ACSI

TR-19 Site Planning

A Guide for Installation

For Reference Only
Not to be Used for Construction

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Disclaimer

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Care has been taken to ensure the information contained within this document is accurate and current. Technical specifications are based on standard operating conditions and are subject to variation.

ACSI reserves the right to make modifications to this document, drawings and specifications provided at any time without notice or obligation, and hereby disclaim responsibility for any damages resulting therefrom.

Only qualified personnel are permitted to operate and maintain the equipment. Personnel should be familiar with and trained in the installation, assembly, operation and maintenance of the equipment and its components. All personnel shall possess current safety and regulatory standards for the country of installation.

The development of the equipment layout, room dimensions, mechanical & electrical specifications is predicated upon the best information obtainable from the site, coupled with the customer's known desires. Architectural and/or electrical changes including relocation of equipment illustrated on these drawings are allowed only following review by ACSI & with ACSI written approval. ACSI reserves the right to make on the job changes because of customer requirements and/or obstacles in construction, etc.

All work is to be in compliance with national & local building safety codes and be supplied and installed by the customer or customer's contractors.

Radiation protection requirements, where needed per national or local code, shall be specified by a qualified health physicist.

The customer understands that non-compliance with the physical and service requirements may cause equipment damage, shorten equipment life, or cause equipment deficiencies. The manufacturer's warranty shall be rendered void under those circumstances.

The Customer will carry such insurance and provide such evidence of insurance as are required by the terms of the Advanced Cyclotron Systems Acquisition Agreement.

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Confidentiality

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This document and information contained within is proprietary to Advanced Cyclotron Systems Inc. and shall not be used, disclosed and/or duplicated without the express written authorization of Advanced Cyclotron Systems Inc.
This is a confidential document and should not be accessed by any person not directly involved with the purchase and installation of an ACSI TR-19 cyclotron.

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Please pay attention to the following warnings, cautions, and notes found throughout this guide.

WARNING

This message indicates that if a particular procedure or process is not followed as described serious injury or death may occur to the operator or others in the operating environment.

CAUTION

This message indicates that if a particular procedure or process is not followed as described, damage or destruction may occur to the cyclotron or associated equipment.

NOTE

This message is information that is not related to safety but may be helpful for performing operation tasks or facilitating a process.

ACSI

The Company and its People

Advanced Cyclotron Systems, Inc. (ACSI) is a world leader in the design and manufacturing of cyclotron equipment, including PET and SPECT radioisotope production cyclotrons. We manufacture and supply complete systems for radioisotope and radiocompound production.

ACSI has been in business for over 20 years and we are backed by our affiliated company EBCO Industries, which is one of Canada's largest manufacturing facilities with over 50 years in manufacturing expertise. Our dedicated team of professionals, scientists and engineers are proud to deliver quality workmanship, on-time delivery, and technological advancements for the industry. Our headquarters and manufacturing facility is located in Richmond, BC, Canada.

Our Customers and Market

We manufacture and supply cyclotrons to nuclear medicine markets worldwide, including the United States, Canada, Europe and Asia. Our users include hospitals, universities, research facilities and commercial distributors of medical isotopes.

ACSI is committed to the technological advancements in the industry with on-going research and development of cyclotron systems, targetry and radiochemical production systems. We are further committed to our customers by sharing new developments with our existing customers to ensure that they continue to be the leaders of tomorrow.

Certification

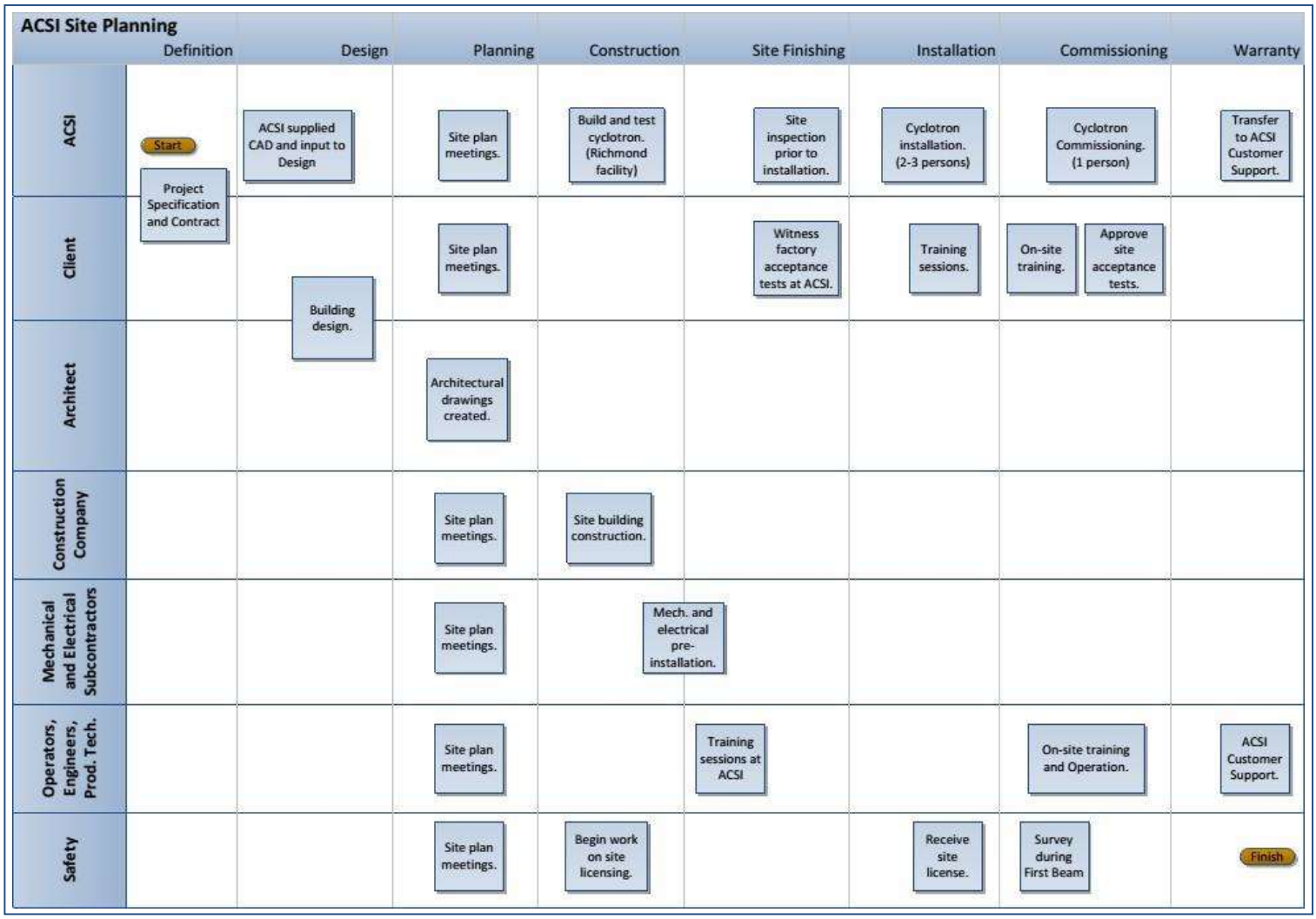
ACSI is certified by ISO 9001 and 13485

Site Planning Overview

About This Guide

This guide is an in-depth look at the site planning process that begins upon purchase of an ACSI TR-19 cyclotron. Found within it are all the necessary site requirements as well as descriptions of the processes involved in taking delivery of the machine, from the early planning stages through installation.

The Site Planning and Installation Process 1.4 nr



Required Key People

Customer Project Coordinator

It is best if one person is designated the customer's lead contact person for the cyclotron project. This keeps the lines of communication clear throughout.

Radiation Safety Officer (RSO)

This is a key role that is required for the safety of all personnel working in the cyclotron facility during and post installation. Typically during the planning stages of the project the RSO is working on the site licensing application for the production of radioisotopes.

Operators/Engineers

ACSI recommends each cyclotron facility requires a lead operator or engineer to run the cyclotron and perform regular maintenance.

The ACSI Team

Project Manager

ACSI designates a project manager for each cyclotron project. The project manager works closely with the customer project coordinator through all phases of the project to ensure successful completion. All communication from the customer should be routed through the ACSI project manager.

Installation Team

The installation team is typically made up of 2 or 3 technologists that perform the installation of the cyclotron, beamlines, and targetry.

Commissioning Team

The commissioning team is made up of ACSI operators that perform the initial tuning of the machine, site acceptance testing, and customer onsite training.

Customer Support

Following the commissioning phase, the project moves into the warranty phase and beyond. At this time communication is transferred to ACSI's customer support department that will schedule service trips and field any technical support related issues.

TR-19 Overview

ACSI's TR-19 cyclotron is a variable energy cyclotron that accelerates negative hydrogen ions. Standard operating beam current is 200 µA, upgradeable to 300 µA operation. Two extraction probes are inserted radially into the acceleration plane, allowing the extracted beam energy to be varied from 14 to 19 MeV. This radial motion is also used to vary the split ratio from 1:100 to 50:50 in dual irradiation operation. The TR-19 uses an external, multi-cusp ion source.

Different beam line configurations are available for the TR-19 based on the amount of space and layout of the vault at each site. The TR-19 can mount up to 8 targets (more with beamlines). ACSI also provides a full range of targetry for production of various PET radioisotopes.

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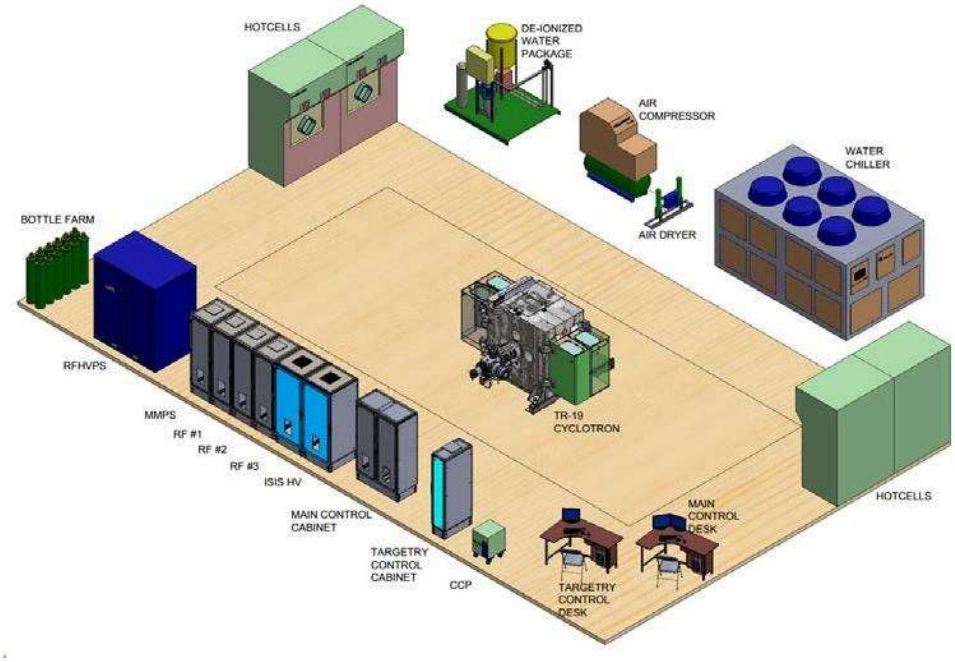

Figure 1 – Locally Shielded TR-19 Cyclotron and Ancillary Equipment

Layout

Cyclotron Vault

The design of the cyclotron vault is an integral part of the site layout and requires a significant amount of planning to ensure a functional and safe design. ACSI will provide design input and recommendations based on past experience, calculations, and field radiation surveys, however the customer is ultimately responsible for the final vault design. ACSI recommends the vault be constructed of low sodium concrete with a minimum density of 2.35 T/m^3.

