Prosedur Perawatan Siklotron

Syefudin Ichwan, S.T., M.T.

Pelatihan Petugas Keahlian Pada Fasilitas Produksi Radioisotop dan Radiofarmaka dari Siklotron untuk Area Produksi dan Area Sarana Penunjang Kritis bagi Pegawai PT Global Onkolab Farma
30 Juni – 11 Juli 2025

Direktorat Pengembangan Kompetensi BRIN

BIODATA

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- Pengalaman :
  - Operasi, Perawatan dan Aplikasi siklotron CS-30 (2005-2021)
  - Project desain system target cair, padat dan gas
  - Project desain pengukur medan magnet
  - Project desain perangkat proses radioisotope I-131
- Karir :
  - BATAN (2005-2021)
  - BRIN-ORTN (2021-sekarang)

LATAR BELAKANG

Siklotron adalah mesin pemercepat partikel secara siklis yang tergolong dalam kategori teknologi tinggi. Selain itu, mesin siklotron juga dikenal sangat sensitif terhadap perubahan parameter, baik akibat pemakaian maupun pengaturan (set-up). Oleh karena itu, proses perawatan mesin siklotron merupakan pekerjaan yang menuntut pengetahuan, ketelitian, dan kedisiplinan tinggi.

Kegiatan perawatan mesin siklotron mencakup seluruh bagian sistem, termasuk mekanik, elektronik, dan perangkat lunak, sehingga menjadi lingkup pekerjaan yang sangat kompleks. Secara teknis, pabrikan biasanya telah menyediakan panduan dan dukungan berupa buku manual maintenance serta tenaga teknisi pemeliharaan.

Namun demikian, dalam pengoperasian siklotron untuk pelayanan medis yang menuntut kontinuitas tinggi, dibutuhkan peran aktif dari operator untuk turut menjalankan sebagian perawatan ringan. Kegiatan ini sangat penting dalam menunjang kelangsungan dan keandalan operasi siklotron.

MANFAAT

- Manfaat setelah mendapatkan materi ini peserta dapat mengetahui prosedur perawatan bagian siklotron yang sesuai dengan lingkup tanggung jawabnya dalam menjalankan tugas mengoperasikan mesin siklotron.

TUJUAN PEMBELAJARAN

(meliputi kompetensi dasar dan indikator keberhasilan)

1. Kompetensi Dasar

- Mengetahui jenis-jenis perawatan pada mesin siklotron
- Mengetahui prosedur perawatan bagian-bagian siklotron (PETtrace 800)

2. Indikator Hasil Belajar

Setelah selesai pembelajaran diharapkan peserta mampu:

- Menjelaskan jenis perawatan siklotron beserta contohnya.
- Menjelaskan langkah-langkah dalam menyusun perawatan siklotron

POKOK BAHASAN

- Teori perawatan siklotron
- Bagian-bagian PETtrace 800
- Jadwal Perawatan Terencana
- Jadwal Perawatan oleh Operator
- Prosedur Perawatan
- Diagnosis

1 Teori Perawatan Siklotron

a. Perawatan Preventif (Preventive Maintenance)

Tindakan perawatan yang dilakukan secara rutin untuk mencegah kerusakan sebelum terjadi, meliputi:

- Inspeksi visual terhadap komponen utama seperti sumber ion, sistem Radio Frekuensi (RF), magnet, dan sistem transfer berkas.
- Kalibrasi ulang perangkat elektronik seperti generator RF dan magnet.
- Pembersihan sistem vakum untuk menghilangkan kontaminasi.
- Pengujian tekanan pada sistem vakum.

b. Perawatan Korektif (Corrective Maintenance)

Perbaikan yang dilakukan setelah terdeteksi adanya kerusakan atau penurunan performa, meliputi:

- Identifikasi penyebab masalah menggunakan alat diagnostik.
- Penggantian komponen yang rusak, seperti foil karbon atau katoda sumber ion.
- Reparasi komponen yang mengalami kegagalan fungsi, seperti deflector elektrostatik.

c. Perawatan Prediktif (Predictive Maintenance)

Tindakan perawatan berdasarkan analisis kondisi komponen menggunakan data real-time, meliputi:

- Monitoring performa komponen secara real-time menggunakan sensor.
- Analisis data dari sistem kontrol untuk mendeteksi tren penurunan performa.
- Penggantian atau perbaikan komponen sebelum terjadi kerusakan total.

d. Perawatan Darurat (Emergency Maintenance)

Perbaikan yang dilakukan segera setelah terjadi kerusakan mendadak yang mengganggu operasi siklotron, meliputi:

- Identifikasi cepat sumber kerusakan.
- Isolasi komponen yang rusak untuk mencegah kerusakan lanjutan.
- Perbaikan atau penggantian komponen kritis dengan prioritas tinggi.

Prosedur perawatan siklotron

Prosedur perawatan siklotron adalah serangkaian tindakan sistematis yang dirancang untuk memastikan bahwa semua komponen siklotron berfungsi secara optimal, aman, dan efisien.

Prosedur ini mencakup langkah-langkah preventif, inspeksi, perbaikan minor, hingga penggantian komponen utama.

Tujuan utama perawatan siklotron adalah untuk meminimalkan downtime, mencegah kerusakan mendadak, dan memperpanjang masa operasional siklotron.

10

2 Bagian-bagian PETtrace 800

GE HealthCare

PETtrace 800 series

Service Manual – Maintenance

2169049-100
Revision 33

GE HealthCare

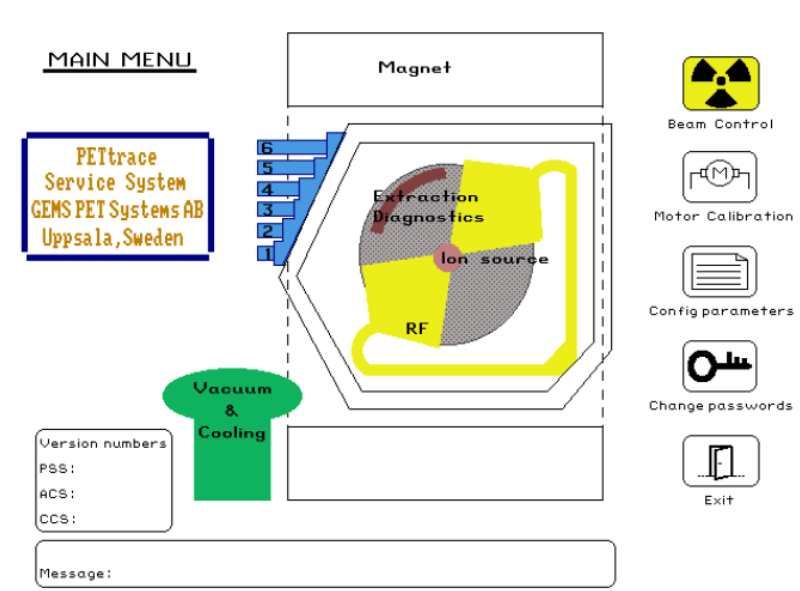
PETtrace 800 series

Service Manual – Accelerator

2169047-100
Revision 37

Siklotron PETtrace 800

Apa yang ada
didalam siklotron
PETtrace?



