MINItrace Magni
MINItrace Qilin
Site Planning Guide

2232993-100
Revision 16

Revision history

Revision	Date	Reason for change
16	3 February 2025	Sec. 5-13-2, Table 5-8: Specification and operating pressure for He cooling gas updated. [NC-00059434] Sec. 8-3-1: Warning added for lifting eye bolts. [ECR2389458]
15	7 October 2024	Updated to include MINItrace Magni [HCSDM00785664]: Title of manual updated on front page and header. Product name replaced with “cyclotron (system)” where applicable. Sec. 1-2, 1-2-2-4: TRACERcenter node added. Sec. 2-2-1-1, 2-7, 2-8, 8-3-1-: Weight of CCAB updated. Sec. 2-4: Ethernet connections added. Sec. 2-5-2: Specifications for floor ducts updated. Sec. 2-6: TRACERcenter node and Ethernet connections added. Sec. 2-8: Figure 2-13 updated. Sec. 3-2-1: Beam current range updated. Sec. 3-2-5, 3-2-6: Introduction and measurement of isodose rate curves updated due to higher beam currents and new target. Sec. 5-2: GOST and EAC standards removed, EMC standard updated, disclaimer added. [PCR 23-182] Sec. 5-9: Design principle for ventilation updated. Sec. 7-2-3: Table 7-2 updated with network cables to workstation. Sec. 9-3: TRACERcenter node and Ethernet connections added. App. A (new): Site planning for Solid target platform added.
14	8 April 2024	Sec. 5-13-2: Note added about pressure range for hydrogen and methane regulators. [PCR 24-020]
13	28 September 2023	Branded to GE HealthCare. New layout. Sec. 1-2-2-13, Cleaning and waste: New section. [PCR 15-117] Sec. 2-2-2: Added information on bench radiation shield. [PCR 21-304] Sec. 2-5-1: Removed "GE responsibility". Added reference to sec. 2-7. [PCR 21-069] Sec. 2-8: Added information on bench radiation shield. [PCR 21-304] Sec. 5-6-2, 5-6-3, 5-13-1: Removed ref. to supply panel. [PCR 21-051] Sec. 5-6-3: Added specifications. Changed differential pressure. [PCR 22-018, 18-375] Sec. 5-13: Uppdated according to gas spec. (5473460GSP). [PCR 20-044] Sec. 7-3-2, 7-4: Removed reference to supply panel. New figure 7-2. [PCR 21-051] Sec. 7-3-2: Added note on recommended filter. [PCR 22-018, 18-375] Sec. 7-6: Updated safety interlocks in table 7-4. [PCR 21-357] Sec. 8-3: New section added about lifting straps and eye bolts. [PCR 20-222] Sec 10-2: Removed specific crane capacity, added metric tons and T20 bits. [PCR 19-379] Added information on mobile mini lift. [PCR 21-304]

Revision	Date	Reason for change
12	27 May 2019	Sec. 2-2-1-1: Weight of CCAB updated in Table 2-5. [PCR 17-022] Sec. 2-7: Weight of CCAB updated in Table 2-9. [PCR 17-022] Sec. 5-2: Directives updated. [PCR 16-140] Sec. 5-6-2: Note added. Sec. 5-13-2: Note about gases added. [PCR 15-126] Gas tube specifications updated. [PCR 15-186] Sec. 7-3-2: Fig. 7-2, dimensions in table corrected.
11	7 August 2015	Sec. 5-2: New section added with compliance with regulatory requirements. [PCR 15-095] Sec. 5-3: New section added with facility safety. [PCR 13-158]
10	16 October 2014	Rebranded to MINItrace Qilin. [PCR 14-229] Sec. 7-5: Figure 7-6 and 7-7 updated. [PCR 14-229]
09	12 June 2014	Table 2-10: Service laptop info updated. [PCR 11-028] Fig. 2-11 removed. [PCR 11-028] Table 5-2: Table note updated. [PCR 11-028] Table 7-1: MSS description updated. [PCR 11-028]
08	11 June 2013	Sec. 1-2-2-12, 3-4: Compile LOTO procedures. [PCR 13-141] Sec. 3-4, 6-2: “Should” changed to “must”. [PCR 13-141] Sec. 5-2: New section with altitude requirements. [PCR 13-141]
07	11 March 2013	Sec. 5-10: Gas specification sections and tables restructured and updated. [PCR 12-104] Sec. 5-10-1: Compressed air specification updated to 6–6.5 bar. [PCR 11-145] Table 6-1: Maximum allowed THD added. [PCR 12-121] Fig. 7-4: Compressed air specification updated to 6–6.5 bar. [PCR 11-145] Sec. 7-4-2: Compressed air specification updated to 6–6.5 bar. [PCR 11-145]
06	24 October 2011	New section 1-2-2-11 inserted: Additional equipment and materials. Info on printer added. [PCR 10-062] Table 5-8: Dimension changed from 1/4" to 1/8". [PCR 10-165] Sec. 5-10-2-1: Gas warnings and recommendation of gas detection equipment added. [PCR 09-186] Table 6-1 and section 6-5: Variation of nominal line voltage changed from ±5% to ±10%. [PCR 10-178] Fig. 7-3, 7-5, 7-7 updated. *(Converted to Skribenta.)*
05	7 December 2009	Sec. 1–2, Sec. 2–6: Access to Internet recommended. [PCR 09-226] Sec. 1–2-2-8: Table modified. Sec. 5–6: Ventilation of high-radiation areas. [PCR 09-040] Sec. 5–10–2: Ion source gas specs modified. [PCR 07-139] Gas regulators recommendation modified. Customer supplied gas tubes added. [PCR 07-139] Sec. 6–6: 208 VAC removed as mains voltage option. Info added on transformers. [PCR 05-010, DOC0438404SPN] Ch. 8: Crate table modified. Ch. 11: Info on test chemicals changed. [PCR 09-238]

Revision	Date	Reason for change
04	12 December 2006	Reformatting, conversion to GE Inspira fonts, relinking of all graphics. New cover. Minor editorial changes throughout the document. *Chapter 3:* Changed values in illustration 12 and 13. Values increased by 25% Text added (radiation levels). *Chapter 5.* Table 20, $H_2{}^{15}O$ gas quality changed. Purity changed for some gases.
03	16 May 2005	*Section Gas and Liquid Distribution:* Extended info in Item 1 (re. gas supply tubing). *Section 2–2–1–2 Equipment:* Table 6 rows rearranged (to match Table 31). *Section 2–5–1 Load and Pressure:* Text “GE responsibility” added. *Section 2–7:* Integrated radiation shield weight altered to 39 900 kg. *Section 2–8:* In Illustration 4: Weight 50350 kg changed to 52950 kg. *Section 3–2–1 General:* Typical beam current range changed from 25–40 µA to 25–50 µA. *Section 3–2–4 Area Description:* Paragraphs slightly rearranged. Figure “2 Curies” changed to “3 Curies”. Unit mS/h corrected to µS/h *Section 3–2–5 Radiation levels:* Comprehensive isodose curve information (partly new) summarized in a new table (Table 13). Ill. 12 updated. Ill. 12 and 13 modified to enable ruler measurement. *Section 3–2–6 Waste Gas System:* Thoroughly updated. *Section 5–3–3 Primary Cooling:* Figures (kW) in Table 15, 16 and 17 updated to provide consistency in all of sections 5–3–1 Air Cooling, 5–3–2 Cooling Water, 5–3–3 Primary Cooling and 5–3–5 Heatload to Water. Furthermore, primary cooling flow figure in Table 17 updated. *Section 5–10–2 Gas Supply and Gas Regulators:* Partly updated/rewritten. Former tables 19–20–21–22 replaced by one comprehensive table (Table 20 Gas Overview: Quality-Bottle Size-Pressure-Pressure Range) [SPR 05-123]. *Chapter 6 Power Requirements* thoroughly updated [SPR 03-196]: New LOTO information, total power consumption figure in Table 22 modified from 35 to 40 kW, UPS info added. *Chapter 7 Interconnect Data:* Supply Panel dwg in Table 25 updated. All dwgs on pages 94–99 updated. *Section 7-5 Gas Piping Interconnects* modified with respect to GE/customer responsibility, tubing contamination, etc. *Chapter 8 Shipping And Delivery Data:* Crate Weight data (Right Rear and Right Door) in Table 31 updated.

Revision	Date	Reason for change
02	22 November 2001	Weight information in Table 6, 11 and 32 (pages 25, 33 and 103) updated. Gamma dose contour maps (on page 50–51) replaced. Sections 6–2 Power requirements and 6–3 Recommended Power Distribution System (page 77–80) updated. MINItrace Service System (MSS) Laptop not included in product. Affects pages 35, 43, 59, 87.
01A	20 April 2000	Illustration 12 on page 49 added (Isodose curves for neutrons). Illustration 22–27 on page 94–99 modified due to Supply Panel modifications. Figures added to Table 33 on page 103 (Crate Dimensions).
01	5 April 2000	The main structure of the document is intact, but a number of facts and figures are revised.
00	6 December 1999	Initial document release.

Customer Documentation Portal

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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.
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Table of Contents

1 Purpose and responsibilities

1-1 Introduction

This manual applies to the following cyclotron systems:

- MINItrace Magni
- MINItrace Qilin

If content is applicable only to MINItrace Magni, the system is referred to as MINItrace Magni. If content is applicable only to MINItrace Qilin, the system is referred to as MINItrace Qilin.

The manual contains physical, electrical, network, plumbing, and magnetic data necessary for planning and preparing a site for the cyclotron systems.

Pre-installation work is done to prepare the customers premises for the installation of the cyclotron system products.

This material is not intended to be a substitute for a qualified site planner, or project coordinator. Nevertheless, it provides some of the guidelines that are needed to successfully plan the site.

Note!
For site planning information for the Solid target platform, see Appendix A Site planning – Solid target platform.

1-1-1 Purpose

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

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

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

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

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

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

Note!
Since this equipment involves the use of radionuclides, 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

A great amount of details is involved in the planning and construction of a PET facility. One of the best ways to insure a successful project is to have one person in charge with the responsibility of managing the entire project.

This Project Coordinator should be involved in every phase of development of the project, from concept of the facility to installation and startup of the equipment. Ideally, this person should be thoroughly familiar with the construction process. If possible, the Project Coordinator should have a background in medical facility construction. If such a person is not available on the staff, it is recommended that the services of a local site planner or construction manager be secured. In any case, this person would be the primary contact and liaison between the customer and GE HealthCare.

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 schedule and adjusting that schedule as needed 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. Should any such assistance be required, GE HealthCare personnel are willing, and considerably well qualified, to help and ensure that your installation is a successful one.

1-2 Responsibilities

The customer is responsible for all site preparation, except by other agreement with GE HealthCare. Such preparation may include, but is not limited to, the following work:

- Cost analysis, construction, renovation or alterations and modifications when not specifically provided for in the contract.
- Procurement of all material required to carry out the work.
- Storage of the system equipment prior to installation on site.
- Installation of lighting.
- Installation of adequate air conditioning and ventilation for the PET site.
- Demolition, removal and cleaning of existing structures.

- Fire control devices as may be required by local codes.
- Permits, inspections, licensing, etc.
- Permits and licensing for producing and handling of radionuclides.
- Installation of electrical conduit, junction boxes, ducts, surface raceways, outlets and line safety switches.
- Installation of TRACERcenter node (computer) as integration point between the cyclotron system and the hospital network.
- Installation of wires not supplied by GE HealthCare such as:
  - the facility input power line to the Mains Distribution Panel, the Power Distribution Unit, as well as any emergency power lines.
  - the electrical contractor shall test and tag all wires at both ends. Color-coded wires are recommended for easier identification. Wires shall be continuous without splices. Insulation on all equipment ground wires must be green with a yellow stripe.
- Installation of non-electrical lines such as water plumbing and air conditioning equipment. Also of recommended compressed air and vacuum to radiochemistry lab. All lines must be clearly labeled.
- Installation of structural reinforcements as required.
- Installation of air and cooling water equipment, if necessary.
- All work must comply with all applicable national and local building and safety codes.
- Unless specifically mentioned, GE HealthCare **does not** provide or install:
  - the facility input power lines to the power distribution unit, the power lines required for the Mains Distribution Panel or Internet connection line, nor raised flooring, conduit, junction boxes, ducts, plumbing, water treatment equipment or any radiation protection material.

Note!
Initial planning for future upgrades, if so desired, can minimize renovation expenses. Site planning information is continuously changing due to product evolution.
GE HealthCare will make every reasonable effort to maintain accuracy of site planning information. Final construction documents should be sent to the GE HealthCare site planning group for review.

1-2-1 Installation

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 is to identify the different responsibilities of the customer and GE HealthCare in the project. For additional information regarding the time and resources required for installation refer to Section 1-2-3 Installation flow chart on page 23.

1-2-1-1 Facility planning

Initially, the facility planning will define the details in the building and facility specification and GE HealthCare will supply all necessary information. The building design must be approved by GE HealthCare prior to the start of the installation of the equipment.

1-2-1-2 Rigging

The equipment is typically delivered to the site in three 20 feet containers. A rigging company will be contracted to unload the equipment from the containers and transport the components into the cyclotron facility to their proper locations. The unloading and rigging will be supervised by GE HealthCare personnel.

1-2-1-3 Mechanical installation

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

- mechanical assembly
- electrical wiring
- installation of plumbing
- installation and connection of gas lines
- alignment of critical components and documentation thereof

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

1-2-1-4 Start-up

Subsystem 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.

Generally, the subsystems are started in the following chronological order:

1. Control system
2. Cooling water system
3. Vacuum system
4. Magnet system
5. Extraction system
6. Diagnostic system
7. RF system

8 Ion source system

9 Target system

10 Radiochemistry system

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

Beam tests

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

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

Radionuclide production and radiochemistry: When proper cyclotron performance has been demonstrated, the GE HealthCare system engineer will begin the production of the radionuclides in order to optimize the target system performance. The yields of the different products will be brought to their specified levels.

Performance test

When all subsystems are working, the equipment will be ready for a performance test.

1-2-2 Conditions and responsibilities for site planning, construction, installation and start-up

1-2-2-1 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 radionuclides.	x	

1-2-2-2 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 and outlets.		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

1-2-2-3 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	

1-2-2-4 Electricity

Item no.	Item	Customer	GE HealthCare
1	Specification of Main power Distribution Panel (MDP) loads.		x
2	Provision and installation of Main power Distribution Panel (MDP).	x	
3	Provision, installation and connection of electrical power cables between the Main power Distribution Panel (MDP) and the mains connection (ac power input) of both GE HealthCare power supply cabinets.	x	
4	Provision and installation of at least four single-phase electrical utility outlets for powering, for example, computers and monitor.	x	
5	Provision, installation and connection of power cables between power supply cabinets and loads.		x
6	Provision, installation and connection of control cables.		x
7	*If the site is any of the two options shown in Figure 2-1 and Figure 2-2:* Provision and installation of cable duct for interconnection cables (cables supplied by GE HealthCare) from power supplies and electronic control units.		x

Item no.	Item	Customer	GE HealthCare
8	*If the site is NOT any of the two options shown in Figure 2-1 and Figure 2-2:* Interconnection cables, supplied by GE HealthCare, from power supplies and electronic control units are to be located in ducts. The customer must supply and install these ducts and it is the customer's responsibility to ensure that this cable routing system meets local electrical codes and requirements.	x	
9	Installation of TRACERcenter node (computer) as integration point between the cyclotron system and the hospital network to, for example, provide Internet access. The computer can be ordered separately from GE HealthCare.	x	

1-2-2-5 Cooling water system

Item no.	Item	Customer	GE HealthCare
1	Provision of closed deionized cooling water system.		x
2	Provision and installation of external chiller for cooling of the water in the secondary cooling unit (a closed loop deionized water system).	x	
3	Provision and installation of control system to keep cooling water to cyclotron at a temperature of 10–13°C (50–55°F).	x	
4	Specification of heat load for external chiller.		x
5	Provision and installation of panel with connectors and shut-off valves for primary supply of cooling water and make-up water.	x	
6	Provision and installation of water manifolds with flow guards for equipment to be cooled.		x
7	Provision and installation of all piping from GE HealthCare supplied water manifolds to heat loads.		x
8	Provision and installation of all water pipes from the secondary cooling unit (a closed deionized cooling water system) to the Control Cabinet (CCAB) and Radio Frequency Power Generator (RFPG).		x
9	Provision and installation of all water pipes from the external chiller to the secondary cooling unit (a closed loop deionized water system).	x	
10	Filter supplied on external chiller cooling loop to protect heat exchanger.	x	
11	A connection for city water to the secondary cooling unit (a closed loop deionized water system) shall be provided by the customer.	x	

Item no.	Item	Customer	GE HealthCare
12	Provide one-way valve on city water line to the secondary cooling unit in order to eliminate back streaming.	x	

1-2-2-6 Compressed air

Item no.	Item	Customer	GE HealthCare
1	Provision and installation of compressed air system, including connectors, 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

1-2-2-7 Ventilation

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

1-2-2-8 Gas and liquid distribution

Item no.	Item	Customer	GE HealthCare
1	Provision and installation of: • gas supply with gas bottles/tanks • regulators for ion source gas and target gas (and optionally also process gases) • clean, high quality tubes between gas bottles and the supply panel	x	
2	Provision and installation of piping from the target system in the cyclotron room to the chemistry processing systems in the radio-chemistry laboratory.		x
3	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	

1-2-2-9 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	

Item no.	Item	Customer	GE HealthCare
2	Access hatch or other entrance to the cyclotron room 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

1-2-2-10 Installation of cyclotron

Item no.	Item	Customer	GE HealthCare
1	The customer is required to ensure that the site is properly prepared and ready, allowing the installation to progress without delay or interruption.	x	
2	GE HealthCare will inspect the site before the start of installation. The installation of the equipment will not be started until GE HealthCare has approved the site conditions.		x
3	Assembly of cyclotron.		x
4	Commissioning of equipment and performance testing.		x

1-2-2-11 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. Printer is optional, hence not supplied with the system. For MINItrace Qilin instructions for connecting a printer are found in the current software release note.	x	

1-2-2-12 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	

Item no.	Item	Customer	GE HealthCare
2	The complete installation for radionuclide production has to be designed for a safe handling of activity with respect to personal safety of the staff and the surroundings.	x	
3	Calculations on all radiation shielding. The responsibility for adequate radiation protection, final decisions concerning the arrangement of shielding and handling of induced activities (air, water, targets, etc.) according to requirements from the local and national authorities.	x	
4	Provision and installation of safety devices like “beam” on signs, door interlocks, alarms, emergency switches according to customer needs and local codes.	x	
5	Provision of local codes and working regulations that apply to GE HealthCare staff.	x	
6	Compile site-specific Lock-Out and Tag-Out (LOTO) procedures, in cooperation with GE HealthCare, for the subsystems that are subject to LOTO.	x	

1-2-2-13 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 Types of waste on page 22.	**x**	
3	Sorting and packing of waste according to provided state and/or local laws and regulations.		**x**
4	Disposal of waste.	**x**	

Types of waste

- Wood (pallets, pallet collars, crates, etc.)
- Plastic (cans, packing material, styrofoam™, etc.)
- Iron (screws, nail plates, cans, etc.)
- Aluminum (material used for securing load during shipping, etc.)
- Lead (remainders from installation, etc.)
- Paper (cardboard, packing material, etc.)

1-2-3 Installation flow chart

The typical installation cycle for the cyclotron system is approximately five weeks. Table 1-1 shows the top-level installation schedule for the system.

Table 1-2 identifies the essential customer and GE HealthCare resources and the site preparation status necessary to perform the installation efficiently.

Table 1-1: Typical installation cycle for the cyclotron system

Activities	Weeks				
	1	2	3	4	5
Ship to customer 1–5 weeks					
Rigging 5 days	x				
Mechanical installation 5 days		x			
Electrical installation 5 days		x			
Start-up, subsystems			x		
Beam test 2 days				x	
Target test 3 days				x	
Performance test procedure					x

Table 1-2: Typical installation flow chart

GE HealthCare activity	**Rigging** Place cyclotron and radiation shield into room	**Mechanical** installation and piping. **Electrical** installation and cabling.	**Start-up and calibration**	**Cyclotron system test**	**Performance test procedure**
Time	5 days	5 days	5 days	5 days	2–5 days
Personnel required	1 GEPS repr. Local rigging company	1 GEPS repr. 1 local FE	1 GEPS repr. 1 local FE	1 GEPS repr. 1 local FE 1 customer physicist	1 GEPS repr. 1 local FE 1 customer physicist
Required customer status for above					
Site preparation	Cyclotron area complete	Site ready (rooms, environmental, power, water chiller installed)	All gas and media supplies available	Physicist available for test	Chemist available. All lab equipment operating. Chemistry lab routines established.
Procedure preparation	All licensing complete				

2 Space planning

2-1 Introduction

When developing a floor plan there are special considerations that must be taken into account due to the radiation produced during operation.

The radionuclides are produced in designated targets and then transported to the radiochemistry lab where they are further processed. The final products are transported from the radiochemistry lab to the PET-site or its vicinity.

Special care must be taken during the design phase of the PET facility to design for both logical product and patient flow within the PET facility.

2-2 Room sizes

Table 2-1 contains a list of minimum dimensions for adequate service access and traffic concerns in a PET cyclotron facility.

Facility designs using an integrated radiation shield is shown in Figure 2-1 and Figure 2-2 below.

