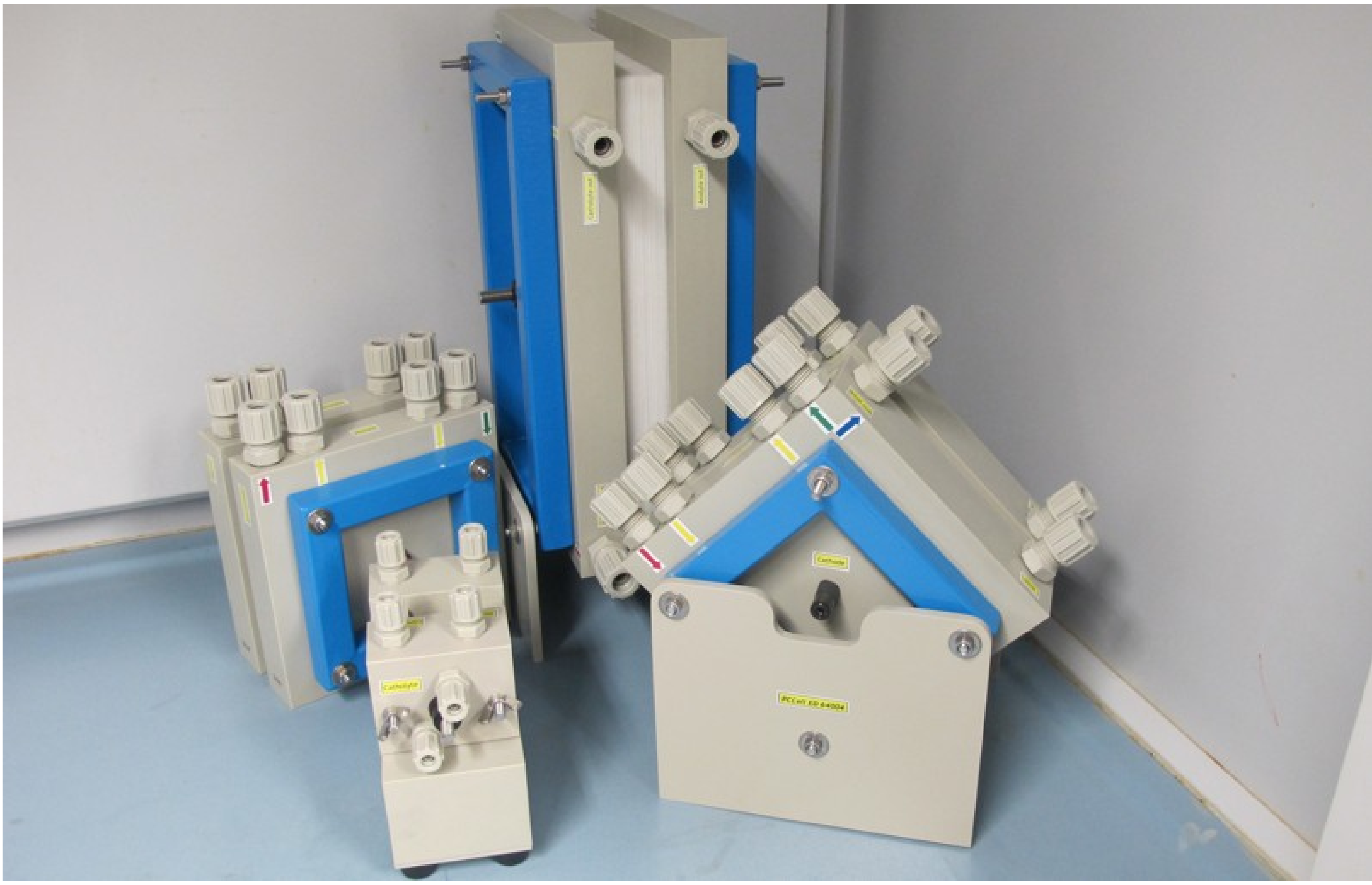
Electrodialysis Cell Unit

PC*Cell* Micro ED, ED 64002,

ED 64004 and ED 200



Technical Description

Read these operation & maintenance instructions before start up!
To be held for future reference.

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CE

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PCCell Laboratory Electrodialysis Cells

Handling instructions

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1. General

The electrodialysis cell units Micro-ED, ED 64002, ED 64004 and ED 200 are used in laboratory electrodialysis processes to remove ions from one solution (diluate). The ions are collected in another solution (concentrate). The electrodialysis cell units allow to carry out different types of experiments for a variety of application, to examine the characteristics of ion exchange membranes in use. It is designed as an easy-to-manage laboratory cell.

The PCCell Micro-ED unit is especially suited for small amounts of solution. It can be used with an open middle chamber for two or four milliliters of diluate solution or as a standard ED with up to 25 cell pairs. In first case, only the concentrate solution is circulated, while the diluate can be stirred in the open chamber. In the standard operation mode diluate and concentrate are circulated.

The ED 64002 and ED 64004 have an active membrane area of 64 cm^2 per membrane and an effective size of 110 x 110 mm. The typical batch sizes of 500 - 2000 ml can be performed (depending on the salt content, matrix material etc). Depending on the requirements those batch sizes are scale-able to lower and higher volumes.

The ED200 has an active membrane area of 200 cm^2 per membrane and an effective size of 125 x 260 mm. The typical batch sizes of 2000 - 20000 ml can be performed (depending on the salt content, matrix material etc). Depending on the requirements those batch sizes are scale-able to lower and higher volumes.

This cell with a process length of 20 cm can also be used in a multi-step mode for single pass desalination. For such application, different types of spacers are available.

A standard electrodialysis cell unit consists of an anode chamber, a cathode chamber and a membrane stack between them. This configuration allows the setup of a variety of processes.

1.1. Standard electrodialysis

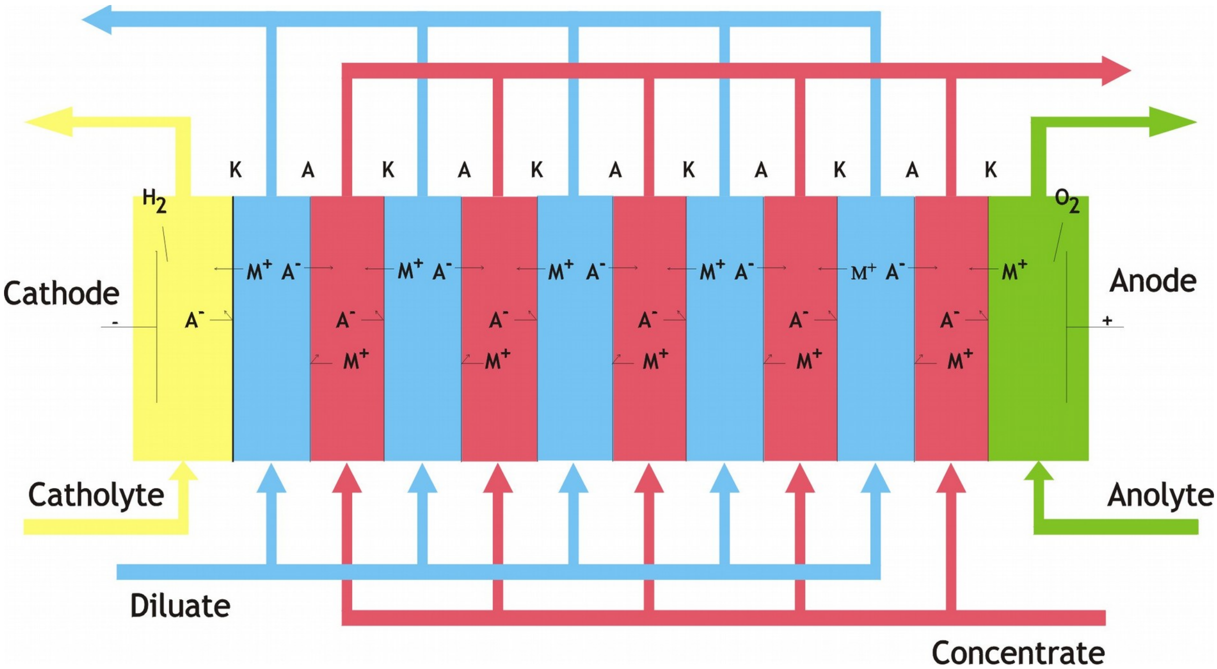

Fig. 1: Functional setup of an ED stack. Salts are removed in cells called "Diluate" and are collected in the Concentrate. Beside this, the electrodes need a solution, the Catholyte and the Anolyte.

A membrane stack for a standard ED consists of n (typically 5, 10, 50 or even 100) cell pairs, which are formed by n+1 cation exchange membranes, n anion exchange membranes and 2 n spacers.

At the shown polarity (Fig. 1), one of the cell systems is the diluate (where the ions are removed) and the other one is the concentrate in which the ions are collected. If the polarity is changed, the function of the cell system changes accordingly.

A complete ED System is set up by this ED Cell in combination with an ED pump unit, e.g. PCCell B-ED 1 and the external solvent tanks build (Fig. 2). Please note in this context, that the ED cell is only one part of the complete system and will work properly only in combination with the other parts.

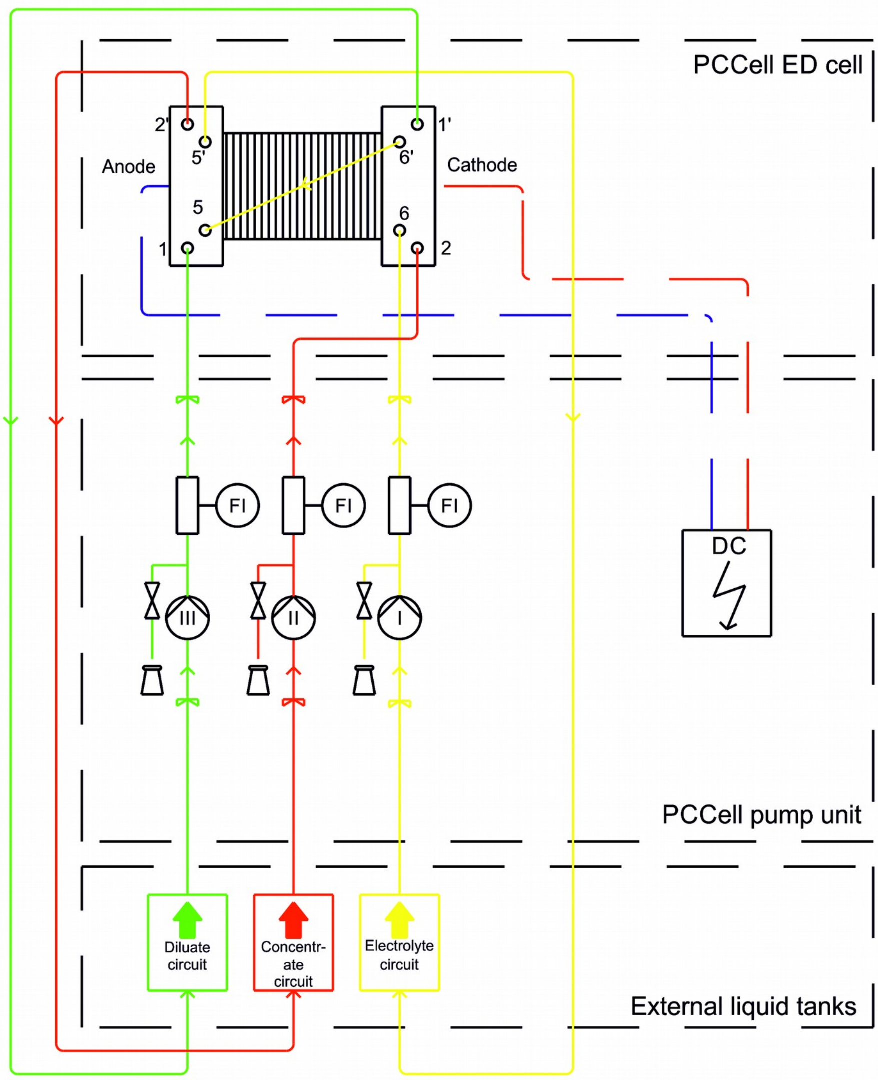

Fig. 2: Example of a complete ED setup, consisting of the stack (upper dotted rectangle),the ED pump unit (middle) and the external electrolyte containers (below).

1.2. Electrodialysis with polarity reversal (EDR)

By changing the polarity of cathode and anode, the function of the diluate circuits and concentrate circuits are changed, too because the direction of the ions is reversed.

Thus, at places where oversaturation took place, now diluting processes take place and vice versa. By doing so, a (more) stable ED process can be achieved.

Beside the electrical change, also a change of the inlet and outlets of the cell need to be performed and can be done by a PCCell T-Valve set.

