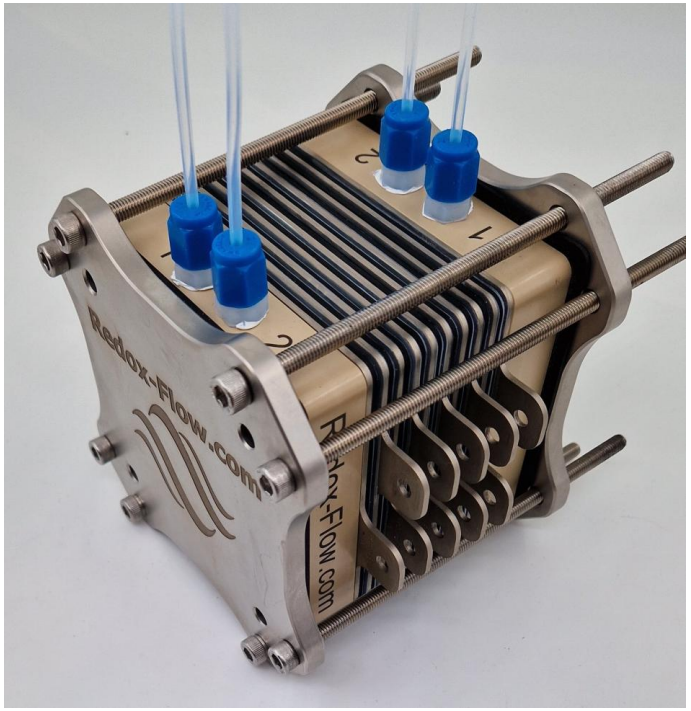
# X-stack

## Overview & assembly manual

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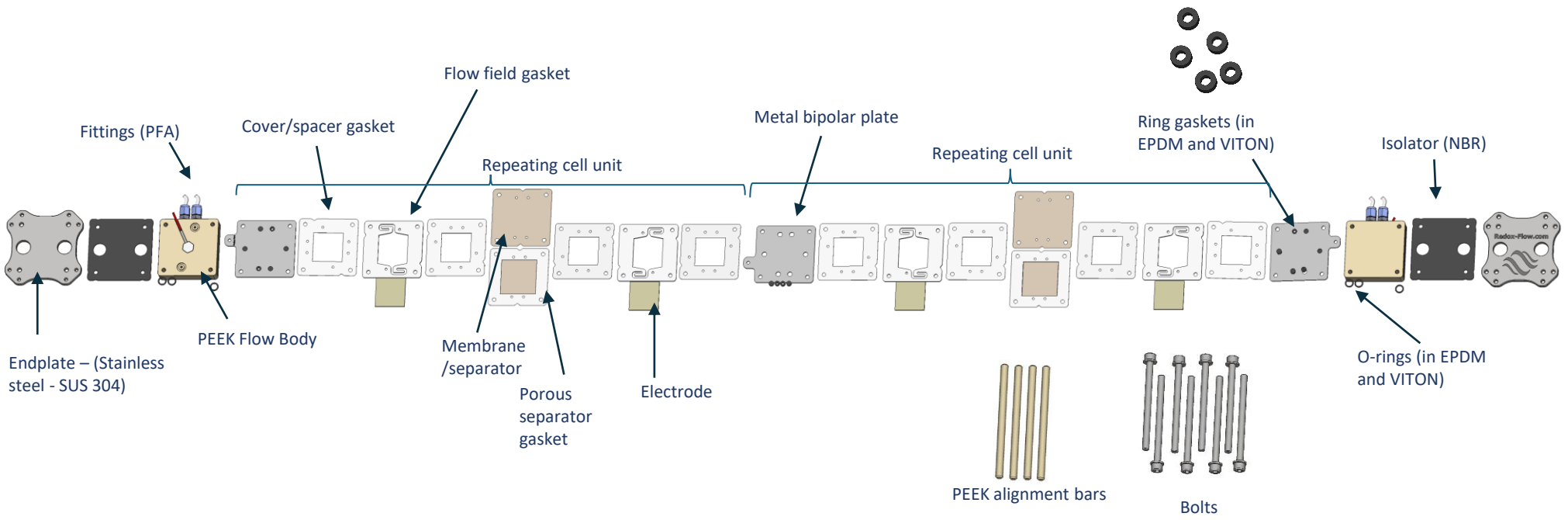
|---|---|
| Version date | March 16 - 2025 |
| Manual version | 2.1 - visit www.redox-flow.com for updated versions and spare parts |
| Notes | This equipment is intended for research purposes only and can be applied for different purposes. There is no guarantee on performance, corrosion or lifetime of the equipment. See https://redox-flow.com/termsandconditions/ for more information. |

# Overview of variants & components included in the cell package

General notes

- All gaskets are ordered separately - can be delivered in PTFE, EPDM and VITON
- Color of gaskets vary. PTFE is white, while VITON and EPDM are black. In this manual gaskets are depicted as white only, however, it represents all gasket materials (PTFE, VITON and EPDM)
- Membranes and electrodes are not included in the cell package – can be ordered separately
- Number of cells in the stack are ordered individually

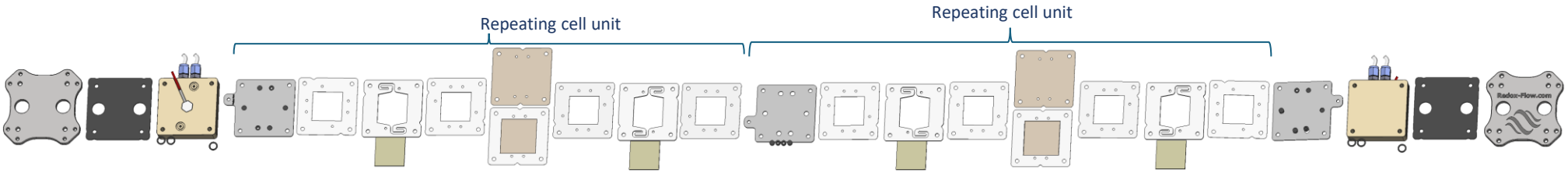



visit www.redox-flow.com for updated information and spare parts

# Assembly

- Image below shows the overall assembly of the stack
- Assembly goes from left to right with the components turned and rotated as shown in the image.
- Following pages shows a detailed description

NOTE: The order of assembly does not strictly need to follow this manual. Depending on use and experience, assembly can deviate from this manual.