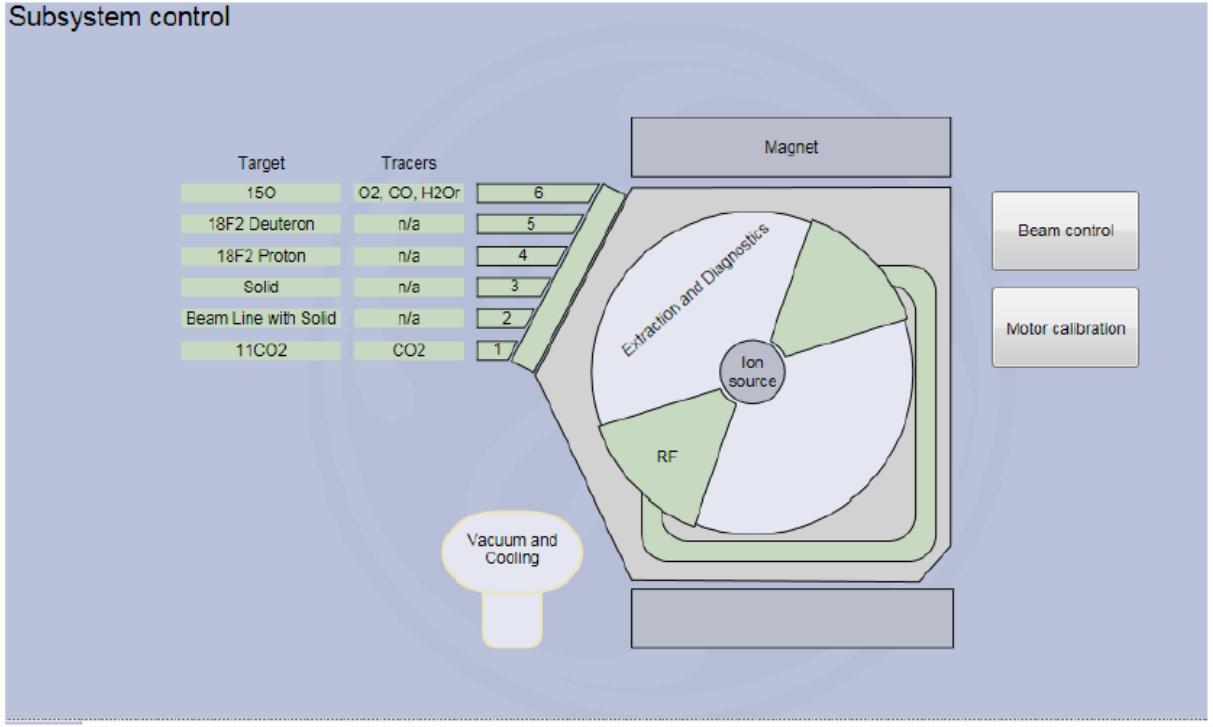
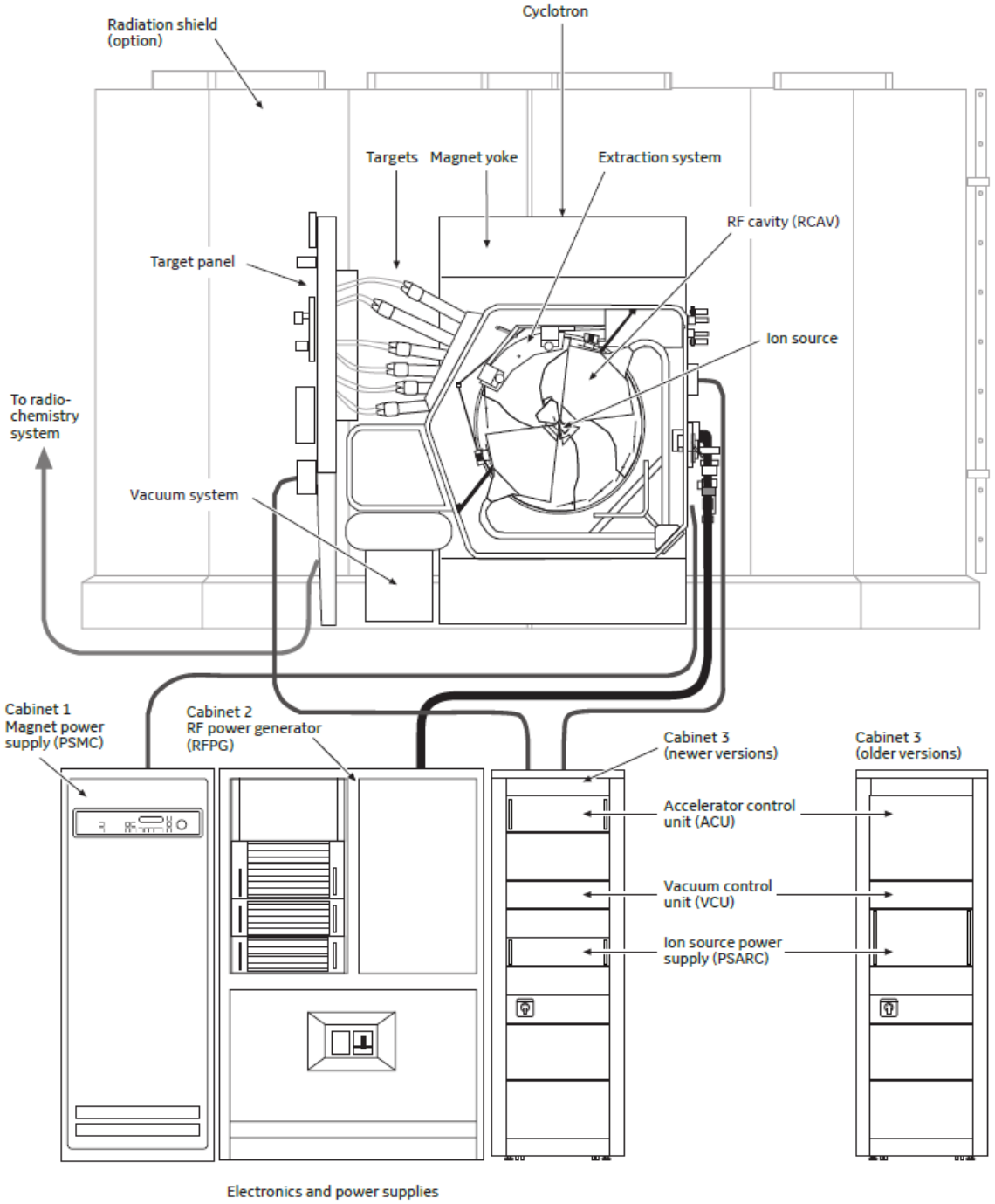
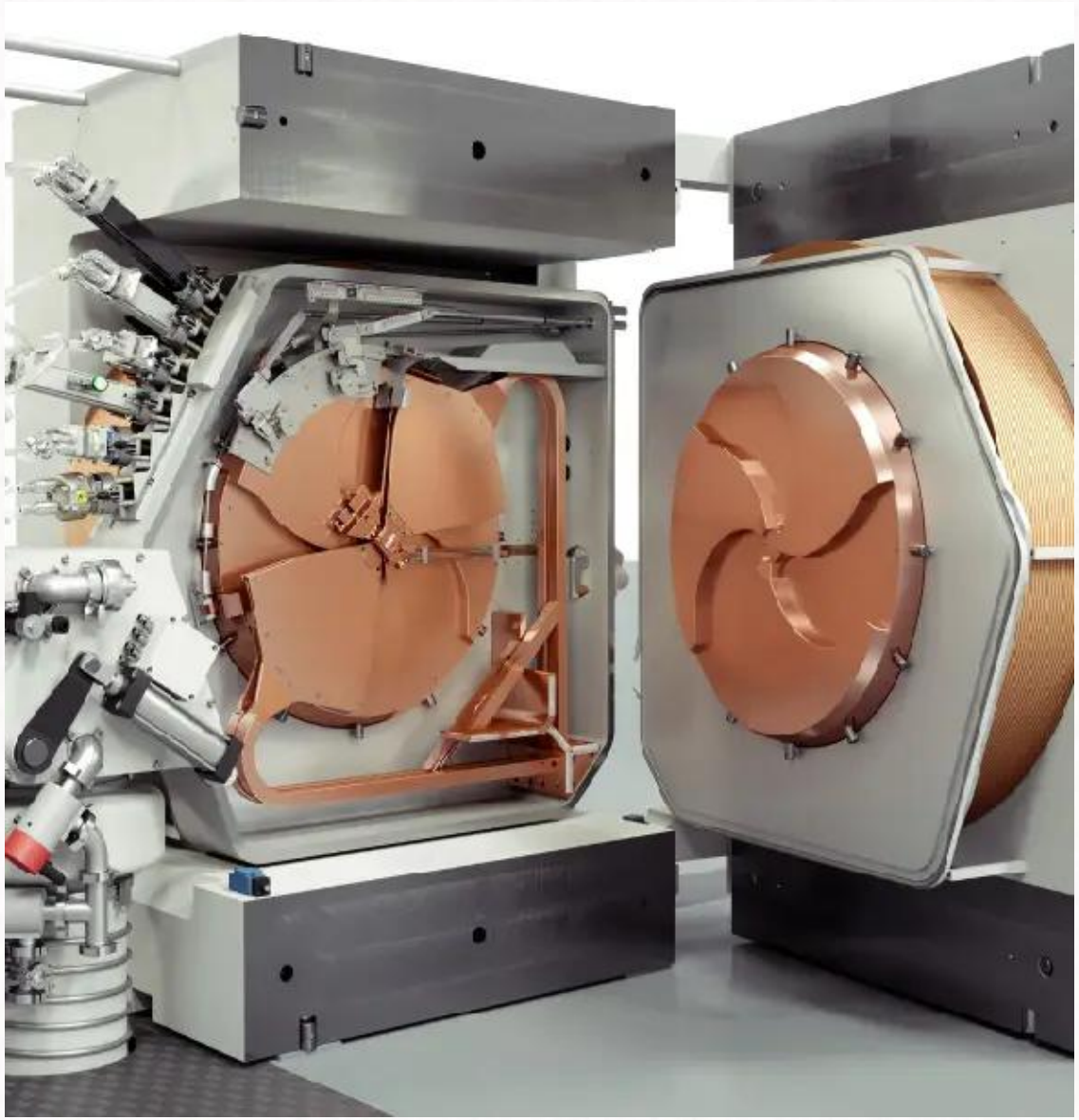
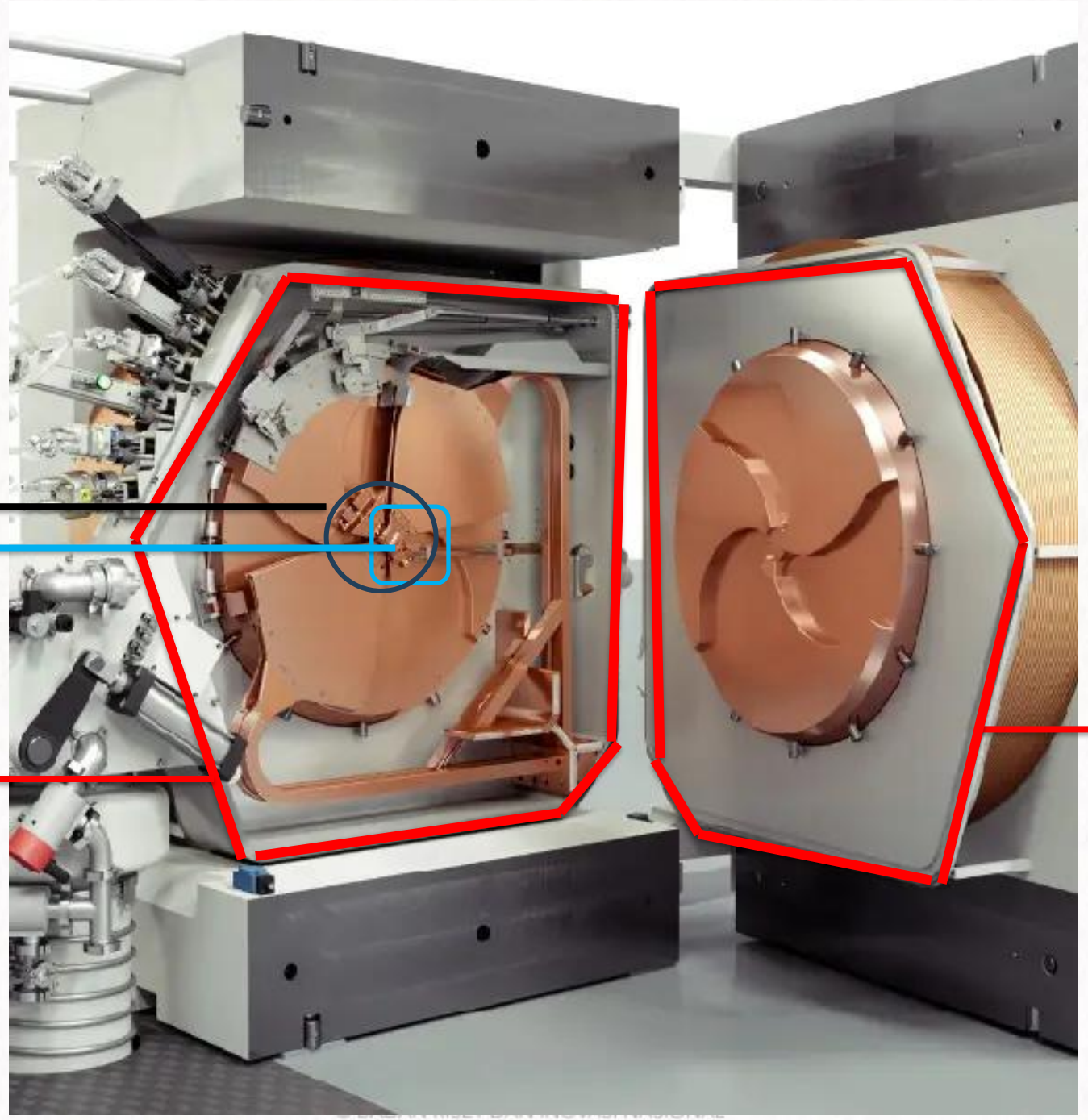


