

# MINItrace

## Site Planning Guide

Class A





## REVISION HISTORY

Revision	Date	Reason for change
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 $\pm 5\%$ to $\pm 10\%$ . [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]
04	12 December 2006	Reformatting, conversion to GE Inspira fonts, relinking of all graphics. New cover. Minor editorial changes throughout the document. <i>Chapter 3:</i> Changed values in illustration 12 and 13. Values increased by 25% Text added (radiation levels). <i>Chapter 5.</i> Table 20, H <sub>2</sub> <sup>15</sup> O gas quality changed. Purity changed for some gases.

Revision	Date	Reason for change
03	16 May 2005	<p><i>Section Gas and Liquid Distribution:</i> Extended info in Item 1 (re. gas supply tubing).</p> <p><i>Section 2-2-1-2 Equipment:</i> Table 6 rows rearranged (to match Table 31).</p> <p><i>Section 2-5-1 Load and Pressure:</i> Text "GE responsibility" added.</p> <p><i>Section 2-7:</i> Integrated radiation shield weight altered to 39 900 kg.</p> <p><i>Section 2-8:</i> In Illustration 4: Weight 50350 kg changed to 52950 kg.</p> <p><i>Section 3-2-1 General:</i> Typical beam current range changed from 25–40 <math>\mu</math>A to 25–50 <math>\mu</math>A.</p> <p><i>Section 3-2-4 Area Description:</i> Paragraphs slightly rearranged. Figure "2 Curies" changed to "3 Curies". Unit mS/h corrected to <math>\mu</math>S/h</p> <p><i>Section 3-2-5 Radiation levels:</i> Comprehensive isodose curve information (partly new) summarized in a new table (Table 13). Ill. 12 updated.</p> <p>Ill. 12 and 13 modified to enable ruler measurement.</p> <p><i>Section 3-2-6 Waste Gas System:</i> Thoroughly updated.</p> <p><i>Section 5-3-3 Primary Cooling:</i> 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.</p> <p><i>Section 5-10-2 Gas Supply and Gas Regulators:</i> 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].</p> <p><i>Chapter 6 Power Requirements</i> thoroughly updated [SPR 03-196]: New LOTO information, total power consumption figure in Table 22 modified from 35 to 40 kW, UPS info added.</p> <p><i>Chapter 7 Interconnect Data:</i> Supply Panel dwg in Table 25 updated. All dwgs on pages 94–99 updated.</p> <p><i>Section 7-5 Gas Piping Interconnects</i> modified with respect to GE/customer responsibility, tubing contamination, etc.</p> <p><i>Chapter 8 Shipping And Delivery Data:</i> Crate Weight data (Right Rear and Right Door) in Table 31 updated.</p>
02	22 November 2001	<p>Weight information in Table 6, 11 and 32 (pages 25, 33 and 103) updated.</p> <p>Gamma dose contour maps (on page 50–51) replaced.</p> <p>Sections 6-2 Power requirements and 6-3 Recommended Power Distribution System (page 77–80) updated.</p> <p>MINItrace Service System (MSS) Laptop not included in product. Affects pages 35, 43, 59, 87.</p>
01A	20 April 2000	<p>Illustration 12 on page 49 added (Isodose curves for neutrons).</p> <p>Illustration 22–27 on page 94–99 modified due to Supply Panel modifications.</p> <p>Figures added to Table 33 on page 103 (Crate Dimensions).</p>
01	5 April 2000	<p>The main structure of the document is intact, but a number of facts and figures are revised.</p>

Revision	Date	Reason for change
00	6 December 1999	Initial document release.



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# 1 PURPOSE AND RESPONSIBILITIES

## 1-1 Introduction

This document contains the physical, electrical, plumbing and magnetic data necessary for planning and preparing a site for a MINItrace tracer production system.

Pre-installation work is done to prepare the customers premises for the installation of the tracer production products.

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

### 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 MINItrace tracer production system is to be installed.

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

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

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

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

Generally, workers with experience in this kind of project should be used. Contractors and other personnel with experience in general construction only, may fall short of the mark of a good project installation, if specific background in medical 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 radioactive isotopes, compliance with Nuclear Regulatory Commission Regulations, or similar regulatory requirements, depending on the site location, must be demonstrated.*

*Regulatory compliance should be arranged for as an early step in the site planning process.*

### 1-1-2 Project Coordinator

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 Purchaser and GE.

The Project Coordinator should keep in close contact with all of the contractors, subcontractors, GE and administrative personnel, as well as planners and architects. Maintaining a schedule and adjusting that schedule as needed is the responsibility of the Project Coordinator.

GE can provide a site planning service to assist the Purchaser with site preparation. Please contact your local GE representative. Should any such assistance be required, GE personnel are willing, and considerably well qualified, to help and ensure that your installation is a successful one.

## 1-2 Responsibilities

The Purchaser is responsible for all site preparation, except by other agreement with GE. 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 radioisotopes.
- Installation of electrical conduit, junction boxes, ducts, surface raceways, outlets and line safety switches.

- Installation of wires not supplied by GE 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.

**Note!**

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

- 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 **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 evaluation of the product. GE will make every reasonable effort to maintain accuracy of site planning information. Final construction documents should be sent to the GE 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 in the project. For additional information regarding the time and resources required for MINItrace installation refer to [Section 1-2-3 Installation flow chart on page 21](#).

### 1-2-1-1 Facility planning

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

### 1-2-1-3 Mechanical installation

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

### 1-2-1-4 Start-up

#### Subsystem start-up

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

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 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.

Radioisotope production and radiochemistry: When proper cyclotron performance has been demonstrated, the GE system engineer will begin the production of the isotopes 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	Cust.	GE
1	GE shall elect one responsible project leader with whom the Purchaser will communicate.		x
2	The Purchaser is required to inform GE about project schedule and changes in project schedule.	x	
3	The Purchaser is responsible for applying for permits and licensing for producing and handling of radioisotopes.	x	

#### 1-2-2-2 Building design and equipment layout

Item no.	Item	Cust.	GE
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 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	Cust.	GE
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	Cust.	GE
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 power supply cabinets.	x	
4	Provision and installation of at least four single-phase electrical utility outlets for powering the Master System and accessories (service laptop, etc.).	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	<i>If the site is any of the two options shown in <a href="#">Figure 2-1</a> and <a href="#">Figure 2-2</a>:</i> Provision and installation of cable duct for interconnection cables (cables supplied by GE) from power supplies and electronic control units		x
8	<i>If the site is NOT any of the two options shown in <a href="#">Figure 2-1</a> and <a href="#">Figure 2-2</a>:</i> Interconnection cables, supplied by GE, from power supplies and electronic control units are to be located in ducts. The Purchaser must supply and install these ducts and it is the Purchaser's responsibility to ensure that this cable routing system meets local electrical codes and requirements.	x	
9	A connection for Internet access close to the Control Cabinet is recommended.	x	

## 1-2-2-5 Cooling water system

Item no.	Item	Cust.	GE
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 maximum 13°C.	x	
4	Specification of heat load for external chiller.		x

Item no.	Item	Cust.	GE
5	Provision and installation of water manifolds with flow guards for equipment to be cooled.		x
6	Provision and installation of all piping from GE supplied water manifolds to heat loads.		x
7	Provision and installation of all water pipes from the secondary cooling unit (a closed deionized cooling water system) to the Control Cabinet (CCAB) and Radio Frequency Power Generator (RFPG).		x
8	Provision and installation of all water pipes from the external chiller to the secondary cooling unit (a closed loop deionized water system).	x	
9	Filter supplied on external chiller cooling loop to protect heat exchanger.	x	
10	A connection for city water to the secondary cooling unit (a closed loop deionized water system) shall be provided by the Purchaser.	x	
11	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	Cust.	GE
1	Provision and installation of compressed air system, including shut off valves and terminations to GE supplied manifolds.	x	
2	Provision and installation of compressed air manifolds and connections from manifolds to loads.		x

#### 1-2-2-7 Ventilation

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

#### 1-2-2-8 Gas and liquid distribution

Item no.	Item	Cust.	GE
1	Provision and installation of: <ul style="list-style-type: none"> <li>gas supply with gas bottles/tanks</li> <li>regulators for ion source gas and target gas (and optionally also process gases)</li> <li>clean, high quality tubes between gas bottles and the supply panel</li> </ul>	x	

Item no.	Item	Cust.	GE
2	Provision and installation of piping from the target system in the cyclotron room to the chemistry processing systems in the radiochemistry 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	Cust.	GE
1	Provision of access roads for trucks with adequate capacity up to off-loading point.	x	
2	Access hatch or other entrance to the cyclotron 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	Cust.	GE
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 will inspect the site before the start of installation. The installation of the equipment will not be started until GE 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	Cust.	GE
1	<p>Provision of operating supplies like ion source gases, target and processing gases, dry nitrogen etc. This includes all chemicals, starting material, consumables and media needed in the production.</p> <p>Provision of a complete chemistry laboratory including necessary test equipment in order to perform the acceptance test protocol.</p> <p><b>Note!</b> A printer is not supplied with the system.</p> <p>Recommended printers to connect to the Master System:</p> <ul style="list-style-type: none"> <li>Hewlett Packard™ printers (Laserjet™ or similar model)</li> </ul>	x	

## 1-2-2-12 Safety

Item no.	Item	Cust.	GE
1	The complete radiochemical production facility where the equipment from GE will be installed is the responsibility of the Purchaser.	x	
2	The complete installation for radioactive isotope production has to be designed for a safe handling of activity with respect to personal safety of the staff and the surroundings.	x	
3	Calculations on all radiation shielding. The responsibility for adequate radiation protection, final decisions concerning the arrangement of shielding and handling of induced activities (air, water, targets, etc.) according to requirements from the local and national authorities.	x	
4	Provision and installation of safety devices like “beam” on signs, door interlocks, alarms, emergency switches according to customer needs and local codes.	x	
5	Provision of local codes and working regulations that apply to GE staff.	x	

## 1-2-3 Installation flow chart

The typical installation cycle for the MINItrace tracer production 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 resources and the site preparation status necessary to perform the installation efficiently.

Table 1-1: Typical MINItrace installation cycle

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 MINItrace installation flow chart

GE activity	<b>Rigging</b> Place cyclotron and radiation shield into room	<b>Mechanical</b> installation and piping. <b>Electrical</b> installation and cabling.	<b>Start-up and calibration</b>	<b>Cyclotron system test</b>	<b>Performance test procedure</b>
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
<b>Required customer status for above</b>					
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 radioactive isotopes 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	
	[m <sup>2</sup> ]	[ft <sup>2</sup> ]	[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	
	[m <sup>2</sup> ]	[ft <sup>2</sup> ]	[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

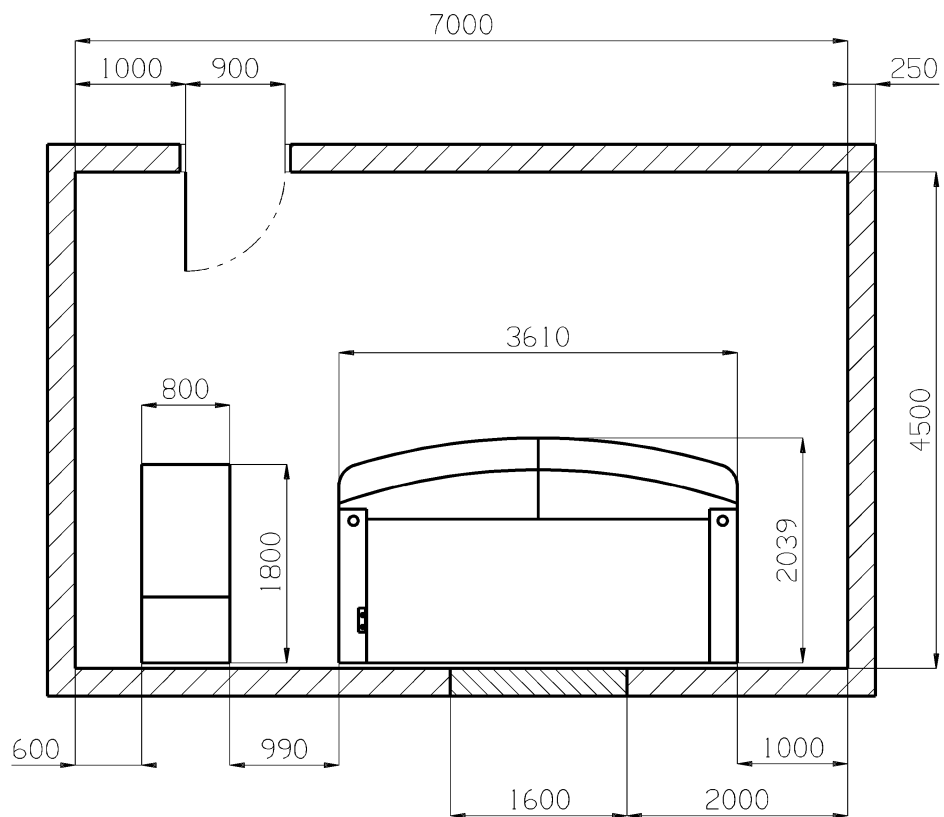
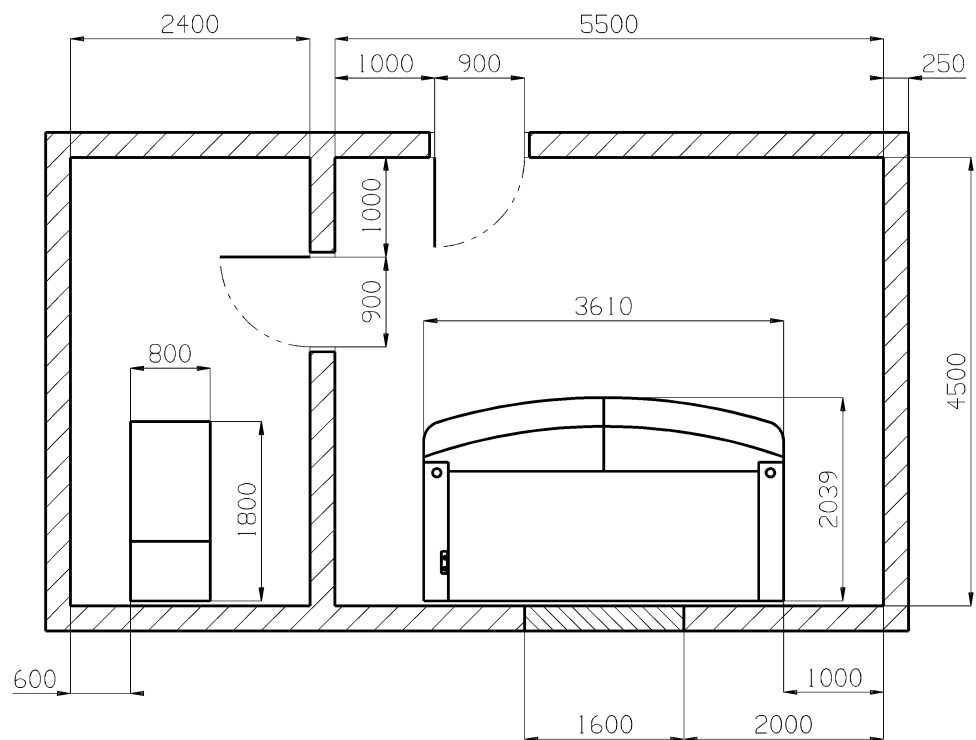


Figure 2-2: Typical dedicated room option facility





## 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 <sup>2</sup>
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)
<b>Weight</b>	300 kg	750 kg
<b>Depth</b>	0.8 m	0.8 m
<b>Width</b>	0.6 m	1.2 m
<b>Height</b>	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 27](#).