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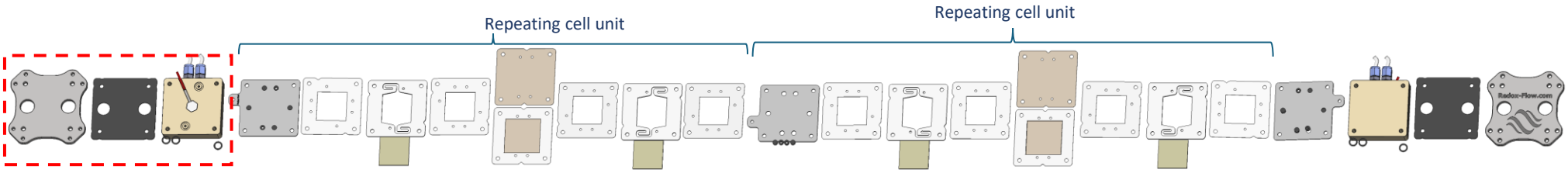
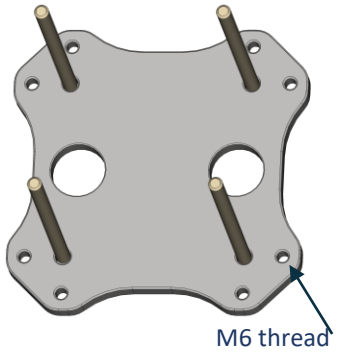
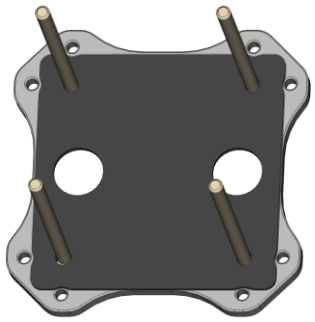
# Assembly – initial assembly



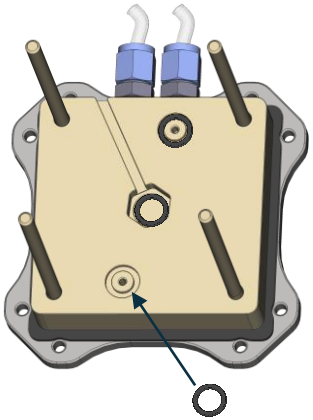




**1**. Threaded endplate is placed with logo downwards

**2**. All four alignment bars are placed in the holes in the endplate

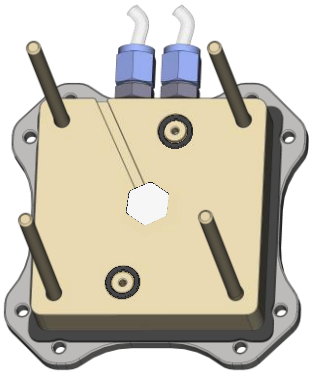


**3**. Isolator is placed on endplate



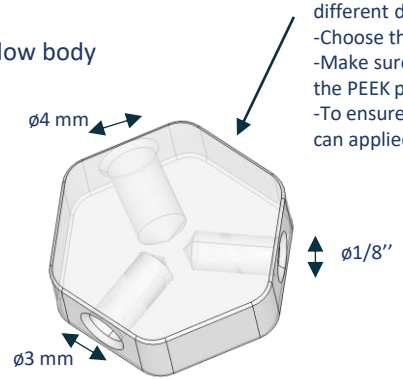
**4**. PEEK flow body is placed on isolator

**5**. All three O-rings are mounted in the PEEK flow body

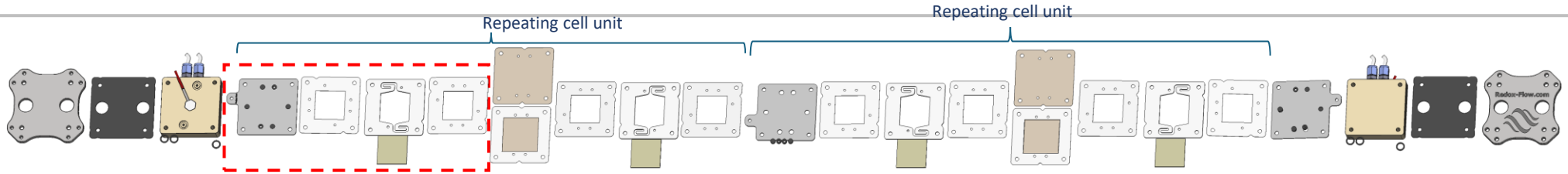


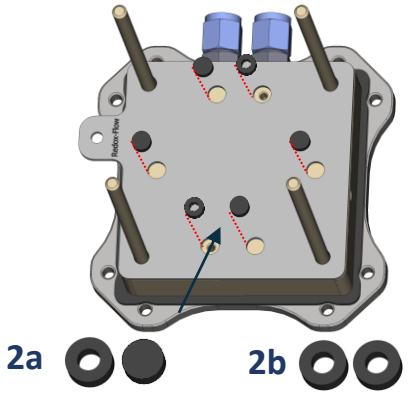
**6**. Alu thermometer holder is placed in the center hole

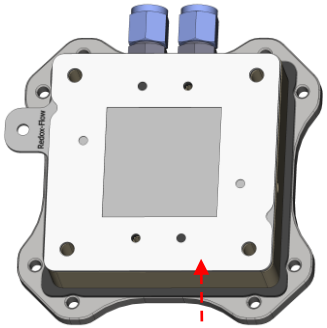
NOTE: The holder comes with three holes with different diameter.
-Choose the hole that fits your thermometer best
-Make sure the hole points toward the groove in the PEEK plate
-To ensure good thermal contact a little grease can applied in the hole.

