Efficiency Wall-Jet Cell FC2

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INTRODUCTION

FC2 cell with Wall-Jet (WJ) hydrodynamics provides reproducible electrochemical measurements with well-defined efficiency and current flow dependence. Wall-Jet electrochemical cells FC2 have been characterized by measurement of $[Fe(CN)_6]^{3-}/[Fe(CN)_6]^{4-}$ redox couple. Measurements were performed in the range of Reynolds numbers from 0,067 to 21,3 for flow 0,1 – 32 mL/hr.

The current efficiency specifies the ratio between current, which is measured and current, which would arise, if the electrode reaction involved all substances that entered in the cell. The knowledge of WJ cell efficiency and current flow dependency simplifies the experiment design [2]. The excellent reproducibility between cells enables their practical use. The knowledge of current and efficiency dependency on flow enables the optimization of microdialysis devices.

EXPERIMENT AND METHOD

The cell FC2 (BVT Technologies, www.bvt.cz, Brno, CZ) was connected directly to a linear pump Technic I (AMV, http://www.amvtechnics.cz, Brno, CZ) using plastic capillaries of internal diameter (ID) 0,3mm. The sensor was inserted into the cell and locked. The cell is optimized that there is no accumulation of air bubbles. The cell is connected using the USB Bioanalyzer (BVT Technologies, www.bvt.cz, Brno, CZ) to computer. For the experiment it was used a solution of 10 mM ferri-ferro cyanide and sensor AC1.W2.R1 (BVT Technologies, www.bvt.cz, Brno, CZ) with a platinum working electrode and a reference Ag/AgCl electrode. Data were recorded in program of Bioanalyzer and analysed using the Excel.

RESULTS AND DISCUSSION

Principle of the flow cell measurement

Schematic chart of the cell with dimensions is in fig. 1.A. The photography of the cell is in Fig. 1 B. The cell is designed for the standard screen printed electrodes AC1 or CC1 (BVT Technologies, www.bvt.cz, Brno, CZ). It enables simple exchange of the electrodes and their effective use.

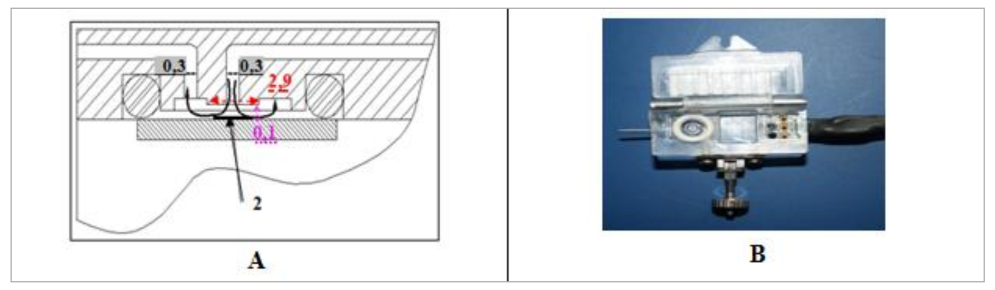


Fig. 1. A: Arrangement of flow cell FC2 wall jet. (Cell dimensions are given in millimeters.) B. FC2 wall-jet photo.

Cell current

The cell current [nA] satisfies the power law with a = 2294,2 and b = 0,255 (standard deviation is 8,2 % and 14,7 % respectively). Average values of three cell currents are shown in the Fig. 2. The values a and b are in agreement with data published by Kuritaa (2000)[1].

$$I = 2294 \cdot Q^{0,255} \; ; \; [I] = nA, \; [Q] = mL/hr$$

Properties and stability of pump flow

Key role for the measurement quality plays the pump and syringe. Real flow rates are shown in Fig. 3. The pump Technic I gives sufficient flow stability after 100 s of stabilization (Fig. 4) at extremely low flow rates the flow rate is influenced by piston movement and by instability, caused by the drops of liquid, which fall at the end of output tubing. (Fig. 3) The stabilization at low flow rates increases to 200 s. The stability of the flow is significantly influenced by the pump position (see poster Comparison of pumps, syringes and flow stability by I. Ventrubová). Stable and reproducible dependency of current on flow can be used as flowmeter . It enables effective study of hydrodynamic properties of microdialysis and microfluidic systems.