Table 2-1: Minimum room dimensions – integrated room option

Room	Minimum area		Type minimum dimension	
	[m²]	[ft²]	[m]	[ft]
Cyclotron/power supply room	32	345	7 × 4.5	23 × 15
Radiochemistry lab	30	323	6 × 5	20 × 17

Table 2-2: Minimum room dimensions – dedicated room option

Room	Minimum area		Type minimum dimension	
	[m²]	[ft²]	[m]	[ft]
Cyclotron room	25	269	5.5 × 4.5	18 × 15
Power supply room	7.5	81	3 × 2.5	10 × 9
Radiochemistry lab	30	323	6 × 5	20 × 17

Figure 2-1: Typical integrated room option facility

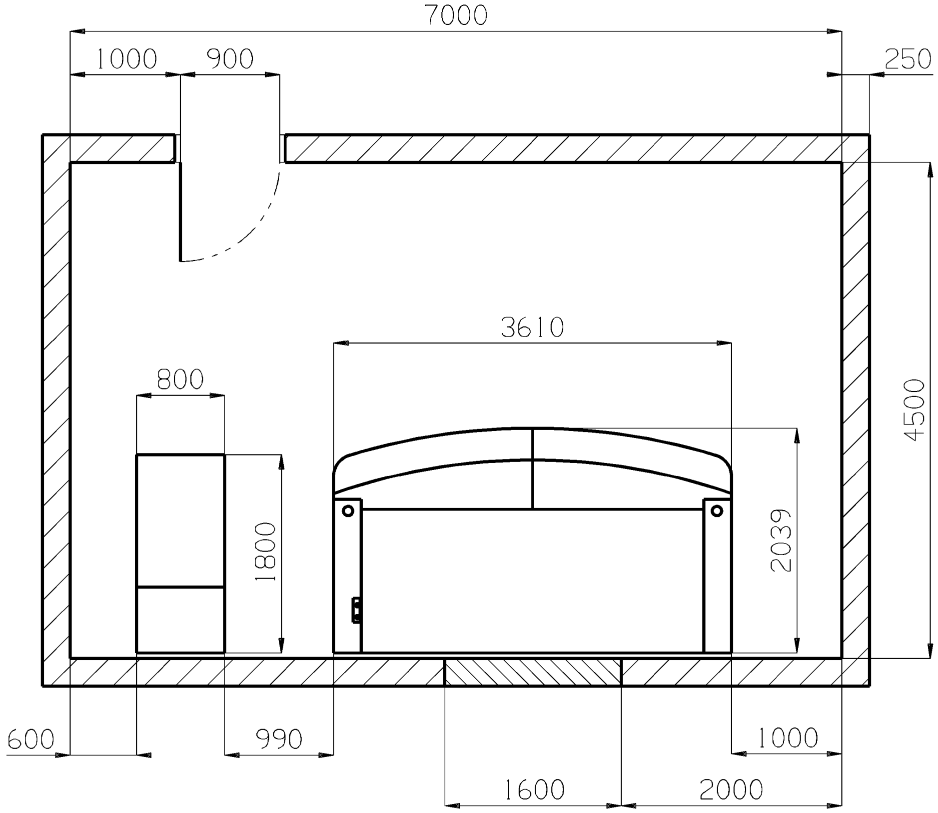
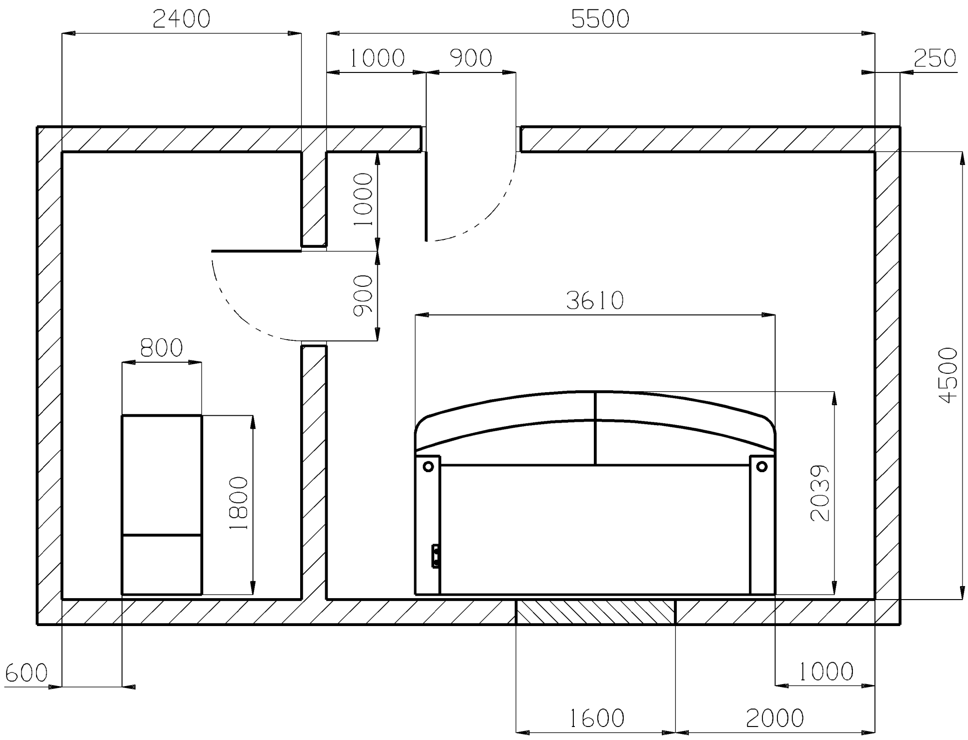


Figure 2-2: Typical dedicated room option facility



2-2-1 Cyclotron room

The cyclotron room will be the area in which the cyclotron, the target support system with targets, and other support systems for the accelerator are installed.

Table 2-3: Cyclotron room size (integrated room option)

Recommended area	32.0 m^2
Length	7.0 m
Width	4.5 m
Height	2.5 m

Other recommendations can be made to meet specific customer requirements.

2-2-1-1 Equipment

The cyclotron will be transported into the cyclotron room in a number of pieces with the following dimensions:

Table 2-4: Cyclotron dimensions

Weight of radiation shield, right rear	11 100 kg
Weight of radiation shield, right door	7 600 kg
Weight of radiation shield, left rear	11 200 kg
Weight of radiation shield left door	7 400 kg
Weight of magnet	10 700 kg
Total weight of cyclotron system (fully equipped)	52 950 kg
Total length	3.60 m
Total width	2.10 m
Total height	2.15 m

Table 2-5: Cabinet sizes

	Control Cabinet (CCAB)	Radio Frequency Power Generator (RFPG)
Weight	380 kg	750 kg
Depth	0.8 m	0.8 m
Width	0.6 m	1.2 m
Height	1.8 m	1.8 m

2-2-1-2 Entrance

Installation entrance and/or in-house transportation of cyclotron according to Section 2-3 Minimum access requirements on page 29.

2-2-1-3 Construction and layout

The concrete should be well cured, and the room painted and cleaned completely, before the installation begins. All cable and water connections are fed into the shield from above.

It is recommended that the room is equipped with floor drains.

Connections, designed to prevent radioactive leakage, are needed for:

- Ventilation ducts
- Electrical power feed
- Primary cooling water (raw water) lines
- Compressed air pipes
- Target and chemistry gas pipes
- Drains

2-2-2 Radiochemistry production facility

The complete design of the radiochemistry production facility, which is the responsibility of the customer, will also include a radiochemistry laboratory (hot lab).

The user interface (workstation) of the control system is comprised of a computer, monitor, keyboard, and mouse. These units do not require a separate room and can be placed on a desk in the radiochemistry laboratory or another location within the facility. There must though be a network connection between that location and the router in the Control Cabinet.

Space for analytical instruments such as GC and HPLC is necessary.

Working areas, rinsing and washing area must be available.

Adequate ventilation in the radiochemistry lab is utterly important. The air is to be exhausted through the hot cells.

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 Minimum access requirements

Table 2-6 lists the clearance opening dimensions for doors and hallways required by the cyclotron equipment. Table 2-7 specifies the minimum ceiling opening needed when cyclotron and radiation shield is delivered vertically into a site. Installation or replacement of components must be taken into consideration when determining hallway and door dimensions. Refer to Chapter 8 Shipping and delivery data for the cyclotron shipping dimensions.

Table 2-6: Minimum hall way/door dimensions

Component	Minimum hallway/door width [mm]	Minimum hallway/door height [mm]
Magnet	1300	1900
Radio Frequency Power Generator (RFPG)	900	1900
Control Cabinet (CCAB)	700	1900
Integrated radiation shield	1600	2200

Table 2-7: Minimum ceiling opening

Component	Minimum hole dimensions [mm]
Cyclotron	1300 × 1300
Radiation shield	2000 × 1700

2-4 Cabling considerations

In case of an **integrated room option facility** (according to Figure 2-1) or a **dedicated room option facility** (according to Figure 2-2), a cable duct is provided by GE HealthCare to run cables from power supplies and electronic control units.

In case the site is not in accordance with any of the two examples mentioned above, the cable duct (that might have to be supported by a raceway) is provided by the customer.

Care must be taken to protect interconnecting cords and cables from physical damage.

Cable runs throughout the system must be in accordance with local and national codes.

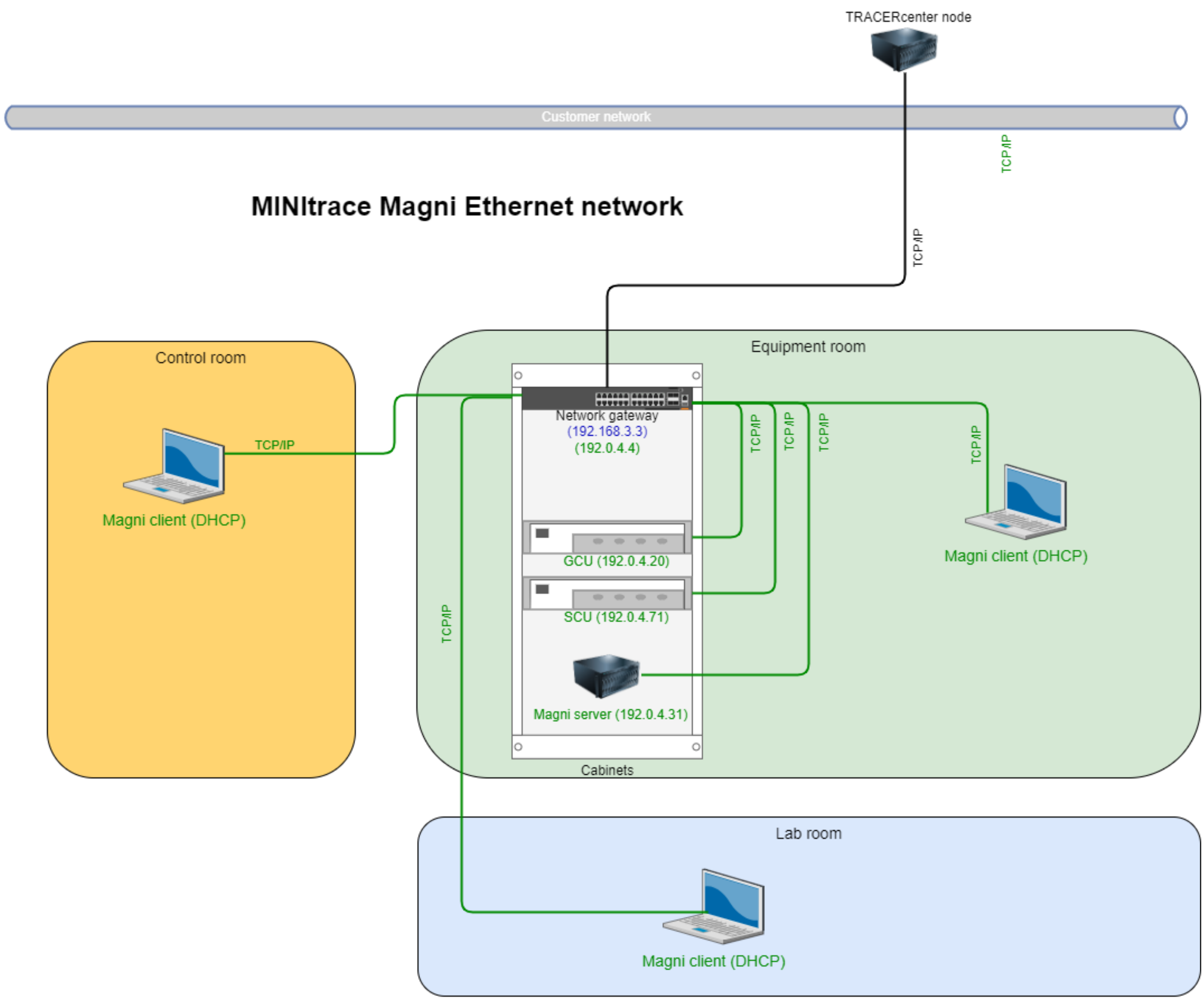
2-4-1 Ethernet communication network overview for MINItrace Magni

There must be an Ethernet network connection between the router in the Control Cabinet and each location where it shall be possible to control the cyclotron.

Figure 2-3 shows an example on how the control systems and computers in MINItrace Magni are linked together through an Ethernet communication network.

For a network overview for MINItrace Magni including Solid target platform, see Figure A-2.

Figure 2-3: Ethernet communication network overview for MINItrace Magni



2-5 Flooring

2-5-1 Load and pressure

Weight consideration must be taken when designing the cyclotron room (see Section 2-7 Floor loading and weights on page 34).

Special arrangements should be taken during the preparation of the floor:

- Before installation of the radiation shield, the floor is to be covered with epoxy.
- The final epoxy layer should have a smooth surface and be approximately 4–7 mm thick.

Table 2-8: Floor tolerance

Area where the epoxy will be used (approximately)	5100 × 3400 mm
Variation in the horizontal plane	< ±3 mm

See Section 2-7 Floor loading and weights on page 34 for information on floor requirements.

2-5-2 Floor ducts for radioactive gases, liquids, and solids

Shielding of radioactive liquids/gases/solid target material is the responsibility of the customer if no other agreements are made. It is however necessary to include it in the site planning when it affects the concrete work.

The radioactive liquids/gases/solid target material are produced in the cyclotron target system. From the cyclotron to the hot lab (where they enter a hot cell or process cabinet) the routing can be done in different ways. In areas where personnel can be exposed to dose from the radioactive liquid/gas/solid target material, the pipes and tubes must be shielded.

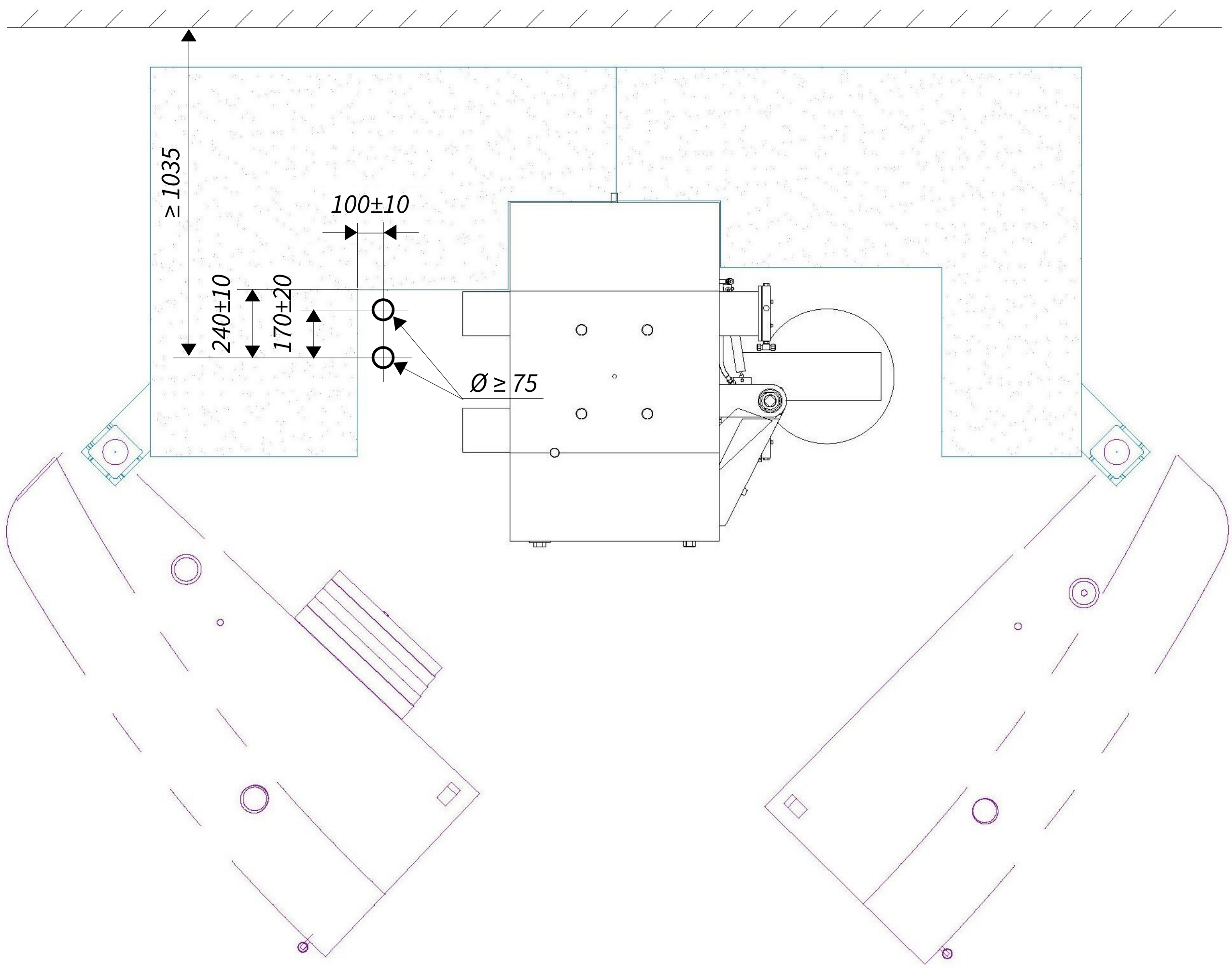
An adequate shielding is achieved by 40–50 mm of lead or corresponding thickness for concrete.

Two ducts in the concrete floor from the cyclotron is required to enable anticipated target configurations. That means two holes in the floor below the targets. For specifications, see Table 2-9.

Table 2-9: Ducts and holes specifications

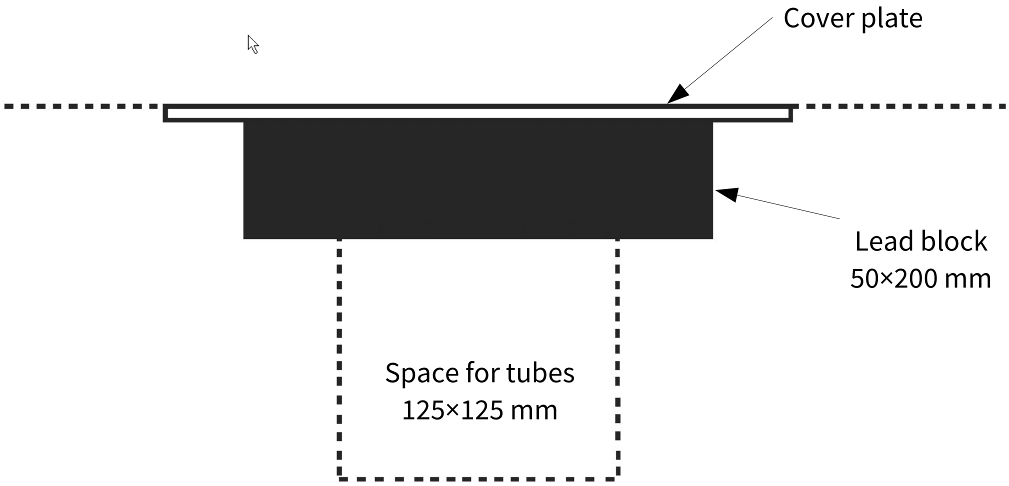
Parameter	Specification
Number of ducts	Two
Type of duct	Smooth inside layer
Duct width	Minimum 75 mm (inner diameter)
Bending radius	Minimum 350 mm (to center of duct)
Position of holes	See Figure 2-4

Figure 2-4: Location of holes relative to radiation shield and rear wall [mm]



For a concrete floor under construction there is an inexpensive and easy way to design shielded floor trenches. A suggested trench profile is shown in Figure 2-5.

Figure 2-5: Trench profile



For rooms with a finished floor there are lead shields (provided by vendors like Von Gahlen and Comecer) available for tubing.

Note!
Accomodation of a target switch panel will, if placed in the floor trench, require a separate assessment of the floor/trench design. Contact GE HealthCare for consultance.

2-6 Architectural reminders

- Pay attention to isogauss limits, not only for placement in rooms but also for isogauss limits with respect to outside environment.
- The customer must establish protocols to prevent persons with cardiac pacemakers, neurostimulators and biostimulation devices from entering magnetic fields greater than 5 gauss (exclusion zone).
- A lockable storage cabinet should be provided. It will be used for storing documentation and tools.
- Ethernet connections must be provided between the Control Cabinet room and each location where it shall be possible to control the cyclotron.
- *MINItrace Magni*: The customer must provide a *TRACERcenter node*, an integration point between the cyclotron system and the hospital network. The TRACERcenter node is a computer provided by the customer. The computer can also be ordered separately from GE HealthCare. The TRACERcenter node enables access to, for example, production reports and production data from the cyclotron system, and also to Internet and future remote connectivity.
- *MINItrace Magni*: There must be an Ethernet connection between the Control Cabinet room and the TRACERcenter node (see Section 2-4-1 Ethernet communication network overview for MINItrace Magni on page 30).

2-7 Floor loading and weights

This section contains loading considerations for the cyclotron system. Listed in Table 2-10 are the weights, floor loading and normal mounting methods for the cyclotron components.

Table 2-10: Cyclotron floor loading

Component	Weight [kg]	Overall area w × d [mm]	Floor load [kg/m²]	Mounting
Integrated radiation shield (fully equipped)	39 900	3600 × 2100	16 300	Set on floor
Magnet	10 700	700 × 835	17 800	Set on floor
Control Cabinet (CCAB)	380	600 × 800		Set on floor
Radio Frequency Power Generator (RFPG)	750	1200 × 800		Set on floor
Roughing vacuum (mechanical) pump	27	450 × 190		Set on floor (next to diffusion pump)
Workstation	13			Set on table
CSC (Cyclotron Support Cabinet)				Wall mounted on radiation shield
TSC (Cyclotron Target Support Cabinet)				Wall mounted on radiation shield
Helium cooling system/systems				Placed in TSC (Target Support Cabinet)

2-7-1 Cyclotron loading considerations

In addition to the weight of the magnet, special considerations must be given to the weight of the rigger equipment along the rigging route. Structural reinforcement may be required along the magnet rigging route. It is required that a structural engineering analysis is performed on the cyclotron room and rigging route to determine its load bearing capacity.

The cyclotron is to be transported in an upright position.

A dedicated transport system is used for the cyclotron and the integrated radiation shield. There are lifting devices attached to the base of the cyclotron and shielding parts. The lifting devices are positioned so that the parts are balanced. When mounted, the lifting devices increase the height by approximately 50 mm.

The cyclotron is completely assembled, except for some minor parts when delivered to the customer.

2-7-2 Anchoring and seismic considerations

The center of gravity for the cyclotron system components is provided in Section 2-8 System components on page 35 for use in seismic calculations. Check local seismic codes to determine if the cyclotron magnet must be mounted to the floor.

It is the responsibility of the customer to obtain any and all approvals necessary for the construction of equipment support.

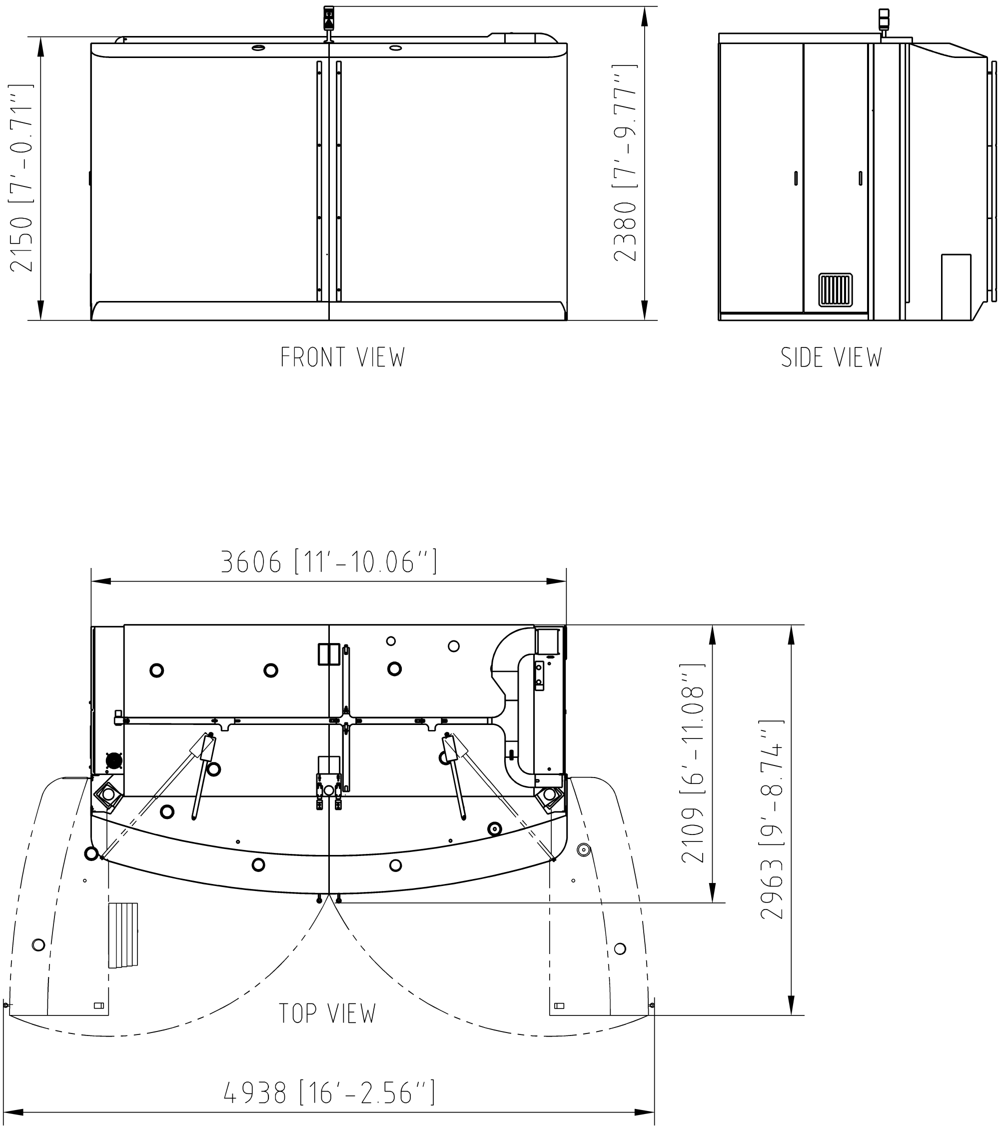
2-8 System components

The scope of the system components are shown in this section.