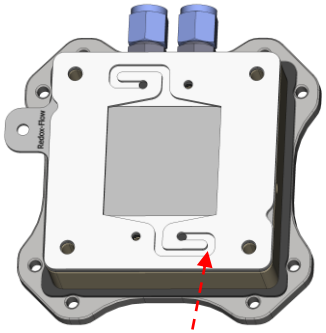


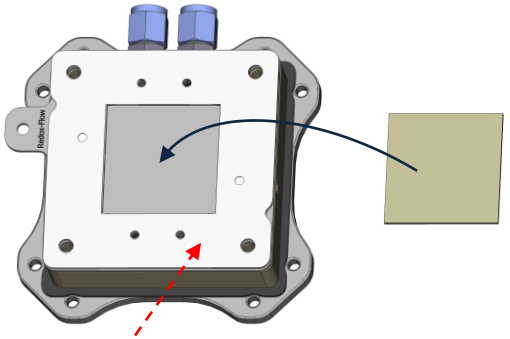
# Assembly – Repeating cells







**1**. Bipolar plate is placed on PEEK flow body
NOTE: The tap of the current collector can be placed either to the left side (as shown) or to the right. It can also be turned towards the bottom

**3**. *Cover gaskets* is mounted

**4**. *Flow field gasket* is mounted

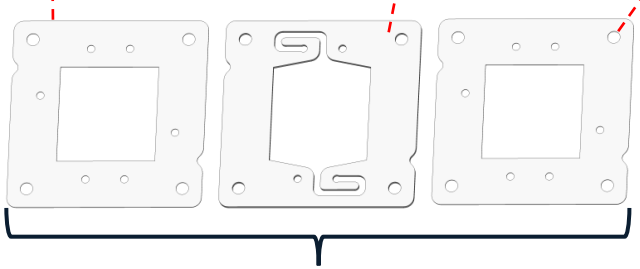
**5**. *Cover gaskets* is mounted

**6**.Electrode is placed inside the gaskets

**2a**. **In first and last bipolar plate in the stack** *Ring gaskets* with holes and without holes are mounted in bipolar plate. *Ring gasket* with holes must be placed in the holes for the inlet/outlet of PEEK flow body.
NOTE: Ring gaskets without holes are used for blocking the manifold

**2b**. **For all bipolar plates (except start and end) in the stack** only *Ring gaskets* with holes are used.

## IMPORTANT NOTES

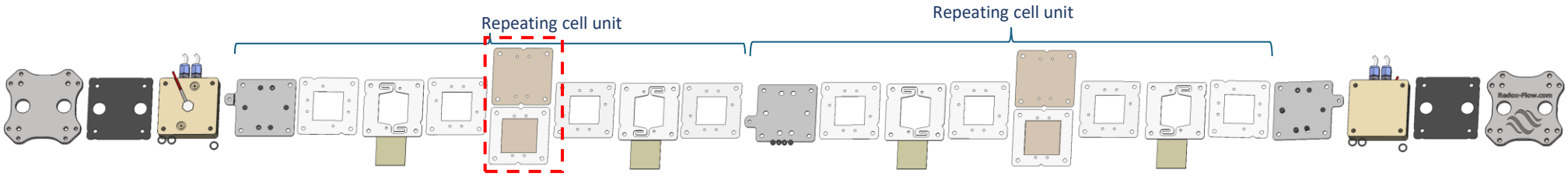


**A.** The final compressed thickness of the electrode is determined by the sum of the thicknesses of all stacked gaskets. Depending on the electrode varying compression is needed to ensure good electrical contact to the current collector

**B.** Several gaskets of all three types can be stacked on top of each of to fine-tune final compressed electrode thickness

**C.** It is recommended to have the *flow field gasket* with a thickness of 1.5 mm to 2.0 mm. This is to minimize shunt currents.
NOTE: If *flow field gasket* with a thickness of 1.0 mm or lower is used, this can lead to significant hydraulic resistance.

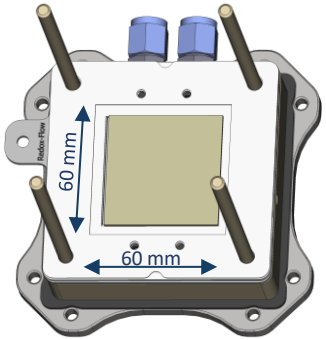
# Assembly – Repeating cells – A. Porous Separators




## A. Assembly with porous separators

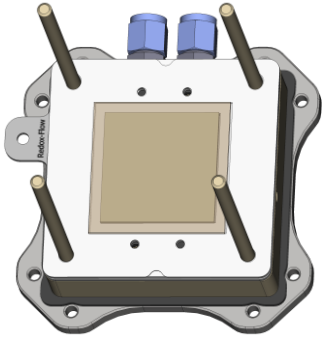
If the cell is operated with a porous separator use this section. If not go to section B on next page.

For porous separators it is in most cases necessary to include a *porous separator gasket* to prevent leaking out through the side of separator




**1**. The *porous separator gasket* is placed on the previous gaskets NOTE: The open area of the *porous separator gasket* is 60mm x 60mm

**2**. Cut a 60 mm x 60 mm separator



**3**. Place the separator inside the *porous separator gasket*

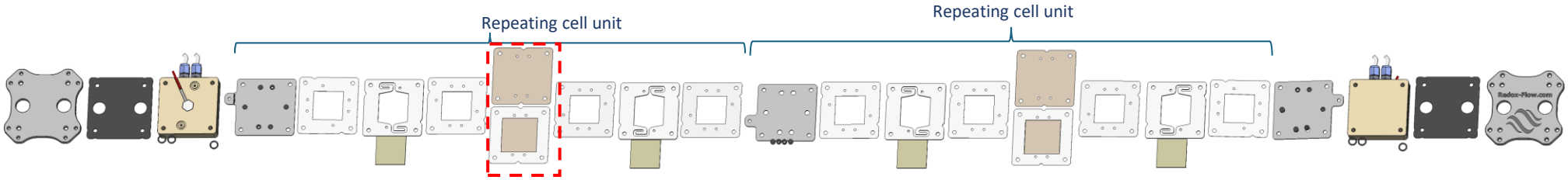
## IMPORTANT NOTES

**A.** It is recommended to have *a porous separator gasket* thickness, that has the same thickness or slightly thinner than the thickness of the porous separator (e.g. within 0.0 mm to 0.1 mm)

**B.** Several *porous separator gaskets* can be stacked on top of each of to fine-tune final thickness

**C.** It is recommended to use either VITON or EPDM (compressible) as the main gasket and fine tune with PTFE gaskets. This will make sealing easier.