Vault Wall Thickness

The following table shows the recommended vault wall thickness for different configurations. Even if the recommended values listed below are used, it is recommended to perform shielding simulations prior to making a final decision on vault wall thickness as different isotopes at different energies and beam currents can produce substantially different neutron and gamma fields (refer to the shielding simulations section below).

	Vault wall and ceiling thickness 150 uA cyclotron	Vault wall and ceiling thickness 300 uA cyclotron
Locally shielded with no beamlines	1.5-1.8 m	1.8 m
Locally shielded one side beamline	2.0 m	2.0 m
Unshielded	2.0 m	2.0 m
Self-shielded	0.5 m	0.6 m

Table 1 – Vault Wall Thickness

Equipment Weight

	Weight
Cyclotron without shielding	25,000 kg
Local Shield (4 local shields std config)	1,900 kg (ea)
Self-shielded cyclotron	92,000 kg
Vertically split beamline	6,000 kg
Ion Source	400 kg
Water Package	1000 kg
Base Frame	1300 kg
Heaviest Power Supply Cabinet (RF#1&2)	1200 kg

Table 2- Equipment Weight

Room Sizes

The minimum internal dimensions of the cyclotron vault will vary depending on the number and configuration of beamlines and targetry. The following table shows typical internal vault and room dimensions.

	Minimum internal dimensions (l x w x h)
Vault for locally shielded, no beamlines	5.5 x 4.5 x 2.7 m
Vault for locally shielded, one side beamline	7.5 x 4.5 x 2.7 m
Vault for Self-shielded	6.0 x 5.5 x 3.2 m
Equipment Room	6.5 x 3.5 x 2.7 m
Services Room (optional)	2.5 x 2.0 x 2.7 m
Cyclotron Control Room	3.0 x 3.0 x 2.2 m

Table 3 – Room Sizes

The distance between the power supplies and the cyclotron should not exceed 10 meters and the distance between the main control cabinet and the power supplies should not exceed 20 meters. There is no restriction on the distance to the control console.

Vault Door

Access to the vault is typically through a plug, sliding, or maze style door. The door requires the same shielding effectiveness as the walls and is therefore usually quite large and heavy, except in the case of a maze style entrance. ACSI can provide input into the advantages and disadvantages of each style and help to reach a final decision that is best suited to the facility.

Vault Floor

The vault floor shall support the weight of the complete cyclotron, local shielding, and beamlines (see equipment weight section above). The floor must be level to less than 12mm in 10m, washable, and smooth. The concrete shall be sealed, and painted with an epoxy coating to minimize dust collection and increase ease of contamination removal.

Equipment Room

The equipment room is where the power supply cabinets are located as well as other ancillary equipment. The power supply cabinets will occupy an area approximately 6.0 m x 3.0 m with additional space required for beamline power supplies, with a minimum ceiling height of 2.75 m (suitable height for standard electrical cabinets). Refer to ACSI supplied facility layout plans for further details.
Considerations need to be made to ensure the power supplies will fit through the building hallways, elevators, etc. and into the equipment room. Access underneath all cabinets must be maintained so a trench or raised floor is necessary.

Services Room

The services room is typically comprised of the water package and air compressor. There should be clear access to move equipment in with an access opening large enough to fit the water package (see water package dimensions in Cooling Water section). The water package can also be located in the equipment room depending on the layout.

Control Room

The control room is where the cyclotron operator(s) sit when operating the cyclotron and is typically located in a convenient, non-active area outside the vault. The control room consists of the control computer, two (or more) 24" monitors, ACSI light beacons, and an emergency stop button. A dedicated phone line and internet access is a requirement for this area.

Active Maintenance Area

The active or "hot" maintenance area is used to service radioactive components. A 2m long bench as well as fumehood with lead shielding to work behind is recommended. This room should be located in a controlled, active area and have a full set of dedicated tools.

Raised Floor

Raised flooring is typically used under the power supplies to maintain access. Once installed, ACSI can provide a detailed drawing specifying where tiles require cutting in order to run cables into cabinets. It is important to ensure that all tile stands are bolted to the floor rather than just using adhesive.

Base Frame Installation

With permission from the customer, ACSI will send the base frame 3-4 weeks prior to the cyclotron delivery so it can be installed in advance. The base frame has to be level to within ±0.1 mm, anchored to the concrete, and grouted.

Beamline

The TR-19 standard beamline is a vertically split configuration as seen in Figure 2. In this configuration, a combination magnet steers the beam to either the upper or lower beamline. This allows the addition of more targetry as well as separating the targetry away from the cyclotron.

The addition of a beamline to the TR-19 adds a significant amount of complexity to the site planning process. More power supplies are needed in the equipment room and the vault must be larger to accommodate the additional components.

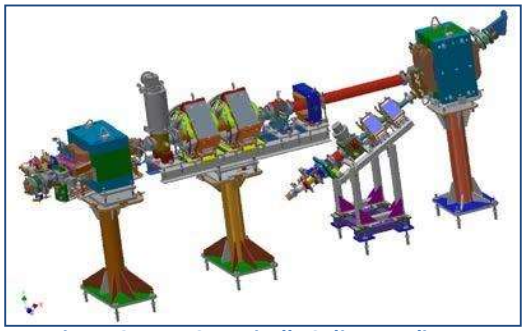

Figure 2 - TR-19 Vertically Split Beamline

Shielding

The customer is responsible for creating an adequate shielding structure (vault) for the cyclotron. The structure must comply with local and national requirements. Final drawings of radiation protection from a specialist must be reviewed by ACSI prior to installation.

- Locally Shielded Cyclotron
  This is ACSI's standard model TR-19 with large 'clamshell' shields located on either side of the machine surrounding the targets (see Figure 1).

- Self-Shielded Cyclotron
  This option is not as commonly used but is available for sites where a standard vault is not possible. Maintenance of this machine becomes more difficult due to restricted access caused by the additional shielding.

If the TR-19 has a beamline, the clamshell shielding is left off the side of the machine where the beamline is located. Custom shielding can be placed around the targets at the end of the beamline, if requested.

WARNING

The TR-19 cyclotron creates ionizing radiation while in use and will remain activated even after is has been shut off. Appropriate compliance and licensing must be arranged by the customer early in the planning process to ensure all regulatory requirements are met for equipment installation and use, including radioisotope production and transfer within the facility. All areas containing radioactive materials must be shielded.

Shielding Calculations and Simulations

It is generally recommended that Monte Carlo simulations be carried out prior to construction of the vault to obtain the best possible estimate for radiation fields. ACSI can supply these simulations, although they are not part of the standard contract.

Site Environment

HVAC and Environmental Specifications

The cyclotron requires an HVAC system to control temperature, pressure, humidity, condensation, and generally maintain a comfortable working atmosphere. This system should be fully functional prior to the start of the cyclotron installation and is the responsibility of the customer. The following table shows the HVAC and environmental requirements of each room.

	Heat Load	Air Changes per hour	Pressure (difference with vault)	Temperature	Max. temp fluctuation	Relative Humidity
Vault	2 kW	3-5	-25 Pa	20°C ± 2°C	2°C / hr	≤60%
Equipment Room	8 kW	n/a	0 Pa	20°C ± 2°C	2°C / hr	≤60%
Services Room	5 kW	n/a	0 Pa	--	--	--

Table 4 – Environmental Specifications

WARNING

Some processes require the use of radioactive gases. Steps must be taken to ensure that the escape of such gases can be controlled in a safe and efficient manner. Escaped gas must not be allowed to enter the HVAC system.

Pump Exhausts

Pump exhausts from the cyclotron roughing pumps shall be filtered and connected into the nuclear ventilation system or a gas holdup system inside vault. ACSI can work with the customer to ensure this is implemented.

Facility Safety

Radiation protection requirements must always be an integral part of facility planning. Zoning suitable for a radioactive facility should be implemented to prevent personnel exposure, the spread of contamination, and for product quality. In addition, appropriate PPE should be worn at all times in the facility. Compliance with local regulatory requirements must be achieved prior to running first beam. For more information on setting up a safe facility to produce radionuclides, refer to the IAEA's Technical Report Series on the subject.

Cyclotron Safety Systems

The TR-19 has an internal safety system that works primarily to minimize risks involving working around high voltages and limiting radiation exposure. For a more detailed look at this system please refer to the TR-19 Operating Manual.

Customer Interlocks and Site Interface

Vault Door

The interface between the vault door and the cyclotron control system is done through the customer interlock schematic and associated logic in the PLC. As this logic changes due to local regulations and customer preferences, it is recommended that a discussion take place early on in the project to specify the final design of the interlocking system.

As a minimum requirement, the limit switches from the vault door must be hardwired into the cyclotron safety system. Additionally, an "open button enable" can be used to protect against the 'door open' button being active when the cyclotron is running.

A 'last person out' (LPO) or 'Area Searched' routine should be part of the procedure to close the vault door. This can be implemented by ACSI or the door manufacturer. An LPO system comes standard with the cyclotron but many customers choose to implement their own (in which case the ACSI supplied system in disabled). Typically an 'area searched' button located on the far side of the vault must be pressed prior to closing the vault. This is to signify the area has been searched for injured personnel, left-behind equipment, or system abnormalities. Once pressed, personnel have a defined amount of time to clear the vault and close the door.

Radiation Monitoring System

It is possible to interface the radiation monitoring system with the cyclotron control system. An example of this would be if high radiation fields are present inside the vault and the vault door is open, then sound the ACSI supplied audible alarm. (Or prevent the door from opening at all.)

Hotcell Interlocks

The customer may choose to interlock the hotcells with the cyclotron control system. An example of this would be to not initiate an isotope transfer without the hotcell 'door-closed' signal enabled.

Beacons and "Beam On" Lights

ACSI supplies light beacons as shown on the right-hand side of Figure 3. They have 3 lights: red, yellow, and blue that turn on in sequence to signify MM, RF, and finally Beam On. The customer may also choose to add additional lights around the facility as shown in the adjacent figure. The ACSI supplied beacons also have an audible alarm that sounds after the LPO button is pressed.

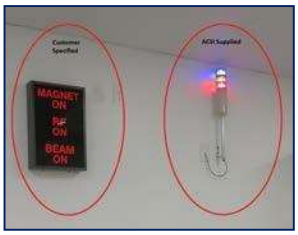

Figure 3 - Beacons

Emergency Stop Buttons

ACSI supplies 3 emergency stop buttons in various locations around the facility. When pressed, these buttons put the cyclotron into a "safe mode" with high power turned off, all valves closed, and vacuum maintained.

Lighting

Normal working light levels should be provided in all rooms prior to installation of the cyclotron. Emergency lighting is to be provided by battery pack (or emergency generator) which is activated upon loss of power to the building. The intensity of the emergency lights should be sufficient to clearly light all parts of the vault and equipment room.

Seismic Considerations

The customer and sub-contractor shall provide pre-engineered seismic restraint systems to meet the total design of lateral force requirements for support and restraint of piping, conduit, cable trays and other similar systems and equipment where required by the local building code. Seismic restraints are to be constructed to allow for thermal expansion. Supports are to be provided so that upon application of seismic forces, piping, cable trays and conduits do not displace sufficiently to damage adjacent or connecting equipment, or building members. It is the responsibility of the customer to meet all local codes for vibration and seismic requirements.