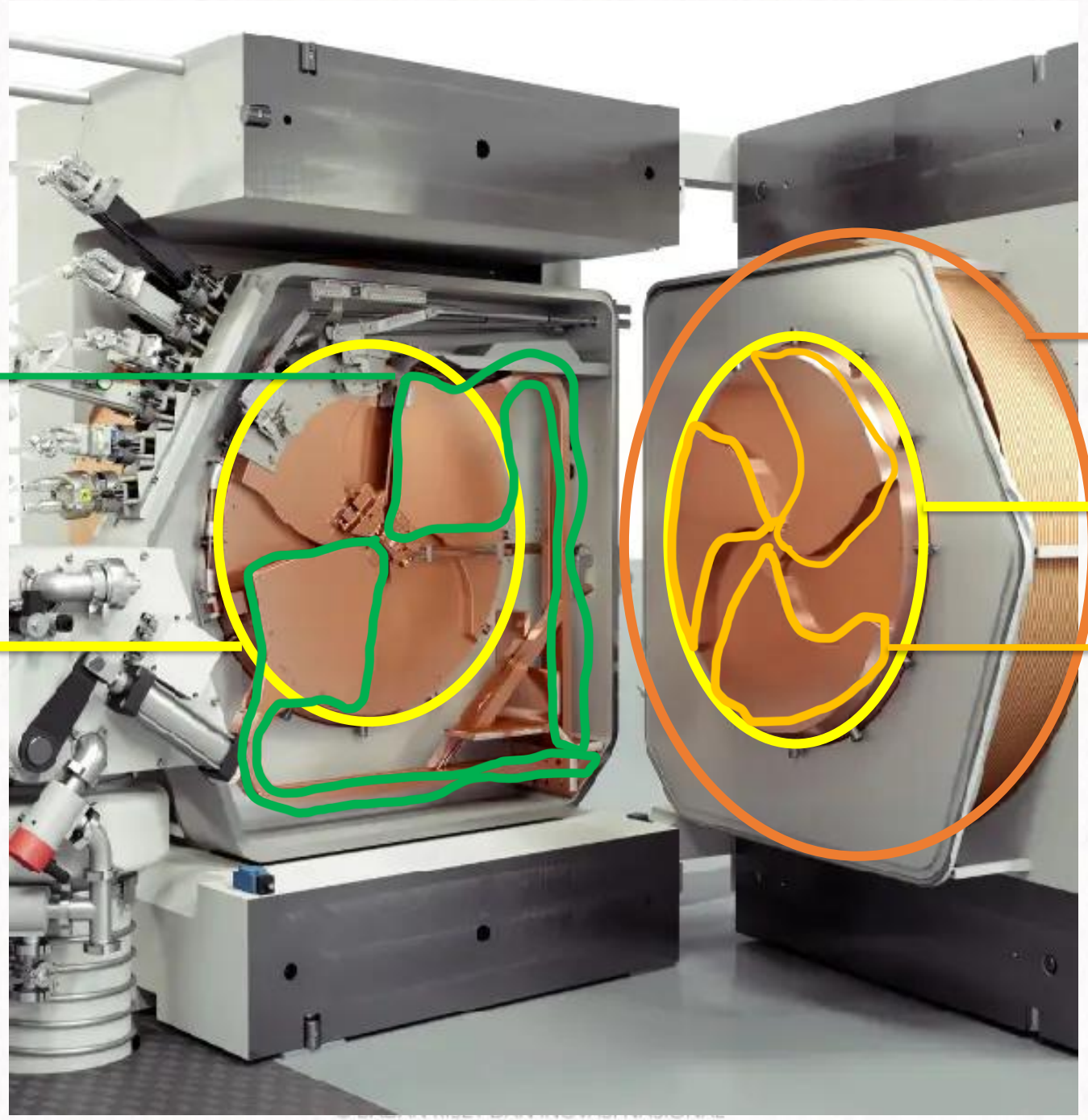
Figure 2-1: Accelerator overview



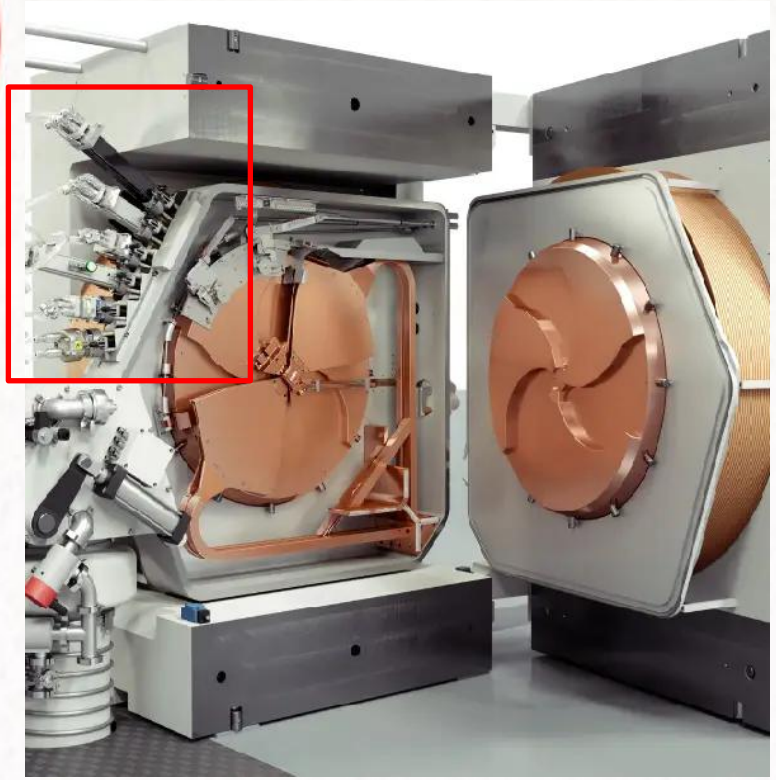



Daerah Pusat
(central region)
Ion source
Tangki (vacuum chamber)
Tutup tangki

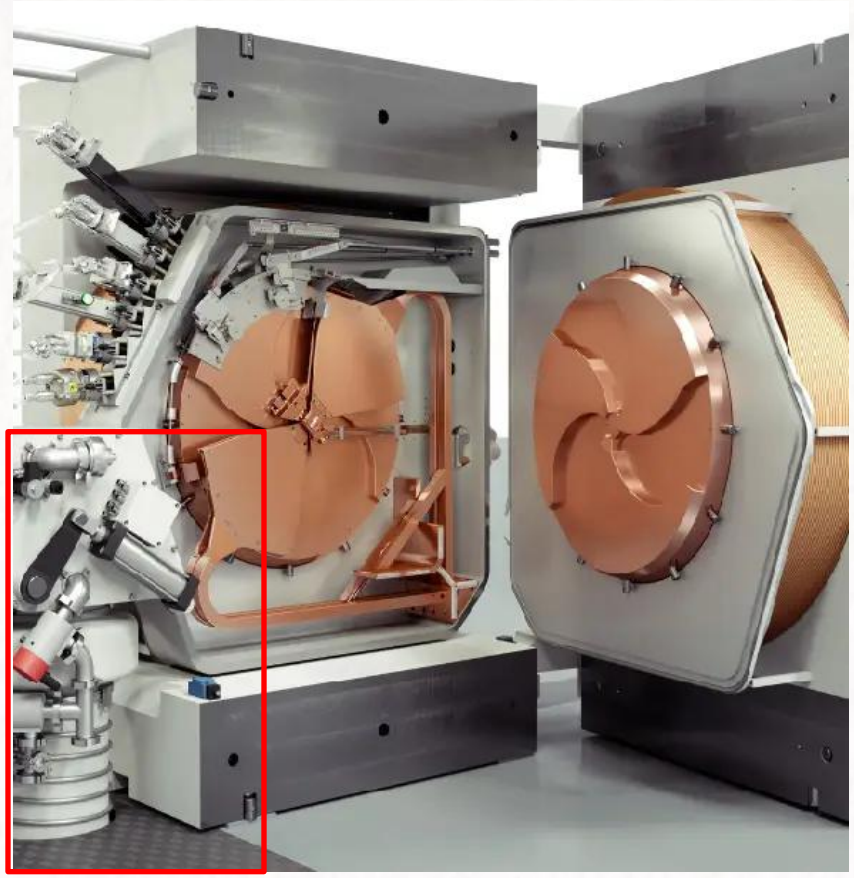
Central region


Dees
Pole magnet
Koil magnet
Pole magnet
Magnet sectoral

Target

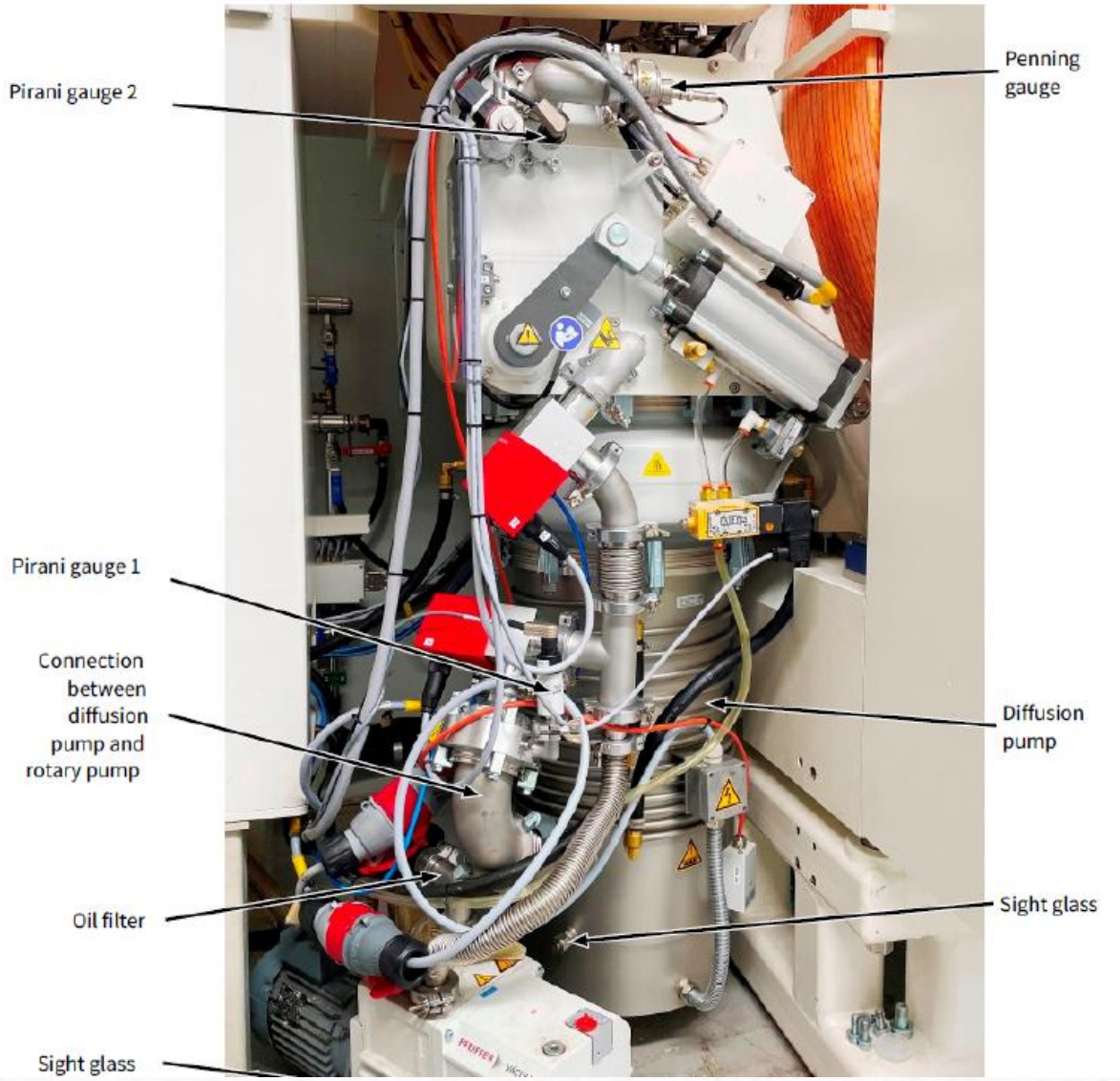


Diffusion Pump



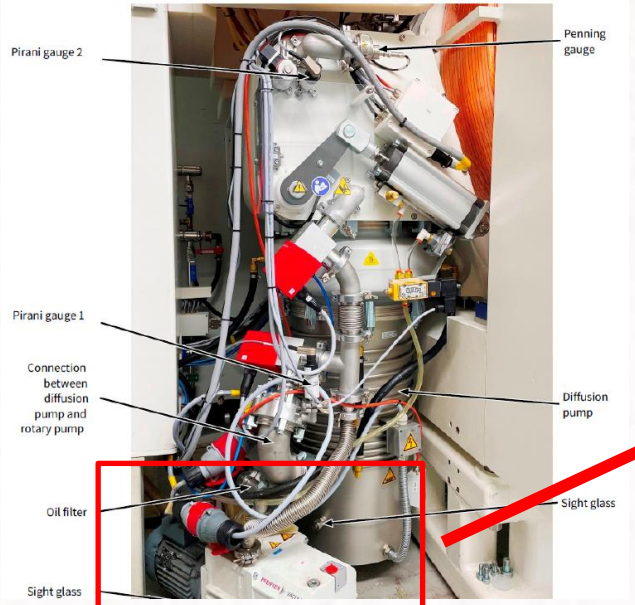
Vacuum

Figure 5-12: Vacuum pumps



Rotary pump

Figure 5-12: Vacuum pumps



RF
Power Generator

Figure 4-1: RF system block diagram

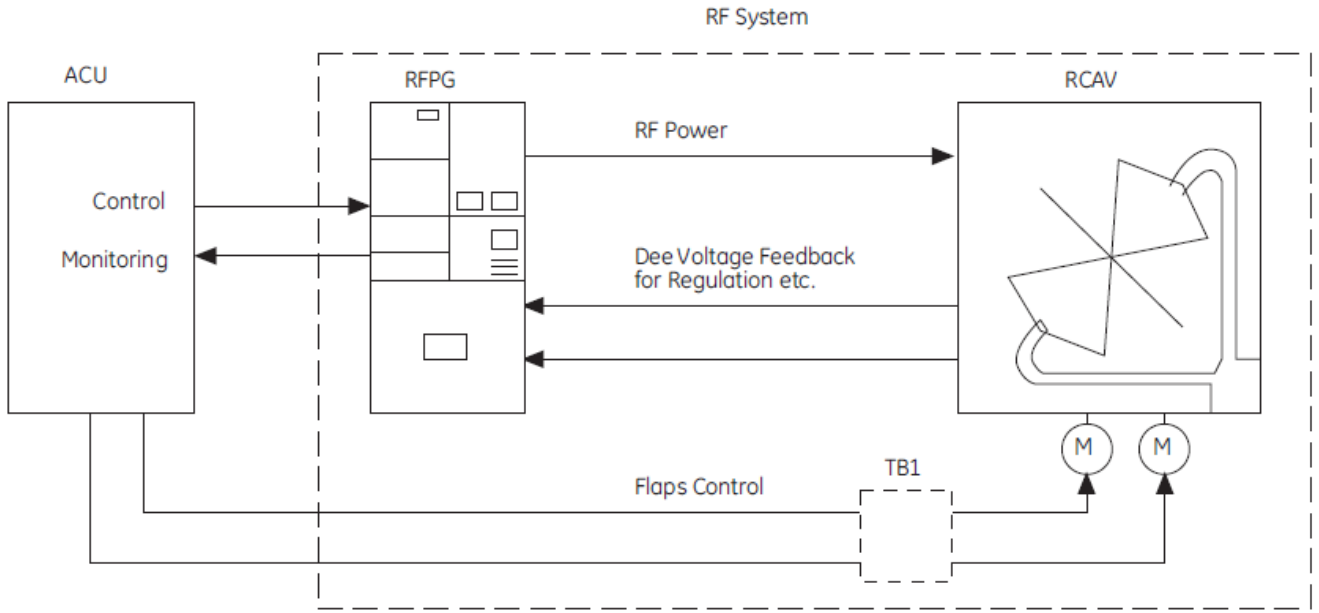
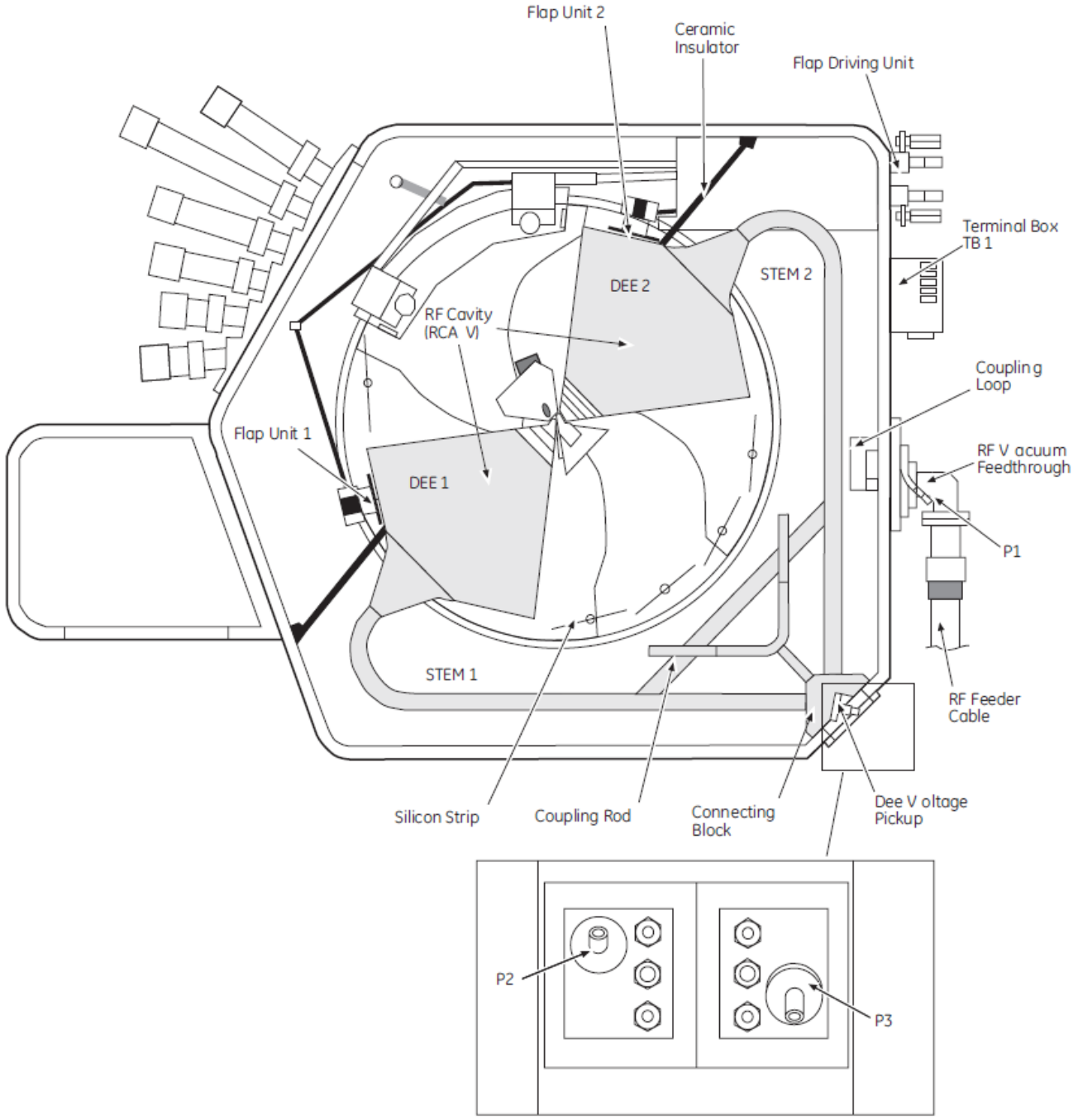


Figure 4-2: RF Cavity (RCAV)



3 Planned Maintenance schedule

(Jadwal Perawatan Terencana)

LOTO

5-4 LOTO (Lock-Out and Tag-Out) kits, LOTO tags, LOTO instructions

LOTO kits are orderable through the following numbers:

- **Full European Electrical LOTO kit**, can be used World Wide (W.W.): spare part number **2334312**.
- **Set of 10 LOTO Tags**, English: spare part number **2355715**.

  Tags are to be ordered with Spare part number 2334312 (Full European Electrical LOTO kit because the Electrical kit does not contain tags.
- **Radiopharmacy valve LOTO kit**: spare part number **2398878**.

  (This valve LOTO kit 2398878 includes 5 tags.)

It is recommended that every Field Engineer has personal LOTO kits (one Electrical LOTO kit and one valve LOTO kit).

5-4-6-4 Cyclotron subsystems – LOTO procedures

Note!