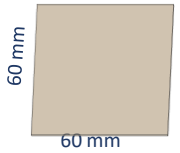
# Assembly – Repeating cells – B. Thin Membranes




## B. Assembly with dense & thin membranes

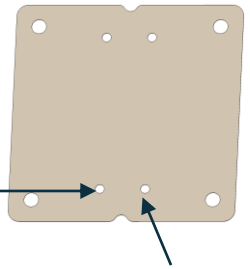
If the cell is operated with a dense and thin membrane a *porous separator gasket* is not necessary, and membranes of variable areas can be used.

**1a**. Use a membrane with a minimum dimension of 60 mm x 60 mm



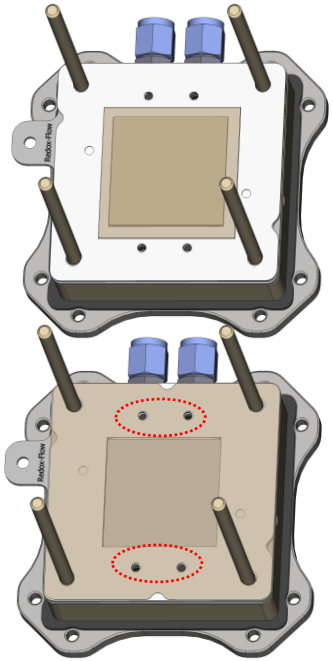

**OR**

**1b**. Use a membrane with the same outer dimensions as the gaskets (approximately 100 mm x 100 mm)
NOTE: The holes for the manifold must be in the range 4 mm to 5 mm



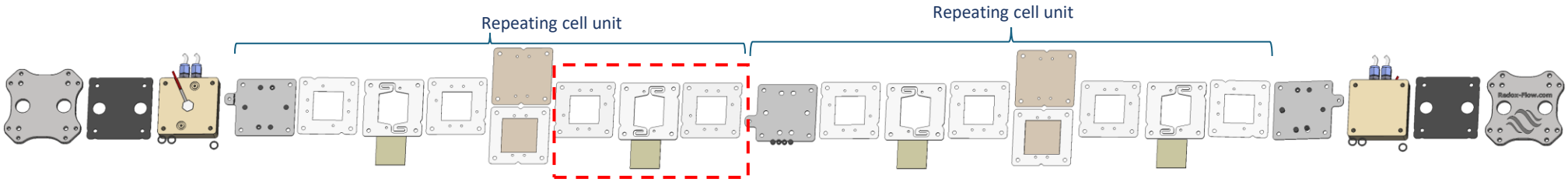

**OR**

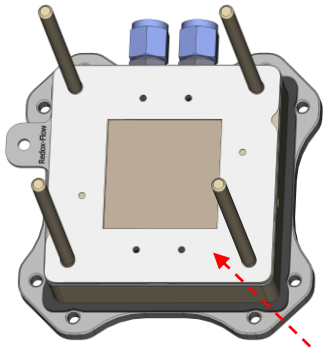
**1c**. Use a membrane with any dimension in between 1a and 1b
NOTE: Membranes have to fully cover or not cover the manifold holes



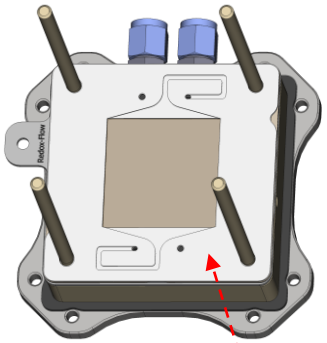
**2**. Mount the membrane
Note: The manifold holes must be exactly on top of the holes in the previous gasket