Connections between Sub-systems

Penetrations, Conduits, Cable trays, and Trenches

All cable trays and penetrations are the responsibility of the customer and must be installed prior to the arrival of the equipment and commencement of installation. Power and signal cables shall be separately routed and run separate from water lines. Cables and piping for building utilities shall be laid in different cable trays from the routing housing the cyclotron utilities. ACSI shall provide recommendations of location, size and number of cable trays and penetrations that are required and the location of the connection points for the electrical services to the equipment to be installed.

It is the responsibility of the customer to provide and install all conduits and electrical wiring from the main breaker panels to the cyclotron and related equipment. All electrical services shall be installed and made ready prior to the commencement of the installation of the cyclotron and related equipment. ACSI supplies and connects the interconnecting cables between the cyclotron system components.

For large penetrations into the vault such as ones used for HVAC ductwork, five leg ducts through the wall is recommended whenever possible. For those that cannot be bent (RF, water, rabbit), it is recommended to be high to the ceiling and far from any equipment (high voltage, cooling system, vacuum system, etc.) to minimize radiation leakage out of the vault. Also, all conduit and duct runs shall have large radius, sweeping bends. Trenches should be at least 300 mm deep outside bunkers and well shielded (preferably with lead).

If the distance between the high voltage cabinet to the ion source is less than 10 m, insulated high voltage cables are used (preferred method). If the distance is larger than 10 m, copper cable duct is used and appropriate penetrations are required. This will be discussed with the customer during the initial planning stage of the project.

Radioisotope Transfer Lines 5.3 nr.

The customer will supply and install all transfer lines, tubes and pipes from the cyclotron to the radiochemistry laboratory and to the inside of the hotcells, with the exception of the high current solid target transfer line. ACSI will provide the customer with a list of specifications for all transfer lines/pipes/tubes for the cyclotron and specific targets. This will also be detailed in the drawing package.

Shielding of Transfer Lines

The transfer lines carrying radioisotopes from the targets to the hotcells needs to be shielded in areas where personnel are present. Depending on the size of the transfer lines, different ways of shielding are available. It is the responsibility of the customer to supply and install this shielding, but ACSI will provide input to help design the best ways of accomplishing this.

Shielding for small polyethylene, and stainless steel liquid and gas transfer lines is accomplished by embedding conduits in the concrete slab usually 40 cm below the slab. Alternatively, shielded trenches can be run along backs of hotcells and to areas where the isotopes are needed.

PET Solid Target Transfer System (coin style target)

ACSI does not currently provide an automated method of transferring the small solid target. The small solid target is transferred manually with an ACSI supplied shielded container. If the customer requires an automated transfer, ACSI can provide a custom solution; as well there are off-the-shelf options available.

RF Transmission line

The RF system on the TR-19 includes a 50 ohm copper, transmission line (waveguide) that is used for transferring RF power to the cyclotron. A 100 mm penetration is required from the RF#3 cabinet to the cyclotron in the vault. The size of the copper tube is 80 mm in diameter. The transmission line requires straight segments, 45°, and 90° bends only and will be installed by ACSI.

Power

AC Power Requirements

ACSI will provide the detail design of the AC electrical power required for operation of the TR-19 cyclotron. This includes all electrical load capacities, total installed power for the cyclotron, circuit breaker and panel specifications, cabling specifications, and all other necessary schematics as part of the ACSI supplied drawing package.

The customer is responsible for supplying and installing all breaker panels and for making all connections to ACSI equipment. It is the responsibility of the customer to ensure that all electrical designs and services are in accordance with local code requirements.

NOTE

It is important to note that the total power consumed while running the TR-19 cyclotron is a function of the operating mode and will vary greatly depending on system state.

Total Installed Power	100 - 125 kW (depending on configuration)
Power for single beamline	25 kW
Voltage 1	480 VAC, 3Φ
Voltage 2	208 VAC, 3Φ
Voltage 3	120 VAC, 1Φ
Voltage Stability	± 5%
Frequency	60 Hz ± 0.5 Hz

Table 5 - North American Power Requirements

Total Installed Power	100 - 125 kW (depending on configuration)
Total Installed Power with single beamline	25 kW
Voltage	380/220 VAC, 3Φ
Voltage Stability	± 5%
Frequency	50 Hz ± 0.5 Hz

Table 6 – European and Asian Power Requirements

*For power configurations different than listed above please consult with an ACSI engineer.

ACSI recommends installing the following single phase power outlets:
(**Values listed for North America only. For Europe and Asia use standard local power**)
Vault:

- 3-5 x 120 VAC, 1Φ, 15 A
- 1 x 120 VAC, 1Φ, 20A for portable leak detector
- 1 x 208 VAC, 3Φ, 12 kVA for portable welding equipment (optional)

Equipment and Services Rooms:

- 2 x 120 VAC , 1Φ, 15 A

Control Room:

- 4 x 120 VAC , 1Φ, 15 A for powering the control equipment

DC Power
The cyclotron uses DC to power many of the magnets. The DC power supplies are located inside ACSI supplied cabinets located in the equipment room. ACSI will provide all the required DC cable and will perform the installation of all DC powered components including running and terminating the cables.

Ambient Radio Frequency Interference
The power supply should be completely free of noise or transients (especially RF) from other electrically operated equipment. Surges, sags or instantaneous variations in line voltage from external sources must not exceed 5% or have more than 0.2 second/5 cycles duration, or occur more than 10 times per hour. Circuit breakers should have a time delay of greater than one cycle to withstand switch-on surge.

Additional Electrical Notes
All electrical conductors, power, signal and ground, must be run in conduit or duct systems. All wires specified shall be stranded, flexible, thermo-plastic, color coded, copper only, duct termination points or stubbed conduit ends, unless otherwise specified. The sub-contractor shall ring out and tag all wires at both ends. All wire runs must be continuous copper and free from splices.

Physical connection of primary power to ACSI equipment is to be made by a qualified electrical contractor with the supervision of an ACSI representative. The ACSI representative would be required to identify the physical connection location, and insure proper handling of ACSI equipment.

All conduit sizes shall be verified by the architect, electrical engineer or contractor, in accordance with local codes.

AC Power Test
It is recommended that the power supply be monitored to ascertain the average line voltage, surges, sags, impulses and frequency of the supply voltage. The analysis of a simulated load, using a power systems analyzer capable of the above specifications, should be carried out over a continuous seven day period prior to installation. The results of this analysis should be reviewed with the local service representative to determine whether a voltage/frequency stabilizer, power line protector or filters are required to be installed by the customer. This should be part of the pre-installation work, to comply with ACSI specified electrical requirements.

Emergency Stops
ACSI supplies emergency stops located at various points around the facility that, when pressed, put the cyclotron into safe mode.

UPS (Uninterruptible Power Supply)
The customer shall supply UPS for the control PC and the PLC located in the control cabinet. The capacity of the UPS shall be 3.5 kVA with 30 minutes holding time; power shall be with three output channels of a minimum of 700 watts each. One will be used for the control PC computer and one will be used for the PLC.

Emergency Power (Generator)
Electrical Loads that require emergency generator power will be specified in the ACSI supplied drawing package. They are loads such as the turbo pumps, cryo pumps, and emergency facility lighting.

Site Grounding Requirements

The Customer is to provide the wiring from ground connection points provided on TR-19 devices to the ground system. The building ground system is to be low impedance and equipped with a way to eliminate loop currents. Advanced Cyclotron Systems Inc. will advise on the number and location of the ground connection points.

The Customer is required to provide 3 low impedances high current ground points in the floor of the cyclotron room as follow: one near the cyclotron magnet and one at both ends of the power supply cabinets. An RF ground shall be provided, in addition to the equipment ground. The RF grounding shall be located adjacent to the RF equipment cabinet and shall be terminated by a copper plate, the location and dimensions to be confirmed by Advanced Cyclotron Systems Inc.

Services

Compressed Air

Compressed air is used to operate pneumatically actuated devices and supply cooling to critical components of the RF system. The customer shall provide instrument quality, regulated air with the following specifications:

Supply Pressure	620 kPa (80 – 90 psi)
Flow rate	250-350 l/m
Tank volume	500 L
Oil content	≤ 1 ppm
Max particle size	≤ 5 micron
Dew Point	Min. 10°C Below Ambient Temp

Table 7 - Compressed Air Specifications

The customer is required to connect compressed air to manifolds located on ACSI equipment. There are 3-5 air connections on the cyclotron and ancillary equipment, depending on the configuration. These will be detailed on the ACSI supplied drawing package. Typically ½" poly-tubing or copper pipe is used to run air into the vault.

In addition, a number of regulated compressed air outlets (incl. a valve, 0-690 kPa regulator, 5 micron filter) are recommended throughout the facility at the following locations:

- Cyclotron Vault - 2 outlets
- Equipment Room - 1 outlet
- Maintenance Room(s) - 1 outlet each

Cooling Water

To maintain an effective operating temperature, many of the TR-19 components are water cooled including the cyclotron and ancillary equipment. ACSI provides a closed loop, de-ionized water circulation system, known as the "water package" to accomplish this task.

The customer is required to provide a chiller and pumping system to remove the heat from the water returning to the water package. These two systems interface together through a heat exchanger located on the ACSI supplied water package. Refer to the following table for the chiller specifications.

Supply Temperature	4-15°C typ.
Heat Removal Rate – Cyclotron	80 kW
Heat Removal Rate – Single Beamline	20 kW
Flow Rate (no beamlines)	200 l/m typ.
Flow Rate (single beamline)	225 l/m typ.
Max pressure at inlet	650 kPa
Pressure drop across heat exchanger	35 kPa

Table 8 - Chiller Specifications – Primary Side

NOTE

These specifications apply to water only. They may change if glycol is added.

In addition, the customer should install a filter on the chilled water supply, between the chiller and the water package. The customer should also provide a valved potable water supply (10-12 liters / min).

Additionally, the ACSI supplied water package includes a de-ionization column and filters that need to be replaced on a regular basis. Refer to the preventive maintenance schedule for more information.

Water Package Space Requirements
The water package dimensions are as follows:
1.5 x 1.8 x 2.0 m (l x w x h)

100 cm of clearance is required on all sides of the water package to service the pumps, de-ionizing column, and service panel.

The customer is to provide and install all cooling water piping and connections between the chiller and the ACSI water package, as well as the piping between the water package and the ACSI water manifolds and vacuum components inside the cyclotron vault.

Figure 4 - Water Package

Typically 2” pipe or hose is used for the main water supply and return into the vault from the water package. The water manifold is supplied with solder type fittings, but can be exchanged for NPT connections if requested. Please note that ACSI supplies a customized water piping schematic as part of the drawing package that provides all relevant details and specifications pertaining to the water cooling system and mechanical piping installation, including pipe sizes and materials to be used.

Water System Additional Requirements

For maintenance purposes, install corresponding unions in all water lines above the water package, (see picture right).

Unions can be socket (as pictured) or flanged. Also they could be PVC (recommended for bigger sizes, 2.5" and bigger), metal (copper, stainless steel), depending on the pipe material

Install bypasses prior to each water manifold (1" hose with valves), (see pictures below).

These are for cleaning the pipes after the piping work is complete and for regular maintenance purposes. For future water lines, where applicable, install a bypass (1" hose with valves) to run extra water (amount of water that will be required for the future components). This way there won't be a need to bypass this extra water through the water package.