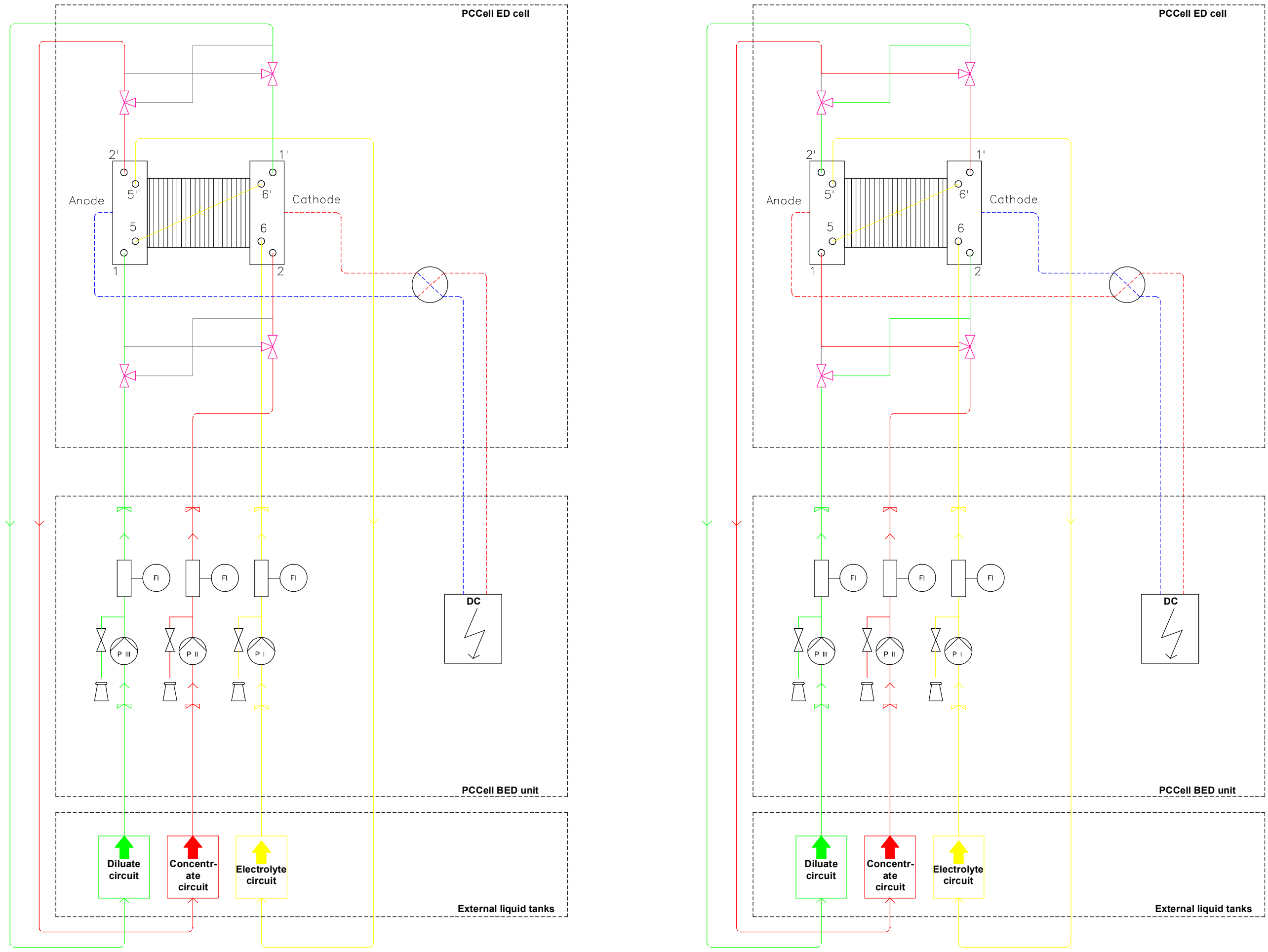

Fig. 3: ED in normal operation(left) and EDR process in inverse operation(right).

Note!
To operate the electrodialysis in EDR mode, you require:
a) an EDR option in the ED cell (both electrodes need to be able to be used as anode)
b) a manual change of current direction as well as concentrate/diluate inlet or an EDR upgrade of the pump unit.

1.3. The three-chamber ED cell

Figure 4 shows the setup of a three chamber ED, as used in Electrodialysis with bipolar membranes (EDBM). The membrane package consists of triples, one of the four circuits of the cell is not in use. The bipolar membrane produces H+ and OH- converting the salt “MA” in its corresponding Acid “HA” and base “MOH”.

Fig. 5 shows a P&I diagram including different measurement devices as an example with the conversion of NaCl:

$$NaCl + H_2O \text{ --> } NaOH + HCl$$

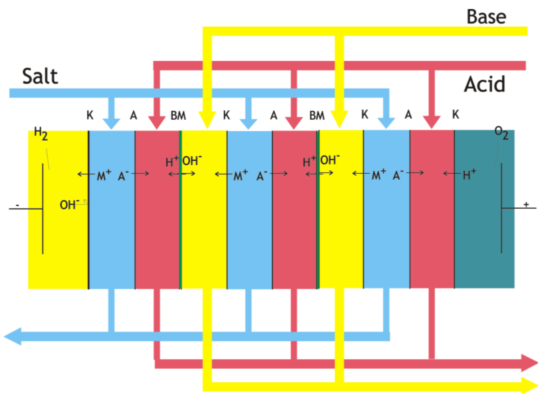

Fig. 4: Functional setup of a three chamber ED stack.

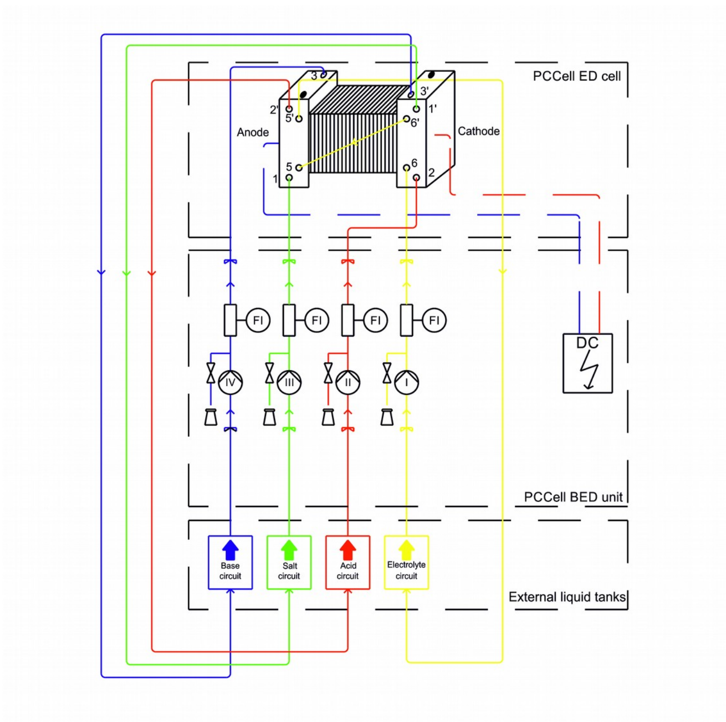

Fig. 5: Exemplary P&I diagram of a complete setup for production of HCl and NaOH from sodium chloride.

1.4. The four-chamber ED cell

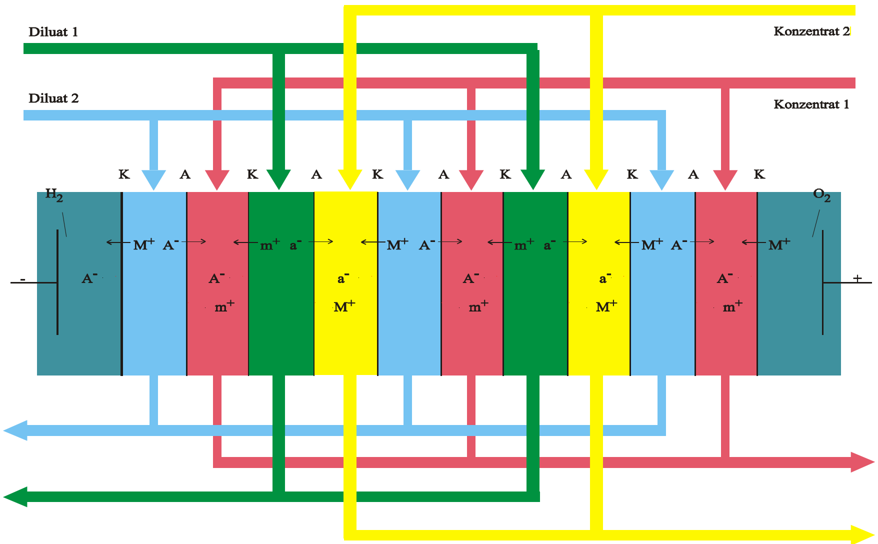

Fig. 6: Functional setup of a four chamber ED stack.

The stack consists of quad-pairs. Each quad-pair comprises two diluates, in which the anions move to the anode in one compartment and the cations in the other compartment. The speciality of this process is that both compartments are not the same but different (Concentrate 1 and Concentrate 2). Each of it collects the anion from one salt stream and the cation from the other. Thus, a chemical reaction takes place. For example:

$$Na_2SO_4 + 2\ KCl \dashrightarrow K_2SO_4 + 2\ NaCl$$

2. Technical Data

2.1. Electrodialysis cell components

The PCCell electrodialysis cells consists of the components shown in the following:

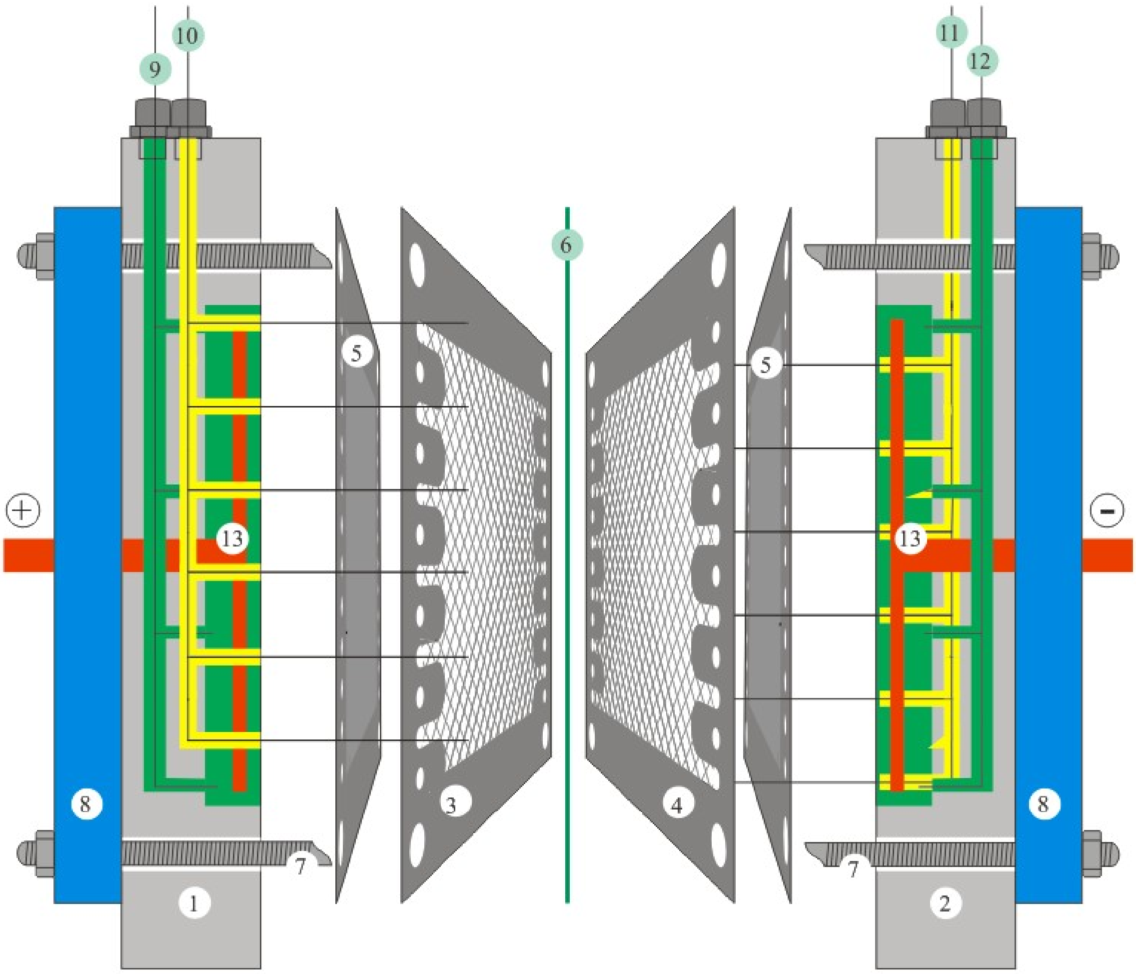

Fig. 7: Schematic view of a PCCell electrodialysis cell with its functional parts.

