

Improved Electrodes for Capacitive Deionization

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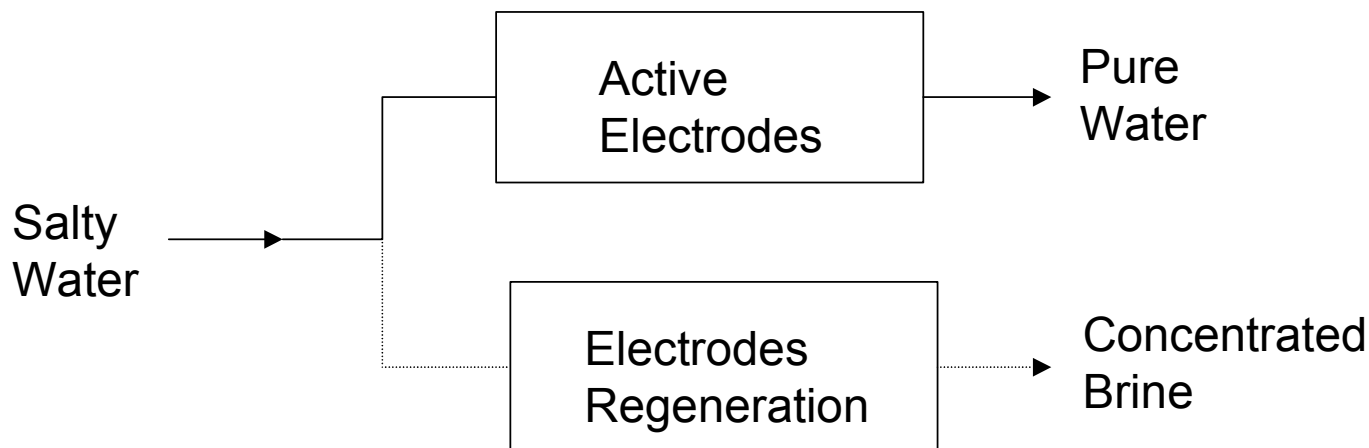
**2004 NSF Design, Service and Manufacturing Grantees
and Research Conference, Birmingham, AL**

January 2004

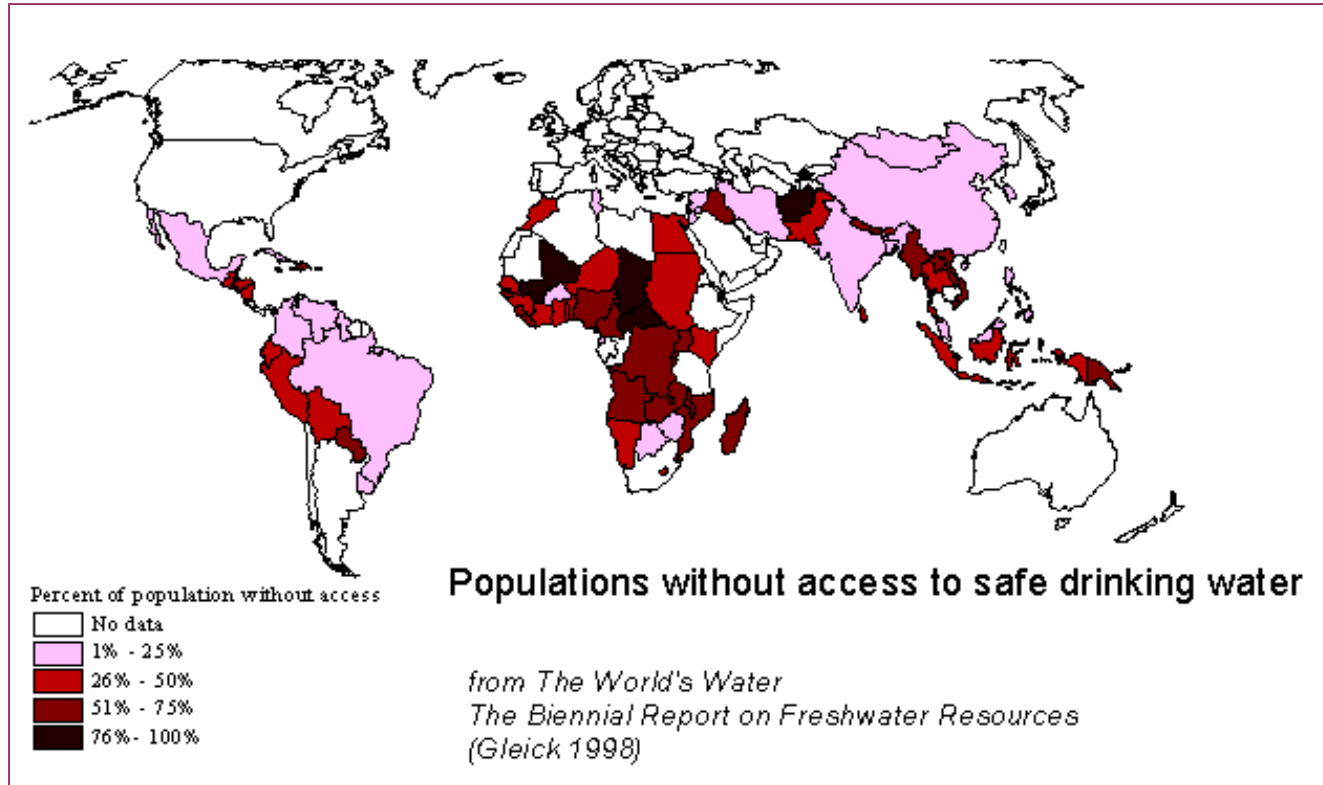
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What is capacitive deionization?