# Assembly – Repeating cells

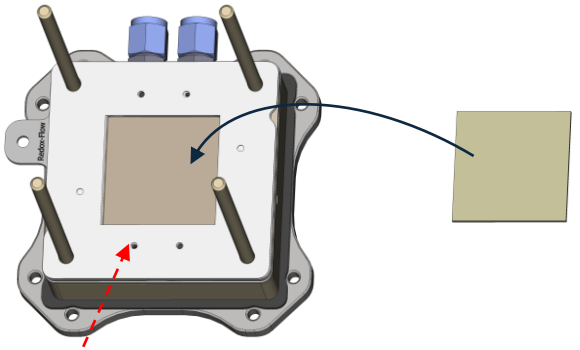


**1**. *Cover gaskets* is mounted



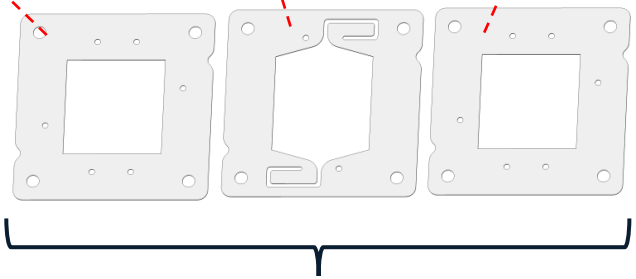
**2**. *Flow field gasket* is mounted



**3**. *Cover gaskets* is mounted

**4**.Electrode is placed inside the gaskets

## IMPORTANT NOTES

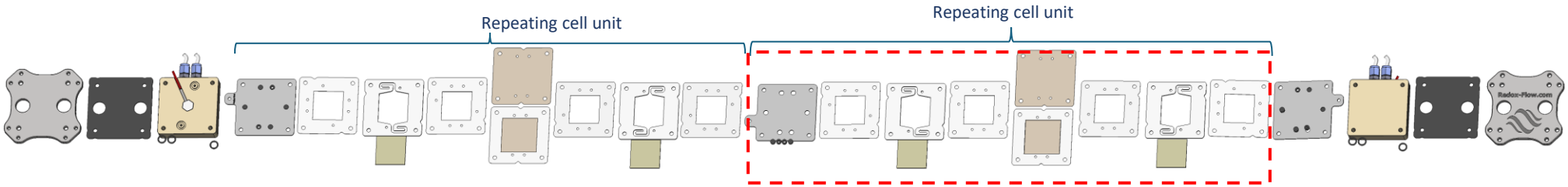


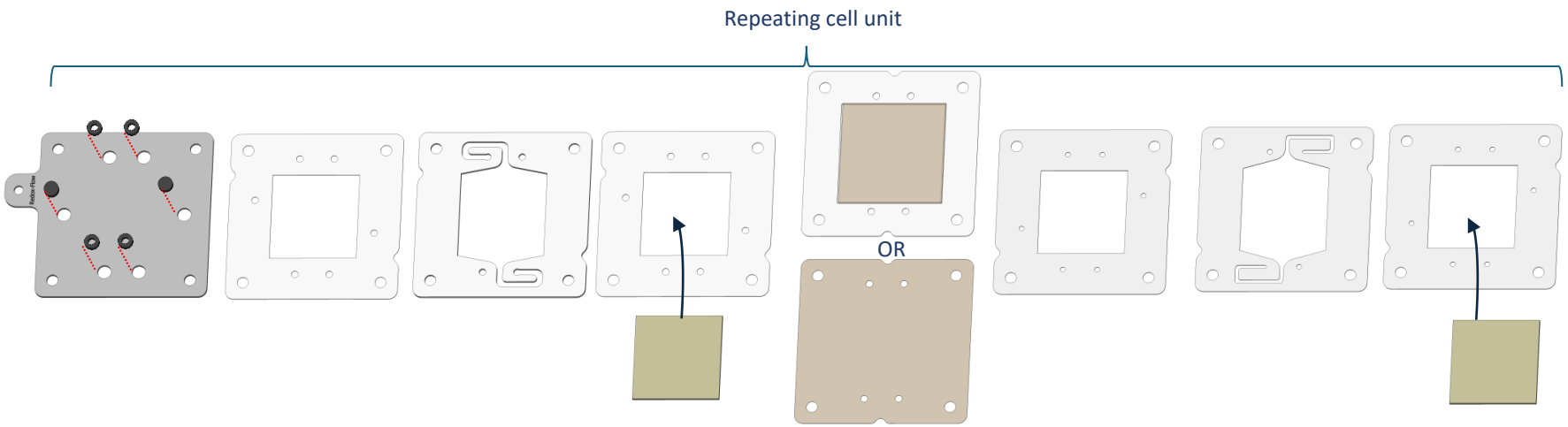
**A.** The final compressed thickness of the electrode is determined by the sum of the thicknesses of all stacked gaskets (as shown on previous page).

**B.** Several gaskets of all three types can be stacked on top of each of to fine-tune final compressed electrode thickness

**C.** It is recommended to have the *flow field gasket* with a thickness of 1.5 mm to 2.0 mm. This is to minimize shunt currents.
NOTE: If *flow field gasket* with a thickness of 1.0 mm or lower is used, this can lead to significant hydraulic resistance.

# Assembly – Repeating cells

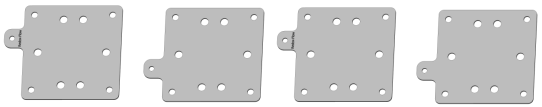


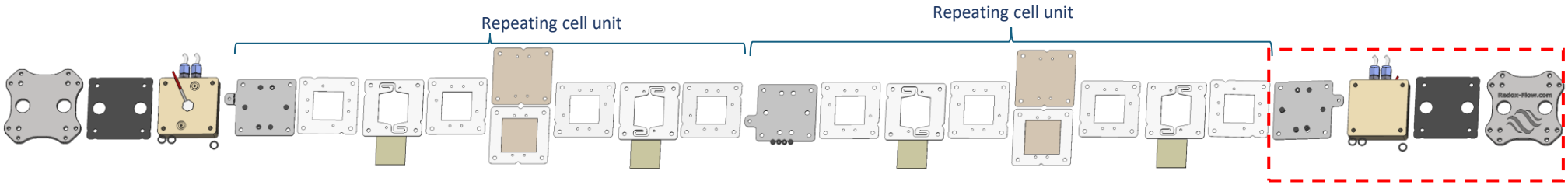

## SUBSEQUENT CELLS IN THE STACK

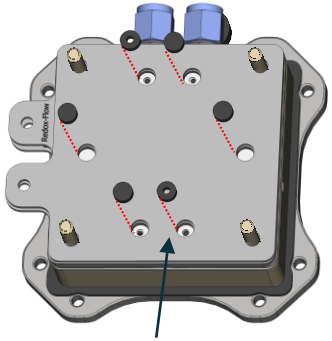
**A.** All subsequent cells in the stack follow the scheme outlined above and described in detail in the previous pages of the manual.

**B.** The bipolar plates (current collectors) can be mounted in different ways. Only requirement is that the four holes are at the top and bottom. It is recommended to alternate the position of the tab from top to bottom between cells (see the image at right)



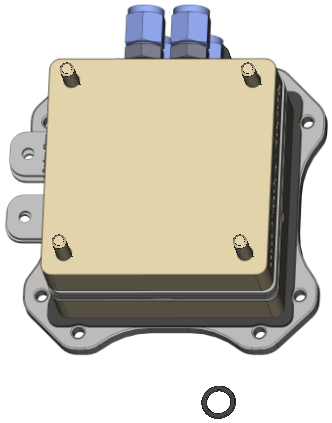
# Assembly – Final assembly



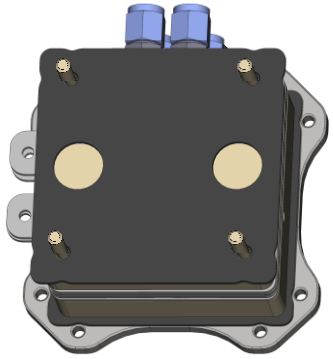
**1**. Last bipolar plate is mounted on the cell

**2**. *Ring gaskets* with holes and without holes are mounted in bipolar plate. *Ring gasket* with holes must be placed in the holes for the inlet/outlet of PEEK flow body.

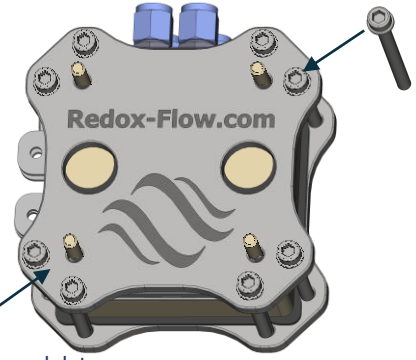


**3**. All two/three O-rings are mounted in the PEEK flow body (opposite side)
NOTE: If a thermometer is also used on this side, the thermometer holder should also be mounted.

