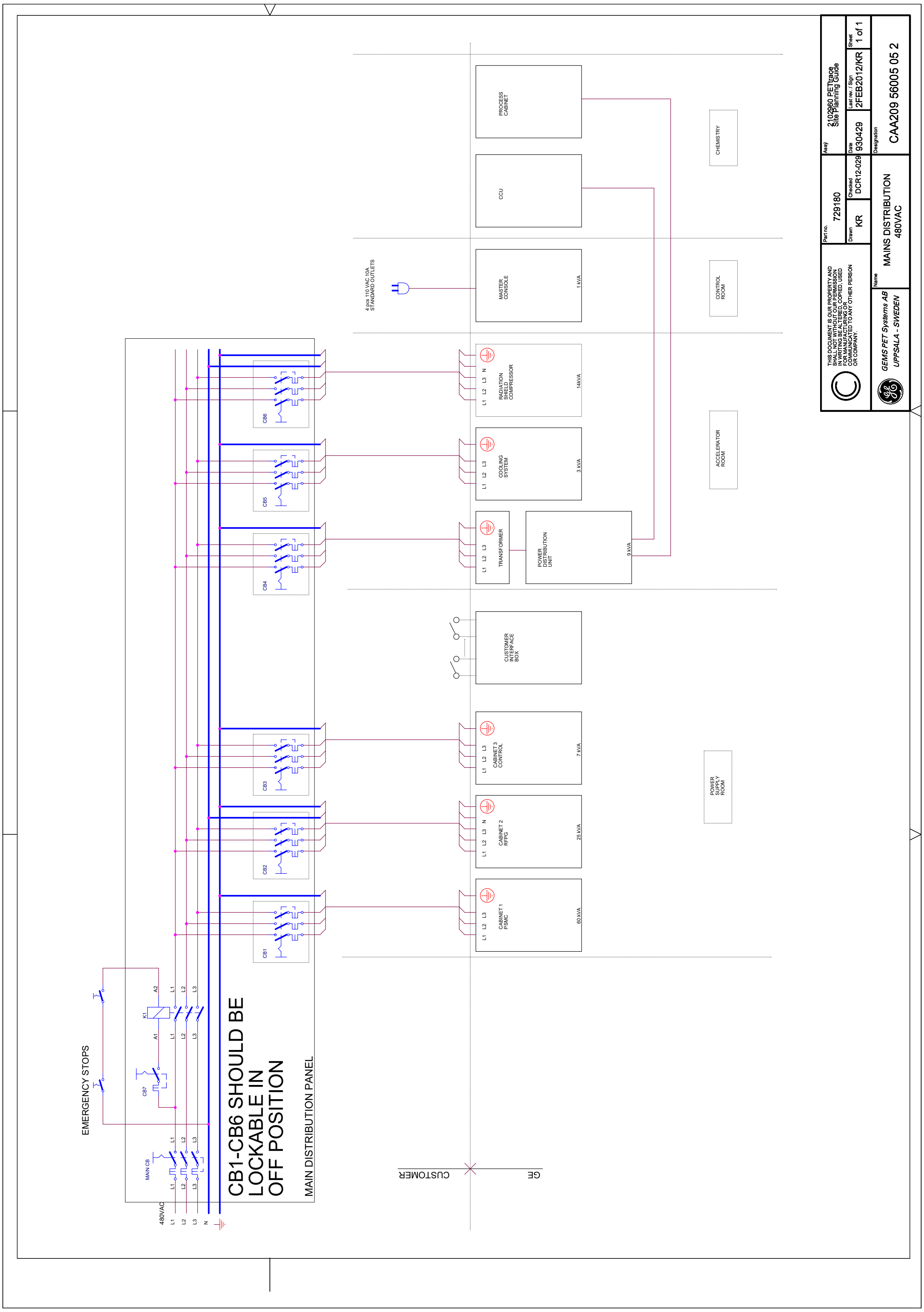


Figure 6-6: Mains Distribution 480 VAC, CAA209 – 56005



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 HealthCare uses a Component Designator System for identification of cyclotron components. All subsystem cabinets and components are referred to by their component designators in the 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 7-3 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 when using the water piping interconnect tables in this chapter.

Figure 7-5 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

Designator	Description
Cyclotron system	
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
MCS	Master (Control) System
CCU	Chemistry Control Unit

Designator	Description
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_2O process unit (^{15}O water process system)
NAPS	Ammonia process system (^{13}N-NH_3)
NAEU	Ammonia terminal box (Ammonia Electronic Unit)
PDUT	PDU transformer
PCAB	Process Cabinet (^{11}C and ^{15}O process panels)
Gas piping connections only	
CPP	Carbon-11 product panel
OPP	Oxygen-15 product panel
LPP	Liquid product panel
WGU	Waste gas unit
WGP	Waste gas panel
GE HealthCare service equipment	
PSS	PETtrace 800 Service System (service laptop)
Cyclotron system options	
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

7-2-1 Power and signal 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.

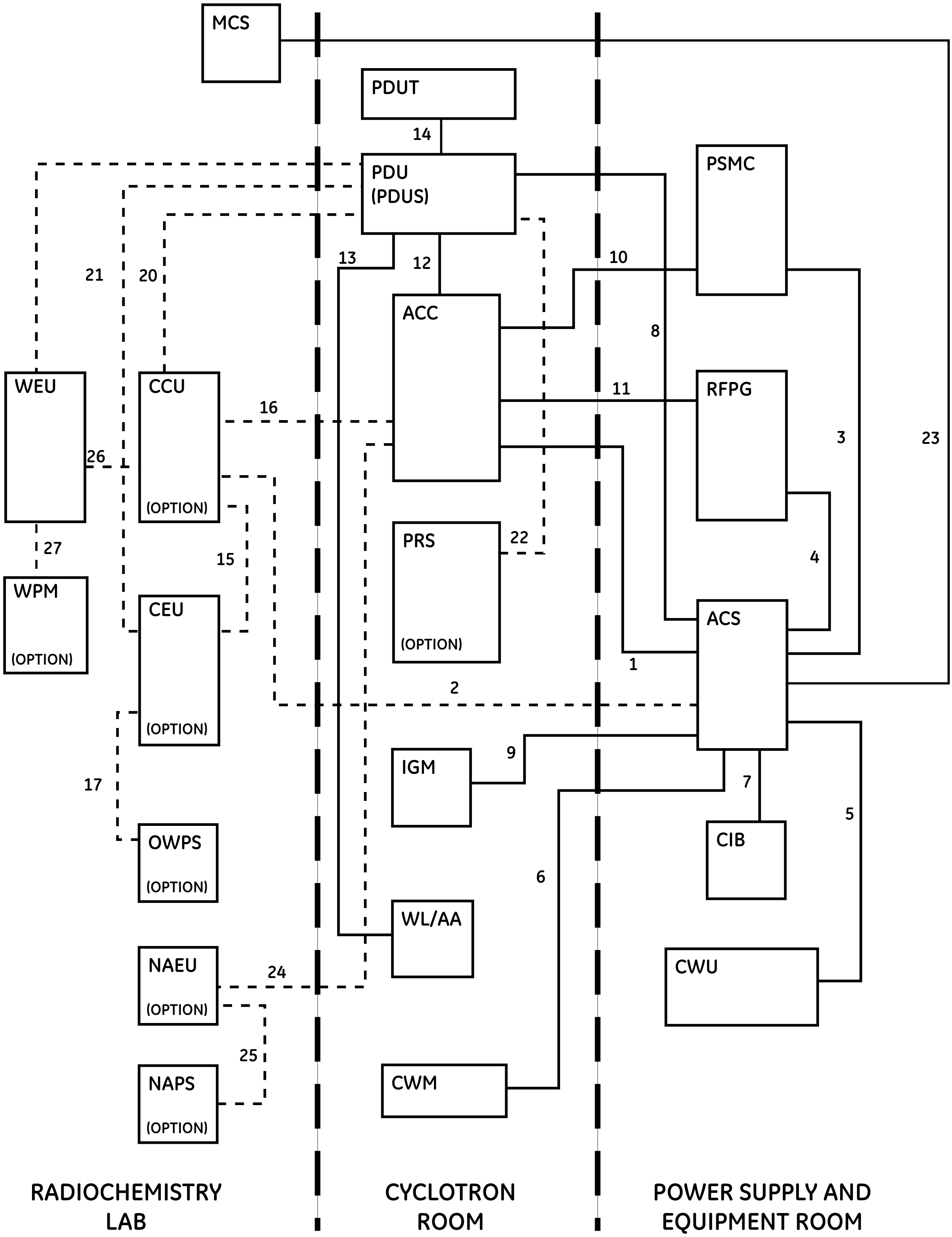
Figure 7-1 shows the Group cable interconnect diagram for a standard cyclotron system. Each group contains one or more cables.