Bypass on Beamline Water Man

Floor Drains

A floor drain is required in the vault, under all water manifolds, near the water package, and in the equipment room. Please note that floor drains in active areas should drain into an active holding tank that meets local regulations.

RF Specifications

Resonators	Single or Dual Frequency
Dee Voltage	50 kV
Coupler	Movable
Amplifier	40 kW (output)
Frequency Synthesizer	Model 2023A
RF High Voltage Power Supply	15kV DC / 100 kW (output)

Table 9 - RF Specifications

Gases Required for Operation

The customer is responsible for the installation of all gases required for cyclotron operation. This includes the regulators for the gas bottles, as well as the installation of all gas lines. The following table shows the required gases as well as the size and material of the gas supply lines.

Gas	Where Used	Grade	Pressure Range	Tubing	Purity
UHP Hydrogen	Ion Source	K	-100 to +200 kPa	¼" SS Tubing	99.9995%
UHP Helium	Cryopumps, Targetry Gas Transfer, Cooling	-	0 – 550 kPa	¼" Tubing	UHP
Nitrogen	Roughing Network	-	0 – 300 kPa	¼" Tubing	-

Table 10 - Gases

*Please note that this table does not include targetry load gases required to perform acceptance testing.

Targetry

For a detailed description of all services required onsite for targetry in order to complete the site acceptance testing, please refer to the ACSI document titled "Targetry Site Requirements."

Radiation Protection and Safety Regulations

Permits

Prior to commissioning, the customer must provide regulatory compliance and certification as well as any necessary licenses and / or permits for the production of radioisotopes and radiopharmaceuticals. The customer must ensure that all required permits are in order for ACSI to produce full beam to target, three weeks after start of installation.

Radiation Monitoring

It is the responsibility of the customer to provide radiation monitoring in compliance with local standards. At minimum, the following equipment for radiation monitoring should be installed:

- Radiation monitor inside the cyclotron vault with display of radiation rate.
- Radiation alarm equipped with sound and light signals in the event radiation levels exceed the threshold.
- Controlled access to vault.
- Radiation monitors inside each hot cell and in general areas around hot cells to detect leakage.
- Radiation monitors on exhaust ducts from cyclotron and hot cells to detect emissions from the facility.

Applicable Safety Regulations

Safety regulations vary depending on country. The customer should ensure that all applicable regulations are met and a safety plan is devised prior to construction of the site. The customer should designate a safety supervisor and radiation safety officer to oversee the entire installation and commissioning process.

Fire Safety

Fire safety systems are specified by local code. Depending on location, the facility may or may not require fire safety systems including sprinklers inside the cyclotron vault. There are other types of fire safety systems which are better suited to a cyclotron facility, including:

- CO_2 System
- Sapphire "Clean Agent" Fire Suppression System

Consult with ACSI for more information on fire safety.

Taking Delivery

Site Readiness (Prior to Delivery)

Prior to ACSI equipment and personnel arriving onsite, the following items must be complete to ensure that the facility is ready to begin installation.

1. Flooring has been sealed and painted and is 100% complete in the vault and equipment rooms. (This includes the installation of any raised flooring.)
2. Vault and equipment room walls are painted and sealed.
3. Chiller is installed and working.
4. Air compressor is installed and working.
5. HVAC system is complete and working.
6. Site is at a suitable level of construction i.e., dust free and free from large amounts of workers in the vault and equipment room areas.
7. Electrical panels are installed and conduits/wires are ready to be run to ACSI equipment.
8. Base frame anchored and grouted
9. High speed internet is available in the control room.

Shipping

If shipping within North America the TR-19 cyclotron typically requires a flat deck truck to ship the main magnet and one 53' trailer to ship the rest of the equipment (approx. 30 crates).
ACSI can arrange shipping from our factory in Richmond, BC Canada to anywhere in the world. The following table describes the shipping containers necessary if shipping overseas.

	Container	Gross Weight (kg)
TR-19 Cyclotron Main Magnet	20' Open Top	30,000
Ancillary Equipment (approx. 30 crates)	40' Standard High Cube	20,000

Table 11 - Shipping Specifications

Rigging

Once the cyclotron and additional equipment arrive onsite, under ACSI supervision, the customer is responsible for rigging the equipment into the vault. This includes organizing a crane to be onsite when the equipment arrives.

The following steps describe a typical rigging process and can usually be completed within one day.

1. Crane arrives onsite
2. Roof plug is removed (if applicable)
3. Local shields are lowered into the vault as well as all other heavy equipment
4. Truck carrying magnet is positioned near crane
5. Main magnet is lifted into the vault and positioned on linear bearings on previously installed base frame (refer to base frame installation section)
6. Local shielding is mounted on cyclotron
7. Roof plug is replaced

In addition to the crane, the following items are needed onsite during the rigging process for offloading the additional equipment.

- 1 x 3000 kg forklift with long reach or telescopic forks
- 1 x standard pallet jack
- 1 x narrow pallet jack

The rigging and uncrating process produces a large amount of packaging material waste including wood, plastic, and foam. It is the customer's responsibility to ensure there is provision to dispose of these materials.

Note that if any lateral movement of the cyclotron is necessary during the rigging process (i.e. the roof plug is not directly over the base frame), a more complicated rigging procedure is necessary. ACSI can provide a separate procedure for rolling the cyclotron laterally into position.

CAUTION

It is necessary to ensure that the rigging company has proof of insurance for all activities to the value of $10,000,000 U.S.

Storage

The customer shall provide ACSI with an acceptable (4m x 4m minimum) on-site secured storage area for equipment and tools.

Installation and Commissioning

ACSI separates these two phases of the project at the time when power is turned on to all the subsystems of the cyclotron. Installation refers to the onsite process up to the point of power being turned on. Following this point, the onsite process is referred to as commissioning. It is during the commissioning phase of the project that the site acceptance testing takes place.

Installation Process

The installation of a TR-19 cyclotron usually takes between 3-5 weeks depending on the configuration of the system (lengthier installations resulting from additional beamlines and targetry). During this process, the ACSI installation team (usually made up of 2-3 technicians) uses assembly procedures and an installation checklist to help guide the process.

Commissioning and Site Acceptance Testing

The commissioning process is typically carried out by one or two ACSI cyclotron engineers that work through the contractually agreed upon, site acceptance testing document. The scope of the site acceptance testing is to ensure that the system meets its specifications and fulfills the contractual obligations. Customer approval of the site acceptance testing documents is required upon completion. Upon signed approval of this document by all required parties, the warranty period begins.

Site Access during Installation and Commissioning

The customer shall ensure ACSI personnel have access to the site 24 hours a day, 7 days a week during the installation and commissioning period. Expenses incurred by ACSI due to site non-availability during this time will be chargeable to the customer as stated in the contract.

Appendices

Summary of Responsibilities

Description of Task	Customer	ACSI
Rigging	✔	
Chilled Water Supply	✔	
Water connections between vault water manifold and cyclotron		✔
Water connections between chiller and ACSI water package	✔	
Water connections between ACSI water package and water manifold in vault	✔	
AC power connections to all ACSI cabinets	✔	
Instrument Quality Air Compressor	✔	
Air connections to all equipment	✔	
Installation of all valved compressed air outlets	✔	
Air supply lines to our equipment	✔	
All gas bottles required for cyclotron (H, He, N)	✔	
Gas Transfer Line connections	✔	
Cable Trays and trenches	✔	
Installation of RF transmission line		✔
Isotope transfer lines from targets to hotcells	✔	
Shielding of the transfer lines	✔	
Monte Carlo Radiation Field Simulations	✔	
ACSI Supplied Site Drawing Package for Vault (input for architect)		✔
Specifying location of all trenches, cable trays, feed-thrus, and penetrations		✔
Lab equipment, gases, chemicals and reagents required for SAT tests	✔	

Table 12 - Responsibilities

TR-19 Photos

Recommended Tools

Please note that this list is not meant to be exhaustive, it is just to give an idea of some of the tools that will be required onsite following commissioning.

Helium Mass Spectrometer (leak detector)	Fluke Multimeter	Metric Hand Tools
SAE Hand Tools	Weller Temp Controlled Soldering Iron	Precision Hand Tools for Electronics
Coaxial Stripper and Crimper	Tube cutters and benders	Stubby wrenches

Other

Notes

ACSI

TR-19 Site Planning

A Guide for Installation

For Reference Only
Not to be Used for Construction

ACSI Contact Information

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Disclaimer

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Care has been taken to ensure the information contained within this document is accurate and current. Technical specifications are based on standard operating conditions and are subject to variation.

ACSI reserves the right to make modifications to this document, drawings and specifications provided at any time without notice or obligation, and hereby disclaim responsibility for any damages resulting therefrom.

Only qualified personnel are permitted to operate and maintain the equipment. Personnel should be familiar with and trained in the installation, assembly, operation and maintenance of the equipment and its components. All personnel shall possess current safety and regulatory standards for the country of installation.

The development of the equipment layout, room dimensions, mechanical & electrical specifications is predicated upon the best information obtainable from the site, coupled with the customer's known desires. Architectural and/or electrical changes including relocation of equipment illustrated on these drawings are allowed only following review by ACSI & with ACSI written approval. ACSI reserves the right to make on the job changes because of customer requirements and/or obstacles in construction, etc.

All work is to be in compliance with national & local building safety codes and be supplied and installed by the customer or customer's contractors.

Radiation protection requirements, where needed per national or local code, shall be specified by a qualified health physicist.

The customer understands that non-compliance with the physical and service requirements may cause equipment damage, shorten equipment life, or cause equipment deficiencies. The manufacturer's warranty shall be rendered void under those circumstances.

The Customer will carry such insurance and provide such evidence of insurance as are required by the terms of the Advanced Cyclotron Systems Acquisition Agreement.

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Confidentiality

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This document and information contained within is proprietary to Advanced Cyclotron Systems Inc. and shall not be used, disclosed and/or duplicated without the express written authorization of Advanced Cyclotron Systems Inc.
This is a confidential document and should not be accessed by any person not directly involved with the purchase and installation of an ACSI TR-19 cyclotron.

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Please pay attention to the following warnings, cautions, and notes found throughout this guide.

WARNING

This message indicates that if a particular procedure or process is not followed as described serious injury or death may occur to the operator or others in the operating environment.

CAUTION

This message indicates that if a particular procedure or process is not followed as described, damage or destruction may occur to the cyclotron or associated equipment.

NOTE

This message is information that is not related to safety but may be helpful for performing operation tasks or facilitating a process.

ACSI

The Company and its People

Advanced Cyclotron Systems, Inc. (ACSI) is a world leader in the design and manufacturing of cyclotron equipment, including PET and SPECT radioisotope production cyclotrons. We manufacture and supply complete systems for radioisotope and radiocompound production.

ACSI has been in business for over 20 years and we are backed by our affiliated company EBCO Industries, which is one of Canada's largest manufacturing facilities with over 50 years in manufacturing expertise. Our dedicated team of professionals, scientists and engineers are proud to deliver quality workmanship, on-time delivery, and technological advancements for the industry. Our headquarters and manufacturing facility is located in Richmond, BC, Canada.

Our Customers and Market

We manufacture and supply cyclotrons to nuclear medicine markets worldwide, including the United States, Canada, Europe and Asia. Our users include hospitals, universities, research facilities and commercial distributors of medical isotopes.

ACSI is committed to the technological advancements in the industry with on-going research and development of cyclotron systems, targetry and radiochemical production systems. We are further committed to our customers by sharing new developments with our existing customers to ensure that they continue to be the leaders of tomorrow.