### 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 lab

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

The operator interface of the control system is comprised of a keyboard and flat-screen. 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.

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

Minimum 1 m × 1 m work surface should be reserved as cleaning area of contaminated items and this area has to be surrounded by adequate radiation shielding, e.g. lead bricks.

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.

## 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 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.

## 2-5 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 30](#).

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 (GE responsibility).
- The final epoxy layer will have a smooth surface and be approximately 4–7 mm thick.

See [Table 2-8](#) for information on the floor.

**Table 2-8: Floor tolerance**

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

### 2-5-2 Floor ducts for radioactive gases

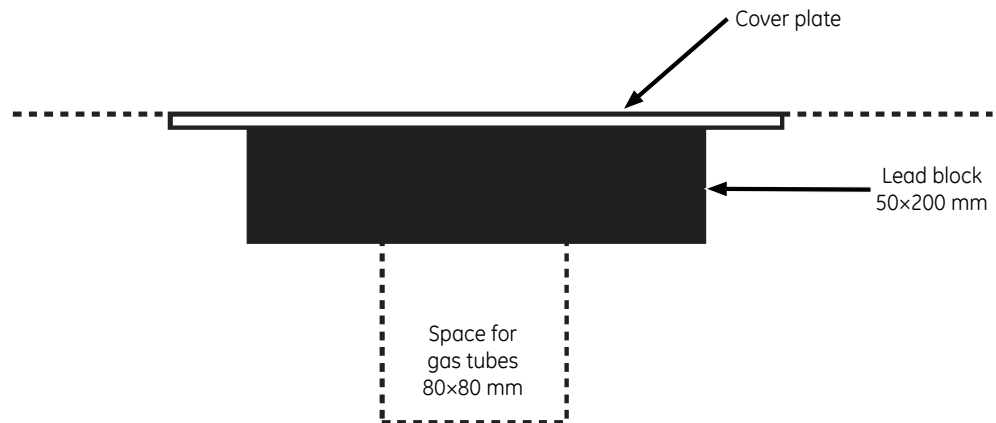
Shielding of radioactive liquids/gases is the responsibility of the customer if no other agreements are made. It is however necessary to include it in the site planning when it affects the concrete work.

The radioactive liquids/gases 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 pipes, the pipes must be shielded.

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

For a concrete floor under construction there is an inexpensive and easy way to design shielded floor ducts. A suggested duct profile is shown in [Figure 2-3](#).

**Figure 2-3: Duct profile**



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

## 2-6 Architectural reminders

- 1 Pay attention to isogauss limits, not only for placement in rooms but also for isogauss limits with respect to outside environment.
- 2 Two telephone lines must be supplied in the power supply room for installation and serviceability purposes. Telephone lines are to be provided and paid for by the customer.

**Note!**

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

- 3 A lockable storage cabinet should be provided. It will be used for storing documentation and tools.
- 4 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).

## 2-7 Floor loading and weights

This section contains loading considerations for the MINItrace tracer production system. Listed in [Table 2-9](#) are the weights, floor loading and normal mounting methods for the cyclotron components.

**Table 2-9: Cyclotron floor loading**

Component	Weight [kg]	Overall area w × d [mm]	Floor load [kg/m <sup>2</sup> ]	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)	300	600 × 800		Set on floor
Radio Frequency Power Generator (RFPG)	750	1200 × 800		Set on floor
Master System	36	475 × 540		Set on table
Roughing vacuum (mechanical) pump	27	450 × 190		Set on floor (next to diffusion pump)
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 delivery route. Structural reinforcement may be required along the magnet delivery route. It is required that a structural engineering analysis is performed on the cyclotron room and delivery route to determine its load bearing capacity.

It is strongly recommended to transport the cyclotron 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 MINItrace tracer production system components is provided in [Section 2-8 System components on page 31](#) 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.

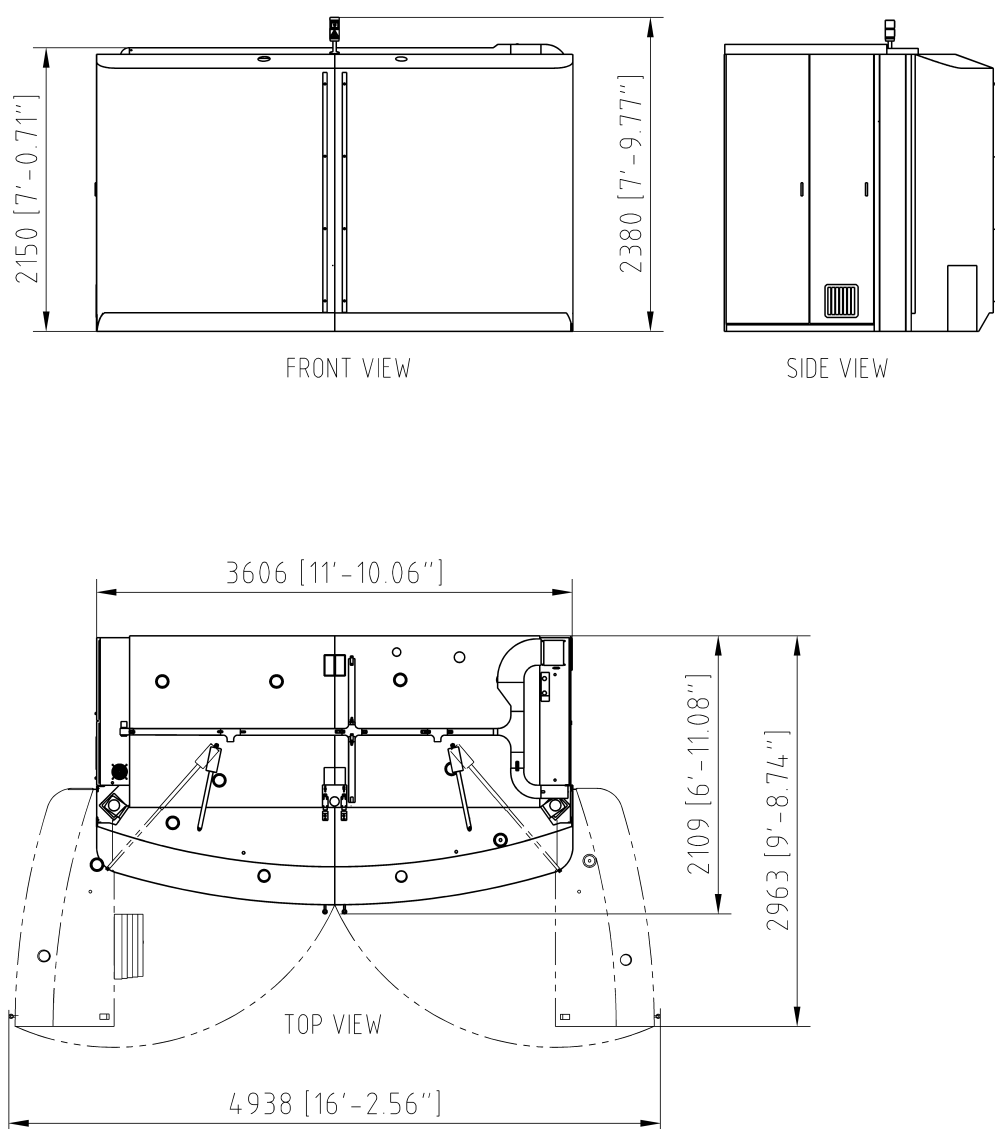
## 2-8 System components

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

**Table 2-10: MINItrace tracer production system component illustration list**

Illustration name	Illustration number
Cyclotron overall layout	<a href="#">Figure 2-4</a>
Cyclotron minimum service area	<a href="#">Figure 2-5</a>
Cyclotron dimensions	<a href="#">Figure 2-6</a>
Control Cabinet (CCAB)	<a href="#">Figure 2-7</a>
Radio Frequency Power Generator (RFPG)	<a href="#">Figure 2-8</a>
Roughing vacuum (mechanical) pump	<a href="#">Figure 2-9</a>
Master System	<a href="#">Figure 2-10</a>
Service laptop (provided by customer) to run MINItrace Service System (MSS) software.	The laptop to run MINItrace Service System (MSS) software is <b>not included</b> in the product. The laptop <b>must be able to read CD-ROM</b> disks.

Figure 2-4: Cyclotron overall layout



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

WEIGHT 52950 kg



Figure 2-5: Cyclotron minimum service area

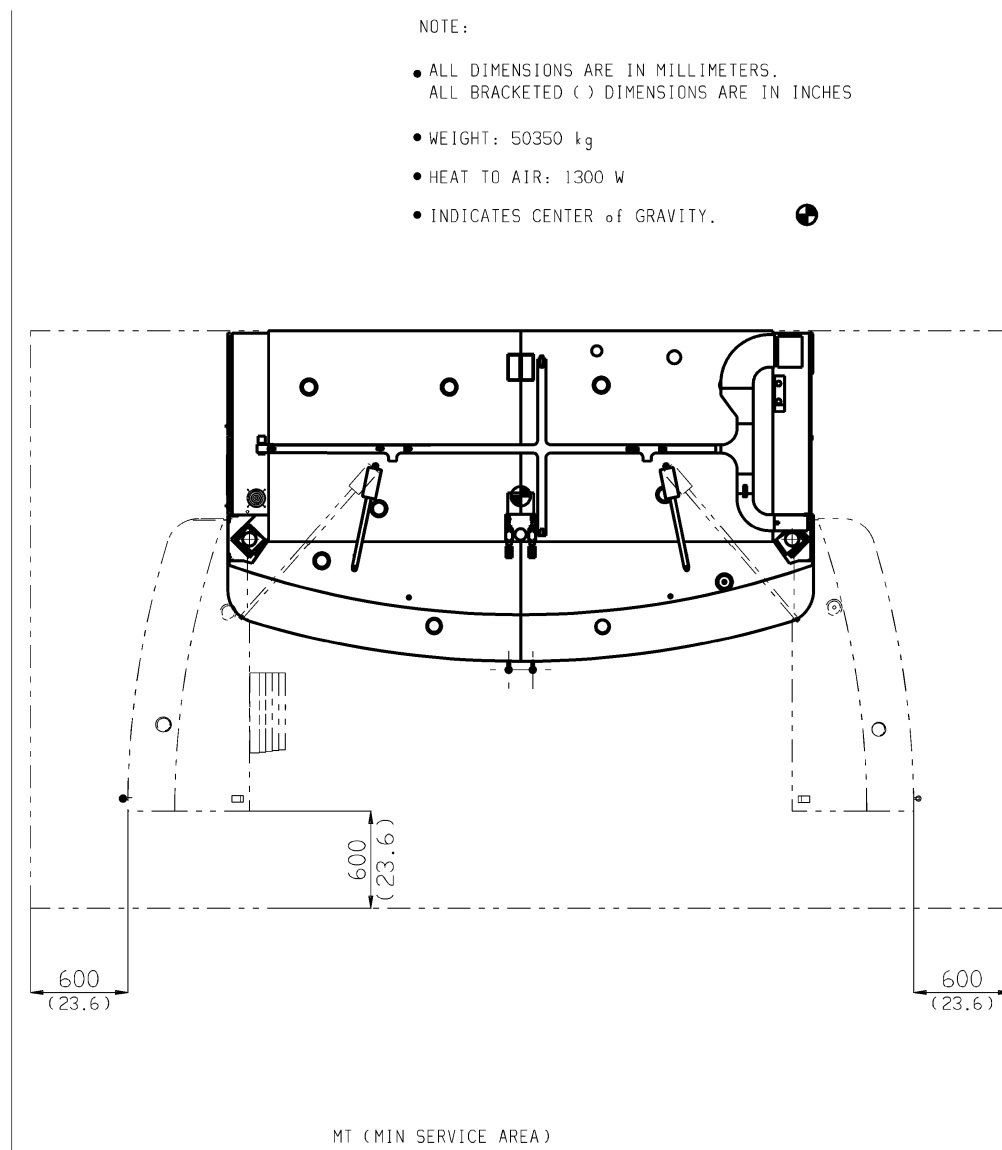
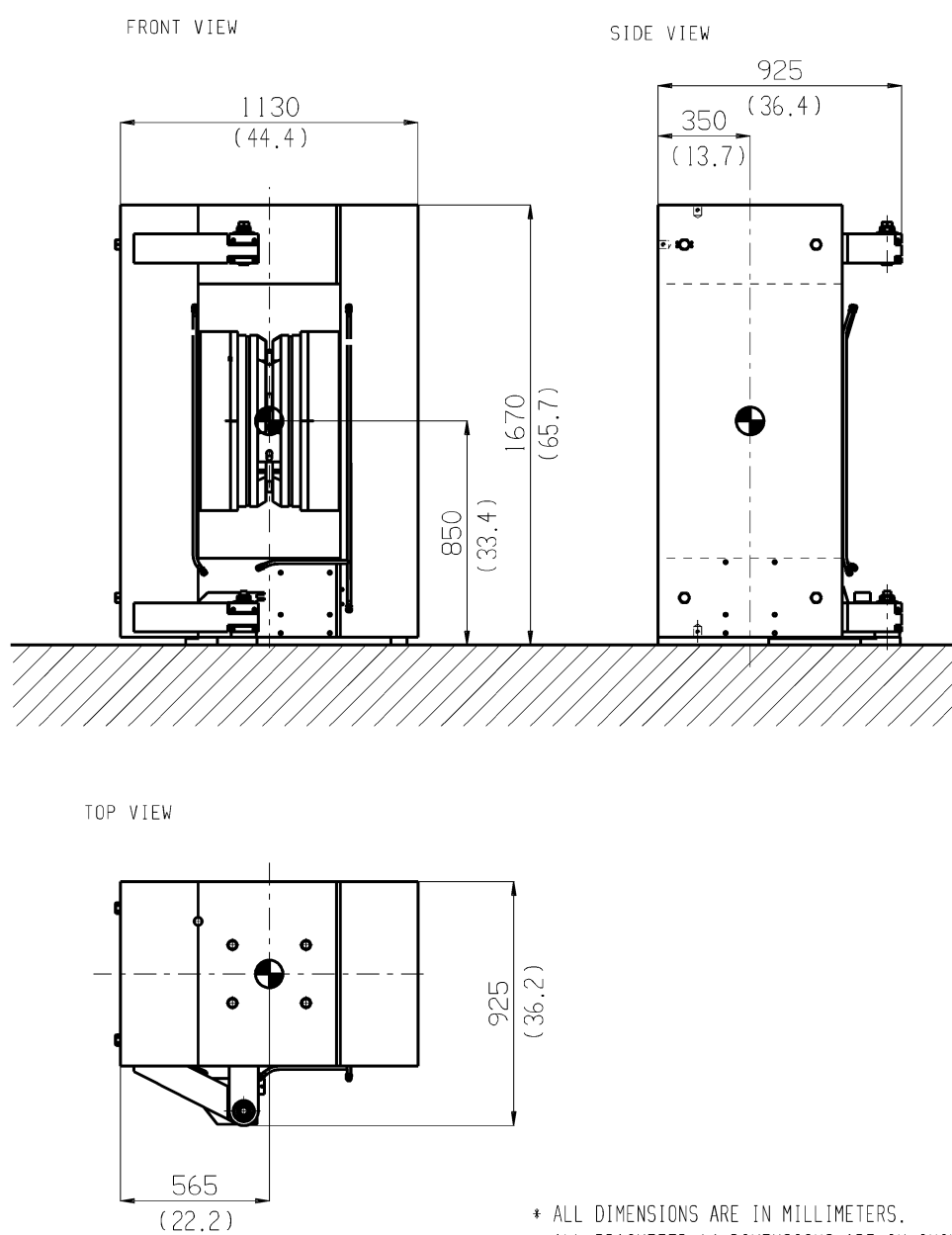


