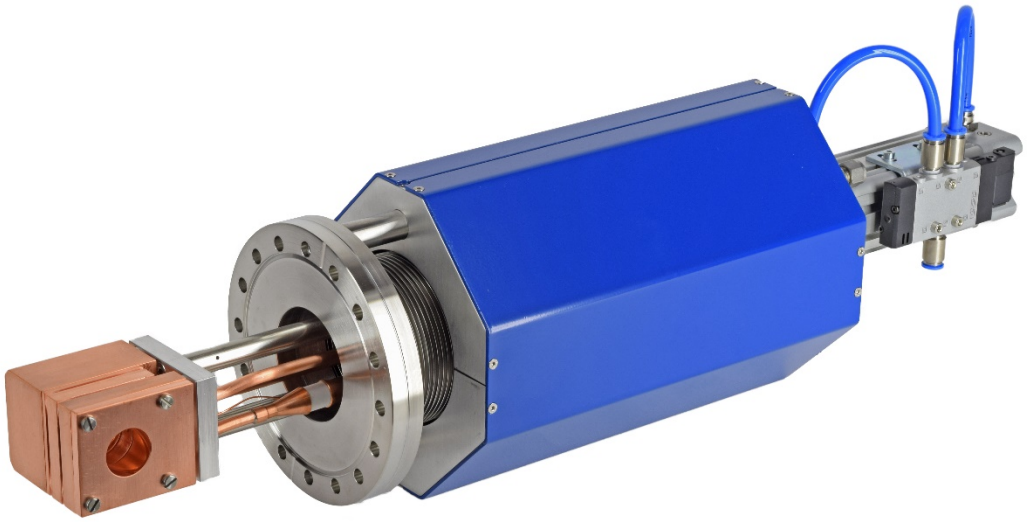
VERSION 2.0

USER MANUAL

FARADAY CUP
FC-25.1K



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D-Pace

ABOUT D-PACE

D-Pace supplies products and services to the international commercial accelerator industry. Our areas of expertise include beamline systems, beam diagnostic devices, and ion sources for research, industrial, and commercial accelerator systems.

We provide:

- Precision accelerator equipment – accelerator sub-systems, industrial beamline systems, or individual components such as magnets, vacuum chambers, beam diagnostic devices, and electrostatic devices.
- High performance, filament powered and RF powered, reliable DC volume-cusp negative ion sources: H^- / D^- / C_2^- . Ion sources are licensed from and backed with TRIUMF & University of Jyväskylä support
- Professional ion-optical modeling, engineering, mechanical design, drafting and documentation services – industrial beamline systems and components.

Our knowledgeable design staff are well-versed in the special details associated with designing accelerator-related equipment. D-Pace works with experts worldwide to meet our customer's needs, and is committed to innovation, quality and customer satisfaction.

We take pride in offering our customers:

- High quality, thorough work.
- Confidentiality, integrity, and professionalism.
- Individual tailoring based on customer values and requirements.
- Flexibility, including onsite work.

D-Pace is located in beautiful Nelson, British Columbia, Canada.

REVISIONS

V1.0	2017-DEC-12	DP/PJ	First release
V2.0	2019-JAN-14	TS/GM	Fonts corrected. "About D-Pace" updated. Air Connections/ Cooling Water Connections spec updated. Cooling Water Inlet Pressure spec removed. Pressure Drop spec added. Figure 5: Position limit switch wiring diagram title added. Figure 6: Faraday cup signal wiring options added. Table 4: Instrumentation load resistor modules added. Figure 2: FC-25.1K dimension updated and Cushioning Adjustment Screw added. Figure 8: Faraday cup head inserted/retracted. added.

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FIGURES

TABLES

1 INTRODUCTION

The D-Pace FC-25.1k, Faraday Cup is a compact Faraday cup with an insertable, water-cooled head. When inserted, the beam is intercepted by the back cup, from which beam current is measured. Beam current can also be measured on the front plate, referred to as the “collimator”, to determine if beam is spilled outside of the cup. An intermediate electrode plate, referred to as the “bias ring”, between the front plate and back cup, is held at an electrical potential, providing suppression of electrons attempting to travel out of the cup. A pneumatic cylinder moves the cup head into the beam path during operation. The back cup and collimator are water-cooled. All three main elements of the head are made of copper.

