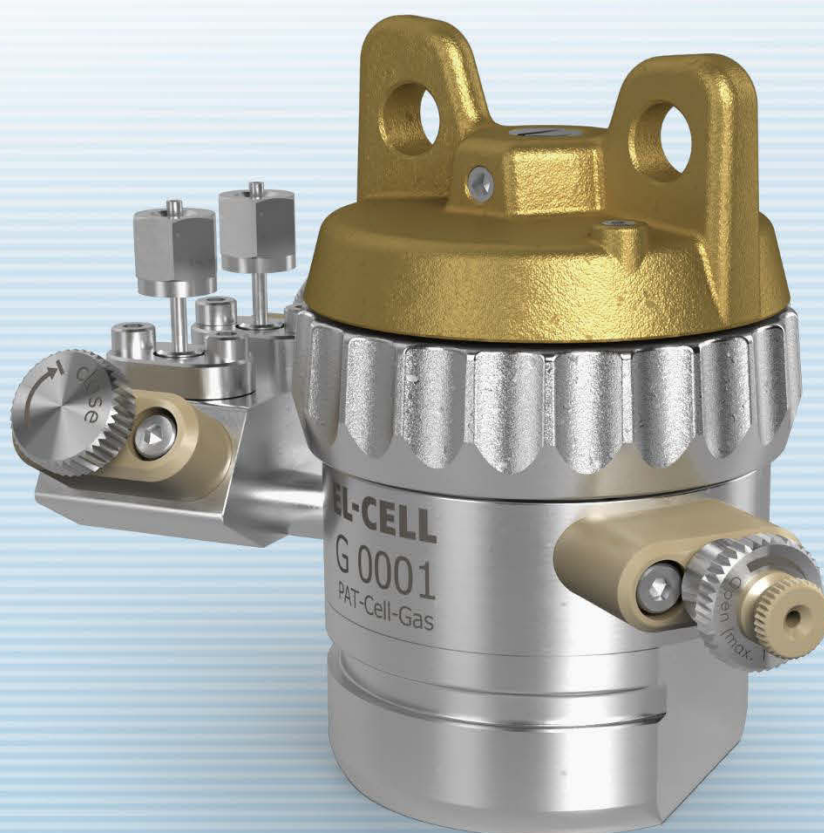


User Manual

Release 1.22

PAT-Cell-Gas

Electrochemical test cell for in-situ gas analysis in a flow-through set-up



The information in this manual has been carefully checked and believed to be accurate; however, no responsibility is assumed for inaccuracies.