Figure 7-2 shows an Ethernet communication network overview.

For information on mains power connections and emergency off circuit wiring, see Chapter 6 Power requirements.

During the site construction process, the customer 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 HealthCare service representatives will route the GE HealthCare 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)*.

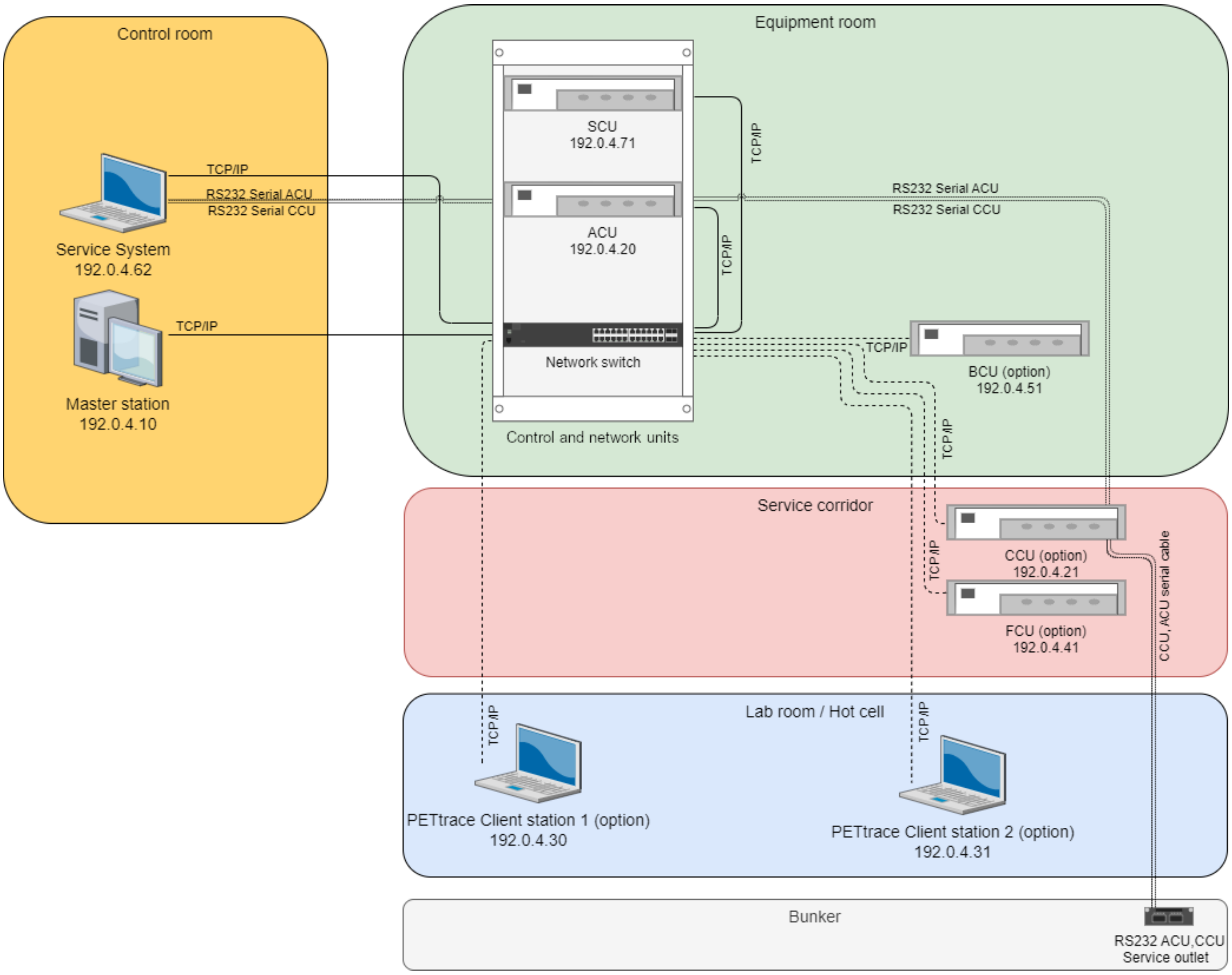
7-2-2 Ethernet communication network overview

Figure 7-2 is an overview of the Ethernet communication network. It shows how the control systems are linked together via the network switch.

The control systems for the options Standard chemistry systems (^{11}C and ^{15}O process panels, H_2O process unit, ammonia process unit, (CCS)), $^{18}F_2$ Proton target (FCS) and Beam Line (BCS) are also shown.

For an overview including PETtrace Solid target platform, see Section A-7-3 Ethernet communication network overview on page 174.

Figure 7-2: Ethernet communication network overview



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.

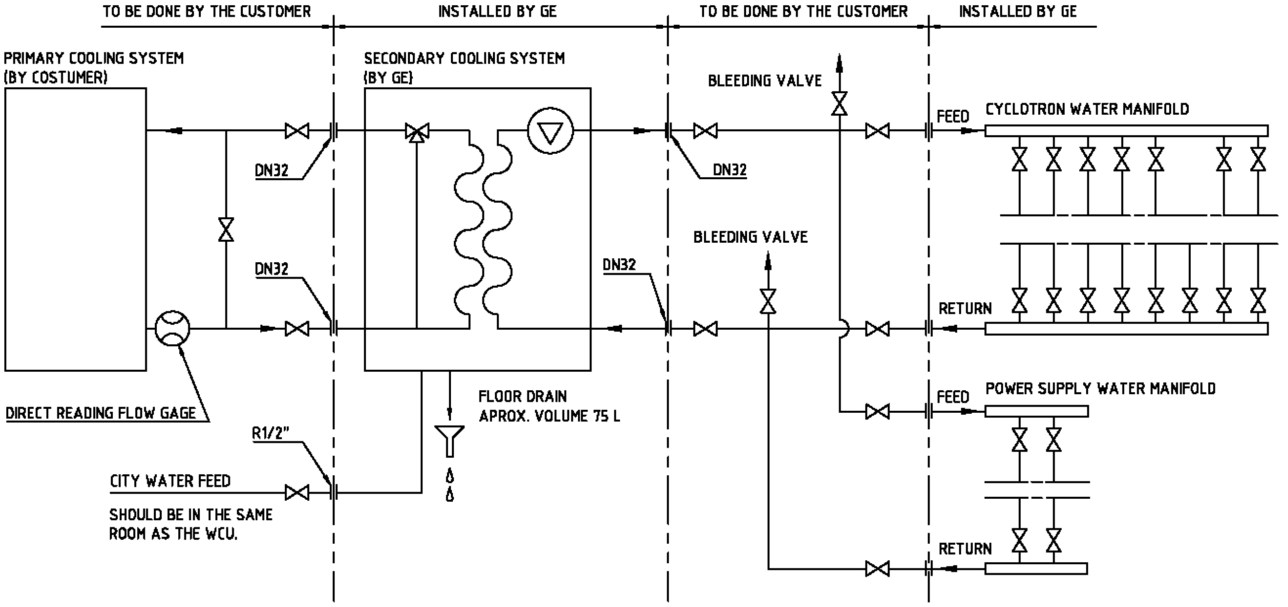
A sketch of the water cooling system is shown in Figure 7-3.

The complete water cooling system includes secondary cooling unit and water manifolds (parts of the GE HealthCare delivery). The customer is responsible for the piping between these units and for water hoses to accelerator sub systems. The customer is also responsible for the supply of primary water at a correct temperature and flow to the secondary cooling unit.