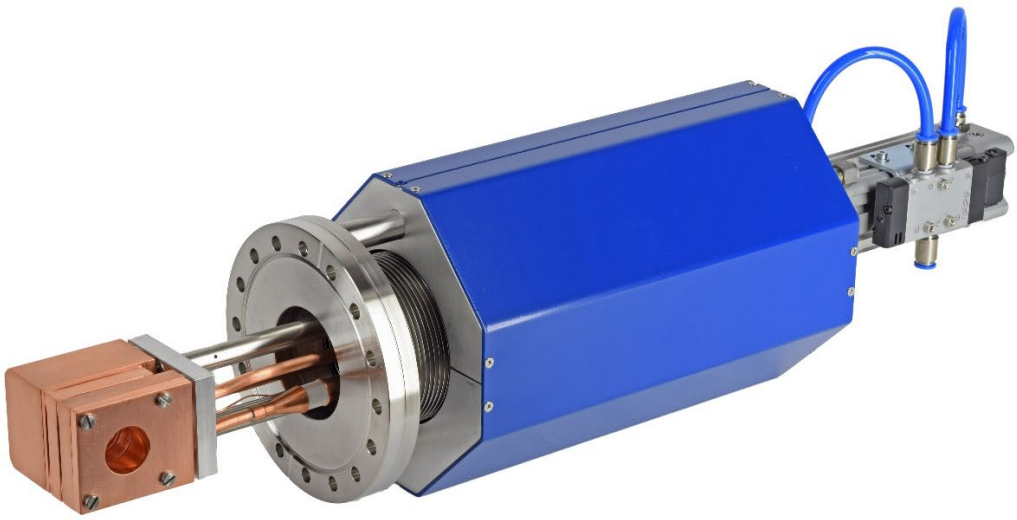


Figure 1: Isometric view of FC-25.1K Faraday Cup.

The FC-25.1K Faraday Cup is designed for measuring beam currents in the nA to mA range, of charged particle beams with energies less than 1 MeV. A maximum beam power of 1kW, and power density of 500 W/cm², can be used with the Faraday cup. The system is design to operate within high-vacuum range, down to 1×10^{-7} Pa.

Beam-intercepting components are made from copper. A high-energy version which utilizes graphite beam-intercepting components is available.

2 SAFETY

The user should be familiar with the basic operating principles of a Faraday cup prior to operating the FC-25.1K Faraday Cup. The user must be familiar with making sensitive measurements, and understand methods to mitigate electrically noisy environments through grounding techniques, wire routing, and shielding. The user must also be familiar with high voltage safety, and high-vacuum cleanliness.

2.1 WARNING SYMBOLS

The system utilizes the following warning symbols on the device and within this manual. To avoid injury or death, the warnings and accompanying descriptions shown below must be observed.

WARNING – RISK OF ELECTRICAL SHOCK

WARNING – RISK OF HAND INJURY / PINCH POINT

WARNING – RISK OF DANGER – REFER TO MANUAL

2.2 BEAM VOLTAGE

The Faraday cup is a beam-intercepting device. Probes, cables, and current meters can reach high voltages when a beam strikes a beam diagnostic device, such as the Faraday cup. Grounding is performed through the mounting flange of the Faraday cup.

WARNING	Do not operate the Faraday cup without all cables connected to their current meters. High voltages will develop which can cause injury or death, and damage sensitive components within the device.

WARNING Never touch, connect, or disconnect cables from the Faraday cup or their current meters when the beam is on.

WARNING Do not operate the Faraday cup without all covers in place. Unprotected, high-voltage components are exposed when covers are removed.

2.3 BIAS VOLTAGE

The Faraday cup is designed to be used with a high-voltage power supply for the bias electrode, which provides electron-suppression. The Faraday cup and attached cables can reach dangerous electrical potentials when the Faraday cup is operated. This Faraday cup is designed to operate with a maximum bias voltage of ± 500 V.

WARNING Do not operate the Faraday cup without all covers in place. Unprotected, high-voltage components are exposed when covers are removed.

WARNING Do not touch the Faraday cup while the beam is on, or while bias voltage is supplied to the Faraday cup. Ensure all cables have been removed, prior to handling.

2.4 MECHANICAL HAZARDS

The Faraday cup has internal moving parts which, if exposed, can cause serious injury to the user.

WARNING Do not operate the Faraday cup without all covers in place. Unprotected, high-voltage components are exposed when covers are removed.

WARNING Do not operate the Faraday cup without all covers in place. Without these covers dangerous pinch-points are exposed, which can seriously harm the user.

3 DESCRIPTION

3.1 SPECIFICATIONS

Max. Beam Power	1000 W
Max. Beam Power Density	500 W/cm^2
Max. Particle Energy	1 MeV (copper beam-interception components)
Collimator I.D.	Ø25 mm
Collimator	55 mm × 65 mm
Flange	6" CF (DN100 CF)
Max Travel	79 mm
Actuation Operation	24 VDC, 1.3 W solenoid with 10 meter flying leads.
Air Connection	6 mm O.D. tube push fitting
Air Supply Pressure	340 kPa (50 psi) ⩾ Pressure ⩾ 760 kPa (110 psi)
Air Quality	Compressed air per ISO8573-1:2010 [7:4:4]
Actuation Speed Adjustment	One-way flow control valves on exhaust air
Cooling Water Type	De-ionized, resistance > 1 MΩ·cm
Cooling Water Flow	⩾ 1 L/min (600W beam) ⩾ 1.5 L/min (1 kW beam)
Cooling Water Pressure Drop	85 psi @ 3L/min (3 kW) 65 psi @ 2.5 L/min (2.5 kW) 45 psi @ 2L/min (2 kW) 24 psi @ 1.5L/min (1.5 kW) 15 psi @ 1L/min (1 kW)
Cooling Water Inlet Temp.	< 20 °C
Cooling Water Connections	½", 12.7mm O.D. tube fittings
Faraday Cup Signal Connector	Isolated BNC, female
Collimator Signal Connector	Isolated BNC, female
Bias Ring Connector	Grounded MHV, female