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EL-Cell GmbH

Tempowerkring 8

21079 Hamburg - Germany

phone: +49 40 79012-737

fax: +49 40 79012-736

e-mail: info@el-cell.com

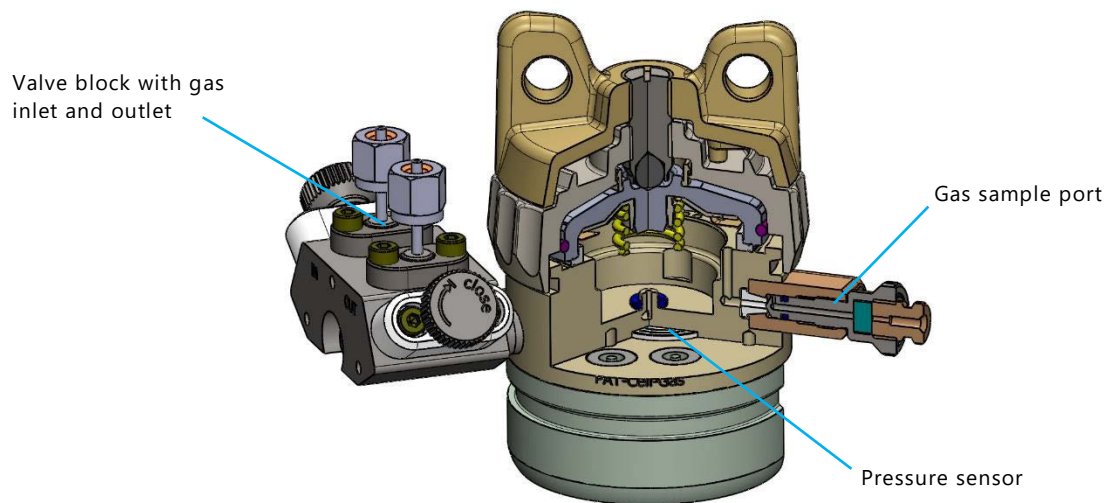
web: www.el-cell.com

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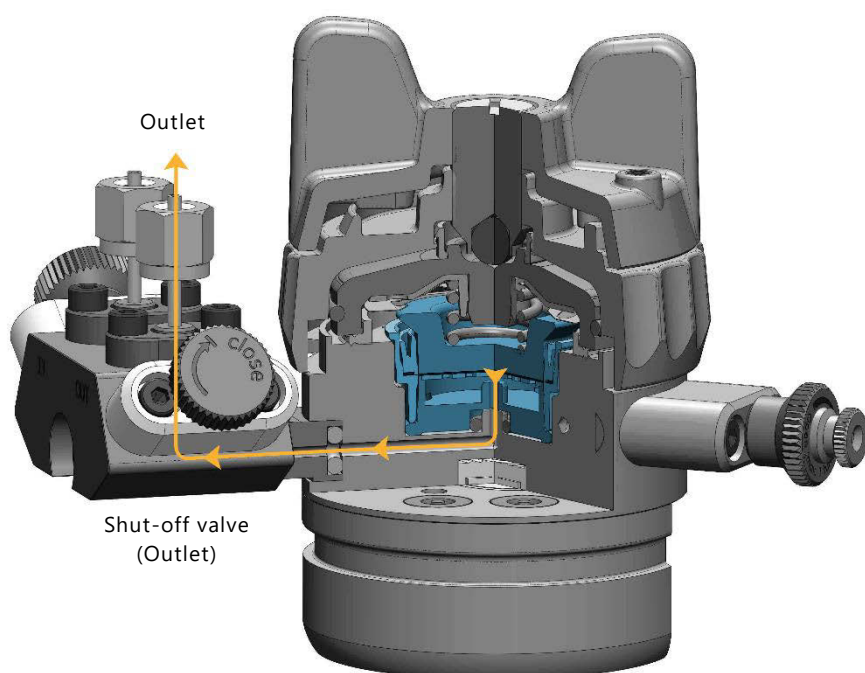
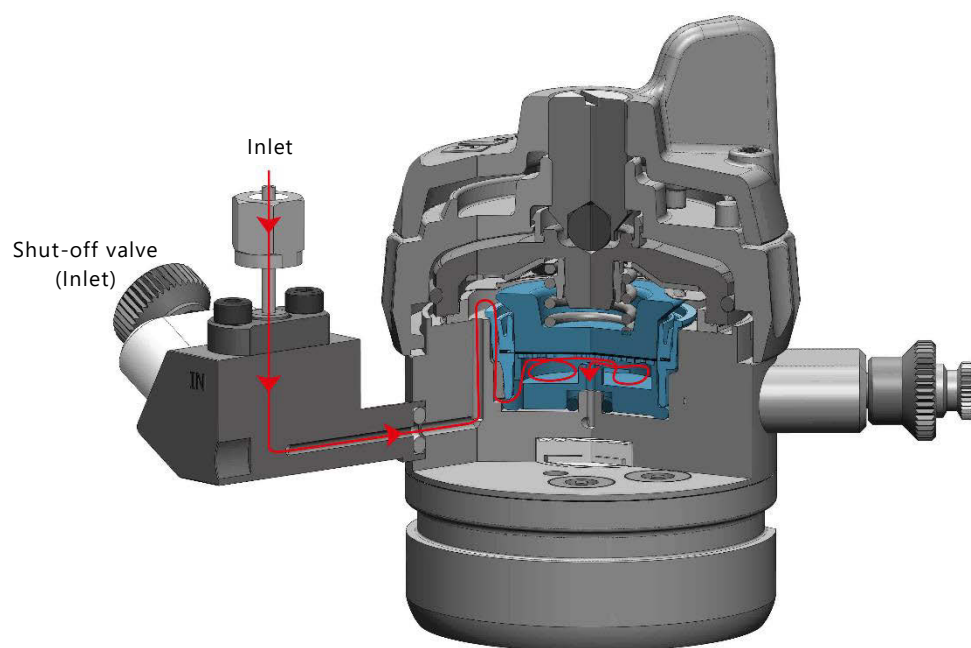
1 Product description

The PAT-Cell-Gas is a test cell dedicated for in-situ gas analysis of battery materials in a flow-through set-up. For that purpose, the test cell features a gas inlet and outlet and optionally a built-in pressure sensor and a valve port for gas sample removal with a syringe. The test cell is typically connected to peripheral equipment for gas supply and gas analysis. This manual covers the test cell only.



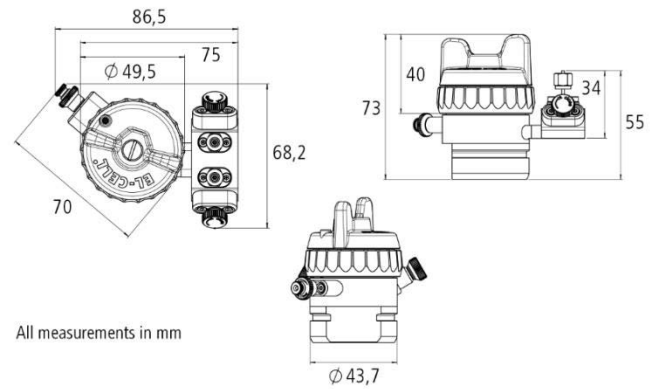
Features

- PAT series test cell with gas inlet and outlet
- The inside PAT-Core (cell stack) is comprised of a lower gas permeable electrode, a separator and the upper (counter) electrode.
- The cell can be operated with or without reference electrode
- The gas-permeable electrode is seated on a special lower plunger for current and gas feed.
- Two different lower plungers are available: with perforated plate (for minimum pressure drop) or with flow field (for optimized plug flow)
- The incoming gas is directed to the lower electrode of the cell stack and leaves the cell through the central bore in the lower plunger.
- Option P: Laser welded pressure sensor, 0 to 3 bar abs. This option is only operable in combination with the PAT-Tester-x or the PAT-Press box.
- Option S: Gas sample port
- Electrode feedthroughs with glass-to-metal seals
- Helium leak tested for high tightness

Schematic view: Gas inlet and outlet

2 Technical data

- Length: **86.5 mm**
- Width: **68 mm**
- Height: **73 mm**
- Weight: **0.6 kg**
- Gas connection:
1/16 inch Swagelok Tube Fitting
- Electrode diameter: **18 mm**
- Temperature resistance **-20 to +70 °C**

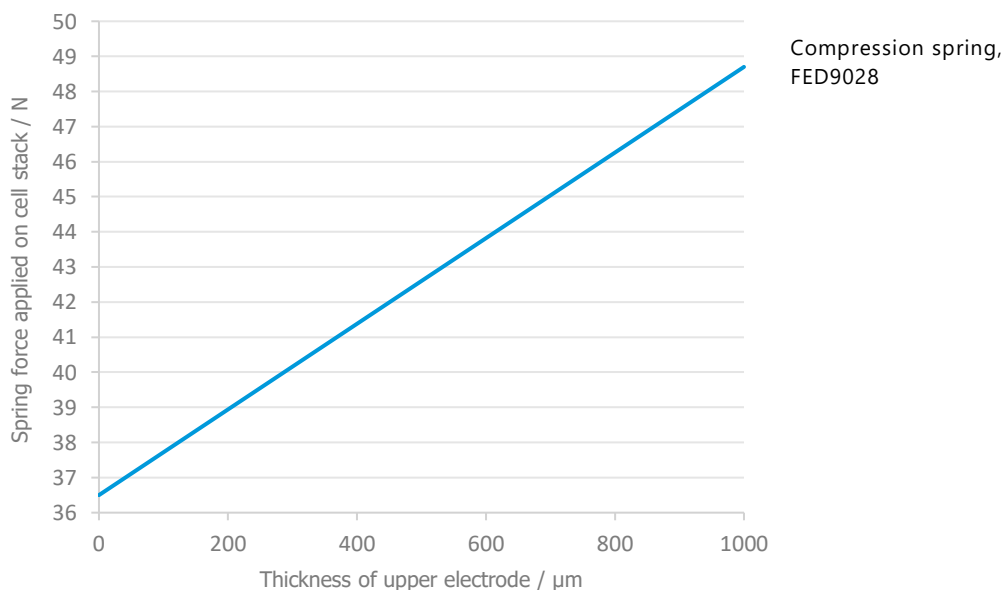


2.1 Dead volume

PAT-Cell-Gas with metal seal:

- PAT-Cell-Gas without PAT-Core: **8.275 ml**
- PAT-Cell-Gas with PAT-Core (Lower plunger AIR): **4.638 ml**
- PAT-Cell-Gas with PAT-Core (Lower plunger flow field): **3.915 ml**

2.2 Spring force in relation to the thickness of the upper electrode:



3 Variants

PAT-Cell-Gas



Features

Gas inlet and outlet

PAT-Cell-Gas P



Features

- Gas inlet and outlet
- Laser welded pressure sensor, 0 to 3 bar abs

PAT-Cell-Gas S



Features

- Gas inlet and outlet
- Gas sample port

PAT-Cell-Gas SP



Features

- Gas inlet and outlet
- Gas sample port
- Laser welded pressure sensor, 0 to 3 bar abs

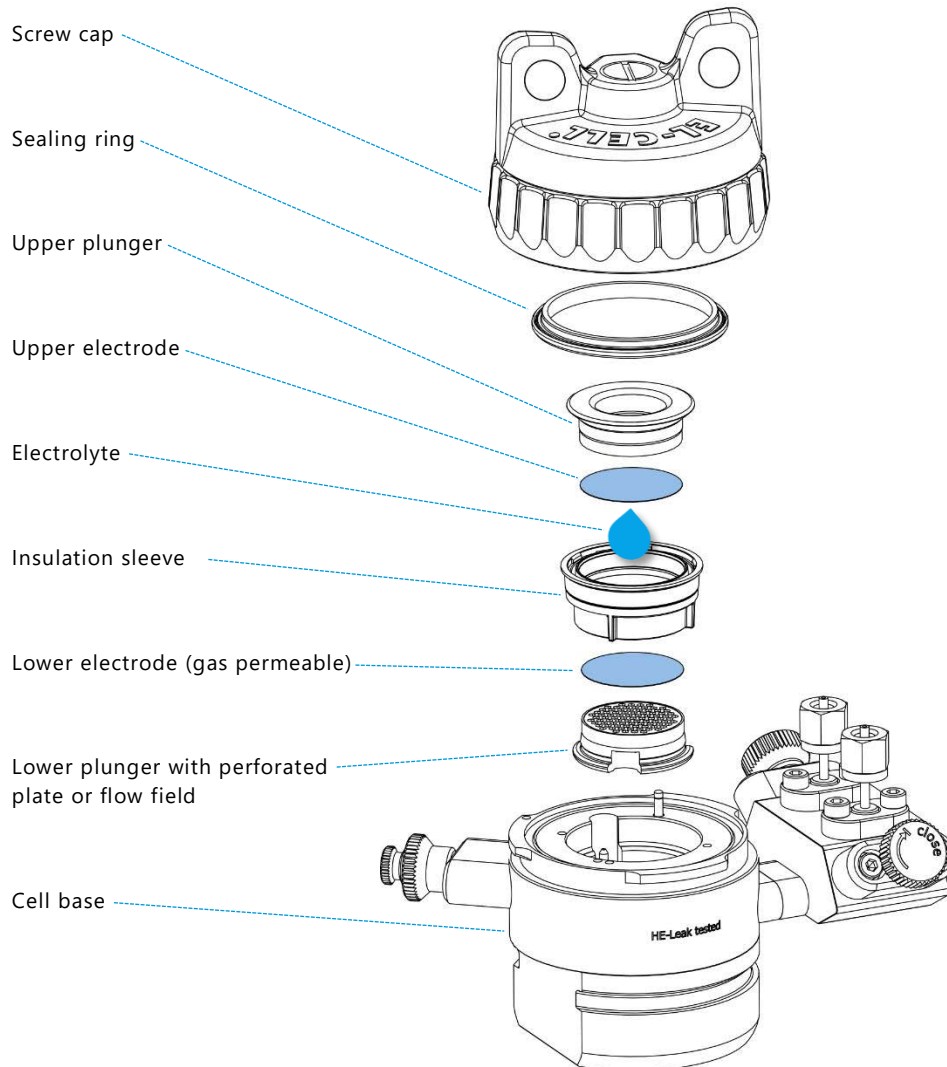
4 Safety precautions

Use proper safety precautions when using hazardous electrode materials and electrolytes. Wear protective glasses and gloves to protect you against electrolyte that may accidentally spill out during disassembly. Upon cell disassembly, dispose all materials properly. Metallic lithium and some insertion compounds may decompose heavily in contact with water and other solvents, and can cause fire.

5 Assembly of the PAT-Cell-Gas

This section describes how to assemble the PAT-Cell-Gas test cell. A more detailed description of the PAT-Core can be found in a separate manual.

Note: The assembly has to take place under the protective atmosphere in a glove box.