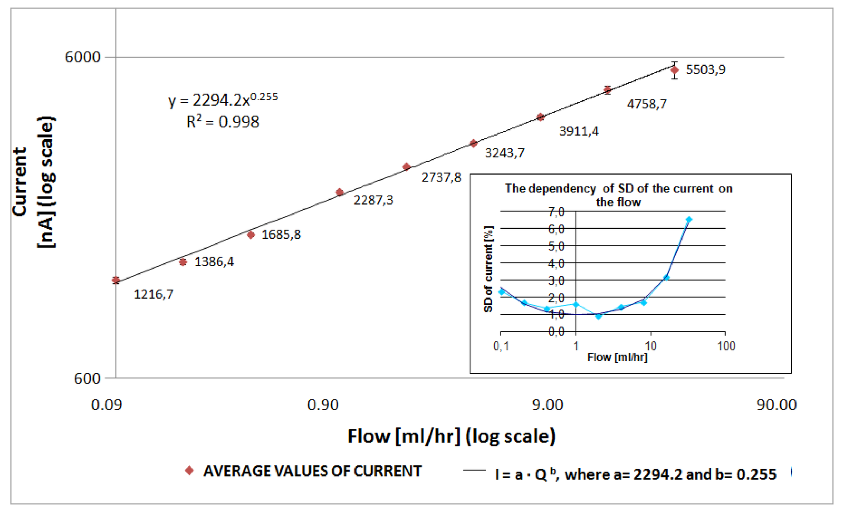


Fig. 2. Dependency of cell current on flow (log scale axis).

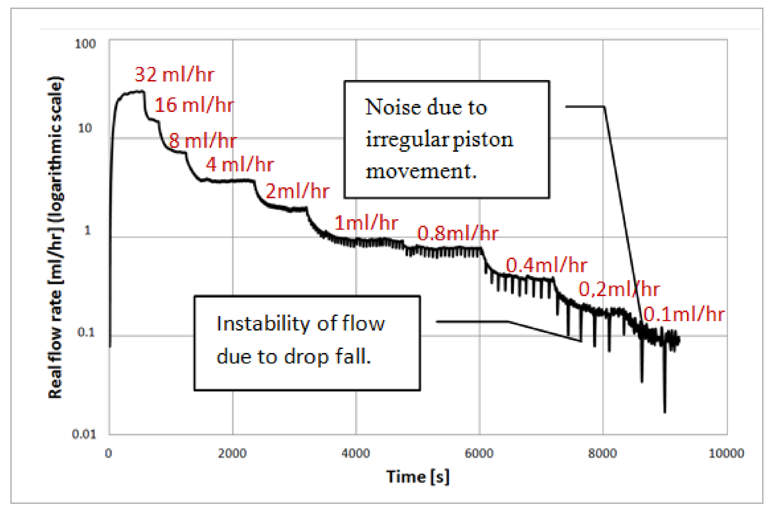


Fig. 3. Real flow rate in time PUMP AVM Technic I.

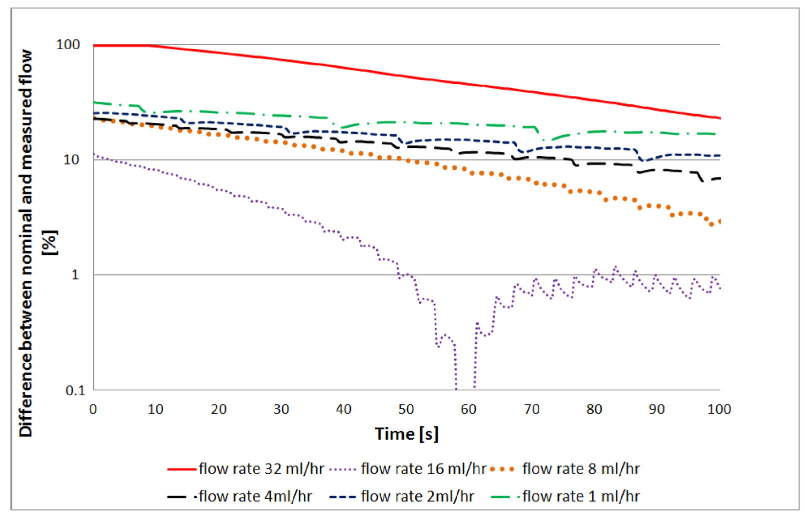


Fig. 4. Stabilization of the flow when flow is decreased to a half. The flow is expressed as percentage of nominal flow 1 – 32 mL/hr.

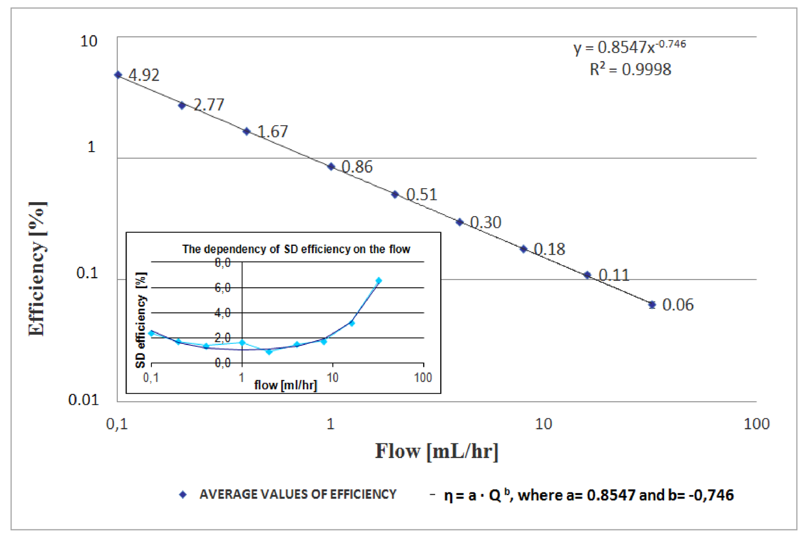


Fig. 5. Efficiency at different flow rates (log scale axis).