Table 2-11: System components illustration list

Illustration name	Illustration number
Cyclotron overall layout	Figure 2-6
Cyclotron minimum service area	Figure 2-7
Cyclotron dimensions	Figure 2-8
Control Cabinet (CCAB)	Figure 2-9
Radio Frequency Power Generator (RF-PG)	Figure 2-10
Roughing vacuum (mechanical) pump	Figure 2-11
Workstation	Figure 2-12
Bench radiation shield	Figure 2-13

Figure 2-6: Cyclotron overall layout



ALL DIMENSIONS ARE IN MILLIMETERS
ALL BRACKETED [] DIMENSIONS ARE IN INCHES.

WEIGHT 52950 kg

Figure 2-7: Cyclotron minimum service area

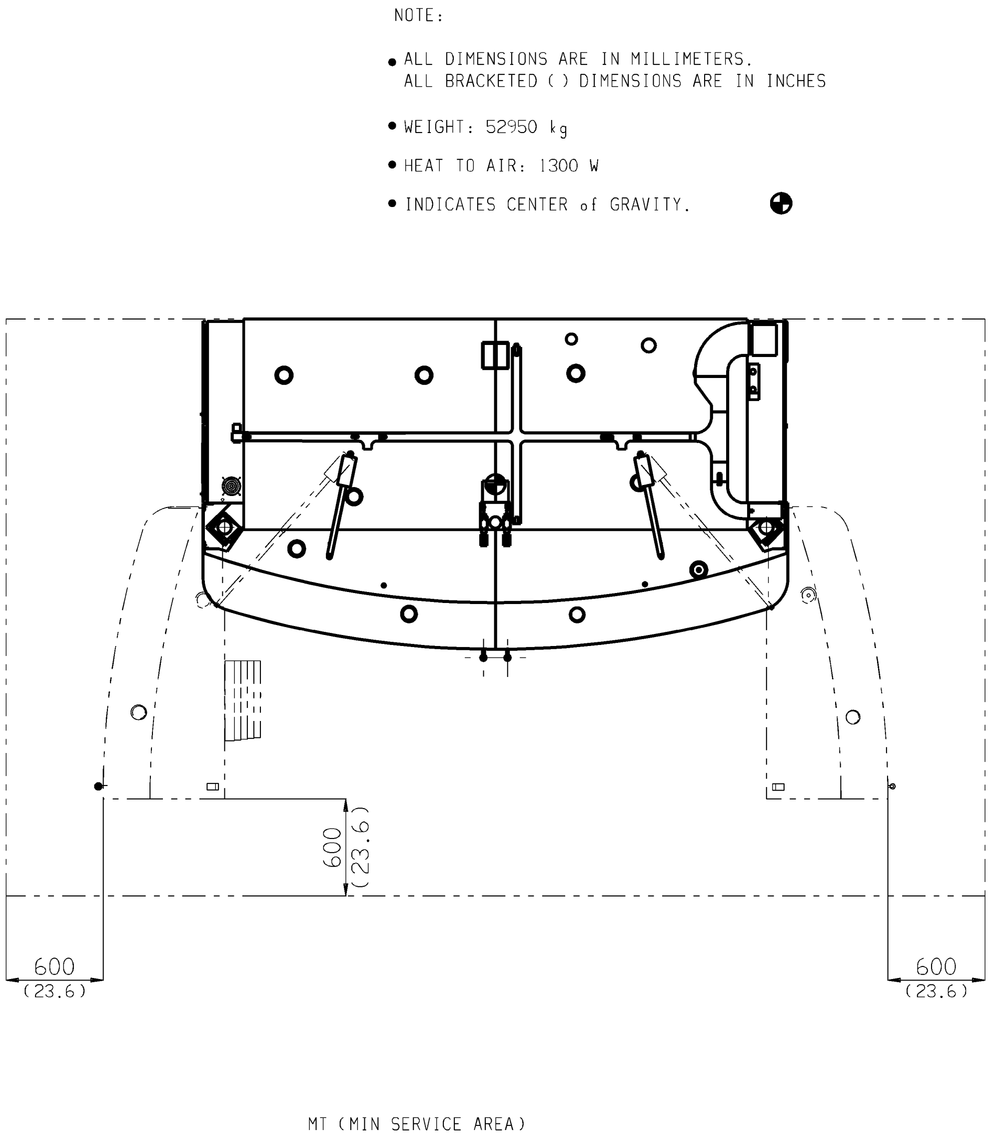


Figure 2-8: Cyclotron dimensions

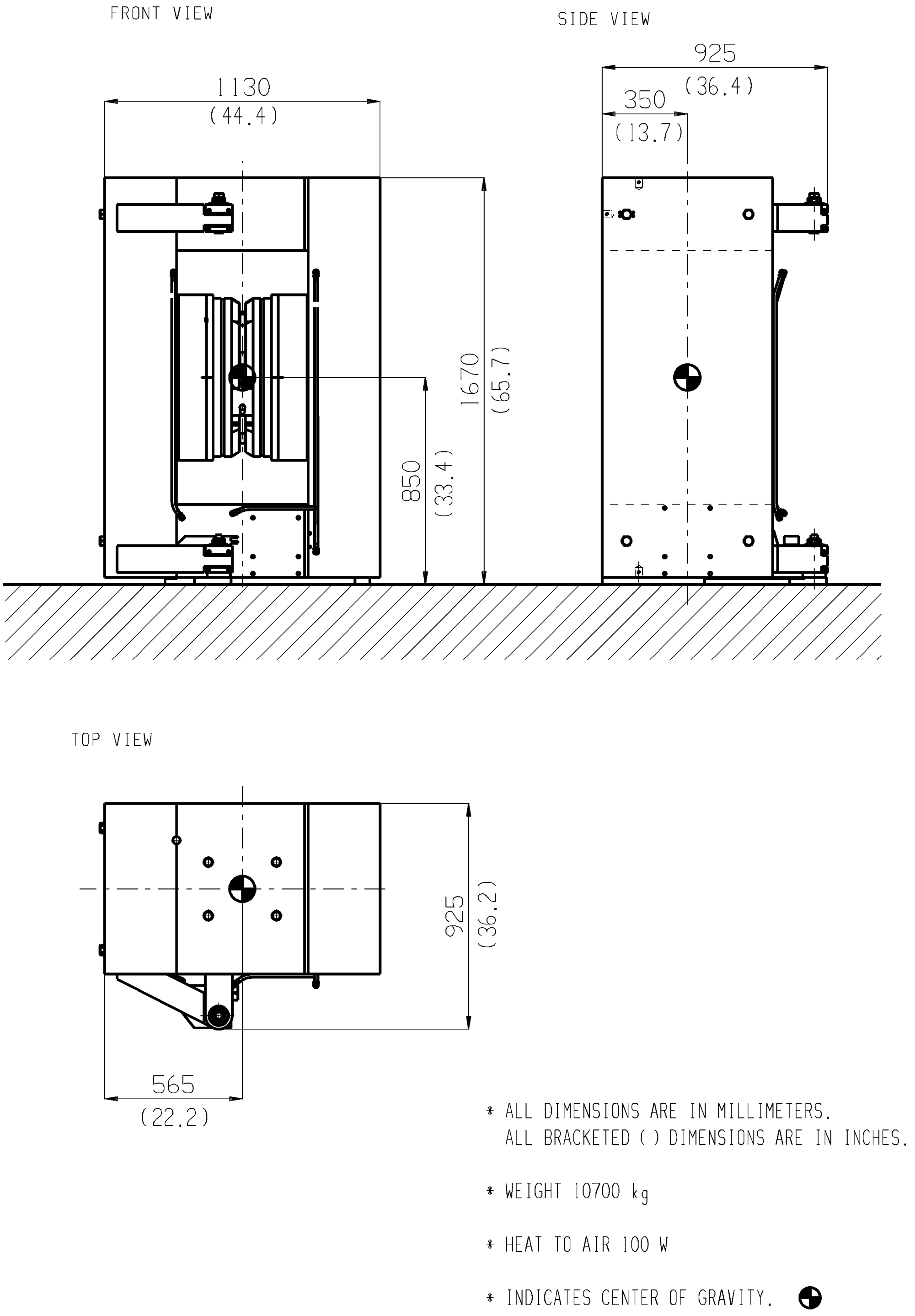


Figure 2-9: Control Cabinet (CCAB)

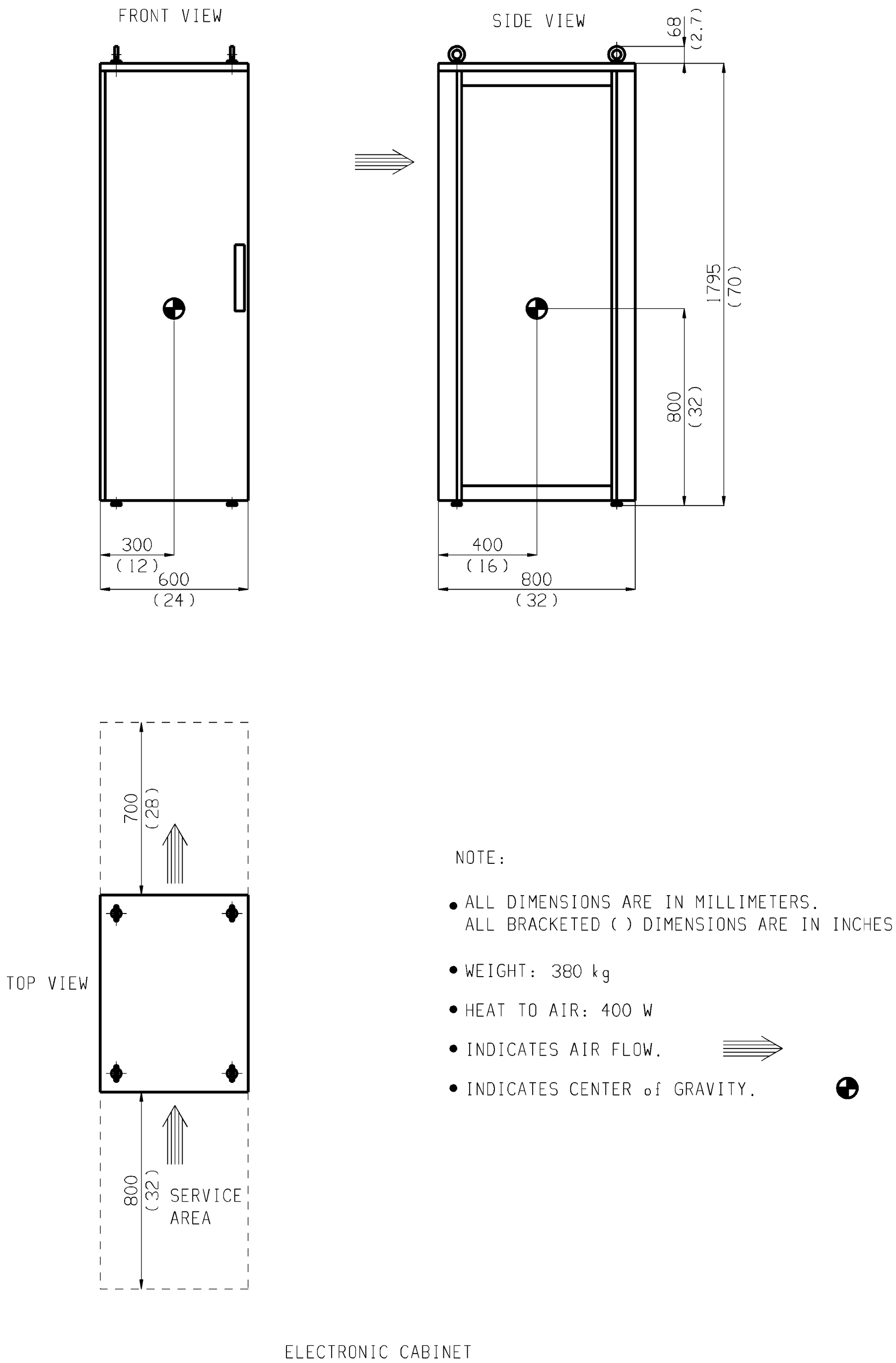


Figure 2-10: Radio Frequency Power Generator (RFPG)

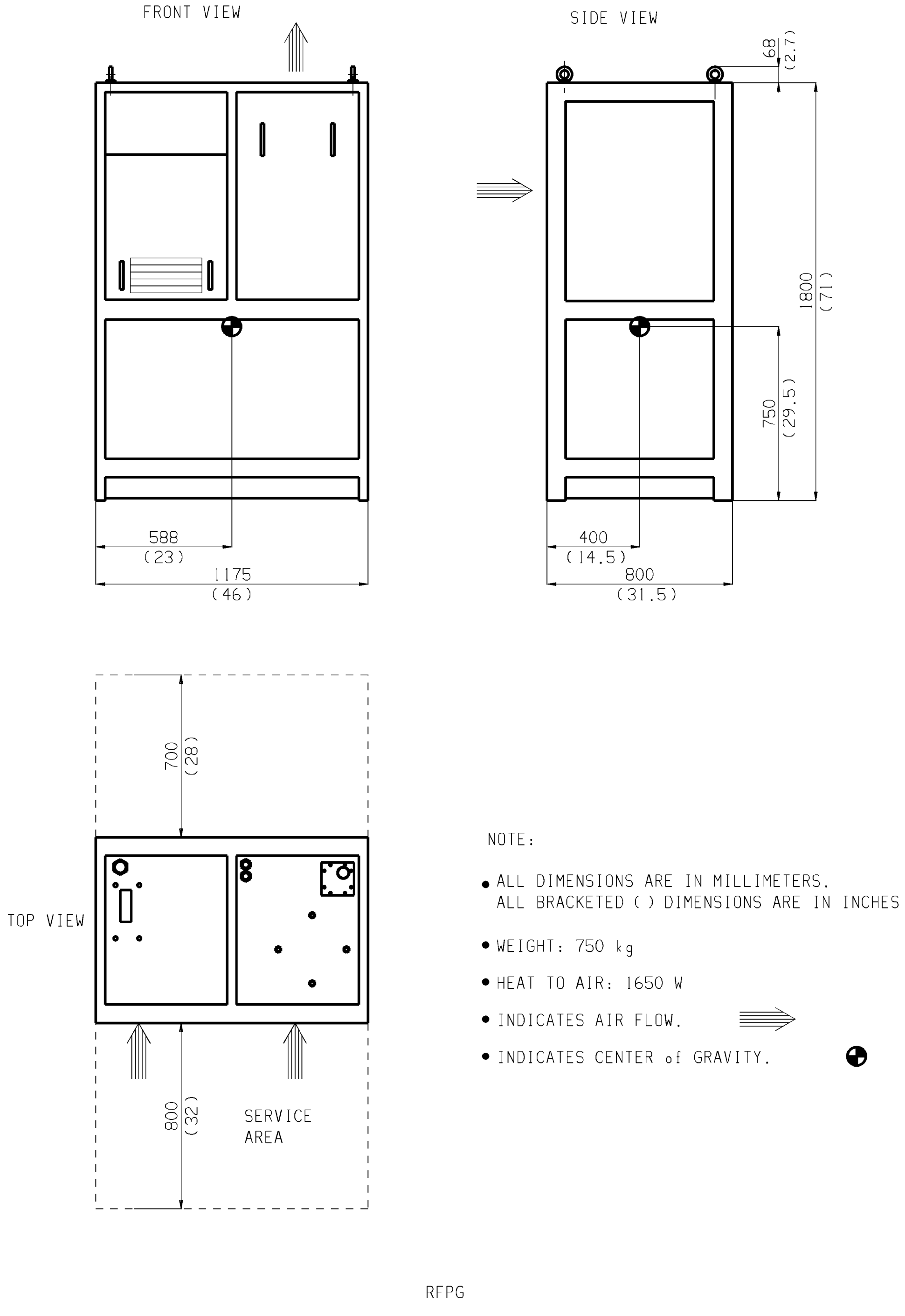


Figure 2-11: Roughing vacuum (mechanical) pump

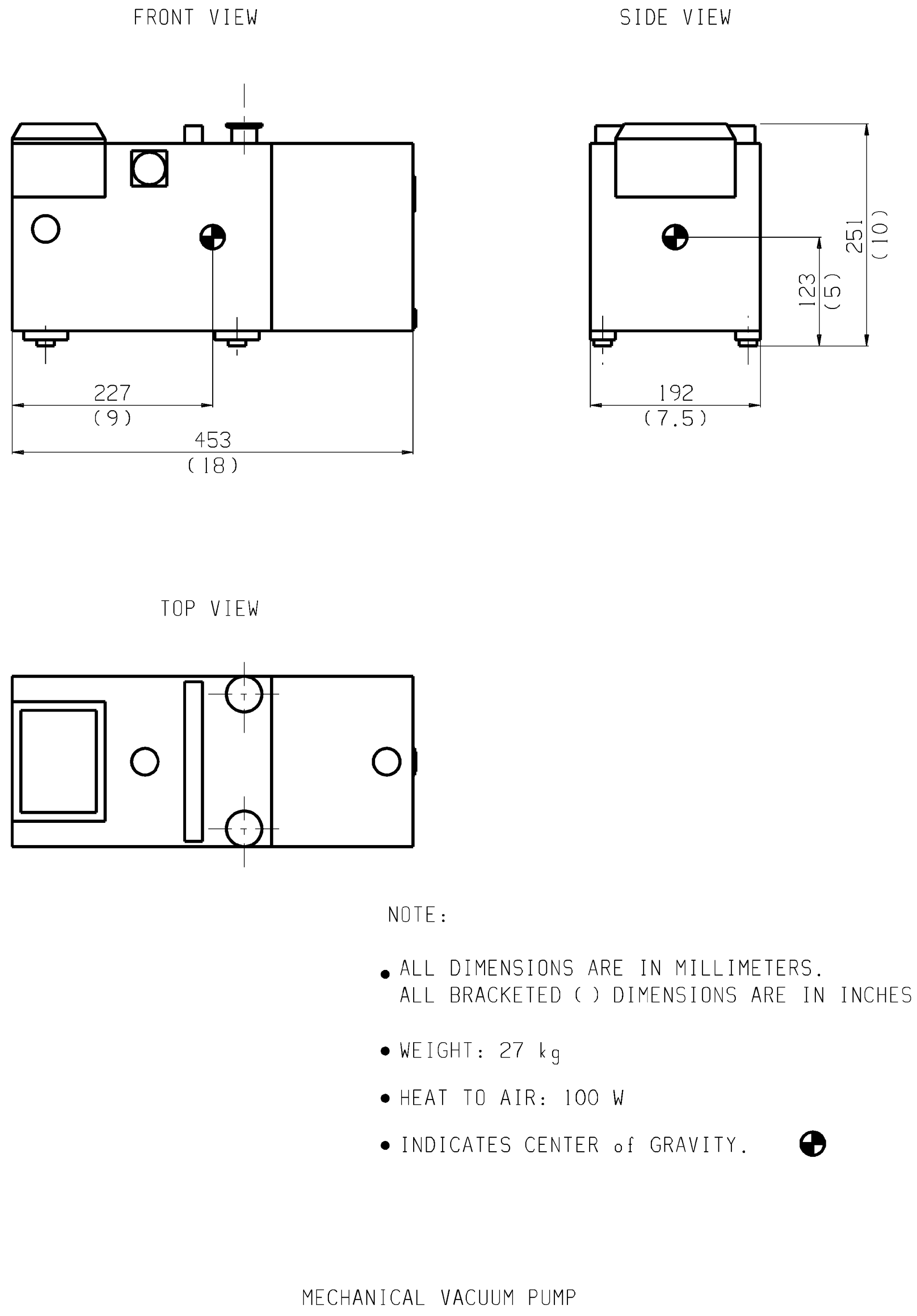


Figure 2-12: Workstation

The workstation at the control desk includes as follows:

- Computer
  - MINItrace Magni: Laptop (weight: 3 kg)
  - MINItrace Qilin: Desktop (weight: 9 kg)
- Monitor (weight: 4 kg)
- Keyboard
- Mouse

Note!
It is possible to connect additional workstations to the cyclotron network (client stations/multi-stations). By using one or more stations, the cyclotron application can be viewed or controlled from more than one location.

Example from MINItrace Qilin:

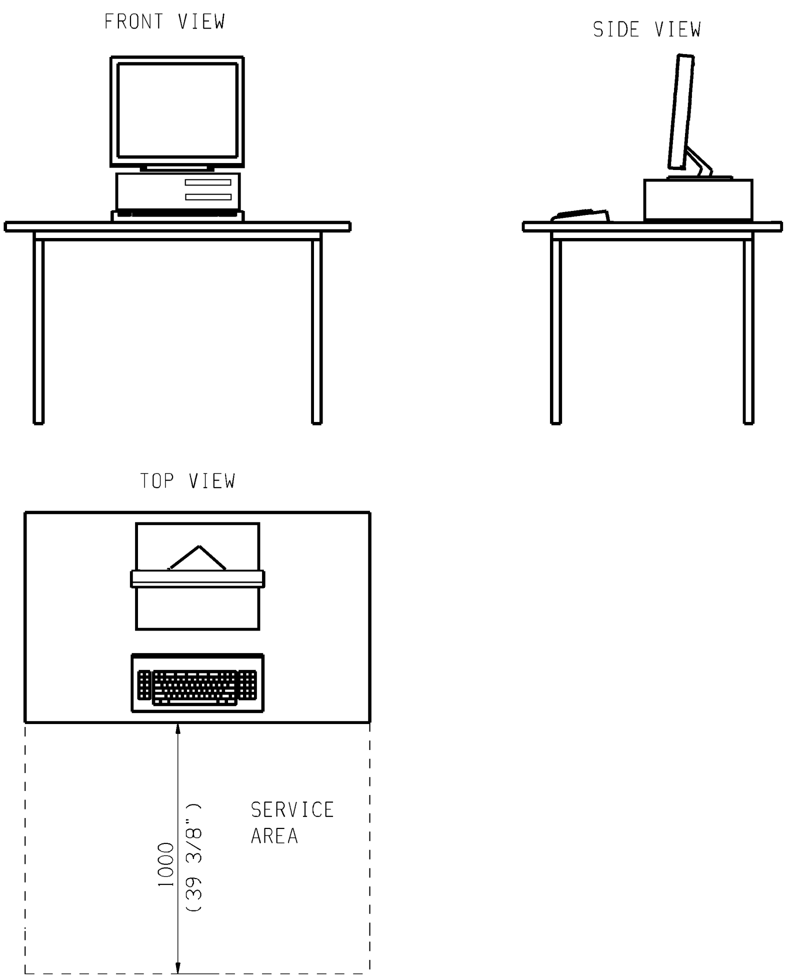
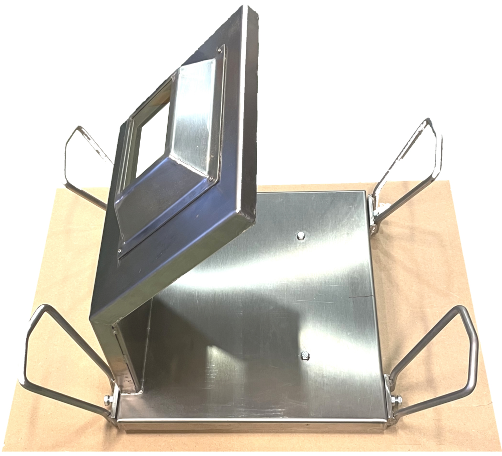
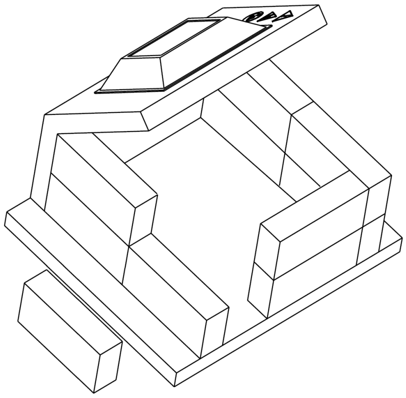


Figure 2-13: Bench radiation shield

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.