Max. Bias Ring Potential	± 500 V
Position Limit Switches	2 switches: (1) Inserted, (1) Retracted
Position Limit Switch Type	N.O. Reed Switch, 2-wire, 5-30 V, 80 mA max. Provided with 1 meter long flying leads.
Device Size Outside Vacuum	176 mm Wide × 154 mm Long × 518 mm Tall
Insertion Length	Customer-specific

Table 1: FC-25.1K specifications.

3.2 DIMENSIONS

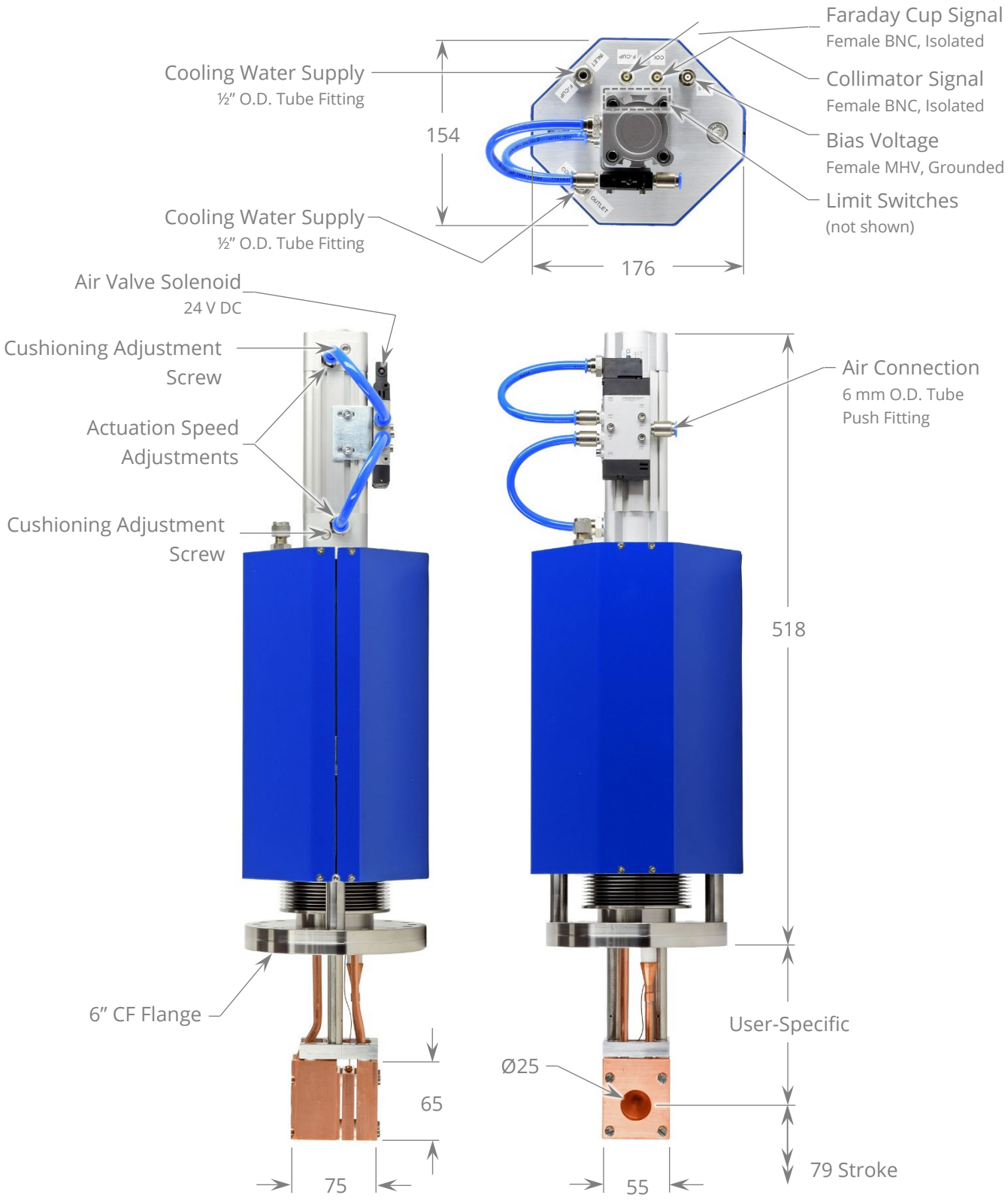


Figure 2: FC-25.1K dimensions.