**4**. PEEK flow body is mounted



**5.** Isolator is mounted




Hole for bolts in endplate is without a thread

**6**. Unthreaded endplate is placed with logo downwards

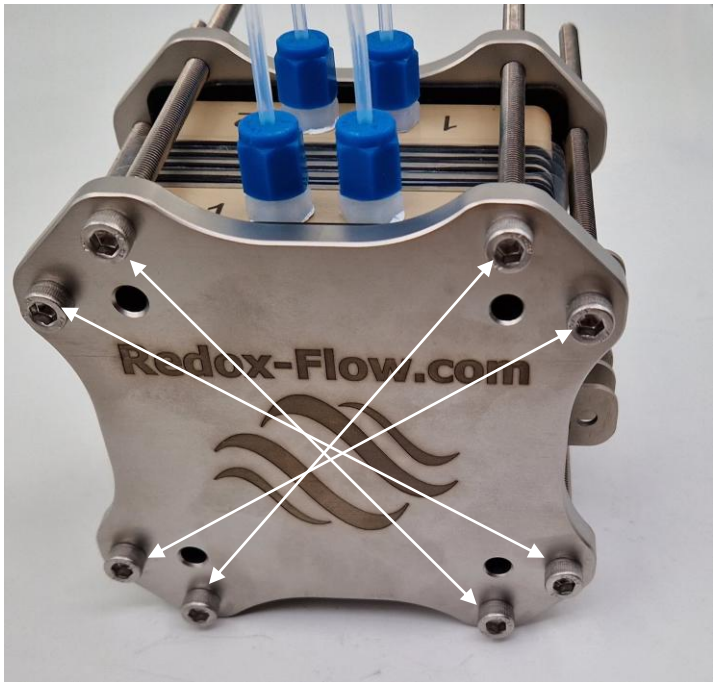
7. All eight bolts are placed in the outmost holes in the endplate
NOTE: Use bolts with correct length
NOTE: Keep alignment bars in the cell – they are taken out during the tightening of the cell

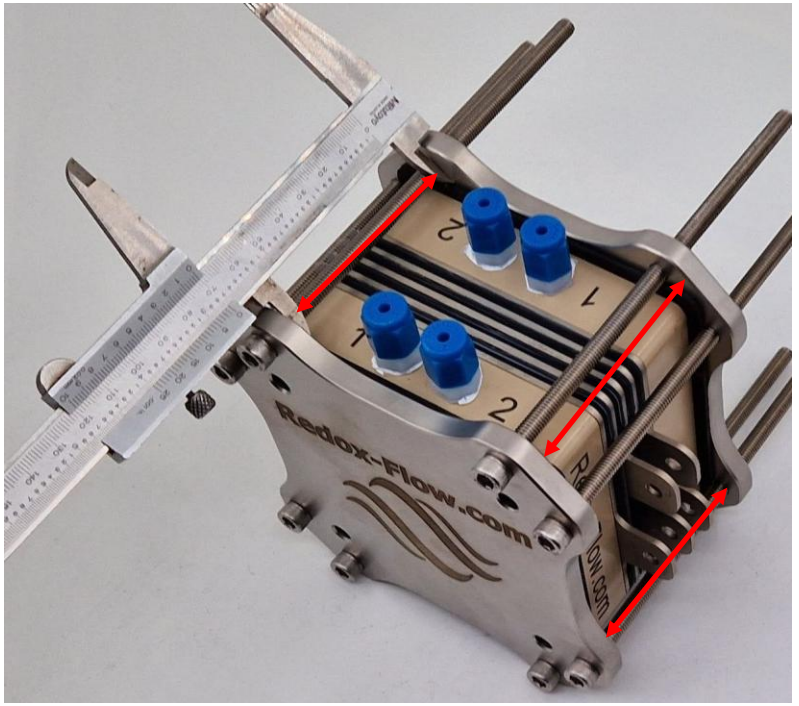
CELL IS NOW ASSEMBLED AND READY FOR TIGTHENING

# Assembly – Final assembly


The integrity of gasket assembly can be inspected on the stack from the outside. The notches in the gaskets between each half cell must alternate as shown below

# Assembly – Final assembly




**STEP 1**

- Hex bolts are cross tightened up to 6 Nm.
- Alignment bars are removed before cell is completely tightened - if left in the cell, there is a (small) risk of leaks inside channels for the alignment bars

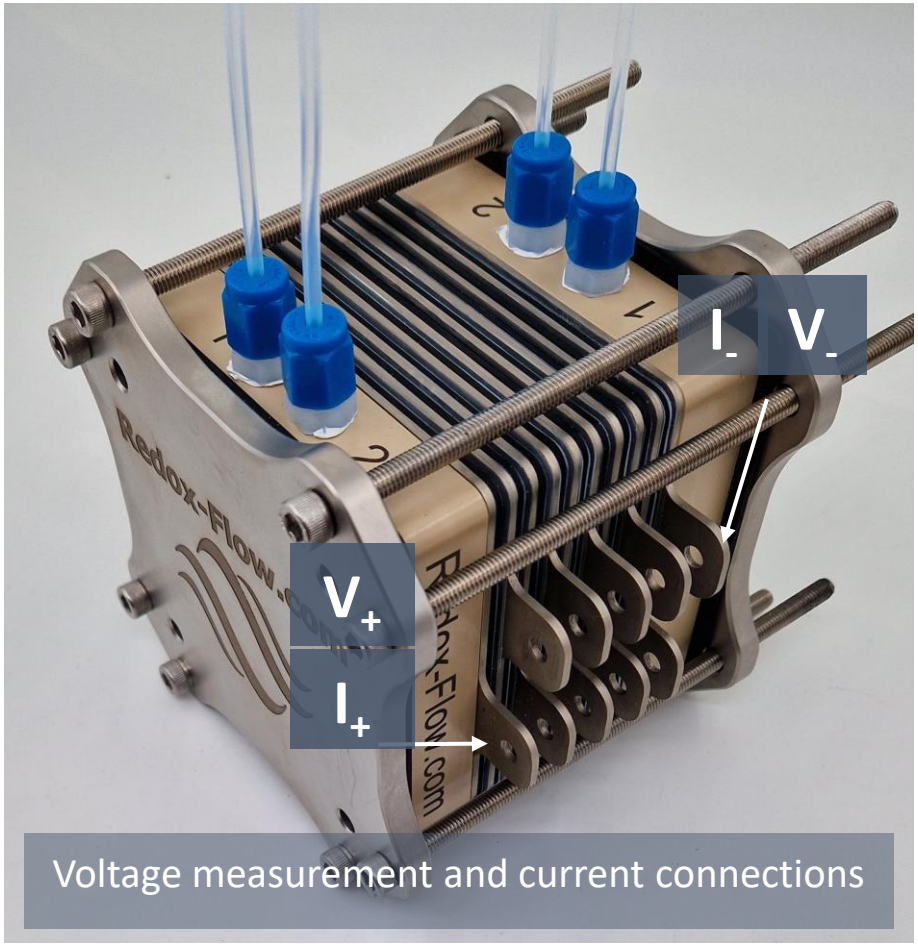
**STEP 2**

- Quality of the cross tightened is checked by measuring the distance between the endplates at all four corners with a caliber
- The distance should not vary more than 0.1-0.2mm
- NOTE: Step 1 and 2 can be performed iteratively.