The customer is responsible for the Mains Distribution Panel, the gas supply panel and the compressed air panel. Therefore, these units can be designed in several different ways. In some cases, a suitable LOTO kit needs to be created by the local GE HealthCare FE together with the customer.

The pictures below only show examples of how LOTO devices are used.

Table 5-5: Electricity

Location	Procedure	Illustration
Mains Distribution Panel (MDP) PSMC, CAB 1	Use a suitable Breaker Lock-Out device from your personal LOTO kit to lock out the circuit breaker on the MDP dedicated for the PSMC. Follow the standard LOTO procedures and mark with LOTO tag.	

Table 5-6: Electricity

Location	Procedure	Illustration
Mains Distribution Panel (MDP), CAB 2	Use a suitable Breaker Lock-Out device from your personal LOTO kit to lock out the circuit breaker on the MDP dedicated for CAB 2. Follow the standard LOTO procedures and mark with LOTO tag. Verify that the RFPG is free from charged energy.	

5-5-6 PM safety analysis

The table below is based on the normal cyclotron PM.

For each maintenance task, the table describes:

- Risk levels:

Green:	OK to proceed with task.
Yellow:	Proceed with caution.
Red:	Do not proceed until all safety precautions have been completed.

- Hazard
- Cause
- PPE (appropriate personal protection equipment, i.e. personal film dosimeter, personal electronic dosimeter, personal finger dosimeter, safety shoes, shoe covers, full body lab coat, safety glasses or face shield, protective gloves, etc.)
- Control measures

Note!
The safety analysis in Table 5-19 is only a means of assistance, not an exhaustive analysis of all possible situations.

TASK: Disconnect targets					