#	Description	Art No.
1,2	Electrode end plates	
3, 4, 5, 6	Membrane stack	
7, 8	Screw set	
9, 12	Electrolyte inlet	
10, 11	Concentrate and diluate inlets	
13	Electrodes	

2.2. Nomenclature of the cells

The description of the cells is according the following scheme:

Cell type	Number of cell pairs	Membranes	Type
ED 64 002-	010-	2201-	ED1
ED Q380-	T10-	1131-	ED1

Cell type	ED 64 002/004, ED 200, ED Q380...
Number and type of cell pairs	005 = 5 cell pairs (cp) 010 =10 cell pairs T10 = 10 cell triplets (tp) Q20 = 20 quad-pairs (qp)
Cation membrane	Code according datasheet:
Anion membrane	(www.pccell.de/publi/ PCAMembranes.pdf)
Bipolar membrane	0 = no bipolar 1 = standard bipolar
Spacer type	1 = Polypropylene 0,45 mm 2 = Polyester 0,35 mm 3 = PP food grade
ED type	ED1 = conventional ED EDR = electrodialysis reversal ED3 = three cell stages with one center electrode

2.3. Cell sizes

Stack type		Micro-ED	ED 64	ED 200	ED 1000 A	ED 1000 H
Characteristic		ED	ED/EDBM	ED	cont-ED	ED
Effective membrane area	cm2	6	64	207	950	1050
Membrane size	cm	6 x 4	11 x 11	12,5 x 26	30 x 50	30 x 50
Spacer type	mm	0,45	0,45	0,35/0,45	0,35/0,45	0,35/0,45
Processing length	cm	2,8	8	20	70	38
Nominal flow-through / cell	l/h	0,5	8	8	10	30
Membranes per unit	max pcs	25	60	100	200	200
Eff. membrane area / unit	max m2	0,02	0,38	2,0	20	20

Stack type		ED Q380	ED 1600	ED Q1600	ED 2500	ED 4000 H
Characteristic		ED/EDBM	ED	ED/EDBM	ED	ED
Effective membrane area	cm2	380	1840	1600	2530	4000
Membrane size	cm	25 x 25	40 x 46	50 x 50	46 x 55	50 x 100
Spacer type	mm	0,45	0,45	0,45	0,45	0,45
Processing length	cm	20	40	40	55	85
Nominal flow-through / cell	l/h	10	-	25	-	50
Membranes per unit	max pcs	60	200	240	200	400
Eff. membrane area / unit	max m2	2,28	36	38,4	50	160

2.4. Spacer types

Spacer type		0,35 mm	0,45 mm	0,5 mm
Characteristic		Low process length	High chemical stability	Low pressure drop
Thickness	µm	350	450	500
Material	cm	Silicone / Polyester	Silicone / Polypropylene	Silicone / Polypropylene
Mesh type		45°	45°	45°

2.5. Technical specifications

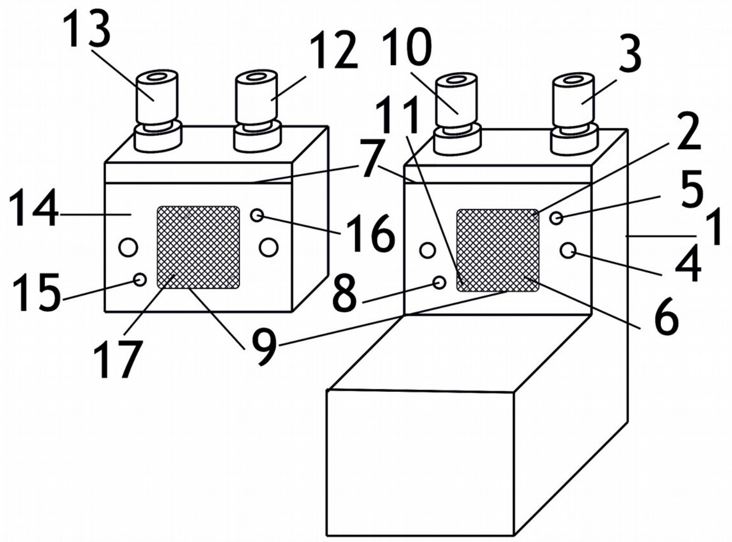

Fig. 8: PCCell Micro-ED electrode end plates.

#	Description
1	Anode block (PP)
2	Anolyte liquid outlet
3	Concentrate (diluate) outlet
4	Clamping bolt hole
5	Concentrate (diluate) connector hole outlet to spacer
6	Anode
7	Membrane and spacer size and position
8	Concentrate (diluate) connector hole to inlet
9	Electrode compartment
10	Concentrate (diluate) inlet
11	Anolyte liquid inlet
12	Diluate (concentrate) outlet
13	Diluate (concentrate) inlet
14	Cathode block (PP)
15	Diluate (concentrate) connector hole to inlet
16	Diluate (concentrate) connector hole to outlet
17	Cathode

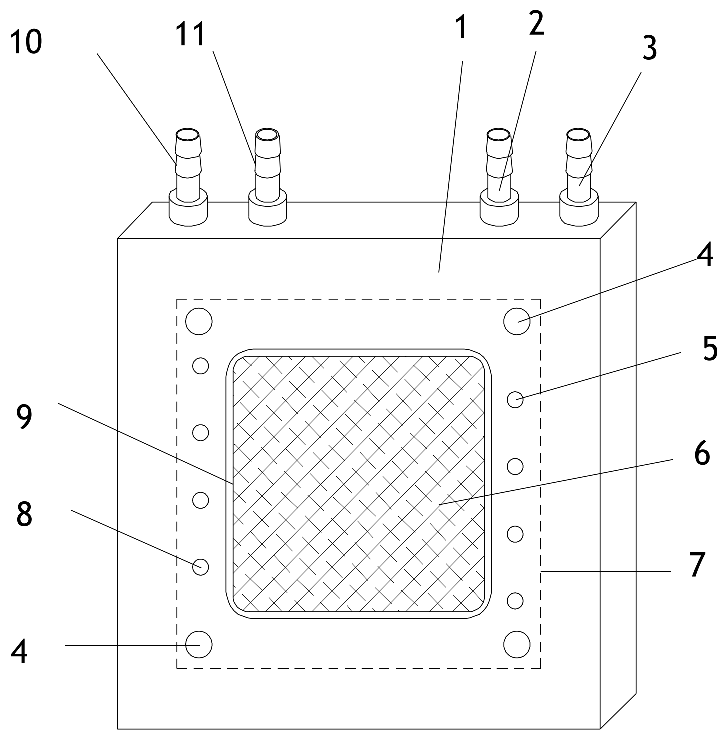

Fig. 9: PCCell ED 64002 electrode end plates.

#	Description
1	Electrode block (PP)
2	Electrolyte liquid inlet
3	Concentrate (diluate) inlet
4	Clamping bolt hole
5	Concentrate (diluate) connector hole to spacer
6	Electrode
7	Membrane and spacer size and position
8	Diluate (concentrate) connector hole to outlet
9	Electrode compartment
10	Diluate (concentrate) outlet
11	Electrolyte liquid outlet

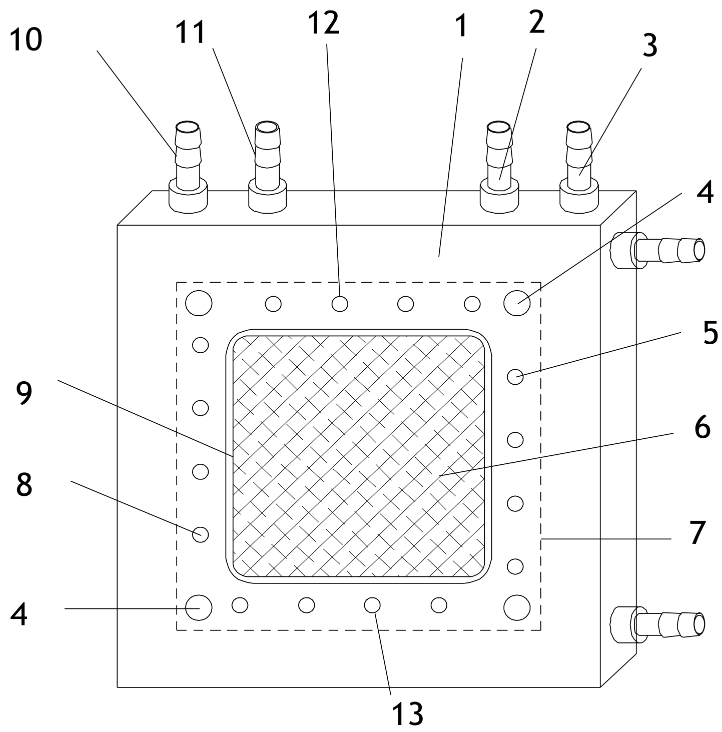

Fig. 10: PCCell ED 64 004 anode end plate.

#	Description
1	Electrode block (PP)
2	Electrolyte liquid inlet
3	Concentrate (diluate) inlet
4	Clamping bolt hole
5	Concentrate (diluate) connector hole to spacer
6	Electrode
7	Membrane and spacer size and position
8	Diluate (concentrate) connector hole to outlet
9	Electrode compartment
10	Diluate (concentrate) outlet
11	Electrolyte liquid outlet
12	Concentrate (diluate) connector hole to spacer
13	Diluate (concentrate) connector hole to spacer
Not shown	Rack set to mount the stack

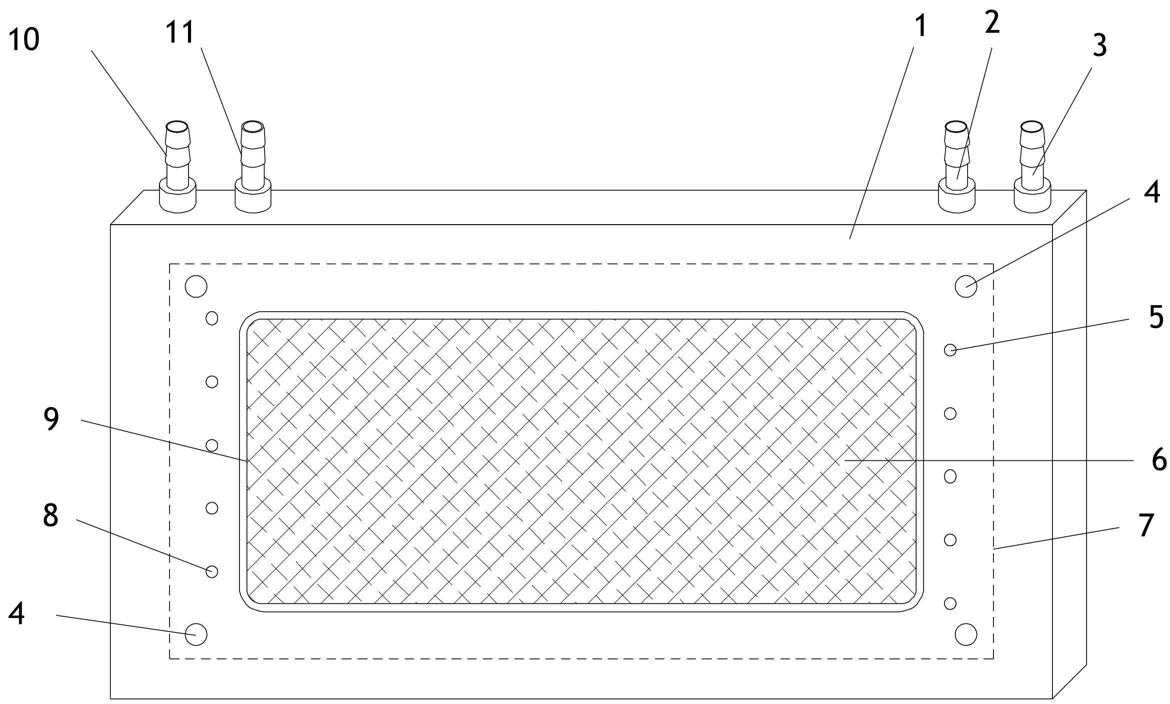

Fig. 11: PCCell ED 200 electrode end plate.