- **Method for water desalination.**
- **Operating principle**
 - Liquid flows between high surface area electrode pairs having a potential difference of 1.2 v dc.
 - Ions and other charged particles are attracted and held on the electrode of the opposite charge for later release into a rinse stream.



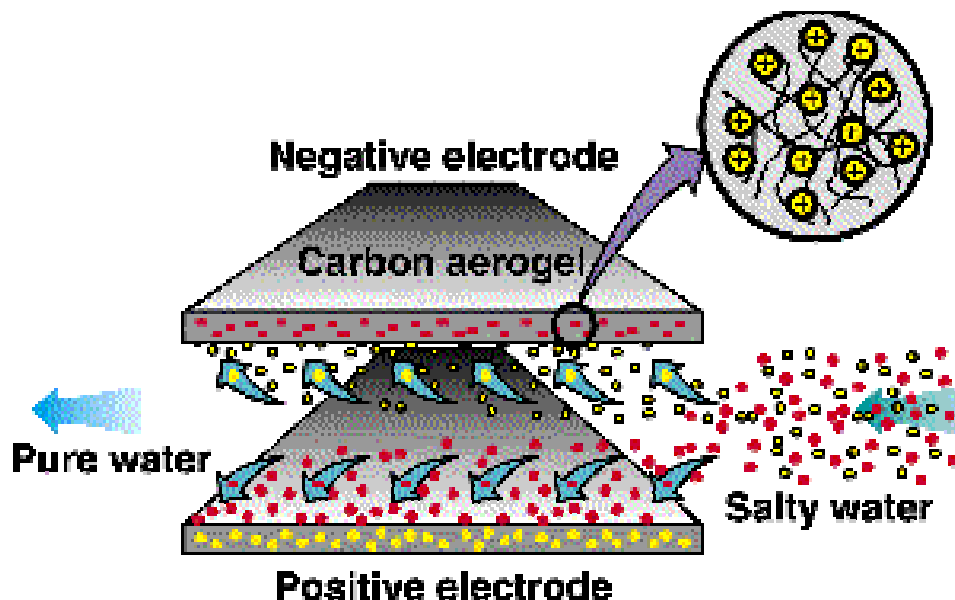
The Water Crisis



Serious shortages now in Middle East and Africa. World Bank projects 2.5 billion people by year 2025 will not have access to clean drinking water.