4 INSTALLATION

4.1 UNPACKING AND INSPECTION

Before unpacking the FC-25.1K Faraday Cup, inspect the packaging for any damage that may have occurred during shipping. If damage is present, document the damage, and immediately notify the responsible transport service and D-Pace. If no damage is present, carefully unpack the Faraday cup and inspect the device for damage. Again, if damage of the device is present, immediately notify the responsible transport service and D-Pace.

4.2 INSTALLATION

The FC-25.1K Faraday Cup has been inspected and tested prior to packaging, and is ready for installation. The installer should be familiar with making sensitive measurements and understand methods to mitigate electrically noisy environments through grounding techniques, wire routing, and shielding. The installer should also be familiar with working with high-voltages, and working with items to be used in high-vacuum environments.

The FC-25.1K Faraday Cup may be installed in any position, including horizontally or vertically. When installing, orient the Faraday cup so that the cup opening is facing upstream, into the oncoming beam.

The vacuum flange of the Faraday cup is the only mechanical connection. This flange is a 6" CF flange, and will require the following items (not included with FC-25.1K) to mount to the user's vacuum chamber:

- Qty = 1 — 6" CF flange copper gasket.
- Qty = 16 — Flange connection hardware, as required by the user's vacuum chamber. (Typically this is a set of 5/16-24 bolts or M8 bolts, with washers and nuts)

Once the Faraday cup is securely attached to the user's vacuum chamber, the remaining cooling water, electrical, and pneumatic connections can be made.

4.3 WATER CONNECTIONS

Cooling water is required for beam powers greater than 1 W. This cooling is required to remove heat deposited in the Faraday cup head, and prevent damage to the cup.

Connect ½" O.D. tubing to the water inlet and outlet connectors on the Faraday cup. Either metal or plastic tubing may be used.

D-Pace recommends the use of water flow and temperature interlocks, in the user's control system, to avoid accidental damage of the Faraday cup. If the water flow is less than 1 L/min or the return water temperature exceeds 50 °C, the Faraday cup head should be retracted from the beam, and the beam should be shut off.

Figure 3 shows the two cooling water connections. A single cooling water circuit flows through the back cup and collimator. Table 2 lists the connection type, and input water cooling requirements for the FC-25.1K Faraday Cup.

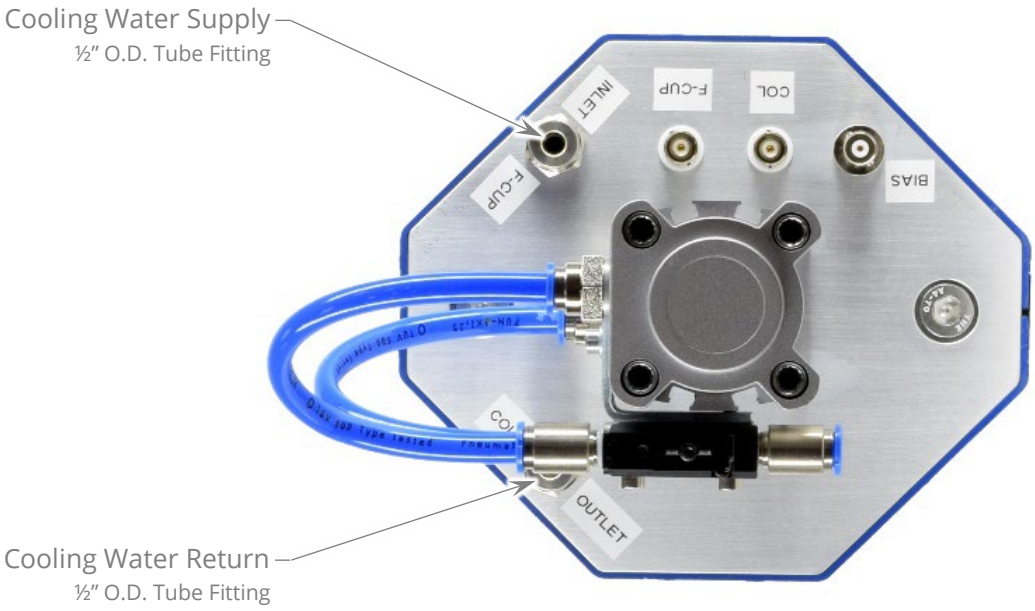


Figure 3: Water connections.

Cooling Water Connections	½" O.D. tube fittings
Cooling Water Type	De-ionized, resistance > 1 MΩ·cm
Cooling Water Flow	⩾ 1 L/min (600W beam) ⩾ 1.5 L/min (1000W beam)
Cooling Water Pressure Drop	85 psi @ 3L/min (3 kW) 65 psi @ 2.5 L/min (2.5 kW) 45 psi @ 2L/min (2 kW) 24 psi @ 1.5L/min (1.5 kW) 15 psi @ 1L/min (1 kW)

Table 2: Water connection and input requirements.