#	Description
1	Electrode block (PP)
2	Electrolyte liquid inlet
3	Concentrate (diluate) inlet
4	Clamping bolt hole
5	Concentrate (diluate) connector hole to spacer
6	Electrode
7	Membrane and spacer size and position
8	Diluate (concentrate) connector hole to outlet
9	Electrode compartment
10	Diluate (concentrate) outlet
11	Electrolyte liquid outlet

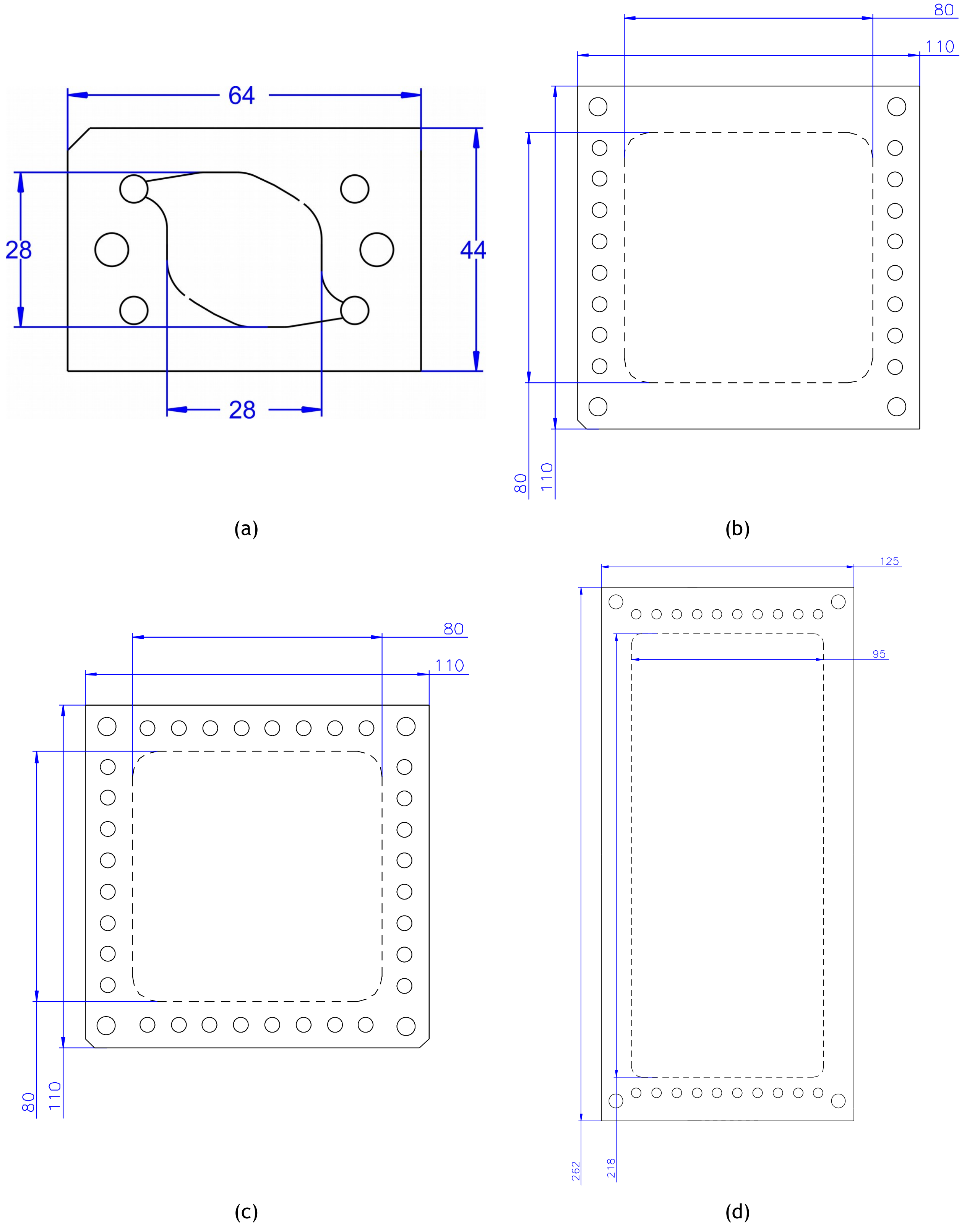

Fig. 12: PCCell Micro-ED (a), ED 64002 (b), ED 64004 (c) and ED 200 (d) membrane size (in mm). Dotted square area: active membrane area.

	Micro-ED	ED 64002	ED 64004	ED 200
Width	150 mm	165 mm	190 mm	165 mm
Depth	70 mm	150 mm	150 mm	150 mm
Height	140 mm	190 mm	190 mm	300 mm
Weight	0.75 kg	2.5 kg	3 kg	4 kg

Tab 1: Dimensions and weight (ca).

	Micro-ED	ED 64002	ED 64004	ED 200
Membrane size	60 x 40 mm	110 x 110 mm	110 x 110 mm	125 x 262
Active membrane area	6 cm^2	64 cm2	64 cm2	207 cm^2
Number of membranes	Max. 25 cp	Max. 60 cp	Max. 60 cp	Max. 100 cp
Processing length	28 mm	80 mm	80 mm	200 mm
Membrane spacing	Electrode-membrane: ca. 1 mm Over cells: 0.5 mm			
Current Connectors	4 mm banana plugs			

Tab 2: General properties and specification of stack types.

	Material
Cell frame	Polypropylene
Tubes	Polyethylene
Electrodes	Titanium with Pt/Ir coating, stainless steel
Sealing	EPDM
End spacer	Silicone / polypropylene
Spacer ED 200oem	Silicone / polypropylene

Tab. 3: Medium contacting materials / end plate materials.

	Silicone / PP	Food silicone / PP	Silicone / PES
Thickness	0.45	0.45	0.35
Orientation mesh to flow rate	45°	45°	45°

Tab 4: Spacer specification.

	PVC	Silicone	Viton	EPDM	Food approved silicone / polyethylene	Silicone / polyester	Silicone /PVDF	Silicone / polyethylene
End spacer	1	1	1	1		1	1	
Spacer Micro-ED	1	1			1	1	1	1
Spacer ED 64 0 02					1	1		1
Spacer ED 64 0 04					1	1		1
Spacer ED 200					1	1	1	1

Tab. 5: Spacer options.
1 = available

	Cell connection			
Type	4 mm banana plugs (standard) or via firmly mountable connector cable (optional).  DANGER! Only connect the cell with a galvanically isolated DC current circuit.			
Maximum Ratings	Micro-ED	ED 64002	ED 64004	ED 200
Current:	ca. 0.6A*	ca. 5A*	ca. 5A*	ca. 16 A*
	ATTENTION! More than 12.8 A should be avoided as overheating of contacts can hardly be managed.			
	Micro-ED	ED 64002	ED 64004	ED 200
Voltage:	Max. 2 V / cp Max. 30 V per cell	Max. 2 V / cp Max. 30 V per cell	Max. 2 V / cp Max. 30 V per cell	Max. 2 V / cp Max. 30 V per cell

Tab 6: Electrical connecting data.
* (the application, temperature etc. might reduce the rating of the electrical connectors), over this value, a safe operation requires avoiding overheating of electrode studs and contacts.

	Micro-ED	ED 64002	ED 64004	ED 200
Type (tube DN/ d)	4/ 6 mm	8/ 10 mm	8/ 10 mm	8/ 10 (10/ 12) mm
Flow through electrolyte circuits:	Nominal 25 l/ h	Nominal 150 l/ h	Nominal 150 l/ h	Nominal 150 l/ h
Nominal flow through concentrate and diluate per single cell	0.1-0.5 l / h (10 cell pairs result in 1-5 l / h)	4-8 l / h (10 cell pairs result in 40-80 l / h)	4-8 l / h (10 cell pairs result in 40-80 l / h)	5 – 10 l/h (10 cell pairs result in 50-100 l / h)
Max. pressure	Trans-membrane pressure has to be kept zero: Never pump only one of the diluate / concentrate circuits!			
Pressure drop over cell	Max. 0.5 bar			

Tab 7: Hydraulic connecting data.

2.6. The hydraulic connectors of the cells

The six functional liquid compartments (catholyte, anolyte, concentrate 1, diluate 1, concentrate 2 and diluate 2) require one inlet and outlet each (see Tab. 8). Their direction can generally be changed, however flow-in and -out of diluate and concentrate should be at the same cell face (if 1 is chosen as the first inlet, 2 should be chosen as the corresponding inlet) to reduce trans-membrane pressure.

Liquid loop	Connector No.	Remarks
Catholyte	6 - 6'	Connectors on cathode block.
Anolyte	5 - 5'	Connectors on anode block.
Concentrate 1	2 - 2'	
Diluate 1	1 - 1'	If 2 is the inlet of concentrate, 1 should be used as inlet of the diluate
Concentrate 2	3 - 3'	
Diluate 2	4 - 4'	

Tab 8: The six hydraulic loops of an ED cell.
* The connectors for diluate and concentrate are situated diagonally opposite of each other, those of the electrode chambers in the interior at the same sides respectively.

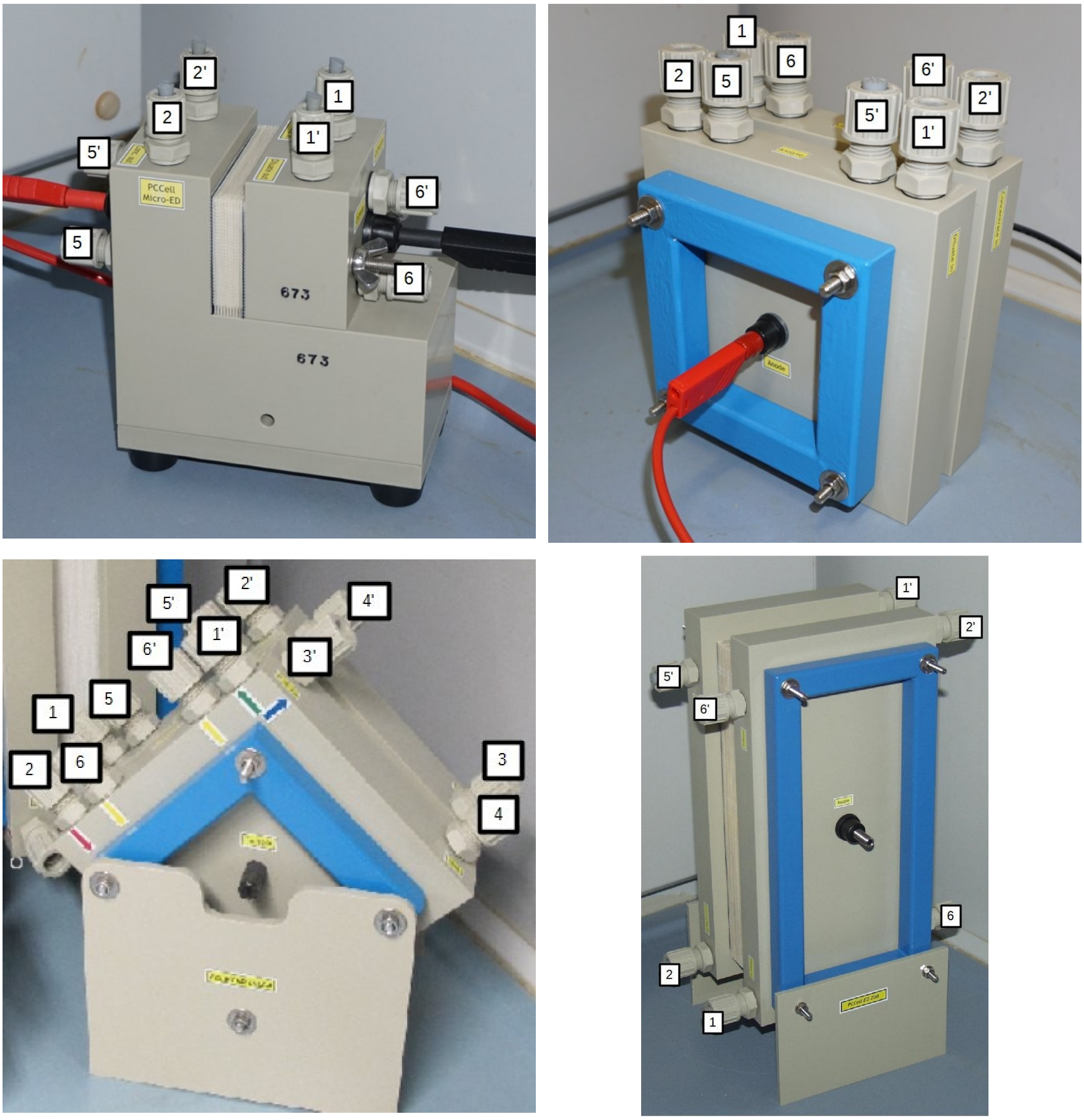

Fig. 13: The PC Cell ED cells with connectors (described in Tab 8). In the upper row on the left side, there is the Micro-ED. In the upper row on right side, there is the ED 64002 with the anode side in front. In the lower row on the left side, there is the ED 64004 with cathode side in front. In the lower row on the right side, there is the ED 200 with the cathode side in front.

2.7. Multiple stage operation with the ED 200

Multiple stage operation can be performed by special spacer sequences. With the model ED 200, different configurations can be performed by combination of two, three or more stages in combination with one or more center electrodes. Depending on the number of stages, inversed outlet end-plates can be required.

Stages	Process length	End plate geometry	Number of center electrodes	Code (example with 10 cell pairs per stage and standard membranes)
1	20 cm	Standard	0	ED 200-010-1101 -ED1 / EDR
2	40 cm	Inversed special cathode plate	0	ED 200-010-010-1101 -ED1
3	60 cm	Standard	0	ED 200-010-010-010-1101 -ED1
			1	ED 200-010-010-010-1101 -ED2
4	80 cm	Inversed special cathode plate	1	ED 200-010-010-010-010-1101 -ED2

Tab. 9: Typical configurations of ED 200 operated in multiple stages.