Figure 2-6: Cyclotron dimensions



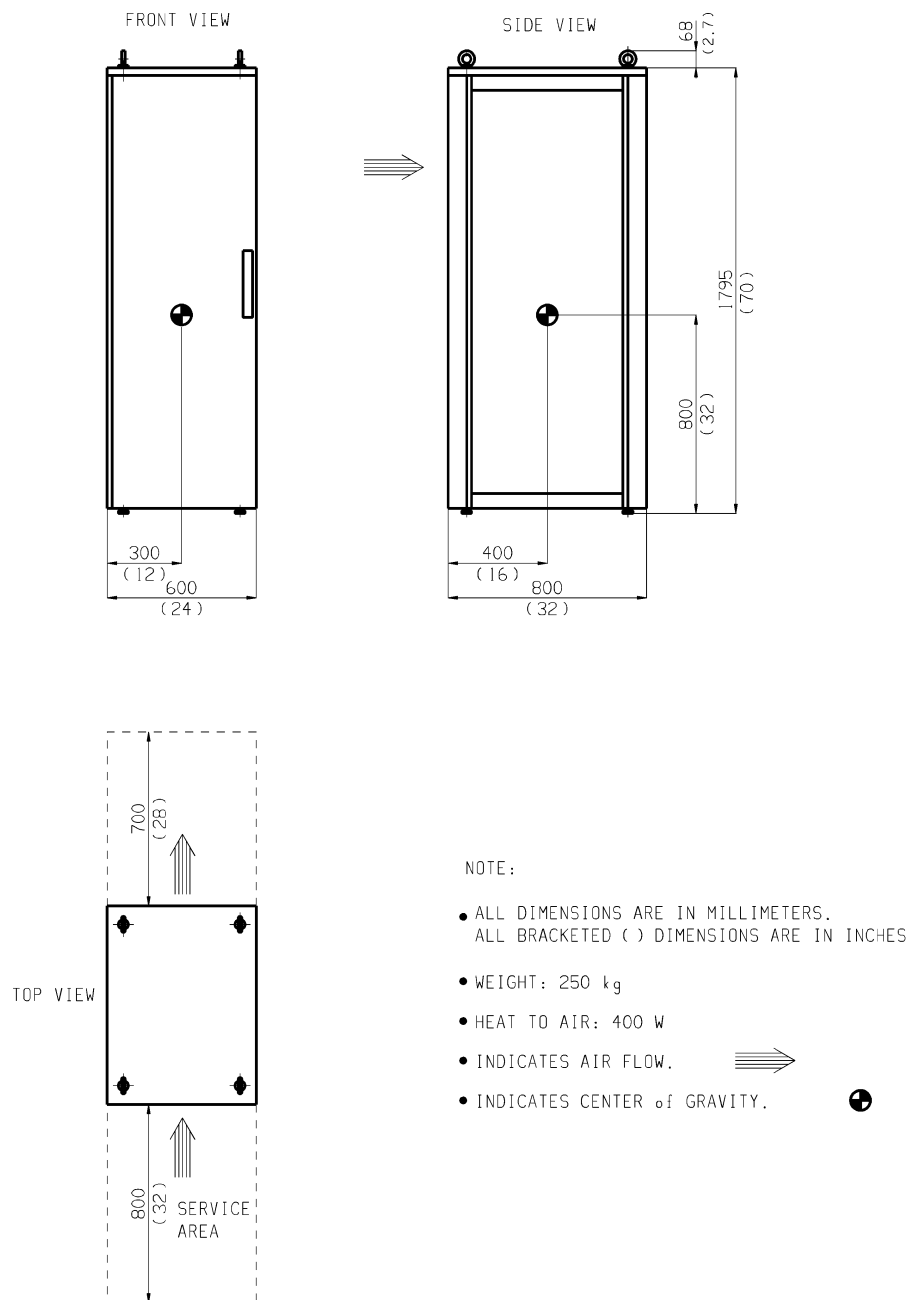
\* ALL DIMENSIONS ARE IN MILLIMETERS.  
ALL BRACKETED ( ) DIMENSIONS ARE IN INCHES.

\* WEIGHT 10700 kg

\* HEAT TO AIR 100 W

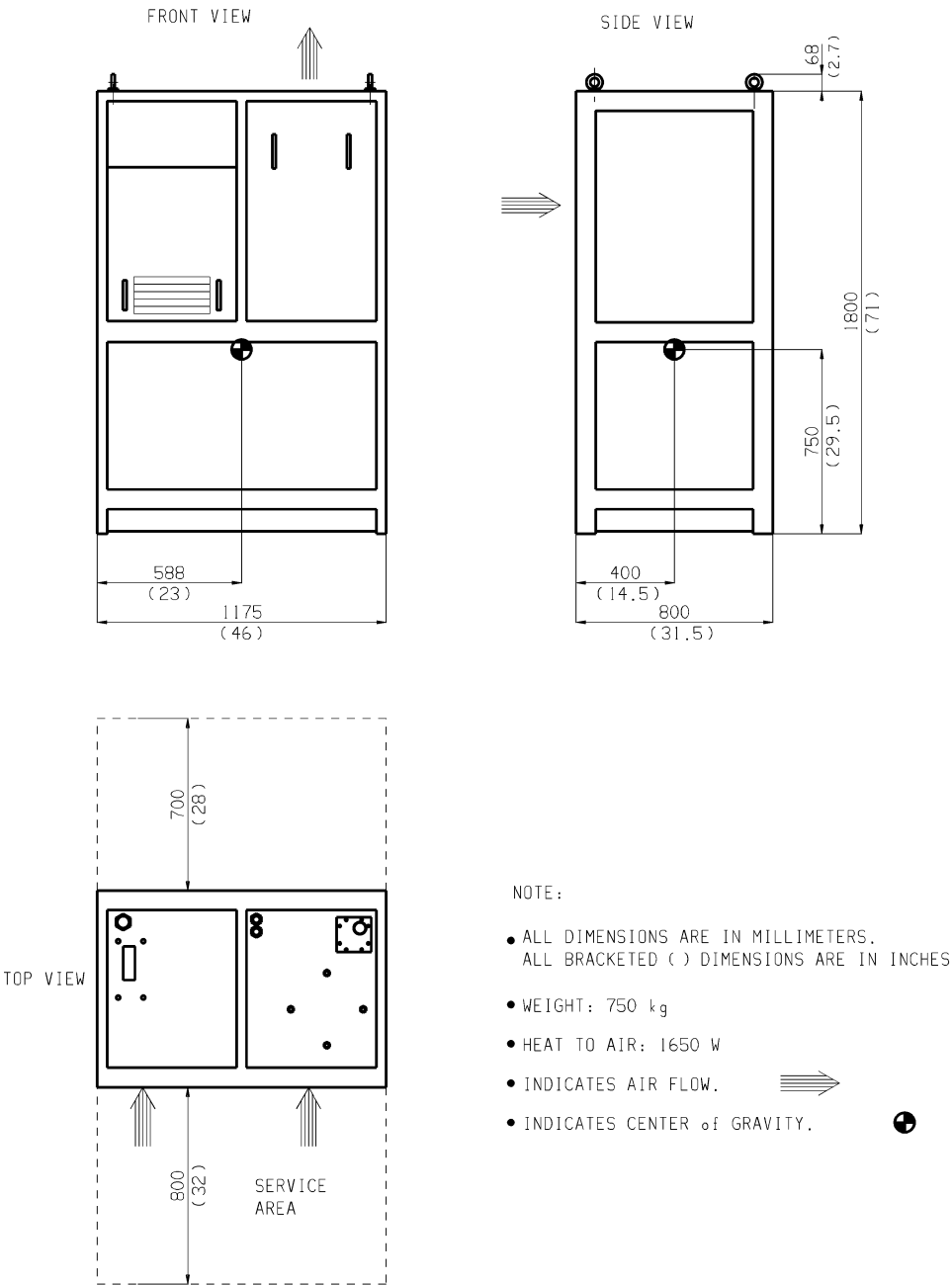
\* INDICATES CENTER OF GRAVITY.

Figure 2-7: Control Cabinet (CCAB)

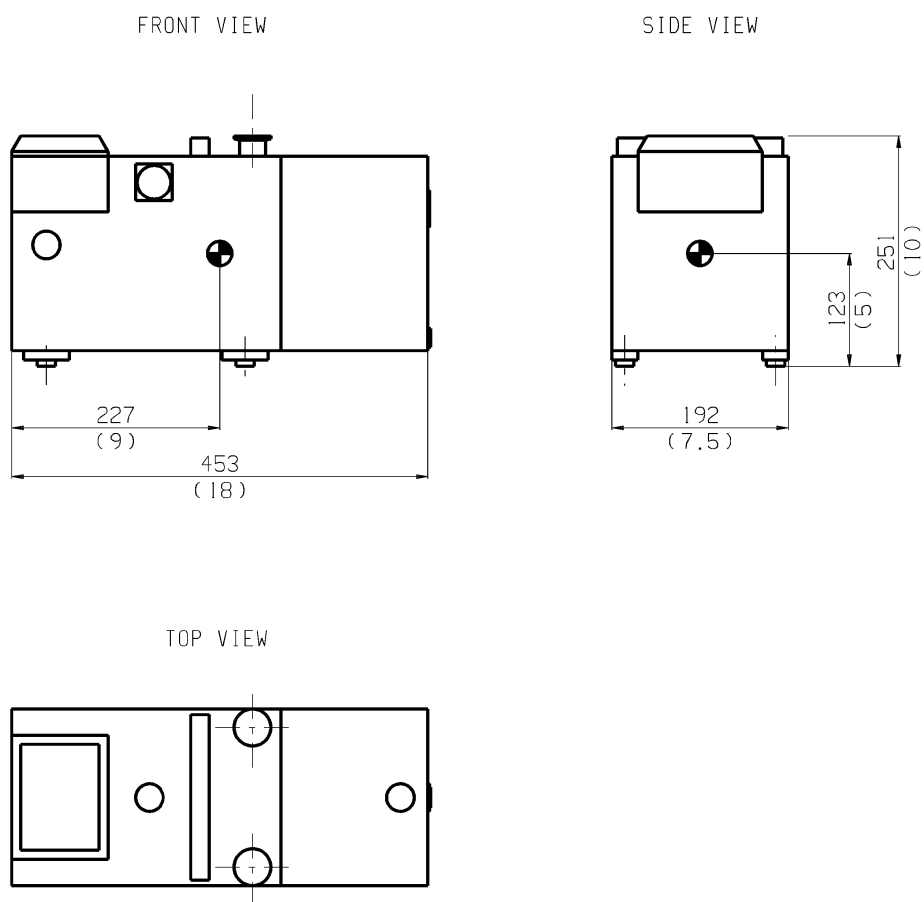



ELECTRONIC CABINET

Figure 2-8: Radio Frequency Power Generator (RFPG)



RFPG

**Figure 2-9: Roughing vacuum (mechanical) pump****NOTE:**

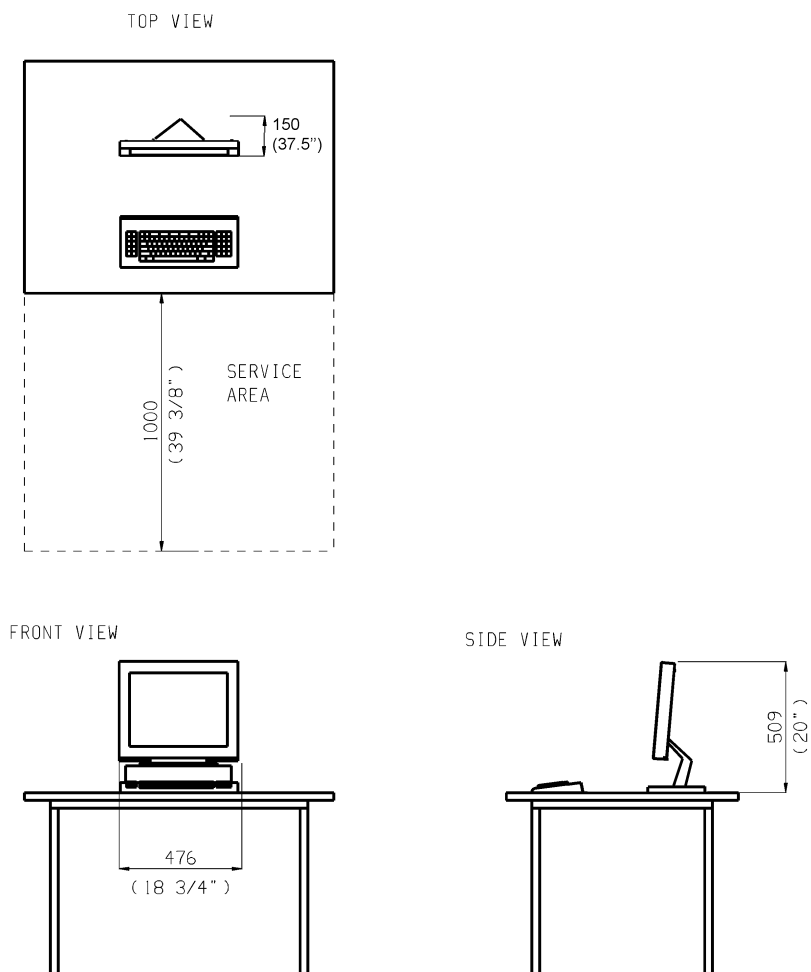
- ALL DIMENSIONS ARE IN MILLIMETERS.  
ALL BRACKETED ( ) DIMENSIONS ARE IN INCHES
- WEIGHT: 27 kg
- HEAT TO AIR: 100 W
- INDICATES CENTER of GRAVITY. 