Certification

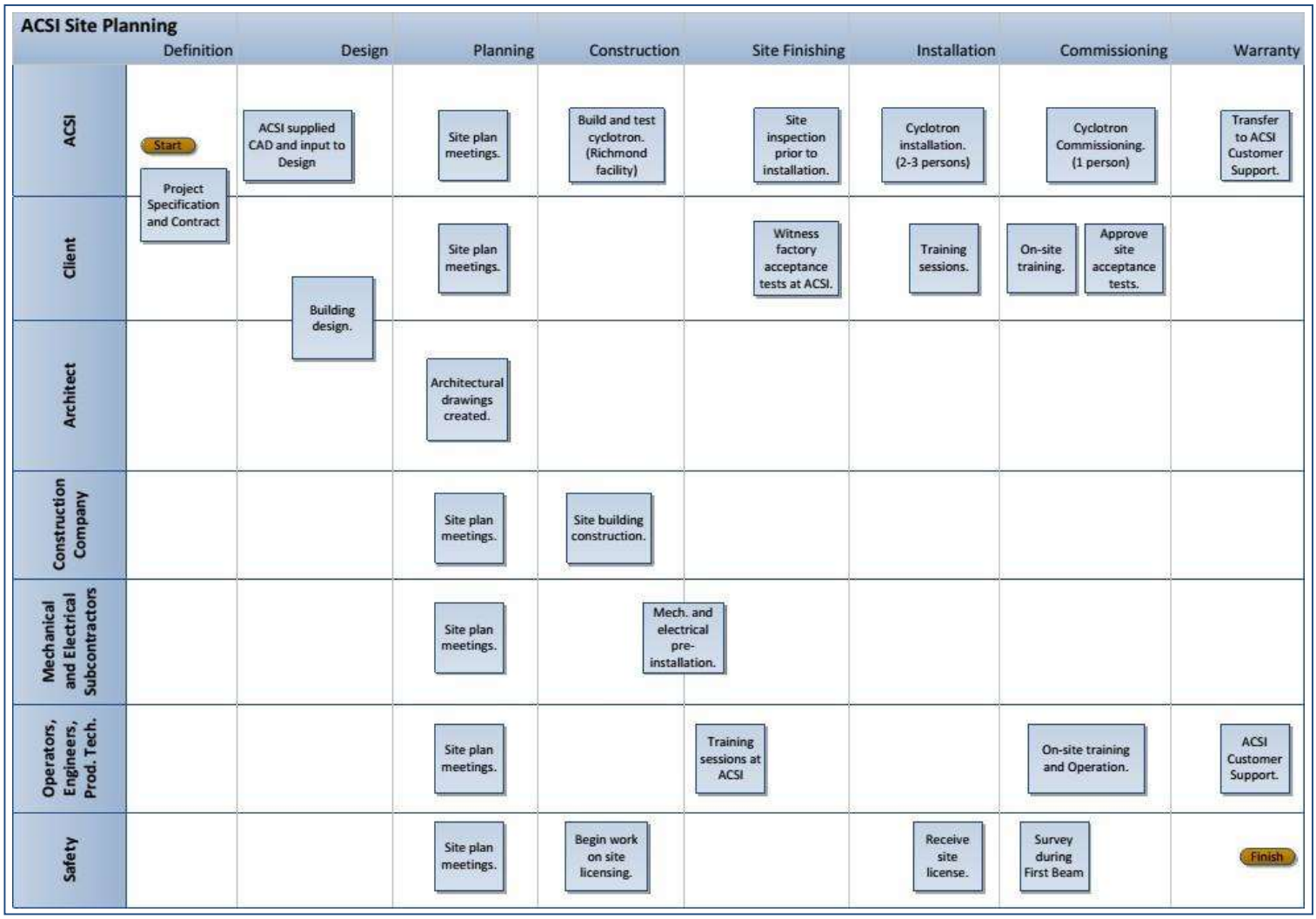
ACSI is certified by ISO 9001 and 13485

Site Planning Overview

About This Guide

This guide is an in-depth look at the site planning process that begins upon purchase of an ACSI TR-19 cyclotron. Found within it are all the necessary site requirements as well as descriptions of the processes involved in taking delivery of the machine, from the early planning stages through installation.

The Site Planning and Installation Process 5.2;1,4 nr



Required Key People

Customer Project Coordinator

It is best if one person is designated the customer's lead contact person for the cyclotron project. This keeps the lines of communication clear throughout.

Radiation Safety Officer (RSO)

This is a key role that is required for the safety of all personnel working in the cyclotron facility during and post installation. Typically during the planning stages of the project the RSO is working on the site licensing application for the production of radioisotopes.

Operators/Engineers

ACSI recommends each cyclotron facility requires a lead operator or engineer to run the cyclotron and perform regular maintenance.

The ACSI Team

Project Manager

ACSI designates a project manager for each cyclotron project. The project manager works closely with the customer project coordinator through all phases of the project to ensure successful completion. All communication from the customer should be routed through the ACSI project manager.

Installation Team

The installation team is typically made up of 2 or 3 technologists that perform the installation of the cyclotron, beamlines, and targetry.

Commissioning Team

The commissioning team is made up of ACSI operators that perform the initial tuning of the machine, site acceptance testing, and customer onsite training.

Customer Support

Following the commissioning phase, the project moves into the warranty phase and beyond. At this time communication is transferred to ACSI's customer support department that will schedule service trips and field any technical support related issues.

TR-19 Overview

ACSI's TR-19 cyclotron is a variable energy cyclotron that accelerates negative hydrogen ions. Standard operating beam current is 200 µA, upgradeable to 300 µA operation. Two extraction probes are inserted radially into the acceleration plane, allowing the extracted beam energy to be varied from 14 to 19 MeV. This radial motion is also used to vary the split ratio from 1:100 to 50:50 in dual irradiation operation. The TR-19 uses an external, multi-cusp ion source.

Different beam line configurations are available for the TR-19 based on the amount of space and layout of the vault at each site. TR-19 gali pritvirtinti iki 8 taikinių (more with beamlines). ACSI taip pat teikia daugybę taikinių įvairiems PET radioizotopams gaminti.

4.1 nr.

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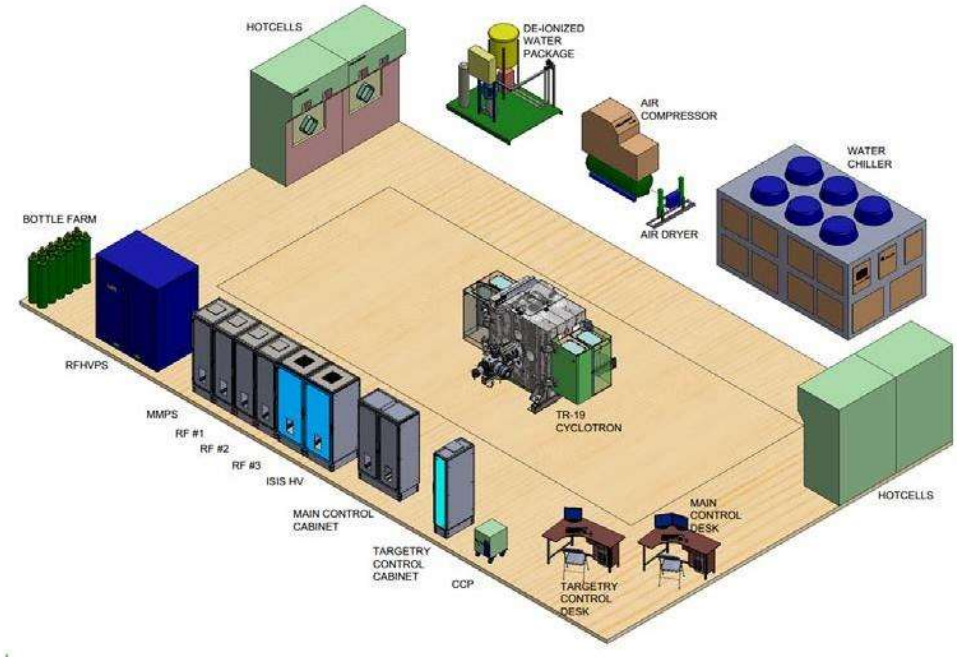

Figure 1 – Locally Shielded TR-19 Cyclotron and Ancillary Equipment

Layout

Cyclotron Vault

The design of the cyclotron vault is an integral part of the site layout and requires a significant amount of planning to ensure a functional and safe design. ACSI will provide design input and recommendations based on past experience, calculations, and field radiation surveys, however the customer is ultimately responsible for the final vault design. ACSI recommends the vault be constructed of low sodium concrete with a minimum density of 2.35 T/m^3.

Vault Wall Thickness

The following table shows the recommended vault wall thickness for different configurations. Even if the recommended values listed below are used, it is recommended to perform shielding simulations prior to making a final decision on vault wall thickness as different isotopes at different energies and beam currents can produce substantially different neutron and gamma fields (refer to the shielding simulations section below).

	Vault wall and ceiling thickness 150 uA cyclotron	Vault wall and ceiling thickness 300 uA cyclotron
Locally shielded with no beamlines	1.5-1.8 m	1.8 m
Locally shielded one side beamline	2.0 m	2.0 m
Unshielded	2.0 m	2.0 m
Self-shielded	0.5 m	0.6 m

Table 1 – Vault Wall Thickness

Equipment Weight

	Weight
Cyclotron without shielding	25,000 kg
Local Shield (4 local shields std config)	1,900 kg (ea)
Self-shielded cyclotron	92,000 kg
Vertically split beamline	6,000 kg
Ion Source	400 kg
Water Package	1000 kg
Base Frame	1300 kg
Heaviest Power Supply Cabinet (RF#1&2)	1200 kg

Table 2- Equipment Weight

Room Sizes

The minimum internal dimensions of the cyclotron vault will vary depending on the number and configuration of beamlines and targetry. The following table shows typical internal vault and room dimensions.

	Minimum internal dimensions (l x w x h)
Vault for locally shielded, no beamlines	5.5 x 4.5 x 2.7 m
Vault for locally shielded, one side beamline	7.5 x 4.5 x 2.7 m
Vault for Self-shielded	6.0 x 5.5 x 3.2 m
Equipment Room	6.5 x 3.5 x 2.7 m
Services Room (optional)	2.5 x 2.0 x 2.7 m
Cyclotron Control Room	3.0 x 3.0 x 2.2 m

Table 3 – Room Sizes

The distance between the power supplies and the cyclotron should not exceed 10 meters and the distance between the main control cabinet and the power supplies should not exceed 20 meters. There is no restriction on the distance to the control console.

Vault Door

Access to the vault is typically through a plug, sliding, or maze style door. The door requires the same shielding effectiveness as the walls and is therefore usually quite large and heavy, except in the case of a maze style entrance. ACSI can provide input into the advantages and disadvantages of each style and help to reach a final decision that is best suited to the facility.

Vault Floor

The vault floor shall support the weight of the complete cyclotron, local shielding, and beamlines (see equipment weight section above). The floor must be level to less than 12mm in 10m, washable, and smooth. The concrete shall be sealed, and painted with an epoxy coating to minimize dust collection and increase ease of contamination removal.

Equipment Room

The equipment room is where the power supply cabinets are located as well as other ancillary equipment. The power supply cabinets will occupy an area approximately 6.0 m x 3.0 m with additional space required for beamline power supplies, with a minimum ceiling height of 2.75 m (suitable height for standard electrical cabinets). Refer to ACSI supplied facility layout plans for further details.
Considerations need to be made to ensure the power supplies will fit through the building hallways, elevators, etc. and into the equipment room. Access underneath all cabinets must be maintained so a trench or raised floor is necessary.