1. Put the special lower plunger onto the worktop with the perforated plate / flow field pointing upwards. Make sure that the O-ring seal at the bottom of the plunger is in place. Make sure that the perforated plate is properly inserted on top of the plunger (only when using the two-piece perforated version of lower plunger)
2. Put the **insulation sleeve** onto the worktop with the smaller side pointing upwards.
3. Insert the **lower gas-permeable electrode** into the sleeve with the active layer facing downwards.
4. Push the **lower plunger** into the insulation sleeve.
5. Align the contact spring of the sleeve with the reference pin inside the **cell base**. Then insert the assembly into the cell base.
6. Evenly dispense approx. 100 µL of **electrolyte** on top of the separator with a pipette. Note: The optimum amount of electrolyte will depend on the thickness and porosity of the separator and the electrodes used.
7. Insert the **upper electrode** into the insulation sleeve with the active layer facing downwards.
8. Attach the **upper plunger**.
9. Attach the cell lid and tighten the wing nut in order to seal the cell. NOTE: Replace the lid seal after each experiment. You can choose between different sealing materials: PE, PEEK, PTFE and Al. PE has lower water permeability than PEEK, but significantly higher air permeability. PE should not be used above 50°C. Al seals show the best overall performance.
10. Close the two shut-off valves at the inlet and the outlet of the cell.
11. The cell can now be removed from the glovebox and connected to the peripheral equipment such as gas supply and mass spectrometer.

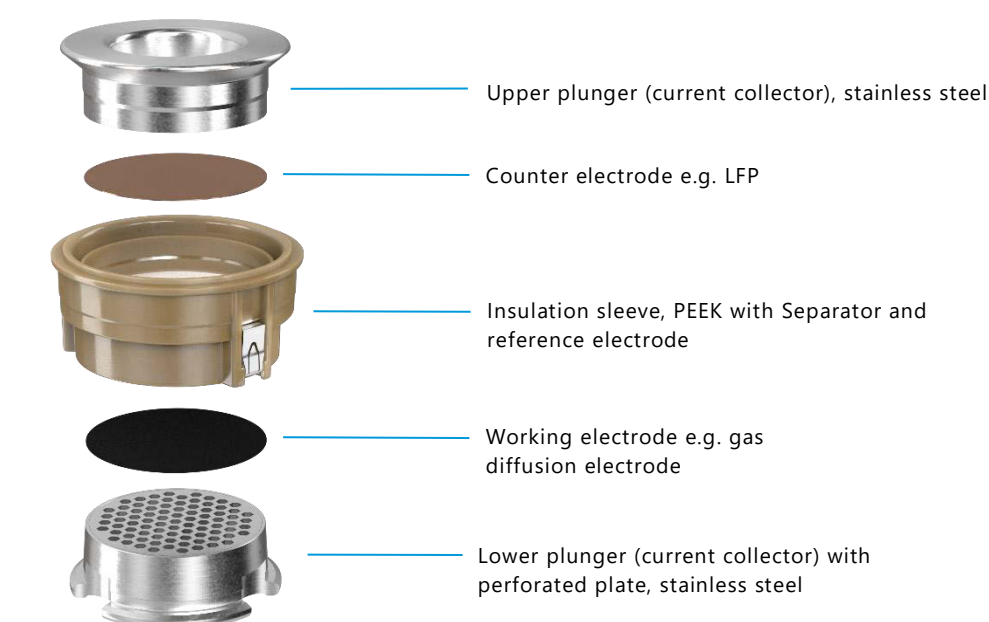
6 Working modes of the PAT-Cell-Gas

There are two dedicated lower plunger available for the PAT-Cell-Gas for different testing purposes.

6.1 Mode 1: Air mode

The lower plunger with perforated plate allows for electrochemical characterization of gas diffusion electrodes used for instance in Li-air batteries. The lower electrode is contacted by and "breathes" through the perforated stainless steel current collector supporting it. During operation, the pressure gradient building up between cell headroom and the gas volume below the perforated plate effectively prevents back-mixing. The relatively large volume below the perforated is at the expense of time resolution, but makes this solution robust against clogging of the gas path.