MECHANICAL VACUUM PUMP

Figure 2-10: MINItrace Master System

NOTE:

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



MASTER SYSTEM

**Figure 2-11: MINItrace Service System (MSS)**

The laptop to run MINItrace Service System (MSS) software is **not included** in the product.  
The laptop **must be able to read CD-ROM** disks.





## 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 MINItrace 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 Purchaser 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 Purchaser.

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 MINItrace cyclotron produces charged particles (protons) with an energy content of 9.6 MeV. Typical beam currents are in the range of 25–50  $\mu$ A.

The primary beam is stopped very quickly 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 so-called 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 MINItrace tracer production system is delivered with an integrated radiation shield and is intended to be put in a so-called "Controlled Area". Even if the level of radiation around the MINItrace system is low, installation of a MINItrace system 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 embrace 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.

The most commonly used short-lived positron emitters include Carbon-11, Nitrogen-13, Oxygen-15 and Fluorine-18. Batches up to 3 Curies of isotopes can be produced and transferred from the irradiated target to the hot cells. These radioisotopes are transferred in small diameter tubes, which are typically covered with 3–5 cm of lead for protection depending on the attenuation requirements. The activity administered to the patient is typically 5–20 mCi.

**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 radioisotopes 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 MINItrace cyclotron with the integral 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 MINItrace with its radiation shield is placed in a room classified as controlled/restricted area. The average dose rates in the the cyclotron room is low, refer to numbers below.

Having in mind that radiation outside the shield only exists during isotope production and that the cyclotron does not call for any specific actions inside the cyclotron room during isotope production the dose load to staff related to isotope production could be limited.

However, if, by any reason, personnel have to enter the cyclotron room during isotope production, still the dose load will be limited due to the low average dose rates inside the room.

In addition to this, the local radiation safety organization will work out good working practices and apply the ALARA principles (As Low As Reasonably Achievable) for the work in the controlled/restricted areas and accumulated dose related to isotope production in the cyclotron can be kept to a minimal portion of the total dose uptake.

### 3-2-5-1 Average dose rates around the radiation shield

#### **Average dose rate: < 10 $\mu\text{Sv/h}$**

Operation conditions:

- Target placed in port 1 (about 1 m above floor level)
- Beam current: 50  $\mu\text{A}$
- Target:  $^{18}\text{F}^-$  with Oxygen-18 water (enrichment >95%)

Measurement conditions:

- Gamma + neutrons
- Height from floor level: 1 m
- Distance from shield surface: 1 m

#### **Note!**

*If the performance falls outside the specifications, the supplier has the right to make corrections of the shield in agreement with the customer. This could have a small impact on the esthetic impression.*

### 3-2-5-2 Instrumentation

Used instruments should have a valid calibration, it is also important to remember that radiation instruments in general have wide tolerances.

Typical tolerances:

- Neutron instruments:  $\pm 40\%$
- Gamma instruments:  $\pm 15\text{--}20\%$

#### **Note!**

*Sometimes it is also recommendable to use ion chamber instruments (instead of GM types) for gamma measurements due to the better energy linearity.*

### 3-2-6 ISO dose rate contours

The following gamma and neutron dose rate contours ([Figure 3-1](#) and [Figure 3-2](#)) shows the outer boundary of the given dose rate figures (i.e. not exactly ISO dose rate contours).

The main intention with the given contours is for general site planning actions and design of wall dimensions if radiation attenuation is necessary in order to coop with radiation regulations in public contiguous areas.

The tolerances in position of the iso lines are as follows:

- Neutrons: 5  $\mu\text{Sv/h}$  contour  $\pm 0.5$  m
- Gamma: 20  $\mu\text{Sv/h}$  contour  $\pm 0.5$  m
- Gamma: 10  $\mu\text{Sv/h}$  contour  $\pm 0.7$  m

#### 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 MINItrace):

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

The isodose contours on the following spread provide information according to [Table 3-1](#):

**Table 3-1: Radiation levels vs. beam current**

Type of radiation	Illustration number	Operating conditions
<b>Neutron</b> radiation isodose rate contours	<a href="#">Figure 3-1</a>	<p><b>Beam current:</b> 50 <math>\mu</math>A (protons)</p>
<b>Gamma</b> radiation isodose rate contours	<a href="#">Figure 3-2</a>	<p><b>Target position:</b> 1 (located 1 m above floor level)</p> <p><b>Target media:</b> Oxygen-18 water (95% enriched)</p> <p><b>Produced tracer:</b> <math>^{18}\text{F}</math>- fluoride</p> <p><b>Note!</b> Dose rate levels are <b>directly proportional</b> to beam current.</p> <p>The isodose contours displayed in <a href="#">Figure 3-1</a> and <a href="#">Figure 3-2</a> are based on 50 <math>\mu</math>A beam current. Other contours are easily estimated by using the formula:</p> $\text{ISODOSE}_{X \mu\text{A}} = \text{ISODOSE}_{40 \mu\text{A}} * (X/50)$ <p><b>Example:</b> A beam current of 25 <math>\mu</math>A reduces the isodose rate levels in <a href="#">Figure 3-1</a> and <a href="#">Figure 3-2</a> to half.</p>

Figure 3-1: Typical neutron radiation isodose contours for MINItrace radiation shield

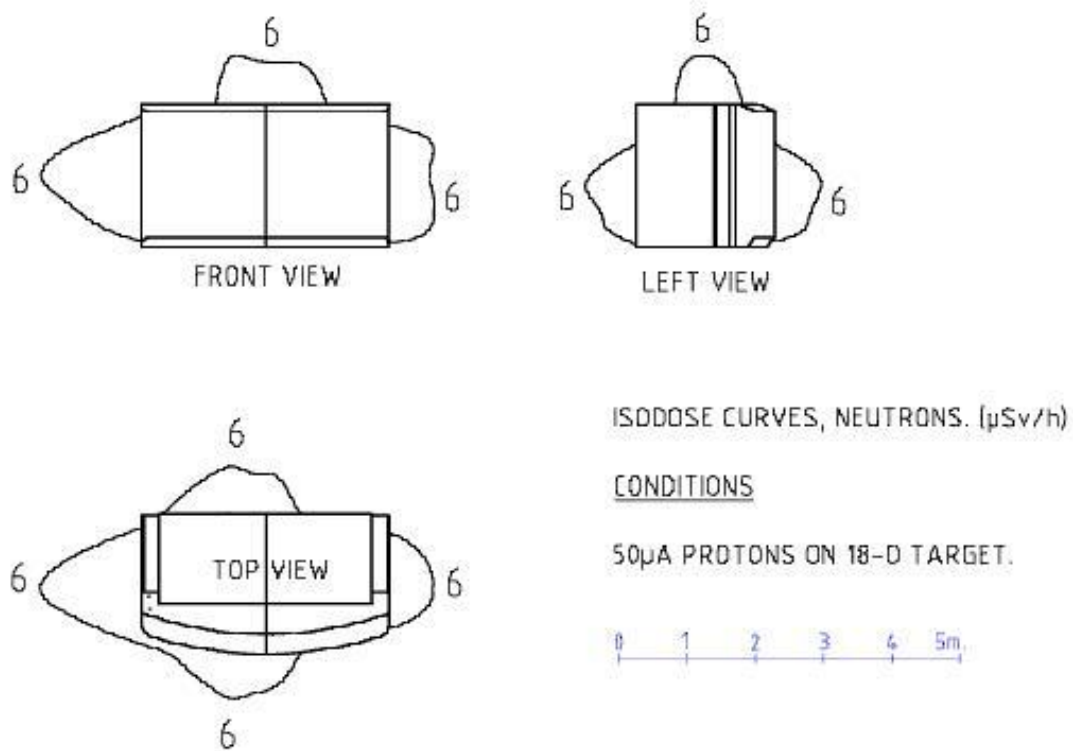
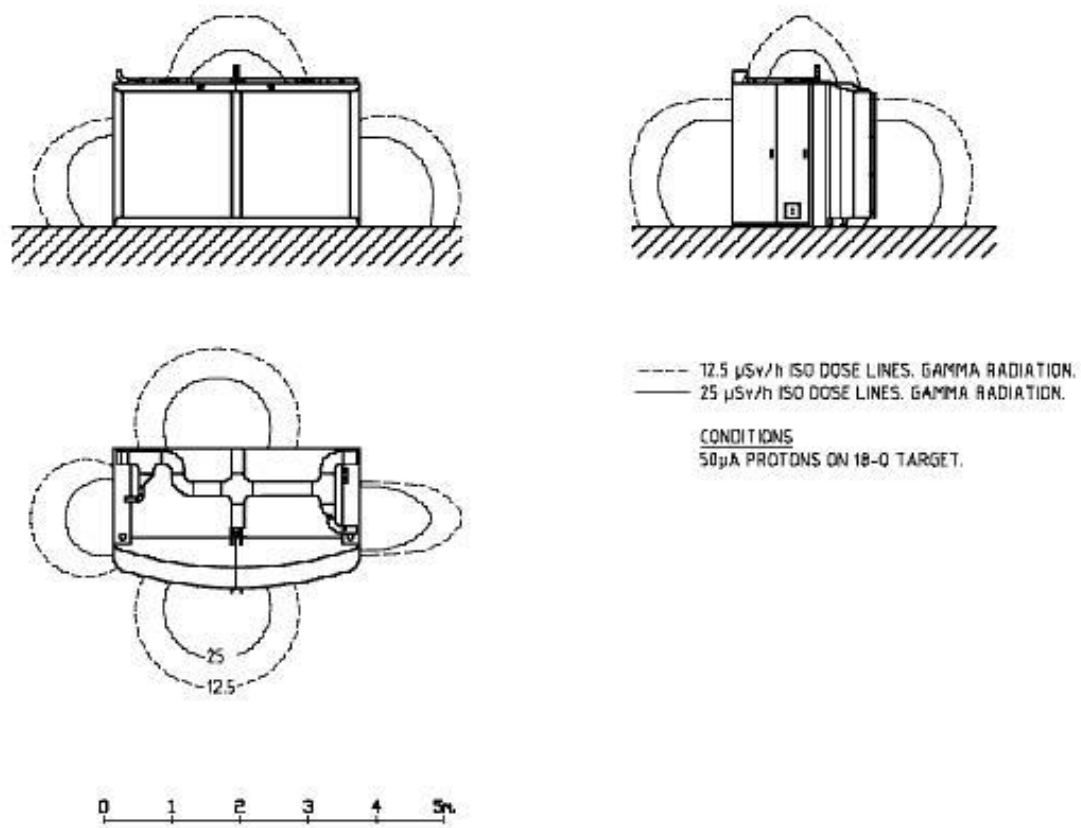


Figure 3-2: Typical gamma radiation isodose contours for MINItrace radiation shield





### 3-2-7 Waste gas system

Radioactive waste gases from the  $^{11}\text{C}$  and  $^{15}\text{O}$  process systems (with half-lives 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, i.e. for the  $^{11}\text{C}$  and  $^{15}\text{O}$  process systems 200 minutes.

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

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

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

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

### 3-4 Service and safety

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

See [Section 6-2 LOTO \(Lock-Out and Tag-Out\) on page 70](#) 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 (e.g. PET-scanners, nuclear cameras, MR cameras, cardiac pacemakers, neurostimulators and other biostimulation devices) or can affect the magnetic field (e.g. 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

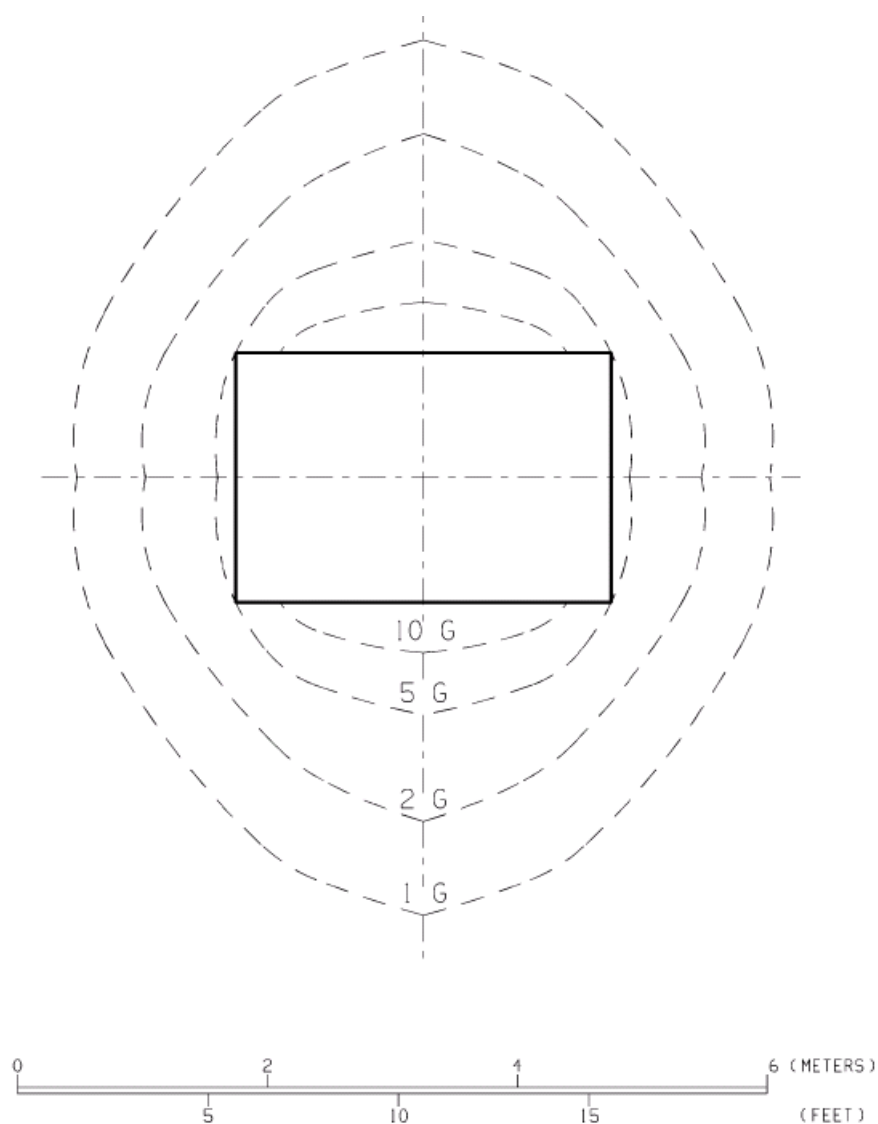
Magnetic shielding can be used to reduce the fringe fields surrounding the cyclotron magnet to minimize effects on the external environment.

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.

