DCA INSTRUMENTS

User Manual

Metal Organic Precursor Injector (MOPI)

Including Motor Control Unit (MCU-VA)

MODEL: MOPI-4-Single, MOPI-4-Dual, MOPI-12

These are the original English instructions

CE

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DISCLAIMER

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The information provided in this documentation contains general descriptions and/or technical characteristics of the performance of the Component contained herein. This documentation is not intended as a substitute for and is not to be used for determining suitability or reliability of these components for specific user applications. It is the duty of any such user or integrator to perform the appropriate and complete risk analysis, evaluation, and testing of the Components with respect to the relevant specific application or use thereof. Neither DCA Instruments Oy nor any of its affiliates or subsidiaries shall be responsible or liable for misuse of the information that is contained herein. If you have any suggestions for improvements or amendments or have found errors in this publication, please notify us.

All pertinent state, regional, and local safety regulations must be observed when installing and using this Component. For reasons of safety and to help ensure compliance with documented system data, only the manufacturer shall perform repairs to components.

When devices are used for applications with technical safety requirements, the relevant instructions must be followed.

Failure to observe this information can result in injury or equipment damage.

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Component Modifications

Year	Type	Modifications
2024	MOPI-12-01	
2024	MOPI-4-01 (single)	
2024	MOPI-4-02 (dual)	

Document Revisions

Date	Version Number	Document Changes
14-02-2024	1.0	First issue
19-02-2024	1.01	Text revisions

Table of Contents

1 PREFACE

1.1 Purpose of These Instructions

Thank you for purchasing this Metal Organic Precursor Injector (MOPI). The purpose of this document is to make you familiar with the features and functions of the MOPI, so that you can safely operate it as an end-user.

This documentation should therefore be regarded as an integral part of the MOPI. These instructions are intended for the following product models:

- Metal organic precursor injector – for large substrates (> 4”) MOPI-12-01
- Metal organic single-precursor injector – for small substrates (≤ 4”) MOPI-4-01 (a.k.a MOPI-4-single)
- Metal organic dual-precursor injector – for small substrates (≤ 4”) with two precursors MOPI-4-02 (a.k.a MOPI-4-dual)

1.2 Using this manual

To make best use of this manual:

- **Read the entire manual first.** Do not attempt to operate or perform maintenance of any kind on the product before you have thoroughly reviewed this manual.
- **Pay close attention to all safety information!** All MBE applications include inherent hazards and require strict adherence to safety standards. Read *Operator Safety* in this preface for critical safety information. Also see *Safety Hazards* in this preface to learn how safety hazards are indicated in this manual.
- **Use this manual as a tool for putting your own knowledge into practice.** This manual does not cover the theory, principles, or best practices for any particular MBE application. It aims to provide useful information to help you achieve your own objectives.
- **Remember that many DCA products are configurable.** It is not possible to address all aspects of all configurations in a single manual. If you are not finding the information you need, please consult *Additional Resources* in this preface, or contact us using the *Technical Support* information.
- **Refer to all graphics in context.** The graphics in this manual may not exactly match your product. Graphics are intended to illustrate only the features relevant to the topic at hand. Any optional, configurable, or missing features are identified, if contextually relevant.

1.3 Explanation of Safety Warnings

⚠DANGER

Indicate a hazardous situation which, if not avoided, will result in death or serious injury.

⚠WARNING

Indicates a hazardous situation which, if not avoided, could result in death or serious injury, and/or may result in significant system damage.

⚠CAUTION

Indicates a hazardous situation which, if not avoided, could result in minor or moderate injury, and/or minor system damage.

NOTICE

Indicates information considered important, but not hazard related.

1.4 Intended User

This manual is intended for trained UHV-process professionals, technicians, and persons under the direct guidance of such individuals. If you are not among these groups, please do not attempt to use the information in this manual to operate the equipment.

Read and understand this manual and its safety instructions before using this product. Failure to do so can result in serious injury or component/system damaged.

The manufacturer is not liable for cases of material damage or personal injury caused by incorrect handling or non-compliance with the safety instructions. In such cases, the warranty will be voided.

1.5 Obtaining Documentation and Information

1.5.1 Additional Resources

In addition to these user instructions, the following related documentation should be consulted:

- 01_XXXX_UHV deposition system_DCA User Manual (if applicable)
- 02_UHV System Bakeout_DCA User Guide (if applicable)
- 03_DCA Control Software Manual (if applicable)
- 04_General User Interface DCA User Manual (if applicable)
- Julabo Magio MS-BC4 Heating Circulator Operating manual
- Turbo molecular pump manual (e.g. Pfeiffer HiPace)
- Eurotherm 3500 Series User Manual
- TDK power supplies
- Baratron Capacitance manometer

1.5.2 List of Component Manuals Ordering Documentation

Documentation, user instructions and technical information can be requested by contacting DCA Instruments Oy at info@dca.fi.

1.5.3 Other languages

This is the English user manual. Manuals in other languages are available upon request.

1.5.4 Documentation Feedback

If you are reading DCA Instruments Oy product documentation on the internet, any comments can be submitted on the support website. Comments can also be sent to info@dca.fi.

We appreciate your comments.

1.5.5 Technical Support and Service

For other service-related questions, information, technical assistance, or ordering user instructions, please contact the manufacturer:

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2 CRITICAL INFORMATION

This chapter provides important safety information, product cautions and a summary of important notes about your DCA component.

2.1 Safety Precautions

Carefully study this user guide and any related documentation listed in 1.5.1. Only properly trained personnel should operate or maintain the product.

2.1.1 Personal protective Equipment

The MOPI should be handled per general UHV practices. Powder-free protective gloves should be used to avoid contamination.

2.1.2 Installation safety information

Inspect the MOPI system for damage before installation. If there is any visible damage, do not install the MOPI and notify DCA within one week of receiving the product. Failure to notify DCA within this time period may affect the users right to claim for repairs or replacement under warranty.

2.1.3 Maintenance safety information

All cleaning and maintenance tasks shall only be carried out by qualified and skilled personnel. To ensure the optimal performance of the MOPI system, regular maintenance shall be carried out by qualified personnel in accordance with the manufacturer's instructions.

Maintenance and inspection should be done on a regular basis. If there is any visible damage, excessive overheating, or instability of the component, stop using it and consult the troubleshooting guide in this manual.

⚠WARNING

Modifications to the MOPI system are not permitted. Any alterations made to the MOPI system without written permission from the manufacturer will void the warranty. Unauthorized alterations may lead to hazardous situations.

See the Appendix for an overview of the spare parts. You can always order spare parts by contacting the manufacturer.

Only clean the component with a lint-free cleanroom compatible cloth and suitable solvent (e.g., ethanol or IPA).

The MOPI may feature safety marks in areas that pose a risk of injury or with other important instructions. Always replace missing or damaged safety marks immediately. If you replace safety marks with new ones, make sure that you place the new safety marks in the same places.

2.1.4 Repair and Modification Safety Information

⚠WARNING

DO NOT attempt to repair components without permission and explicit instructions from the manufacturer. Contact DCA Instruments if the system/component requires repair. Do not attempt to modify the system/components before consulting DCA Instruments.

2.1.5 Safe Disposal

Do not dispose of electric equipment, accessories, and packaging together with household waste material (only for EU countries). In observance of European Directive 2012/19/EC on waste of electric and electronic equipment and its implementation in accordance with national law, electric equipment that have reached the end of their life shall be collected separately and returned to an environmentally compatible recycling facility.

2.2 Graphical Symbols

2.2.1 Explanation of safety information on the system

Table 1 below provides safety information relevant for the MOPI. The labels are located as close as possible to the relevant area it is applicable to.

Table 1 Explanation of safety information relating to the system and the location of safety labels.

Symbol	Warning / Caution	Hazard Location
	**HIGH VOLTAGE** May cause electric shock or burn. Trained personnel only.	Electronic racks Motor Control Unit Power supplies Heating jacket cables
	**HOT SURFACE** Contact with skin may cause burns. Do not touch during heating.	Heating jackets
	**FLAMMABLE MATERIAL** Flammable gas. No smoking or open flames. **Refer to the relevant MSDS of the loaded material and follow all recommended safety precautions.** **Ensure the pump exhaust is connected to a suitable outlet to neutralise any potential hazard.**	MOPI Source Tank
	**TOXIC MATERIAL** Hazard: Poisoning Take care to avoid coming into contact with toxic material. **Refer to the relevant MSDS of the loaded material and follow all recommended safety precautions.** **Ensure the pump exhaust is connected to a suitable outlet to neutralise any potential hazard.**	MOPI Source Tank

2.2.2 Personal Protective Equipment

PPE	Instruction
	Wear UHV-compatible gloves when handling the component.
	Wear respiratory protection when opening the chamber with hazardous/toxic materials.

3 INTRODUCTION

3.1 Product Description – Metal Organic Precursor Injector

The MOPI system delivers uniform deposition of a metal organic precursor onto a heated substrate within a UHV process chamber, e.g., as part of a hybrid-molecular beam epitaxy (MBE) process. The precursor reacts with the heated substrate surface to deposit a metal as part of the epitaxial film, while the organic by-products are released and removed by the vacuum pumping system.

The MOPI system (Fig. 3-1) is comprised of:

- An injector – mounted to the process chamber.
- Gas manifold – connects the injector, source tank, and pump.
- Pressure sensor – provides pressure feedback of the gas manifold.
- Motorised metering valve – controls/regulates the pressure in the gas manifold.
- Pumping system – turbo molecular pump and scroll with exhaust line (to be connected to scrubber).
- Heating jackets – regulates the temperature of the gas manifold and source tank.
- Shut-off valves (pneumatic) – to the source tank (dual source only), pump, and injector.
- Gas safety cabinet (optional) - houses the source tank(s).