Some requirements and recommendations (see also Section 5-6-3 Secondary cooling unit on page 98):

- Piping dimensions should be adopted to the DN32 connections used.
- Use appropriate materials:
  - Stainless steel is preferred.
  - Copper can also be used, but is the second choice.
  - Plastic tubes can and have been used, but in GE HealthCare's experience, associated plastic fittings are less reliable long term.
  - Iron/carbon steel piping/tubing **should never** be used.
- Flow: > 120 l/min (see Section 5-6-3 Secondary cooling unit on page 98 for details)
- Temperature: 10–15°C (50–59°F)
- Pressure drop over pipe connections to the water system at normal operation (120 l/min): < 1.3 bar (see Section 5-6-3 Secondary cooling unit on page 98 for details).

Figure 7-3: Cyclotron water cooling system schematics



7-3-1 Secondary cooling unit

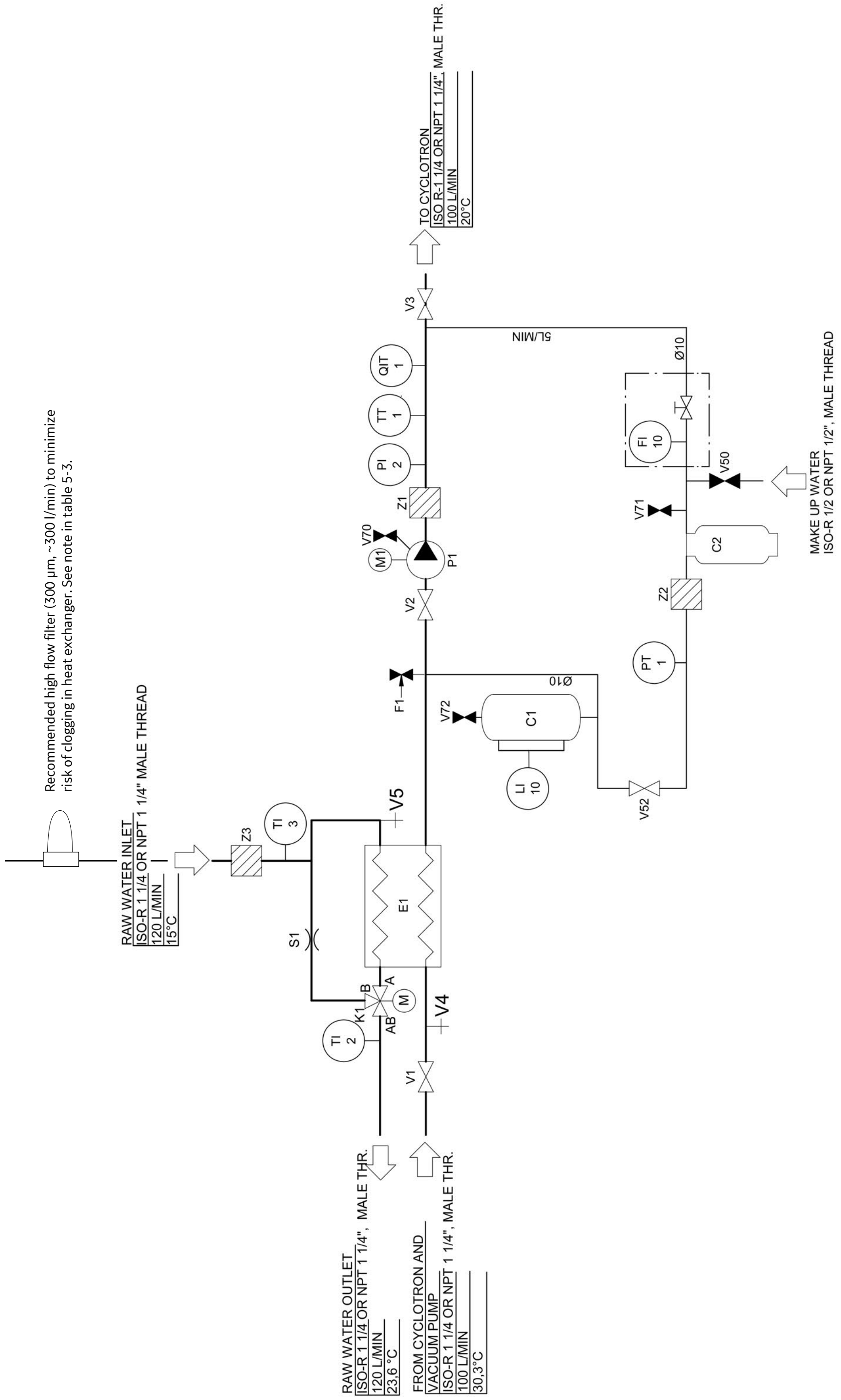
The secondary cooling unit may be placed in a separate room, or in the power supply room. If absolutely necessary, you may place the secondary cooling unit inside the cyclotron vault. Keep in mind, however, that the higher radiation levels in the vault will complicate service work and also potentially cause damage to the electronics inside the secondary cooling unit. This, in turn, can limit the life time of the unit and have impact on the service contract.

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 7-4.

Physical dimensions of the secondary cooling unit are available in Section 2-2-4 Cooling system room on page 35.

Figure 7-4: 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 7-3.

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 m.

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 43.

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 as well as 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 customer’s gas regulators and the cyclotron

2 Between the cyclotron and the chemistry process units

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 HealthCare.

The piping system uses Swagelok™ connections of standard dimensions.

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

To not delay the start-up of the system it is important that all necessary gases are available at the time for cyclotron installation start.

Figure 7-5 shows all interconnections included in the GE HealthCare delivery. Apart from the tubes between the gas cylinders and the customer's gas regulators, all pipes for gas and liquids and all connectors indicated on the illustration are parts of the GE HealthCare delivery.

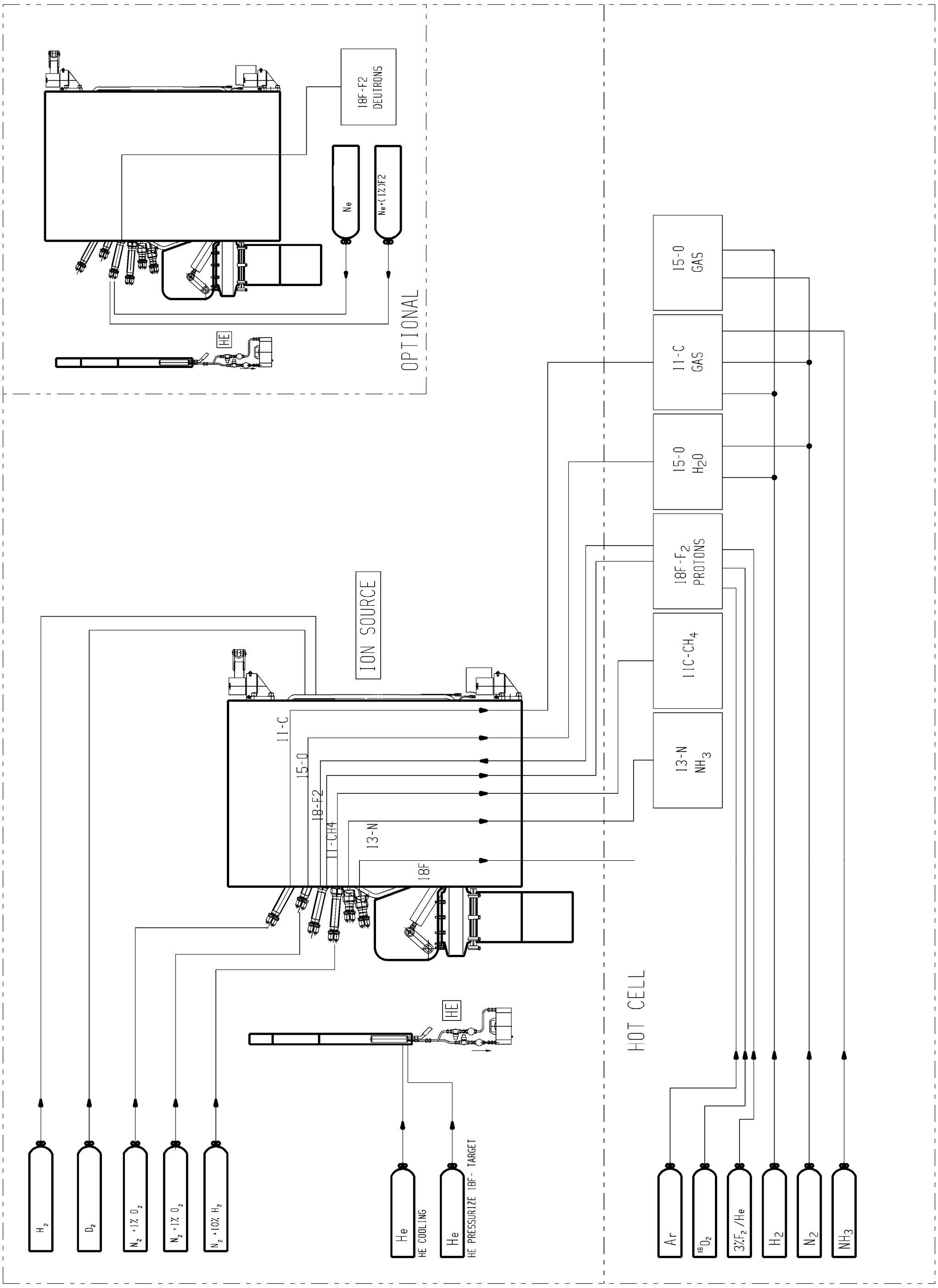
Note!
The customer should provide the tubes between the gas cylinders and the customer's regulators. See *Section 1-4-9 Gas and liquid distribution on page 22.*