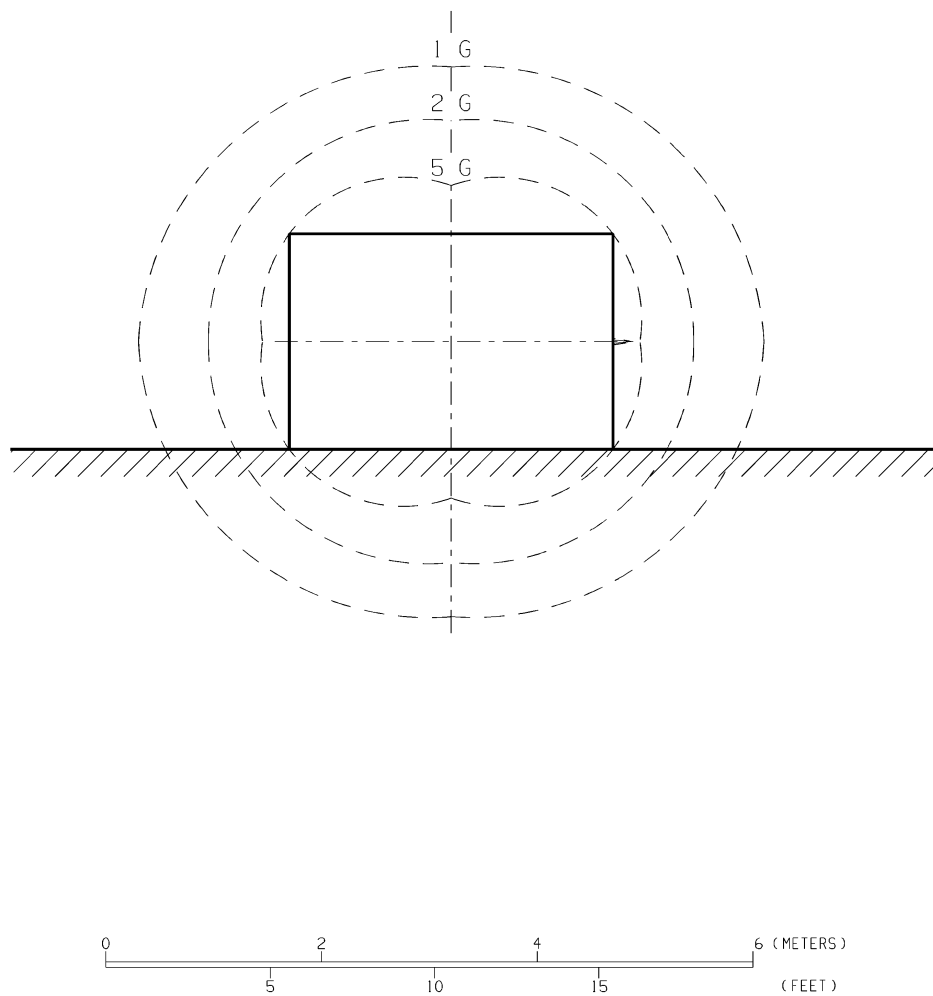
The GE site planning group has the capability to design magnetic shields which meet a broad range of site requirements.

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



MAGNETIC FIELD MINItrace  
TOP VIEW

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



MAGNETIC FIELD MINItrace  
SIDE VIEW



## 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 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 <sup>1</sup>	18–25	65–77	± 3 (± 6)	3	30–60	5	3
Radiochem. lab <sup>2</sup>	18–25	65–77					
Other laboratories <sup>2</sup>	18–25	65–77					

<sup>1</sup> Cyclotron room not expected to be regular working area.

<sup>2</sup> Environment conditions for working personnel have to be specified by the customer.

### 5-3 Cooling requirements

#### 5-3-1 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 and non-MINItrace equipment.

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		Radiochemistry lab	
	Watt	BTU/h	Watt	BTU/h
Cyclotron	-	-		
Control Cabinet (CCAB)	1000	3400		
Radio Frequency Power Generator (RFPG)	2000	6800		
Master System			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 <sup>1</sup>	100	340		
Cyclotron Support Cabinet (CSC)	100	340		
Cables	200	680		

<sup>1</sup> Service laptop provided by customer. Intermittent use.

### 5-3-2 Cooling water

An **external chiller** should be supplied and connected, by the customer, to the secondary cooling unit (a closed loop deionized water system), via the supply panel (see [Section 7-3-2 Water pipe connections at the supply panel on page 85](#)).

The external chiller (a cooling tower or a refrigeration system) must supply an inlet water temperature of not more than 13°C, in order to enable temperature regulation of the closed loop deionized cooling water system within  $20 \pm 1^\circ\text{C}$ .

A connection for **make-up water** to the secondary cooling unit shall be provided by the customer. The make-up water is connected via the supply panel (see [Section 7-3-2 Water pipe connections at the supply panel on page 85](#)).

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

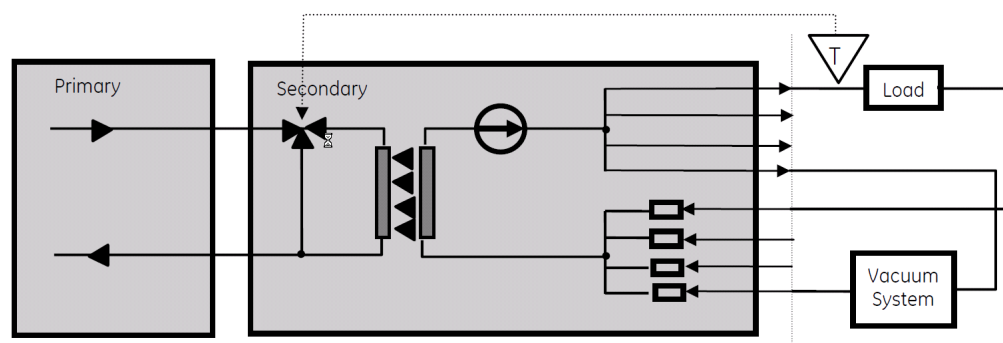


Table 5-3: Cooling water requirements

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

### 5-3-3 Primary cooling

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

**Table 5-4: Primary cooling water system requirements**

Cooling capacity	40 kW
Load variation range	1–35 kW
Flow	50–70 l/min
Inlet temperature to secondary cooling unit	Maximum 13°C
Maximum system pressure	0.6 MPa
Differential pressure (heat exchanger)	Approximately 0.05 Mpa

The primary cooling water circuits are connected to the secondary cooling system via the supply panel (see [Section 7-3-2 Water pipe connections at the supply panel on page 85](#)).

### 5-3-4 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 guarantees the conductivity level and that particles do not come into the cooling circuit.

### 5-3-5 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.

### 5-3-6 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 of  $20 \pm 1^\circ\text{C}$ , independent of heat load to the water system.

## 5-4 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.

## 5-5 Noise

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

Table 5-5: Typical noise level readings

Cyclotron room	70 dB
Radiochemistry lab	65 dB

## 5-6 Room ventilation

The entire PET facility should be divided into separate zones depending on the level of activity. 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 level to higher 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.

## 5-7 Ambient radio frequency interference

The cyclotron system utilizes high power radio frequency to produce the potential voltages to accelerate the beam. The RF power generator produces 10 kW at  $101 \pm 0.5$  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

## 5-8 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 5-6](#).

**Table 5-6: Hazardous gases and radioactive liquids**

<b>Hazardous gases:</b>	
Hydrogen (H <sub>2</sub> )	Risk for explosion in different mixing proportions with air. Always provide for good ventilation. Avoid open flames. After processing, H <sub>2</sub> main valve should be closed by hand for double security.
<b>Radioactive liquids available at product outlets or at the output of dedicated process units:</b>	
<sup>18</sup> F-F <sup>-</sup> (aq)	Liquid containing <sup>18</sup> F <sup>-</sup> should be handled with special care. During storage, it should be kept in sealed bottles in lead boxes to prevent any unwanted contact. Contact with skin is dangerous.
<sup>13</sup> N-NH <sub>3</sub> (aq)	–

## 5-9 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.

## 5-10 Utility requirements

### 5-10-1 Compressed air supply

Compressed air, supplied by the customer, is provided in the cyclotron room by means of the Supply Panel (see [Section 7-4 Compressed air piping interconnects on page 87](#)).

Dry compressed air with a:

- pressure of 0.6 MPa (6 bar)
- 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. 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).

See also [Section 7-4-2 Compressed air connection at the supply panel – customer responsibilities on page 88](#).

### 5-10-2 Gas supply and gas regulators

All **gas cylinders** and **regulators** (except the  $^{18}\text{F}$ -He carrier gas regulator; see [Table 5-9](#) and [Figure 7-6](#)), and **gas tubes** (not included in the MINItrace delivery) **must be supplied by the customer**.

The operation of the equipment delivered from GE 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 supply panel (see [Section 7-5 Gas piping interconnects on page 89](#)).

The supply of ion source gas ( $\text{H}_2$ ) and He cooling gas (He) should be close to the cyclotron room.

Further, in the operation of the complete radioisotope 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.

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

### 5-10-2-1 Gases supplied by customer

The listed gas specifications in [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<sub>2</sub>) and deuterium (D<sub>2</sub>) gas is explosive at certain mixing proportions with air. Provide adequate ventilation.



**WARNING!**

Methane (CH<sub>4</sub>) 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 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
2.0	99.0%	1 % (10000 ppm)
2.5	99.5%	5000 ppm
3.0	99.9%	1000 ppm
3.5	99.95%	500 ppm
4.0	99.99%	100 ppm
4.5	99.995%	50 ppm
5.0	99.999%	10 ppm
5.5	99.9995%	5 ppm
6.0	99.9999%	1 ppm

## 5-10-2-2 Gas regulator recommendations

Table 5-7: Gas regulator recommendations

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

## 5-10-2-3 Gas tube recommendations

Table 5-8: Gas tube recommendations

Parameter	Value/description
Material	Seamless and welded stainless steel
Quality/grade	Thermocouple cleaned and capped
Dimension	1/8"

Table 5-9: Gas overview: quality / bottle size / pressure / pressure range

Auxiliary system	Gas	Purpose	Quality (minimum purity)	Pressure MPa [bar] [psi] (or flow, ml/min )	± MPa [bar] [psi]	Utilizes supply panel?	Note
Ion Source	H <sub>2</sub>	Operation gas	6.0	0.5 MPa [5 bar] [73 psi]	±0.02 MPa [±0.2 bar] [±29 psi]	Yes	Pressure range determined by using a frit and setting hydrogen pressure on the regulator.
All targets	He	Cooling	4.5	0.15 MPa [1.5 bar] [22 psi]	±0.05 MPa [±0.5 bar] [±7 psi]	Yes	–

Tracer systems	Gas	Purpose	Quality	Pressure <sup>1</sup> (flow)	Pressure range	Utilizes supply panel?	Note
<sup>18</sup> F-	He	Transport gas	5.5	<b>Note: Regulator provided by GE!</b> 0.5 MPa [5 bar] [73 psi]	±0.2 MPa [±2 bar] [±29 psi]	Yes	Tube from bottle splits in two lines by means of extra regulator on Supply Panel.
<sup>18</sup> F-	He	Operation	5.5	2.5 MPa [25 bar] [363 psi]	OG: ±0.1 MPa [±1 bar] [±14 psi]	Yes	
<sup>13</sup> N-NH <sub>3</sub>	CH <sub>4</sub> (Methane)	Operation Transport	5.5	0.4 MPa [4 bar] [58 psi]	-0.1 MPa +0.2 MPa -1 bar +2 bar -14 psi +29 psi	Yes	Long tubing and vertical distance between cyclotron and Radiochemistry System may require higher pressure.
<sup>11</sup> CO <sub>2</sub>	1%O <sub>2</sub> / N <sub>2</sub>	Target gas	1%O <sub>2</sub> : 3.5 N <sub>2</sub> : 5.5	0.9 MPa <sup>1</sup> [9 bar] [130 psi]	±0.1 MPa [±1 bar] [±15 psi]	Yes	–
	N <sub>2</sub>	Transport gas	5.5	0.3 MPa [3 bar] [45 psi] (Flow 400 ml/min)	±0.1 MPa [±1 bar] [±15 psi] (±50 ml/min)	Yes	Set pressure to 2.5 bar and adjust the flow with the needle valve.
H <sub>2</sub> <sup>15</sup> O	1%O <sub>2</sub> / <sup>15</sup> N <sub>2</sub>	Target gas	1%O <sub>2</sub> : 3.0 <sup>15</sup> N <sub>2</sub> : 3.0	0.9 MPa <sup>1</sup> [9 bar] [130 psi]	±0.1 MPa [±1 bar] [±15 psi]	No	Very expensive gas.
	5%H <sub>2</sub> + Ar	Transport gas	H <sub>2</sub> : 3.0 Ar: 5.5	0.3 MPa [3 bar] [44 psi] (Flow 400 ml/min)	±0.1 MPa [±1 bar] [±14 psi] (±50 ml/min)	Yes	Adjust pressure to achieve correct flow. Pressure range 2–3 bar.

<sup>1</sup> Regarding operating pressure: The table gives initial pressure. Final pressure in gas target must not exceed 2.4 MPa [24 bar] [350 psi].



### 5-10-3 Liquid supply (supplied by customer)

Table 5-10: Target liquid specifications

Target	Liquid specification	
$^{18}\text{F}$ -	$^{18}\text{O}$ - $\text{H}_2\text{O}$ , [ $^{18}\text{O}$ ]-enrichment > 97%, deionized, sterile filtered Conductivity < $3.3 \times 10^{-6}$ (S/cm) Sterile and free of pyrogens.	
	$\text{H}_2\text{O}$	> 99.9%
	Ca	< 0.2 ppm
	Mg	< 0.1 ppm
	Na	< 0.5 ppm
	K	< 0.2 ppm
	Fe	< 0.1 ppm
	$\text{NH}_3$	< 1 ppm
	F	< 0.3 ppm
	Br	< 0.2 ppm
	C	< 7 ppm
	pH	$6.5 \pm 0.2$
$^{13}\text{N}$	$^{16}\text{O}$ - $\text{H}_2\text{O}$ , deionized, sterile filtered, 18 Mohm	

## 5-11 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.

## 5-12 Safety systems

The MINItrace tracer production system delivered from GE includes a number of interlock systems to guarantee safe system operation.

The tracer production system is however only a part of a total PET system 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.

### 5-12-1 Illuminated signs

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

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

### 5-12-2 Mains Distribution Panels (MDP) safety systems

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

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

### 5-12-3 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<sub>AC</sub>/V<sub>DC</sub>, 2 A are accepted.

The status information available is:

- 1    Magnet ON            Closed contact between terminal 3 and 15 when main coil power supply (PSMC) is on.
- 2    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 loops is broken, the beam is immediately stopped.