TASK	RISK LEVEL	HAZARD	CAUSE	PPE	CONTROL MEASURES
Disconnect all targets using the service laptop	OK to proceed with task	None			Refer to the Service System instructions. Make sure that pressure in targets is completely released.
TASK: Enter inside the cyclotron room					
TASK	RISK LEVEL	HAZARD	CAUSE	PPE	CONTROL MEASURES
Measure radiation level in the room	Do not proceed until all safety precautions have been completed	Radiation	Ionization effect		See General advice above. Always request approval from the customer radiation safety officer.
TASK: Stop water cooling to targets					
TASK	RISK LEVEL	HAZARD	CAUSE	PPE	CONTROL MEASURES
Switch off water valves to targets on manifold	Proceed with caution	Radiation	Potential radiation in the cyclotron room		The task will take 2 min to accomplish. Do not start any job if the dose rate is too high. Always request approval from the customer radiation safety officer.

Planned Maintenance schedule

Table 5-21: PM schedule

Item	Interval	Procedure/remarks	Reference
ACCELERATOR			
Magnet system			
Water connections	6months	Check water connections.	*dir. 2169047-100*
Yoke actuator system	6months	Check yoke actuator system.	*dir. 2169047-100*
Magnet Power Supply, PSMC	6months	Tighten terminal screws, check voltage output.	*dir. 2169047-100*
Magnet system	6months	Check function of magnet system.	*dir. 2169047-100*
RF system			
RF system mechanics	6months	Check alignment of Dees and flaps, fine tuning system. Check condition of vacuum feedthrough.	No instructions available
RFPG	6months	Check function of RF Power Generator.	
RF system	6months	Check RF system operation.	