4.4 ELECTRICAL CONNECTIONS

The FC-25.1K Faraday Cup has six (6) electrical connections: two (2) beam signal connections, one (1) bias voltage connection, and one (1) solenoid valve connection, and two (2) limit switch connections. These connections are shown in Figure 4. Table 3 lists the electrical connection types.

To minimize electrical noise induced on the Faraday cup signal wires, route the signal wires at least 50 cm away from other cables.

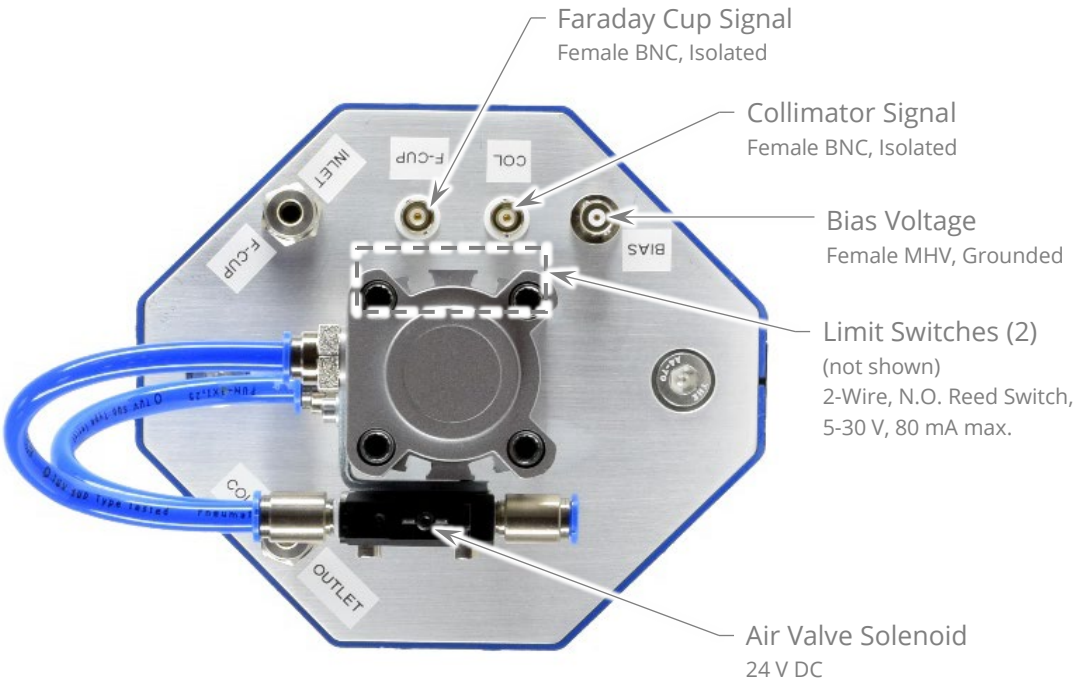


Figure 4: Electrical connections.

Faraday Cup Signal Connector	Isolated BNC, female
Collimator Signal Connector	Isolated BNC, female
Bias Ring Connector	Grounded MHV, female
Max. Bias Ring Potential	± 500 V
Air Valve Solenoid	24 V DC
Position Limit Switches	2 switches: (1) Inserted, (1) Retracted
Position Limit Switch Type	N.O. Reed Switch, 2-wire, 5-30 V, 80 mA max. Provided with 2.5 m long flying leads.

Table 3: Electrical connections.

The connection diagram for the two position limit switches is shown below.

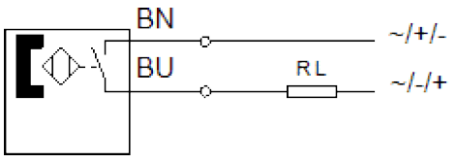


Figure 5: Position limit switch wiring diagram.

Depending on the Faraday Cup option purchased, the cup and collimator signals may be wired in one of three configurations shown in Figure 6.

Option A: Straight-Through-Connection Option (Figure 6a)

With this option, the collimator and cup are internally wired directly to their respective BNC connectors. This option is typically selected for customers who will provide their own load resistor or current meter. This is the recommended option for low beam currents (<20µA). **It is strongly recommended to install a spark gap or voltage clamping diode across the output for both safety reasons, and to protect customer's instrumentation.**

Option B: External-Instrumentation-Resistor Option (Figure 6b)