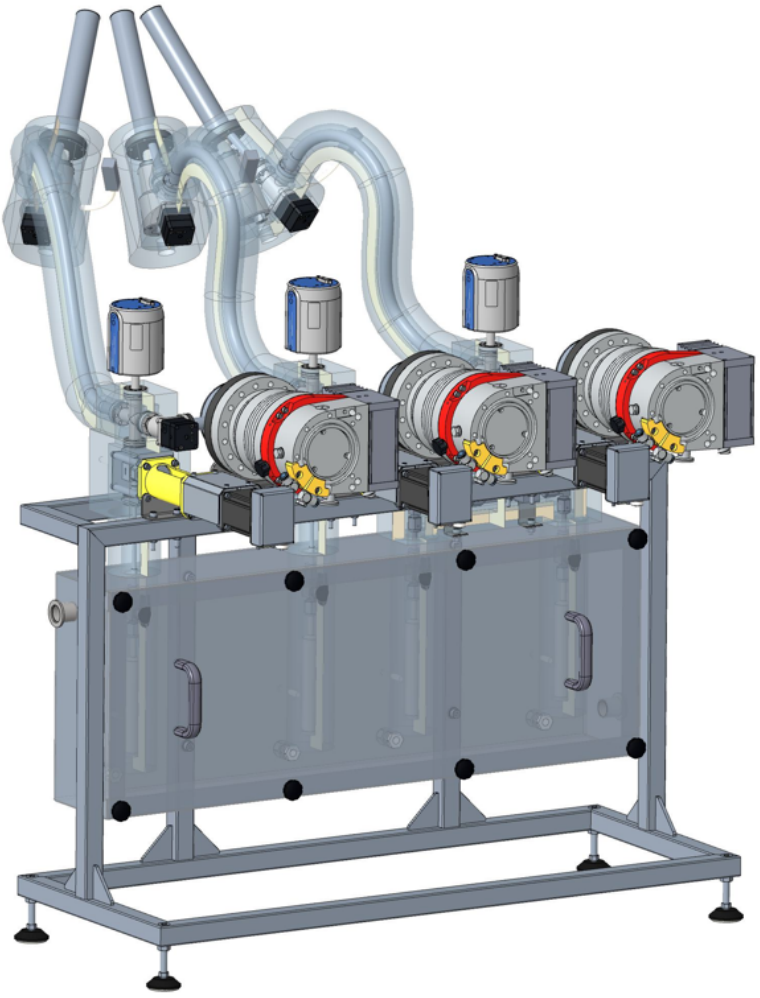


Fig. 3-1 MOPI system overview (with sthree separate injectors) and gas safety cabinet.

The MOPI flux is carefully regulated with pressure feedback control. A pressure sensor (Baratron/ capacitance manometer), motorised needle valve, and a Eurotherm PID controller are used to ensure the flux remains stable

throughout the deposition process. The precursor temperature determines the vapour pressure in the source tank. The temperature is regulated by the Eurotherm PID controller (ET), a heating jacket that surrounds the source tank (Tank-J), a K-type TC, and a solid-state relay. The heating jacket (Tank-J) temperature may be set from the ET or using the DCA Control Software.

The gas manifold must be maintained within a suitable temperature range; too low temperature will condense the precursor and will result in unstable flux; too high temperature will crack the precursor into its by-products that may clog the metering valve and/or lead to defects. The optimal temperature range of the manifold is dependent on the precursor material. A stable temperature of the gas manifold is achieved using a second heating jacket (Manifold-J), K-type TC, solid-state relay. The temperature regulation of this heating jacket is performed by a second Eurotherm PID controller (Fig. 5-4).

3.1.1 MOPI-4

The MOPI-4 injector features an internal heating element. The injector temperature is controlled by the ET, TDK power supply, and K-type TC.

3.1.2 MOPI-12

The MOPI-12 injector features a cone section that is connected to a thermal bath; this ensures the temperature remains within the preset limits. This feature is required for larger process chambers, where manipulator radiation could heat the cone above the limit, causing precursor cracking. the MOPI flux. The cone section is connected to a close-loop thermal bath thermostat with supply and return lines. The temperature of the thermal bath is regulated by the internal thermostat PID controller.

Additionally, the MOPI-12 injector shares the second heating jacket, Manifold-J2 (i.e. it extends to surround the injector).

3.1.3 MOPI System Materials

The MOPI source is compatible with a number of precursors (consult DCA for others not listed here):

- Titanium isopropoxide / titanium tetraisopropoxide (TTIP)
- Vanadyl isopropoxide / Vanadium(V) trisisopropoxide oxide (VTIP)
- Hafnium Tetrabutoxide (HTB)
- Zirconium Tetrabutoxide (ZTB)

⚠CAUTION

It is the user's responsibility to check the Material Safety Data Sheet of the precursor and ensure the necessary handling and safety precautions are observed and implemented during loading, operation, and disposal.

3.2 MOPI-12 System Standard Features

The schematic below (Fig. 3-2) identifies the source features.

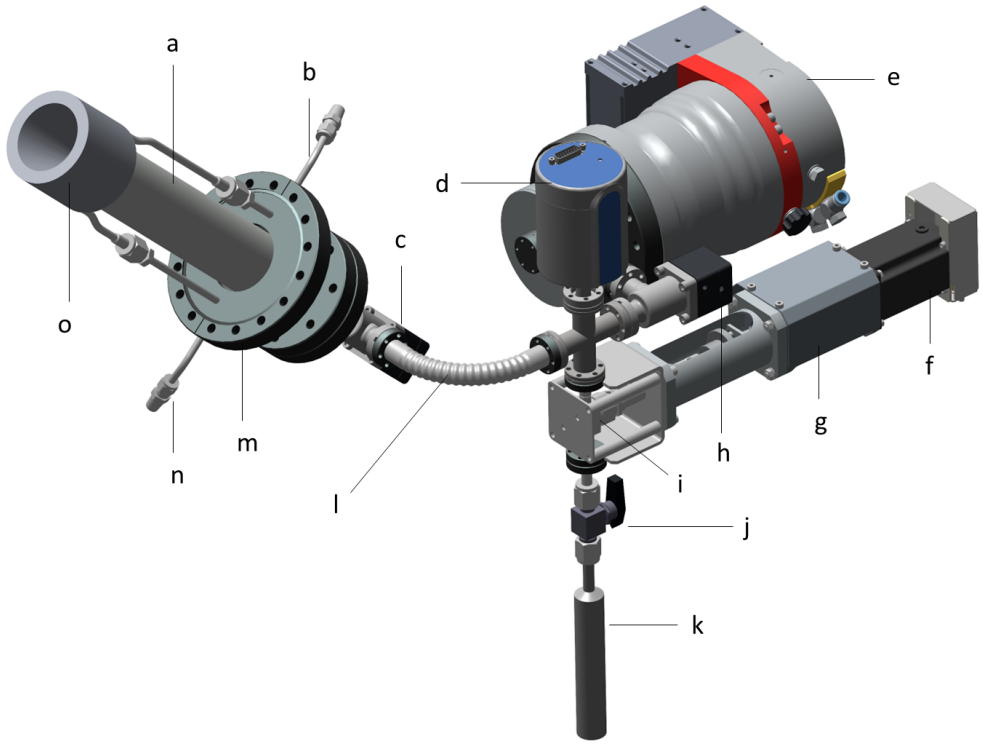


Fig. 3-2 Schematic of the Metal Organic Precursor Injector System (MOPI-12 injector) with part descriptions given in Table 2.

Table 2 Description of the MOPI system shown in Fig. 3-2.

Part	Description
a	Injector (with heating jacket)
b	Outlet for cone section (Swagelok® 6 mm)
c	DN16CF electro-pneumatic right-angle valve (Run)
d	Capacitance manometer/Baratron (0.1 Torr, heatable to 80°C)
e	Turbo molecular pump (HiPace 300)
f	Valve stepper motor
g	Valve drive/gear, Torque limiter
h	DN16CF electro-pneumatic right-angle valve (Pump)
i	Metering valve
j	Manual supply valve (source ampule)
k	Source tank/ampule (with heating jacket)
l	DN16CF SS bellows to injector connected to pump manifold (with heating jacket)
m	Mounting flange (DN100CF)
n	Inlet for cone section (Swagelok® 6 mm)
o	Injector cone

3.3 MOPI-4 System Standard Features

The MOPI-4 system features are identical to the MOPI-12 parts c – l, described in Fig. 3-2 and Table 2 above. The MOPI-4 injector features are described separately in Fig. 3-3 and Table 3 below.

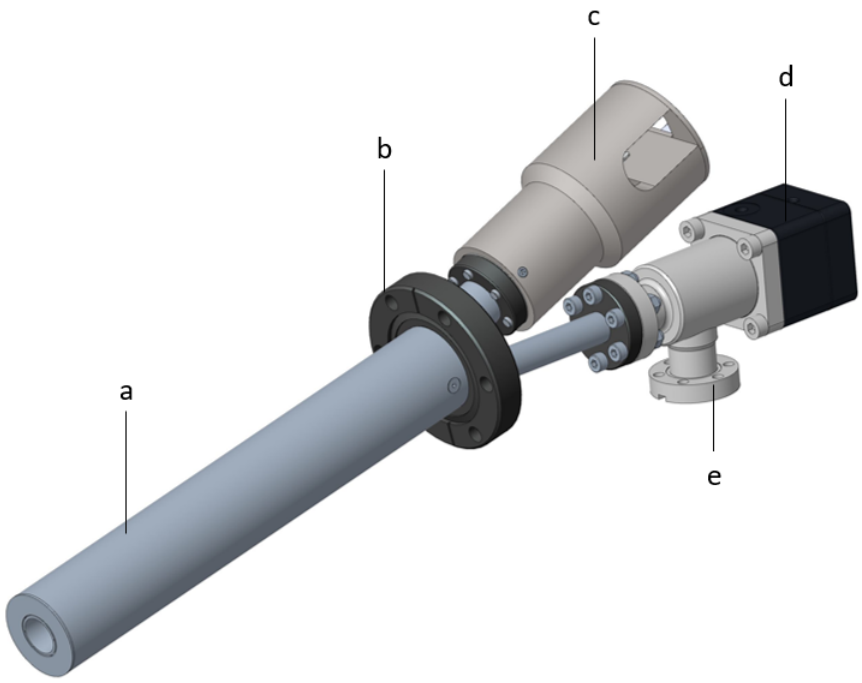


Fig. 3-3 Schematic of the MOPI-4 injector with part descriptions given in Table 3.