PETtrace 800 Service Manual Maintenance_SM_2169049-100_33

5-7 Planned Maintenance schedule

Item	Interval	Procedure/remarks	Reference
Ion source system			
Ion source maintenance	35000–40000μAh	Replace anode and cathodes. Clean the ion source.	*dir. 2169047-100*
		Note! *The quality of the ion source gas and gas delivery tubing, as well as having a completely leak free ion source gas delivery system, will strongly affect the maintenance interval of the ion source. Central region tuning and beam shape (beam width) will also affect the maintenance interval, since it determines the ion source efficiency or relation between ion source arc current and beam current on target.*	
Gas handling system	6months	Check flow regulation and pressure.	*dir. 2169047-100*
Ion source test	6months	Perform ion source test.	*dir. 2169047-100*
Extraction system			
Foil carousel	6months	Check foils, replace if necessary.	*dir. 2169047-100*
Carrier	6months	Check function.	*dir. 2169047-100*
Driving screw assembly	6months	Check driving screw assembly.	*dir. 2169047-100*
Drive unit	6months	Check function of the drive unit.	*dir. 2169047-100*
Diagnostic system			
Flip-in probe	6months	Clean and adjust flip-in probe. Calibrate beam read-out at flip-in probe.	*dir. 2169047-100*
Extraction foil current	6months	Calibrate beam read-out at extraction foil.	*dir. 2169047-100*
Beam collimators	6months	Check beam collimators and calibrate beam read-out.	*dir. 2169047-100*
Vacuum system			
Roughing pump	6months	Replace roughing pump oil.	*dir. 2169047-100*
Diffusion pump	5 years	Clean diffusion pump, replace jet system, and replace oil.	*dir. 2169047-100*
Pirani gauges	6months	Clean and calibrate Pirani gauges.	*dir. 2169047-100*
Penning gauge	6months	Clean Penning gauge.	*dir. 2169047-100*

Item	Interval	Procedure/remarks	Reference
Ion source system			
Ion source maintenance	35000–40000μAh	Replace anode and cathodes. Clean the ion source.	*dir. 2169047-100*
		Note! *The quality of the ion source gas and gas delivery tubing, as well as having a completely leak free ion source gas delivery system, will strongly affect the maintenance interval of the ion source. Central region tuning and beam shape (beam width) will also affect the maintenance interval, since it determines the ion source efficiency or relation between ion source arc current and beam current on target.*	
Gas handling system	6months	Check flow regulation and pressure.	*dir. 2169047-100*
Ion source test	6months	Perform ion source test.	*dir. 2169047-100*
Extraction system			
Foil carousel	6months	Check foils, replace if necessary.	*dir. 2169047-100*
Carrier	6months	Check function.	*dir. 2169047-100*
Driving screw assembly	6months	Check driving screw assembly.	*dir. 2169047-100*
Drive unit	6months	Check function of the drive unit.	*dir. 2169047-100*
Diagnostic system			
Flip-in probe	6months	Clean and adjust flip-in probe. Calibrate beam read-out at flip-in probe.	*dir. 2169047-100*
Extraction foil current	6months	Calibrate beam read-out at extraction foil.	*dir. 2169047-100*
Beam collimators	6months	Check beam collimators and calibrate beam read-out.	*dir. 2169047-100*
Vacuum system			
Roughing pump	6months	Replace roughing pump oil.	*dir. 2169047-100*
Diffusion pump	5 years	Clean diffusion pump, replace jet system, and replace oil.	*dir. 2169047-100*
Pirani gauges	6months	Clean and calibrate Pirani gauges.	*dir. 2169047-100*
Penning gauge	6months	Clean Penning gauge.	*dir. 2169047-100*

Planned Maintenance schedule

Preventive maintenance

4 Operator Maintenance schedule

(Jadwal Perawatan oleh Operator)

Operator Maintenance schedule

#	Location	System	Action	Schedule
1	Control	Master	Shut down the cyclotron and logout from the Master	6, 12, and 24 months
2	PS room	Vacuum	Record the vacuum pressure	6, 12, and 24 months
3	PS room	Vacuum	Press OFF on the VCU and note the time (wait 2 hours)	6, 12, and 24 months
4	PS room	Vacuum	Press VENT on the VCU	6, 12, and 24 months
5	Service laptop	Target	Disconnect all targets (SW)	6, 12, and 24 months
6	Cyclotron	Target	Switch off the water valves to the targets on the water manifold	6, 12, and 24 months
7	Cyclotron	Target	Remove the targets from the cyclotron	6, 12, and 24 months
8	Cyclotron	Magnet	Remove the door bolt on the magnet	6, 12, and 24 months
9	Cyclotron	Magnet	Open the magnet door	6, 12, and 24 months
10	Cyclotron	Magnet	Check the magnet door motor (closed door)	12 and 24 months

5-9 Sequence list for Planned Maintenance

#	Location	System	Action	Schedule
104	Vault	Target	Check the fill volume of the liquid targets	6, 12, and 24 months, alt. based on usage
105	Vault	Target	Change 1/16" tubings between the liquid targets and the hot cell	6, 12, and 24 months, alt. based on usage
106	Control	Master	Login to the MASTER	6, 12, and 24 months, alt. based on usage
107	Control	Master	Start up the accelerator	6, 12, and 24 months, alt. based on usage
108	Control	Master	Fill the $^{18}F^-$ target with $H_2{}^{16}O$	6, 12, and 24 months, alt. based on usage
109	Control	Master	Run $^{18}F^-$ production on 10 µA for 10 min	6, 12, and 24 months, alt. based on usage
110	Control	Master	Repeat steps 108 to 109 twice more	6, 12, and 24 months, alt. based on usage
111	Control	Master	Repeat steps 108 to 109 for each $^{18}F^-$ and ^{13}N target on the system	6, 12, and 24 months, alt. based on usage
112	Control	Master	Run ^{13}N, ^{15}O and $^{11}CO_2$ productions, if possible	6, 12, and 24 months, alt. based on usage
113	Compressor	Radiation shield	Check the compressor (filter elements)	6, 12, and 24 months
114	Compressor	Radiation shield	Check the compressor (oil and oil filter)	6, 12, and 24 months
115	Cyclotron	Radiation shield	Do air manifold maintenance	6, 12, and 24 months
116	Cyclotron	Radiation shield	Check the doors (water levels)	6, 12, and 24 months
117	Cyclotron	Radiation shield	Check the doors (microswitches)	6, 12, and 24 months
118	ProCab	ProCab	Measure the voltages in CCU Gen II	6, 12, and 24 months

#	Location	System	Action	Schedule
123	ProCab	ProCab	Do a test of the ^{15}O valves	6, 12, and 24 months
124	ProCab	ProCab	Do a leak check of the ^{15}O system	6, 12, and 24 months
125	ProCab	ProCab	Do a test of the gas flow regulators on the ^{15}O panel	6, 12, and 24 months
126	ProCab	ProCab	Do a test of the ^{15}O ovens	6, 12, and 24 months
127	$^{18}F_2$ Proton target system	$^{18}F_2$ Proton target system	Do a visual inspection of the tubing and connectors	6, 12, and 24 months
128	$^{18}F_2$ Proton target system	$^{18}F_2$ Proton target system	Do a visual inspection of the valves	6, 12, and 24 months
129	$^{18}F_2$ Proton target system	$^{18}F_2$ Proton target system	Verify the function of the pressure transducers	6, 12, and 24 months
130	$^{18}F_2$ Proton target system	$^{18}F_2$ Proton target system	Do a visual inspection of the control box (opened) and electronic devices	6, 12, and 24 months
131	$^{18}F_2$ Proton target system	$^{18}F_2$ Proton target system	Change the NaF trap, soda lime, and molecular sieve (including filters)	6, 12, and 24 months
132	$^{18}F_2$ Proton target system	$^{18}F_2$ Proton target system	Change the oil in the vacuum pump	6, 12, and 24 months
133	$^{18}F_2$ Proton target system	$^{18}F_2$ Proton target system	Do a gas pressure test to leak check the target	6, 12, and 24 months
134	$^{18}F_2$ Proton target system	$^{18}F_2$ Proton target system	Check that the lift on the $^{18}F_2$ proton panel works properly	6, 12, and 24 months
135	$^{18}F_2$ Proton target system	$^{18}F_2$ Proton target system	Check the interlocks	6, 12, and 24 months

#	Location	System	Action	Schedule
123	ProCab	ProCab	Do a test of the ^{15}O valves	6, 12, and 24 months
124	ProCab	ProCab	Do a leak check of the ^{15}O system	6, 12, and 24 months
125	ProCab	ProCab	Do a test of the gas flow regulators on the ^{15}O panel	6, 12, and 24 months
126	ProCab	ProCab	Do a test of the ^{15}O ovens	6, 12, and 24 months
127	$^{18}F_2$ Proton target system	$^{18}F_2$ Proton target system	Do a visual inspection of the tubing and connectors	6, 12, and 24 months
128	$^{18}F_2$ Proton target system	$^{18}F_2$ Proton target system	Do a visual inspection of the valves	6, 12, and 24 months
129	$^{18}F_2$ Proton target system	$^{18}F_2$ Proton target system	Verify the function of the pressure transducers	6, 12, and 24 months
130	$^{18}F_2$ Proton target system	$^{18}F_2$ Proton target system	Do a visual inspection of the control box (opened) and electronic devices	6, 12, and 24 months
131	$^{18}F_2$ Proton target system	$^{18}F_2$ Proton target system	Change the NaF trap, soda lime, and molecular sieve (including filters)	6, 12, and 24 months
132	$^{18}F_2$ Proton target system	$^{18}F_2$ Proton target system	Change the oil in the vacuum pump	6, 12, and 24 months
133	$^{18}F_2$ Proton target system	$^{18}F_2$ Proton target system	Do a gas pressure test to leak check the target	6, 12, and 24 months
134	$^{18}F_2$ Proton target system	$^{18}F_2$ Proton target system	Check that the lift on the $^{18}F_2$ proton panel works properly	6, 12, and 24 months
135	$^{18}F_2$ Proton target system	$^{18}F_2$ Proton target system	Check the interlocks	6, 12, and 24 months
136	$^{18}F_2$ Proton target system	$^{18}F_2$ Proton target system	Visually inspect and change the insulators if needed between the $^{18}F_2$ proton target and the proton target panel	6, 12, and 24 months