Services Room

The services room is typically comprised of the water package and air compressor. There should be clear access to move equipment in with an access opening large enough to fit the water package (see water package dimensions in Cooling Water section). The water package can also be located in the equipment room depending on the layout.

Control Room

The control room is where the cyclotron operator(s) sit when operating the cyclotron and is typically located in a convenient, non-active area outside the vault. The control room consists of the control computer, two (or more) 24" monitors, ACSI light beacons, and an emergency stop button. A dedicated phone line and internet access is a requirement for this area.

Active Maintenance Area

The active or "hot" maintenance area is used to service radioactive components. A 2m long bench as well as fumehood with lead shielding to work behind is recommended. This room should be located in a controlled, active area and have a full set of dedicated tools.

Raised Floor

Raised flooring is typically used under the power supplies to maintain access. Once installed, ACSI can provide a detailed drawing specifying where tiles require cutting in order to run cables into cabinets. It is important to ensure that all tile stands are bolted to the floor rather than just using adhesive.

Base Frame Installation

With permission from the customer, ACSI will send the base frame 3-4 weeks prior to the cyclotron delivery so it can be installed in advance. The base frame has to be level to within ±0.1 mm, anchored to the concrete, and grouted.

Beamline

The TR-19 standard beamline is a vertically split configuration as seen in Figure 2. In this configuration, a combination magnet steers the beam to either the upper or lower beamline. This allows the addition of more targetry as well as separating the targetry away from the cyclotron.

The addition of a beamline to the TR-19 adds a significant amount of complexity to the site planning process. More power supplies are needed in the equipment room and the vault must be larger to accommodate the additional components.

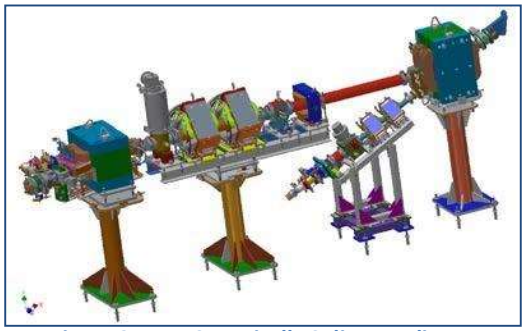

Figure 2 - TR-19 Vertically Split Beamline

Shielding

The customer is responsible for creating an adequate shielding structure (vault) for the cyclotron. The structure must comply with local and national requirements. Final drawings of radiation protection from a specialist must be reviewed by ACSI prior to installation.

- Locally Shielded Cyclotron
  This is ACSI's standard model TR-19 with large 'clamshell' shields located on either side of the machine surrounding the targets (see Figure 1).

- Self-Shielded Cyclotron
  This option is not as commonly used but is available for sites where a standard vault is not possible. Maintenance of this machine becomes more difficult due to restricted access caused by the additional shielding.

If the TR-19 has a beamline, the clamshell shielding is left off the side of the machine where the beamline is located. Custom shielding can be placed around the targets at the end of the beamline, if requested.

WARNING

The TR-19 cyclotron creates ionizing radiation while in use and will remain activated even after is has been shut off. Appropriate compliance and licensing must be arranged by the customer early in the planning process to ensure all regulatory requirements are met for equipment installation and use, including radioisotope production and transfer within the facility. All areas containing radioactive materials must be shielded.

Shielding Calculations and Simulations

It is generally recommended that Monte Carlo simulations be carried out prior to construction of the vault to obtain the best possible estimate for radiation fields. ACSI can supply these simulations, although they are not part of the standard contract.

Site Environment

HVAC and Environmental Specifications

The cyclotron requires an HVAC system to control temperature, pressure, humidity, condensation, and generally maintain a comfortable working atmosphere. This system should be fully functional prior to the start of the cyclotron installation and is the responsibility of the customer. The following table shows the HVAC and environmental requirements of each room.

	Heat Load	Air Changes per hour	Pressure (difference with vault)	Temperature	Max. temp fluctuation	Relative Humidity
Vault	2 kW	3-5	-25 Pa	20°C ± 2°C	2°C / hr	≤60%
Equipment Room	8 kW	n/a	0 Pa	20°C ± 2°C	2°C / hr	≤60%
Services Room	5 kW	n/a	0 Pa	--	--	--

Table 4 – Environmental Specifications

WARNING

Some processes require the use of radioactive gases. Steps must be taken to ensure that the escape of such gases can be controlled in a safe and efficient manner. Escaped gas must not be allowed to enter the HVAC system.

Pump Exhausts

Pump exhausts from the cyclotron roughing pumps shall be filtered and connected into the nuclear ventilation system or a gas holdup system inside vault. ACSI can work with the customer to ensure this is implemented.

Facility Safety

Radiation protection requirements must always be an integral part of facility planning. Zoning suitable for a radioactive facility should be implemented to prevent personnel exposure, the spread of contamination, and for product quality. In addition, appropriate PPE should be worn at all times in the facility. Compliance with local regulatory requirements must be achieved prior to running first beam. For more information on setting up a safe facility to produce radionuclides, refer to the IAEA's Technical Report Series on the subject.

Cyclotron Safety Systems

The TR-19 has an internal safety system that works primarily to minimize risks involving working around high voltages and limiting radiation exposure. For a more detailed look at this system please refer to the TR-19 Operating Manual.

Customer Interlocks and Site Interface

Vault Door

The interface between the vault door and the cyclotron control system is done through the customer interlock schematic and associated logic in the PLC. As this logic changes due to local regulations and customer preferences, it is recommended that a discussion take place early on in the project to specify the final design of the interlocking system.

As a minimum requirement, the limit switches from the vault door must be hardwired into the cyclotron safety system. Additionally, an "open button enable" can be used to protect against the 'door open' button being active when the cyclotron is running.

A 'last person out' (LPO) or 'Area Searched' routine should be part of the procedure to close the vault door. This can be implemented by ACSI or the door manufacturer. An LPO system comes standard with the cyclotron but many customers choose to implement their own (in which case the ACSI supplied system in disabled). Typically an 'area searched' button located on the far side of the vault must be pressed prior to closing the vault. This is to signify the area has been searched for injured personnel, left-behind equipment, or system abnormalities. Once pressed, personnel have a defined amount of time to clear the vault and close the door.

Radiation Monitoring System

It is possible to interface the radiation monitoring system with the cyclotron control system. An example of this would be if high radiation fields are present inside the vault and the vault door is open, then sound the ACSI supplied audible alarm. (Or prevent the door from opening at all.)

Hotcell Interlocks

The customer may choose to interlock the hotcells with the cyclotron control system. An example of this would be to not initiate an isotope transfer without the hotcell 'door-closed' signal enabled.

Beacons and "Beam On" Lights

ACSI supplies light beacons as shown on the right-hand side of Figure 3. They have 3 lights: red, yellow, and blue that turn on in sequence to signify MM, RF, and finally Beam On. The customer may also choose to add additional lights around the facility as shown in the adjacent figure. The ACSI supplied beacons also have an audible alarm that sounds after the LPO button is pressed.

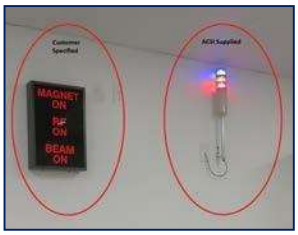

Figure 3 - Beacons

Emergency Stop Buttons

ACSI supplies 3 emergency stop buttons in various locations around the facility. When pressed, these buttons put the cyclotron into a "safe mode" with high power turned off, all valves closed, and vacuum maintained.

Lighting

Normal working light levels should be provided in all rooms prior to installation of the cyclotron. Emergency lighting is to be provided by battery pack (or emergency generator) which is activated upon loss of power to the building. The intensity of the emergency lights should be sufficient to clearly light all parts of the vault and equipment room.

Seismic Considerations

The customer and sub-contractor shall provide pre-engineered seismic restraint systems to meet the total design of lateral force requirements for support and restraint of piping, conduit, cable trays and other similar systems and equipment where required by the local building code. Seismic restraints are to be constructed to allow for thermal expansion. Supports are to be provided so that upon application of seismic forces, piping, cable trays and conduits do not displace sufficiently to damage adjacent or connecting equipment, or building members. It is the responsibility of the customer to meet all local codes for vibration and seismic requirements.

Connections between Sub-systems

Penetrations, Conduits, Cable trays, and Trenches

All cable trays and penetrations are the responsibility of the customer and must be installed prior to the arrival of the equipment and commencement of installation. Power and signal cables shall be separately routed and run separate from water lines. Cables and piping for building utilities shall be laid in different cable trays from the routing housing the cyclotron utilities. ACSI shall provide recommendations of location, size and number of cable trays and penetrations that are required and the location of the connection points for the electrical services to the equipment to be installed.

It is the responsibility of the customer to provide and install all conduits and electrical wiring from the main breaker panels to the cyclotron and related equipment. All electrical services shall be installed and made ready prior to the commencement of the installation of the cyclotron and related equipment. ACSI supplies and connects the interconnecting cables between the cyclotron system components.

For large penetrations into the vault such as ones used for HVAC ductwork, five leg ducts through the wall is recommended whenever possible. For those that cannot be bent (RF, water, rabbit), it is recommended to be high to the ceiling and far from any equipment (high voltage, cooling system, vacuum system, etc.) to minimize radiation leakage out of the vault. Also, all conduit and duct runs shall have large radius, sweeping bends. Trenches should be at least 300 mm deep outside bunkers and well shielded (preferably with lead).

If the distance between the high voltage cabinet to the ion source is less than 10 m, insulated high voltage cables are used (preferred method). If the distance is larger than 10 m, copper cable duct is used and appropriate penetrations are required. This will be discussed with the customer during the initial planning stage of the project.

Radioizotopų perdavimo linijos 5.3 nr.
Klientas tieks ir sumontuos visas perdavimo linijas, vamzdžius ir vamzdelius nuo ciklotrono iki radiochemijos laboratorijos ir į karštųjų elementų vidų, išskyrus didelės srovės kietą tikslinę perdavimo liniją. ACSI pateiks klientui visų ciklotrono perdavimo linijų / vamzdžių / vamzdelių specifikacijų sąrašą ir konkrečius taikinius. Tai taip pat bus išsamiai aprašyta brėžinių pakete.

Shielding of Transfer Lines
The transfer lines carrying radioisotopes from the targets to the hotcells needs to be shielded in areas where personnel are present. Depending on the size of the transfer lines, different ways of shielding are available. It is the responsibility of the customer to supply and install this shielding, but ACSI will provide input to help design the best ways of accomplishing this.

Shielding for small polyethylene, and stainless steel liquid and gas transfer lines is accomplished by embedding conduits in the concrete slab usually 40 cm below the slab. Alternatively, shielded trenches can be run along backs of hotcells and to areas where the isotopes are needed.

PET Solid Target Transfer System (coin style target)
ACSI does not currently provide an automated method of transferring the small solid target. The small solid target is transferred manually with an ACSI supplied shielded container. If the customer requires an automated transfer, ACSI can provide a custom solution; as well there are off-the-shelf options available.

RF Transmission line
The RF system on the TR-19 includes a 50 ohm copper, transmission line (waveguide) that is used for transferring RF power to the cyclotron. A 100 mm penetration is required from the RF#3 cabinet to the cyclotron in the vault. The size of the copper tube is 80 mm in diameter. The transmission line requires straight segments, 45°, and 90° bends only and will be installed by ACSI.