Table 3 Description of the MOPI-4 injector parts shown in Fig. 3-3.

Part	Description
a	Injector (with internal heating element)
b	DN38CF mounting flange
c	Power and TC connection
d	Pneumatic shut-off valve (Run/Process)
e	DN16CF port connection to MOPI gas manifold

3.4 MOPI System Accessories

The MOPI system should only be used with the original accessories supplied with the product. The accessories supplied are listed in Table 4 below.

Table 4 Summary of accessories included with the MOPI source and their intended use.

Accessory	Purpose	MOPI-4	MOPI-12
DC Power Supply	For injector heater	TDK GENH 60-12.5	N/A
Thermostat Thermal Bath	Temperature regulation of injector cone, sends temperature readback (analog signal) to ET3504.	N/A	Julabo Magio MS-BC4
Eurotherm PID Controller	Heating jacket temperature regulation (Tank-J, Manifold-J) Valve control (CM pressure feedback) Julabo thermostat SP (analog signal)	ET3508 (dual-loop) x 3	ET3508 (dual-loop) x1 ET3504 (3-loop) x1
Motor Control Unit	Receives input from ET and output control signal to the stepper motor. Includes a human-machine interface (HMI), communication interface, and digital interface. The IP address is labelled on the MCU rear panel.	MCU-VA-MOPI	MCU-VA-MOPI
Stepper motor	Connected to the metering valve.	DCA# 11464 M-2231-6.0ED 500	DCA# 11464 M-2231-6.0ED 500
Stepper motor cable	Connects stepper motor to MCU-VA	✓	✓
Needle/Metering valve	All-metal metering valve for pressure control, heatable to 200°C	✓	✓
Baratron capacitance manometer (CM)	Pressure feedback, up to 0.1 Torr, 0.001% resolution. Heated to 80 °C. Sensor cable is connected to ET	MKS Baratron	MKS Baratron
Right-angle valves (RAV) Electro-pneumatic	Controls precursor flow within the MOPI system (source, pump, run).	DN16CF x2 DN16CF x4 (dual source)	DN16CF x2
Heating jackets	Self-regulated with solid-state relay. The power supply turns off when temp. exceeds 120°C. K-type TC temp. feedback to ET.	Tank-J Manifold-J Tank2-J (dual source)	Tank-J Manifold-J
Turbo molecular pump (TMP)	Mounted to DN100CF flange. Additional pump accessories include: - OmniController	Pfeiffer HiPace300	Pfeiffer HiPace300

	- 10m connection cable - 10m interface cable - Power failure vent valve - Air-cooling fan - Protection screen		
Scroll pump	Connected to the TMP. It is recommended that the exhaust of the scroll is connected to a suitable scrubber for the source material.	Pfeiffer HiScroll 6 (or similar)	Pfeiffer HiScroll 6 / APC-15 (or similar)

The MOPI source shall not be operated outside of the scope set out in this user manual. Interlocks may be implemented to protect the component/system from error conditions that may occur, and these should be enabled during normal operation.

Only use the MOPI within the specified performance limits as described in these instructions.

3.5 MOPI - Specification

Table 5 Specifications of the Metal Organic Precursor Injector.

Feature	MOPI-12	MOPI-4-01/MOPI-4-02
Ampule Volume	See APPENDIX I – AMPULE DIMENSIONS	See APPENDIX I – AMPULE DIMENSIONS
Manifold Max. Temp	120 °C	120 °C
Tank Max. Temp	120 °C	120 °C
Thermocouple	Manifold jacket: K-type Tank jacket: K-type	Injector filament: K-type Manifold jacket: K-type Tank jacket: K-type
In-vacuum length	292 mm	192 mm
Mounting flange	DN100CF	DN40CF

3.6 Product Description – Motor Control Unit (MCU-VA)

The needle valve motion is motorized using a stepper motor (part f, Fig. 3-2) and may be controlled locally from the motor control unit, MCU-VA, (Fig. 3-4) mounted in the electronic rack or remotely from the desktop PC with the DCA Control Software provided.

The DCA motorized valve driver for the needle/metering valve is comprised of the following items:

- Stepper motor with differential position encoder
- MCU-VA with HMI, communication interface, digital interface, analog control interface
- Motor cable, sensor cable
- Mains MCU power cable
- Handheld control (possibly shared with other MCUs)
- Mounting hardware for the motor
- Optional for metering valves: Torque limiter

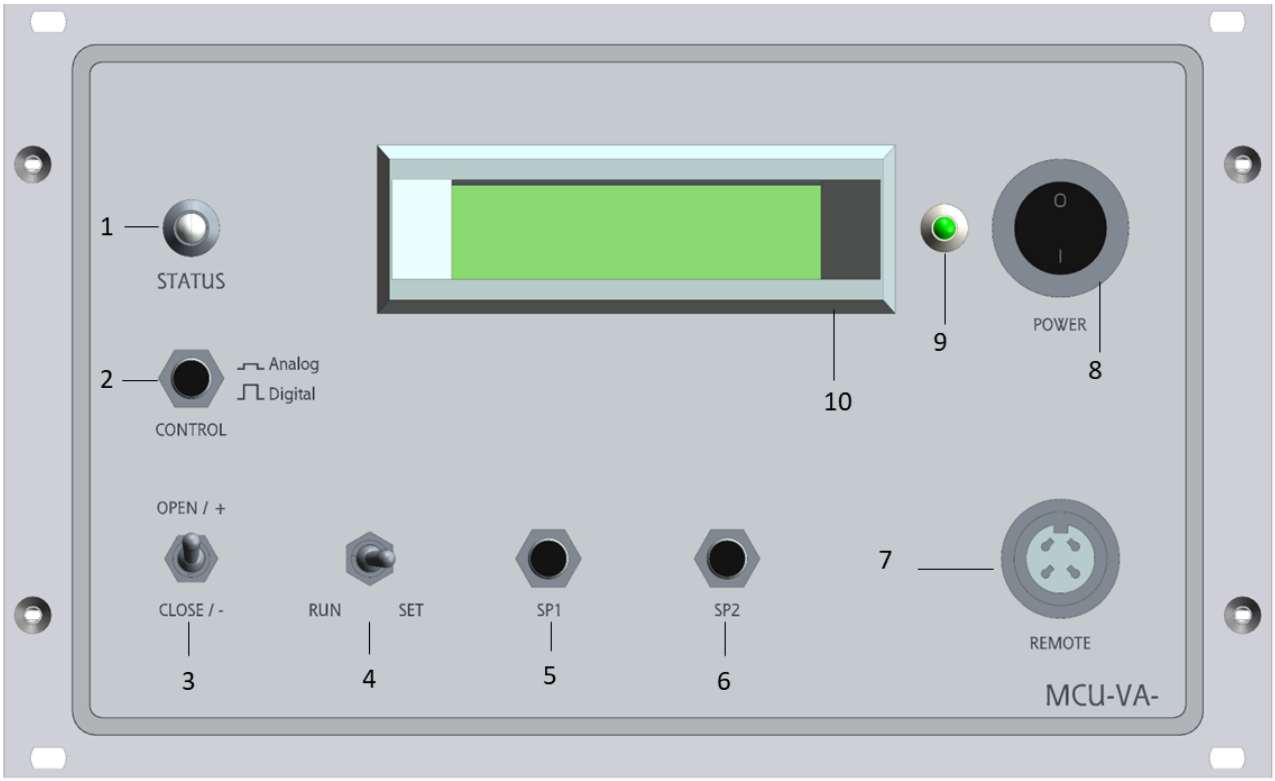


Fig. 3-4 MCU-VA Front panel: 1. Status LED, 2. Control mode selector Analog/Digital, 3. Jog toggle Open/Close, 4. Mode toggle Run/Set, 5. Setpoint 1 push button, 6. Setpoint 2 push button, 7. Socket for handheld control with jog toggle, 8. Main power switch, 9. Power LED, 10. Display.

The DCA motorized valve drive is specially made for needle and metering valves used on DCA valved sources. It comprises a stepper motor with an integrated differential position encoder for precise and reliable positioning and stall detection. A mechanical torque limiter (TL) is available for metering valve drives. The TL detects the valve's closed position based on a preset closing torque threshold and protects the valve mechanism from over-torquing. The motor control unit (MCU) allows the operation of the valve in either of the following ways:

a) Using the Human Machine Interface (HMI)
The valve can be virtually continuously adjusted by jogging the motor using the jog-toggle at the controller or handheld control. The MCU features two push buttons for fast positioning to two independently and freely define-able position set-points.

b) Using the Computer Interface (Ethernet), applicable equally with 1)
The valve can be adjusted to any position set-point given via a simple communication protocol.