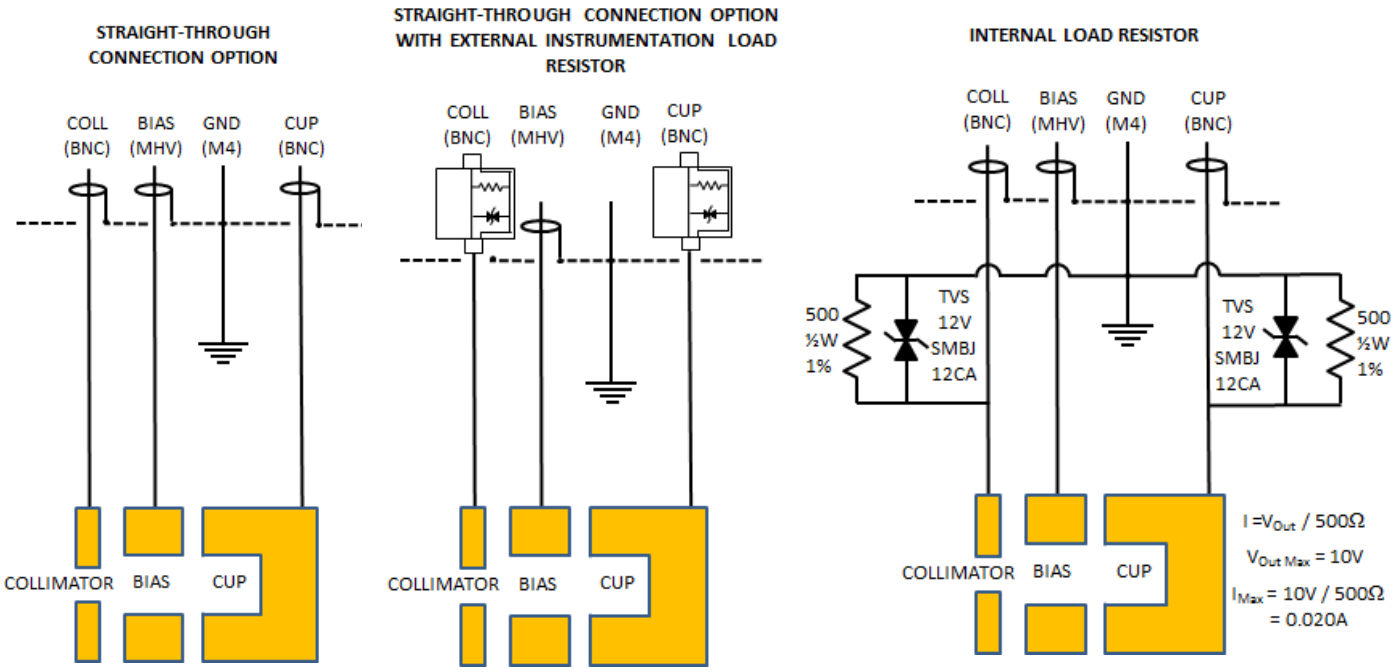
With this option, the collimator and cup are internally wired directly to their respective BNC connectors as in Option A, but two external instrumentation load resistor modules (example, Model# ACC100) are provided. These modules contain a current shunting resistor which connects the beam current signal to ground through a load resistor. The output from this module is a voltage proportional to the beam current. Model# ACC100 has a 500±1 Ohm resistor, which results in a ±10V output with ±20mA input. Other resistor values are available (see Table 4). A transient voltage suppressor (TVS) diode is connected in series with the instrumentation resistor. The TVS diode clamps the output voltage to < 15V. The instrumentation load resistor module has a male BNC input connector and a female BNC output connector. This option is typically selected where the beam current to be measured is relatively high (> 20µA) and it is possible that alternate load resistor values may be required. Refer to Appendix for Procedure 2020054: Load Resistor Connection for Faraday Cups, and specification sheet.

Instrumentation Resistor Model	Shunt Resistor (Ohms ± 1%)	Clamping Voltage (V)	Max I_{in} (V_{out}= 10V)
ACC 100	500	15	20mA
ACC 101	5K	15	2mA
ACC102	50K	15	200µA
ACC103	500K	15	20µA

Table 4: Instrumentation load resistor modules.

Option C: External-Instrumentation-Resistor Option (Figure 6c)

With this option, the same instrumentation load resistor and TVS diode described for Option B is permanently installed within the Faraday cup. This option is typically selected where the beam current to be measured is relatively high (> 100µA) and it is unlikely that a change in the load resistor value is likely. The internal load resistors also provide minor space savings over the external load resistor option.



a: Straight through connection option.

b: External instrumentation load resistor option.

c: Internal load resistor option

Figure 6: Faraday cup signal wiring options.

4.5 AIR CONNECTION

The actuation of the FC-25.1K Faraday Cup is achieved by a pneumatic cylinder, operated by a solenoid valve. A single air connection is located on the solenoid valve, shown in 7. Table lists the air connection size and type, and lists the required air quality.