Fig. 14: ED 200 with center electrode and two stages on the right side of center electrode and one stage on the left side of electrode. Flow from right to left.

3. Available Components and Accessories

3.1. Punching tool

Models

Order No.	Type
ED 08002-punch	Punching tool ED08002
ED 64002-punch	Punching tool ED64002
ED 64004-punch	Punching tool ED64004
ED 200-punch	Punching tool ED200

Other sizes on request.

Application area:

The punching tool is used to punch membranes, spacers or sealing for PCCell's Electrodialysis cell units.

Use:

A punching sandwich is prepared as shown in Fig. 15 and pressed between two parallel stable planes in a workshop-press with a pressure of 0,5 - 4 t (see below).

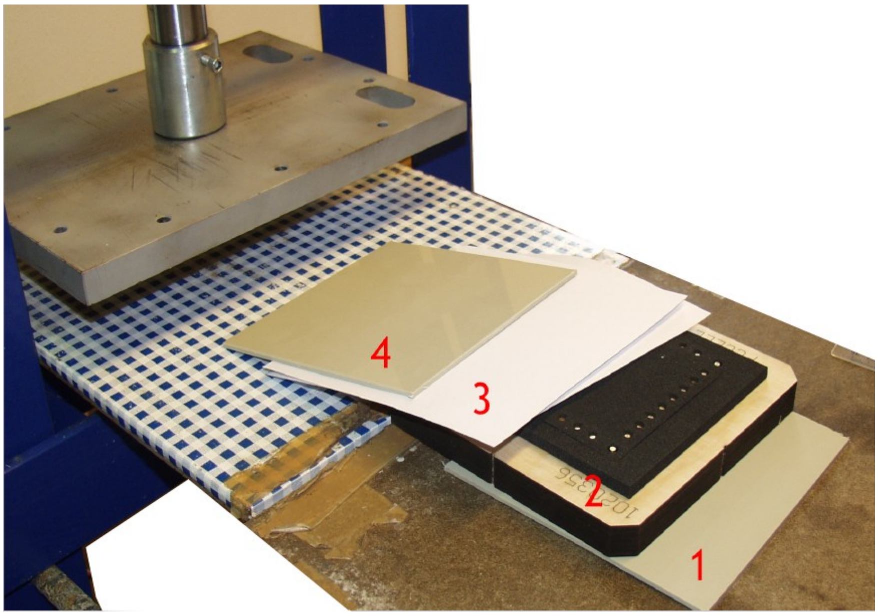

Fig. 15: A punching sandwich in front of a hydraulic press (not included in this punching tool set).

3.2. Pre-filters:

PCCell provides small pre-filter intended to provide particle free diluate and concentrate directly before entering the ED stack.

Models

Order No.	Type	Pore size
ED 64-104-156	Filter F10 housing and mounting set for ED 64	20 µm
ED 200-102-176	Filter F20 housing and mounting set ED 200	20 µm
ED 64-104-158	Replacement Filter-part 20 µ for F10 housing	20 µm
ED 200-102-176	Replacement Filter-part 20 µ for F20 housing	20 µm

Fig. 16: Application example on a bench scale pump unit: The filter (1) is mounted with the screw connection (2) at the T-piece of the pressure measurement device. The hose connection (3) is screwed into the filter body and connects the hose in direction to the ED stack.

3.3. Tools and accessories

Models

Order No.	Type	Description
ED 64-104-277	Torque wrench set for ED cells	1/4 "; 4-24 Nm
ED 08-tube	PVC tube DN04/ d06	Length 1 m
ED 64-tube	PVC tube DN08/ d10	Length 1 m
ED 200-tube	PVC tube DN10/ d12	Length 1 m

3.4. Replacement Parts

Models

Order No.	Type	Description
ED 08-104-612	Replacement bolt set for Micro ED	
ED 64-104-157	Replacement bolt set for ED 64 135 mm	
ED 64-104-612	Replacement bolt set for ED 64 165 mm	
ED 200-104-612	Replacement bolt set for ED 200 165 mm	
BED1-620-313	Sample valve for ED 64/BED1	
ED 08-104-783	Fitting nut ED 08002	Tube DN04/ d06
ED 64-104-783	Fitting nut ED 64	Tube DN08/ d10
ED 200-104-783	Fitting nut ED200	Tube DN10/ d12
ED 08-104-784	Ferrules for fitting No. ED08-104-783	
ED 64-104-784	Ferrules for fitting No. ED64-104-783	
ED 64-104-784	Ferrules for fitting No. ED200-104-783	

3.5. Spacers

Spacer type	Micro-ED	ED 64002	ED 64004	ED 200
Silicone/ PP spacer (450 µm)	ED 08-115-086	ED 64-102-086	ED 64-104-086	ED 200-102-086
Silicone/ PP end-spacer (450 µm)	ED 08-115-085	ED 64-102-085	ED 64-104-085	ED 200-102-085
Silicone/ PP spacer (750 µm)		ED 64-102-785		
Silicone/ PP end-spacer (750 µm)				
Silicone/ PES spacer (350 µm)	ED 08-115-088	ED 64-102-088	ED 64-104-088	
Silicone/ PES end-spacer (350 µm)	n/a	n/a	n/a	n/a
PTFE/ PE/ EPDM spacer (1 mm)			ED 64-106-091	

3.6. Open center chambers

A membrane sample can be used between tow open center chambers in a typical arrangement as shown in Fig. 17. It allows operation of the membrane and measurement of membrane potentials and voltage drops during operation with the aim of Haber-Luggin capillaries.

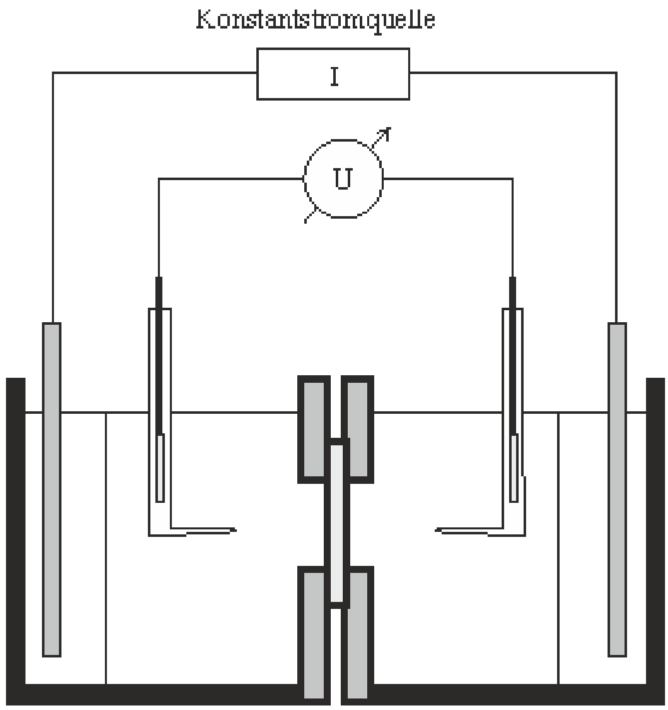

Fig. 17: Measurement of voltage drops over the membrane with center chamber with external access for Haber-Luggin capillaries.

A cell with three open chambers (two membranes under investigation) is shown in Fig. 18.

Fig. 18: A micro ED with three open center chambers for measurement of voltage drop and membrane potentials.

Order No.	Type	Description
ED 08-115-440	Open chamber 5 ml for Micro ED	Thickness = 6 mm
ED 08-115-441	Open chamber 4 ml for Micro ED	Thickness = 5 mm
ED 08-115-442	Open chamber 6 ml for Micro ED	Thickness = 8 mm

4. Application Examples

The PCCell laboratory ED cells are intended to be operated in a batch process when the solution passes the cell multiple times with a certain flow rate until it is processed to the desired extent. These cells can also be used for engineering the conditions of continuous operation and the ED 200 cell type is specially designed to perform such processes.

Typical application areas might be in the:

- desalination of salt water,
- stabilization of wine,
- whey demineralisation,
- fermentation broth workup
- desalination of alcoholic/polyalcoholic or sugar solutions
- pharmaceutical application and
- pickling bath recycling.

4.1. Batch desalination ED 64

This example shows a batch desalination where an PCCell ED 64 stack with 10 cell pairs transfer the salt from one batch (Diluate) into another batch of solution (Concentrate) according the simplified scheme in Fig. 19. The experiment is performed with an BED 1-2 bench top unit and the data plots are provided by the PCCell PC Frontend.

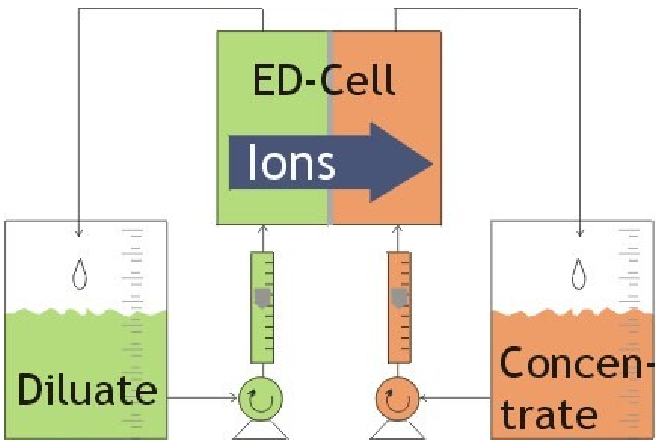

Fig. 19: Simplified scheme of a batch desalination.

4.1.1. 0,5 m NaCl with 1 kA / m²

In the first part, the salt from 1.0 L 0,5 m NaCl feed solution is collected in 1.0 L 0,5 NaCl by performing a current of 1 kA/m² (voltage and current course of the experiment shown in Fig. 20).

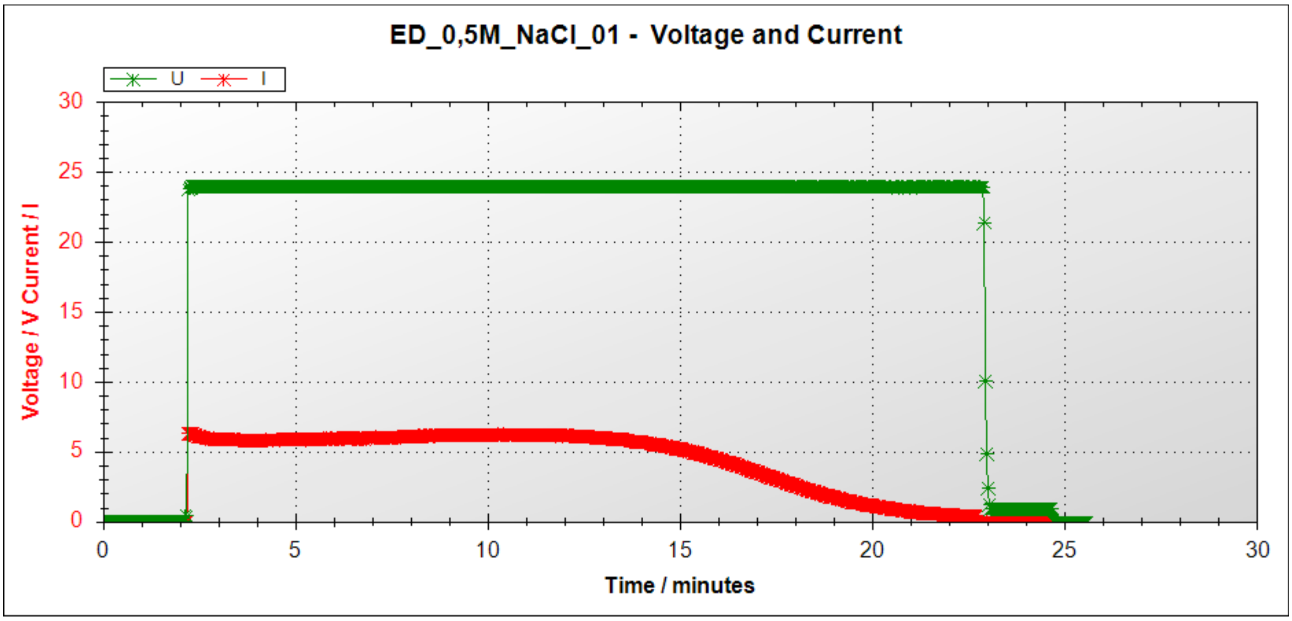

Fig. 20: U and I applied to the ED cell. Start and End of the batch is determined by time of power-on and -off switch.