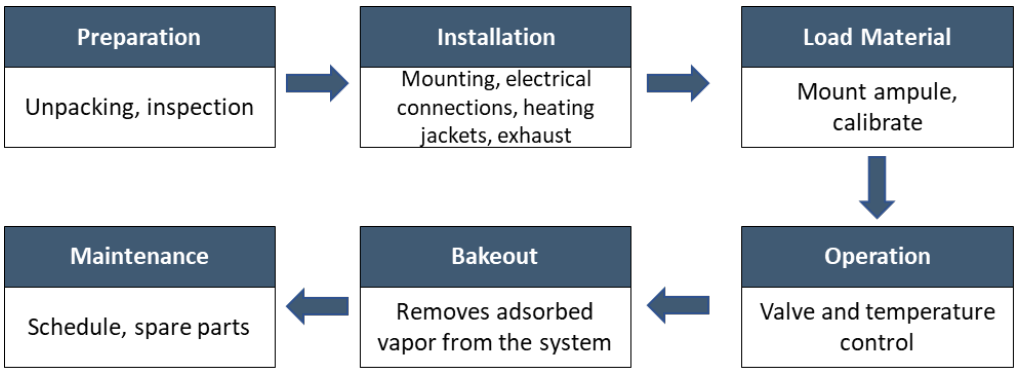
c) Using the analog control interface, applicable alternatively to a) and b)
The valve can be adjusted according to an analog control signal ranging 0…+5 VDC.

3.7 Motor Control Unit – Standard Features

The MCU-VA has the following standard features:

- Supports valve drives of DCA valved sources with stepper motors and differential encoders.
- User interface (HMI) for position-based valve control
  - Jog toggle for position adjustment.
  - Two programmable position set-points
  - Status indication, position read-out
  - Optional handheld remote control
- Digital interlock input
- Configurable: speed, backlash compensation, interlock response
- Input (0…5V) for analog position programming
- Ethernet interface for remote control

3.8 Operational Flow Chart



4 PREPARATION

4.1 How to Transport and Store the MOPI source

Ensure the source is removed from the chamber for transport. Solid protective cover must be placed over the in-vacuum regions of these components. This must be placed horizontally (i.e., supported by the mounting flange) within a suitable sized container. Sufficient padding should be used to secure the item in place.

4.1.1 Lifting, handling, and transporting the components

To lift the components safely:

1. Avoid touching the in-vacuum region of the component/system unless wearing clean-room compatible gloves.
2. When placing the component on a surface, ensure it is supported by the mounting flange/support frame that can withstand the weight and that it is stable (i.e., will not freely rotate or topple) without support.

To handle the system/components safely:

1. Consult individual component manuals before handling, mounting, or disassembling.
2. Do NOT disconnect cables from components before switching off the power.
3. Handle outer vacuum sections only using UHV cleanroom compatible gloves.
4. DO NOT handle in-vacuum parts that may be contaminated with material.

5 INSTALLATION

5.1 Mounting the Source

The following tools and accessories are required during this procedure:

- 1 x 13mm wrench
- 2 x 14mm wrenches
- Bolts and nuts according to the system design
- 1x DN100CF/ DN40CF silver-coated Cu gasket
- 5mm Allen key

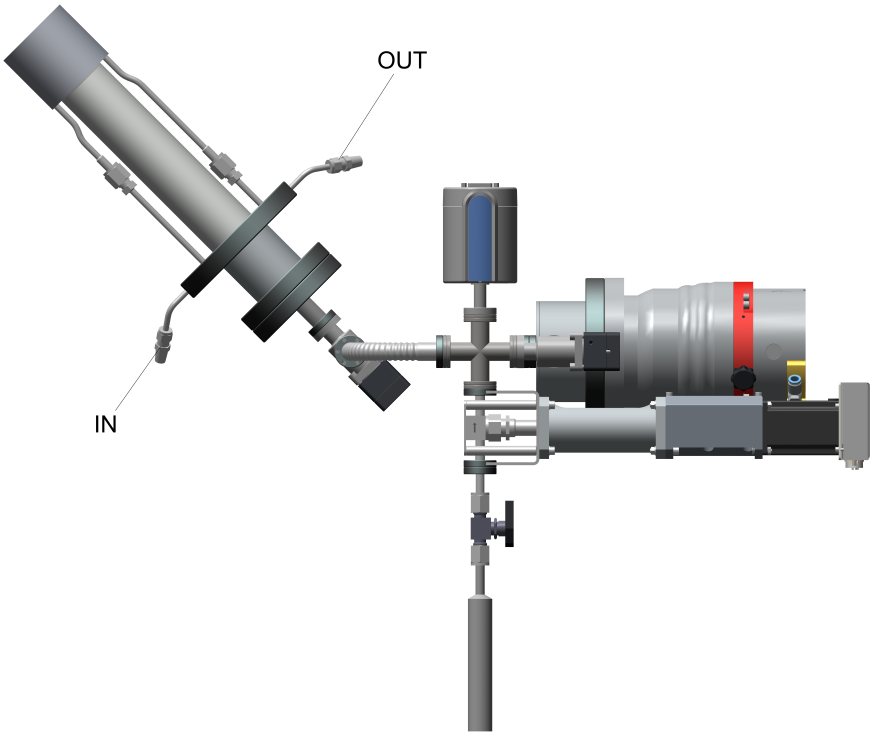


Fig. 5-1 Schematic showing the correct mounting orientation for the MOPI-12 model, with the injector outlet/inlet lines marked.

The MOPI-12 injector must be mounted in the correct orientation for safe operation. The water outlet/inlet should be positioned so that the Swagelok connection is pointing directly upward/downward respectively (Fig. 5-1).

The MOPI-4 injector may be mounted in any orientation.

Before mounting the MOPI source into the vacuum system, check that the in-vacuum length of the source is correct and according to the system design. Ensure that the injector can freely move into the vacuum system during installation. To avoid any damage to the source or to the vacuum system, move the injector in slowly and stop immediately if any unwanted friction occurs.

Using a crisscross pattern, tighten the flange with suitable bolts and nuts. In some cases, stud bolts may be required.

5.2 Liquid Bath Connections (MOPI-12 only)

NOTICE

Refer to the Julabo Heating Circulator manual for detailed operating and installation instructions.

Connect the liquid circulator supply and return lines to the correct 6mm Swagelok connectors, these are marked IN/OUT.

Fill the liquid bath with a suitable liquid. Galden© fluid can be heated above 95 °C, while water is limited to 95°C. When using water, follow the instructions of the bath manual to select suitable properties. In general, de-ionized de-calcified water is preferable.

5.3 Heating Jackets

Each heating jackets is powered by a solid-state relay within the ET housing (located in the electrical rack). A K-type thermocouple is connected to each jacket; the resistance for each heating jacket varies so each one is regulated separately by the ET controller.

NOTICE

The MOPI-4 heating jackets (Manifold-J1 and Manifold-J2) should have the same temperature SP. When changing the SP (e.g. Manifold-J1) via the DCA Control Software, it automatically updates the second heating jacket (Manifold-J2) to have the same SP. However, if the SP is changed locally (i.e. at the ET), the second manifold jacket will NOT change automatically and must also be set manually.

NOTICE

When handling the heating jackets, it is advised to use appropriate personal protective equipment as the heating jackets contain glass fibres that may irritate the skin.

The heating jacket(s)should be mounted (except tank) after the thermocouple cables, and water connections (MOPI-12 only) are attached.

⚠CAUTION

RISK OF OVERPRESSURE! Do NOT heat the ampule for the first time before removing inert gas!

If heating jackets need to be replaced see APPENDIX III - SUPPLIED ACCESSORIES, CONSUMABLES, AND SPARE PARTS.

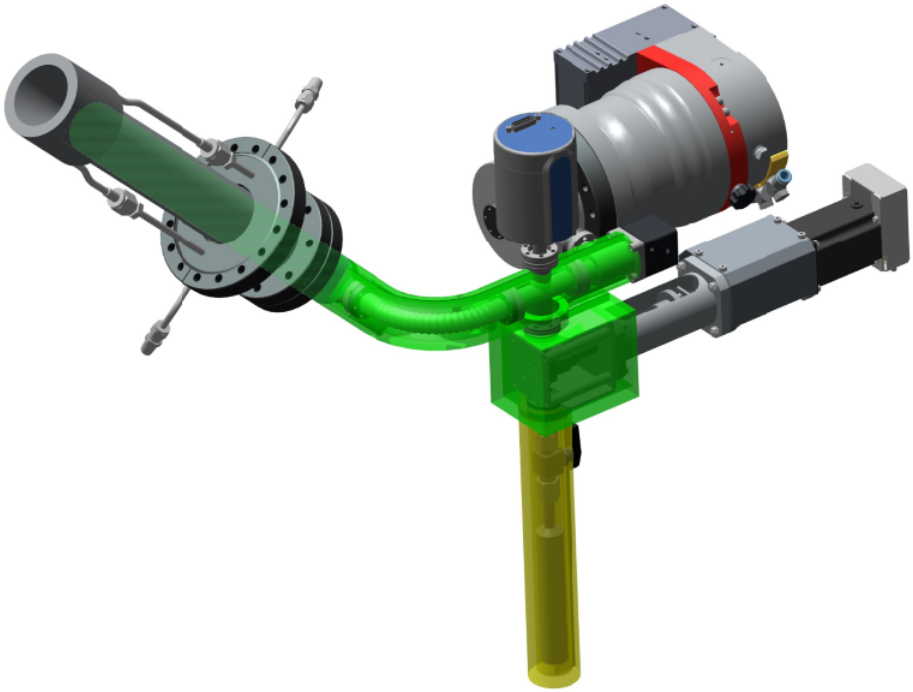


Fig. 5-2 Schematic showing the heating jackets (green & yellow) for the MOPI-12 source.

5.4 Electrical Connections

⚠WARNING

HIGH VOLTAGE! The heating jackets are controlled by 220 VAC, use caution when handling the electrical cables! Always ensure the POWER IS OFF before connecting/disconnecting any electrical cables from the system!

The schematics (Fig. 5-3 and Fig. 5-4) show an overview of the MOPI system set-up with the electrical connections and loop # assignment.