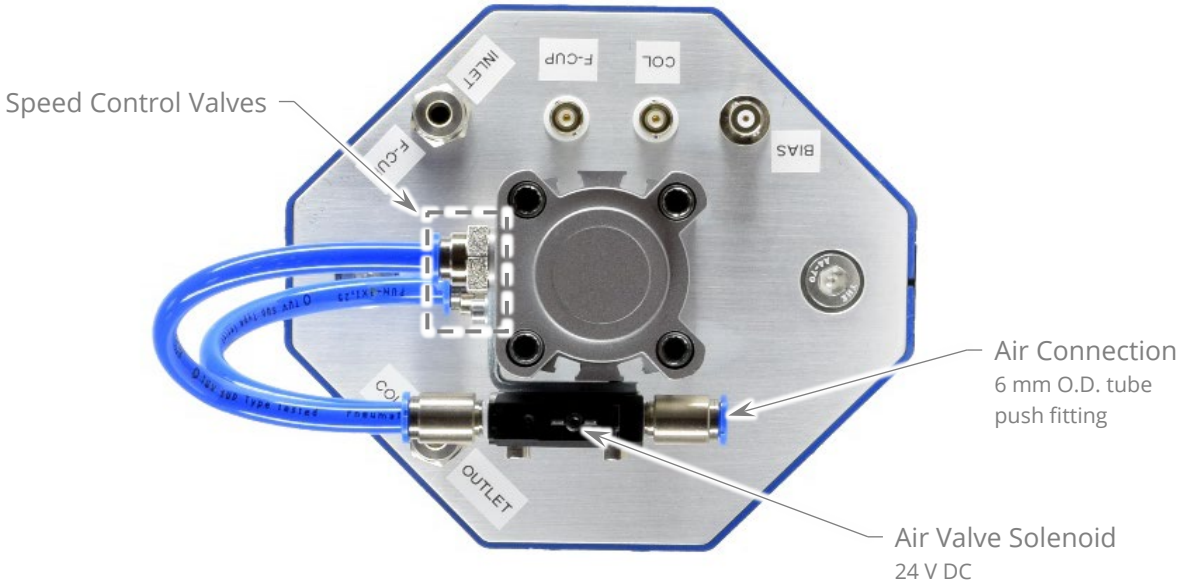
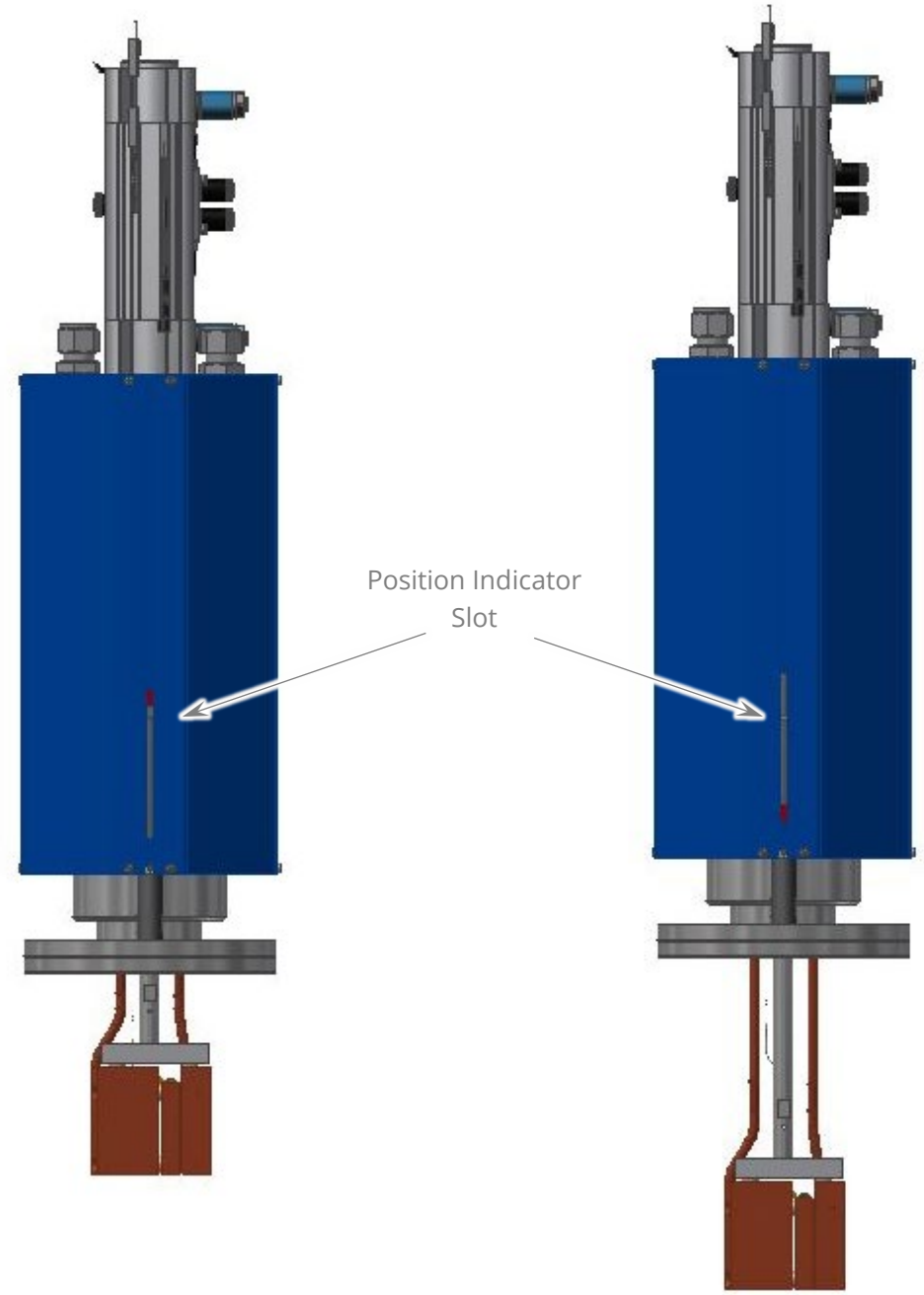


Figure 7: Air connection and speed control valves.