#	Location	System	Action	Schedule
141	Solid target platform	Solid target station	Replace the pneumatics connection block on the solid target station	24 months
142	Solid target platform	Solid target station	Replace the inflatable gasket in the solid target station	24 months
143	Solid target platform	Solid target station	Replace the limit switches (7 pcs.)	24 months
144	Solid target platform	Capsule Handling Station	Verify the function of the hot cell door interlock	6, 12, and 24 months
145	Solid target platform	Capsule Handling Station	Verify the function of the emergency stop button	6, 12, and 24 months
146	Solid target platform	Solid target station/Capsule Handling Station	Verify that the capsule runs smoothly through the transfer tube and all switches trigger correctly	After any service intervention

Operator Maintenance schedule

Preventive maintenance

5 Maintenance procedures

(Prosedur Perawatan)

5-10 Instructions for Planned Maintenance

5-10-2 Maintenance procedures

5-10-2 Maintenance procedures

WARNING!

Apply LOTO as applicable in accordance with GE HealthCare procedures and local restrictions. For LOTO procedures, see Section 5-4-6 LOTO procedures for the PETtrace 800 system on page 162.

Sequence #	MASTER SYSTEM (software)	
1	SHUT DOWN THE CYCLOTRON AND LOG OUT FROM THE MASTER	
	Location: Control room	6 months, 12 months, and 24 months

MAINTENANCE INFORMATION

The cyclotron system must be shut down before any actions can be done on the system.

PROCEDURE

1 At the Master System, click **Maintenance** in the main menu.

2 Click **PETtrace 800** and then **Shutdown**.

3 Wait until the **Messages** window disappears and cyclotron status is OFF in the **Status** window.

4 Click the **Exit** button in the **PETtrace 800** menu. You will be asked to confirm before you are logged off from the Master System.

5 Turn off all gas supply (on gas tanks).

For more information about shutting down the system, refer to *PETtrace 800 series PETtrace Kunpeng Operator Guide (dir. 5397086)*.

Sequence # 2	VACUUM	
	RECORD THE VACUUM PRESSURE	
	Location: PS room	6 months, 12 months, and 24 months

MAINTENANCE INFORMATION

Before the vacuum system is turned off and the vacuum chamber is opened the pressure should be recorded. This gives you an idea about the vacuum status before and after the maintenance.

PROCEDURE

Read the different vacuum pressures and record them in the maintenance form. (On a VCU with TPG 300, use the **sensor** key to toggle between sensors.)

Sequence # 3	VACUUM	
	PRESS OFF ON THE VCU AND NOTE THE TIME (wait 2 hours)	
	Location: Control room	6 months, 12 months, and 24 months

MAINTENANCE INFORMATION

When **OFF** is pressed on the VCU the diffusion pump starts to cool down. This will take about 2 hours. During this time the diffusion pump should not be opened as this can cause the pump-oil to be burned.

PROCEDURE

1 At the VCU, press the **OFF** button.

   a The high vacuum valve will close.

   b The diffusion pump is turned off.

   c The roughing pump continues backing the diffusion pump for approx. 45 minutes.

2 Note the time.

Sequence # 5	TARGET	
	DISCONNECT ALL TARGETS (SW)	
	Location: Service laptop	6 months, 12 months, and 24 months

MAINTENANCE INFORMATION

The targets need to be software-disconnected from the service laptop.

PROCEDURE

1 At the service laptop, in the **MAIN MENU** window, click at the target you want to disconnect.

2 In the selected target window, click **DISCONNECT TARGET**.

3 Repeat the steps above for each connected target.

For more information, see Chapter 4 PETtrace 800 Service System (PSS) software.

Sequence # 6	TARGET	
	SWITCH OFF THE WATER VALVES TO THE TARGETS ON THE WATER MANIFOLD	
	Location: Cyclotron	6 months, 12 months, and 24 months

MAINTENANCE INFORMATION

On the water manifold 1, inside the cyclotron room, there are two valves (one for upper and one for lower targets) for the target water cooling.

PROCEDURE

Switch off the three water valves for target cooling.

For more information about the water cooling system, refer to *PETtrace 800 series Service Manual – Accelerator (dir. 2169047-100)*.

Sequence # 11	MAGNET	
	CHECK THE MAGNET DOOR MOTOR (opening of door)	
	Location: Cyclotron room	12 months and 24 months

MAINTENANCE INFORMATION

If the magnet yoke opens too much the flap- and extraction motors can be damaged. The magnet yoke motor is located on the upper right side of the magnet.

WARNING! Pinch hazard

The magnet yoke will shut with high force if the magnet door switch is operated or if the PSMC is accidentally turned on.

PROCEDURE

1 Move the magnet door (with the door pendant control) to the OPEN position. Check for unusual noise level from the yoke actuator motor.

2 Check that the magnet door not opens too much (too close to the flap- and extraction motor).

3 Fill in the maintenance form.

For more information, refer to *PETtrace 800 series Service Manual – Accelerator (dir. 2169047-100)*.

Sequence # 12	ION SOURCE	
	REMOVE THE FOIL CAROUSELS AND THE ION SOURCE ANODE	
	Location: Cyclotron room	6 months, 12 months, and 24 months

MAINTENANCE INFORMATION

Before starting the ion source work, remove the foil carousels and store them in a safe place. The foil carousels can be radioactive.

WARNING! Radioactivity

Always monitor the radiation levels. Keep longest possible distance to the hot spots.

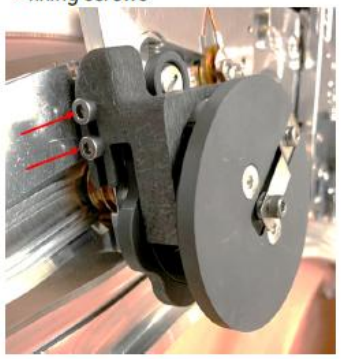
The ion source body contains two ion sources in the same shell. On Planned Maintenance the anodes and cathodes must be replaced, but at some sites only one of the ion sources is used and in those cases only this one needs to be replaced. Build-ups in the ion source need to be removed or cleaned.

Extraction Gen II only:

Carrier 1

Carousel shield in open position
→ stop screw for open position

Carousel shield in closed position
→ fixing screws



6 Diagnosis

6 Diagnostics

The diagnostic information on the following pages is presented in a five column table, as follows:

Error message	Possible cause (Parameter)	Possible solution (Action)	Related spare part
This column contains fault messages displayed on the Master System screen.	This column may contain possible causes to the fault incurred.	This column suggests ways of solving the problem.	This column may contain spare part data (name, number, etc).

6-1 Diagnostics guide

Error message	Possible cause (Parameter)	Possible solution (Action)	Related spare part
ACS fault at safety interlocks, I/O board is missing	One of the VME I/O boards in the ACU is not responding.	Print errorlog and check number for board 0=DIO_1, 1=DIO_2, 3=AI, 4=AO, 5=SMB Then check select LED on I/O board should be flashing or on if working. Try to change board.	I/O board
ACS fault at safety interlocks, illegal parameter	An illegal parameter is received.	Print errorlog, report to service engineer and try again.	
ACS fault at safety interlocks, safety door is open	The door to the cyclotron vault or the radiation shield is open.	Close the door	
ACS fault at startup, I/O board is missing	One of the VME I/O boards in the ACU is not responding.	Print errorlog and check number for board 0=DIO_1, 1=DIO_2, 3=AI, 4=AO, 5=SMB Then check select LED on I/O board should be flashing or on if working. Try to change board.	
ACS fault during foil change, out of foils	All foils are used up.	Time for service. Change to new foils	
ACS fault for balance, regulation fault	The balance motor has not reached position within 120 seconds (old_motor_speed)	Check the motor	
ACS fault in ARC current regulation, regulation fault	ARC current has exceeded its limits. (ARC current)	Print errorlog, report to service engineer and try again.	