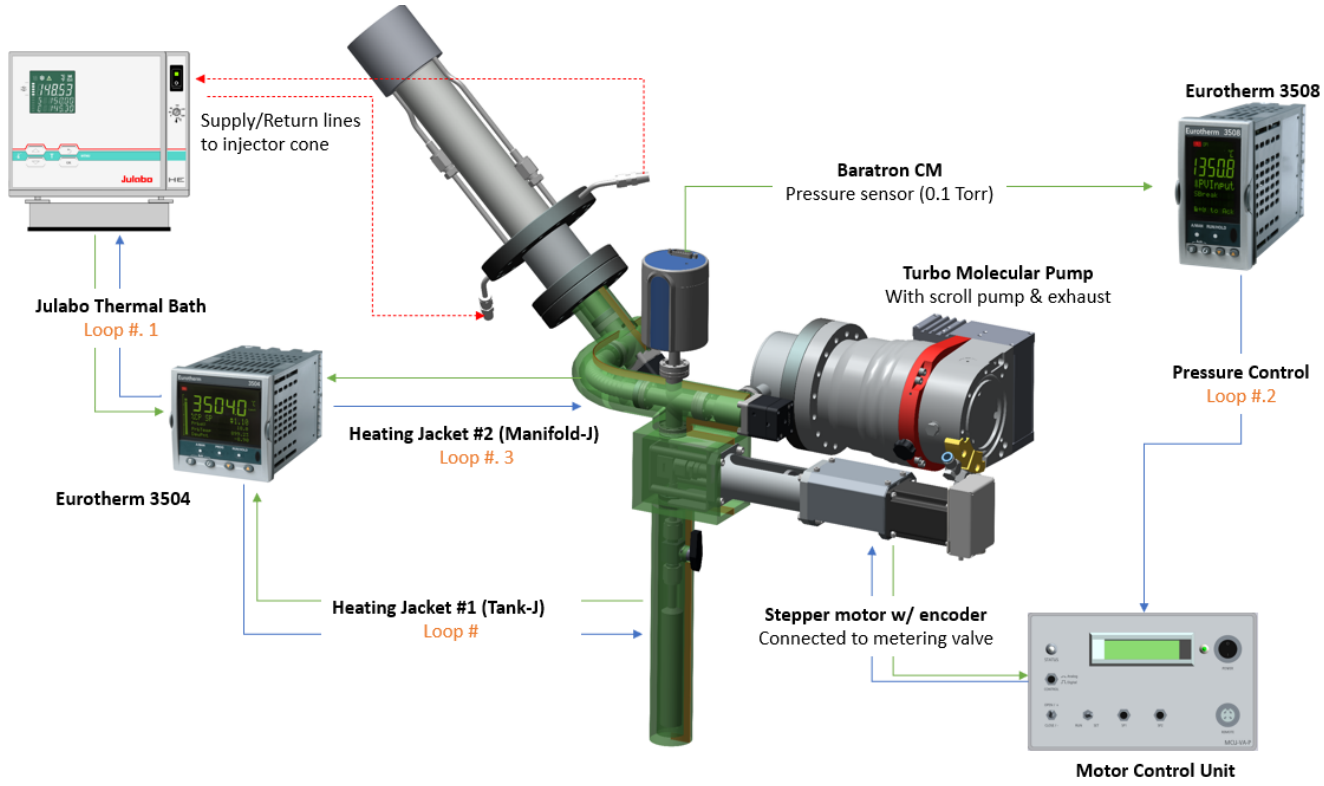


Fig. 5-3 Schematic showing the MOPI-12 component connections with loop # assignment.

Table 6 Description of the loop # assignment for MOPI system.

Loop	MOPI-4	MOPI-12
Loop #	Source tank heating jacket (Tank-J)	Source tank heating jacket (Tank-J)
Loop #.1	Injector	Injector Cone (Julablo)
Loop #.2	Pressure control (Output)	Pressure control (Output)
Loop #.3	Manifold heating jacket (Manifold-J1)	Manifold heating jacket (Manifold-J)
Loop #.4	Manifold heating jacket (Manifold-J2)	-
Loop #.5	Source tank 2 heating jacket (Tank2-J) - dual source only	-

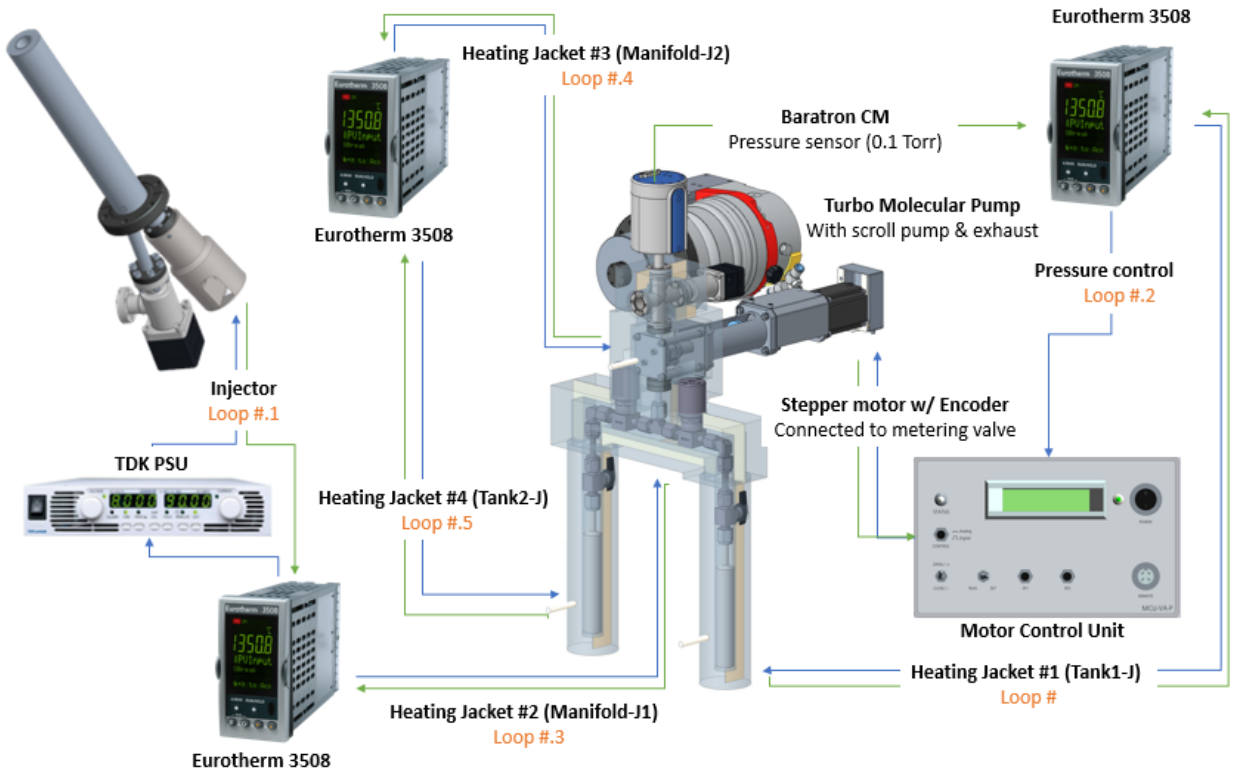


Fig. 5-4 Schematic showing the MOPI-4 component connections with loop # assignment.

Perform the following to ensure the electrical connections are correct:

1. Connect the TC from heating jackets to the ET3508/3504 unit according to the wiring instructions and markings on the TC connectors. The thermocouple cables are labelled according to Eurotherm control loop numbering (see Table 6).
2. Connect the Baratron capacitance manometer to the ET3508 to monitor the pressure.
3. Connect the sensor cable from the ET3508 to the MCU-VA-M – see also section 5.6.
4. For the MOPI-4, connect the ET3508 to the TDK PSU and to the injector.

5.5 Check the Eurotherm Settings

NOTICE

Refer to the Eurotherm 3500 Series User Manual for detailed operating instructions.

This section gives a short introduction to the basic features of the Eurotherm temperature control unit as it is in DCA's default configuration. You can operate the Eurotherm from the front panel or using the serial communication port.

During normal operation it is recommended to use the automatic PID control with a suitable temperature ramp for heating and cooling.

NOTICE

A typical temperature ramp for the MOPI source tank is 3 °C/min.

The user should be aware that unsuitable PID control coefficients can lead to severe power oscillations which might damage the source. If the power oscillates during the first heating, autotune the PID parameters already at a low temperature. The autotuning can then be redone at a mid-point of the operating temperature range to achieve optimum stability in the whole range.

NOTICE

Familiarize yourself with the following operations from the Eurotherm control panel:

- Setting a ramp
- Setting a OPHi
- Setting a setpoint
- Switching between auto mode and manual mode
- Tuning the PIDs

5.6 MCU-VA-MOPI Valve Control Unit

1. Mount the stepper motor and torque limiter to the motor support using the four Allen screws provided (Fig. 9-1).
2. With the MCU-VA-MOPI powered OFF connect to the appropriate sockets indicated in Fig. 5-5:
    a. the motor cable (J2),
    b. encoder/sensor cable (J3),
    c. I/O cable (J6),
    d. mains cable (J1),
    e. and communication cable (J4) for PC control.

⚠CAUTION

Do not plug/unplug any cables whilst the MCU-VA-M is powered on.

NOTICE

It is highly recommended that a DCA engineer performs the first initialization procedure for the MCU-VA-MOPI.

