Optimization of a reverse electrodialysis device

*Jonathan I. Hernández Hernández#1, Ayrton A. Medina Rodríguez #2, Vianey García Paredes*3, Damián Manzo Hernández*4, Edgar Mendoza #5 y Rodolfo Silva #6*

stm.jonathanhdez@gmail.com1, ayrtonamedinar@gmail.com2, EMendozaB@iingen.unam5.mx, RsilvaC@iingen.unam.mx6
 # CEMIE-Océano, Instituto de Ingeniería, Universidad Nacional Autónoma de México. Circuito Escolar. CP 04510, Mexico City, Mexico.
vianeygar04@gmail.com3, damianmanzo90@gmail.com4
**National Technological Institute of Mexico, TecNM, Technological Institute of Atitalaquia, Ave. Tecnológico, 9, CP 42970, Hidalgo, Mexico.*

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In reverse electrodialysis (RED) the chemical energy of the salinity gradient of two solutions is converted into electrical energy through the use of ion-exchange membranes. This work presents an RED device in which the internal part of the cell is modified to include a serpentine with obstacles in the path of the solution fluxes. The net power delivered by the cell in different tests with various salt concentrations, was compared for the conventional RED device and the optimized configuration.

INTRODUCTION

One of the challenges facing humanity today is to ensure sufficient energy in the face of a growing world population. Innovative solutions to exploit new forms of energy are needed that will allow present and future generations guaranteed energy availability [1].

As the use of fossil fuels is unsustainable, developing alternative routes for energy production has become a priority [2]. Energy security in the coming years could come through the generation of solar, wind, biomass and ocean energy. Of those sources, ocean energy is the least exploited and one of the most promising [3], since the ocean is a virtually inexhaustible source of energy.

Salinity gradient energy (SGE) makes use of the difference in salinity between seawater and freshwater [4]. SGE, also called blue energy, has most potential at river mouths, where a large body of freshwater flows into the sea. The theoretical global potential for salt gradient energy has been estimated at about 2.6 TW [5].

EXPERIMENTAL SET UP

RED is a membrane-based technology in which the controlled mixing of saline solutions is used to generate electricity. A RED cell is composed of a matrix of cationic and anionic exchange membranes, arranged alternately (CEM and AEM) and stacked between two electrodes [6]. The conventional RED design [7], separates the membranes with spacers to keep the distance between the membranes constant. The compartments thus formed are fed alternately with concentrated and diluted salt solutions, (Fig. 1).

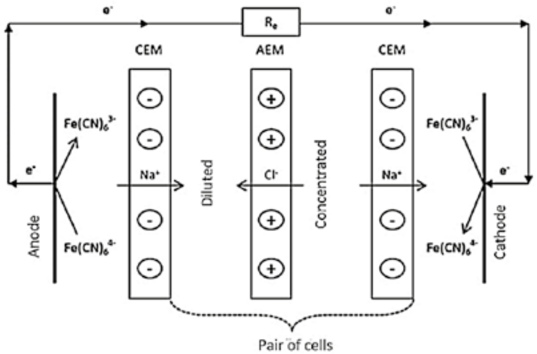
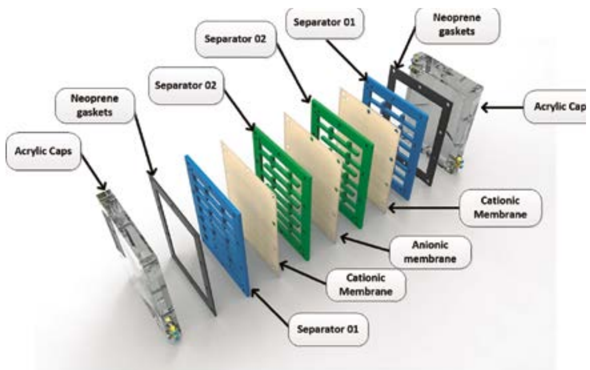


Fig. 1 Schematic representation of the RED principle.