Capacitive Deionization on Porous Carbon Electrodes

Ions stored on the surface of the porous carbon



The more accessible surface area the more ions that can be stored.

Farmer, J.C., D.V. Fix, G.V. Mack, R.W. Pekala and J.F. Poco (1996). *J Electrochem. Soc.* **143**, 159-169.

Previous Work

- **CDT developed at LLNL using carbon aerogel based electrodes.**
- **CDT Systems, Inc. (Dallas TX) licensed technology.**
- **Problems**
 - Carbon aerogel synthesis is complicated and the main component (resorcinol) is too expensive for commercial production.

Project Goals

- **Develop improved carbon electrodes for capacitive deionization**
- **Approach:**
 - Optimize the pore structure for ion removal
 - Reduce cost of carbons

Ideal Pore Size Distribution for Carbon Electrodes

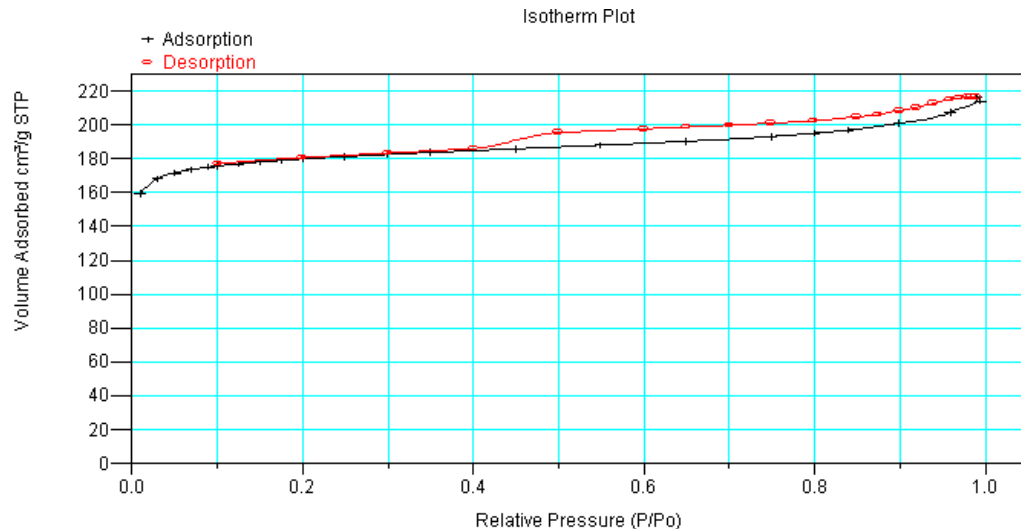
- **Mesopores (2 - 50 nm) for water access**
- **Micropores (< 2 nm) for high surface area**
- **Benefits:**
- **Increased Capacity**
 - Pores large enough for the ions to enter yet still maintain high surface areas.
- **Increased Rate**
 - Large pores increase rate of ion transport through the electrode resulting in decreased ionic resistance.

TDA's Mesoporous Carbons

- **Carbon produced using conventional production methods (no need for supercritical solvent extraction)**
- **Production consists of two steps**
 - Mixing solutions
 - Heat treatment
- **Materials costs are < \$4/kg of carbon**

Typical Properties of TDA Carbon

Density (g/cm ³)	BJH Average Pore Size (nm)	Total Surface Area (m ² /g)	Total Pore Volume (cc/g)	Micropore Volume (cc/g)
0.5	4.0	600	0.3	0.2



Mesopores allow access to high surface area micropores

Nitrogen isotherm showing hysteresis due to mesopores.