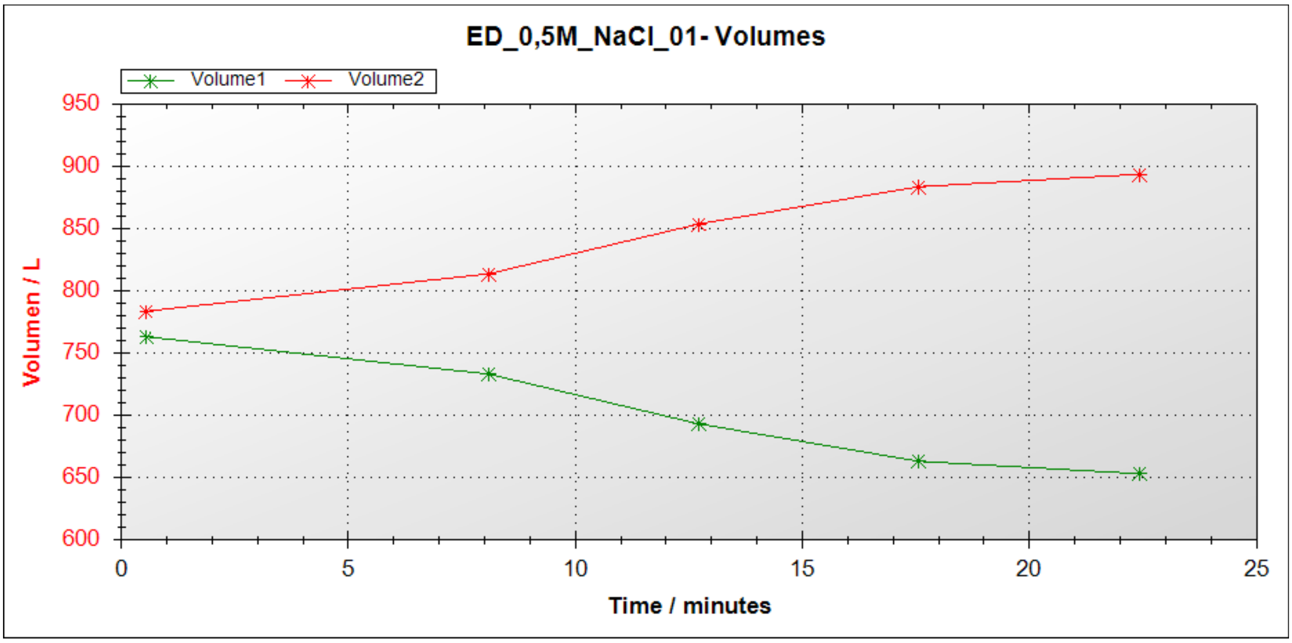

Fig. 21: Volumes in the concentrate (red) and diluate (green) (for Diluate 215 ml tube/cell and pump volume need to be added and for the concentrate, the dead volume is 240 ml).

Fig. 21 shows the volume and Fig. 22 shows how the conductivity develops during the desalination process. This conductivity is visualized in ppm NaCl online according Fig. 23 by the PCCell PC Frontend.

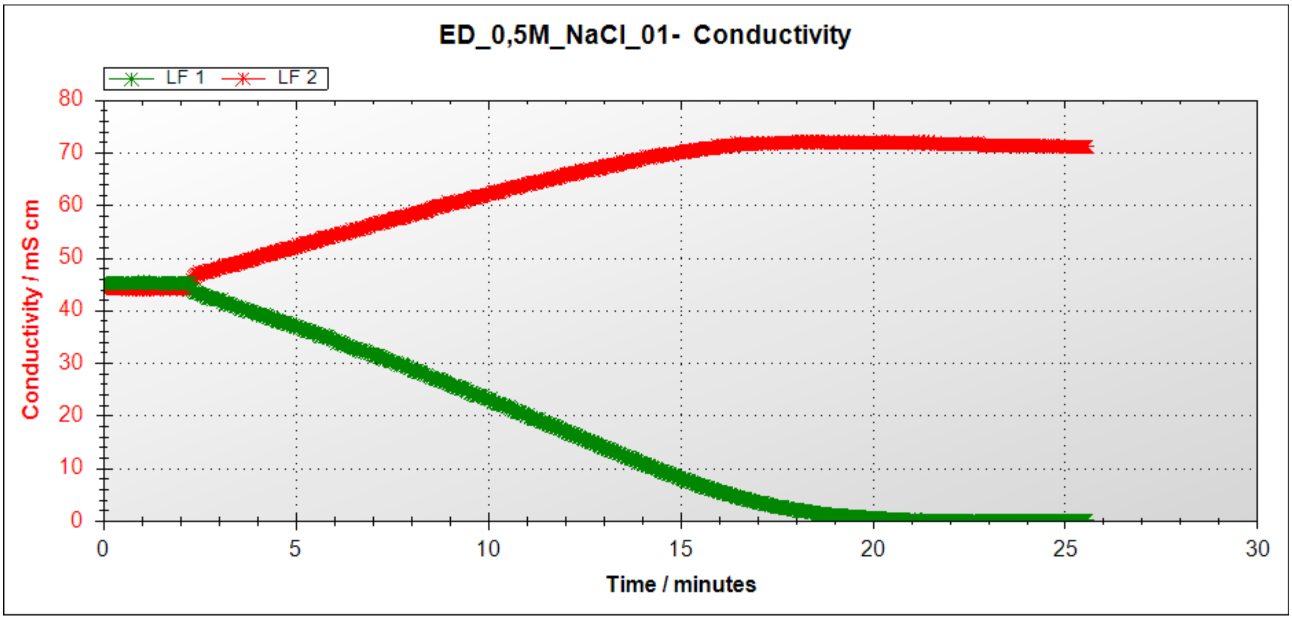

Fig. 22: Conductivities in concentrate (red) and diluate (green): In the first two minutes, no change is observed, once the current is switched on, salt moves from concentrate to diluate.

The amount of salt and water in the compartments can be calculated from volume and concentration data and can be related to the charge flown.

Example: 1 L 0,5 m NaCl removed 98% with 0,58 F corresponds to a current efficiency of 84,5%. The volume loss of 760 – 655 = 105 ml corresponds to about 12 mol water per mol of NaCl. Thus a 21% NaCl solution can be considered as transferred.

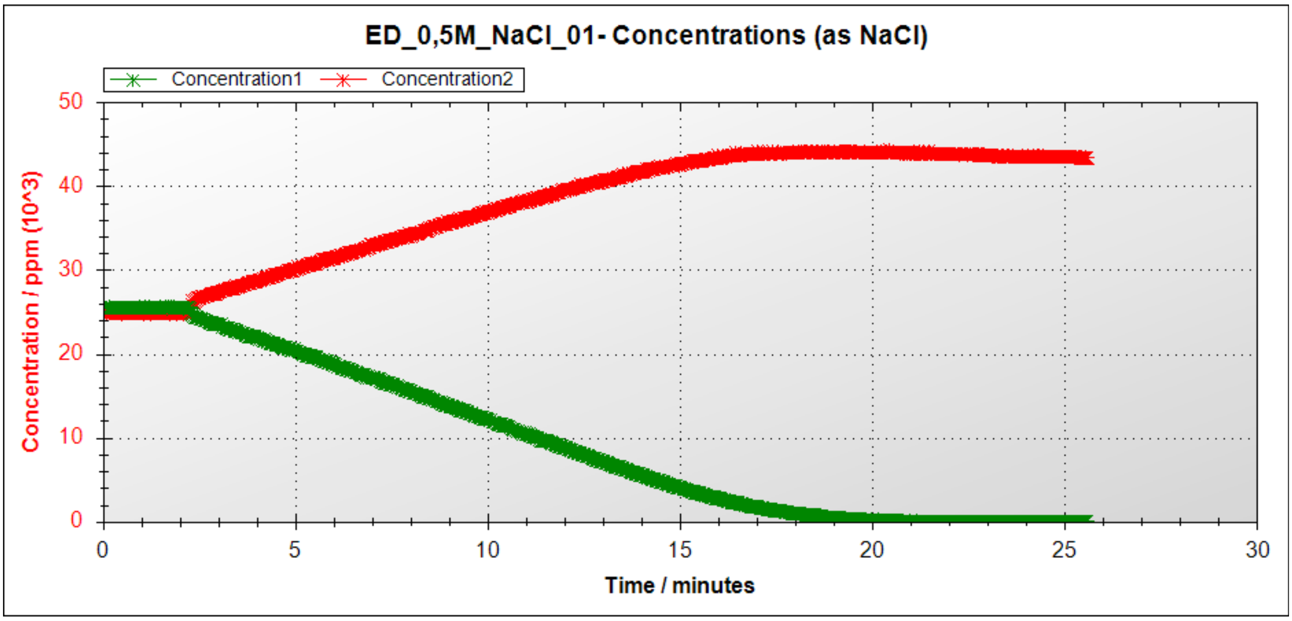

Fig. 23: Concentration in ppm in concentrate (red) and diluate (green).

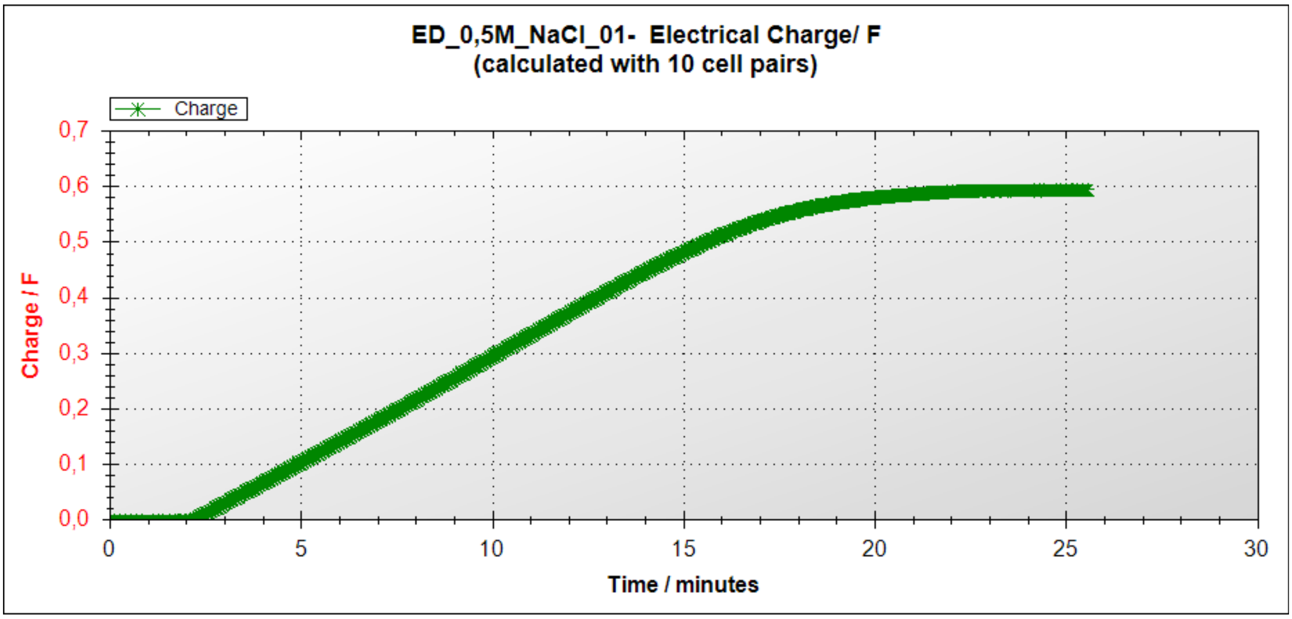

Fig. 24: Charge in Faradays.

4.1.2. 0,5 m NaCl with 0,5 kA / m²

In the second part, a similar desalination run (1.0 L 0,5 m NaCl diluate is desalinated into 1.0 L 0,5 NaCl) is performed with a current density of 1 kA/m² (voltage and current course of the experiment shown in Fig. 25): The volumes (Fig. 26) and the conductivities (Fig. 27) develop respectively.

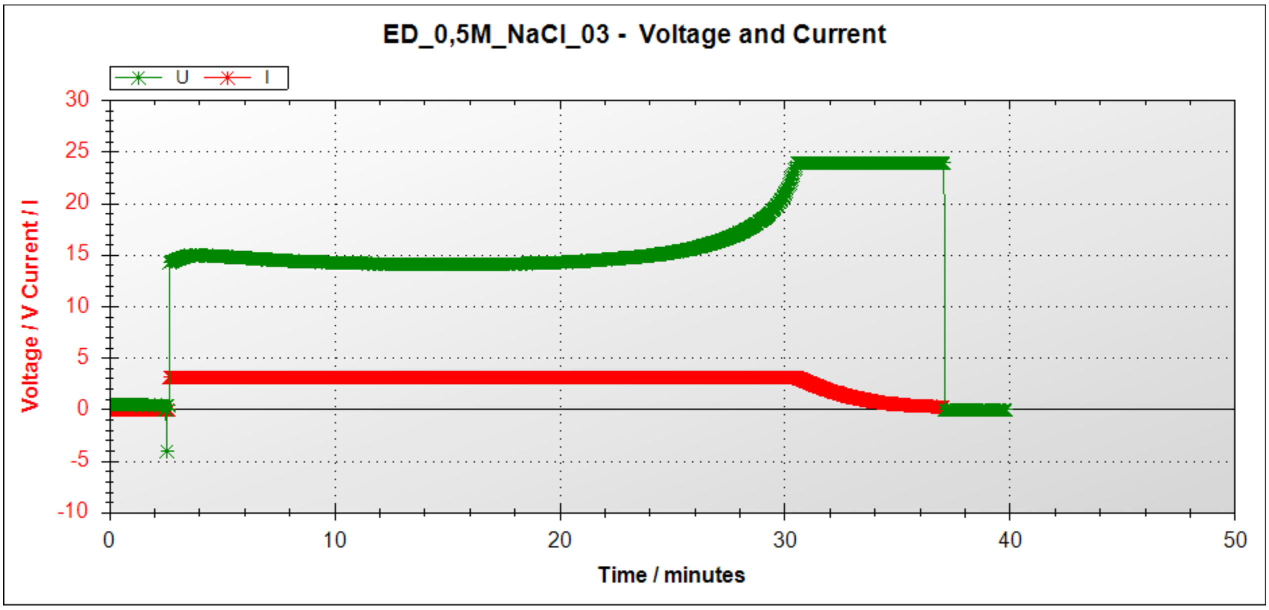

Fig. 25: U and I applied to the ED cell. 3,2 A corresponds to 500 A / m² (Cell area = 64 cm²).