PAT-Core configuration example

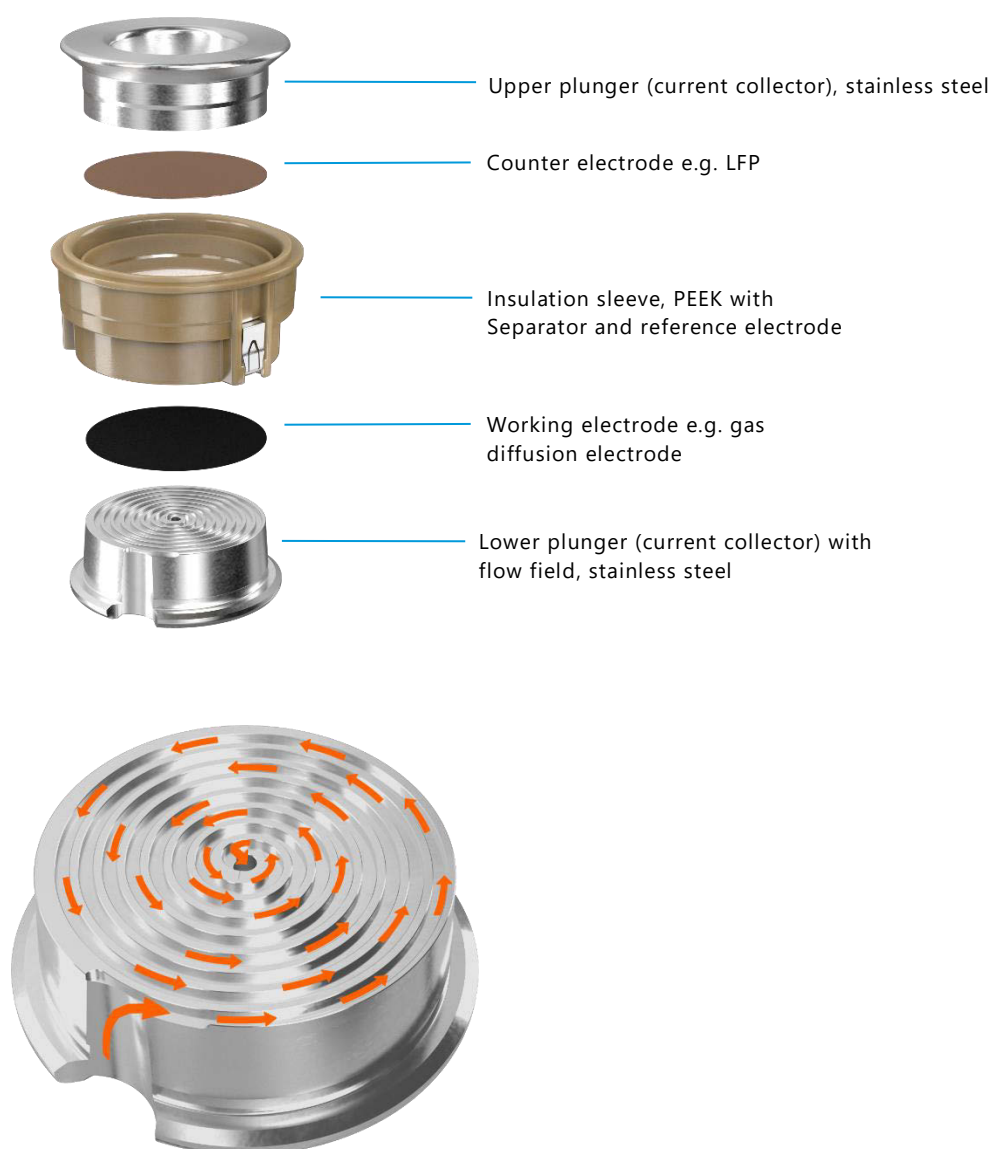


Gas flow inside the lower plunger

6.2 Mode 2: OEMS mode

The PAT-Core setup using a lower plunger with flow field provides almost perfect plug-flow of the purge gas being essential for quantitative time-resolved analysis. Gases evolved or consumed at the working electrode may be analysed through the composition change of the gas stream that is to be passed along the spiral-type flow field below the working electrode. The composition of the outgoing gas can be analyzed by e.g. mass spectrometry. The pressure gradient between cell headroom and spiral-type flow field effectively prevents back-mixing. This and the tiny gas volume of the flow field ensure best possible time resolution.

PAT-Core configuration example



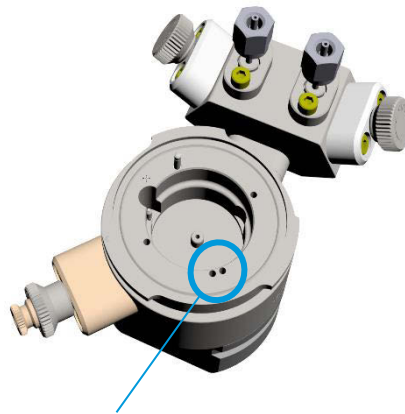
Gas flow along the flow field

7 Disassembly and cleaning

After disassembly, dispose all single-use PAT-Core components and the electrodes properly. Plungers made of stainless steel have to be cleaned with plenty of water. If necessary, remove persistent dirt from the plungers with aqueous nitric acid (20%, 2 hours at room temperature). The other cell components must not come into contact with nitric acid. Before re-use inside the glove box, completely disassemble the cell and dry the cell parts in vacuum (<0.01 mbar) at 80 °C for at least 12 hours.

For the cell variants with pressure sensor (options P and SP), the two adjacent holes at the top of the cell base (circled in the picture below) make connection to the laser welded pressure sensor located inside the lower part of the cell base. In order to avoid corrosion, no liquids must enter these holes during cell assembly, cell operation and cleaning.

For the cell variants without pressure sensor, the two adjacent holes are dead-ended. Still, avoid contamination with electrolyte and other liquids.

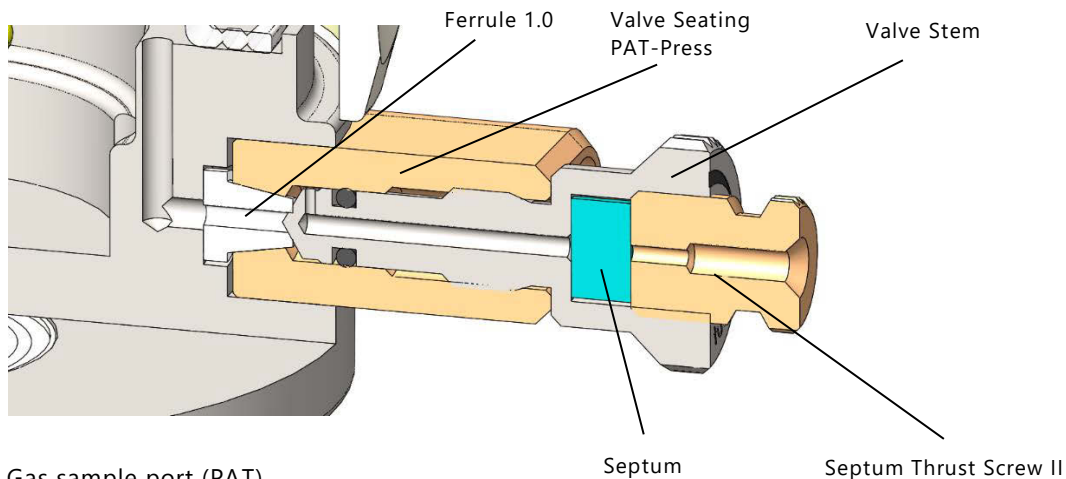


Holes towards the stainless steel membrane of the laser welded pressure sensor (options P and SP). For all other options, these holes are dead-ended.

Avoid contact with electrolyte or other liquids!

8 Sample valve with septum port (options S and SP)

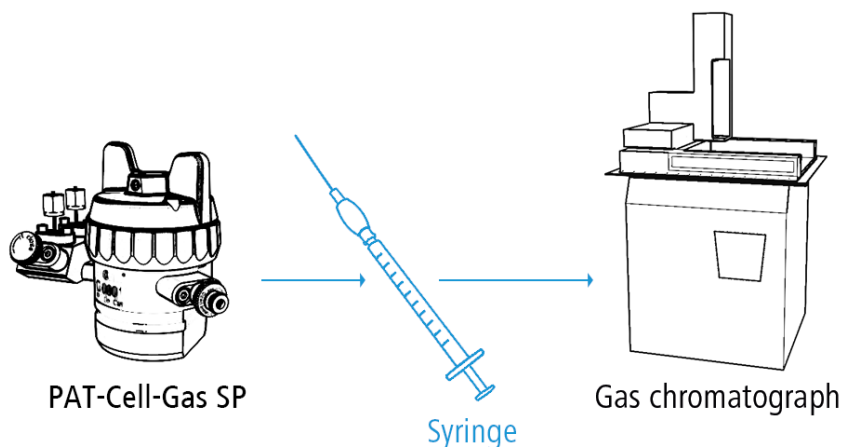
The gas sample valve serves to draw gas samples for further characterization from the head space of the test cell.