Two different types of cells were analysed. The conventional cell, with a hollow compartment, is described in detail in [8]. The proposed cell (Fig. 2), has obstacles and a serpentine between the separators, to improve its efficiency. Both cells were equipped with the same type of membrane and redox pair. The effective area of each of the membranes was 100 cm^2.



(Hernandez_fig2.png)
Fig. 2 View of the RED cell with the proposed new separators.

The configuration of the cells is shown in Fig. 3. In the conventional cell the internal part of the spacer is hollow and the path of the saline solution is perpendicular to the direction of the inlet flow. In the proposed cell, the effective area was not altered, but spacers with obstacles were added to slow down the mixing of the solutions, thus improving the ion exchange through the membranes.

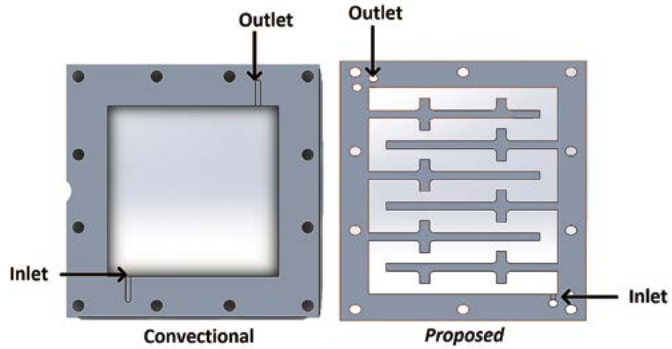


Fig. 3 Spacers employed in the tests.

The scheme of the device operation is shown in Fig. 4. Three gear pumps were used to provide freshwater, saltwater, titanium electrodes and potassium ferro-ferricyanide electrolyte solution to the model. The input flow to the cell was regulated by the pumps and the data acquisition system recorded the electrical power produced. The data was sent to a computer, stored and then processed.

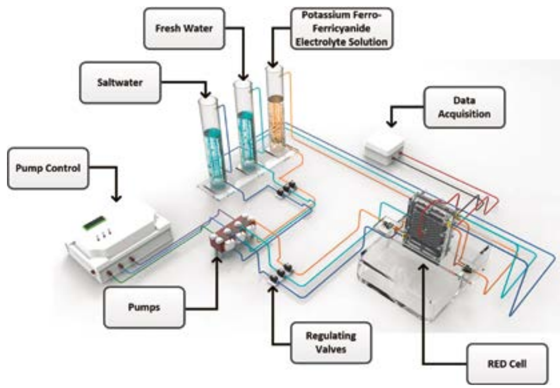


Fig. 4 View of the cell operation.

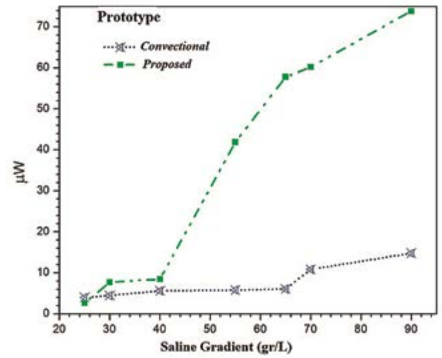


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Fig. 5 Comparison of power recorded for the two cells.

RESULTS

Seven tests were performed with 3 repeatability validations each for both cell configurations. The relationships between the salinity gradients and the power produced. (Fig. 5) shows that the higher the salinity gradient, the higher the electrical power obtained. The salinity gradients used in the tests ranged from 25 to 90 (g/l). The duration of each test was 5 minutes. The value of the electrical power presented in Fig 5 corresponds to the measure when the stationary condition was reached.

CONCLUSIONS

A modified RED cell was developed, with separators to improve the electrical power delivered. By creating disturbances to the flow path, it is possible to improve the mixing inside the cell and, at the same time, achieve a greater ion exchange, so that the ions released increase the amount of electrical power obtained. It was observed that the higher the salinity gradient, the higher the electrical power ratio compared to the classic cell, meaning that this device will perform better with high salinity gradients.