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 43.

Figure 7-5: 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 push button emergency switches marked SYSTEM EMERGENCY OFF, equipped with guards to prevent inadvertent actuation. Emergency switches should be located near each exit in the cyclotron room and the power supply room. See Chapter 6 Power requirements. (Refer to local regulations for details on the implementation of emergency switches.)
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 Chapter 6 Power requirements.
Power for Master System	Provide and install power outlets for Master System and printer (if any). ***Note!*** *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. Customer radiation safety interlocks should be installed in two parallel, independent interlock chains. Each interlock thus comprises two independent switches/breakers. The two customer interlock chains are connected to the cyclotron safety system in the CIB.

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 Section 5-14-4 Customer supplied gas regulators on page 111.
Gas tubes	Provide gas tubes between the gas bottles and the regulators. See Section 5-14-5 Customer supplied gas tubes on page 111.
Compressed air supply	Clean, dry air, 0.6MPa, 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).

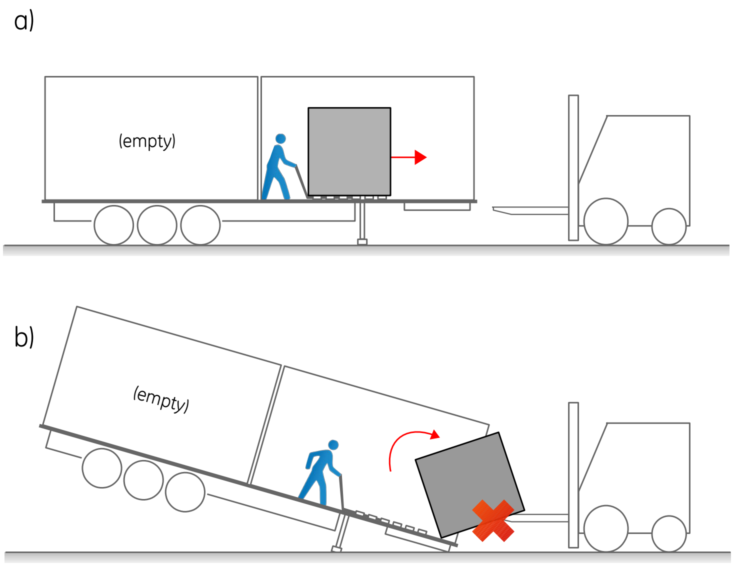
The unshielded system requires a storage area of 25 square meters. If the shipment includes the integrated radiation shield, double the storage area to 50 square meters.

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 cyclotron should be unloaded by using a heavy mobile crane. When unloading, lift the magnet clear of the trailer bed and then remove the trailer. If vertical space is limited, remember to take the height of the container and the length of the lifting straps/chains into account when computing the total required lifting height. The accelerator magnet ships in the upright position, and arrives with four swiveling lifting eye bolts attached to the yoke. Use the crane, a forklift truck or skid loader to unload the remaining crates.

If the magnet needs to be repositioned to allow for unloading, make sure the truck bed is horizontal and well supported, and that the load is well balanced. Never place the magnet or other heavy objects foremost on the trailer bed (see Figure 8-1).

Figure 8-1: Incorrect placement of heavy object on trailer



If the trailer is incorrectly loaded, return the truck and trailer to the loading site and reposition the unit.

WARNING! Heavy object

The weight of the PETtrace magnet is more than 20 metric tons (44,000 lbs), distributed over a relatively small surface.

Never move the magnet on the truck bed or inside the container, or unhook the tractor from the trailer, without first ensuring sufficient support. An unbalanced or unsupported magnet might otherwise cause the trailer/container to tilt.

The lifting straps used for unloading the heavy parts must fulfill the requirements on the labels attached on top of the parts. The attachment of the swiveling lifting eye bolts should be checked before unloading. For more information, see Section 8-2-1 Lifting straps and eye bolts on page 146).

Figure 8-2: Cyclotron 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 is top-heavy.

The safety support legs **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.

8-2-1 Lifting straps and eye bolts

WARNING! Crush hazard

Use lifting straps that fulfill the specifications on the labels on the heavy parts.

Fasten the swiveling lifting eye bolts according to the instructions.

Do not lift a heavy part from a horizontal position. The lifting eye bolts must point straight up.

WARNING! Crush hazard

The lifting eye bolts that are used during rigging of the cyclotron system shall not be used after the installation. The rigging team is recommended to remove all lifting eye bolts from the site after the rigging.

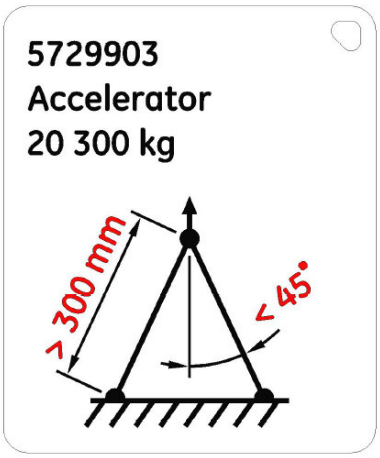
The length and capacity of the lifting straps must meet the specified requirements to ensure safe lifting operations of the heavy parts.

Some of the heavy parts have swiveling lifting eye bolts which must be fastened correctly.

Heavy part labels

Each heavy part has a label with lifting specifications located near the position of the lifting eye bolt (see example in Figure 8-3). The label shows the weight of the part and, if the part has more than one eye bolt, the minimum length of the lifting strap from the eye bolt to the hook, and the maximum angle.

Figure 8-3: Heavy part label (example)



The table below shows the lifting specifications for the heavy parts in the system.

Table 8-1: Lifting strap specifications

Part (number of bolts)	Weight [kg]	Minimum strap length from bolt to hook [mm]
Accelerator (4)	20300	300
RFPG cabinet (4)	750	960
PSMC cabinet (4)	700	660
Cabinet 3 (CAB 3) (4)	240	590
Target panel shield (1)	700	N/A
ProCab[1] (4)	3570	760
Waste gas storage[1] (2)	1500	410
Shielding tank 1–8[1] (8 tanks) (3)	285–580	720–1540
Lead shield 1–5[1] (5 pcs.) (1)	925–1760	N/A
Beamline cabinet[1] (4)	400	590
Quadrupole[1] (2)	400	290

1 Optional

Considerations when selecting lifting straps for a heavy part:

- Weight capacity according to common practice that fulfills the specifications on the labels.
- Minimum length from the lifting eye bolts to the hook that fulfills the specifications on the labels to make sure that the angle is not exceeded.

Swiveling lifting eye bolt

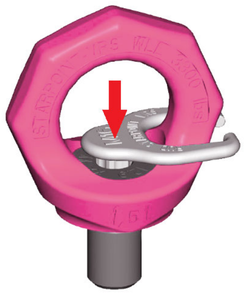
All heavy parts are equipped with swiveling lifting eye bolts (see Figure 8-4). This type of eye bolt swivels to the direction of the load lift, and the working load limit is therefore always at the direction of the load. It removes the risk of bent eyes or over-tightening which would cause unnecessary stress on the stem.