Gas sample port (PAT)
ECC1-00-0155-C

In the closed state, the valve spindle is seated on the PTFE ferrule and is thus preventing any bleeding through the pierced septum.

8.1 How to draw gas samples



1. Pierce the septum with a sample syringe appropriate for the subsequent gas analysis with e.g. a gas chromatograph. We recommend using a syringe with a pencil-point needle in order to prevent clogging when the septum of the sample port is pierced. A 1 ml syringe (LAB0024) and a pencil-point needle (LAB0039) are provided with the equipment.
2. Open the valve by turning the valve handle counter-clockwise by approx. 90 degrees
3. Fill the syringe by drawing back the syringe piston.
4. Close the valve by turning the valve handle clockwise till finger tight, and remove the syringe.

Note: Do not connect the sample port directly or permanently to an external device.

9 Unpacking

Check the contents of the packages against the list given below to verify that you have received all of the required components. Contact EL-CELL, if anything is missing or damaged.

NOTE: Damaged shipments must remain within the original packaging for freight company inspection.

List of components

- PAT-Cell-Gas test cell without PAT-Core

Note: The components of the PAT-Core (insulation sleeves and plungers) must be purchased separately.

Accessories kit for PAT-Cell-Gas with Gas Sample Port

ECC1-00-0315-A

- Septum (10x) [ECC1-00-0097-B/X](#)
- Syringe 1ml (w/o Luerlock) [LAB0024](#)
- Spinal needle pencil-point (27g) [LAB0039](#)
- Sealing ring PEEK (5x) [ECC1-00-0232-D](#)
- Sealing ring PE (10x) [ECC1-00-0232-A/X](#)
- Ferrule 1.0 [ECC1-00-0029-B](#)

Accessories kit for PAT-Cell-Gas without Gas Sample Port

ECC1-00-0315-C

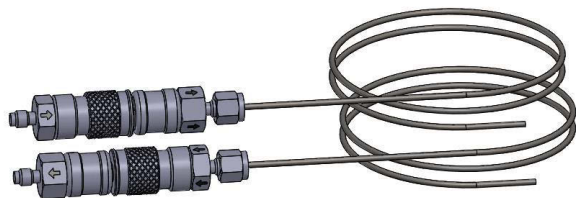
- Sealing ring PEEK (5x) [ECC1-00-0232-D](#)
- Sealing ring PE (10x) [ECC1-00-0232-A/X](#)

10 Accessories

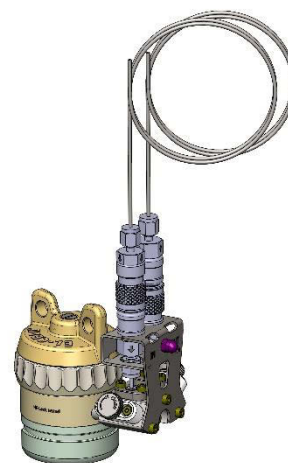
Quick Connect Set

ECC1-01-0080-A

In test mode, the cell must be connected outside the glovebox with the carrier gas supply and a gas meter. This quick connect set with self-locking couplings is suitable for this purpose.

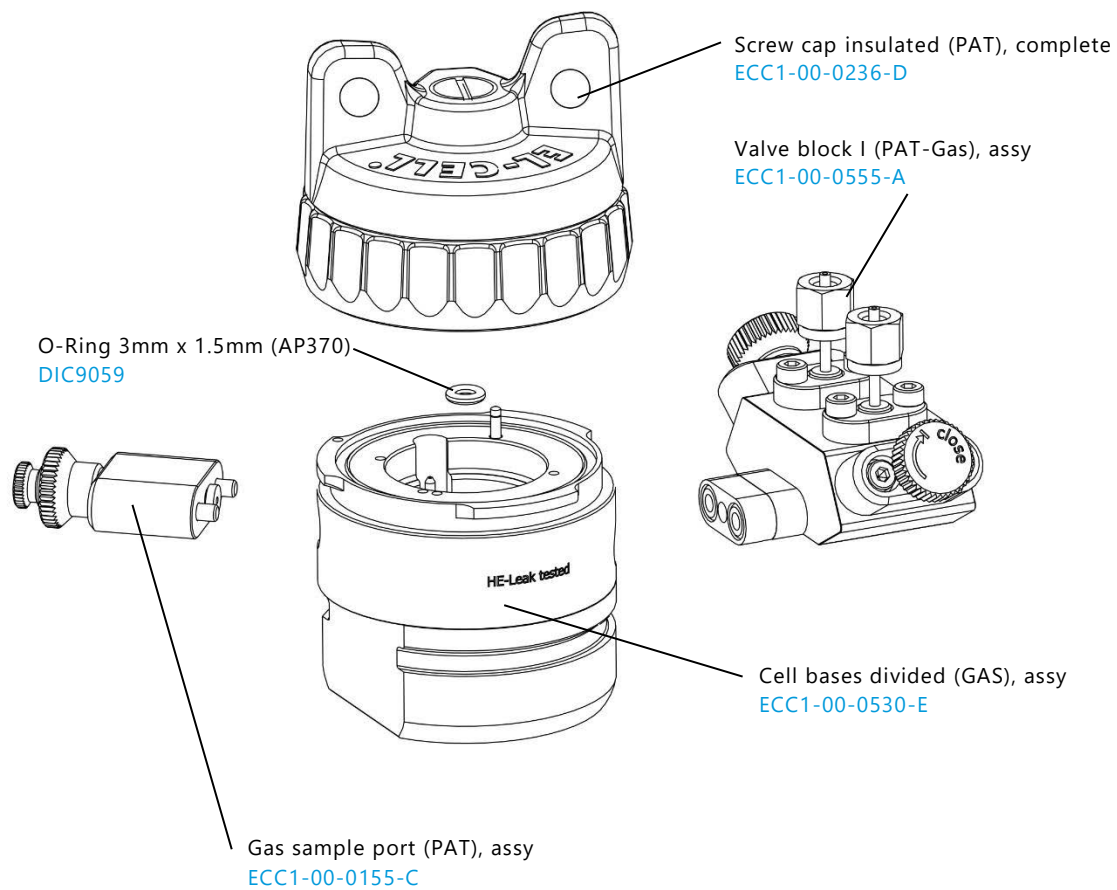
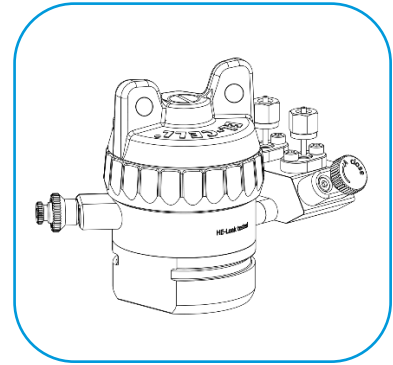