**IMPORTANT NOTES**

- Measurement with caliber is paramount for a tight sealing – It is not a high torque that seals the cell, it is a correct alignment of the flow bodies

# Application notes – Electrical connections



Voltage measurement and current connections

IMPORTANT - It is paramount for safety and reproducible data that the wires for

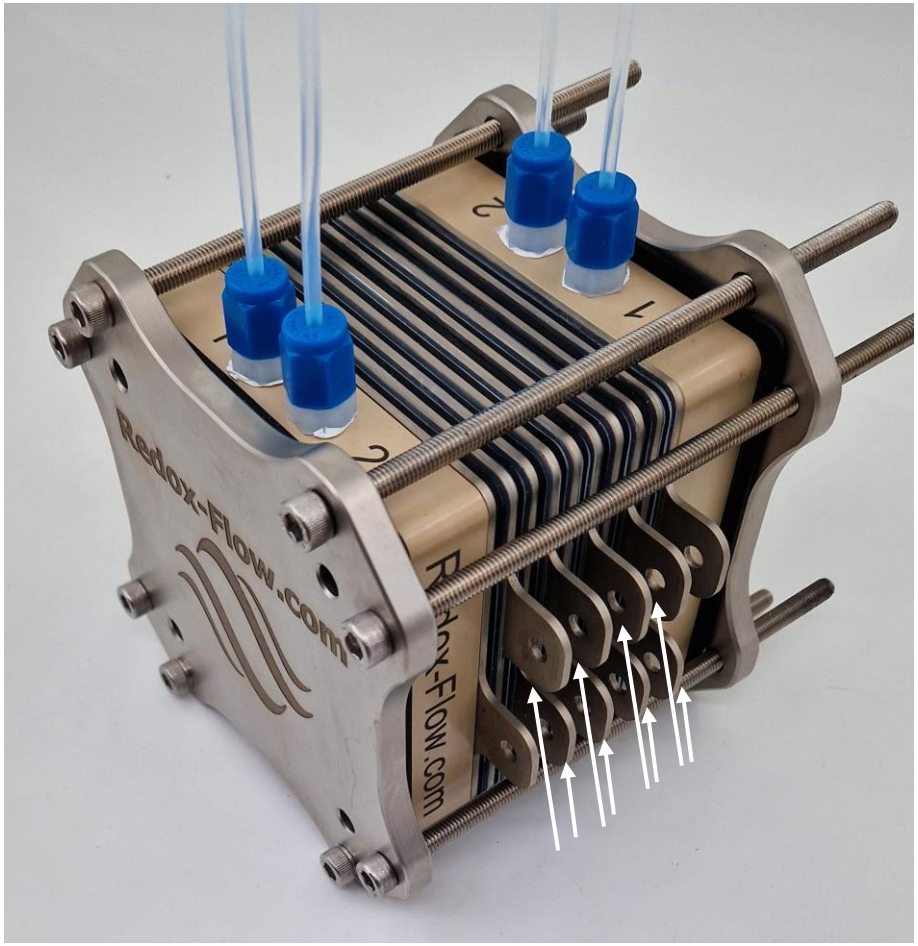
- Electrical current ($I_+$ and $I_-$) are well connected on the current collectors (bipolar plates) at the start and end of the stack. E.g. with cable lugs, bolts other recognized solutions for making proper electrical connections

NOTE: Poorly connected current wires will lead to significant contact resistance between the wire and current collectors. For high current operation (e.g. > 1 A) the contact resistance (even small ones) can lead to significant heating in the contact points.

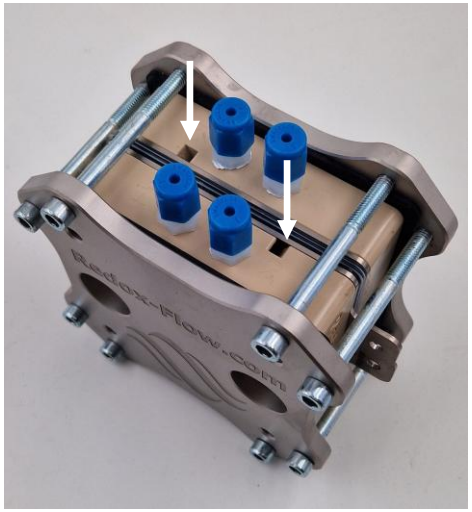
- Voltage measurements ($V_+$ and $V_-$) are mounted on the current collectors to ensure a proper 4-wire configuration

NOTE: As the wires for voltage measurement does not carry any electrical current, there are no strict requirements for the quality of the connection and can e.g. be connected with crocodiles or similar