3 Radiation shielding and safety considerations

3-1 Introduction

The purpose of this chapter is to present an overview of the radiation shielding and safety requirements that should be considered during the planning, design and construction of a cyclotron facility.

The facility designer is encouraged to familiarize himself/herself with the available publications concerning radiation safety and radiation shielding. It is advisable to solicit the assistance of professional expertise in shielding design, the handling of radioactive materials, and the implementation of a PET facility radiation safety program.

A partial list of available publications includes, but is not limited to, the following:

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.

3-1-1 Responsibility for final approval and licensing

This information is provided to assist the customer in determining the requirements for the architectural and radiation shielding design and radiation safety program implementation of a PET facility. Approval of the final design is the responsibility of the customer.

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.

3-2 Materials and methods

3-2-1 General

The cyclotron produces charged particles (protons) with an energy of 9.6 MeV. Typical beam currents are in the range of 25–80 µA depending on cyclotron and target.

The primary beam is stopped immediately when it interacts with matter. In the process of being stopped, the proton beam produces secondary particles, neutrons, which create the primary radiation-shielding problem. Prompt gamma rays are also produced in the target.

The neutrons have a considerable penetrating power and their energy define the thickness of the protection around the accelerator, i.e. how thick the shielding walls have to be. In addition, the charged particle beam and the primary and secondary neutrons produce induced radioactivity in the material being hit, such as internal cyclotron structures. This induced radioactivity is a primary problem of concern with an open cyclotron shield but does not influence the surrounding except for the requirement for some shielded space for the storage of radioactive components.

The cyclotron system is delivered with an integrated radiation shield and is intended to be put in a “Controlled Area”. Even if the level of radiation around the cyclotron is low, installation of a cyclotron close to a public area has to be planned together with professionals in the field of radiation protection.

3-2-2 Protection against neutrons and prompt gamma rays

The charged particle beam from the cyclotron has a well-defined direction. When the beam interacts with matter (target), neutrons and prompt gamma rays are produced, which will be emitted in a isotropic fashion from the target. To reduce the energy of the primary neutrons, the neutrons are moderated in light material surrounding the target (mainly hydrogen rich plastic).

The prompt gamma rays are attenuated in lead walls that surround the target area and further on in the main concrete shield.

The outer shield is made of high density concrete with relatively high hydrogen content and some boron additive.

The hydrogen in the concrete will further moderate the neutrons to a thermal state. The thermalized neutrons will be captured in the radiation shield material and the high dense concrete will attenuate the gamma rays created during the neutron capture.

The high cross section for neutron capture in boron together with the low energy of the created gamma rays has a favorable effect on the overall shield performance and size.

3-2-3 Radiation shield design

The integrated radiation shield consists of a stationary section with an internal cavity matched to the size of the cyclotron. The front section is split in the middle, forming a left and a corresponding right door. Each door is supported by hinges, and the motion (open–close) is done by motor actuators controlled from a hand pendant.

The roller bearing hinges are of virtually non-friction type and the necessary force to drive the door are low and limited to avoid any risk of pinch hazard.

For target maintenance, only the left door has to be opened.

3-2-4 Area description

3-2-4-1 High radiation areas

The space inside the integrated cyclotron shield is considered a “HIGH RADIATION AREA”. The following features are included in the design of this area.

- Appropriate sign is placed at the top of the cyclotron shield.
- Doors are provided and interlocked in such a way that neutron production (i.e. beam on) is impossible with an open door and is stopped if the door is opened.

Commonly used short-lived positron emitters include Carbon-11, Nitrogen-13, Oxygen-15, Fluorine-18, and Gallium-68. Batches up to 4 Curie of radionuclides (depending on radionuclide and cyclotron model) can be produced and transferred from the irradiated target to the hot cells. These radionuclides are transferred in tubes, which are typically covered with 3–5 cm of lead for protection depending on the attenuation requirements.

Note!
The half-value thickness of lead for 511 keV photons is in the range of 0.5 cm.

3-2-4-2 Radiation areas

The areas where the radionuclides are prepared and used are usually identified as “RADIATION AREA”. These areas are restricted to protect individuals from exposure to radiation. These areas are restricted for individuals not permitted to work in classified areas.

The scanner room, blood lab and areas for quality control will also fall under the “RADIATION AREA” category.

Furthermore, the area adjacent to the shield is considered a “RADIATION AREA” and controlled for the purposes of radiation protection.

The cyclotron with the integrated radiation shield has two movable doors, which can be opened by motor actuators to provide access to the cyclotron and target area. The movable sections are electrically interlocked so that the cyclotron can not be operated in an unsafe condition.

3-2-4-3 Unrestricted areas

Areas contiguous to the PET facility classified as unrestricted areas (areas for public use) do not need to be controlled for the purposes of protection from exposure to radiation.

3-2-5 Radiation levels

The cyclotron with its integrated radiation shield is placed in a room which should be classified as a controlled/restricted area. The shielding has been designed such that dose to radiation workers (including those entering the cyclotron room on a periodic basis) shall be well below international occupational health and safety limits. Dose rates must nevertheless be measured, and ALARA practices implemented based on a local site’s requirements and dose constraints.

3-2-5-1 Instrumentation

Instruments used for radiation field measurements should have a valid calibration. It is also important to remember that radiation instruments in general have wide tolerances.

Typical tolerances:

- Neutron instruments: ± 40%
- Gamma instruments: ± 30%

Note!
It is recommended to use an ionization-chamber based instrument (instead of GM types) for gamma measurements due to the better energy linearity.

3-2-6 Isodose rate curves

The isodose rate curves given are intended for general site planning actions and for design of wall dimensions if radiation attenuation is necessary to comply with radiation regulations in public contiguous areas.

Note!
The curves represent a measured example, site-to-site variations can be expected.

3-2-6-1 Dose rate reduction versus distance from shield surface

The rule of thumb is that the dose rates will be reduced approximately a factor of 2 every 0.5 m.

3-2-6-2 Concrete half-value thickness

In order to estimate the wall dimensions for the cyclotron room the following approximate half-value thickness can be applied (according to Monte Carlo simulations specifically made for the cyclotron system):

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

3-2-6-3 Isodose rate curves measurement

This section shows examples of isodose rate curves when irradiating an ^{18}F target and a ^{68}Ga solid target. For gamma radiation, the curves are mapped at both 10 and 20 µSv/hr, and for neutrons at 10 µSv/hr.

The operation conditions are as follows:

Target	Operation conditions
^{18}F target	Irradiated material: $[^{18}O]H_2O$ water (enrichment > 95%) Target position: port 1 (~ 1 m above floor level) Beam current: 80 µA (protons)

Target	Operation conditions
^{68}Ga solid target	Irradiated material: ^{68}Zn (enriched) Target position: port 5 (~ 0.5 m above floor level) Beam current: 60 µA (protons)

Note!
The ports used for the targets are the most anticipated configurations. The gamma and neutron dose rates are similar when comparing irradiations on port 1 and port 5 for a given target type.

Note!
The beam currents used are the product specified currents.

Note!
*Dose rate levels are **directly proportional** to beam current.*

Comments on the measured curves:

- The figures show the isodose rate curves from a top, front, and side perspective taken along the cyclotron midplane, and at 1 meter above the floor. The unit on the axes is meter.
- Parts of some curves are estimations (marked) due to walls and cabinets preventing measurement.
- The curve levels for ^{18}F (80 µA) are higher than for ^{68}Ga (60 µA) for all six scenarios, except near the floor in front of the cyclotron where the gamma dose rate for ^{68}Ga is slightly higher.
  - All six curves for ^{18}F are shown in Figure 3-1–Figure 3-6.
  - The exception curve for ^{68}Ga is shown in Figure 3-7.
- The measurement of the curves has uncertainties and variations (instrument tolerances, floor variations, etc.). To take such effects into account, the dose rates in the figures can be multiplied by a factor of 2 (to model a worst-case scenario).

Figure 3-1: Example of gamma isodose rate curves (top view, 1 m above floor); ^{18}F target on port 1 at 80 µA

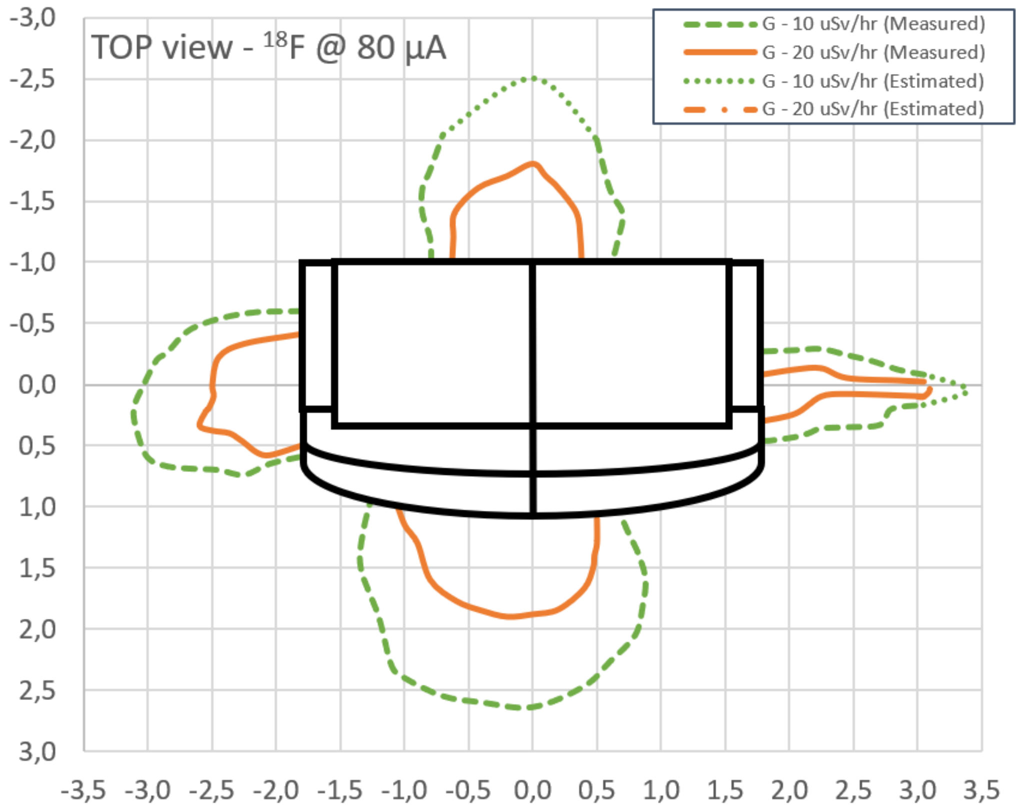


Figure 3-2: Example of gamma isodose rate curves (front view, at cyclotron mid-plane); ^{18}F target on port 1 at 80 µA

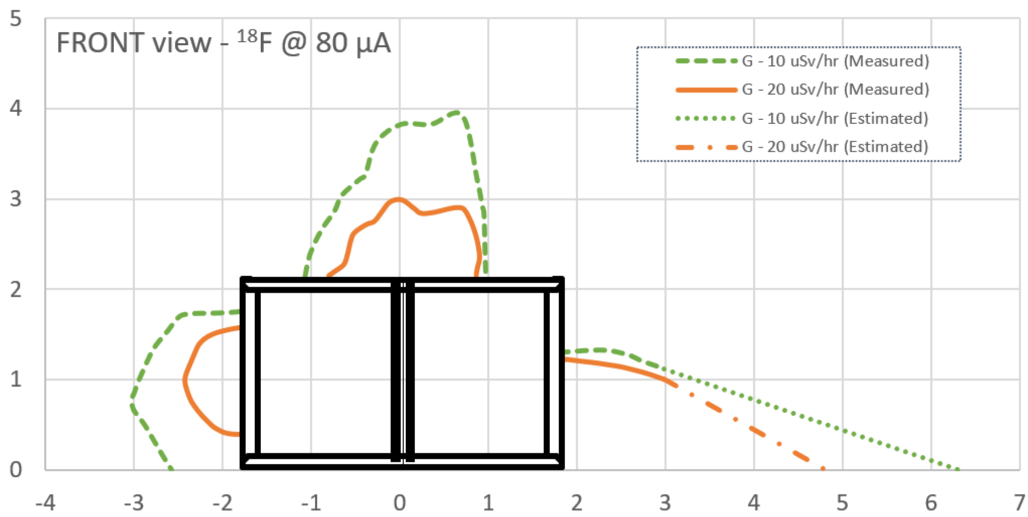


Figure 3-3: Example of gamma isodose rate curves (side view, at cyclotron mid-plane); ^{18}F target on port 1 at 80 µA

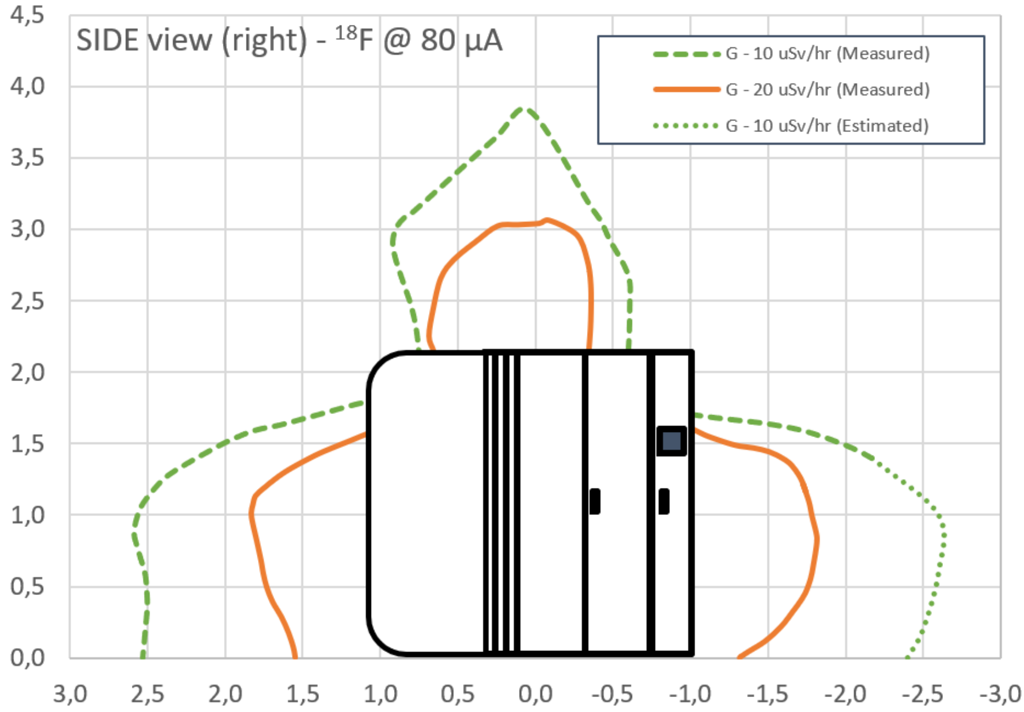


Figure 3-4: Example of neutrons isodose rate curves (top view, 1 m above floor); ^{18}F target on port 1 at 80 µA

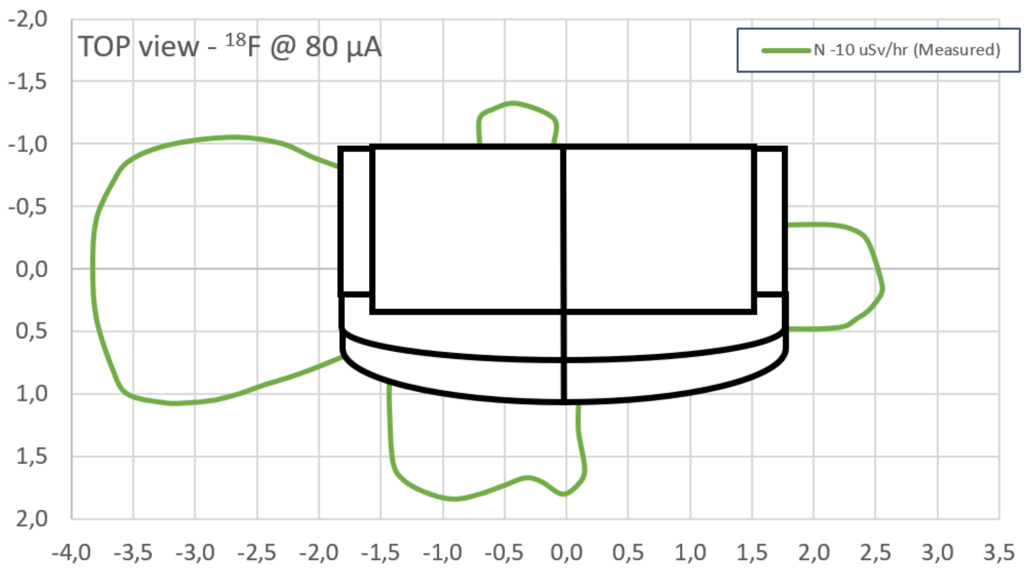


Figure 3-5: Example of neutrons isodose rate curves (front view, at cyclotron mid-plane); ^{18}F target on port 1 at 80 µA

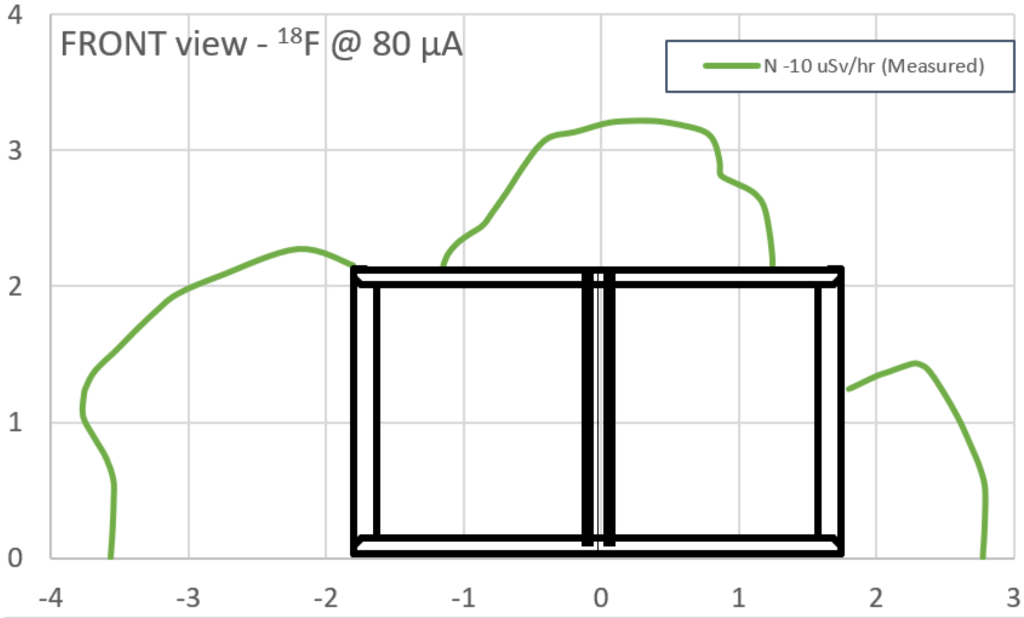


Figure 3-6: Example of neutrons isodose rate curves (side view, at cyclotron mid-plane); ^{18}F target on port 1 at 80 µA

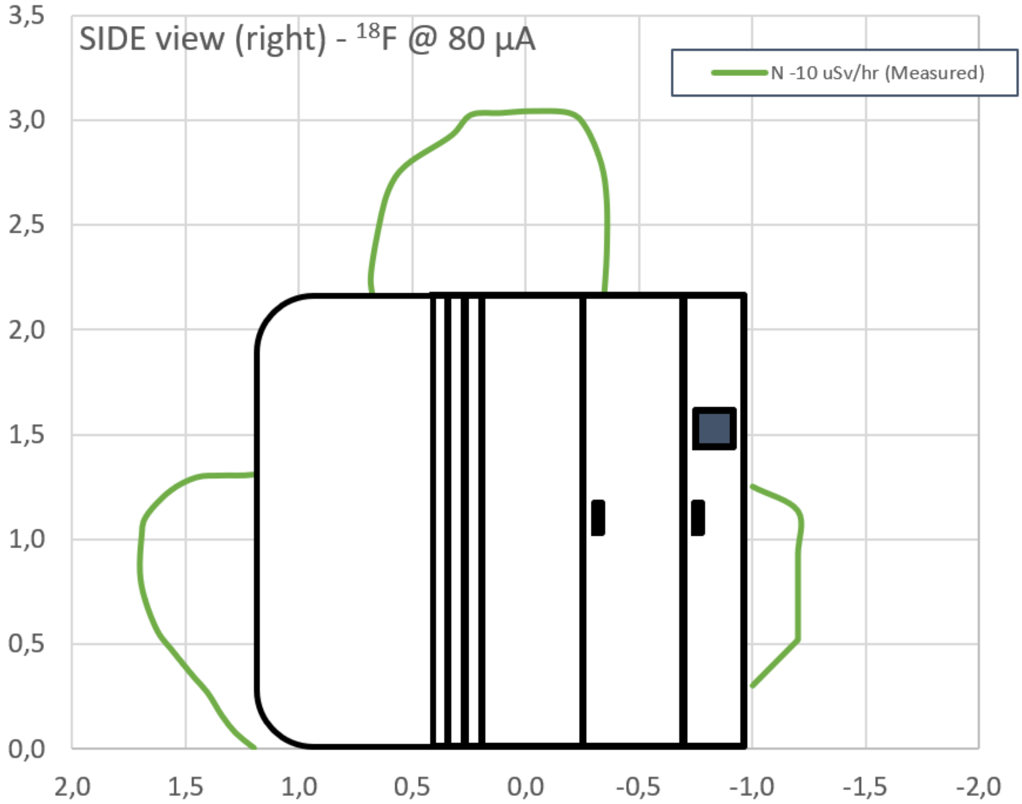
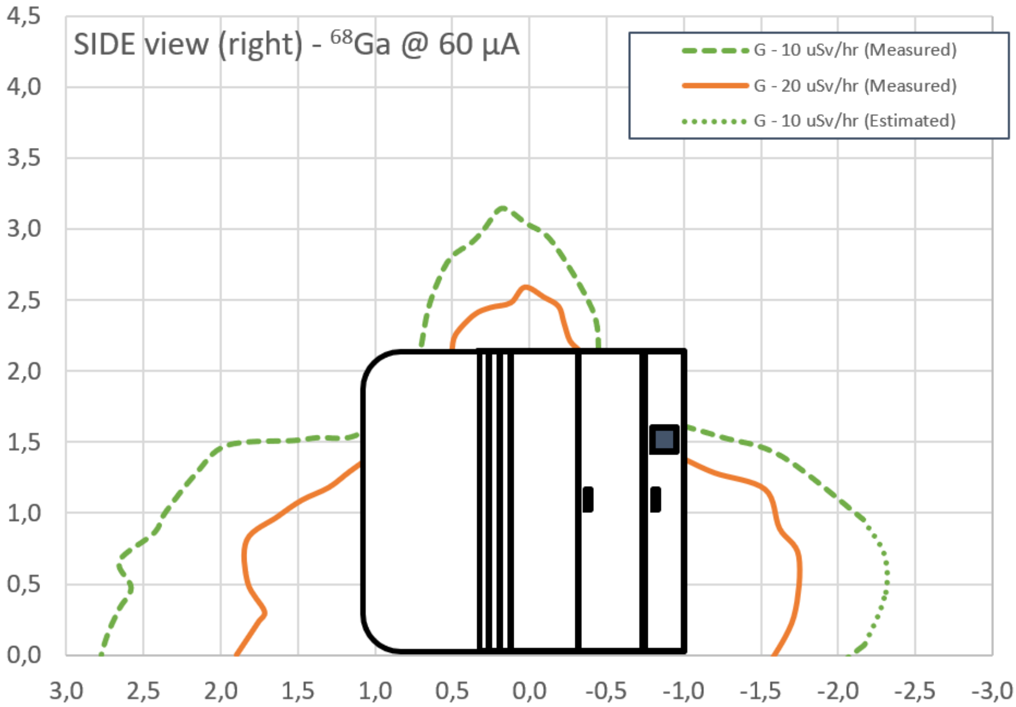


Figure 3-7: Example of gamma isodose rate curves (side view, at cyclotron mid-plane); ^{68}Ga solid target on port 5 at 60 µA



3-2-7 Waste gas system

Radioactive waste gases from the ^{15}O and ^{11}C process systems (with half-lifes in the range of 2–20 minutes) need to decay before they can be released into the normal exhaust or ventilation system. A standard decay time requirement would be 10 half lives, that is, for the ^{11}C and ^{15}O process systems ≤ 200 minutes.