The set includes two self locking couplings (Swagelok) with 500 mm stainless steel tubes 1/16 inch x 0.02 inch. Compatible with 1/16 inch Swagelok Tube Fitting.



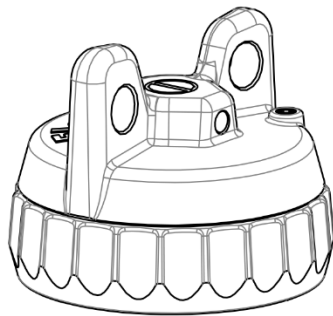
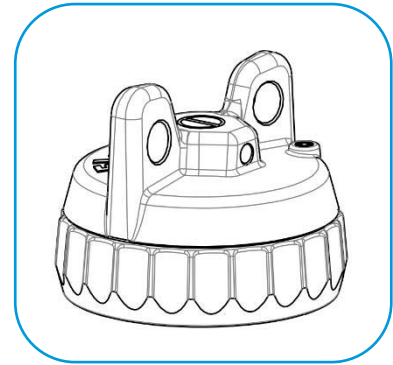
11 Spare parts and consumables

PAT-Cell-Gas SP, complete



Screw cap insulated (PAT), complete

ECC1-00-0236-D



Lid inset (metal seal)
ECC1-00-231-C

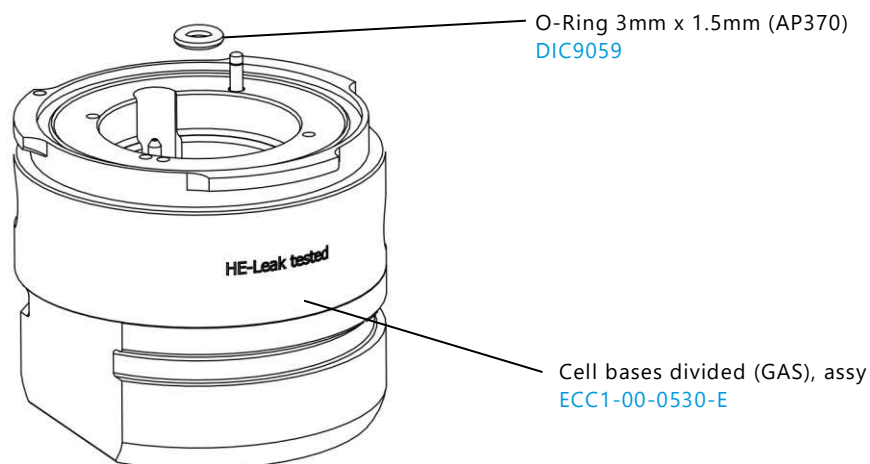
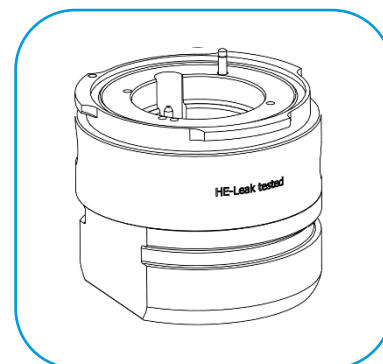
Disc Spring
ECC1-00-0233-A