Power

AC Power Requirements
ACSI will provide the detail design of the AC electrical power required for operation of the TR-19 cyclotron. This includes all electrical load capacities, total installed power for the cyclotron, circuit breaker and panel specifications, cabling specifications, and all other necessary schematics as part of the ACSI supplied drawing package.

The customer is responsible for supplying and installing all breaker panels and for making all connections to ACSI equipment. It is the responsibility of the customer to ensure that all electrical designs and services are in accordance with local code requirements.

NOTE

It is important to note that the total power consumed while running the TR-19 cyclotron is a function of the operating mode and will vary greatly depending on system state.

Total Installed Power	100 - 125 kW (depending on configuration)
Power for single beamline	25 kW
Voltage 1	480 VAC, 3Φ
Voltage 2	208 VAC, 3Φ
Voltage 3	120 VAC, 1Φ
Voltage Stability	± 5%
Frequency	60 Hz ± 0.5 Hz

Table 5 - North American Power Requirements

Total Installed Power	100 - 125 kW (depending on configuration)
Total Installed Power with single beamline	25 kW
Voltage	380/220 VAC, 3Φ
Voltage Stability	± 5%
Frequency	50 Hz ± 0.5 Hz

Table 6 – European and Asian Power Requirements

*For power configurations different than listed above please consult with an ACSI engineer.

ACSI recommends installing the following single phase power outlets:
(**Values listed for North America only. For Europe and Asia use standard local power**)
Vault:

- 3-5 x 120 VAC, 1Φ, 15 A
- 1 x 120 VAC, 1Φ, 20A for portable leak detector
- 1 x 208 VAC, 3Φ, 12 kVA for portable welding equipment (optional)

Equipment and Services Rooms:

- 2 x 120 VAC , 1Φ, 15 A

Control Room:

- 4 x 120 VAC , 1Φ, 15 A for powering the control equipment

DC Power
The cyclotron uses DC to power many of the magnets. The DC power supplies are located inside ACSI supplied cabinets located in the equipment room. ACSI will provide all the required DC cable and will perform the installation of all DC powered components including running and terminating the cables.

Ambient Radio Frequency Interference
The power supply should be completely free of noise or transients (especially RF) from other electrically operated equipment. Surges, sags or instantaneous variations in line voltage from external sources must not exceed 5% or have more than 0.2 second/5 cycles duration, or occur more than 10 times per hour. Circuit breakers should have a time delay of greater than one cycle to withstand switch-on surge.

Additional Electrical Notes
All electrical conductors, power, signal and ground, must be run in conduit or duct systems. All wires specified shall be stranded, flexible, thermo-plastic, color coded, copper only, duct termination points or stubbed conduit ends, unless otherwise specified. The sub-contractor shall ring out and tag all wires at both ends. All wire runs must be continuous copper and free from splices.

Physical connection of primary power to ACSI equipment is to be made by a qualified electrical contractor with the supervision of an ACSI representative. The ACSI representative would be required to identify the physical connection location, and insure proper handling of ACSI equipment.

All conduit sizes shall be verified by the architect, electrical engineer or contractor, in accordance with local codes.

AC Power Test
It is recommended that the power supply be monitored to ascertain the average line voltage, surges, sags, impulses and frequency of the supply voltage. The analysis of a simulated load, using a power systems analyzer capable of the above specifications, should be carried out over a continuous seven day period prior to installation. The results of this analysis should be reviewed with the local service representative to determine whether a voltage/frequency stabilizer, power line protector or filters are required to be installed by the customer. This should be part of the pre-installation work, to comply with ACSI specified electrical requirements.

Emergency Stops
ACSI supplies emergency stops located at various points around the facility that, when pressed, put the cyclotron into safe mode.

UPS (Uninterruptible Power Supply)
The customer shall supply UPS for the control PC and the PLC located in the control cabinet. The capacity of the UPS shall be 3.5 kVA with 30 minutes holding time; power shall be with three output channels of a minimum of 700 watts each. One will be used for the control PC computer and one will be used for the PLC.

Emergency Power (Generator)
Electrical Loads that require emergency generator power will be specified in the ACSI supplied drawing package. They are loads such as the turbo pumps, cryo pumps, and emergency facility lighting.

Site Grounding Requirements

The Customer is to provide the wiring from ground connection points provided on TR-19 devices to the ground system. The building ground system is to be low impedance and equipped with a way to eliminate loop currents. Advanced Cyclotron Systems Inc. will advise on the number and location of the ground connection points.

The Customer is required to provide 3 low impedances high current ground points in the floor of the cyclotron room as follow: one near the cyclotron magnet and one at both ends of the power supply cabinets. An RF ground shall be provided, in addition to the equipment ground. The RF grounding shall be located adjacent to the RF equipment cabinet and shall be terminated by a copper plate, the location and dimensions to be confirmed by Advanced Cyclotron Systems Inc.

Services

Compressed Air

Compressed air is used to operate pneumatically actuated devices and supply cooling to critical components of the RF system. The customer shall provide instrument quality, regulated air with the following specifications:

Supply Pressure	620 kPa (80 – 90 psi)
Flow rate	250-350 l/m
Tank volume	500 L
Oil content	≤ 1 ppm
Max particle size	≤ 5 micron
Dew Point	Min. 10°C Below Ambient Temp

Table 7 - Compressed Air Specifications

The customer is required to connect compressed air to manifolds located on ACSI equipment. There are 3-5 air connections on the cyclotron and ancillary equipment, depending on the configuration. These will be detailed on the ACSI supplied drawing package. Typically ½" poly-tubing or copper pipe is used to run air into the vault.

In addition, a number of regulated compressed air outlets (incl. a valve, 0-690 kPa regulator, 5 micron filter) are recommended throughout the facility at the following locations:

- Cyclotron Vault - 2 outlets
- Equipment Room - 1 outlet
- Maintenance Room(s) - 1 outlet each

Cooling Water

To maintain an effective operating temperature, many of the TR-19 components are water cooled including the cyclotron and ancillary equipment. ACSI provides a closed loop, de-ionized water circulation system, known as the "water package" to accomplish this task.

The customer is required to provide a chiller and pumping system to remove the heat from the water returning to the water package. These two systems interface together through a heat exchanger located on the ACSI supplied water package. Refer to the following table for the chiller specifications.

Supply Temperature	4-15°C typ.
Heat Removal Rate – Cyclotron	80 kW
Heat Removal Rate – Single Beamline	20 kW
Flow Rate (no beamlines)	200 l/m typ.
Flow Rate (single beamline)	225 l/m typ.
Max pressure at inlet	650 kPa
Pressure drop across heat exchanger	35 kPa

Table 8 - Chiller Specifications – Primary Side

NOTE

These specifications apply to water only. They may change if glycol is added.

In addition, the customer should install a filter on the chilled water supply, between the chiller and the water package. The customer should also provide a valved potable water supply (10-12 liters / min).

Additionally, the ACSI supplied water package includes a de-ionization column and filters that need to be replaced on a regular basis. Refer to the preventive maintenance schedule for more information.

Water Package Space Requirements
The water package dimensions are as follows:
1.5 x 1.8 x 2.0 m (l x w x h)

100 cm of clearance is required on all sides of the water package to service the pumps, de-ionizing column, and service panel.

The customer is to provide and install all cooling water piping and connections between the chiller and the ACSI water package, as well as the piping between the water package and the ACSI water manifolds and vacuum components inside the cyclotron vault.

Figure 4 - Water Package

Typically 2” pipe or hose is used for the main water supply and return into the vault from the water package. The water manifold is supplied with solder type fittings, but can be exchanged for NPT connections if requested. Please note that ACSI supplies a customized water piping schematic as part of the drawing package that provides all relevant details and specifications pertaining to the water cooling system and mechanical piping installation, including pipe sizes and materials to be used.

Water System Additional Requirements

For maintenance purposes, install corresponding unions in all water lines above the water package, (see picture right).

Unions can be socket (as pictured) or flanged. Also they could be PVC (recommended for bigger sizes, 2.5" and bigger), metal (copper, stainless steel), depending on the pipe material

Install bypasses prior to each water manifold (1" hose with valves), (see pictures below).

These are for cleaning the pipes after the piping work is complete and for regular maintenance purposes. For future water lines, where applicable, install a bypass (1" hose with valves) to run extra water (amount of water that will be required for the future components). This way there won't be a need to bypass this extra water through the water package.

Bypass on Beamline Water Man

Floor Drains

A floor drain is required in the vault, under all water manifolds, near the water package, and in the equipment room. Please note that floor drains in active areas should drain into an active holding tank that meets local regulations.

RF Specifications

Resonators	Single or Dual Frequency
Dee Voltage	50 kV
Coupler	Movable
Amplifier	40 kW (output)
Frequency Synthesizer	Model 2023A
RF High Voltage Power Supply	15kV DC / 100 kW (output)

Table 9 - RF Specifications

Gases Required for Operation

The customer is responsible for the installation of all gases required for cyclotron operation. This includes the regulators for the gas bottles, as well as the installation of all gas lines. The following table shows the required gases as well as the size and material of the gas supply lines.

Gas	Where Used	Grade	Pressure Range	Tubing	Purity
UHP Hydrogen	Ion Source	K	-100 to +200 kPa	¼" SS Tubing	99.9995%
UHP Helium	Cryopumps, Targetry Gas Transfer, Cooling	-	0 – 550 kPa	¼" Tubing	UHP
Nitrogen	Roughing Network	-	0 – 300 kPa	¼" Tubing	-

Table 10 - Gases

*Please note that this table does not include targetry load gases required to perform acceptance testing.

Targetry

For a detailed description of all services required onsite for targetry in order to complete the site acceptance testing, please refer to the ACSI document titled "Targetry Site Requirements."

Radiation Protection and Safety Regulations

Permits

Prior to commissioning, the customer must provide regulatory compliance and certification as well as any necessary licenses and / or permits for the production of radioisotopes and radiopharmaceuticals. The customer must ensure that all required permits are in order for ACSI to produce full beam to target, three weeks after start of installation.

Radiation Monitoring

It is the responsibility of the customer to provide radiation monitoring in compliance with local standards. At minimum, the following equipment for radiation monitoring should be installed:

- Radiation monitor inside the cyclotron vault with display of radiation rate.
- Radiation alarm equipped with sound and light signals in the event radiation levels exceed the threshold.
- Controlled access to vault.
- Radiation monitors inside each hot cell and in general areas around hot cells to detect leakage.
- Radiation monitors on exhaust ducts from cyclotron and hot cells to detect emissions from the facility.

Applicable Safety Regulations

Safety regulations vary depending on country. The customer should ensure that all applicable regulations are met and a safety plan is devised prior to construction of the site. The customer should designate a safety supervisor and radiation safety officer to oversee the entire installation and commissioning process.

Fire Safety

Fire safety systems are specified by local code. Depending on location, the facility may or may not require fire safety systems including sprinklers inside the cyclotron vault. There are other types of fire safety systems which are better suited to a cyclotron facility, including:

- CO_2 System
- Sapphire "Clean Agent" Fire Suppression System

Consult with ACSI for more information on fire safety.

Taking Delivery

Site Readiness (Prior to Delivery)

Prior to ACSI equipment and personnel arriving onsite, the following items must be complete to ensure that the facility is ready to begin installation.