Figure 8-4: Swiveling lifting eye bolts

Accelerator lifting eye bolts

To fasten a swiveling lifting eye bolt:

1 Insert the star key fully into the bolt head.



2 Tighten the bolt firmly by hand.

3 Pull out the star key.

8-3 Minimum access requirements

8-3-1 Crated system dimensions

Most of the 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 8-2 lists the crate dimensions of the unshielded cyclotron system.

Table 8-2: 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	500	1110
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

Contents	Dimensions (cm) W × D × H	Dimensions (in) W × D × H	Weight (kg)	Weight (lbs)
Rad. shield target VG-TTB/30-GE	70 × 40 × 70	27.6 × 16 × 27.6	250	550
Installation box (Gang box)	160 × 85 × 90	63 × 33.5 × 35.5	400	880
Process panel ^{15}O, ^{11}C 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 8-3 lists the crate dimensions for the radiation shield.

Table 8-3: 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 x45	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

Contents	Dimension (cm) W × D × H	Dimension (in) W × D × H	Weight (kg)	Weight (lbs)
Borax pentahydrate (4 pallets)	122 × 80 × 135	48 × 32 × 53.2	1000	2200
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 8-5: Shield delivery

8-3-2 Uncrated system access requirements

Table 8-4 lists the minimum clearance requirements for doors and hallways. Table 8-5 specifies the minimum ceiling opening needed to deliver the accelerator and radiation shields by crane.

Table 8-4: 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 8-5: Minimum ceiling openings

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

Table 8-6 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 8-6: 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

Note!
All work must be performed in compliance with applicable federal, state and local safety regulations.

Site readiness for each phase of the installation process must be confirmed by an on-site inspection conducted by GE HealthCare personnel. The GE HealthCare 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 rev G

Site information	Local GE HealthCare project manager contact information
Site name:	**Name:**
City:	**Cell phone:**
Address:	**E-mail:**
Order/invoice information	**Site representative contact information (FE, distributor)**
GON:	**Name:**
Invoice account/PO:	**Cell phone:**
Finance contact:	**E-mail:**
Travel information	**TC manager contact information**
Closest airport:	**Name:**
Recommended hotels (GE HealthCare–rate):	**Cell phone:**
Transport to the customer site: Taxi / Public transportation / Rental car	**E-mail:**
General comments	**EHS representative contact information**
	Name:
	Cell phone:
	E-mail:

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

Epoxy flooring (self-shielded cyclotrons only) (E)	#	Verified by/date	Comments
Flooring ready for epoxy-coating 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.	1. 2. 3.

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

PHASE ONE: Shipment and delivery (D)	#	Verified by/date	Comments
D4: Designated space for staging and sorting equipment during the delivery and mechanical installation process	**D4**		
1. A self-shielded cyclotron requires 100+ m^2 (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.		1.	1.
2. The equipment *delivery route* is defined and approved by the owner's engineers. The route must meet all clearance and weight bearing requirements. See the *Minimum access requirements* section in this manual.		2.	2.
3. During the mechanical installation phase, the self-shielded cyclotron requires a *designated space for storing* and mixing of borated water solution. The mixing tank requires *adequate clearances* to be delivered/removed from site and the mixing process requires *adequate power* and a *high-volume, heated water source*. *Ramps* are required for passage over the filling hose. *Trays* are required to collect any spill from hose connections when filling the tanks from a tanker truck.		3.	3.
4. Designated space for storing waste (app. 15–20 m^2 (square meters)) available. Instructions for waste sorting and packing according to state and/or local laws and regulations available. See the *Cleaning and waste* section in this manual.		4.	4.
D5: Delivery EHS aspects	**D5**		
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 *PETtrace 800 series Installation Manual (dir. 2131771-100)*.)		1.	1.
2. Personnel involved in equipment delivery and rigging have received work instructions and information about safety procedures in accordance with *PETtrace 800 series Installation Manual (dir. 2131771-100)*.		2.	2.
D6: Copy of owner's licenses in hand	**D6**		
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. The local GE HealthCare team must have a detailed, thorough understanding of licensing requirements for the specific project.		1.	1.
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.		2.	2.

PHASE TWO: Mechanical installation (M)	#	Verified by/date	Comments
M1: Facility is EHS compliant (provides a safe and clean working environment) 1. Dry *floors*; adequate *lighting* for detailed work; dust free *air*; no exposed electrical wires; controlled temperature and humidity; *limited construction personnel* in all GE HealthCare 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 cyclotron, etc. 2. Self-shielded cyclotrons 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 *PETtrace 800 series Radiation Shield Installation Manual (dir. 2169053-100)*. 3. All concerns must be resolved prior to GE HealthCare personnel arriving at site. 4. In the comments section on this row, provide name and cell phone number for responsible EHS inspector.	**M1**	1. 2. 3. 4.	1. 2. 3. 4. Name: ______________________________ Cell phone: __________________________
M2: Post-delivery construction in the cyclotron magnet-room/vault and the electronics room are 100% completed as per the GE HealthCare drawings and owner supplied construction drawings 1. Except for: Ceiling tiles; mains power connections to electronics cabinets and PDUT; final plumbing connections to WCU (SwedeWater) and GE HealthCare water manifolds. 2. Equipment *delivery routes* and access points are closed up and finished. 3. *Water cooling chiller* for the cyclotron is on-line, flushed and pressure tested. 4. *Make-up water outlet* is operational and located next to WCU. 5. HVAC system is fully operational including properly phased and permanent mains power connected to *MDP*.	**M2**	1. 2. 3. 4. 5.	1. 2. 3. 4. 5.
M3: Required gas cylinders and compressed air system + regulators are installed as per regulatory requirements for explosive and hazardous gases 1. Owner supplied *compressed air system* (stand-alone) is installed and operational for clean/dry/oil free air (6–8 bar). 2. *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 *Utility requirements* section in this manual).	**M3**	1. 2.	1. 2.

PHASE TWO: Mechanical installation (M)	#	Verified by/date	Comments
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.	**M4**	1. 2. 3.	1. 2. 3.
M5: Items S1 to be completed prior to/during the mechanical phase of the project 1. Owner's plumber, network engineer, and electrician must finalize all connections and checks of the electrical, plumbing, network, and compressed air installations within the first 5 days that the GE HealthCare mechanical team is on site. GE HealthCare will provide recommendations and guidance regarding connection points.	**M5**	1.	1.

PHASE THREE: Start-up and calibration (S)	#	Verified by/date	Comments
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 HealthCare manifolds) is finished, pressure tested (12 bar) and <u>all leaks repaired</u>. 3. *Compressed air supply* is connected to GE HealthCare supplied compressed air manifold. 4. Permanent mains power is connected to *PDUT* and all *GE HealthCare 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.)	**S1**	1. 2. 3. 4. 5.	1. 2. Test pressure [bar]: ______________ Test time [h]: __________________ 3. 4. 5. Attach completed test instructions to this checklist.
S2: Confirm all licensing requirements for owner and GE HealthCare 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.	**S2**	1. 2. 3. 4. 5.	1. 2. 3. 4. 5.

PHASE THREE: Start-up and calibration (S)	#	Verified by/date	Comments
S3: Calibrated dose calibrator installed in a suitable hot cell or shielded environment 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
S4: Basic lab equipment and supplies available 1. *Balance* to weigh target deliveries is available. 2. O^{16} *target water* and *ethanol* are available.	**S4**	 1. 2.	 1. 2.
S5: Master control station 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.) **Note:** Recommended printers are: Hewlett Packard™ (Laserjet™ or similar model).	**S5**	 1. 2.	 1. 2. Printer model: ____________________
S6: Radiation safety officer assigned and survey meter available 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: ☐ yes ☐ 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

- Crane with sufficient lifting capacity and reach to unload the magnet from the delivery truck and place it at the final staging point.
- Steel floor plates to cover floors while transporting the magnet, 36 × 12 × 0.25 in.
- Wood blocks, assorted sizes.
- Cordless screwdriver equipped with T20 torx bits for disassembly of packaging materials.