Error message	Possible cause (Parameter)	Possible solution (Action)	Related spare part
ACS fault in BCA system, BCA power fault	Bca power is off.	Check +15 and -15 LEDs on BCA board	
ACS fault in BCA system, BCA power fault	Bca power is off.	Check +15 and -15 LEDs on BCA board	
ACS fault in BCA system, I/O board is missing	One of the VME I/O boards in the ACU is not responding.	Print errorlog and check number for board 0=DIO_1, 1=DIO_2, 3=AI, 4=AO, 5=SMB Then check select LED on I/O board should be flashing or on if working. Try to change board.	I/o boards
ACS fault in BCA system, I/O board is missing	One of the VME I/O boards in the ACU is not responding.	Print errorlog and check number for board 0=DIO_1, 1=DIO_2, 3=AI, 4=AO, 5=SMB Then check select LED on I/O board should be flashing or on if working. Try to change board.	I/o boards
ACS fault in BCA system, illegal parameter	An illegal parameter is received.	Print errorlog, report to service engineer and try again.	
ACS fault in BCA system, illegal parameter	An illegal parameter is received.	Print errorlog, report to service engineer and try again.	
ACS fault in BCA system, probe fault/timeout	Probe not responding for 2 seconds	Check that the magnet is on.	
ACS fault in BCA system, probe fault/timeout	Probe not responding for 2 seconds	Check that the magnet is on.	
ACS fault in BCA system, too high beam current on collimator 1 to 6	Collimator current too high. Used collimator max = 10 µA, unused = 5 µA. (Collimator current 1 to 6)		

Diagnostic =
Corrective maintenance

7 Rangkuman

Jenis Perawatan:

a. Perawatan Preventif (Preventive Maintenance)

Tindakan perawatan yang dilakukan secara rutin untuk mencegah kerusakan sebelum terjadi

b. Perawatan Korektif (Corrective Maintenance)

Perbaikan yang dilakukan setelah terdeteksi adanya kerusakan atau penurunan performa

c. Perawatan Prediktif (Predictive Maintenance)

Tindakan perawatan berdasarkan analisis kondisi komponen menggunakan data real-time

d. Perawatan Darurat (Emergency Maintenance)

Perbaikan yang dilakukan segera setelah terjadi kerusakan mendadak yang mengganggu operasi siklotron

Prosedur Umum Perbaikan:

a. Persiapan dan Keamanan:

- Pastikan mesin siklotron dalam kondisi mati dan aman sebelum memulai pekerjaan.
- Gunakan alat pelindung diri (APD) yang sesuai, seperti sarung tangan anti-statis, kacamata pelindung, dan pelindung dari radiasi.

b. Inspeksi Visual:

- Lakukan pemeriksaan visual untuk mendeteksi adanya kerusakan fisik, korosi, atau keausan.
- Pembersihan Komponen:
- Bersihkan komponen secara hati-hati untuk menghilangkan kotoran atau residu yang dapat mengganggu operasi.

c. Penggantian dan Kalibrasi:

- Ganti komponen yang aus atau rusak dengan komponen baru sesuai spesifikasi pabrikan.
- Kalibrasi ulang untuk memastikan kesesuaian parameter.

d. Pengujian dan Verifikasi:

- Nyalakan kembali sistem dan uji kinerja untuk memastikan semua komponen berfungsi sesuai spesifikasi.

e. Dokumentasi:

- Catat semua perbaikan dan penggantian yang dilakukan, termasuk hasil pengujian.

- **Pedoman perawatan terbaik adalah manual book pabrikan**
- **Buku manual maintenance = Preventive/Corrective maintenance**

- **Maintenance >> Produsen > Agency**
  (+) Personil berpengalaman
  (-) Waktu (biasanya kurang fleksible karena terkait kontrak)
  (-) Biaya (relative mahal)

- **Maintenance >> Operator >> sulit >> ?**
  - Knowledge (fisika, teknis (elektronik, material, geometri))
  - Susah diamati (mengandalkan detector/sensor)
  - Minim referensi
  - Sensitive
  - Resiko bahaya (Radiasi, Kontaminasi, dan Tegangan Listrik)
  - Resiko kerusakan
- **Tips (Win-win) >>Agency local**
  (+) Personil berpengalaman
  (+) Waktu fleksibel
  (+) Biaya lebih terjangkau

Maintenance oleh Operator

1. Kebersihan siklotron

Menjaga kebersihan mesin siklotron (seluruh bagian-bagiannya) dan lingkungan sekitar

2. **Water Supply (pemeriksaan rutin)**

- Level Air reservoir
- Kapasitas Resistansi
- Kebocoran saluran

3. **Air Pressure Supply (pemeriksaan rutin)**

- Tekanan Udara kerja
- Kondisi Dryer
- Filter (penggantian, flashing)
- Kebocoran saluran

4**. Dokumentasi**

- Dokumentasikan setiap kejadian yang tak normal/anomali pada suatu logbook atau perekam lainnya untuk memudahkan penelusuran ketika diperlukan maintenance.
- Catat semua perbaikan/penanganan yang dilakukan ketika maintenance (history)

(Maintenance pada bagian external mesin)

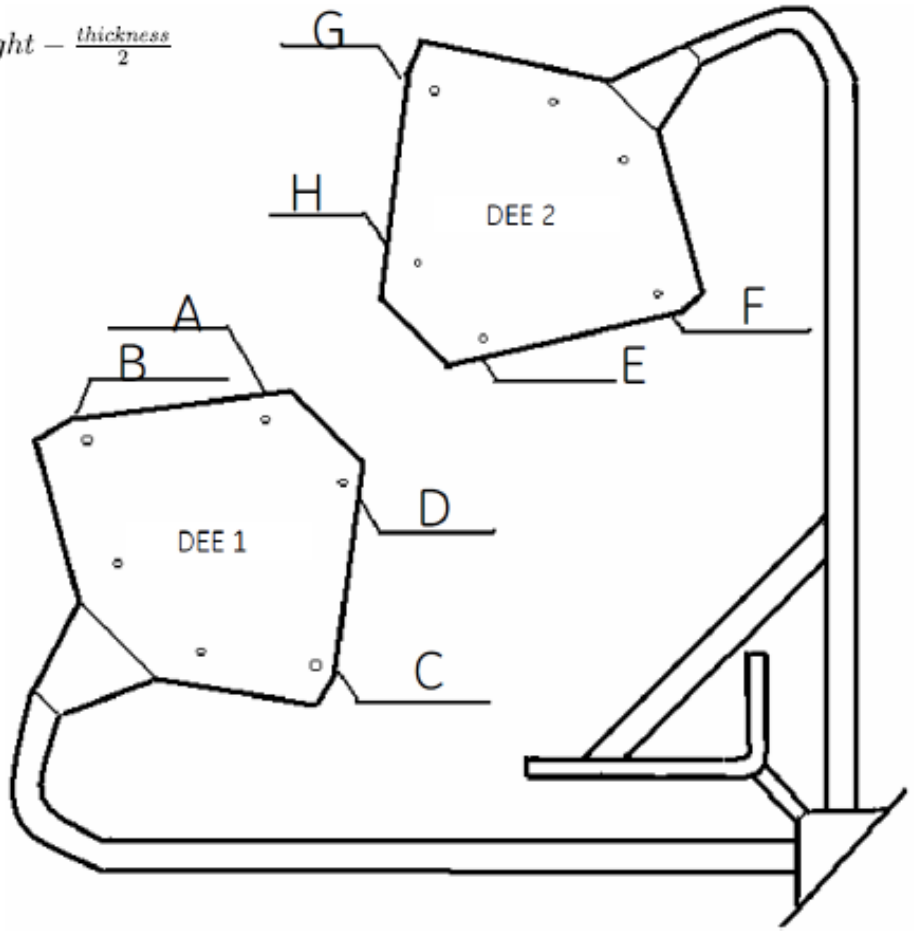
Hal yang cukup mudah dikerjakan, namun berdampak signifikan pada performa dan biaya operasional siklotron

Dees

Studi kasus setting level Dee pada siklotron CS-30, kegiatan setting level Dee sangat sulit dilakukaan meskipun telah ada data dari panduan manual book, referensi dari pengalaman /historical.

Figure 5-6: Measure the Dee heights

$$midplane = height - \frac{thickness}{2}$$



LATIHAN SOAL

Soal Pilihan Ganda

1. **Apa tujuan utama dari perawatan preventif pada siklotron?**
   A. Mengembalikan komponen yang rusak ke kondisi semula
   B. Mendeteksi tren penurunan performa menggunakan data real-time
   C. Mencegah kerusakan sebelum terjadi
   D. Memperbaiki kerusakan mendadak pada sistem

2. **Komponen apa yang biasanya memerlukan inspeksi visual dalam perawatan preventif?**
   A. Sumber ion, sistem RF, magnet, dan sistem transfer berkas
   B. Sensor kontrol performa
   C. Mesin hidrolik pengangkat tangki
   D. Katoda sumber ion yang rusak

3. **Langkah awal dalam perawatan korektif pada sistem siklotron adalah:**
   A. Membersihkan sistem vakum dari kontaminasi
   B. Mengidentifikasi penyebab kerusakan menggunakan alat diagnostik
   C. Melakukan kalibrasi ulang perangkat elektronik
   D. Menganalisis data real-time dari sistem kontrol

4. **Dalam perawatan prediktif, apa yang digunakan untuk mendeteksi tren penurunan performa?**
   A. Inspeksi visual
   B. Pembersihan rutin
   C. Data real-time dari sistem kontrol
   D. Reparasi deflektor elektrostatik

5. **Apa tindakan yang dilakukan dalam perawatan prediktif ketika data menunjukkan komponen mulai menurun performanya?**
   A. Mengisolasi komponen rusak
   B. Menggantinya sebelum terjadi kerusakan total
   C. Mengunci posisi komponen agar stabil
   D. Membersihkannya dengan alkohol atau aseton

Terima Kasih

Atas Perhatian Anda

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