1. Flooring has been sealed and painted and is 100% complete in the vault and equipment rooms. (This includes the installation of any raised flooring.)
2. Vault and equipment room walls are painted and sealed.
3. Chiller is installed and working.
4. Air compressor is installed and working.
5. HVAC system is complete and working.
6. Site is at a suitable level of construction i.e., dust free and free from large amounts of workers in the vault and equipment room areas.
7. Electrical panels are installed and conduits/wires are ready to be run to ACSI equipment.
8. Base frame anchored and grouted
9. High speed internet is available in the control room.

Shipping

If shipping within North America the TR-19 cyclotron typically requires a flat deck truck to ship the main magnet and one 53' trailer to ship the rest of the equipment (approx. 30 crates).
ACSI can arrange shipping from our factory in Richmond, BC Canada to anywhere in the world. The following table describes the shipping containers necessary if shipping overseas.

	Container	Gross Weight (kg)
TR-19 Cyclotron Main Magnet	20' Open Top	30,000
Ancillary Equipment (approx. 30 crates)	40' Standard High Cube	20,000

Table 11 - Shipping Specifications

Rigging

Once the cyclotron and additional equipment arrive onsite, under ACSI supervision, the customer is responsible for rigging the equipment into the vault. This includes organizing a crane to be onsite when the equipment arrives.

The following steps describe a typical rigging process and can usually be completed within one day.

1. Crane arrives onsite
2. Roof plug is removed (if applicable)
3. Local shields are lowered into the vault as well as all other heavy equipment
4. Truck carrying magnet is positioned near crane
5. Main magnet is lifted into the vault and positioned on linear bearings on previously installed base frame (refer to base frame installation section)
6. Local shielding is mounted on cyclotron
7. Roof plug is replaced

In addition to the crane, the following items are needed onsite during the rigging process for offloading the additional equipment.

- 1 x 3000 kg forklift with long reach or telescopic forks
- 1 x standard pallet jack
- 1 x narrow pallet jack

The rigging and uncrating process produces a large amount of packaging material waste including wood, plastic, and foam. It is the customer's responsibility to ensure there is provision to dispose of these materials.

Note that if any lateral movement of the cyclotron is necessary during the rigging process (i.e. the roof plug is not directly over the base frame), a more complicated rigging procedure is necessary. ACSI can provide a separate procedure for rolling the cyclotron laterally into position.

CAUTION

It is necessary to ensure that the rigging company has proof of insurance for all activities to the value of $10,000,000 U.S.

Storage

The customer shall provide ACSI with an acceptable (4m x 4m minimum) on-site secured storage area for equipment and tools.

Installation and Commissioning

ACSI separates these two phases of the project at the time when power is turned on to all the subsystems of the cyclotron. Installation refers to the onsite process up to the point of power being turned on. Following this point, the onsite process is referred to as commissioning. It is during the commissioning phase of the project that the site acceptance testing takes place.

Installation Process

The installation of a TR-19 cyclotron usually takes between 3-5 weeks depending on the configuration of the system (lengthier installations resulting from additional beamlines and targetry). During this process, the ACSI installation team (usually made up of 2-3 technicians) uses assembly procedures and an installation checklist to help guide the process.

Commissioning and Site Acceptance Testing

The commissioning process is typically carried out by one or two ACSI cyclotron engineers that work through the contractually agreed upon, site acceptance testing document. The scope of the site acceptance testing is to ensure that the system meets its specifications and fulfills the contractual obligations. Customer approval of the site acceptance testing documents is required upon completion. Upon signed approval of this document by all required parties, the warranty period begins.

Site Access during Installation and Commissioning

The customer shall ensure ACSI personnel have access to the site 24 hours a day, 7 days a week during the installation and commissioning period. Expenses incurred by ACSI due to site non-availability during this time will be chargeable to the customer as stated in the contract.

Appendices

Summary of Responsibilities

Description of Task	Customer	ACSI
Rigging	✔	
Chilled Water Supply	✔	
Water connections between vault water manifold and cyclotron		✔
Water connections between chiller and ACSI water package	✔	
Water connections between ACSI water package and water manifold in vault	✔	
AC power connections to all ACSI cabinets	✔	
Instrument Quality Air Compressor	✔	
Air connections to all equipment	✔	
Installation of all valved compressed air outlets	✔	
Air supply lines to our equipment	✔	
All gas bottles required for cyclotron (H, He, N)	✔	
Gas Transfer Line connections	✔	
Cable Trays and trenches	✔	
Installation of RF transmission line		✔
Isotope transfer lines from targets to hotcells	✔	
Shielding of the transfer lines	✔	
Monte Carlo Radiation Field Simulations	✔	
ACSI Supplied Site Drawing Package for Vault (input for architect)		✔
Specifying location of all trenches, cable trays, feed-thrus, and penetrations		✔
Lab equipment, gases, chemicals and reagents required for SAT tests	✔	

Table 12 - Responsibilities

TR-19 Photos

Recommended Tools

Please note that this list is not meant to be exhaustive, it is just to give an idea of some of the tools that will be required onsite following commissioning.

Helium Mass Spectrometer (leak detector)	Fluke Multimeter	Metric Hand Tools
SAE Hand Tools	Weller Temp Controlled Soldering Iron	Precision Hand Tools for Electronics
Coaxial Stripper and Crimper	Tube cutters and benders	Stubby wrenches

Other

Notes

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5.3 nr.

What happens when a target blows?

There are 2 foils on ACSI's gas and liquid targets. One separates the target content (gas or liquid) from the cooling window and the other one separates this window from the vacuum of the main tank.

There is helium blowing between these 2 foils in order to cool the foils during irradiation.

If the target failure is catastrophic both foils will blow. In this case some of the target content will get sucked by the vacuum in the main tank and some of this activity will enter the main tank. There is a gate valve that separates the target from the main tank. If there is a difference in vacuum levels between the target and the main tank then the valve will close automatically. However the valve doesn't close quickly enough as to avoid some contamination going inside the tank. Some helium from the helium cooling system will also make it past this valve into the main tank.

The helium recirculation system will shut down the recirculation pumps when either foil blows since the pressure in the system is going to change dramatically. Some activity will be trapped in the lines inside this system. Since this is basically a closed system no activity should scape into atmosphere.

If only the foil separating the window cooling from the main tank blows then the activity will still be contained in the target, but some helium will enter the main tank. It will be easily noticeable since the vacuum on the main tank is going to be affected.

In the past the targets were not secured by a clamp and were only held in place by the vacuum on the target selector. When the target blows and the vacuum is lost the target would fall off releasing the activity. Currently a clamp has been added to each target and they won't fall off even if the vacuum is

What to do after a target failure?

If the activity that goes inside the tank is very low and the vacuum is not greatly affected then the cryopumps can stay on and this activity is going to be trapped in the cryopumps. It can be left to decay on the cryopumps.

However if the vacuum was greatly affected then the cryopumps will shut down. Once the cryopumps have been off for some time it is not possible to turn them back on without regenerating them. In this case you will have to wait 10 half lifes and then regenerate the pumps. You could probably regenerate the pumps earlier but you will be releasing the activity that was trapped on the cryopumps. If you have a system to content the gasses from the exhaust during regeneration then you could do this earlier.

In theory since the vacuum tank and the He recirculation system are both close systems, no activity should leave the cyclotron and get into the air. In practice some activity has escaped from the cyclotron into the air after a target failure.

At TRIUMF (self shielded cyclotron) an enclosure has been built around the cyclotron and any activity on the air will go into the ventilation system for the enclosure. There are filters that would trap the activity before it is released from the ventilation system.

At BCCA (non-shielded cyclotron) the air in the vault is constantly changed not giving enough time for the air to get activated from the cyclotron run. If there is a target failure and activity goes into the air, there are radiation detectors that will trigger the ventilation system to shut down and the activity will get trapped in the vault. You will have to wait about 10 half lifes before you can re-enter the vault.

5.3 nr.

Kas atsitinka, kai taikinys sprogsta?

Ant ACSI dujų ir skysčio taikinių yra dvi folijos. Viena atskiria tikslo turinį (dujas ar skystį) nuo aušinimo lango, o kita atskiria šį langą nuo pagrindinio bako vakuumo.

Kad švitinimo metu folija būtų aušinama, tarp šių dviejų folijų įpučiamas helis.

Jei taikinio triktis yra katastrofiška, abi folijos susprogs. Tokiu atveju dalį taikinio turinio išsiurbs vakuumas pagrindinėje talpykloje, o dalis šio turinio pateks į pagrindinę talpyklą. Yra vartų vožtuvas, atskiriantis taikinį nuo pagrindinės talpyklos. Jei tarp taikinio ir pagrindinės talpyklos vakuumo lygis skiriasi, vožtuvas užsidarys automatiškai. Tačiau vožtuvas neuždaromas pakankamai greitai, kad būtų išvengta užteršimo talpyklos viduje. Dalis helio iš helio aušinimo sistemos taip pat pateks pro šį vožtuvą į pagrindinę talpyklą.

Helio recirkuliacijos sistema išjungs cirkuliacinius siurblius, kai kuri nors folija susprogs, nes slėgis sistemoje kardinaliai pasikeis. Dalis turinio bus įstrigęs šios sistemos linijose. Iš esmės tai yra uždara sistema, todėl jokia turinio dalis neturėtų patekti į atmosferą.

Jei susprogs tik folija, kuri skiria lango aušinimą nuo pagrindinės talpyklos, tada turinys vis tiek išliks taikinyje, tačiau dalis helio pateks į pagrindinę talpyklą. Tai bus lengva pastebėti, nes bus paveiktas pagrindinės talpyklos vakuumas.

Anksčiau taikiniai nebuvo pritvirtinami spaustuku ir buvo laikomi tik vakuume ant taikinių parinktuvų. Jei taikinys sprogtų ir dingtų vakuumas, taikinys nukristų, išlaisvindamas turinį. Šiuo metu prie kiekvieno taikinio pridedamas spaustukas, kuris nenukris net dingus vakuumui.

Ką daryti po taikinio nesėkmės?

Jei rezervuaro viduje esantis turinys yra labai mažas ir vakuumas nelabai paveiktas, kriosiurbliai gali likti atverti ir šis turinys gali būti sulaikomas kriosiurbliuose. Jis gali būti paliktas skilti kriosiurbliuose.

Tačiau jei vakuumas buvo smarkiai paveiktas, kriosiurbliai bus uždaryti. Jei kriosiurbliai kurį laiką buvo išjungti, neįmanoma jų vėl įjungti neregeneravus. Tokiu atveju turėsite palaukti 10 pusinės eksploatavimo trukmės ir regeneruoti siurblius. Greičiausiai galėtumėte regeneruoti siurblius anksčiau, tačiau išleisite turinį, kuris buvo sulaikytas kriosiurbliuose. Jei turite sistemą, skirtą sulaikyti dujas iš išmetamųjų dujų regeneravimo metu, tuomet tai galėtumėte padaryti anksčiau.

Teoriškai vakuuminė talpykla ir helio recirkuliacijos sistema yra artimos sistemos, todėl joks turinys neturėtų palikti ciklotrono ir patekti į orą. Praktikoje pasitaikė, kad tam tikras turinys pateko iš ciklotrono į orą po taikinio sugedimo.

At TRIUMF (self shielded cyclotron) an enclosure has been built around the cyclotron and any activity on the air will go into the ventilation system for the enclosure. There are filters that would trap the activity before it is released from the ventilation system.

At BCCA (non-shielded cyclotron) the air in the vault is constantly changed not giving enough time for the air to get activated from the cyclotron run. If there is a target failure and activity goes into the air, there are radiation detectors that will trigger the ventilation system to shut down and the activity will get trapped in the vault. You will have to wait about 10 half lifes before you can re-enter the vault.

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