The waste gas system for the cyclotron consists of a delay pipe (embedded in the high density concrete of the integrated radiation shield; it vents from the top of the cyclotron) with a length of 200 meters and a total volume of approximately 25 liters.

Thus: With an average waste gas input flow of not more than 125 ml/min over a 200 minute period, and with a total delay pipe volume of approximately 25 liters, the call for a 10 half life period of time is met.

Note!
An abrupt but transitory increase of waste gas input flow will not jeopardize the overall decay requirements, as long as the average flow over any 200 minute period of time does not exceed 125 ml/minute.

3-3 Interlock and monitor systems

The complete installation for radionuclide 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 wired into the cyclotron safety system to provide fail-safe operation.

For more information on how to connect to the cyclotron safety system to use, for example, the hard-wired system interlocks, see Section 5-15-3 Customer Interface Connector (CIC) on page 73.

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

3-4 Service and safety

The facility must be designed to help service personnel perform proper LOTO (Lock-Out, Tag-Out) 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.

See Section 6-2 LOTO (Lock-Out and Tag-Out) on page 78 for further information.

4 Magnetic field considerations

4-1 Introduction

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

Objects within this three-dimensional space can be affected by the magnetic field (for example, PET scanners, nuclear medicine scanners, MR scanners, cardiac pacemakers, neurostimulators and other biostimulation devices) or can affect the magnetic field (for example, structural steel, elevators and other large stationary or moving masses).

Therefore, all ferromagnetic material within this three-dimensional magnetic field must be thoroughly examined to ensure it does not significantly redirect the magnetic field thereby creating magnetic interference problems.

4-2 Exclusion zone

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

4-3 Magnetic shielding

Magnetic shielding can be used to reduce the fringe fields surrounding the cyclotron magnet to minimize effects on the external environment.

Room magnetic shielding generally consists of iron plates installed in the cyclotron room walls, floor and ceiling. To achieve a reduction in the fringe fields of the cyclotron magnet a significant amount of iron is required. Special consideration should be given during cyclotron site selection due to the expense and additional engineering effort required to provide magnetic shielding.

The design of a magnetic shield requires a comprehensive computer analysis, which predicts the effect the shield will have on the magnetic field. The structural capacities of the site and space availability are important factors that must be considered in the design of the shield.

The GE HealthCare site planning group has the capability to design magnetic shields which meet a broad range of site requirements.

Figure 4-1: Cyclotron magnet field isogauss line plot, top view

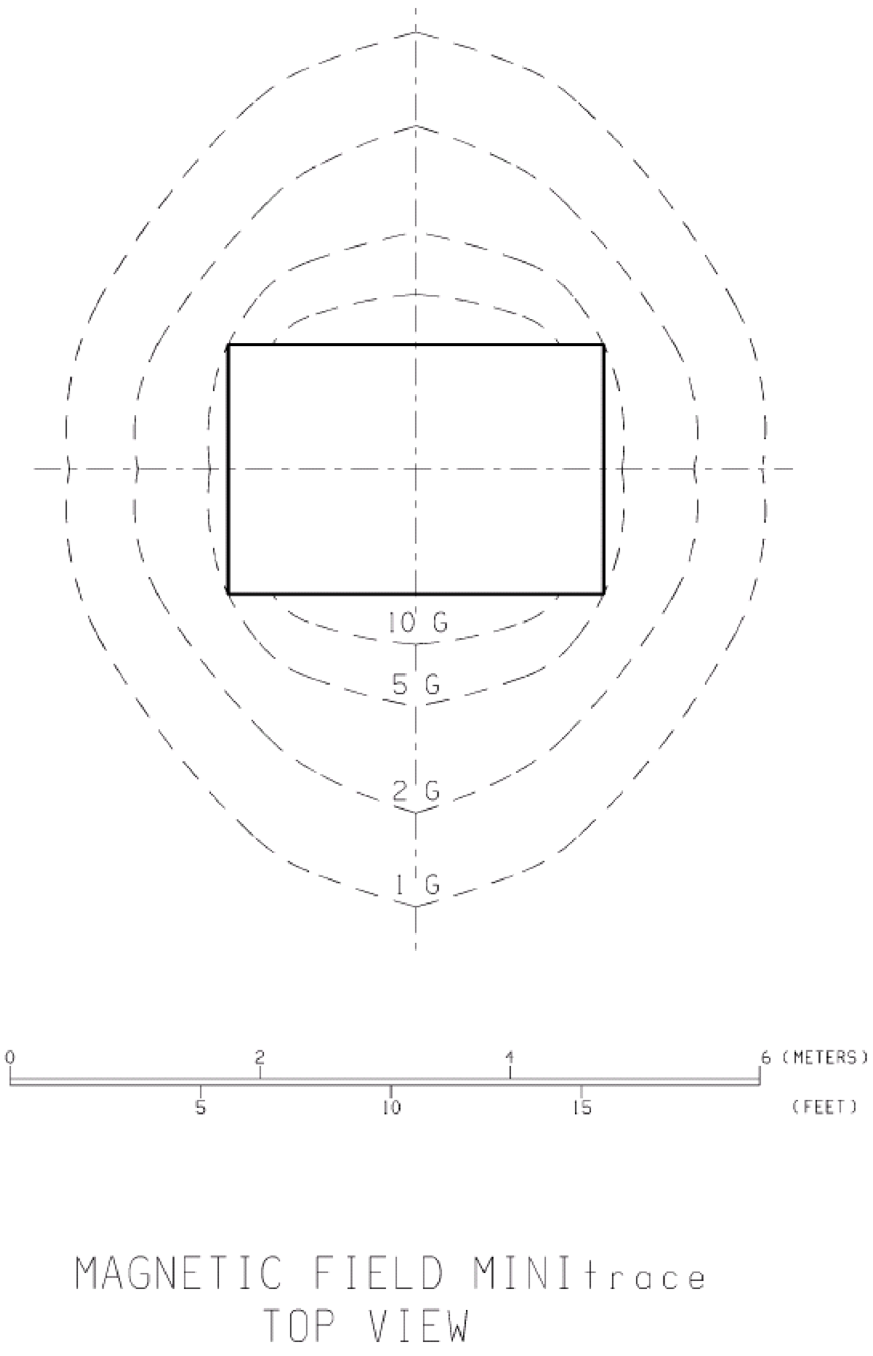
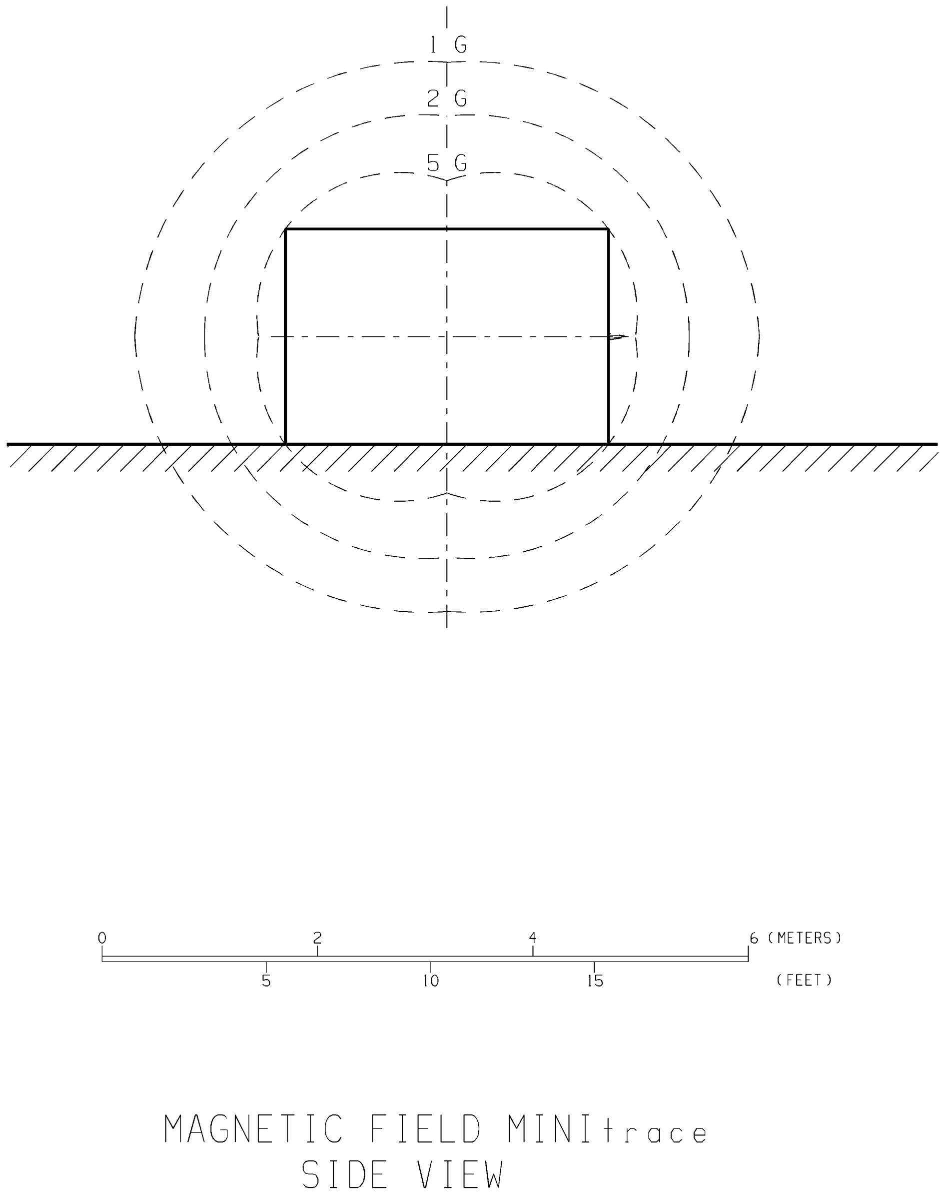


Figure 4-2: Cyclotron magnet field isogauss line plot, front view at midplane



5 Site environment

5-1 Introduction

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

5-2 Compliance with regulatory requirements

Note!
The CE marking information included in this manual is only applicable to MINItrace Qilin. MINItrace Magni is technology in development that represents ongoing research and development efforts. These technologies are not products and may never become products. Not CE marked.

This cyclotron system 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 this cyclotron system (including associated options) only when:

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

This cyclotron system 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

This cyclotron system has been tested for EMC according to the following standard:

- EN 61326-1:2020 concerning electromagnetic emission and immunity.
- Electromagnetic emission compliance:

Class A	This cyclotron system is intended for use in an industrial environment. This cyclotron system 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	This cyclotron system uses RF (radio frequency) energy only for their 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 General Control System allows for external interlock which 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 maximum 2000 m (6562 ft) above sea level.

5-5 Temperature and humidity specifications

Use the specifications listed in Table 5-1 for designing your heating, ventilation and air conditioning systems (HVAC systems).

Table 5-1: Temperature and humidity specifications

	Temp. range		Temp. regulation [°C (°F)]	Temp. change [°C/h]	Relative humidity [%]	Humidity change [%/h]	Max. room gradient [°C (°F)]
	[°C]	[°F]					
Cyclotron room[1]	18–25	65–77	± 3 (± 6)	3	30–60	5	3 (6)
Radiochem. lab[2]	18–25	65–77					
Other laboratories[2]	18–25	65–77					

1 Cyclotron room not expected to be regular working area.

2 Environment conditions for working personnel have to be specified by the customer.

5-6 Cooling requirements

5-6-1 Air cooling

The total **air-cooling** requirement for the cyclotron system is approximately 4.5 kW. These values do not include personnel, lights, water-cooling equipment or other equipment not included in the cyclotron system.

Care must be taken in locating the air conditioning supply and return ducts.

The ventilation system must comply with all applicable, federal, state and local rules and regulations for radiation areas.

Table 5-2: Air cooling requirements

	Cyclotron room		Control room	
	Watt	BTU/h	Watt	BTU/h
Cyclotron	-	-		
Control Cabinet (CCAB)	1000	3400		
Radio Frequency Power Generator (RFPG)	2000	6800		
Computer, monitor			< 500	< 1700
Roughing vacuum (mechanical) pump	100	340		
Diffusion pump	550	1870		
Helium cooling system	350	1190		
Service laptop for MINItrace Service System (MSS) software[1]	100	340		
Cyclotron Support Cabinet (CSC)	100	340		
Cables	200	680		

1 MINItrace Qilin only. Intermittent use.

5-6-2 Cooling water

An **external chiller** must be supplied and connected, by the customer, to the secondary cooling unit (a closed loop deionized water system), via the Cyclotron Support Cabinet (CSC; see Section 7-3-2 Water connections on page 93).

The external chiller (a cooling tower or a refrigeration system) must supply an inlet water temperature in the range 10–13°C. This is required to enable temperature regulation of the closed loop deionized cooling water system in the range 19–21°C.

A connection for **make-up water** to the secondary cooling unit must be provided by the customer. The make-up water is connected in the CSC (see Section 7-3-2 Water connections on page 93).

It is recommended that **floor drains** are provided in the cyclotron room and the radiochemistry laboratory as permitted/required by local code and health physics regulations. Floor drainage should be provided in all building trenches for water and electrical usage.

Figure 5-1: Cooling water system

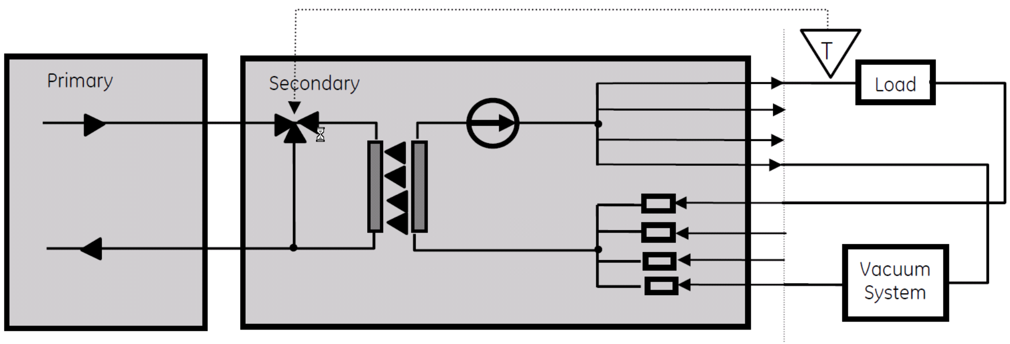


Table 5-3: Cooling water requirements

Component	Cyclotron room	
	Watt	BTU/h
Magnet coils	13 000	44 200
RF cavity	10 000	34 000
Ion source	600	2040
Diffusion pump	2000	6800
Targets	1000	3400
Control Cabinet (CCAB)	1000	3400
Radio Frequency Power Generator (RFPG)	7000	23 800

5-6-3 Primary cooling

The **primary cooling** system (the raw water system) is the water circuit connected to the customer water system.

The primary cooling water circuit is connected to the secondary cooling system via a customer connection point, for example, in the form of a panel with connections supplied by the customer (see Section 7-3-2 Water connections on page 93).

Table 5-4: Primary cooling system specifications/requirements

Parameter	Requirement	Comment
Availability	Continuous	
Flow	50–70 l/min (13–18 US gallon/min)	(No antifreeze added)
Inlet temperature to secondary cooling system	10–13°C (50–55°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]
System pressure	Maximum 6 bar (0.6 MPa, 87 psi)	
Differential pressure at 50 l/min (heat exchanger)	0.5–0.9 bar 0.75 bar with 20% antifreeze 0.80 bar with 40% antifreeze	(Antifreeze increases viscosity)
Capacity	Minimum 40 kW	
Load variation range	1–35 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 5-5: Facility water quality requirements

Parameter	Requirement
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 It is recommended to add a 300 µm high flow capacity filter on the facility cooling water supply line before entering the cyclotron cooling unit, see Section 7-3-2 Water connections on page 93.

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 5-5, an anti-scaling agent should be added to the cooling water.

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

5-6-4 Secondary cooling unit

The **secondary cooling** unit is a complete cooling water recirculation system for the cyclotron.

The secondary cooling unit (the fine water system) is a closed loop system for deionized water. In this water circuit a deionizer and a filter system ensures the conductivity level and that particles do not come into the cooling circuit.

5-6-5 Heatload to water

The cyclotron system can be operated in several different modes with various heat loads to the water cooling system. The normal heatload on the cooling water system when running is approximately 34 kW.

5-6-6 Fine water constant temperature

To maintain a constant temperature in the secondary circuit, a **shunt** regulates the primary circuit flow to the heat exchanger.

The shunt is a part of a system that regulates the primary water flow to the secondary cooling unit to maintain a temperature in the range 19–21°C, independent of heat load to the water system.

5-7 Lighting

Preparation and arrangements for lighting has to be done by the customer and recommended illumination is 500 lux in each room.

Emergency lighting is recommended in the cyclotron room and in other areas as needed.

5-8 Noise

To reduce background noise due to cabinet blowers, etc., acoustical ceilings, walls and floors are recommended.

Table 5-6: Typical noise level readings

Location	Noise level
Cyclotron room	70 dB
Radiochemistry lab	65 dB

5-9 Room ventilation

The entire PET facility should be divided into separate zones depending on the radiation levels. Typically, there are three different levels:

1 High radiation areas (cyclotron vault, hot cells)

2 Radiation areas

3 Unrestricted areas

WARNING!

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

Design the ventilation to transport the facility air from lower radiation level areas to higher radiation level areas. Consequently, the air exiting the cyclotron vault and hot cells 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.

5-10 Ambient radio frequency interference

The cyclotron system utilizes high power radio frequency to produce the potential voltages to accelerate the beam. The Radio Frequency Power Generator (RFPG) produces 10 kW at 101 ± 0.5 MHz. The RF power is contained within a grounded metal structure. The maximum RF noise leakage near the cyclotron is:

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

5-11 Pollution

The site must be clean prior to delivery of the equipment. Although individual components have filters for optimum air filtration, care should be taken to keep air pollution (dust) to a minimum.

Since static discharge can cause system failures or affect its operation, carpeting should be of the antistatic type or treated with an antistatic solution.

When cleaning tile floors, do not use steelwool since that can enter cabinet enclosures and cause internal shortcircuits.

Air locks for in and out passage gives the opportunity to wash hands, change clothes and shoes.

Hazardous gases/liquids and radioactive gases/liquids involved are listed below in Table 5-7.

Table 5-7: Hazardous gases and radioactive liquids

Gases	Hazards
Hydrogen (H_2) Methane (CH_4)	Risk for explosion in different mixing proportions with air. Always provide for good ventilation. Avoid open flames. After processing, close the respective valve on the gas supply panel by hand for double security.
Liquids[1]	**Hazards**
$[^{18}F]F^-$ (aq) $[^{13}N]NH_3$ (aq)	Liquid containing $[^{18}F]F^-$ or $[^{13}N]NH_3$ should be handled with special care. During storage, it should be kept in sealed bottles in lead boxes to prevent any unwanted contact. Never touch your eyes or mouth during work. If radioactive liquid is spilled on the skin, immediately wash with soap under running water.

1 Radioactive liquids vailable at product outlets or at the output of dedicated process units.

5-12 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.

5-13 Utility requirements

5-13-1 Compressed air supply

Compressed air, supplied by the customer, is provided in the Cyclotron Support Cabinet (CSC) in the cyclotron room (see Section 7-4 Compressed air connection on page 94).

Dry compressed air with a:

- pressure of 0.60–0.65 MPa (6.0–6.5 bar, 87–94 psi)
- minimum flow rate of 150 l/min

is required for:

- intermittent actuation of the pneumatic valve operators
- cooling of radiochemistry equipment

Compressed air service to the cyclotron should not be interrupted (i.e. no significant pressure loss) in case of power failure.

Compressed air outlets must be provided in the cyclotron room, the power supply room and the radiochemistry laboratory (if applicable).

5-13-2 Customer supplied gases

All **gas cylinders** and **regulators** (except the $^{18}F^{-}$ He carrier gas regulator, see Table 5-8, Table 5-9 and Figure 7-3), and **gas tubes** (not included in the cyclotron delivery) **must be supplied by the customer**.

The operation of the equipment delivered from GE HealthCare requires an operating supply of ion source gas, target and processing gases, cooling gas, etc. Gases, supplied by the customer, are provided in the cyclotron room by means of the gas supply panel (see Section 7-5 Gas piping interconnects on page 94).

The supply of ion source gas (H_2) and helium cooling gas (He) should be close to the cyclotron room.

Further, in the operation of the complete radionuclide production facility there is a need to transport the generated products to the radiochemistry laboratory for further processing. This distribution will be provided and installed by GE HealthCare.

It is essential that all gases with regulators are completely installed and available for use by the time of cyclotron start-up.

The listed gas specifications in Table 5-8 and Table 5-9 for:

- ion source gas
- target cooling gas
- process gases

indicate the minimum required gas purity and the recommended gas cylinder size.

WARNING!

Hydrogen (H_2) and deuterium (D_2) gas is explosive at certain mixing proportions with air. Provide adequate ventilation.