Air Connection Port	6 mm O.D. tube push fitting
Air Supply Pressure	340 kPa (50 psi) ⩾ Pressure ⩾ 760 kPa (110 psi)
Air Quality	Compressed air per ISO8573-1:2010 [7:4:4]
Actuation Speed Adjustment	One-way flow control valves on exhaust air

Table 5: Air connection and air quality requirements.

The cylinder has adjustable pneumatic cushioning that absorbs energy in the end positions by building up and exhausting an air cushion. The cushioning can be manually adjusted with screws labeled in Figure 2. If the Faraday cup head does not reach the stroke end positions, the adjustment screw must be slightly opened, but tight enough to ensure that the piston does not strike hard against the end positions. Figure 8 shows the position indicator slot to be used as a reference to ensure proper head position.



a: Faraday cup head retracted.

b: Faraday cup head inserted.

Figure 8: Faraday cup head inserted/retracted.

5 OPERATION

The FC-25.1K Faraday Cup is operated by providing a 24 VDC signal to the solenoid valve. This triggers the pneumatic cylinder to extend the Faraday cup head. The Faraday cup may also be operated manually, by pressing the manual override button on the solenoid valve. This method may be used when checking the Faraday cup operation prior to installation.

The speed of the Faraday cup's insertion and retraction can be adjusted with two speed control valves, shown in Figure . These valves control the flow of air being exhausted from the pneumatic cylinder.

5.1 FAIL STATES

The following table describes the position the Faraday cup will assume under various electrical or pneumatic failures.

Failure	Failure State
Loss of pneumatic supply air pressure.	If the Faraday cup is under vacuum, it will insert. If the Faraday cup is not under vacuum, it will remain in the same position when the failure occurred.
Loss of electrical control signal to actuate the Faraday (in either position).	The Faraday cup will retract.
Loss of both electrical control signal, and pneumatic air supply pressure.	Failure state will be the same as the case of loss of only pneumatic air supply pressure.

Table 6: Failure states.

5.2 TROUBLESHOOTING SIGNAL NOISE ISSUES

The following steps can be taken if background noise levels are excessive:

1. Re-route the signal cables away from noise-inducing cables.
2. Ensure the vacuum chamber to which the Faraday cup is mounted is properly grounded.
3. Isolate signal cables from sources of vibration and movement. Cable movement will cause triboelectric current noise.
4. Ensure signal cable connectors are kept clean and dry. Contaminants and moisture can cause leakage currents.

6 SERVICE & MAINTENANCE

The FC-25.1K Faraday Cup contains a number of plastic parts, which will degrade if the Faraday cup is exposed to prolonged radiation. The rate of degradation, and thus frequency of replacement, of these parts is dependent on the amount of radiation.

6.1 INSPECTION SCHEDULE

The following is a recommended maintenance schedule:

Procedure	Frequency
Inspect cooling water system	Daily during use
Monitor cooling water flow	Daily during use and/or Interlock
Monitor cooling water conductivity	Daily during use and/or Interlock
Inspect water tubing	Monthly during use

Table 7: Inspection schedule.

6.2 MAINTENANCE SCHEDULE

Procedure	Frequency
Replace water tubing inside Faraday cup	Every 5 years, or more frequently if exposed to radiation

Table 8: Maintenance schedule.

6.3 CONSUMABLES

The following is a recommended list of spare parts to have on-hand:

Item	Quantity
Flexible tubing coil, polyurethane, 1/2" O.D. × 0.045" wall tube, 1-1/2" O.D. × 7" long coil (Example: part number: 9148T125, supplier: McMaster-Carr)	2

Table 9: Consumables.

APPENDIX

Contents:

- D-Pace Drawing: Faraday Cup Assembly
- Certificate of Conformance
- Procedure 2020054: Load Resistor Connection for Faraday Cups
- Specification Sheet 2120057: FC-25.1K Faraday Cup
- D-Pace Products & Services List

DRAWING: FARADAY CUP ASSEMBLY

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Sheet 1 of 1

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Sheet 2 of 3

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Sheet 3 of 3

CERTIFICATE OF CONFORMANCE

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PROCEDURE 2020054: LOAD RESISTOR CONNECTION FOR FARADAY CUPS

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SPECIFICATION SHEET 2120057: FC-25.1K FARADAY CUP

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D-PACE PRODUCTS & SERVICES LIST

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