# Application notes – Electrical connections




- Individual cell voltages can be measured on each of the PEEK bipolar plates

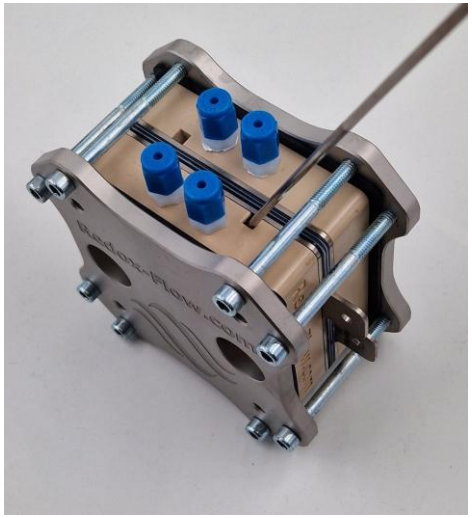


**Holes for thermometers (shown for single cell)**

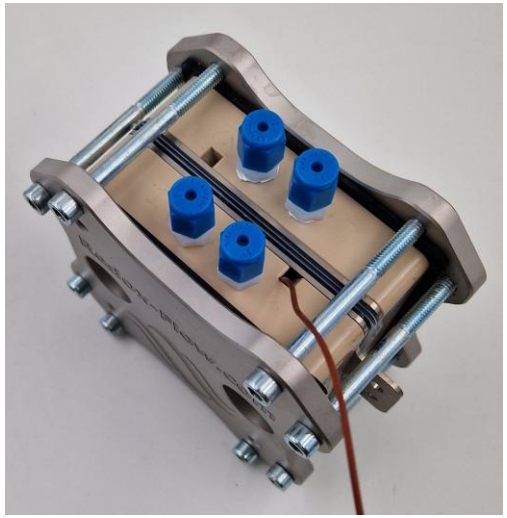
**Temperature sensor**

- In each of the PEEK flow bodies there are holes with direct access to the aluminum thermometer holder. The distance from the PEEK surface to the bottom of the thermometer holder is approximately 55 mm
- The aluminum holder is pressed up against the metal current collector. This ensures very good thermal contact whereby
    - The temperature can be measured fast (very short time delay on temperature changes)
    - The temperature can be measured very precise
- To increase the thermal contact a little grease can be applied to the head of the thermometer or inside the hole of the thermometer holder

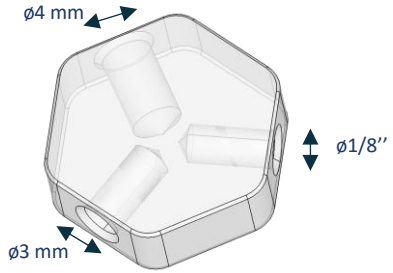
**VERY IMPORTANT**: The thermometer holder is in direct metallic contact with the bipolar plate and will for this reason have the same applied electrical potential as the bipolar plate. **Here is it extremely important that the electrical circuit of the thermometer is electrically isolated from the metal parts**. This is the case for most thermometers with housings (even metallic ones) but can be tested by measuring the electrical resistance with a multimeter between thermometer housing and thermometer measurement wires. However, this is not the case for bare/unprotected thermometer, these can be isolated with tape, shrinking tube or similar.



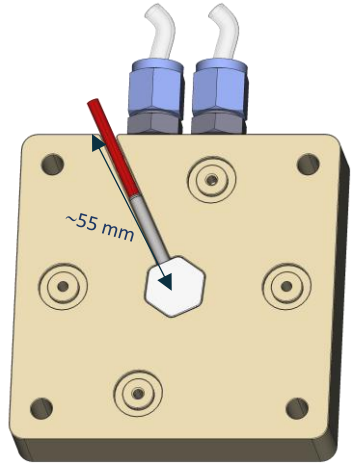
**Mounting with rigid thermometer**



**Mounting with wire thermometer**

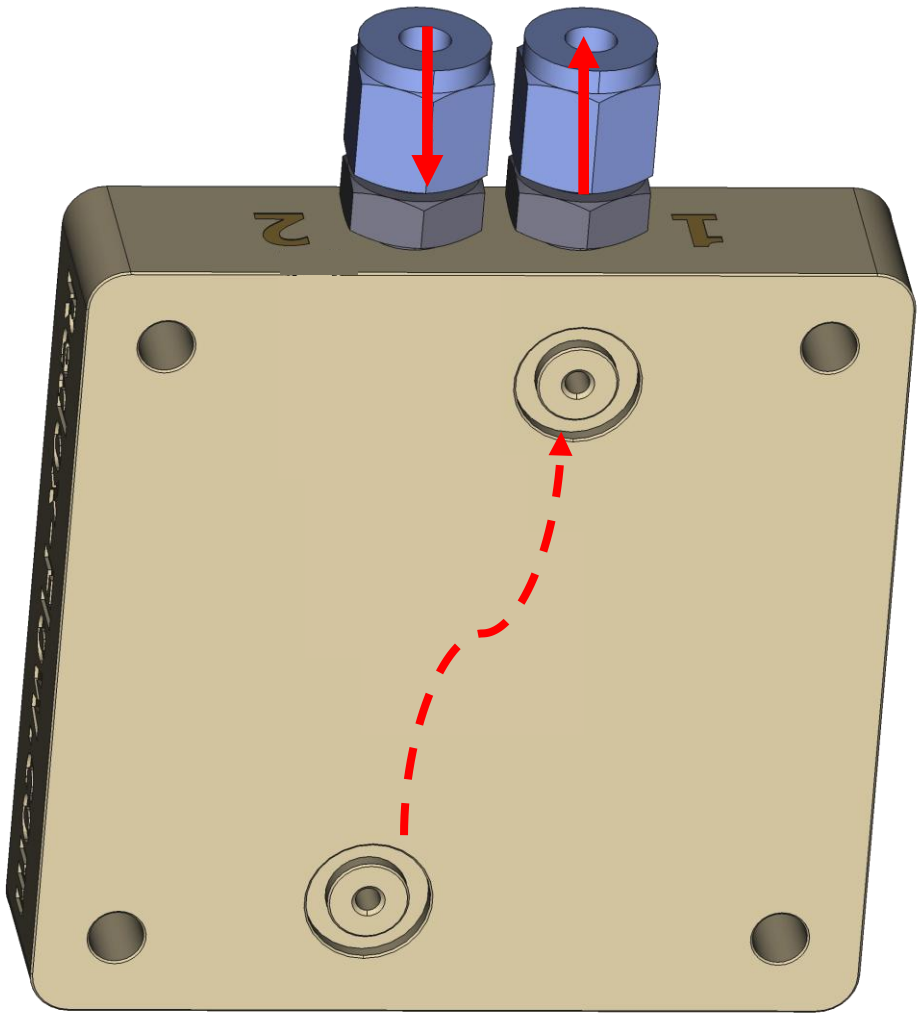



**Thermometer holder**




**Thermometer, holder & PEEK block (metal current collector is mounted on top)**

# Application notes – Hydraulic connections




- For normal operation it is recommended to use **port 1** as outlet of for the liquid and **port 2** as the inlet for the liquid

  NOTE: With this configuration the liquid enters at the bottom and exits at the top. This makes removal of bubbles easier.