WARNING!

Methane (CH_4) gas is explosive at certain mixing proportions with air. 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 recommentd 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 column figures 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

Table 5-8: Gas supplies – auxiliary systems

Used for	Gas specification	Operating pressure [MPa (psi)]	Regulator pressure range [MPa (psi)]	Recommended cylinder size	Tube connection o.d.	Note
Ion source (operation gas)	H_2 (6.0)	0.5 ± 0.02 (73 ± 29)	0.04–1.0 (5.8–145.0)	50 l	1/8"	Pressure range determined by using a frit and setting hydrogen pressure on the regulator. ***Note!*** *The regulator pressure must not exceed 1.0 MPa (145.0 psi).*
Cooling, all targets	He (5.5)	0.16 ± 0.02 (23 ± 3)	0.04–1.0 (5.8–145.0)	50 l	1/8"	

5-13-2-1 Target gases

Table 5-9: Target gas specifications

Target	Gas specification	Operating pressure [MPa (psi)]	Regulator pressure range [MPa (psi)]	Recommended cylinder size	Tube connection	Note
^{18}F- (transport gas)	He (5.5)	0.5 ± 0.2 (73 ± 29)	0.04–1.0 (5.8–145.0)	50 l	1/8"	Tube from bottle splits in two lines by means of extra regulator on supply panel.
^{18}F- (operation gas)		2.5 ± 0.2 (363 ± 29)	0.0–3.5 (0.0–507.0)	50 l	1/8"	
$^{13}N\text{-}NH_3$ (transport and operation gas)	CH_4, methane (5.5)	0.45 ± 0.1 (65 ± 15)	0.04–1.0 (5.8–145.0)	50 l	1/16"	Long tubing and vertical distance between cyclotron and radiochemistry system may require higher pressure. ***Note!*** *The regulator pressure must not exceed 1.0 MPa (145.0 psi).*
$^{11}CO_2$ (target gas)	N_2 (5.5) + 1% O_2 (3.5)	0.9 ± 0.1 (130 ± 15)	0.04–2.1 (5.8–305.0)	50 l		
$^{11}CO_2$ purified (transport gas)	N_2 (5.5)	0.3 ± 0.1 (44 ± 15)	0.04–1.0 (5.8–145.0)	50 l	1/8"	Set pressure to 2.5 bar and adjust the flow with the needle valve. Flow should be 400 ± 50 ml/min.
$H_2{}^{15}O$ (target gas)	$^{15}N_2$ (5.5) + 1% O_2 (3.0)	0.9 ± 0.1 (130 ± 15)	0.0–1.72 (0.0–250.0)	0.4 l	1/16"	Very expensive gas Recommended cylinder: 0.4 l, 5 MPa (> 50 bar, > 725 psi)
$H_2{}^{15}O$ (transport gas)	Ar (5.5) + 5% H_2 (3.0)	0.3 ± 0.1 (44 ± 5 psi)	0.04–1.0 (5.8–145.0)	50 l	1/8"	Adjust pressure to achieve correct flow. Pressure range 2–3 bar. Flow should be 400 ± 50 ml/min.

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

5-13-3 Customer supplied gas regulators

Table 5-10: Gas regulator recommendations

Parameter	Requirement
Type/material	Should match the gas type and quality
Maximum primary pressure	200 bar
Secondary pressure range	As required by the application (see Table 5-8, Table 5-9)
Maximum flow	155 l/min, Cv = 0.02
Stability	+0.04 bar sec. @ -7 bar prim.
Connection	1/8" o.d. Swagelok™

5-13-4 Customer supplied gas tubes

Table 5-11: Gas tube recommendations

Parameter	Requirement
Material	Seamless and welded stainless steel
Quality/grade	Thermocouple cleaned and capped
Dimension	1/8" o.d.

5-13-5 Customer supplied liquids

Table 5-12: Target liquid specifications

Target	Liquid specification	
$^{18}F^-$	$[^{18}O]H_2O$, ^{18}O enrichment > 97%, deionized, sterile filtered Conductivity < 3.3×10^{-6} (S/cm) Sterile and free of pyrogens.	
	H_2O	> 99.9%
	Ca	< 0.2 ppm
	Mg	< 0.1 ppm
	Na	< 0.5 ppm
	K	< 0.2 ppm
	Fe	< 0.1 ppm
	NH_3	< 1 ppm
	F	< 0.3 ppm
	Br	< 0.2 ppm
	C	< 7 ppm
	pH	6.5 ± 0.2
^{13}N	$^{16}O–H_2O$, deionized, sterile filtered, 18 Mohm	

5-14 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.

5-15 Safety systems

The cyclotron system includes a number of interlock systems to ensure safe system operation.

The cyclotron system is however only a part of the entire PET facility and some of the safety systems must be provided by the customer.

These safety systems may include facility services, such as, ventilation, fire protection and customer-supplied power and water systems connected to the cyclotron.

5-15-1 Illuminated signs

Two illuminated information signs are located on the top of the radiation shield:

- RADIATION SIGN Illuminated when ion source power supply (PSARC) is on.
- MAGNET SIGN Illuminated when main coil power supply (PSMC) is on.

5-15-2 Mains Distribution Panels (MDP) safety systems

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 the activated push button must be manually reset in order to restore power to the system.

Service personnel must be able to lock-out and tag-out (LOTO) all individual outgoing mains distribution lines, to prevent accidental electrocution.

5-15-3 Customer Interface Connector (CIC)

From the cyclotron system, the customer can get some hard-wired status information. The information is available as two galvanically insulated relay contacts in the 25-pole D-Sub connector. The customer is free to use these contacts as desired. Voltages and currents up to maximum 24 V_{AC}/V_{DC}, 2 A are accepted.

The status information available is:

- Magnet ON Closed contact between terminal 3 and 15 when main coil power supply (PSMC) is on.
- Radiation ON Closed contact between terminal 2 and 14 when ion source power supply (PSARC) is on.

The status information described above is normally used to alert people with illuminated signs activated by the status outputs.

The customer also has access to two hard-wired interlock inputs to the cyclotron system. These two loops should be independent of each other and potential free. The first loop is connected between connector pin 8 and 20, the second between pin 7 and 19.

When one of the two loops is broken, **the beam is immediately stopped**.

The interlock inputs are normally connected to door switches and radiation detector systems.

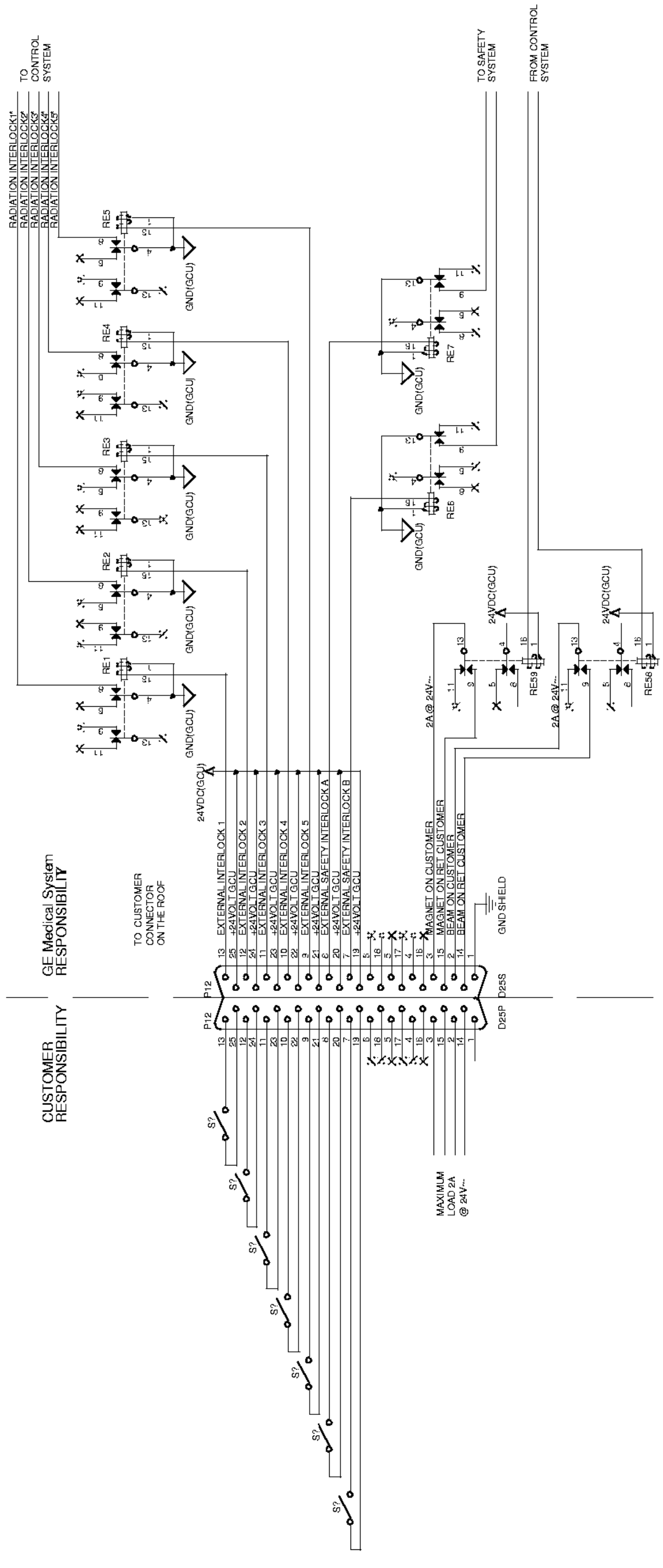
The customer also has access to five safety status inputs. These statuses will show up on the operator's console but **will not stop the beam**. They can be used for, for example, radiation monitoring. All five inputs should be *separate* and *potential free* loops and are connected to connector pins 13 and 25, 12 and 24, 11 and 23, 10 and 22, 9 and 21.

The location of CIC is on the top of the Cyclotron Support Cabinet (CSC) near the cable duct.

All connections for both in and outgoing signals are pins in a 25-pole D-sub connector.

For more details, see Figure 5-2.

Figure 5-2: Customer Interface Connector



5-15-4 Safety systems not included in the cyclotron system

Since the cyclotron system is available in a wide range of countries with different regulations, it is not possible to recommend safety systems applicable everywhere.

5-15-4-1 Radiation monitoring system

Normally a radiation safety system with a number of distributed sensors is used to monitor radiation levels. The sensors can be placed in chemistry areas, in the cyclotron room and in ventilation systems connected to the cyclotron room and chemistry areas.

6 Power requirements

6-1 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 cabinets:

1. Radio Frequency Power Generator (RFPG)
2. Control Cabinet (CCAB)

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 Control Cabinet (CCAB) supplies power to the following subsystems:

1. Ion Source Power supply (PSARC)
2. Magnet Power Supply (PSMC)
3. Cyclotron Support Cabinet (CSC)
4. Control power for Radio Frequency Power Generator (RFPG)
5. General Control Unit (GCU)

The Cyclotron Support Cabinet (CSC) supplies power to the following subsystems:

1. Vacuum system
2. Helium cooling system
3. Secondary water cooling unit
4. Radiation shield drive system

Thus, there are two power feeds for the cyclotron:

- One 25 kVA to the Control Cabinet (CCAB)
- One 25 kVA to the Radio Frequency Power Generator (RFPG)

On top of each cabinet, there are feed-throughs having diameters from 23 to 41 mm.

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 one with a large enough diameter to accommodate the passage of any cable with its connector, with all other cables in the conduit. (Regarding planning power feeds to the cyclotron system, see Section 2-4 Cabling considerations on page 29.)

Position the Mains Distribution Panel (MDP) in the vicinity of the cyclotron cabinets, that is, the Control Cabinet (CCAB) and the Radio Frequency Power Generator (RFPG). 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.

GE HealthCare will specify the number of circuit breakers and their loads for the particular application.

Table 6-1: Power distribution

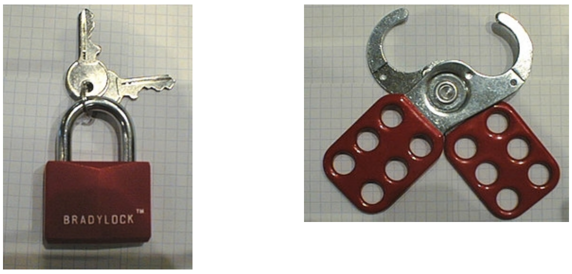
Parameter	Specification
Total power consumption	40 kW (operation)
	3.5 kW (standby)
Installed power	50 kVA
Wire system	3 phase, 5 wire
Variation of nominal line voltage (at CCAB and RFPG input)	± 10%
Maximum allowed THD (Total Harmonic Distorsion)	5%

6-2 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 and CB2 in Figure 6-2 in the MDP must be lockable in the OFF position with a padlock or a Lockout hasps (see Figure 6-1).

Figure 6-1: LOTO Padlock and Lock-Out hasps



6-3 Single-phase outlets

There should be at least four single-phase electrical utility outlets for powering, for example, computers and monitor.

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.

6-4 Emergency facility lighting power

Emergency power is recommended for emergency facility lighting.

6-5 Power requirements

The cyclotron system is designed for common line voltages available throughout the world: 400 VAC and 480 VAC (with a variation of the nominal line voltage of ± 10%), 3 phase, 5-conductor, 50/60 Hz. One power cable for the mains input supply connects to the Mains Distribution Panel (MDP), which is the responsibility of the customer.

From the MDP, both cabinets (the Control Cabinet, CCAB, and the Radio Frequency Power Generator, RFPG) are fed with individual power cables. Size requirements of the power cables must be specified individually for each PET site to meet regulations in the country where the cyclotron is to be installed. However, please note that **the cable outer diameter** should be 23–40 mm and **the cable area** should be between 6–25 mm^2. The **maximum acceptable voltage drop** from the MDP to the cyclotron subsystems is 1%.

Design of power cables can be done with data from the Installed power column in Table 6-2.

Table 6-2: Mains input power

Subsystem	Installed power in kVA	kW during subsystem operation
Control Cabinet (CCAB)	25	20
RFPG	25	19
Computer, monitor	(1)	(0.5)
Total	**50 (51)**	**39 (39.5)**

6-6 Recommended power distribution system

6-6-1 Input voltage

The drawing in Figure 6-2 shows the mains distribution for cyclotron system. The accepted line voltages (400 VAC or 480 VAC) is possible because the input transformers in each subsystem are designed with a number of different strappings.

If the power distribution system does not meet the specifications, a separate transformer is required (see Section 6-6-2 Transforming other site voltages on page 80).

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.

6-6-2 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 transferred 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.

6-6-2-1 To step up/down a 5-conductor site system

Use a Y–autotransformer to feed all subsystems.

6-6-2-2 To step up/down a 4-conductor site system

Use a Delta-Y full transformer to generate a 5-conductor that feeds all subsystems.

6-6-2-3 To only generate a 5-conductor site system

Use a Delta-Y full transformer to generate a 5-conductor that feeds all subsystems.

6-6-3 Emergency stops

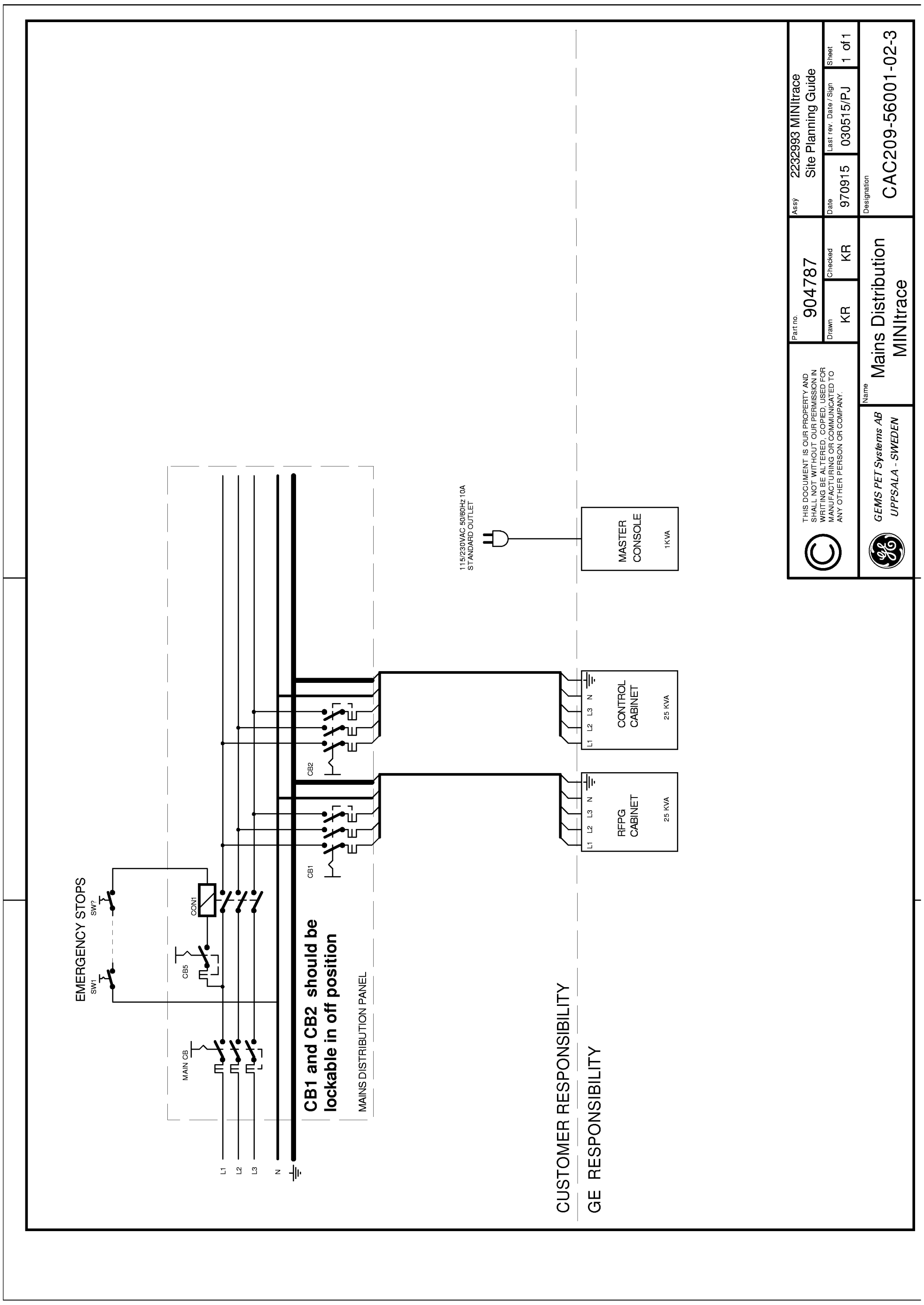
The customer shall provide and install, in accordance with all applicable federal, state and local electrical code requirements, a Low Voltage Low Energy protective disconnect device with local and multi-point (at least one in cyclotron room and one in power supply room) remote control capability to disable all power to the Mains Distribution Panel for the cyclotron. See drawing in Figure 6-2.

The drawing in Figure 6-2 also identifies the customer and GE HealthCare responsibilities for mains power supply to the cyclotron system.

6-7 Residual Current Circuit Breaker (RCCB)

If a Residual Current Circuit Breaker is used, it should handle a minimum of 100 mA leakages current.

Figure 6-2: Cyclotron mains distribution, UP904787 (CAC209-56001)



6-8 UPS (Uninterruptible Power Supply)

It is possible to connect the cyclotron system to an UPS (Uninterruptible Power Supply). 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 experienced 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. 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 computer equipment, external chiller for water cooling, compressed air supply and air condition.

It is highly recommended to install a small UPS to handle computer equipment.

Note!
The data in Table 6-3 is based on the data in Table 6-2 and does NOT include all periphery subsystems that are connected to the cyclotron system, such as external chiller etc. The data for the computer equipment does NOT include printer or other peripheral.

Table 6-3: Recommended sizes of the Uninterruptible Power Supply (UPS)

System	Power consumption [kVA]	Recommended UPS size [kVA]
Cyclotron system	50	60
Computer equipment	0,5	1

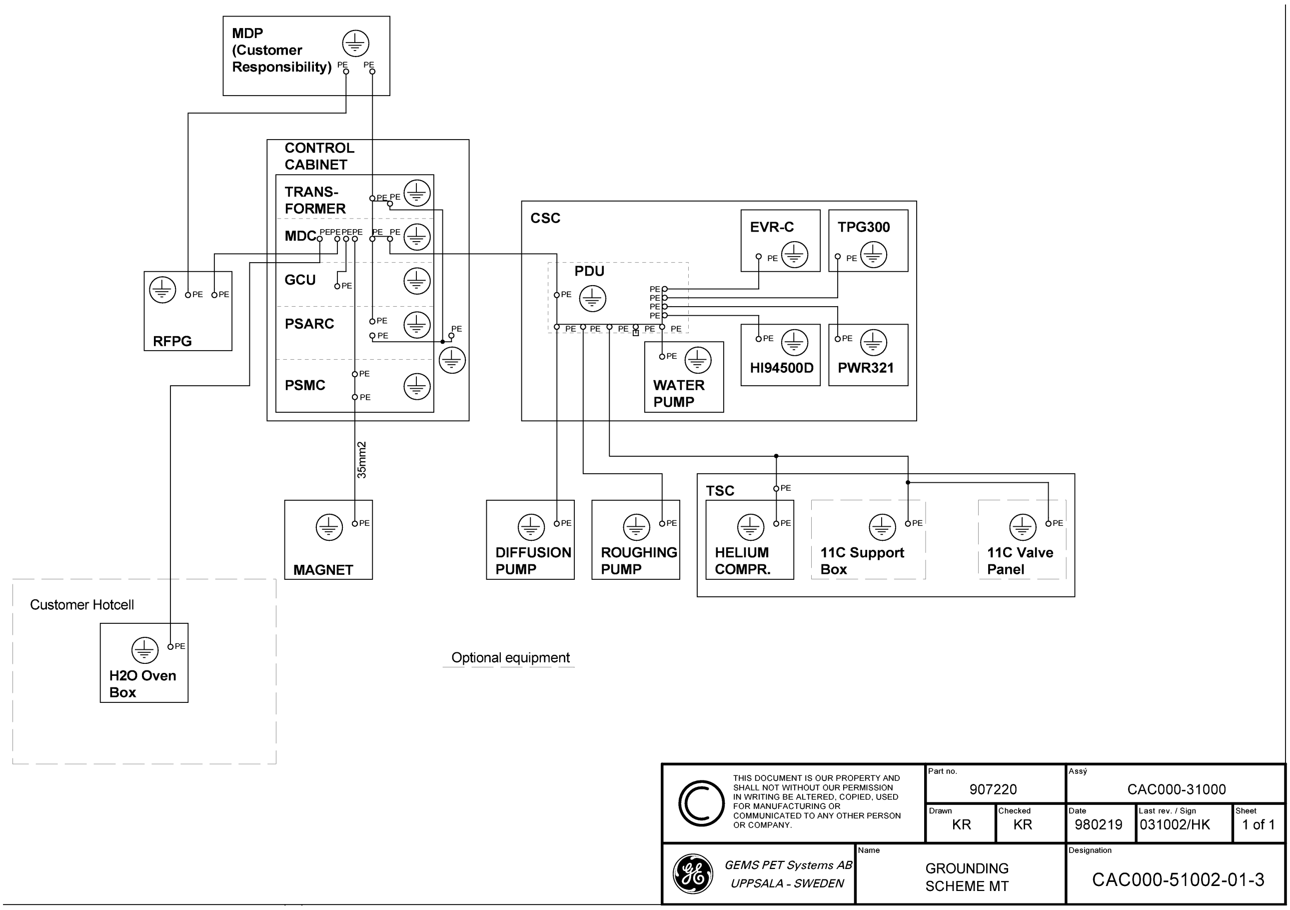
GE HealthCare recommends performing a power survey prior to the installation of the cyclotron system. A quotation on the survey can be requested from GE HealthCare.