Compression Spring
FED9028

Sealing ring

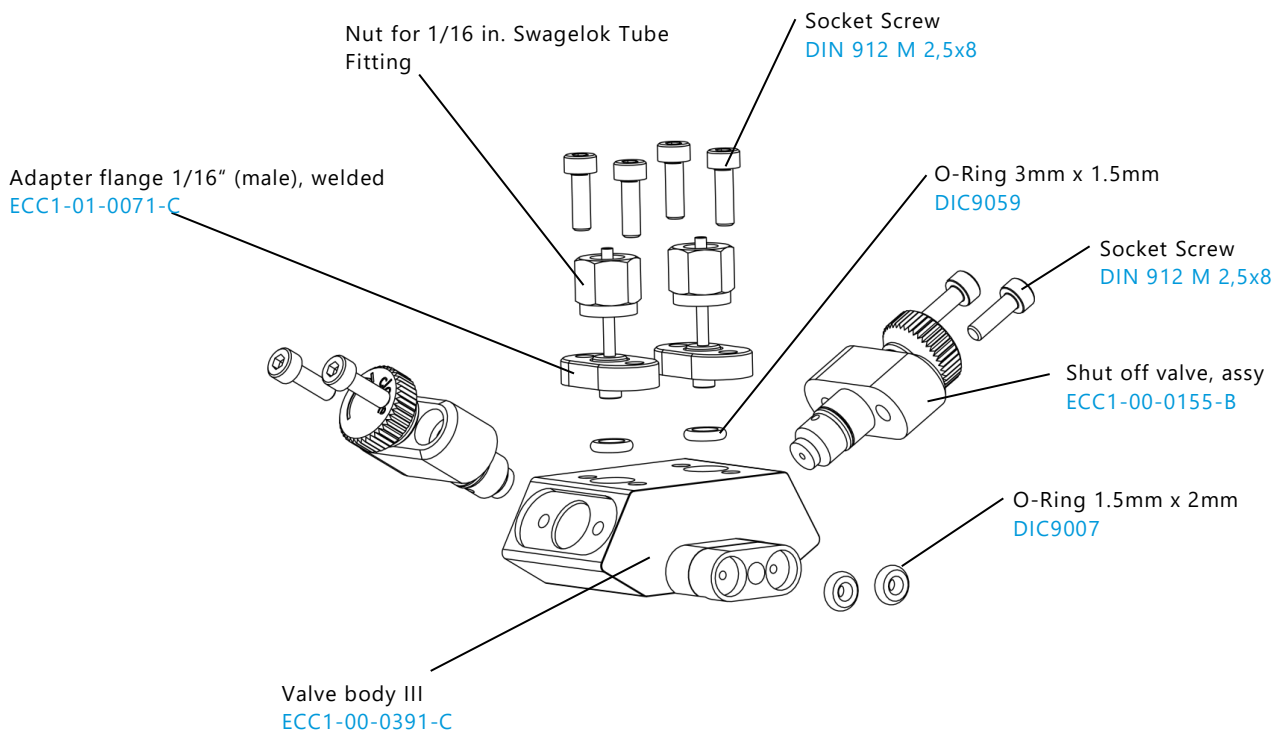
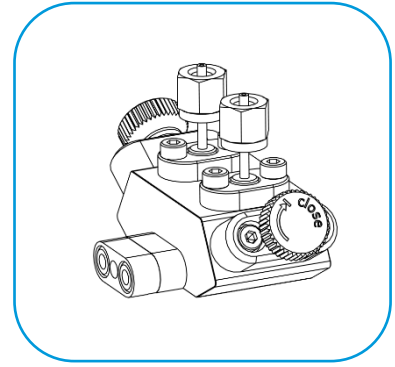
Cell base divided (GAS), assy

ECC1-00-0530-E



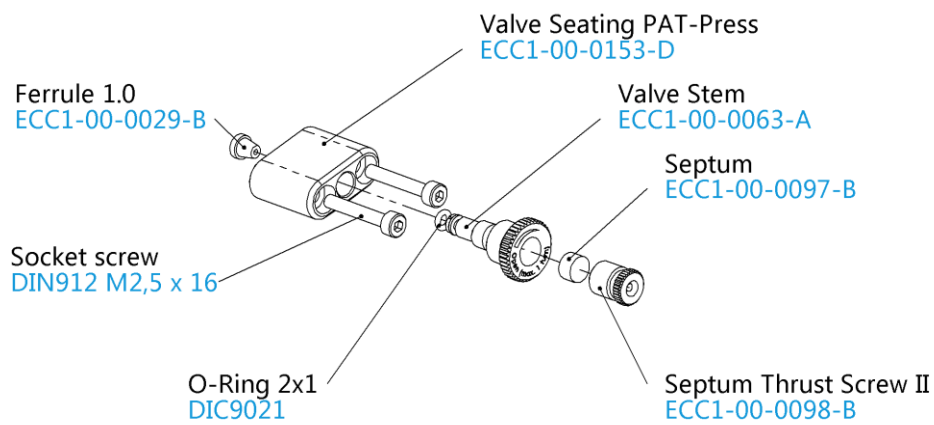
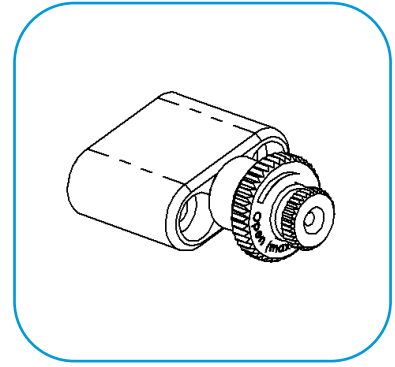
Valve block I (PAT-Gas), assy

ECC1-00-0555-A



Gas sample port (PAT), assy

ECC1-00-0155-C



12 Technical support

Technical support for this product is exclusively provided by EL-Cell GmbH.

EL-Cell GmbH

Tempowerkring 8

21079 Hamburg - Germany

phone: +49 40 79012-737

fax: +49 40 79012-736

e-mail: info@el-cell.com

web: www.el-cell.com

13 Warranty

For a period of one year from the date of shipment, EL-Cell GmbH (hereinafter Seller) warrants the goods to be free from defect in material and workmanship to the original purchaser. During the warranty period, Seller agrees to repair or replace defective and/or nonconforming goods or parts without charge for material or labor, or, at the Seller's option, demand return of the goods and tender repayment of the price. Buyer's exclusive remedy is repair or replacement of defective and nonconforming goods, or, at Seller's option, the repayment of the price.

Seller excludes and disclaims any liability for lost profits, personal injury, interruption of service, or for consequential incidental or special damages arising out of, resulting from, or relating in any manner to these goods.

This Limited Warranty does not cover defects, damage, or nonconformity resulting from abuse, misuse, neglect, lack of reasonable care, modification, or the attachment of improper devices to the goods. This Limited Warranty does not cover expendable items. This warranty is void when repairs are performed by a non-authorized person or service center. At Seller's option, repairs or replacements will be made on site or at the factory. If repairs or replacements are to be made at the factory, Buyer shall return the goods prepaid and bear all the risks of loss until delivered to the factory. If Seller returns the goods, they will be delivered prepaid and Seller will bear all risks of loss until delivery to Buyer. Buyer and Seller agree that this Limited Warranty shall be governed by and construed in accordance with the laws of Germany.

The warranties contained in this agreement are in lieu of all other warranties expressed or implied, including the warranties of merchantability and fitness for a particular purpose.

This Limited Warranty supersedes all prior proposals or representations oral or written and constitutes the entire understanding regarding the warranties made by Seller to Buyer. This Limited Warranty may not be expanded or modified except in writing signed by the parties hereto.