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

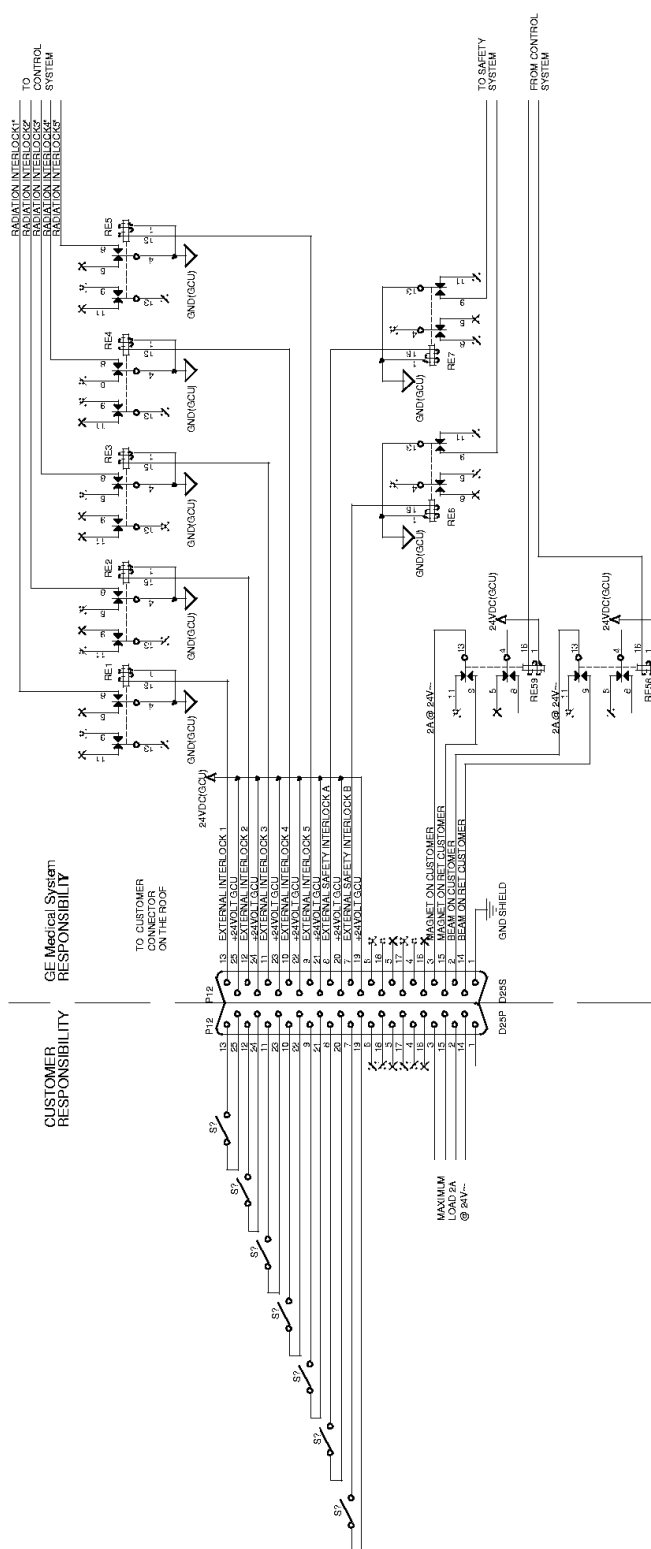
The customer has also access to five safety status inputs. These statuses will show up on the operator's console but will not stop the beam. They can be used for radiation monitoring. All five inputs should be *separate* and *potential free* loops and are connected to connector pins 13 and 25, 12 and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



#### 5-12-4 Safety systems not included in the MINItrace

As the MINItrace tracer production systems are sold in a wide range of countries with different regulations, it is not possible to recommend safety systems applicable everywhere. Some systems typically used at most PET sites.

##### 5-12-4-1 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, cyclotron room and in ventilation systems connected to the cyclotron room and chemistry area.

## 6 POWER REQUIREMENTS

### 6-1 General power distribution

The MINItrace tracer production system requires a customer supplied Mains Distribution Panel (MDP) that meets GE specifications, to provide the power feeds to the following MINItrace 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 Control Cabinet (CCAB)
- One 25 kVA to the Radio Frequency Power Generator (RFPG)

On top of each cabinet, there is a cable feed-through with a diameter of 23–40.5 mm.

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

During the PET suite design process, carefully consider the advantages and disadvantages of raised flooring, conduits, floor ducts and surface raceways for routing cables, as well as the federal, state and local electrical code requirements. If the site uses conduits, choose one with a large enough diameter to accommodate the passage of any cable with its connector, with all other cables in the conduit. (Regarding planning power feeds to the MINItrace, see [Section 2-4 Cabling considerations on page 27.](#))

Position the Mains Distribution Panel (MDP) in the vicinity of the cyclotron cabinets, i.e. 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 will specify the number of circuit breakers and their loads for the particular application.

**Table 6-1: Power distribution**

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%

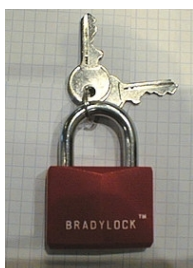
## 6-2 LOTO (Lock-Out and Tag-Out)

### **Note!**

*All mains distribution circuit breakers should 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 should 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 the Master System and accessories (service laptop, etc.).

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

### 6-4 Emergency facility lighting power

Emergency power is recommended for emergency facility lighting.

### 6-5 Power requirements

The MINItrace is designed for common line voltages available throughout the world: 400 VAC and 480 VAC (with a variation of the nominal line voltage of  $\pm 10\%$ ), 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<sup>2</sup>. 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
Master System	(1)	(0.5)
<b>Total</b>	<b>50 (51)</b>	<b>39 (39.5)</b>

## 6-6 Recommended power distribution system

### 6-6-1 Input voltage

The drawing in [Figure 6-2](#) shows the mains distribution for MINItrace. The range of accepted line voltages (400 VAC, 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 72](#)).

**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](#).

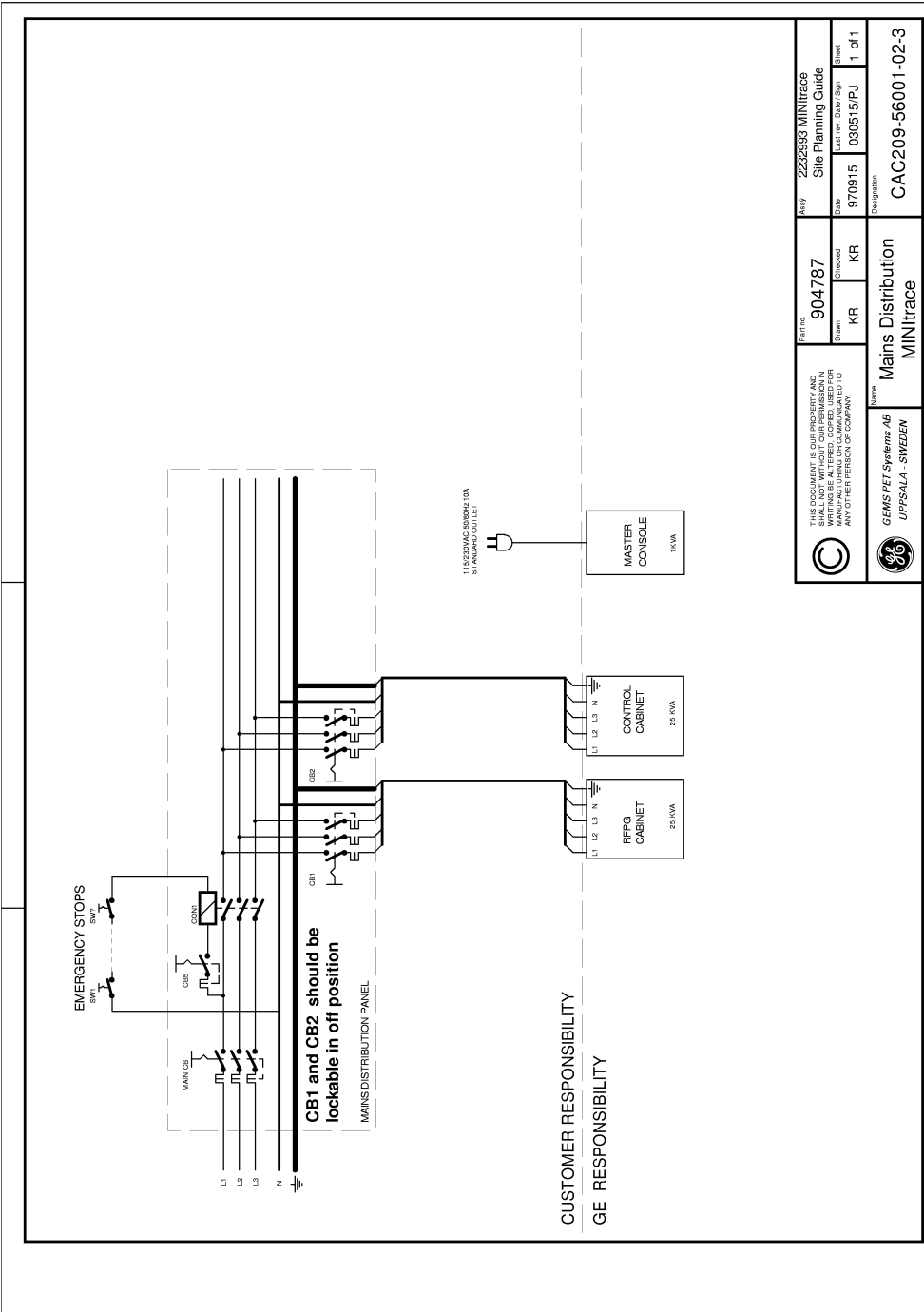
The drawing in [Figure 6-2](#) also identifies the customer and GE responsibilities for mains power supply to the cyclotron system.



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: MINItrace mains distribution, 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 the Master System, external chiller for water cooling, compressed air supply and air condition.*

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

**Note!**

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

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

System	Power consumption [kVA]	Recommended UPS size [kVA]
MINItrace cyclotron	50	60
Master System	0,5	1

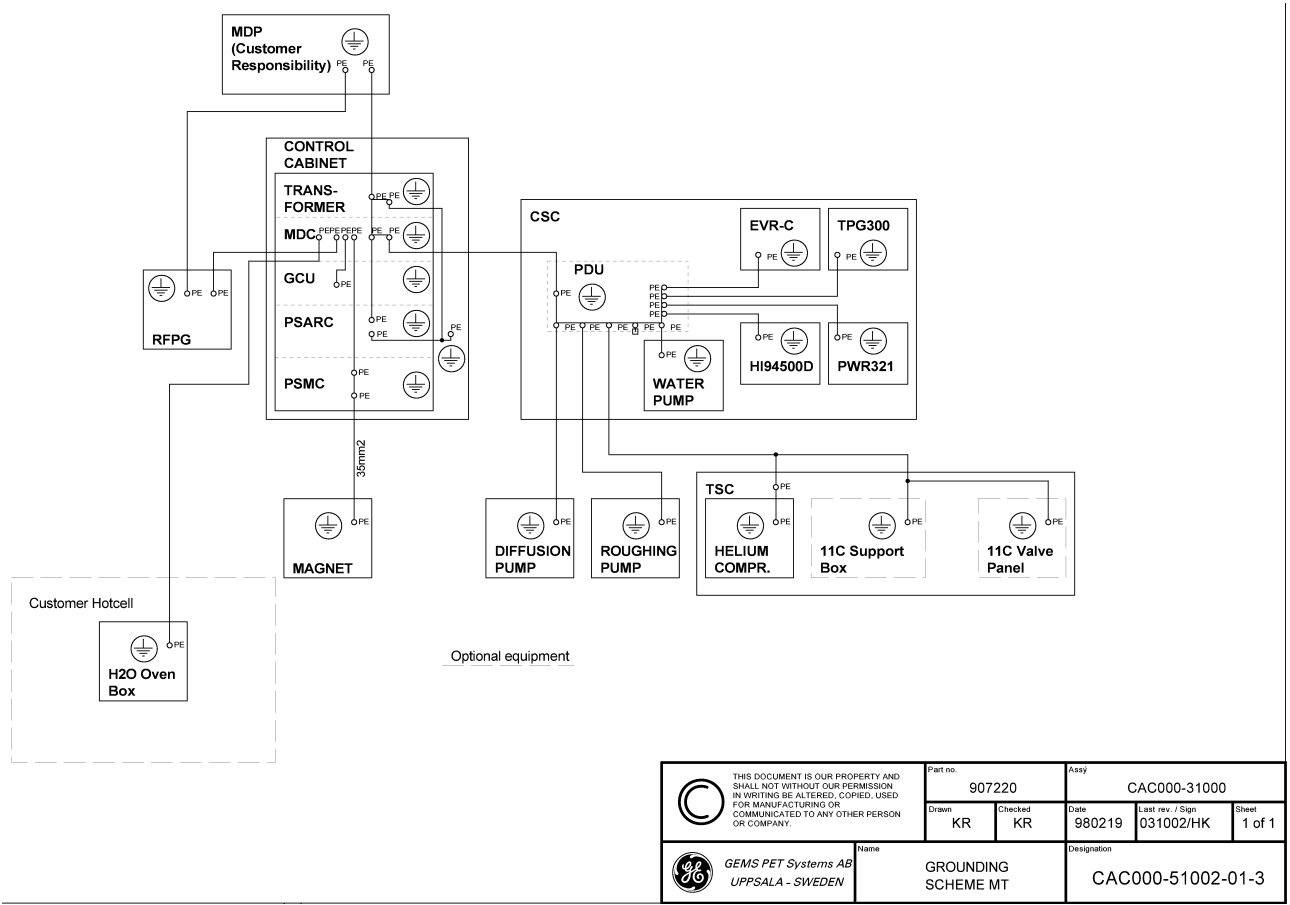
GE recommends and can offer power survey prior to the installation of the MINItrace system.