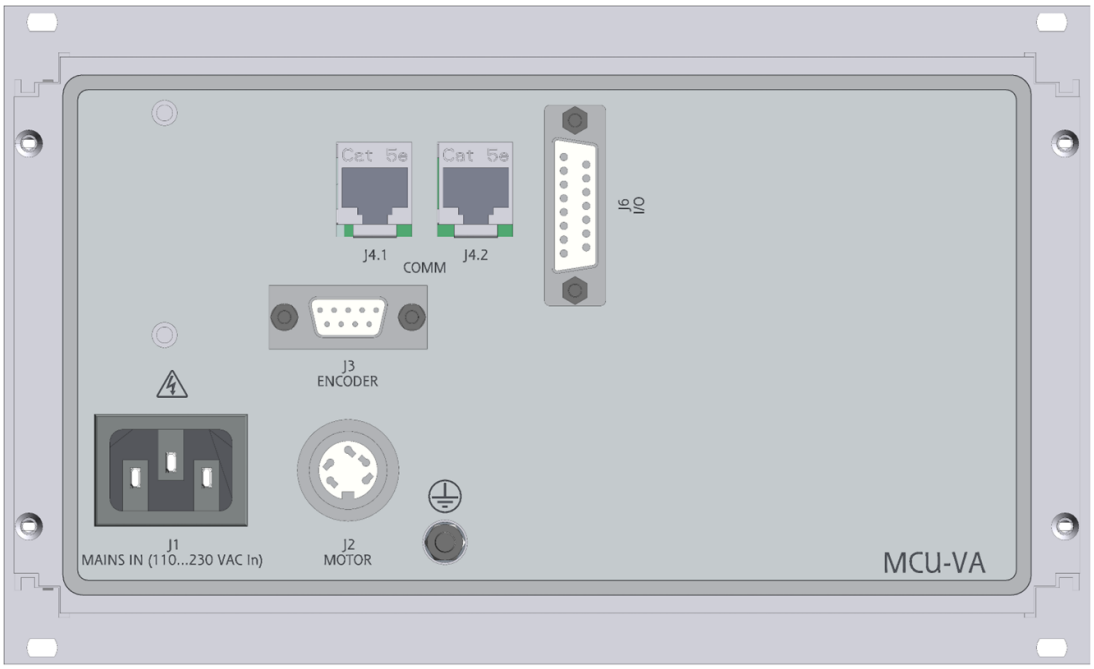


Fig. 5-5 MCU-VA Rear Panel, J1 - Main power, J2 - Stepper motor, J3 – Encoder, J4.1/4.2 – Communication, J6 – Input/Output

The internal Galil motion controller powers up when main and control voltages (via J6) are applied. The stepper motor output and sensor supply voltage remain off as those are controlled by the POWER switch of the MCU.

6 LOADING MATERIAL

⚠WARNING

BEFORE loading the material, refer to the Material Safety Data Sheet of the precursor for instructions on how to handle and the appropriate PPE that must be used.

The safety instructions for handling precursors are outside the scope of this manual. Before attempting to mount the ampule (source tank), the user is responsible for implementing the necessary safety measures and must be aware of the potential hazards that may occur when handling.

Required equipment:

- 16 mm wrench
- 19 mm wrench
- Cooling jacket

6.1 Mounting an ampule for the first time

⚠WARNING

Do NOT heat the ampule before removing the inert gas.

Fig. 6-1 Left: example of the ampule/source tank (left) with a sealed manual valve and VCR cap. Right: shows how the tank is mounted to the MOPI system.

To mount the ampule/tank:

1. Check manual valve of the ampule is closed.
2. Remove the protective VCR seal from the ampule.
3. Mount the ampule securely to the VCR connection in the MOPI system as shown in Fig. 6-1. Ensure it has a tight seal.
4. If possible, cool the ampule with a cooler jacket/ice bath.

6.2 Removing and exchanging an empty ampule

1. Ensure the existing ampule is fully depleted before removal.
2. Check the *RUN* SOV to the chamber is closed.
3. The *PUMP* SOV should remain open.
4. Change the Valve to *MANUAL* mode on the DCA control software.
5. Cool down the tank heating jacket to room temperature and remove the jacket from the ampule.
6. Check the ampule manual SOV, e-p *SOURCE* SOV (MOPI-4 dual only), and metering valve are all open.
7. Turn off the TMP and scroll pump, the pump is connected to an automated vent valve, which automatically vents the manifold with dry nitrogen.
8. Close the ampule manual valve.
9. Remove the Ampule from the system by unscrewing the VCR connector.
10. Replace the ampule by following the steps in section 6.1.

7 SOURCE OPERATION

NOTICE

Refer to the related DCA System and DCA Software manuals provided for operating valve and pump controls.

7.1 Initial Setup

1. Place a cooling jacket around the ampule to cool down to < 10 °C.
2. Check the *RUN* e-p shut-off valve (SOV) is closed from the SVICU/GUI.
3. Check the MCU has initialized and is set to digital mode (see section 8.2 and 8.3).
4. Check the Baratron is operational and at 80 °C.
5. Check that the metering valve is closed from the MCU-VA-MOPI, i.e. position shows 0.0000. MCU status is red (section 8.6.1).
6. If the TMP/scroll pumps are off, start them from the OmniController in the ER.
7. Open the *PUMP* SOV from the SVICU/GUI MOPI screen in the ER to allow the gas manifold to pump down.
8. Open the metering valve gradually (using jog mode from the MCU) so that it is only slightly open (e.g. 5-10.0%).
9. If applicable, open the e-p *SOURCE* SOV from the SVICU/GUI.
10. Slowly open the ampule manual valve to release the inert gas. To ensure the inert gas is removed, it is recommended to continue the pumping process for 3-4 hours (estimated).
11. ONLY once the inert gas has been removed, remove the cooling jacket, and mount the heating jacket to the ampule. Connect the heating jacket TC and power cables.
12. Set the Manifold-J1/J2 heating jackets to suitable temperature (from the DCA Control software) (e.g. 90 °C).
13. Set the tank temperature SP from the ET or the DCA control software. It is recommended that the source tank remains at the SP during operation.

⚠CAUTION

RICK OF OVERPRESSURE! When heating the ampule for the first time, the manual SOV, e-p *SOURCE* valve (if applicable), and motorised metering valve must remain OPEN to prevent overpressure. Once the tank temperature has stabilised at the SP, the valves may be closed.

14. For MOPI-12 only, set the thermal bath temperature from the ET3504 or DCA control software, this should be similar to the manifold temperature.
15. For MOPI-4, set the injector temperature from the ET3504 or DCA control software, this should be similar to the manifold temperature.
16. Close the SOURCE e-p SOV or manual SOV to preserve the source material when not in use.

7.2 Process Operation

1. Set the MCU to analog mode (see section 8.6.2) to allow automated control of the metering valve.
2. Open the manual SOV to the source tank.
3. Open e-p SOV for *SOURCE* (MOPI 4 dual-source only).
4. Set the desired pressure SP from the DCA control software:
    a. Check 'Valve' is in *AUTO* mode.
    b. Set pressure SP 0-100 mTorr.
    c. Ramp rate may be adjusted, i.e. if set to 0, the valve will open at max. speed.
5. Wait for the pressure to stabilise in the manifold, can be observed from DCA control software.
6. Open the *RUN* valve (this automatically closes the pump valve).
7. If necessary, wait for the pressure in the manifold to stabilise before opening the main/source shutter.
8. When the process is complete, open the *PUMP* valve (automatically closed the *RUN* valve).
9. While in standby, the manual SOV for the source tank should also be closed.

8 MOTOR CONTROL UNIT (MCU-VA) LOCAL OPERATION

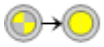
8.1 Remote Control

A handshake protocol is implemented in order to allow remote control of the MCU. DCA Instruments provides a software driver to operate the MCU via its Ethernet interface. Refer to the separate DCA Software manual for detailed instructions.

8.2 Start-Up

Action	Indicator	Description	Display
Switch on 'Power'		MCU starts up and runs self-test.	 MCU displays device name and software version during start-up. Device name includes specifier according to valve type: here As for needle valve (As cracker cell)
		MCU waits for initialization. Operating any control other than that to start initialization causes the Status LED to flicker red.	

8.3 Initialization

Action	Indicator	Description	Display
MCU in Digital control mode (RUN).		MCU needs initialization.	Pos_M ******* Position reading is invalid.
Operate and hold JOG (CLOSE), release when LED STAT is steady on.		MCU performs Homing sequence. Valve is closed until home switch is triggered and then opened as much as needed to reset the state of the switch (creep off the switch). Then, drive adjusts to pre-set offset at valve's fully closed position.	Pos_M -0.458 R R indicates the position read out from the encoder is relative to starting position
		Position reading is reset to 0 and switches from relative (R) to absolute display	Pos_M 0.000 000.0% Valve fully closed. Position reading is referenced to this position.

8.4 Offset Adjustment (Advanced Initialization)

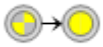
Action	Indicator	Description	Display
MCU in Digital control mode (RUN).		MCU needs initialization.	Pos_M ******* Position reading is invalid.
Press/operate and hold SP1 AND SP2 AND JOG (CLOSE) until the LED STAT is lid steady yellow.	 	The MCU performs the homing sequence. However, at the end, it displays the preset offset (current distance from home switch trip point). *See note below.*	OFFS(e) -0.025* SET
Use JOG to adjust the offset.		Stall detection is disabled during this procedure.	OFFS(e) -0.030* SET Valve without TL: offset is ≤ 0 ('closed' is beyond home switch trip point) Valve with TL: offset is ≥ 0 ('closed' is reached after reversing from home switch trip point).
Press SP2 to apply and save the changes	 	Offset is saved to non-volatile memory. The LED STAT is blinking red/yellow while MCU is busy with that. Position reading is reset to 0.	Pos_M 0.000 000.0% Valve fully closed.

NOTICE

For a valve without torque limiter, the offset corresponds to the travel by which the motor shall 'overturn' the home switch trip point in order to reach the valve's 'closed' position. Care must be taken not to overtorque the valve mechanism.