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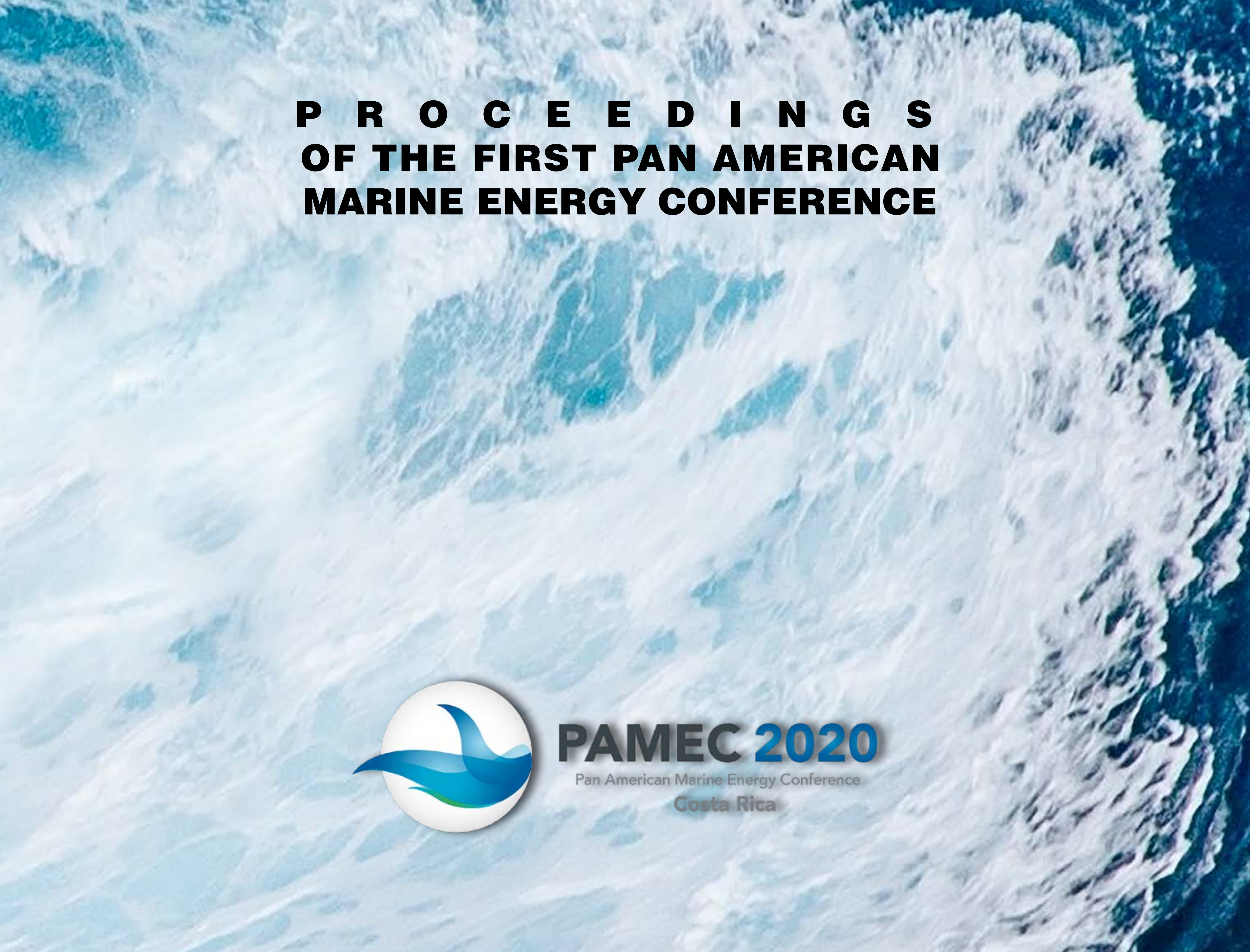

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