6-9 System ground

The cyclotron protective grounding schematic is shown in drawing CAC000-51002-xx-3 (Figure 6-3). 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 6-3: Grounding scheme, CAC000-51002



7 Interconnect data

7-1 Introduction

This chapter addresses cable, cooling water interconnections, compressed air piping and gas piping as well as customer-furnished components required for the cyclotron system. The following topics are discussed:

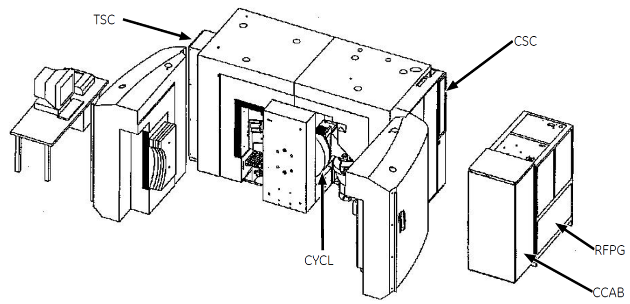
- Overall cable interconnects
- Signal cable interconnects
- Cooling water piping interconnects
- Compressed air piping
- Gas piping interconnects
- Miscellaneous components typically provided by a contractor

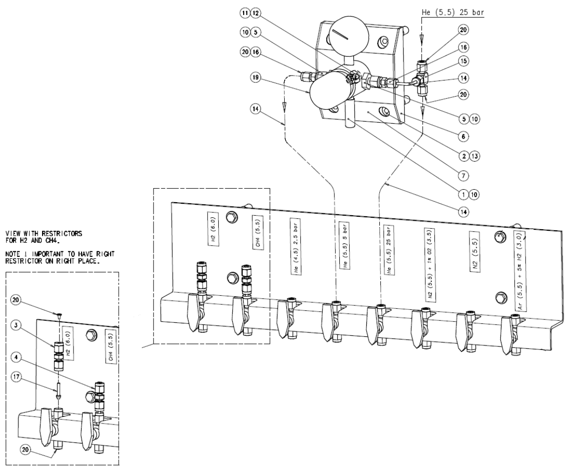
7-1-1 Component designators

GE HealthCare uses a component designator system as a means of identifying all cyclotron system components in a consistent manner. All subsystem cabinets and other components are referred to by their component designators in the interconnect diagrams and tables of this section. (For example, the Power Supply for Magnet Coils is referred to as PSMC).

Refer to Table 7-1 for all component designation.

Table 7-1: Component designation

Cyclotron system	Component designation	Description
	TSC	Target Support Cabinet (incl. He compressor, Liquid Target Fillers (LTF))
	CSC	Cyclotron Support Cabinet (incl. Power Distribution Unit (PDU), Vacuum Control Unit (VCU), secondary cooling unit, Radiation Shield Drive Unit (RSDU) and Customer Interface Connector (CIC))
	RFPG	Radiofrequency Power Generator Cabinet
	CCAB	Control Cabinet (incl. Power Supply for Magnet Coils (PSMC), Ion Source Power supply (PSARC) and General Control Unit (GCU))
	CYCL	Cyclotron (incl. vacuum system and target system)

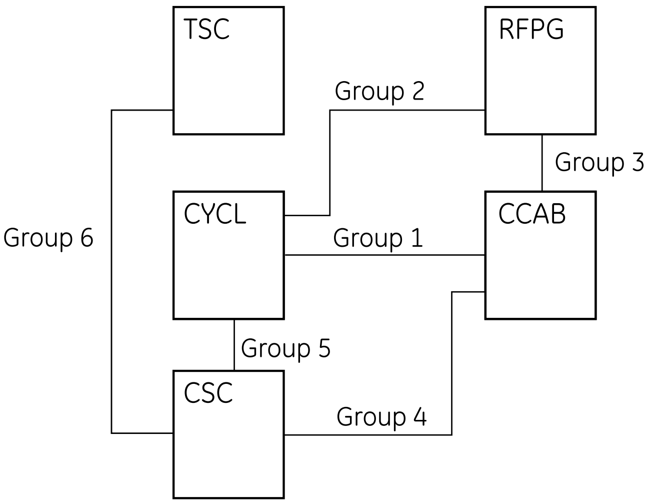
Water, air and gas piping connections	**Component designation**	**Description**
		Gas supply panel
GE HealthCare service equipment	**Component designation**	**Description**
MINItrace Service System	MSS	Service laptop (MINItrace Qilin only)

7-2 Cable interconnects

7-2-1 (Group) cable routing

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

Figure 7-1: Group cable interconnect diagram



7-2-2 Cable interconnect list

Table 7-2 contains information on the cabling interconnects between all cyclotron system components. Interconnects in the system include the following:

- All GE HealthCare supplied subsystem secondary (not mains) power cables
- All GE HealthCare supplied control signal cables

Note that the mains power distribution and emergency shutdown cabling are not included in this table. Refer to Chapter 6 Power requirements, for details regarding the mains power connections and emergency shutdown circuit wiring.

The interconnection cables supplied by GE HealthCare are routed in metallic cable ducts supplied by GE HealthCare.

Control signal cables and secondary power cables should if possible be separated when routed in the same wire duct. The customer must make sure that the cable routing method meets all applicable federal, state and local electrical code requirements.

7-2-3 Definition of terms

The following terms are used in Table 7-2:

Group number	Identifying number referring to bundles (i.e. groups) of tables as shown in Table 7-2.
Area	Cross-sectional area of the combined cables in a group. ***Note!*** *The group area was found by adding up the circular cross-sectional areas of all individual cables within a group. It does not take any fill factors or air space between cables into account. Adhere to applicable electrical codes for fill factors.*
Usable length	Maximum length of a cable between respective cabinets. ***Note!*** *Actual usable length will depend upon the point of access (cabinet top or bottom) and the routing within the cabinets. Worst case (i.e. shortest) lengths are shown. The difference will be about 1.2 m (4 feet).*
Cable id.	Unique name assigned to each GE HealthCare supplied cable. ***Note!*** *This number must be used when making special cable orders*
Cable diameter	Diameter of an individual cable.
Cable leads (AWG/No.)(mm^2/No.)	Gauge (size) of wires and total number of wires within a given cable

Table 7-2: Interconnections list

Group no.	Group area mm² (in²)	Between units		Usable length m (ft)	Cable id.	Cable diam. mm	Connectors		Notes
		From	To				From	To	
1		CCAB	CYCL	40 (120)	PSARC, JHV1	6	SHV	SHV	
					PSMC+	12	Open	Open	Power cable
					PSMC+	12	Open	Open	Power cable
					PSMC-	12	Open	Open	Power cable
					PSMC-	12	Open	Open	Power cable
					PSMC GND	12	Open	Open	Power cable
2		RFPG	CYCL	25 (76)	RF Power	55	EIA 15/8"	EIA 15/8"	See notes regard COAX install. req.
					SKA	5	BNC	BNC	
3		CCAB	RFPG	5 (15)	GCU, P9	13	D37	D37	
					GCU, P10	9	D15	D15	
					MDC, Line	10	Open	Open	Power cable
				10 (30)	SCU LAN Network switch		RJ45	RJ45	
4		CCAB	CSC	40 (120)	GCU, P13	10	D25	D25	
					GCU, P14	13	D37	D37	
					GCU, P15	10	D25	D25	
					GCU, P17	13	D37	D37	
					GCU, P18	13	D37	D37	
					MDC, Line	10	Open	Open	Power cable

Group no.	Group area mm² (in²)	Between units From	To	Usable length m (ft)	Cable id.	Cable diam. mm	Connectors From	To	Notes
5		CSC	CYCL	5 (15)	ACB, P4	10	D25	D25	
					ACB, P6	10	D25	D25	
					ACB, P1	13	D37	D37	
					TPG, IKR	6	SHV	SHV	
					TPG, PI1	5	C91E	C91E	
					TPG, PI2	5	C91E	C91E	
					BV	9	7pole	Open	
					RV	9	7pole	Open	
					VV	6	3pole	Open	
					HVV	6	3pole	Open	
					HVV sw	8	7pole	Open	
					DP Temp sw	6	Open	Open	
					RP	8	Open	Open	
					CP	8	Open	Open	
					DP	11	4pole	Open	
					He Comp	8	Open	Open	
					SH Door SW	8	Open	Open	
					SH Door L Motor	7	Open	Open	
					SH Door R Motor	7	Open	Open	
					Ind Lamp	7	Open	Open	
6		CSC	TSC	10 (30)	ACB, P9	9	D15	D15	
					ACB, P10	9	D15	D15	
					ACB, P11	9	D15	D15	
		CCAB	Workstation	50 (150)	Router		RJ45	RJ45	MINItrace Magni

Group no.	Group area mm^2 (in^2)	Between units		Usable length m (ft)	Cable id.	Cable diam. mm	Connectors		Notes
		From	To				From	To	
		CCAB	Master	50 (150)	Network switch		RJ45	RJ45	MINItrace Qilin

Table 7-3: Connector dimensions

Connector type	Size	Diameter/length [mm]
Cannon D-Sub	D9 D15 D25 D37	65/61 70/61 79/61 92/61
16-A 3-phase connector		82/127
SHV		15/53
BNC		12/30
C91E		20/75
1 5/8" COAX		51/See note below
7 pole round		29/75
4 pole round		29/57
3 pole DIN43650A		35/60

Note!
The RF power feed to the cyclotron. This feeder cable is 1–5/8" coaxial cable, FLEXWELL HF 1-5/8" Cu 2Y, having an outer diameter of approximately 51.0 mm (2.01").

The RF power feed cable has the minimum bending radius as follows:

- single bending – 180 mm (7.1")
- repeated bending – 550 mm (21.7")

The RF power feed cable length must correspond to half the wavelength at 101 MHz, i.e. it must by an integer multiplier value of 1.41 m (4.63 ft):

1.41 m
2.82 m
4.23 m
5.64 m
…
…
…
23.97 m
25.38 m

7-3 Water piping interconnects

7-3-1 Secondary cooling unit

Cooling issues in general are discussed in Section 5-6 Cooling requirements on page 61. A sketch of the cooling water system is shown in Figure 5-1.

The major part of heat dissipated by the cyclotron system is removed by the secondary cooling unit. This unit uses deionized water in a closed loop as the cooling media for the cyclotron and associated power supplies in Control Cabinet (CCAB) and Radio Frequency Power Generator (the RFPG).

The secondary cooling unit is integrated in the cyclotron system. It is placed in the Cyclotron Support Cabinet (CSC). See Table 7-1.

Connections for primary water (raw water) and make-up water are described on the following pages.

7-3-2 Water connections

The customer is responsible for the supply of **primary water** at a specified temperature and flow, as well as **make-up water** connection. Some requirements and recommendations are as follows (see also Section 5-6-3 Primary cooling on page 62):

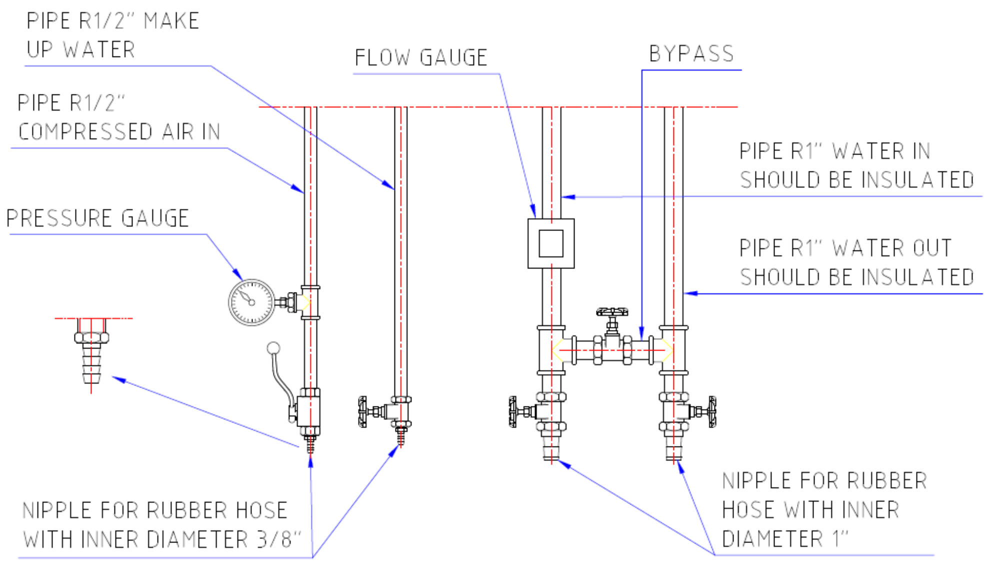
- Use appropriate materials in the primary water circuit:
  - Stainless steel is preferred. Copper can be used, but is the second choice.
  - Plastic tubes can and have been used, but in GE HealthCare's experience, associated plastic fittings are less reliable long term.
  - Iron/carbon steel piping/tubing **should never** be used.

- Connectors (see Figure 7-2):
  - Primary water: nipple for hose with ID 1" (25 mm)
  - Make-up water: nipple for hose with ID 3/8" (10 mm)

- Flow: 50–70 l/min (see Section 5-6-3 Primary cooling on page 62 for details)
- Temperature: Max. 10–13°C (50–55°F) (see Section 5-6-3 Primary cooling on page 62 for details)
- Pressure drop over pipe connections to the water system at normal operation (50 l/min): 0.5–0.9 bar (see Section 5-6-3 Primary cooling on page 62 for details).

A panel with connections and shut-off valves for primary water and make-up water should be installed near the cyclotron (see Figure 7-2).

Figure 7-2: Customer-supplied water and air connections



Note!
To minimize the risk of clogging in the heat exchanger, it is recommmended to install a high-flow filter (300 µm, ~150 l/min) on the customer side. A filter like this is usually bulky and might require maintenance/cleaning. It is therefore recommended to mount it on an easily accessible position, for example, on a wall near the cyclotron. The filter should be mounted in-line with the primary cooling water feed.

7-4 Compressed air connection

The customer is responsible for the supply of clean, dry air (0.60–0.65 MPa, 150 l/min) to the system (see Section 5-13-1 Compressed air supply on page 67 for details).

A 3/8" (10 mm) hose connector should be provided, for example, on the panel with customer water connections (see Figure 7-2).

7-5 Gas piping interconnects

7-5-1 Gas connections at the supply panel

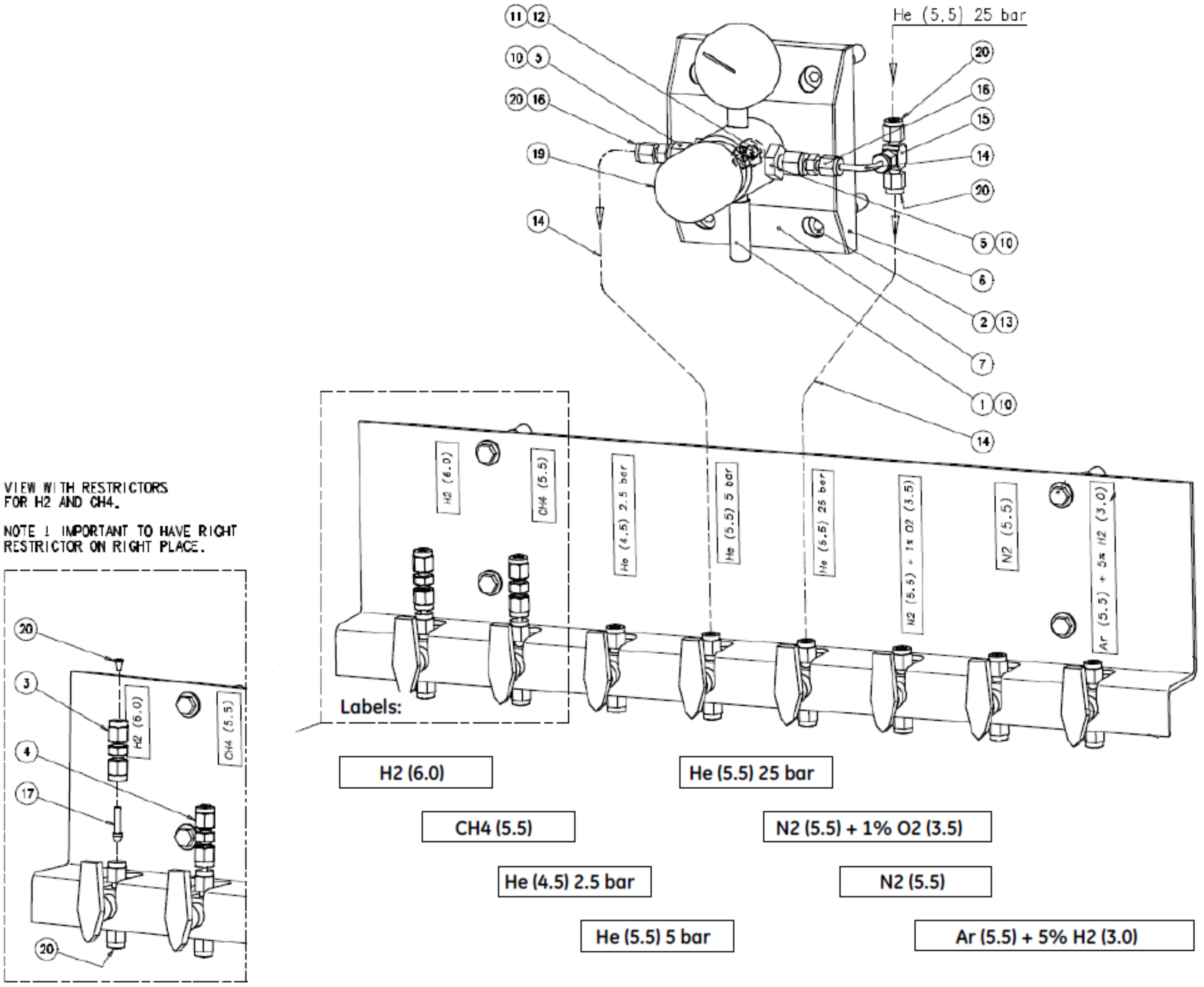
Gases, supplied by the customer, are provided in the cyclotron room by means of the gas supply panel, see Figure 7-3.

Note!
The gas supply panel, including pipes to the cyclotron, water hoses to the Control Cabinet (CCAB) and water hoses to the Radio Frequency Power Generator (RFPG) is part of the GE HealthCare delivery.

In order to meet the specification of high radiochemical purity, the high quality tubing provided by GE HealthCare (between the gas supply panel and the cyclotron) have been purged according to a special washing procedure.

It is important to avoid contamination by media other than those recommended by GE HealthCare.

Figure 7-3: Gas supply panel (part of the GE HealthCare delivery), gas piping



7-5-2 Gas connections at the gas supply panel – customer responsibilities

The customer is responsible for the supply of the necessary ion source gases, process gases and target cooling gases to the gas supply panel, as follows:

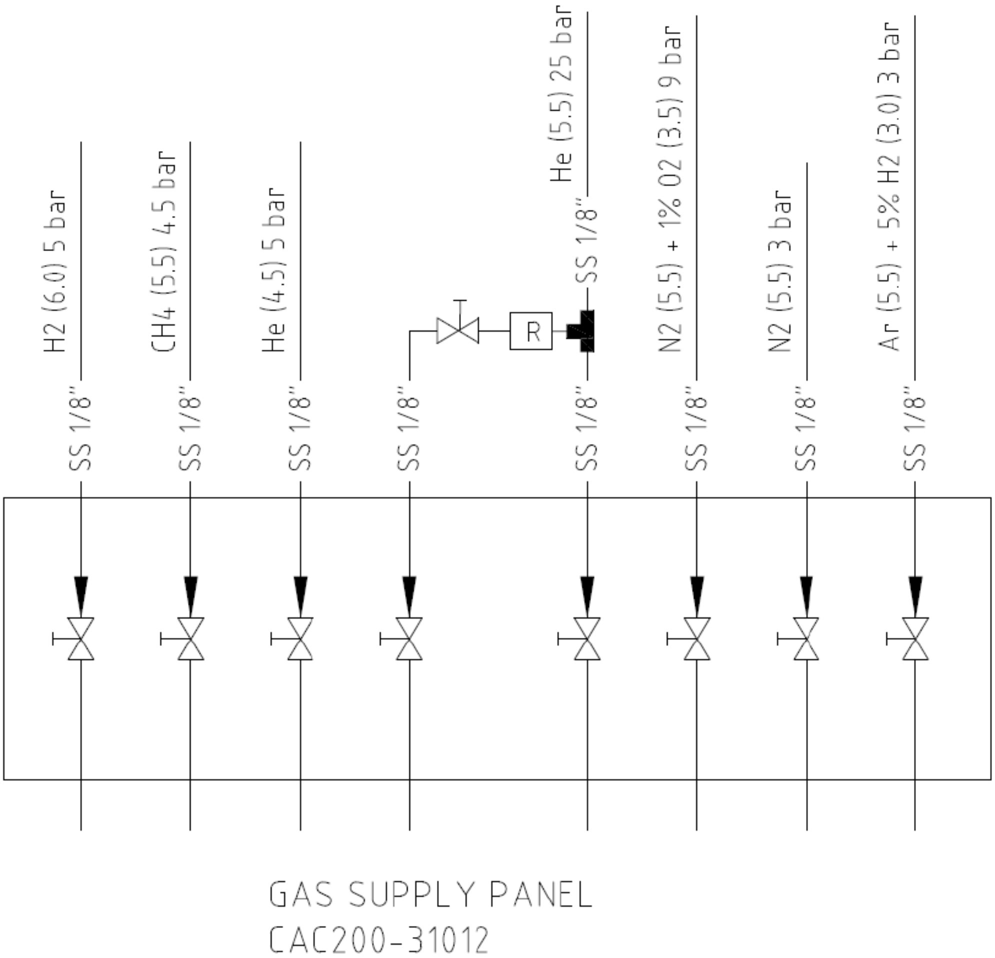
Note!
The customer takes on the responsibility to avoid contamination of gases by installing clean, high quality tubes. Tubes shall meet the GE HealthCare specifications (refer to the site-specific pipe work drawing), and each tube shall be terminated with a filter to avoid foreign impurities to be entered into cyclotron gas systems.

Installation of gas tubes must be performed by specialist, and all gas tubes have to be free from impurities at the point they enter the cyclotron system. Do not let tubing jeopardize gas quality!

Note!
Federal, state or local regulations and laws may apply to the installation of gas bottles and regulators. The customer must make sure that the gas bottles cannot tilt or fall over. They are to be secured by bars, chains or such.

Note!
It is essential that all gases with regulators are completely installed and available for use by the time of the cyclotron start-up.

Figure 7-4: Gas supply panel piping – customer responsibilities



7-5-3 Gas connections to hot cell

Up to 250 m stainless steel o.d. 1/8" tube is included in the GE HealthCare standard installation, and is a part of the GE HealthCare delivery.

For information about duct dimensions needed for gas and liquid tubes, see Section 2-5-2 Floor ducts for radioactive gases, liquids, and solids on page 31.

7-6 Contractor-furnished components

This section lists contractor-furnished components and details for connections to the cyclotron system.