For a valve with a torque limiter, the offset corresponds to the travel that is needed to reverse the motor from the home switch trip point in order to release the lever, so that it rests on the base. The 'closing' position is determined by the torque applied when running into the home switch – this depends on the spring load setting. The spring load must be carefully adjusted not to overtorque the valve mechanism.

8.5 Operation Without Initialization (Emergency Jog)

Action	Indicator	Description	Display
MCU in Digital control mode (RUN).		MCU needs initialization.	Pos_M ******* Position reading is invalid.
Press and hold SP1 AND SP2 until the LED STAT is lid steady yellow.		The MCU switches to Emergency Jog Mode.	
Use JOG to move the drive. **CAUTION!** **See below**		Stall detection and position feedback are disabled in this mode of operation.	Pos_M 0.000R R in position read-out indicates relative measure.
Power down to exit Emergency Jog Mode.			

⚠CAUTION

Risk of damage! Driving against mechanical limits may cause severe damage to the valve!

8.6 Positioning

8.6.1 Digital Control Mode

Action	Indicator	Description	Display
Operate JOG to adjust the valve position.		LED STAT lights up: Yellow: driver is in motion, Red: valve in fully closed position (0) Green: valve in fully open position (according to its set allowed travel). The applied speed is adjustable: see Configuration >jgspd	 Position reading (valve stem displacement): upper line in mm, second line is the percentage of allowed travel.
Press SP1 (SP2) to position the valve at position set-point #1 (#2). Move can be aborted by operating JOG, SP1, or SP2.		LED STAT lights up yellow while the drive is moving. The applied speed is adjustable: see Configuration >mvspd For how to change the position set-point setting: see Configuration >SP1 / SP2	
Operate and hold JOG (CLOSE) AND press SP1 to fully close the valve fast (mvspd applied). Move can be aborted by operating JOG, SP1, or SP2		LED STAT lights up red when Close Position is reached.	
Operate and hold JOG (OPEN) AND press SP2 to fully open the valve fast (mvspd applied). Move can be aborted by operating JOG, SP1, or SP2		LED STAT lights up green when Open Position (according to allowed travel) is reached. The allowed travel is adjustable: see Configuration >Trvl.	

8.6.2 Analogue Control Mode

Action	Indicator	Description	Display
With the Control Mode Selector set to Analog (depressed) all other controls at the HMI are disabled. The Control Mode Selector lights up when Analog position programming is activated.		LED STAT lights up: Yellow: drive is moving, Red: valve in fully closed position (0), Green: valve in fully open position (according to its allowed travel).	 Lower left reading is the spanned relative control signal (ACS). Refer to the Appendices for variables. ACS = (AISc*AIN+AISh)/5V. (AIN being the control voltage between 0 and +5V.) For how to adjust AISc and AISh, see Configuration >AISc/AISh.

See APPENDIX II – LIST OF ERROR CONDITONS for wiring information for the analog input (J6).

NOTICE

The MCU must have been initialized before Analog Control Mode can be applied. If the Control Mode Selector is set to Analog, before initialization, the Status LED flickers red while the control mode indicator flashes.

8.7 Configuration

Action	Indicator	Description	Display
MCU in Digital control mode, mode toggle in SET. Operate JOG to scroll through configuration menus. Use SP1/SP2 to select the variable to be changed.		In case of an interlock getting active, the MCU will leave the configuration mode.	- - Conf_M - - <jgspd> <mvspd> See appendix for the list of variables
Variable selected. Use JOG to increase/ decrease parameter. Press SP1 to discard changes, SP2 to apply and save changes.	 	Hint: By holding SP1 or SP2 for 3 seconds when selecting SP1, SP2 or Trvl for change, the current position reading is copied into the configuration screen. Parameters can be changed within predefined limits. Changes will be internally evaluated before saving. Parameters are saved to non-volatile memory. The LED STAT is blinking red/yellow while MCU is busy with that.	SP1: 0.501* BCK SET * indicates the parameter has been modified.

8.8 Interlock

Action	Indicator	Description	Display
When the interlock is activated, the drive is locked at its current position or forced close, depending on the interlock response setting (see configuration >AMvE) but independently from which control mode is selected or from whether or not the MCU is set for configuration.	   	LED STAT flashes: Red/Yellow: while drive is moving. Off/Red: valve is locked at its closed position (0). Red/Off: drive is locked at arbitrary position, Red/Green: drive locked fully open. If in analog control mode, the analog mode indicator is also flashing while the interlock is active.	Pos_M 1.284 (Intl) Interlock active.

8.9 Error

Action	Indicator	Description	Display
In case an internal error occurs, the MCU stops and displays an error code.		The LED STAT blinks in sequences corresponding to the error code. A homing is required to reset the MCU.	MCU-VA-M Error: 8 See Appendix I for list of error codes.

9 SOURCE MAINTENANCE

Regular inspection and maintenance of the MOPI source is recommended to ensure it operates safely, efficiently, and with optimal performance.

Inspect heating jackets for any damage, replace if there is any visible fraying. Inspect power and thermocouple cabling and replace if they are not functioning correctly or appear damaged.

9.1 Valve Drive

It may be necessary to use a cleanroom compatible lubricant, (e.g. Fomblin® oil/Rocol Sapphire Endure 56), to lubricate the part shown in Fig. 9-1 (red arrow). The valve drive can be removed from the metering valve by unscrewing the four screws (green) shown in Fig. 9-1.

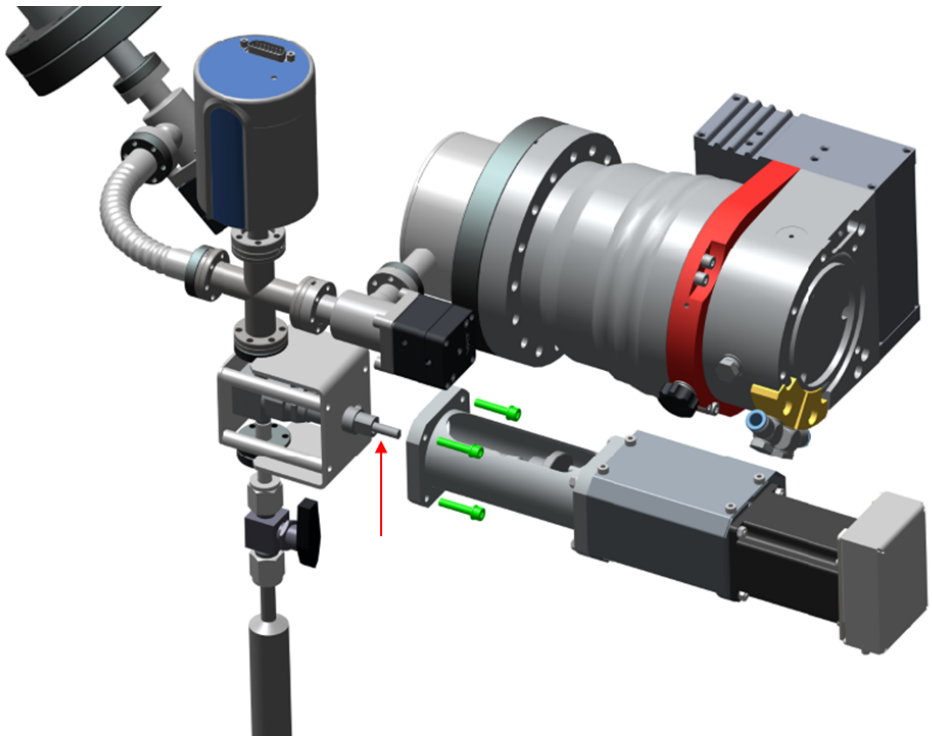


Fig. 9-1 Schematic showing the valve drive removed, the red arrow indicates the area that may require lubrication.

9.2 Torque Limiter (TL)

The torque limiter is located above the stepper motor (position g, Fig. 3-2). To gain access to components of the mechanical torque limiter, remove the four M4 screws and the protective cover.

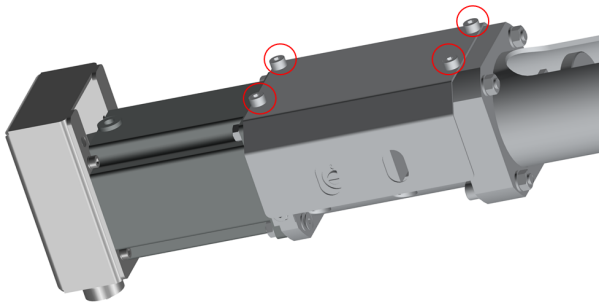


Fig. 9-2 The torque limiter components can be accessed by removing the four Allen screws from the protective cover.

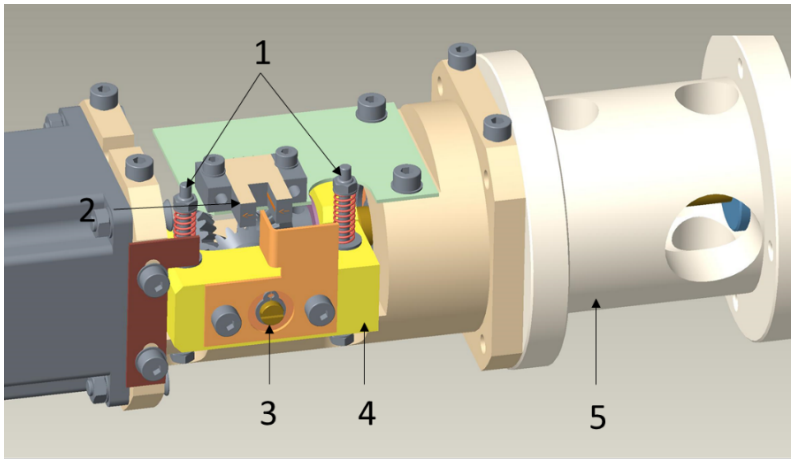


Fig. 9-3 Torque Limiter for metering valve with the following parts identified: 1. Adjustment springs for torque limiter, 2. Optical switch, 3. Manual valve screw (rotate clockwise to close the valve) 4. Lever, 5. Mounting adapter for valve drive.