Current efficiency

The maximum current which can be created on in WJ electrode arrangement is determined as quantity excluded electrons per second form the mass flow of the inputted electroactive compound. It was determined as the product flow in the cell Q, concentration of the substance c and Faraday constant F ($F = 9.6485 \cdot 10^4$ C/mol).

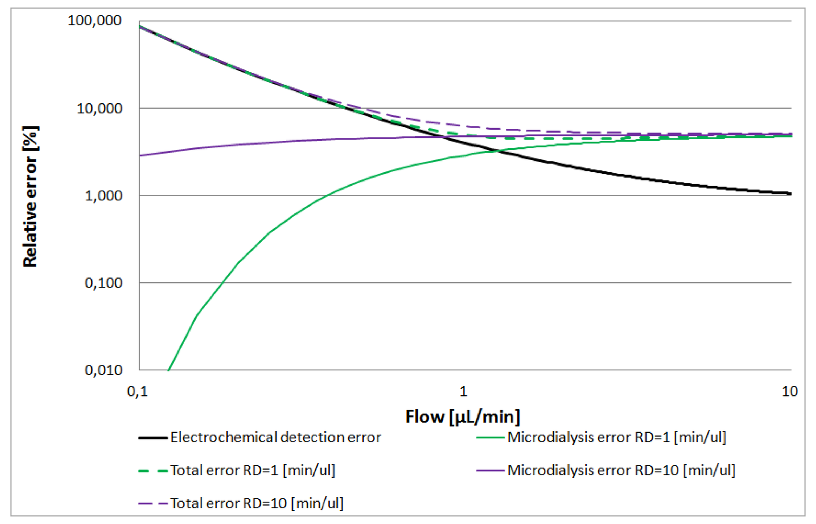
$$I_0 = Q \cdot c \cdot F$$

The efficiency of the cell was determined by calculating the proportion of the measured current I to the current I_0 corresponding to full conversion.

$$\eta = I/I_0$$

Microdialysis

Two important contributions to microdialysis measurement of concentrations are displayed in Fig. 6. Error of concentration if the flow has noise (instability) 5 % and error of electrochemical detection using FC-WJ at same conditions. At high recovery (low flow), the error of electrochemical measurement depreciates the value of measurement. At low recovery low signal and microdialysis error depreciates the measurement. The importance of a flow optimization is obvious. The flow optimization must be done for each microdialysis system.



Mass transfer resistance (R_D,R_D) follows from equation:

$$E_D = \left[1 - exp\left(-\frac{1}{Q_D R_D}\right)\right]$$

Where E_D is recovery.[3]

Fig. 6. Dependence of concentration error measured by microdialysis and FC2 – WJ detector.

CONCLUSION

- The flow cell FC2-WJ with AC1 (D=2mm) sensors format has excellent reproducibility.
- The flow cell FC2-WJ with $[Fe(CN)_6]^{3-}/[Fe(CN)_6]^{4-}$ redox couple can be used as precise flowmeter enabling to test microfluidic devices including microdialysis systems.
- The knowledge of current and current efficiency dependency of flow enables the optimum experiment and device design. ($I = 2294 \cdot Q^{0,255}$, $\eta = 0.8547\, Q^{-0.746}$ $[I] = [nA]$, $[Q] = [mL/hr]$, $[\eta] = [-]$)
- The knowledge of errors of measurement of flow enables flow optimization.
- In optimum conditions the microdialysis error (caused by flow fluctuations) is in equilibrium with electrochemical detection error.

ACKNOWLEDGEMENT

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REFERENCES

1. Kuritaa, R., Tabeib, H., Liuc, Z., Horiuchic, T., Niwa, O., Sensor. Actuat. B-Chem. 71, 82 (2000).
2. Sejnohova R., Hanak V., Krejci, J.: Screen printed electrodes improve mass transfer. In: New perspectives in biosensors technology and applications (Serra P.A., Ed.), InTech, Rijeka, Croatia 2011.
3. Snyder,K. L.; Nathan, C.E.; YEE, A.; Stenken, J.A.; Diffusion and calibration properties of microdialysis sampling membranes in biological media. Analyst, 126, 2001, no. 8,p. 1261-1268.

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