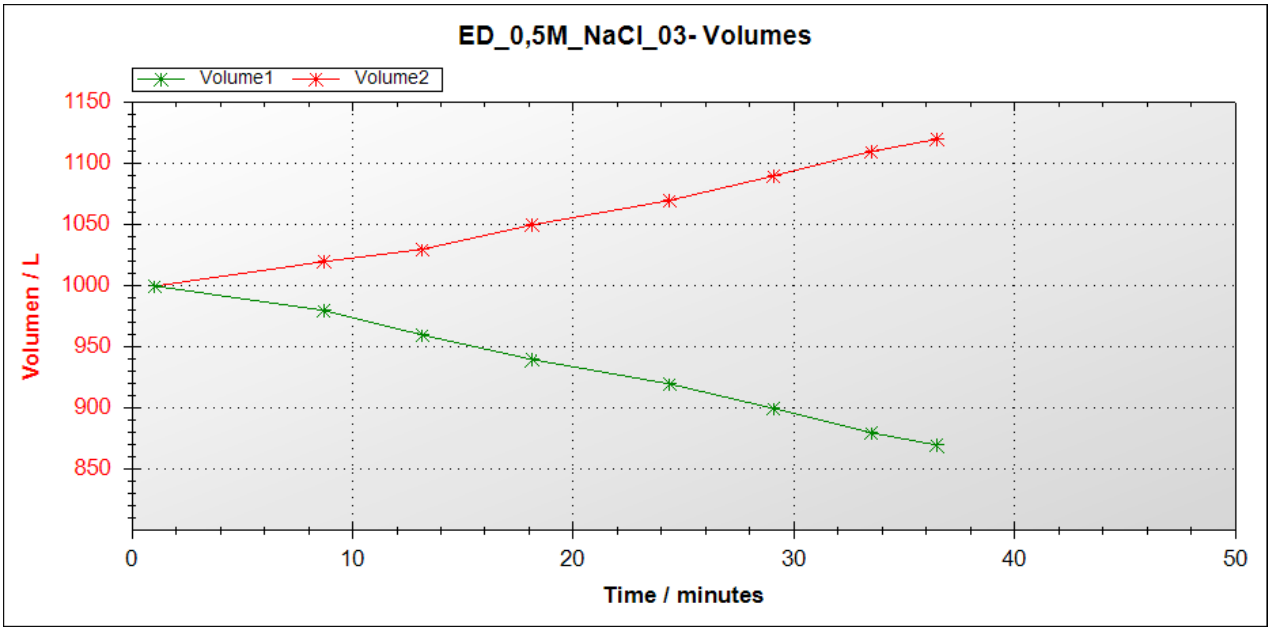

Fig. 26: Volumes in the concentrate (red) and diluate (green). In this case, the total volume is displayed.

In this example, the current efficiency remains similar, as whereas the volume transfer is slightly higher.

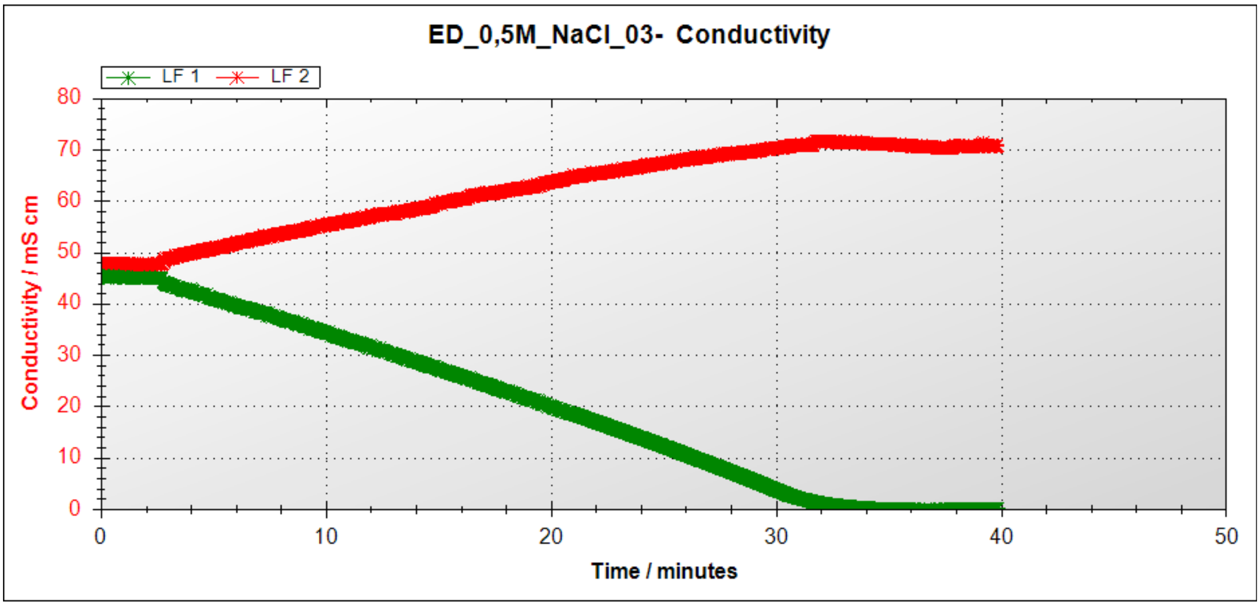

Fig. 27: Conductivities in concentrate (red) and diluate (green).

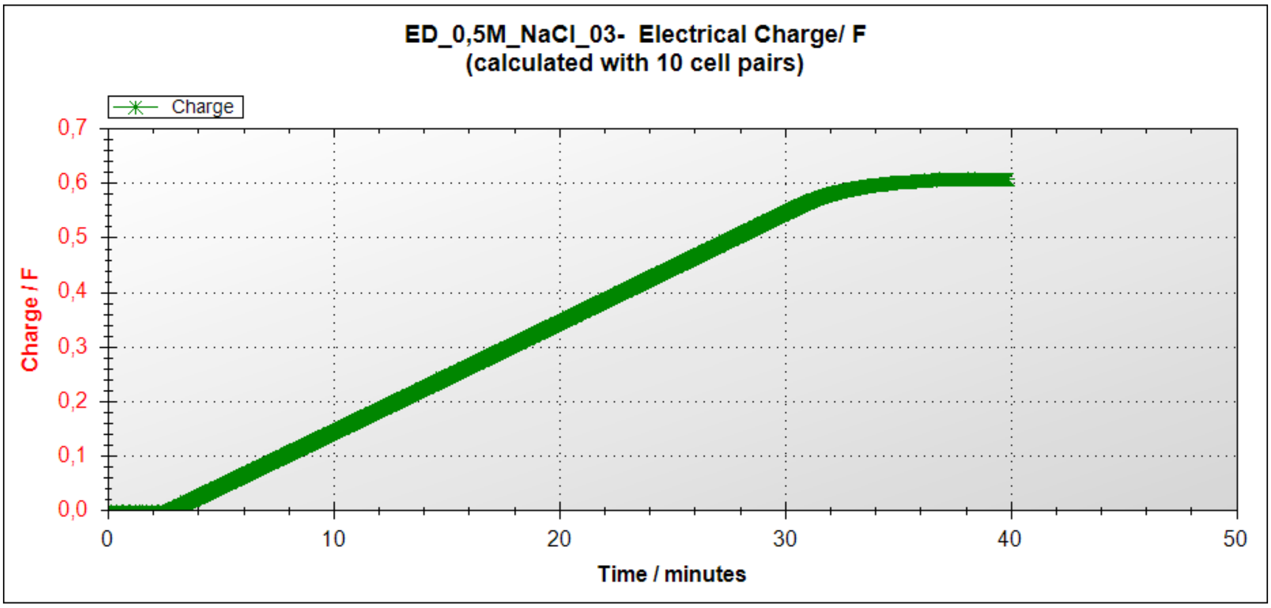

Fig. 28: Charge in Faradays.

4.2. Determining the process length of an ED process

In a batch desalination, the conductivity of the diluate is decreasing over the time of desalination.

Within the desalination process, the ions are removed while the solution is in the cell.

Consequently, the solution enters the ED cell with a certain conductivity (red line) and as long as salt is removed, the conductivity at the outlet of the cell is different (black line). As soon as the desalination is stopped (the applied voltage is removed), the outlet conductivity will become the inlet conductivity (see black line jump at 1:30 h).

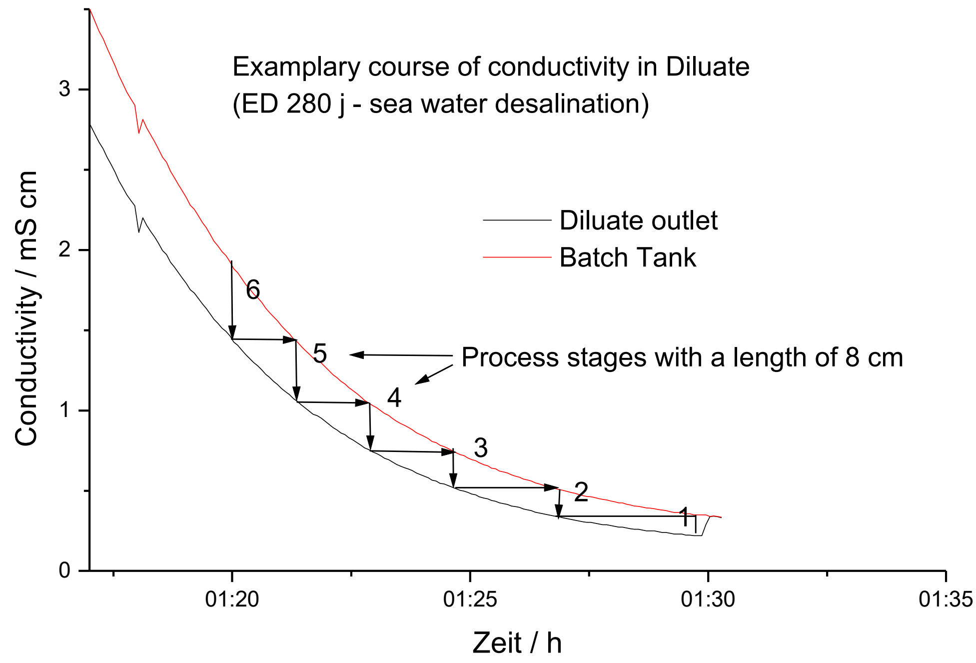

Fig. 29: Conductivity at inlet and outlet of an ED cell during desalination.

The vertical arrows no. 6 to 1 show what happens in a one way through: each conductivity jump is performed by the current at this moment, which decreases from jump 6 to jump 1. A flow speed over the cell is constant and the current flowing at each moment within this experimental section is generated from a constant voltage, it can be concluded that the jump 1 – 5 can be done in one cell with 40 cm process length in one single flow-through.

Finally, by counting the jumps through the complete batch desalination course, the total process length can be calculated.

Typical process lengths for sea water desalination to drinking water are about 2.5 m.

Of course the process length depends on the flow-through speed, voltage, the thickness of the cell, the cell geometry and finally on the amperage (which is also depending on all the said factors).

However, the cell thickness and basic geometry between laboratory and industrial cell is identically. And the flow-through speed should also remain more or less constant between lab and industrial scale. As a rough estimate a target of about 10 cm / s at low concentrations is to be considered as a good value.

4.3. Batch desalination of small sample volumes

A sample solution is desalinated with the micro BED system.