- Jacks and accessories for lifting the magnet, 20 metric ton (45 000 lbs) capacity.
- Equipment to unload and move crates, (for example, fork lift and hand trucks).
- Mobile mini lift to move, for example, the bench radiation shield to its final position.
- Lifting straps with sufficient length and capacity (see Section 8-2-1 Lifting straps and eye bolts on page 146).
- Panel lifters for computer flooring.
- Ramps for passage over the hose when filling the radiation shield tanks.
- 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. As chemical analyses are included in the acceptance test for the site, the laboratory must have all analytical equipment installed in a hot cell and calibrated before the completion of the cyclotron system. The facility should also hire or assign qualified personnel to run the chemistry laboratory. The lab personnel should be present during the analysis portion of the acceptance test.

All chemicals for the 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 required for 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
- 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 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
Thermal conductivity detector
Flame ionization 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
High pressure injection valve

Item
Amino-derivatized 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 Site planning – PETtrace Solid target platform

This chapter describes requirements and conditions to consider when planning the installation of the PETtrace Solid target platform.

For a connections overview of the PETtrace Solid target platform, see Section A-13 PETtrace Solid target platform connections overview on page 178.

Note!
All lengths in this chapter are actual, not bird's eye view.

A-1 Cyclotron

Table A-1: Cyclotron requirements

Parameter	Requirement/description
Available cyclotron configurations	• Vault • Self-shield • Vault with poly-shield ***Note!*** *Cyclotrons with self-shield, or other sub-configurations, might have limitations regarding, for example, the number of solid target stations that can be installed and on which ports. Contact GE HealthCare for consultance.*
Master System software	PC Lynx release 3.4.1 or later

A-2 Solid target station

Table A-2: Solid target station requirements

Parameter	Requirement/description
Target material cooling	Deionized water[1]
Full energy front flange cooling	Deionized water[1]
Degrader cooling	Deionized water[1] High speed recirculating helium[2]
Ports on the cyclotron possible for one solid target station[3]	
Not self-shielded cyclotron	1–6
Self-shielded cyclotron, current version	2–6 (Use of port 1 requires modification of the self-shield.)

Parameter	Requirement/description
Self-shielded cyclotron, older versions in installed base	2 and 3, or 2–6, depending on implemented field modifications. Contact GE HealthCare for consultance.
Beam Line	3–6 (Solid target station cannot be installed at the Beam Line outlet.)
Availablility of free LTF and gas panel locations on the target panel	
Not self-shielded cyclotron	It is recommended to use the supplied side bracket for installing the cooling valve panel on the target panel. Therefore, free locations are not necessary.
Self-shielded cyclotron	One free LTF position needed as minimum. (Restrictions can exist for additional solid target stations. Contact GE HealthCare for consultance.)
Customer Interface Box (CIB)	Terminals 9 and 10 must be used for the CIB connection. If terminals 9 and 10 already are occupied, refer to the assessment for recommended actions. Terminals 7 and 8 are recommended to be used as they signal which type of target (metal or halogen) being used.

1 The water cooling manifold at the target panel will be used.

2 The helium cooling manifold at the target panel will be used.

3 Further limitations can exist for two solid target stations. Contact GE HealthCare for consultance.

Note!
Certain combinations of the solid target station and other targets might have restrictions. Contact GE HealthCare for consultance.

A-3 Capsule Handling Station

Table A-3: Capsule Handling Station (CHS) requirements

Parameter	Requirement/description
Rated voltage	230–120 V AC
Rated current	3–5 A
Phases	Single
Frequency	50–60 Hz
Compressed air (operation)	0.6 MPa (87 psi), 200 NL/min, ISO 8753-1 class 1.4.1 Feed connection: o.d. 8 mm
Compressed air (exhaust to main ventilation)	0.6 MPa (87 psi), 200 NL/min Feed connections: 4 × o.d. 10 mm
Interlock	For connection to hot cell door interlock

Parameter	Requirement/description
Elevation legs	The CHS can be equipped with elevation legs to, for example, allow for a transfer tube hole elsewhere in the hot cell. ***Note!*** *The elevation legs must be ordered separately.* The package includes legs with two lengths: 10 cm (4 pcs.) and 20 cm (4 pcs.). They can be combined to maximum 30 cm. Only the legs in this package may be used.
Dimensions	490 × 370 × 650 mm (W × D × H, including tubes and protruding parts)
Weight	34 kg

A-4 FASTlab

The PETtrace Solid target platform is designed specifically for use with FASTlab 2 Synthesizer for chemical processing to create a radionuclide for labelling.

For more information, refer to *FASTlab 2 Synthesizer Pre-installation and Installation Manual* (DOC1615836).

Table A-4: FASTlab requirements

Parameter	Requirement/description
FASTlab model	FASTlab 2 Synthesizer. Functional and installed in an appropriately ventilated hot cell. ***Note!*** *FASTlab 2 Synthesizer must be dedicated to radiometal activities – it cannot be used for, for example, ^{18}F activities.*
FASTlab application software	Version 3.3.0.14 or later (release 3.4.3.1 or later recommended). ***Note!*** *Windows™ 10 laptop is required if needed to update the software and currently is running Windows XP or Windows 7 (consult GE HealthCare).*
Tube length between FASTlab and CHS	Maximum 5 m

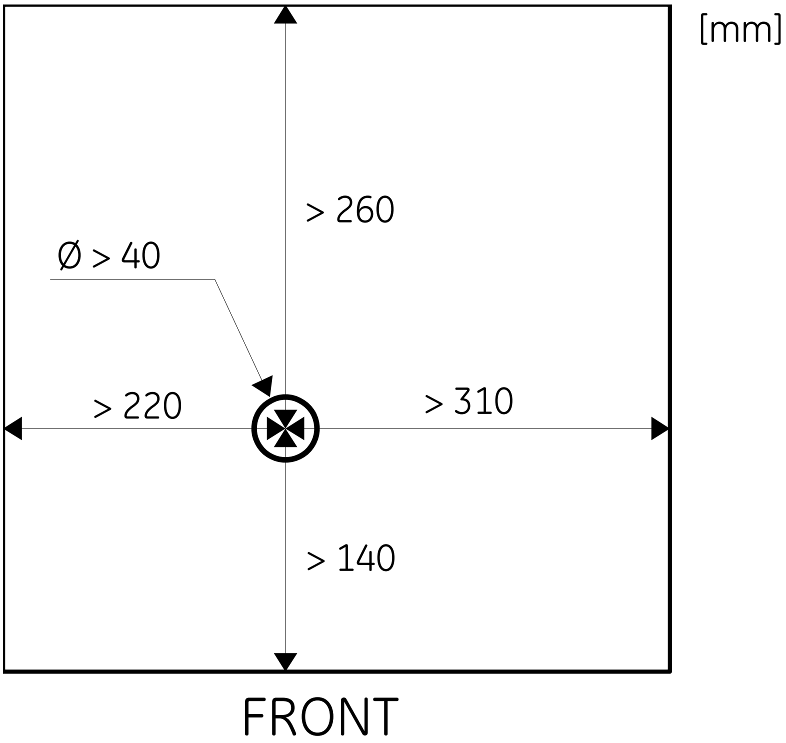
A-5 Hot cells

Note!
Please, contact GE HealthCare to make sure that the intended hot cell configuration and dimensions meet the requirements. Refer also to the product data sheet for PETtrace Solid target platform.