## 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 MINItrace tracer production system. The following topics are discussed:

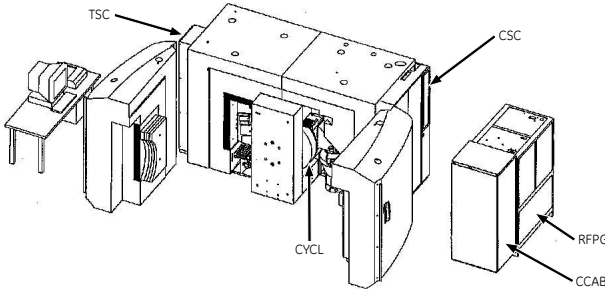
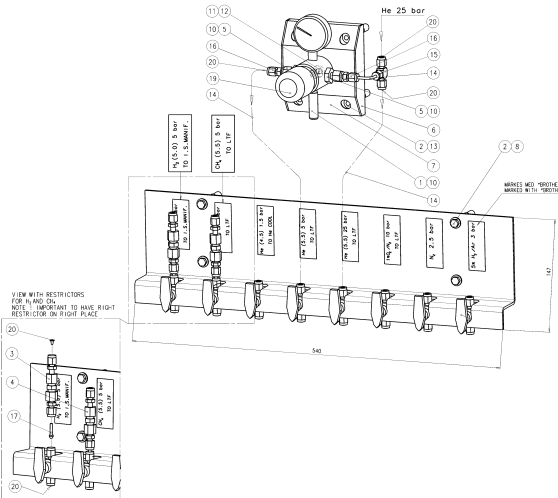
- Overall cable interconnects
- Signal cable interconnects
- Cooling water piping interconnects
- Compressed air piping
- Gas piping interconnects
- Miscellaneous components typically provided by a contractor

#### 7-1-1 Component designators

GE uses a component designator system as a means of identifying all MINItrace tracer production 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

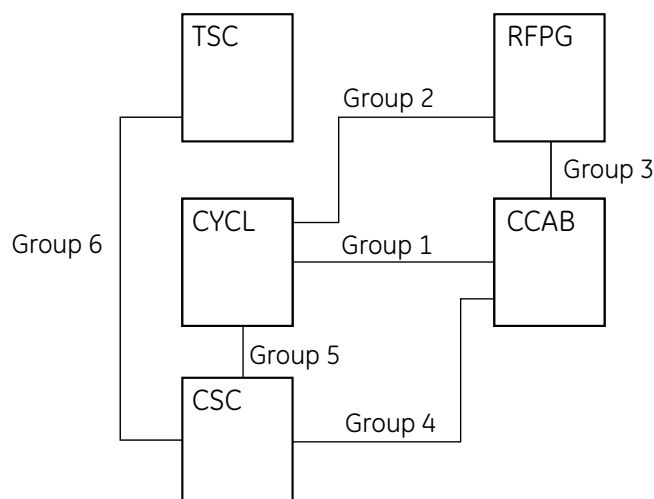
MINItrace tracer production system	Component designation	Description
	TSC	Target Support Cabinet (incl. He compressor, Liquid Target Fillers (LTF))
	CSC	Cyclotron Support Cabinet (incl. Power Distribution Unit (PDU), Vacuum Control Unit (VCU), secondary cooling unit, Radiation Shield Drive Unit (RSDU) 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
		Supply panel
GE service equipment	Component designation	Description
	MSS	The service laptop to run MINItrace Service System (MSS) software is <b>not included</b> in the product. The laptop <b>must be able to read CD-ROM</b> disks.

## 7-2 Cable interconnects

### 7-2-1 (Group) cable routing

Figure 7-1 shows the group cable interconnect diagram for a standard MINItrace tracer production 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 MINItrace tracer production system components. Interconnects in the system include the following:

- All GE supplied subsystem secondary (not mains) power cables
- All GE 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 are routed in metallic cable ducts supplied by GE.

Control signal cables and secondary power cables should if possible be separated when routed in the same wire duct. The customer must assure 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](#):

<b>Group number</b>	Identifying number referring to bundles (i.e. groups) of tables as shown in <a href="#">Table 7-2</a> .
<b>Area</b>	<p>Cross-sectional area of the combined cables in a group.</p> <p><b>Note!</b>  <i>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.</i></p>
<b>Usable length</b>	<p>Maximum length of a cable between respective cabinets.</p> <p><b>Note!</b>  <i>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).</i></p>
<b>Cable id.</b>	<p>Unique name assigned to each GE supplied cable.</p> <p><b>Note!</b>  <i>This number must be used when making special cable orders</i></p>
<b>Cable diameter</b>	Diameter of an individual cable.
<b>Cable leads (AWG/No.)(mm<sup>2</sup>/No.)</b>	Gauge (size) of wires and total number of wires within a given cable



Table 7-2: MINItrace interconnect list

Group no.	Group area mm <sup>2</sup> (in <sup>2</sup> )	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
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 mm <sup>2</sup> (in <sup>2</sup> )	Between units		Usable length m (ft)	Cable id.	Cable diam. mm	Connectors		Notes
		From	To				From	To	
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	

Table 7-3: Connector dimensions

Connector type	Size	Diameter/length [mm]
Cannon D-Sub	D9	65/61
	D15	70/61
	D25	79/61
	D37	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 be 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 5-3 Cooling requirements on page 55](#). A sketch of the cooling water system is shown in [Figure 5-1](#).)

The major part of heat dissipated by the MINItrace tracer production 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](#).

The water piping for:

- primary water (raw water)
- make-up water

is described on the following pages.

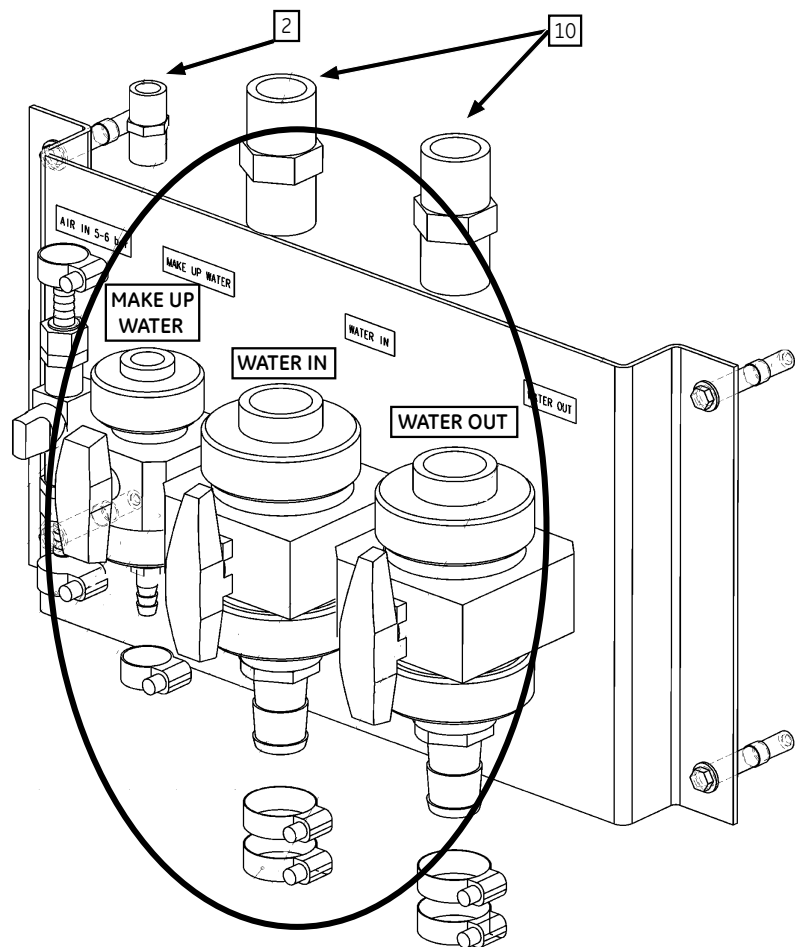
### 7-3-2 Water pipe connections at the supply panel

The **primary water** (raw water) and the **make-up water**, both supplied by the customer, is connected to the cyclotron system by means of the supply panel, see [Figure 7-2](#) below.

**Note!**

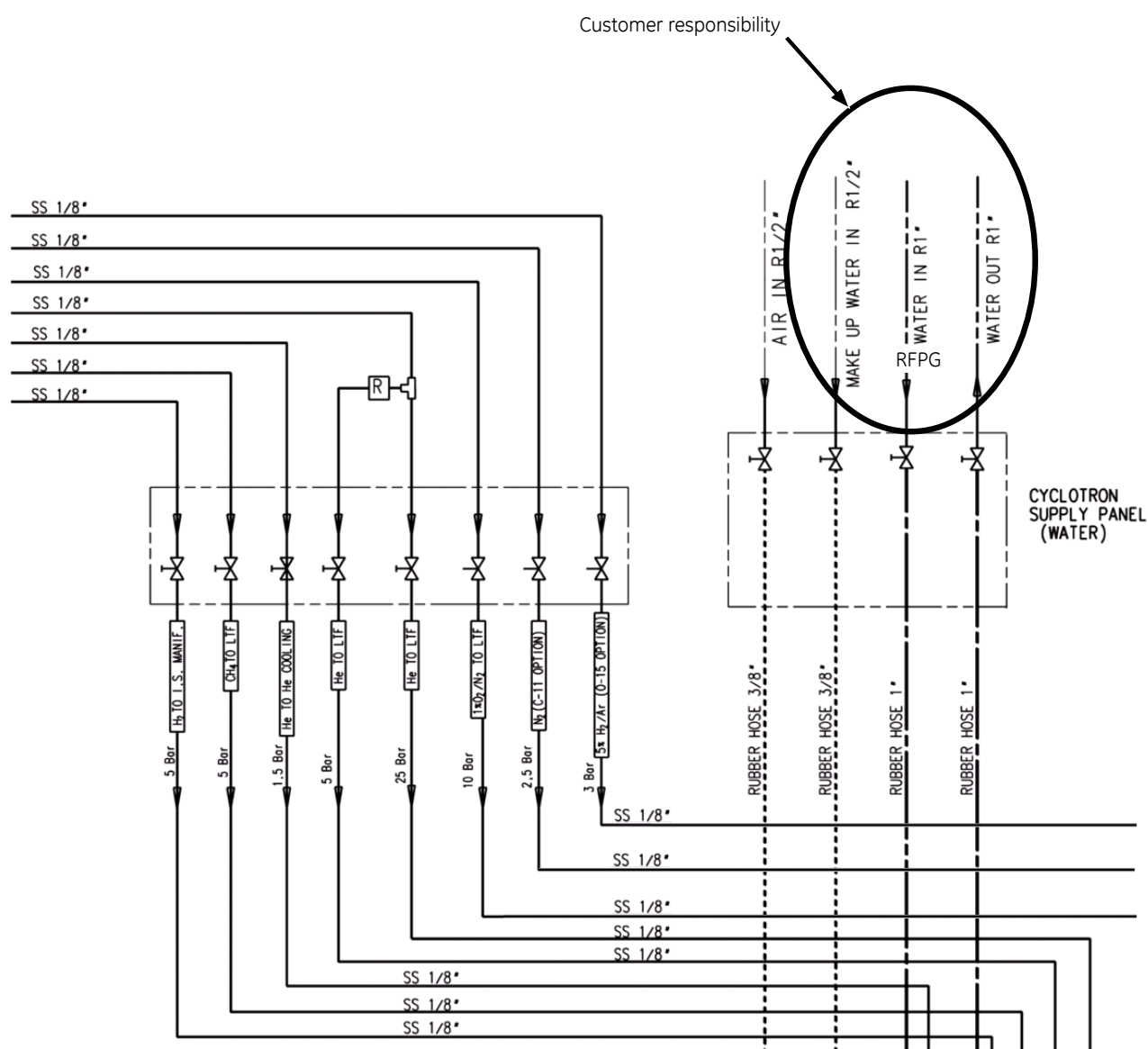
The supply panel, including pipes to the cyclotron, water hoses to the Control Cabinet (CCAB) and water hoses to the Radio Frequency Power Generator (RFPG), is part of the GE delivery.

Figure 7-2: Supply panel (part of the GE delivery), water piping



Position	Quantity	Dimension
10	2	NPT 3/8"
2	1	NPT 1"

- the supply of primary water (raw water) at a correct temperature and flow **to and from** the supply panel
- the supply of make-up water to the supply panel



## 7-4 Compressed air piping interconnects

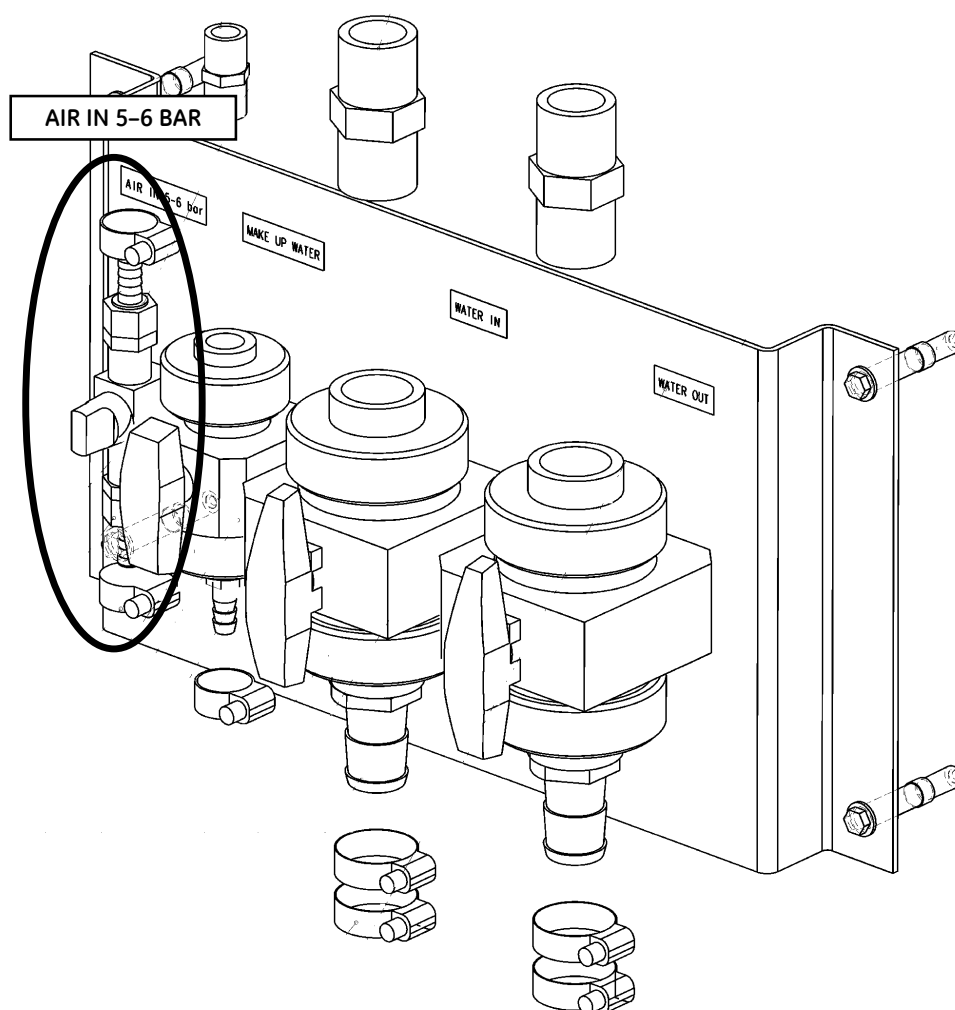
### 7-4-1 Compressed air connection at the supply panel

Compressed air, supplied by the customer, is provided in the cyclotron room by means of the supply panel, see [Figure 7-4](#) below.