Areas that require lubrication are highlighted red in Fig. 9-4.

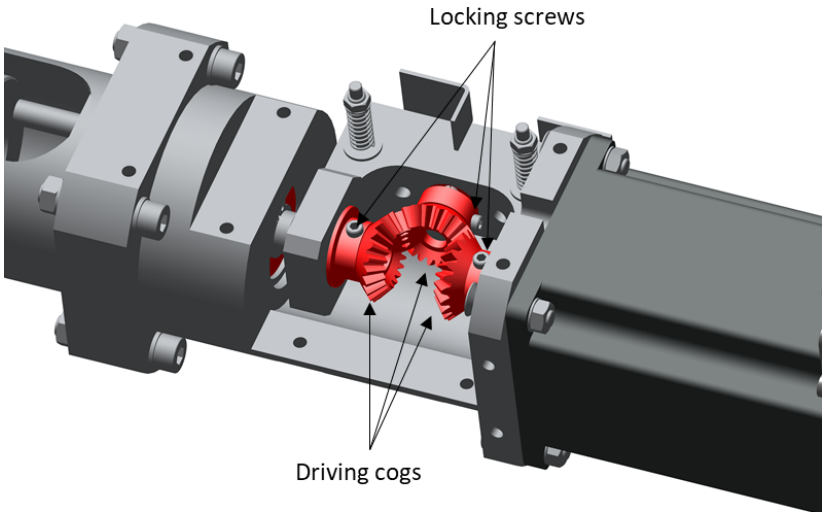


Fig. 9-4 Schematic of the torque limiter with optical sensor removed.

Before performing any adjustments to the torque limiter ensure the MCU-VA-M is powered off.

To increase the closing torque, increase the pre-load of the spring(s) by turning the adjustment nut(s) clockwise.

NOTICE

Driving the valve with increased closing torque will reduce the lifetime of the valve seat. Per factory default setting, the pre-load may be increased by up to seven full nut revolutions with the available motor torque.

9.3 General Source Maintenance

When using the MOPI source, material that is not cracked on the surface of the substrate will accumulate on the chamber walls. Due to its high vapour pressure this could lead to a higher chamber pressure during the deposition process. It is therefore recommended to perform regular bakeouts to desorb the metal-organic material that has accumulated on the internal walls. The periodicity of bakeout is dependent on the source usage, however indicators include flux drifting during deposition or higher than usual base pressure.

It is recommended to remove and clean the source shutter (if applicable) during maintenance periods to remove any precipitate.

Check the heating jackets for any wear and tear and replace if there is any fraying or damage.

Check thermocouple and power cables and replace if they are damaged.

Refer to the separate Pfeiffer HiPace turbomolecular pump and scroll pump manuals for maintenance instructions.

10 WARRANTY

I. DCA Instruments warrants that the Metal Organic Precursor Injector is free from defects in material and workmanship for a period of 12 months from the completed installation date.

II. DCA Instruments shall incur no liability under this warranty if:
    a. the allegedly defective goods are not returned prepaid to DCA Instruments within thirty (30) days of the discovery of the alleged defect and in accordance with DCA Instruments' repair procedures; or
    b. DCA Instruments' tests disclose that the alleged defect is not due to defects in material or workmanship.

III. DCA Instruments' liability shall be limited to either repair or replacement of the defective goods, at DCA Instruments' option.

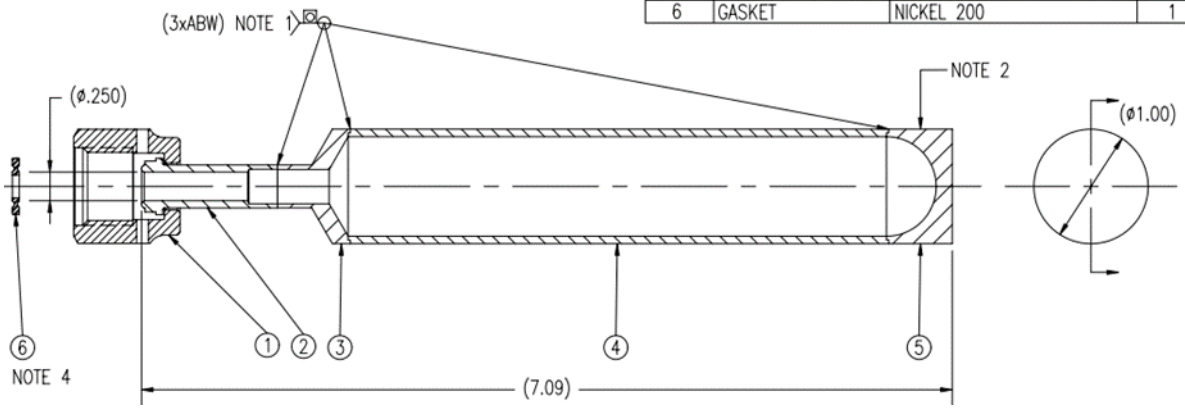
IV. DCA Instruments makes no express or implied warranties regarding the quality, merchantability, or fitness for a particular purpose beyond those that appear in the applicable DCA Instruments user's documentation. DCA Instruments shall not be responsible for consequential, incidental, or punitive damage, including, but not limited to, loss of profits or damages to business or business relations. This warranty is in lieu of all other warranties.

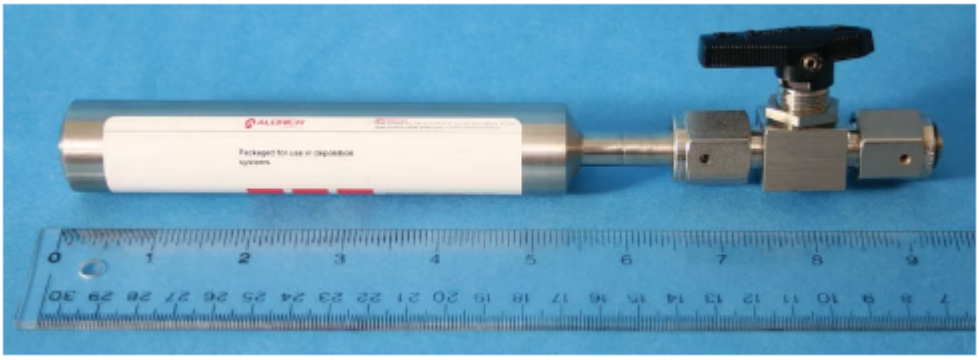
V. Upon expiration of the system warranty, DCA Instruments will release the source code under the following strict conditions:
    a. DCA Instruments software support will be limited to the version written and delivered by DCA Instruments.
    b. The source code is not circulated outside the lab.
    c. No support or upgrade will be offered by DCA Instruments to any and all MBE control software modified by the customer.

APPENDIX I – AMPULE DIMENSIONS

The schematic below shows the precursor ampule dimensions required to fit to the MOPI source. The example below can be sourced from Merck for a number of precursor materials, however other suppliers may be able to provide a compatible solution.

ITEM	PART NAME	MATERIAL	QTY.
1	FEMALE NUT	303 SST	1
2	GLAND	316L EP SST	1
3	CYLINDER TOP	316L EP SST	1
4	CYLINDER BODY	1"x.065 SMLS EP 316L SST	1
5	CYLINDER BOTTOM	316L EP SST	1
6	GASKET	NICKEL 200	1





APPENDIX II – LIST OF ERROR CONDITONS

Code	Meaning	Remarks
5	Home sensor not found	The home sensor is found staying inactive while the driver tries to change its state during the initial closing move. Check the sensor and its wiring. The indicator at the optical through-beam switch should change its state when blocking/unblocking the beam.
6	Can't creep off from Home sensor	The home sensor is found staying active while the driver tries to free the switch during the creep-off step of the homing sequence. See above.
8	Stall detected	Internal motor step clock and encoder counter mismatch. While this could be due to an encoder wiring problem or encoder failure, it may indicate a mechanical problem of the valve or the drive. Check the wiring of the encoder. Check the valve and the drive for mechanical issues. Drive with TL: error is triggered by the home switch being activated unexpectedly while closing the valve (Torque limit exceeded) Consult DCA if the error persists.
10	Positioning error	May be triggered because of a hardware failure of the indexer. Consult the factory.
26	Hardware failure	Consult DCA factory
27	Stop code generator not started	Internal logic error. This error can be triggered in case of an interlock being active while AMvE=1 and the MCU having not finished the homing sequence - to be ignored in this case.

APPENDIX III - SUPPLIED ACCESSORIES, CONSUMABLES, AND SPARE PARTS

For ordering accessories, consumables and/or spare parts, please contact:

DCA Instruments Oy
Aerotie 6, 20360, Turku, Finland
sales@dca.fi
+358 2 238 2500

Supplied accessories/components

Note: Not all items are supplied with each source.

Manufacturer	Item Description	Model
DCA Instruments	Heating jacket- Manifold-J MOPI-4-single	#37037, #37038, #37042
	Heating jacket- Manifold-J MOPI-4-dual	#37037, #37038, #37044
	Heating jacket- Manifold-J MOPI-12	
	Heating jacket- Tank-J	#37043
Edwards	Dry Scroll Pump	nXDS10i
Eurotherm	PID Controller	3500 Series
HemiHeating	Heating jackets	
Julabo	Thermal bath circulator	Magio MS-BC4
Pfeiffer	Turbo molecular pump HiScroll pump	HiPace 300, DCU HiScroll 6
MKS	Baratron Capacitance Manometer	
VAT	e-P RAV	