Table A-5: Hot cell requirements

Parameter	Requirement/description	
Recommended hot cell configuration	Double chambers stacked, with: • CHS in lower chamber • FASTlab 2 Synthesizer in upper chamber with solid target valve box on top	
Tube length between the CHS and FASTlab platform, regardless of hot cell configuration	Maximum 5 m	
	Chamber for FASTlab 2 Synthesizer with solid target valve box on top	**Chamber for CHS**
Space in chamber	Minimum 600 × 600 × 650 mm (W × D × H)	Minimum 600 × 600 × 650 mm (W × D × H)
Lead shielding thickness	Minimum 100 mm	Minimum 100 mm
Anti-corrosion coating	Yes	Yes
Lead window	Optional	Yes
Mains power outlets	100–120/220–240 V AC, ± 10%, 1-phase, 50–60 Hz (1 pc.)	100–120/220–240 V AC, ± 10%, 1-phase, 50–60 Hz (1 pc.)
Network cable feed-through	RJ45 (1 pc.)	RJ45 (1 pc.)
Extra hole for capsule transfer tube	No	Yes ***Note!*** *The hole needs to be in the correct position relative to the inner walls (see Figure A-1).*
Door interlock which can be connected to the CHS	Not applicable	Recommended

Figure A-1: Minimum distances from CHS chamber inner walls to center of transfer tube hole



A-6 Transfer tube

Table A-6: Transfer tube requirements

Parameter	Requirement/description
Length from solid target station to CHS	Maximum 50 m
Bending radius	Minimum 250 mm
Elevation between solid target station and CHS	Maximum 5 m
Tube width	35 mm
Material	Corrugated plastic (polyamide)

A-7 Cabling

A-7-1 Signal and communication cables

Table A-7 shows the maximum path lengths for the long-distance cables included in the shipment.

Table A-7: Cabling path requirements

Parameter		Requirement/description
Signal cables		
From...	**To...**	
Target panel	Customer Interface Box (CIB)	Maximum 40 m
Target panel	Solid Target Control Unit (STCU) in CAB 3	Maximum 40 m[1]
Target station	Solid Target Control Unit (STCU) in CAB 3	Maximum 40 m[1]
Network cables		
From...	**To...**	
Router in CAB 3	Solid target network switch (near hot cell)	Maximum 60 m
Router in CAB 3	Internet connection	Maximum 40 m

1 The cables have large D-Sub 25 connectors pre-attached. Available conduit is required.

Note!
The cabling configuration can be subject to change.

The network cables in Table A-7 can be procured and installed by the customer in advance.

Cable specification: Patch cable, RJ45, Cat 6_A/Class E_A, S/FTP, UL 2556 (FT1), and ROHS/REACH (in EU).

The network cables in Table A-7 must be connected point-to-point (intermediate connections are not allowed).

Regarding the other network cables in the PETtrace Solid target platform, only the cables included in the product shipment must be used.

A-7-2 Mains power cables

Local cables shall be provided as default for installations in Australia, New Zeeland, Brazil, China, UK, Japan, Canada, and Europe (Schuko only). For other regions, contact the local GE HealthCare project management office for further information.

One IEC320 C5 cable and two IEC320 C13 cables are required as described in Table A-8.

For cables not provided with the shipment, the function of any locally supplied mains cables shall be verified at the installation (continuity of each conductor and no short-circuits).

Table A-8: Power cable requirements

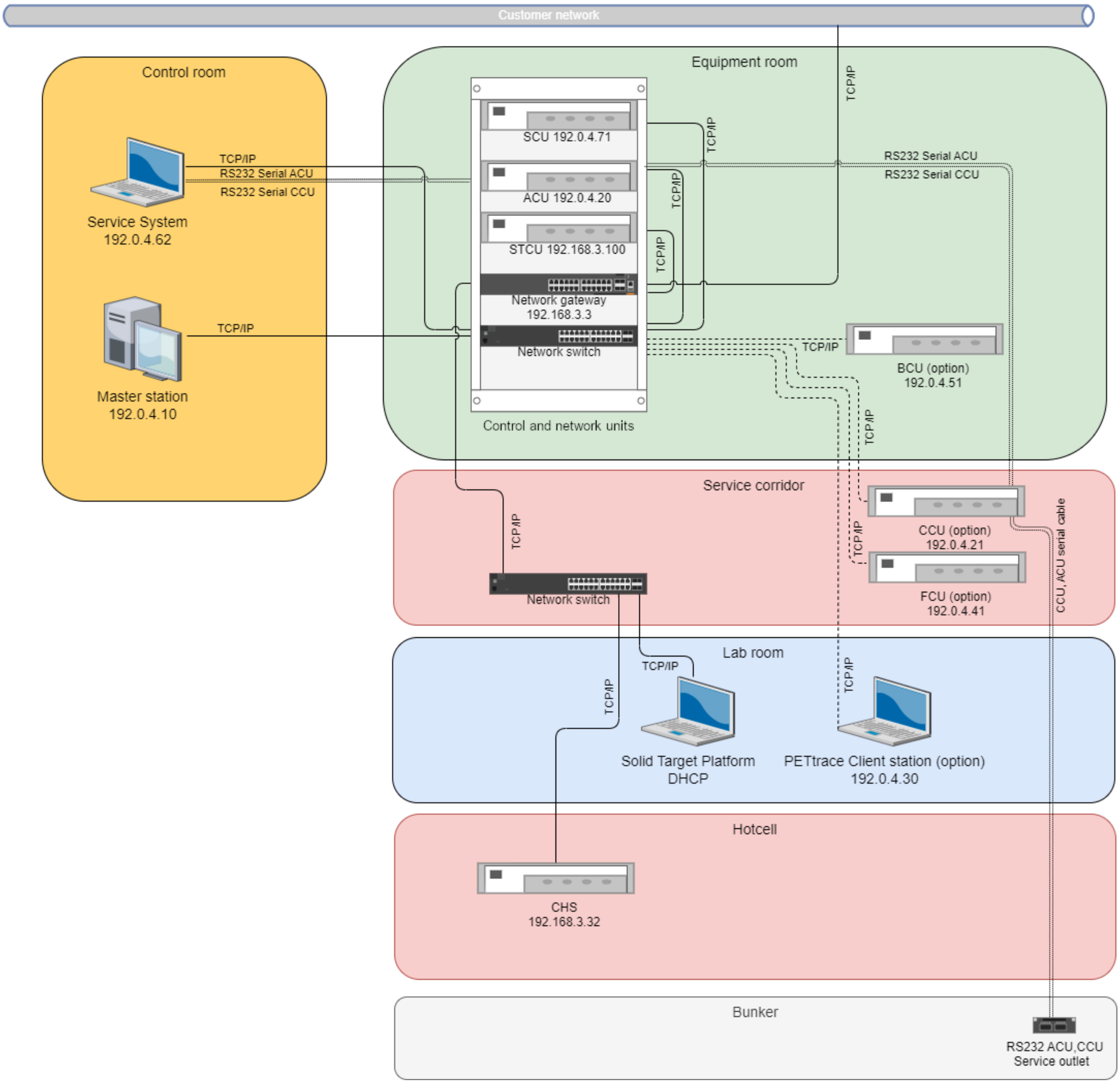
Cable	Requirement/description
Power cable to solid target laptop	Power cable with a local mains plug and an IEC320 C5 connector for the power adapter to the solid target laptop. (The power adapter comes with the solid target laptop.) Minimum 1.8 m, 100–240 VAC, 50–60 Hz, 1.7 A
Power cable to network switch in production lab	Power cable with a local mains plug and an IEC320 C13 connector for the network switch in the production lab. Minimum 1.8 m, 100–240 VAC, 50–60 Hz, 1.0 A
Power cable to CHS in hot cell	Power cable with a local mains plug and an IEC320 C13 connector for the CHS in the hot cell. Minimum 1.8 m, 100–240 VAC, 50–60 Hz, 4/6 A

A-7-3 Ethernet communication network overview

Figure A-2 is an overview of the Ethernet communication network. It shows how the control systems are linked together via network devices.

In addition to the control system for the PETtrace Solid target platform, the control systems for the options standard chemistry systems (^{11}C and ^{15}O process panels, H_2O process unit, ammonia process unit, (CCS)), $^{18}F_2$ Proton target (FCS) and Beam Line (BCS) are also shown.

Figure A-2: Ethernet communication network overview



A-8 Trenches and conduits

Table A-9: Trenches and conduit requirements

Parameter	Requirement/description
Trench/conduit for capsule transfer tube	• Conduit diameter: Minimum 125 mm • Bending radius of tube: Minimum 250 mm Avoid sharp turns, use supplied tube guides. • Radiation shielding of trench/conduit according to federal, state, and/or local regulations. Contact GE HealthCare for consultance. **Self-shielded cyclotron** • Trench in the cyclotron room floor for the capsule transfer tube(s) in addition to the other cyclotron cables, hoses, and tubes. • Consider radiation safety for the trench under the shield (refilling the opening).