Table 7-4: Contractor-furnished electrical component and wiring

Associated equipment	Material and labor provided by customer contractor
Mains Distribution Panel	Provide and install Mains Distribution Panel (MDP) with lockable circuit breakers. Provide mains power cables between MDP and cyclotron subsystems.
Emergency shutdown buttons	Provide and install wall switch box for single push button stations flush mounted. Provide red emergency shutdown push button switch with a guard to prevent inadvertent actuation. Also provide nameplate "SYSTEM EMERGENCY SHUT-DOWN". Locate near each exit in the cyclotron room. See Chapter 6 Power requirements.
Protective disconnect device	Provide and install protective disconnect device with device 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 computer equipment	Provide and install power outlets for computer(s), monitor, etc.
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 Customer Interface Connector on top of the Cyclotron Support Cabinet (see Section 5-15-3 Customer Interface Connector (CIC) on page 73).

Table 7-5: Contractor-furnished cooling water components and piping

Associated equipment	Material and labor provided by customer contractor
Cooling water piping	Provide all primary (facility) cooling water piping to the secondary cooling unit. Provide piping for make-up city water supply to the secondary cooling unit .

Table 7-6: Contractor-furnished gas piping components

Associated equipment	Material and labor provided by customer contractor
Gas regulators	Provide gas regulators for all gases required for cyclotron operation.
Gas tubes	Provide clean, high-quality tubes between the gas bottles and the supply panel.
Compressed air supply	Clean, dry air, 0.6 MPa, 150 l/min. See Section 5-13-1 Compressed air supply on page 67.

8 Shipping and delivery data

8-1 Shipment

All equipment is carefully packed in wooden crates at the factory. For delivery to most installations the crates will be shipped in containers (if applicable the crates will be sent by truck). Refer to Table 8-2 for crate dimensions.

The magnet and the radiation shield are shipped in open top containers and all other crates in a box container type.

8-2 Storage requirements

If, for any reason, the equipment needs to be stored before installation it must be stored in a warehouse protected from weather. The storage temperature should be between 5°C (41°F) and 40°C (104°F) and the relative humidity between 20% and 70% (non-condensing). An area of 25 square meters will be adequate.

8-3 Rigging requirements

Equipment transported to the customer site in standard 20 feet containers:

- Cyclotron
- Radiation shield
- Support equipment

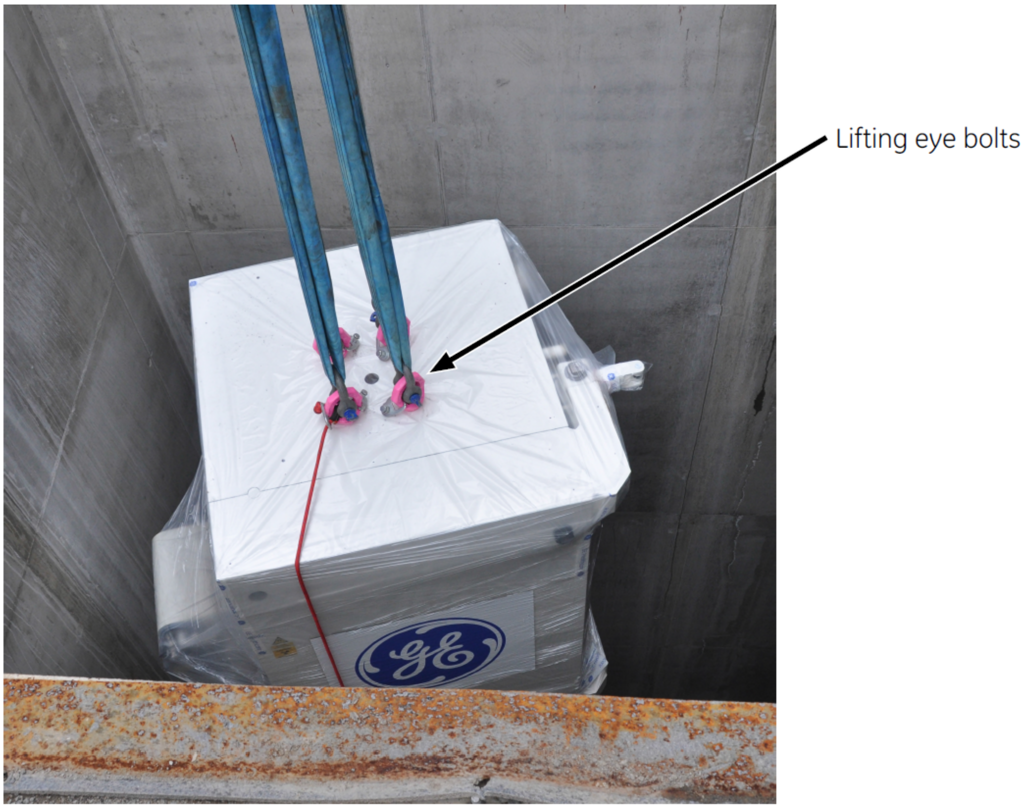
An off-loading area must be prepared in the vicinity of the installation entrance for a heavy mobile crane to unload the cyclotron and radiation shield. It is recommended that the crane can lift the cyclotron directly from the container into the installation entrance. It is also desirable to bring the cyclotron, from the installation entrance to the final position, with a minimum number of turns.

The support equipment can be off-loaded with a fork-lift truck.

With the exception of the vacuum system and the radiation shield, the cyclotron and its subsystem cabinets arrive completely assembled. An experienced rigger is required to plan and supervise the unloading of the system. The easiest way to unload the cyclotron is by heavy mobile crane. The cyclotron 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.

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 8-3-1 Lifting straps and eye bolts on page 101.

Figure 8-1: Cyclotron magnet with lifting eye bolts



Choose the most direct rigging route from the entrance to the PET suite, as corners can be difficult to navigate. Also take both the weight of the magnet and the weight of the rigging equipment into consideration when you plan the route. A structural engineer is required to analyze the cyclotron room and magnet rigging route, to determine the load bearing capacity. Structural reinforcement may be required along the magnet rigging route. When mounted, the lifting fixture increases the height of the cyclotron by about 250 mm.

8-3-1 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 8-2). 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 8-2: 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]
Shield, left rear (3)	12500	710
Shield, right rear (3)	11100	640
Shield, left door (2)	8300	560
Shield, right door (2)	8110	540
Accelerator (4)	10700	260
RFPG cabinet (4)	750	960
Control Cabinet (CCAB) (4)	380	710
Cyclotron Support Cabinet (CSC) (2)	240	360
Target Support Cabinet (TSC) (2)	150	770

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.

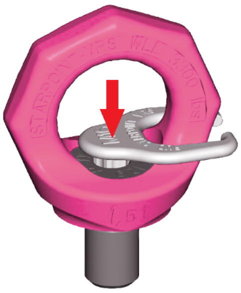
Swiveling lifting eye bolt

All heavy parts are equipped with swiveling lifting eye bolts (see Figure 8-3). 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 8-3: Swiveling 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.

8-4 Crate dimensions

Table 8-2: Crate dimensions

Crate content	Dimension (cm) W × D × H	Crate weight (kg)
Radiation shield, right rear	180 × 140 × 210	11 100
Radiation shield, right door	180 × 74 × 210	7600
Radiation shield, left rear	180 × 140 × 210	12 900
Radiation shield, left door	180 × 74 × 210	8300
Cyclotron Support Cabinet (CSC)	230 × 130 × 76	400
Target Support Cabinet (TSC)	230 × 130 × 76	200
Control Cabinet (CCAB)	97 × 78 × 190	600
RFPG cabinet	135 × 94 × 208	850
Vacuum system and cyclotron parts	115 × 180 × 140	600
Magnet/cyclotron	113 × 110 × 203	11 000
RF cable	150 × 150 × 15	20
Cable channels	300 × 21 × 11	20
Rigging tools	120 × 80 × 120	750

9 Pre-installation checklist

9-1 Introduction

“Pre-installation” refers to work necessary to plan and prepare a site for delivery and installation of equipment. Delay, confusion and waste of manpower can be avoided by completing pre-installation work. It is recommended to have a GE HealthCare service representative make on-site inspections during construction.

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

9-2 General installation reminders

- Have final site construction drawings been reviewed by the GE HealthCare site planning group?
- Have vehicle-parking arrangements been made for installation personnel?
- Is temporary storage space available for use during installation?
- What is the hospital smoking policy?
- Are first aid kits and nonferrous fire extinguishers available at site?
- Have facility arrangements been made for refuse disposal during installation?

9-3 Preparations required in advance of system delivery

The items below must be completed before system delivery. A site inspection by GE HealthCare service representative must be completed before system delivery to ensure site readiness.

- Are all walls, floor and ceiling in the cyclotron room essentially complete except for any removable sections?
- Has a clear rigging route to the cyclotron room been defined for magnet installation (see Section 2-3 Minimum access requirements on page 29)?
- Is a secure space available to store equipment on site?
- Have arrangements been made for the use of special rigging equipment for moving the magnet into the cyclotron room?
- Has work in the cyclotron room been completed or suspended and the cyclotron room closed off to provide a dust-free, closed environment?
- Has all equipment been removed from the cyclotron room to allow space for the magnet with rigging equipment?
- Are 24-hour water and 24-hour power available?
- Have necessary conduits or raceways for power and signal cables been installed?
- Has a rigging route been defined for equipment (see Section 2-3 Minimum access requirements on page 29)?
- Does incoming power have all the specified safety precautions and remote disconnects?

- Is the operator's area complete to provide a dust-free environment for installation of the computer, monitor, and peripherals?
- Is air conditioning running in all rooms?
- Is there an Ethernet network connection between the Control Cabinet room and each location where it shall be possible to control the cyclotron?
- *MINItrace Magni*: Is there a TRACERcenter node (computer) as integration point between the cyclotron system and the hospital network?
- *MINItrace Magni*: Is there an Ethernet network connection between the Control Cabinet room and the TRACERcenter node?

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.
- Wood blocks (assorted sizes).
- Cordless screwdriver equipped with T20 torx bits for disassembly of packaging materials.

- Jacks and accessories (18 metric tons; 40 000 lbs. capacity) for lifting the magnet.
- Equipment for unloading of electronics and other miscellaneous components (for example, fork lift and hand truck).
- Mobile mini lift to move, for example, the bench radiation shield to its final position.
- Lifting straps with sufficient length and capacity (see Section 8-3-1 Lifting straps and eye bolts on page 101).

10-3 Installation equipment

A well equipped tool box will be sent to the site prior to the start of the installation. The box must be returned to GEMS PET Systems immediately after the installation.

10-4 RF and magnetic field survey apparatus

Under normal circumstances there is no need for such apparatus.

11 Analytical and test equipment

11-1 Introduction

For analyzing the yield, radionuclidic purity and chemical purity, the site must be equipped with a chemistry laboratory and personnel trained in radiochemistry and radiopharmacy.

The laboratory must be in operation and all analytical equipment must be calibrated, since the chemistry analysis is included in the performance test for the site.

Some equipment must be placed in a hot cell, for example, the dose calibrator.

All chemicals for the cyclotron 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 processes, please contact GEMS PET Systems AB in Uppsala, Sweden.

11-3 Process chemicals

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

11-4 Other chemicals

The following chemicals should be available for cleaning purposes:

- Acetone
- Diethylether
- Distilled, deionized or nanopure water
- Methanol
- 2-Propanol

11-5 Product quality analytical equipment

Table 11-1: Analytical instruments

Item	Type/specification
Dose calibrator	0–5000 mCi (0–185 GBq) With appropriate calibration factors for the nuclide(s) in question
HPLC including: Columns HPLC Integrator Printer UV detector Injection valve	For analysis of [^{13}N]NH_3 , if not performed with TLC Partisil SAX 10 mm × 25 cm Zorbax SAX 4.6 mm × 15 cm 254 nm
TLC (alternative to HPLC)	[^{18}F]F^- FDG, [^{13}N]NH_3

Table 11-2: Analytical tools

Item	Type/specification
Electronic balances	Resolution 0.01 g
Gas flow meter	0–2000 ml/min
Leak detector	
Multimeter	Voltage, current, resistance, temperature
Radiation survey meter	Portable, 0–1 Sv/h (0–100 Rem/h)
Stopwatch	

Appendix A Site planning – Solid target platform

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

MINItrace Magni is a requirement for Solid target platform.

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	• Self-shielded
Cyclotron application software	Licence for Solid target platform
Solid target application software	Licences for applicable radionuclides

A-2 Solid target station

Table A-2: Solid target station requirements

Parameter	Requirement/description
Target material cooling	Deionized water[1]
Ports on the cyclotron available for the solid target station	Only port 5 may be used

1 The cooling manifold inside the radiation shield will be used.

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

Parameter	Requirement/description
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
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 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

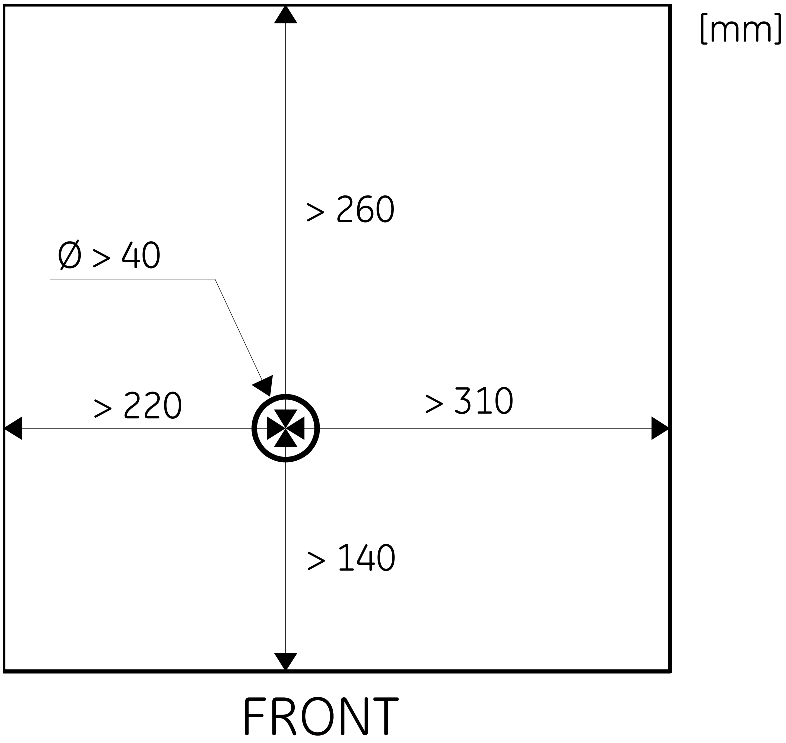
A-5 Hot cells

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 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...**	
Pneumatics panel (valve manifold, near targets)	Solid Target Control Unit (STCU) in CCAB	Maximum 30 m[1]
Target station	Solid Target Control Unit (STCU) in CCAB	Maximum 30 m[1]
Network cables		
From...	**To...**	
Router in CCAB	Solid target network switch (near hot cell)	Maximum 60 m
Router in CCAB	TRACERcenter node	Maximum 40 m

1 The cables have large D-Sub 25 connectors pre-attached. Use available cable conduit in the radiation shield.

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 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).

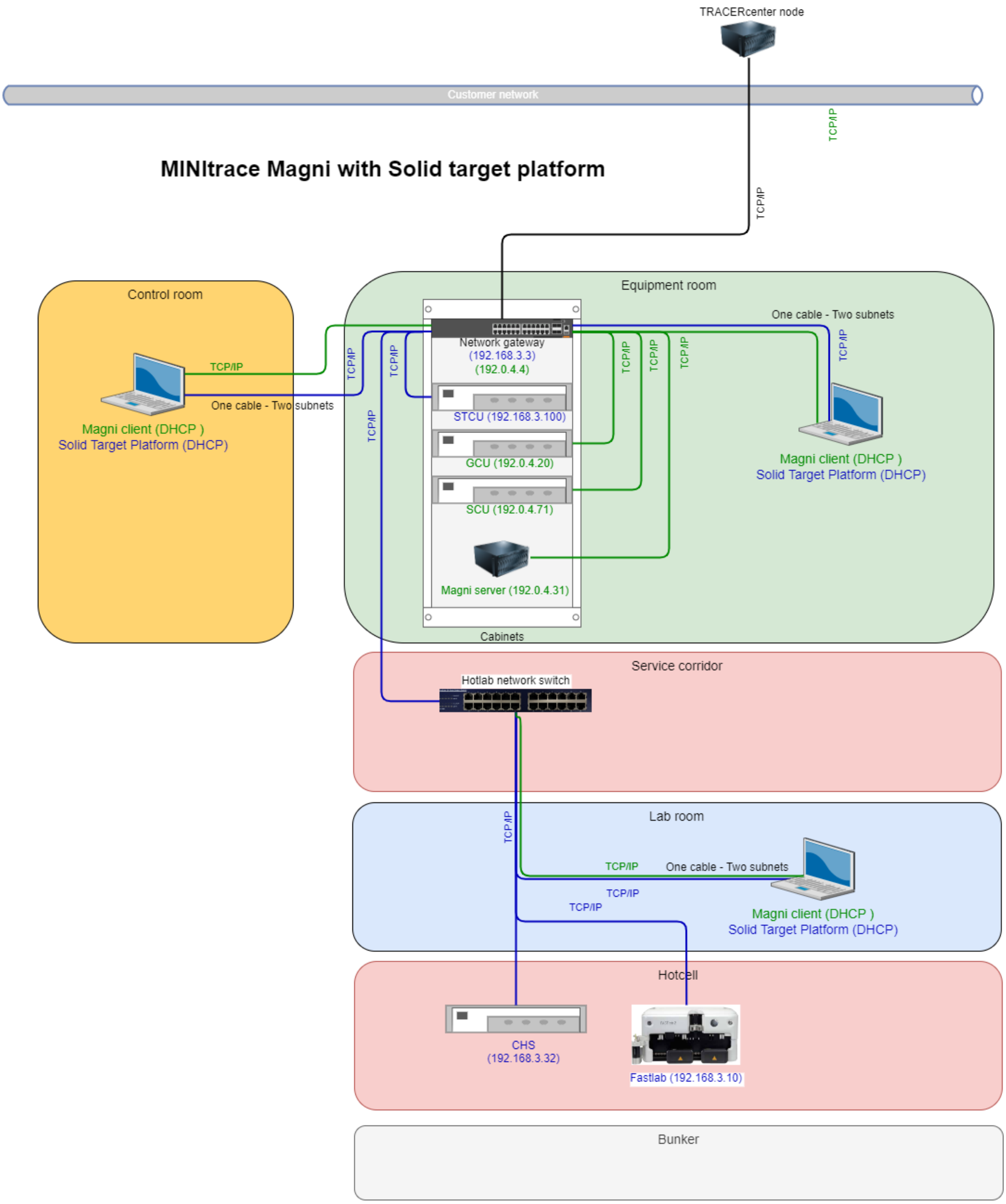
Table A-8: Power cable requirements

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 shows how the control systems and computers in MINItrace Magni (including Solid target platform) are linked together through an Ethernet communication network.

Figure A-2: Ethernet communication network overview including Solid target platform



A-8 Trenches and conduits

Table A-9: Trench and conduit requirements

Parameter	Requirement/description
Trench or conduit in the cyclotron room floor for the capsule transfer tube in Solid target platform and other tubes for liquids and gases.	• 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. Consider radiation safety for trench under the shield (refilling the opening). • For specifications on the ducts from the cyclotron, see Section 2-5-2 Floor ducts for radioactive gases, liquids, and solids on page 31. Contact GE HealthCare for consultance.

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 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
FASTlab platform	Nitrogen (5.0) 0.60–0.80 MPa (87–116 psi)

For more information on gas requirements, see Section 5-13-2 Customer supplied gases on page 67.

A-11 Facility

Table A-12: Facility requirements

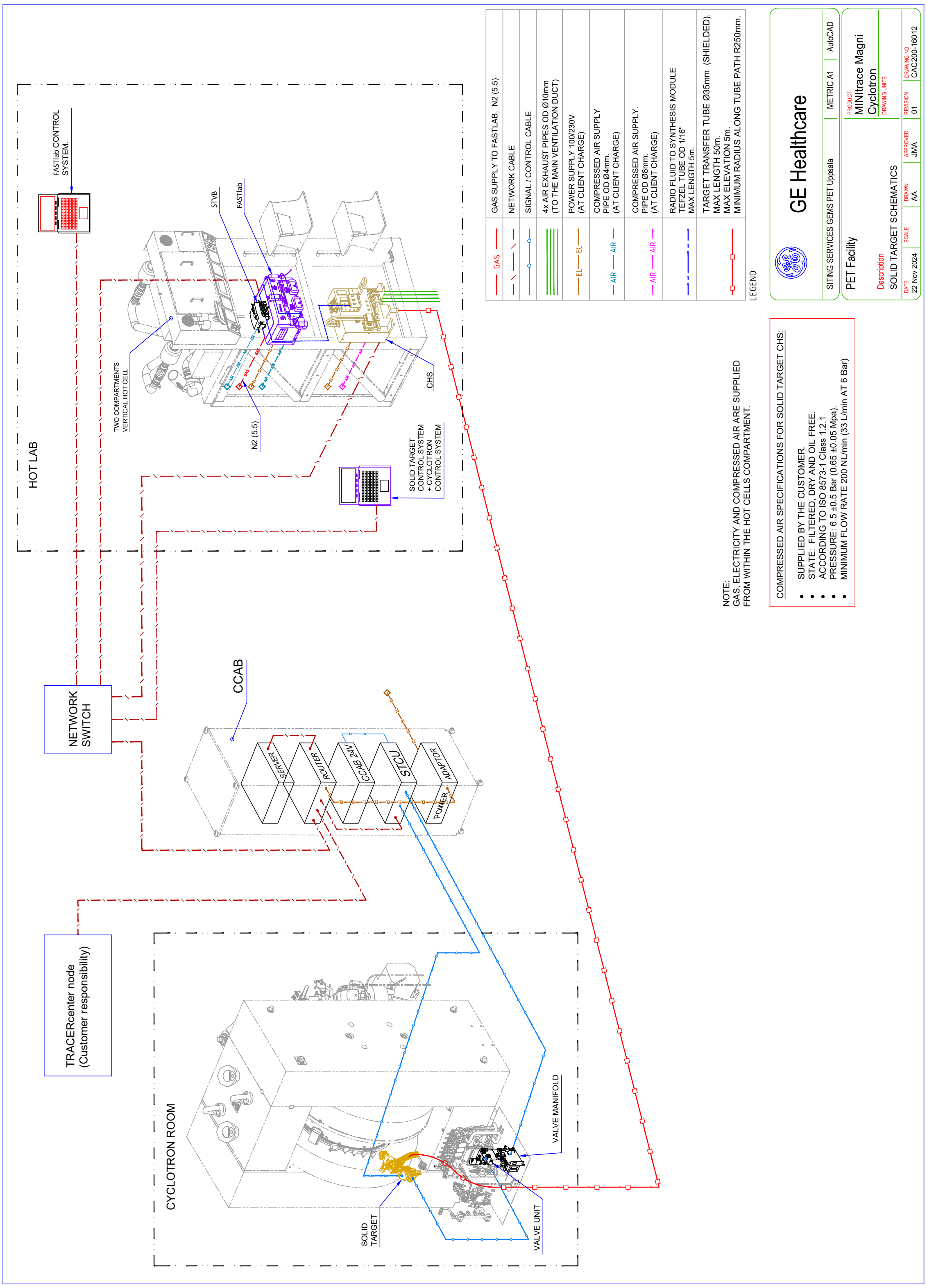
Parameter	Requirement/description
Additional single-phase oulets	Besides inside the hot cell, there should be single-phase electrical utility outlets at least at the following locations: • In the production lab (Solid target platform laptop and the FASTlab laptop) • On the rear/service side of the hot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

- 5 days for installation and 2.5 days for performance verification

A-13 Solid target platform connections overview



For local office contact information, visit
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