**Note!**

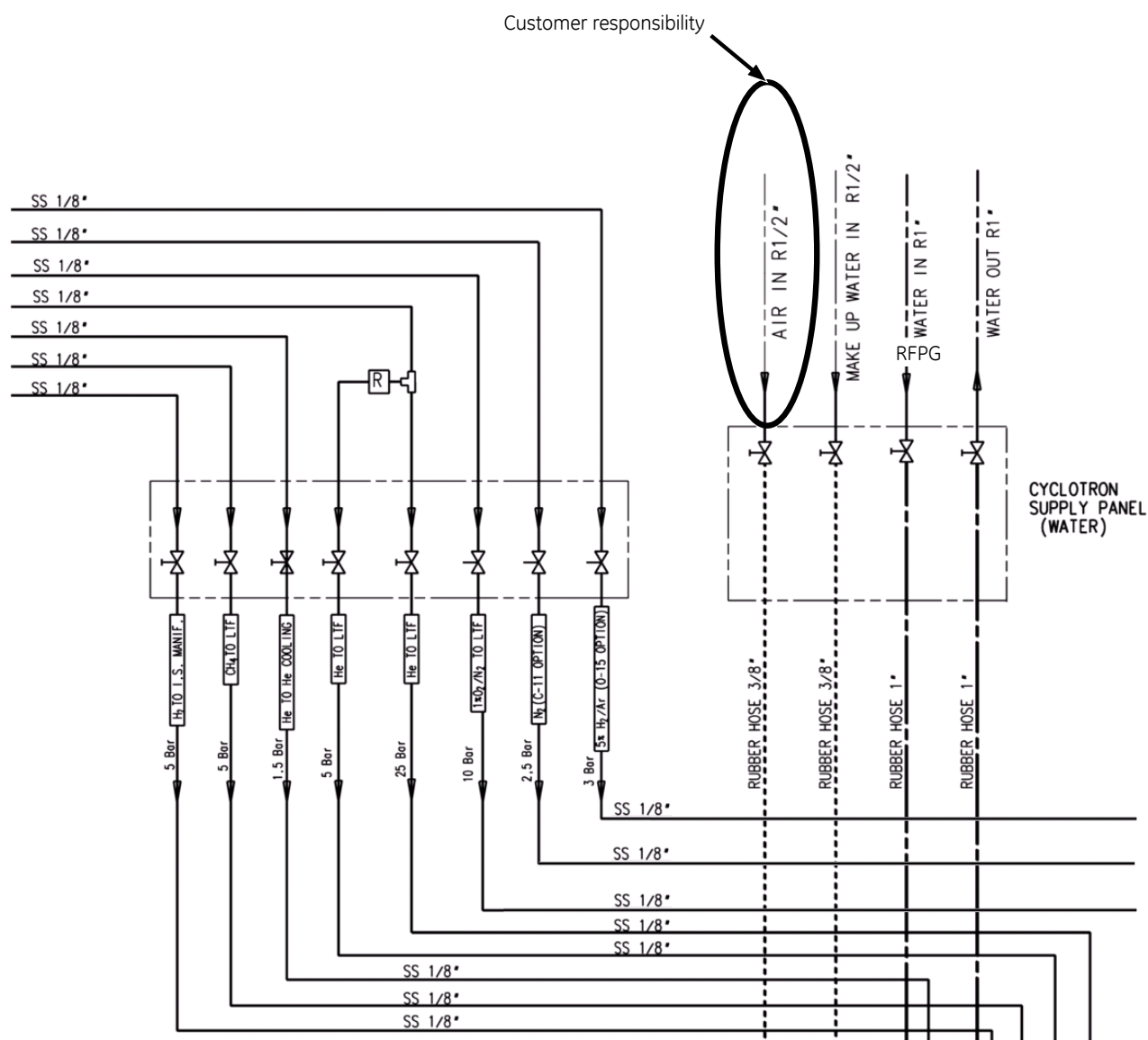
The supply panel, including pipes to the cyclotron, water hoses to the Control Cabinet (CCAB) and water hoses to the Radio Frequency Power Generator (RFPG) is part of the GE delivery.

Figure 7-4: Supply panel (part of the GE delivery), compressed air piping



**The customer** is responsible for the supply of clean, dry air (0.6 MPa, 150 l/min, see [Figure 7-5](#)) to the supply panel.

**Figure 7-5: Supply panel compressed air piping – customer responsibilities**





## 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 supply panel, see [Figure 7-6](#).

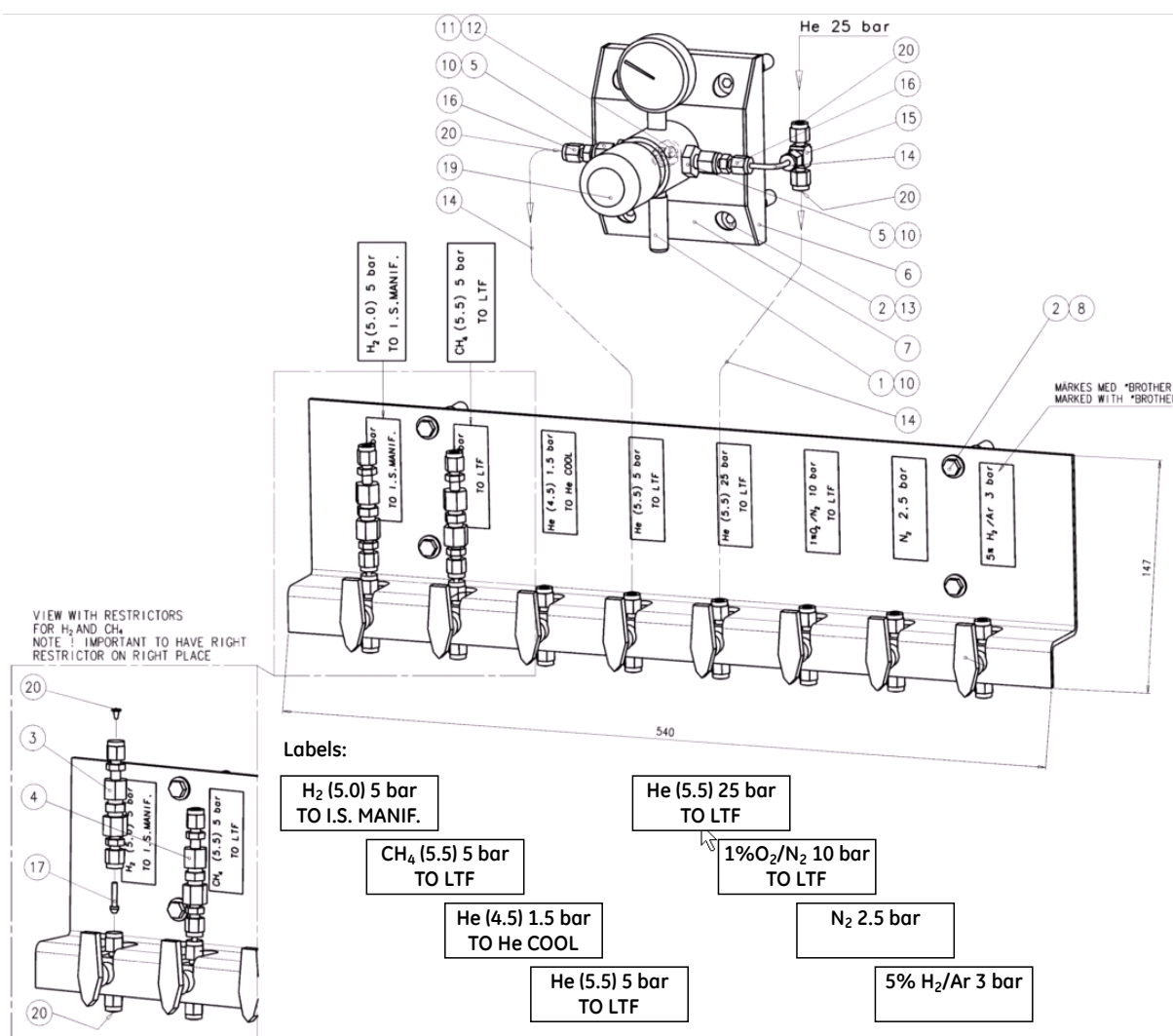
**Note!**

The 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 delivery.

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

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

Figure 7-6: Supply panel (part of the GE delivery), gas piping



### 7-5-2 Gas connections at the 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 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 specifications, 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!*

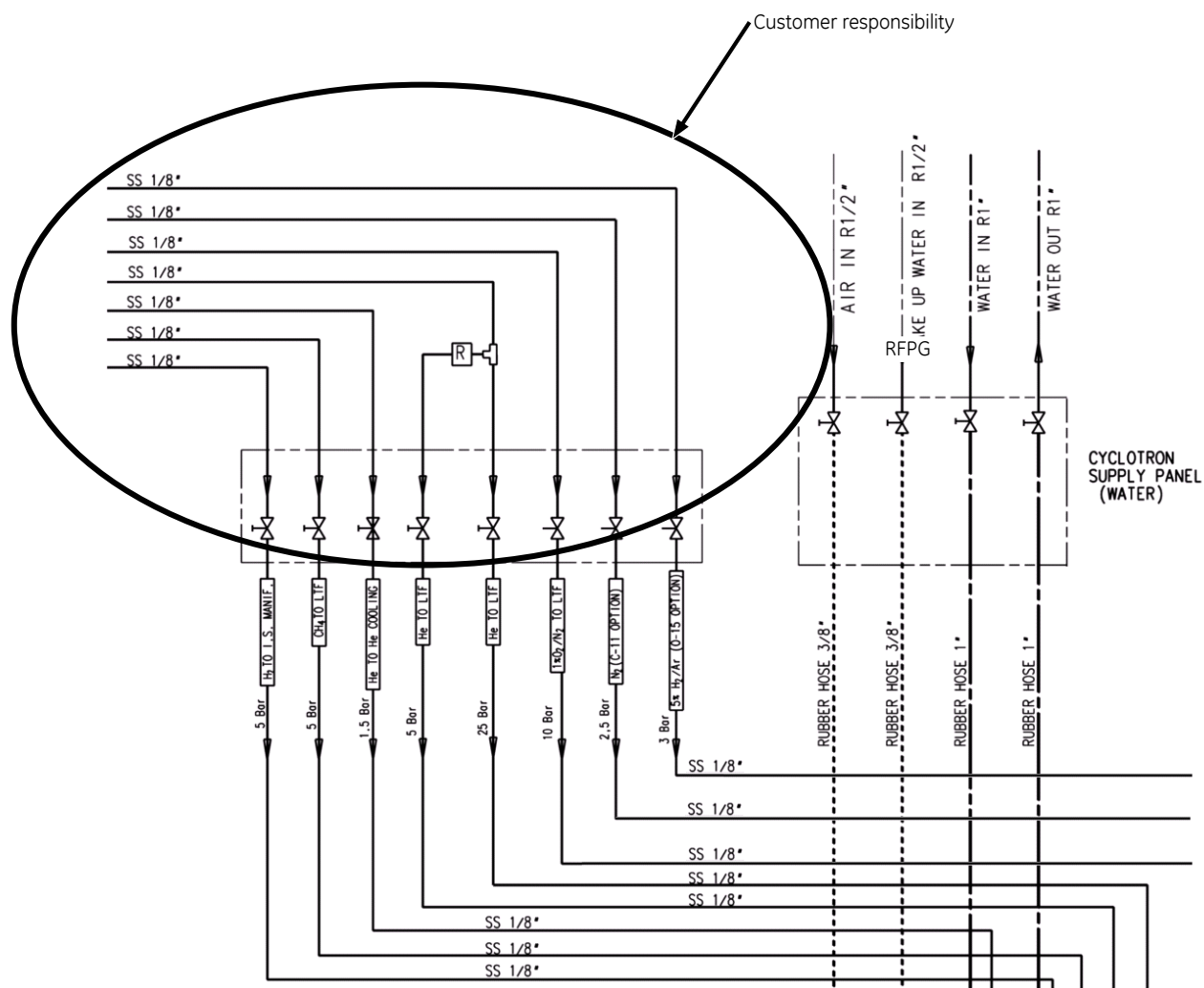
**Note!**

*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 7-7: Supply panel gas piping – customer responsibilities



### 7-5-3 Gas connections to hot cell

Up to 40 m tube is included in the GE standard installation, and is a part of the GE delivery.

For information about duct dimensions needed for gas and liquid tubes, see [Section 2-5-2 Floor ducts for radioactive gases on page 28](#).

## 7-6 Contractor-furnished components

This section lists contractor-furnished components and details for connections to the MINItrace tracer production 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 sub-systems.
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 SHUTDOWN". Locate near each exit in the cyclotron room. See <a href="#">Chapter 6 Power requirements</a> .
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 <a href="#">Chapter 6 Power requirements</a> .
Power for Master System	Provide and install power outlets for Master System and printer.
Safety interlocks	Provide safety interlock components and wiring. Door switches, audible and visual alarms facility system interlocks, etc. as required by federal, state and local regulations.

**Table 7-5: 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 <a href="#">Section 5-10-1 Compressed air supply on page 61</a> .



## 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 8-1](#) 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 Dimensions

**Table 8-1: 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

## 8-4 Rigging

This is routinely be 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 by the mobile crane or a fork-lift truck.



## 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 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

- 1 Have final site construction drawings been reviewed by the GE site planning group?
- 2 Have vehicle-parking arrangements been made for installation personnel?
- 3 Is temporary storage space available for use during installation?
- 4 What is the hospital smoking policy?
- 5 Are first aid kits and nonferrous fire extinguishers available at site?
- 6 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 service representative must be completed before system delivery to ensure site readiness.

- 1 Are all walls, floor and ceiling in the cyclotron room essentially complete except for any removable sections?
- 2 Has a clear route to the cyclotron room been defined for magnet installation (see [Section 2-3 Minimum access requirements on page 27](#))?
- 3 Is a secure space available to store equipment on site?
- 4 Have arrangements been made for the use of special rigging equipment for moving the magnet into the cyclotron room?
- 5 Has work in the cyclotron room been completed or suspended and the cyclotron room closed off to provide a dust-free, closed environment?
- 6 Has all equipment been removed from the cyclotron room to allow space for the magnet with rigging equipment?
- 7 Are 24-hour water and 24-hour power available?
- 8 Have necessary conduits or raceways for power and signal cables been installed?

- 9 Has a delivery route been defined for equipment (see [Section 2-3 Minimum access requirements on page 27](#))?
- 10 Does incoming power have all the specified safety precautions and remote disconnects?
- 11 Is the operator's area complete to provide a dust-free environment for installation of the Master System?
- 12 Is air conditioning running in all rooms?
- 13 Are functioning telephones (as defined in [Section 2-6 Architectural reminders on page 29](#)) available at site for the duration of the installation?

## 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 supplied equipment

- 1 Crane (capacity 50–80 ton) for lifting magnet from delivery truck.
- 2 Steel floor plates to cover floors while transporting the magnet.
- 3 Wood blocks (assorted sizes).
- 4 Jacks and accessories (40 000 lbs. capacity) for lifting the magnet.
- 5 Equipment for unloading of electronics and other miscellaneous components (for example fork lift and hand truck).

### 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 ANALYSIS 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 well educated personnel.

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.

The analytical equipment must be placed in a hot cell.

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 analysis equipment

Table 11-1: Analysis instruments

Item	Type/specification
Dose calibrator	0–5000 mCi (0–185 GBq)
HPLC including:  Columns HPLC  Integrator Printer UV detector Injection valve	For analysis of $^{13}\text{N-NH}_3$ , if not performed with TLC  Partisil SAX 10 mm × 25 cm Zorbax SAX 4.6 mm × 15 cm  254 nm
TLC (alternative to HPLC)	$^{18}\text{F-FDG}$ , $^{13}\text{N-NH}_3$

Table 11-2: Analysis 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	



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