Cell:	Micro-ED
No. of cell pairs:	10
Type of membranes:	PC SA
	PC SK
Current:	
Voltage (max):	22 V
Amperage (max):	0,8 A
Feed solutions:	
Diluate:	180 ml
	NaCl 1.3 M
Concentrate:	180 ml
	NaCl 1.3 M

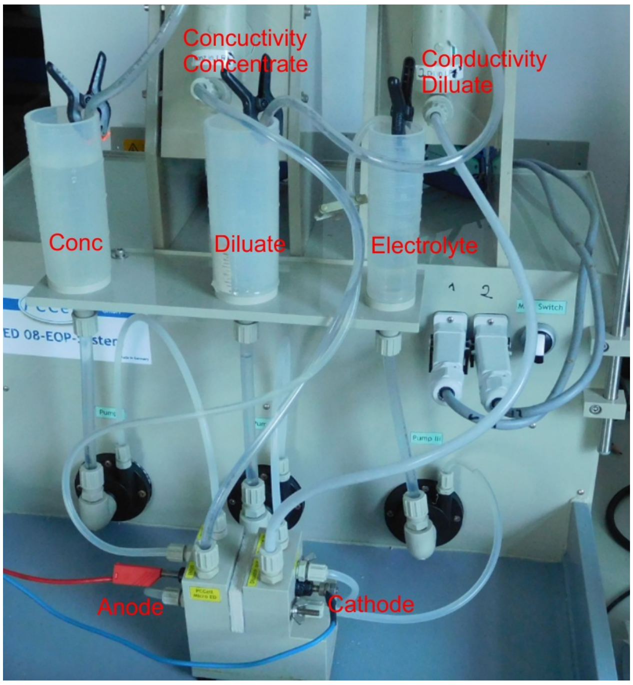

Fig. 30: Setup of the experiment and experimental test conditions.

An experiment to desalinate 1.3 molar NaCl solution has been performed. The experiment has been assembled according to Fig. 30 and the conditions are visualized, monitored and logged with the PC Frontend software.

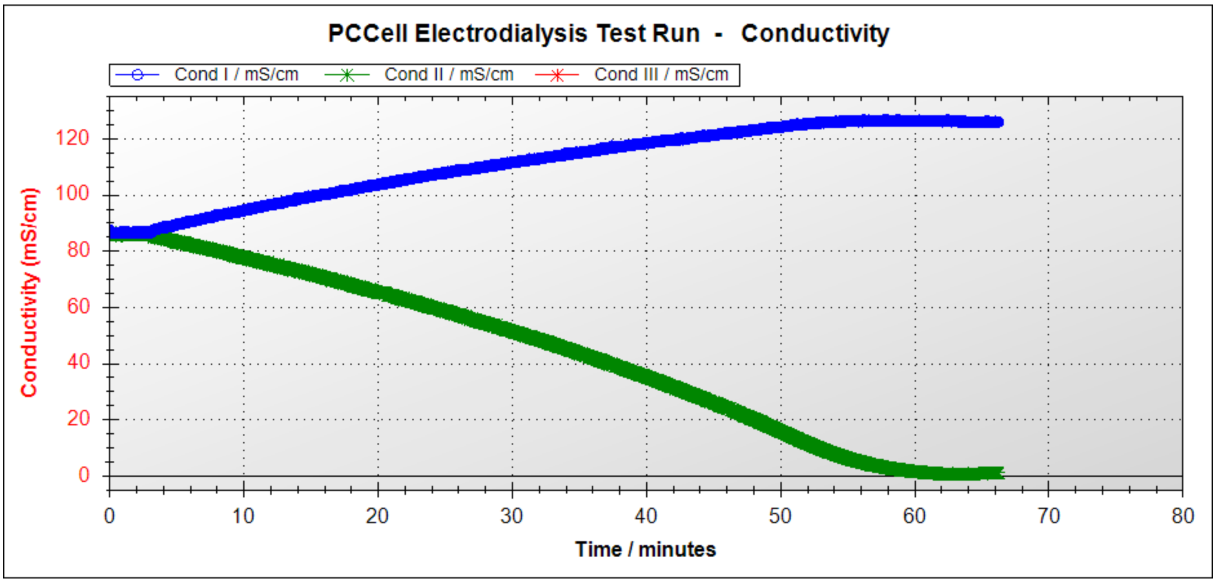

Fig. 31: Conductivity changes against time.

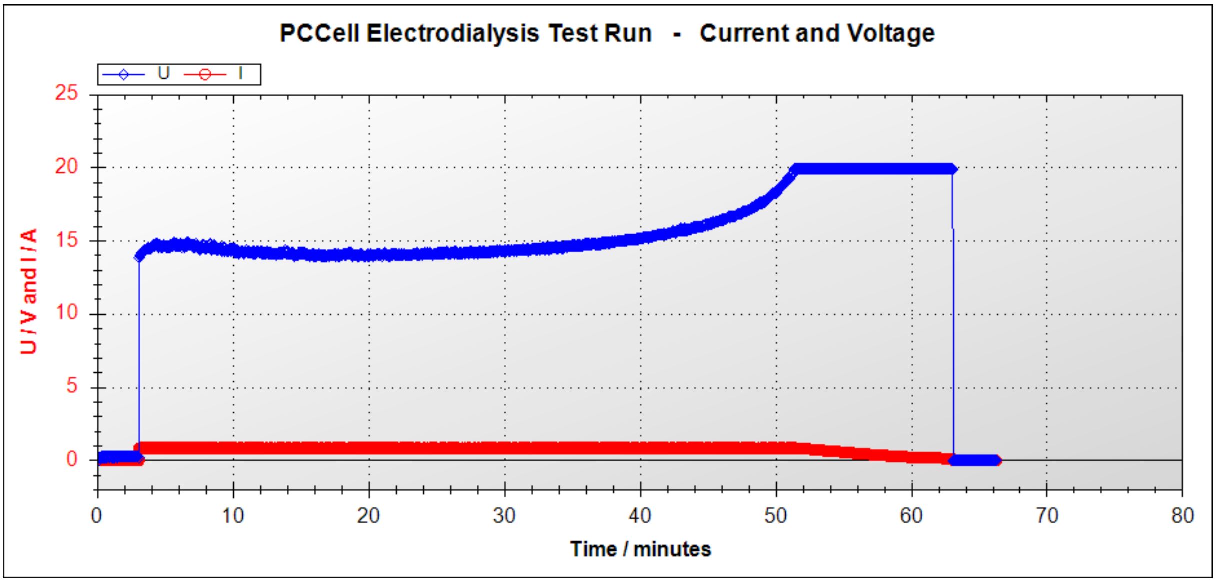

Fig. 32: Current and voltage progress against time.

Fig. 31 shows the conductivities of concentrate/diluate over the time. As long as no current is applied, the conductivity do not change from its starting value of about 86 mS/cm. The conductivity diverge once the current moves the ions. In this example the salt of the diluate has been removed (<1 mS/cm) in about 60 min.

Fig. 32 shows current and voltage progresses. In the beginning, a constant current flow can be achieved at a relatively constant voltage. As the desalination moves forward, the overall conductivity through the cell diminishes and higher voltages are necessary to keep up the current flow. When the voltage limit is reached, current flow (and with it desalination rate) decreases.

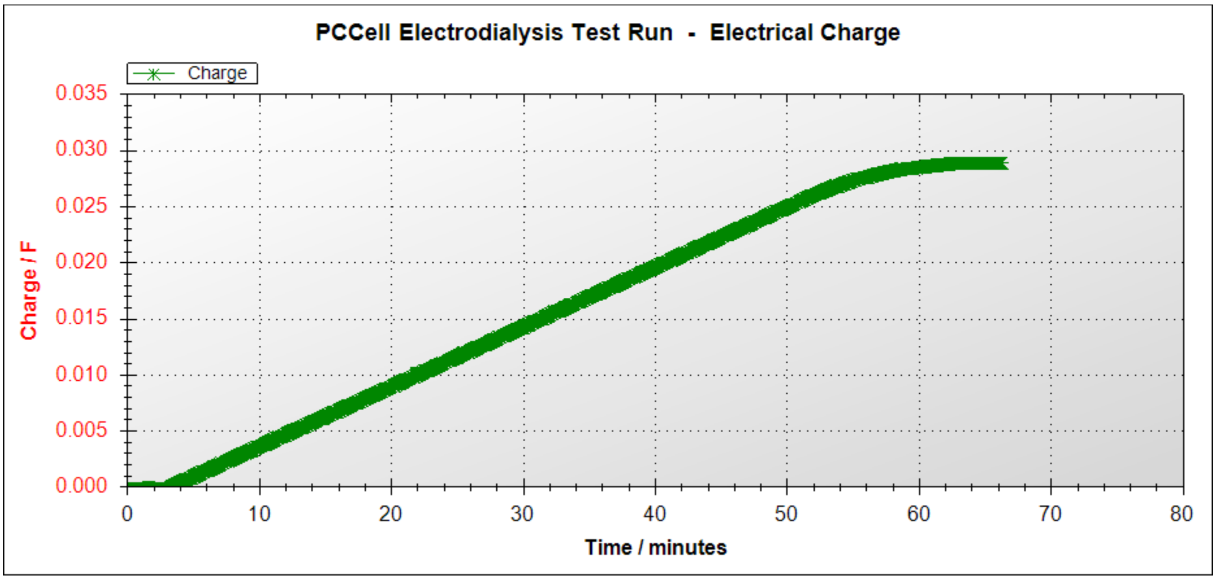

Fig. 33: The online view of the coulomb counter in the PC Frontend.

The PC Frontend contains a coulomb counter and can online display conductivities, pH and temperature in relation to the charge.

4.4. Determination of water co-transfer (EOP measurement)

The micro-BED system comprises a coulomb counting device, used to apply automatically a 120 As package of charge to a given volume. The volume difference is determined volumetrically or gravimetrically. By this method, the amount of water per charge is easily determined and it can be correlated to the amount of ions transferred by this charge.

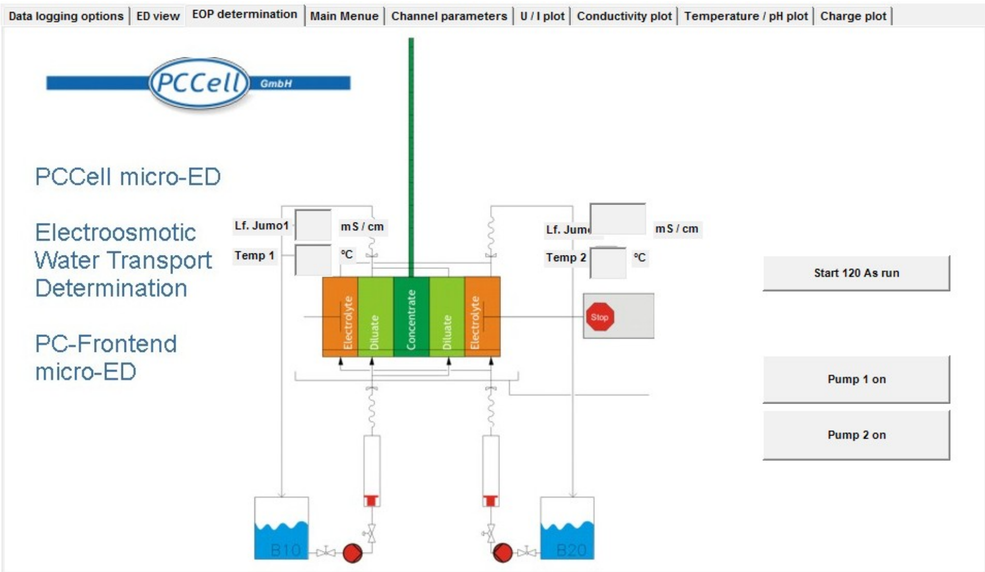

Fig. 34: Screenshot of the automatic water transfer measurement device.

Fig. 35 shows some typical results obtained by this method.

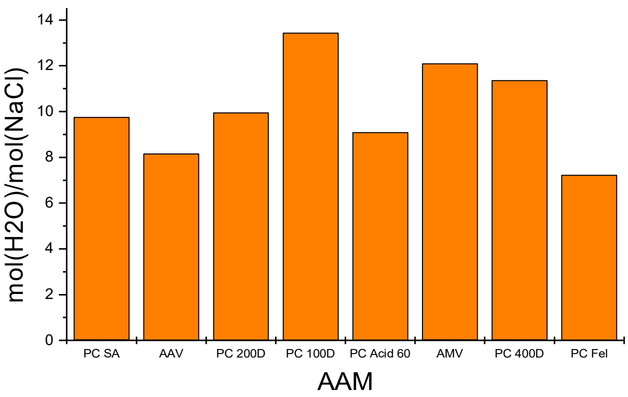

Fig. 35: Exemplary results for different anion exchange membranes in sodium 1 M NaCl.

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PCCell GmbH

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The undersigned manufacturer Headquarter:

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Lebacherstraße 60
66265 Heusweiler
Germany

declares under its sole responsibility that the product series:

Model: ED 64002, ED 64004 and ED 200

is compliant to the essential safty rules (if applicable) stated in the directives:

Low voltage directive 2006/95/CE

We decline any responsibility for damages to person or things due to tampering on the maschine or lack or omission of maintenance and /or not authorized reparation.

Heusweiler, 04.12.2013

P. Altmeier

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Geschäftsführer

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