A-9 Compressed air

Table A-10: Compressed air requirements

Parameter	Requirement/description
Solid target station and supporting valve panels	0.60–0.70 MPa (87–101 psi) (No special connections are needed. Existing compressed air connections at the target panel will be used.)
CHS (normal operation)	0.6 MPa (87 psi), 200 NL/min, ISO 8753-1 class 1.4.1 Feed connection: o.d. 8 mm
CHS (exhaust to main ventilation)	0.6 MPa (87 psi), 200 NL/min Exhaust connections: 4 × o.d. 10 mm
Lock-Out and Tag-Out (LOTO) of CHS	The customer is reponsible for providing LOTO devices and procedures for the compressed air supply to the CHS

Parameter	Requirement/description
Solid target valve box and FASTlab platform	0.60–0.70 MPa (87–101 psi) ISO 8573-1 class 1.2.1 (recommended) Feed connection: o.d. 4 mm ***Note!*** *The pressure range is tighter than FASTlab platform alone due to the maximum 0.7 MPa rating on the valves in the solid target valve box. A "tee" is provided in the system to connect the two units.*

A-10 Gases

Table A-11: Gas requirements

Parameter	Requirement/description
Cyclotron proton source	H_2 (6.0) (hydrogen)[1] Operating pressure: 0.1 ± 0.05 MPa (15 ± 7 psi)
Helium cooling of target station	He (5.5) (helium)[1] Pressure: 0.38 ± 0.03 MPa (55 ± 5 psi) ***Note!*** *Helium cooling requires a helium compressor being installed on the cyclotron system.*
Cyclotron deuteron source (optional)	D_2 (2.7) (deuterium)[1] Operating pressure: 0.1 ± 0.05 MPa (15 ± 7 psi)
FASTlab platform	Nitrogen (5.0) 0.60–0.80 MPa (87–116 psi)

1 For more information, see Section 5-14-2 Customer supplied media on page 105.

A-11 Facility

Table A-12: Facility requirements

Parameter	Requirement/description
Additional single-phase oulets	Besides inside the hot cell, there should be single-phase electrical utility outlets at least at the following locations: • In the production lab (PETtrace Solid target platform laptop and the FASTlab laptop) • On the rear/service side of the hot cell (network switch)

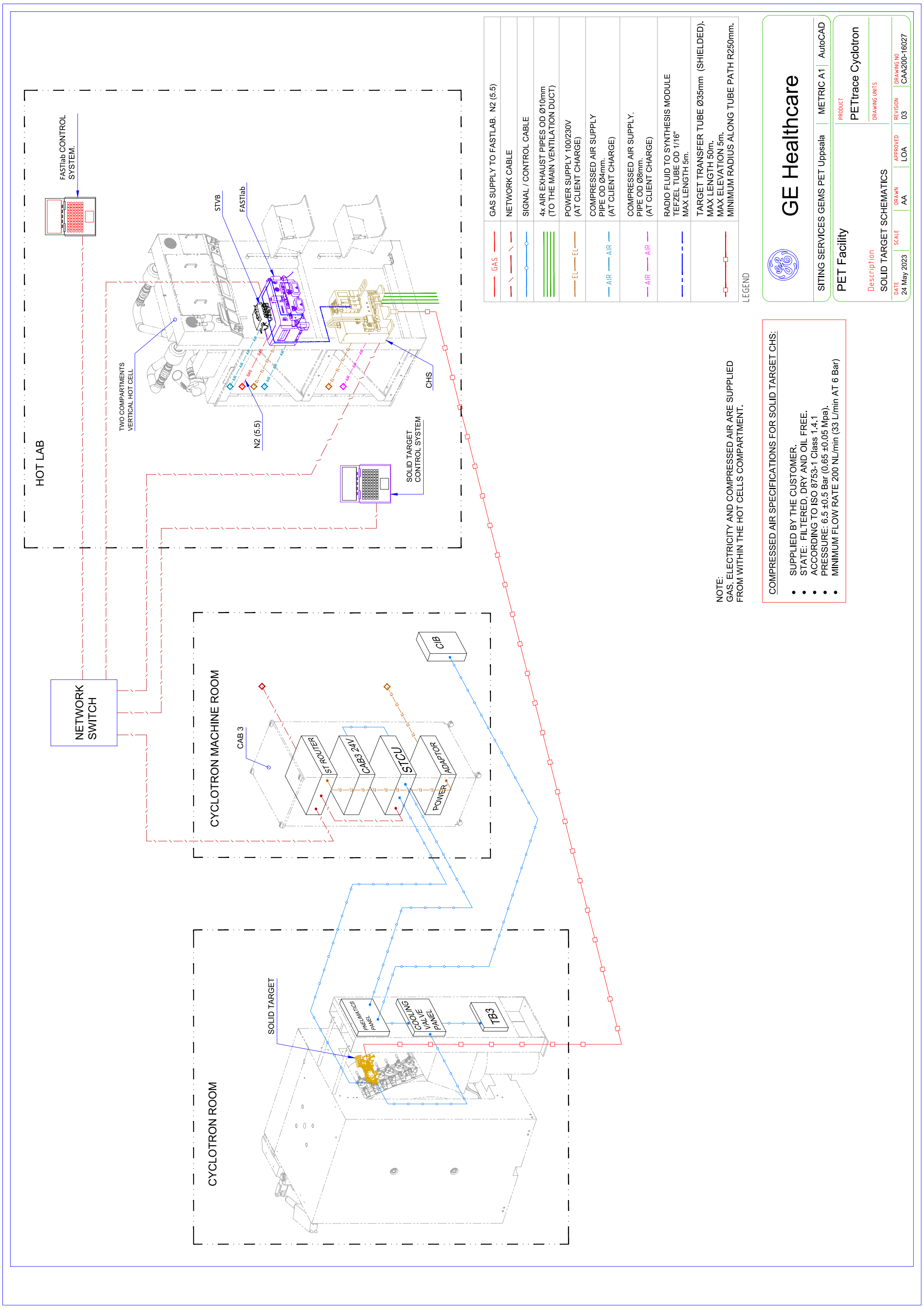
Parameter	Requirement/description
Ventilation (radiation)	Appropriately ventilated and shielded area(s) (for example, hot cell) for both CHS and FASTlab platform
Ventilation (non-radiation)	Appropriate ventilation for chemical preparation (for example, snorkel or fume hood)
Chemical and radiation safety programs and approvals	Established and obtained for the site by the customer

A-12 Installation time

Estimated additional time needed for installing the PETtrace Solid target platform:

- Not self-shielded cyclotron: 4 days for installation and 2.5 days for performance verification
- Self-shielded cyclotron: 5 days for installation and 2.5 days for performance verification

A-13 PETtrace Solid target platform connections overview



Appendix B Glossary

Glossary of Terms, Abbreviations and Acronyms

This appendix 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}C chemistry system
CCS	Chemistry Control System
CCU	Chemistry Control Unit
CEU	Chemistry Electronics Unit

CIB	Customer Interface Box
CIU	Control Interface Unit
CO	Column in ^{15}O chemistry system
CPU	Central Processing Unit
CWM	Cooling Water Manifold
D	
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)
E	
EOB	End of bombardment
EOP	End of process
EOS	End of synthesis
F	
F	Flow regulator
FWD, FWD PWR	Forward power (RF)
G	
GSPU	Grid Screen Power Unit (RFPG)
H	
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 Electronics Unit)
NAPS	Ammonia Process System ($^{13}N-NH_3$)
O	
O	Oven
OC	Oven, ^{11}C chemistry system
OO	Oven, ^{15}O chemistry system
OPP	Oxygen-15 Product Panel
OWPS	H_2O Process Unit (^{15}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 ^{11}C, ^{15}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
R	
RCAV	RF Cavity
REFL, REFL PWR	Reflected power (RF)
RF	Radio Frequency
RFPG	RF Power Generator
RP	Roughing Pump
RSC	Radiation Shield Compressor (with receiver)
RSM	Radiation Shield Compressed Air Manifold
RV	Roughing Valve
S	
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
V	
V	Valve
VC	Valve in ^{11}C chemistry system
VCU	Vacuum Control Unit
VMEbus	Backplane bus for use in microcomputer systems
VO	Valve in ^{15}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)

For local office contact information, visit
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