Electrode Screening

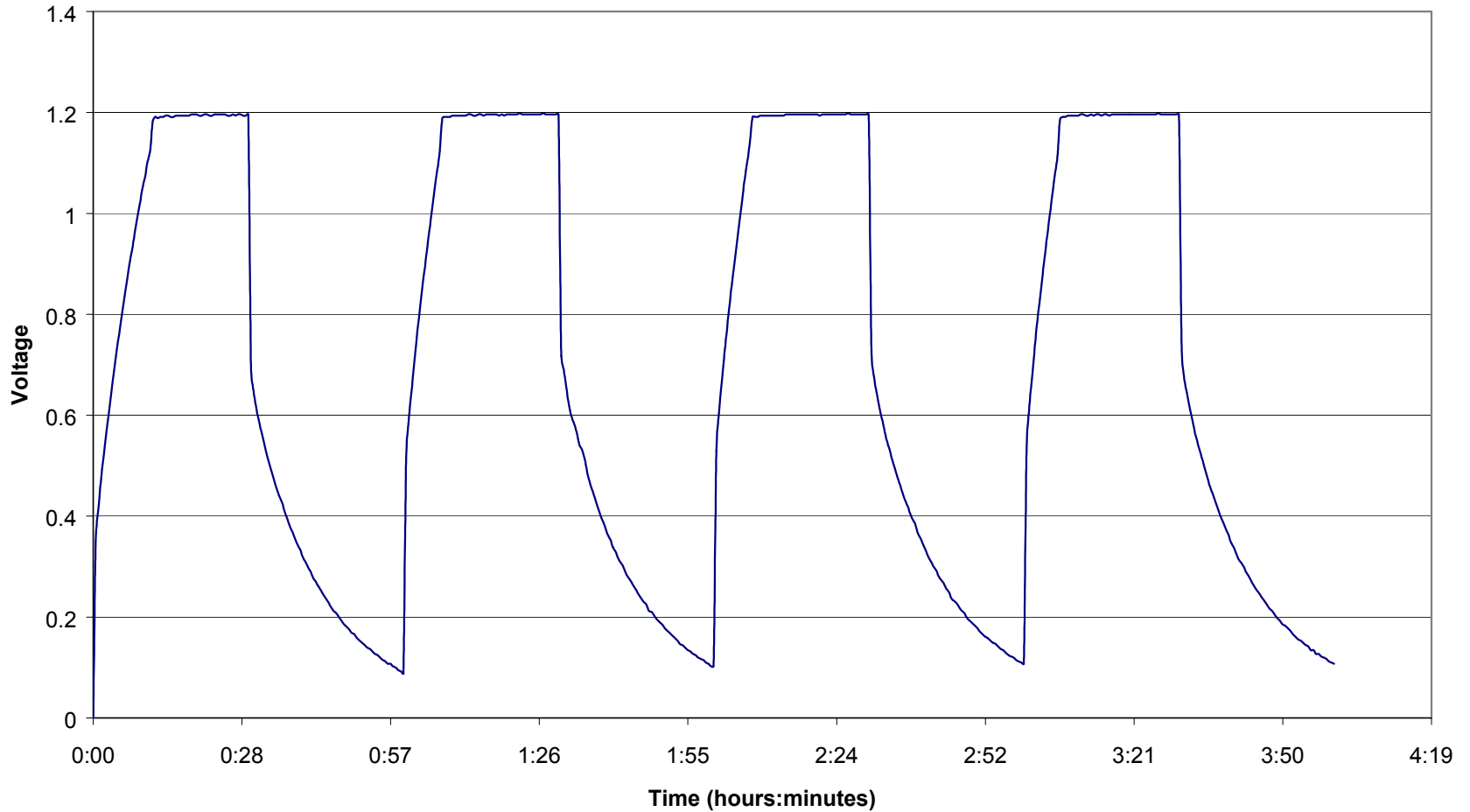
- **Two electrode 5 cm X 7.5 cm x 0.1 cm**
- **10,000 ppm NaCl**
- **Charge/discharge 1.2 to 0 V**
- **Amount of NaCl stored derived from the cumulative discharge energy calculated from the discharge curve**
 - $E = V^2/R \times T$ where E = energy (J), V = voltage, R = resistance of the resistor (ohms), and T = time in seconds.

Test Brick



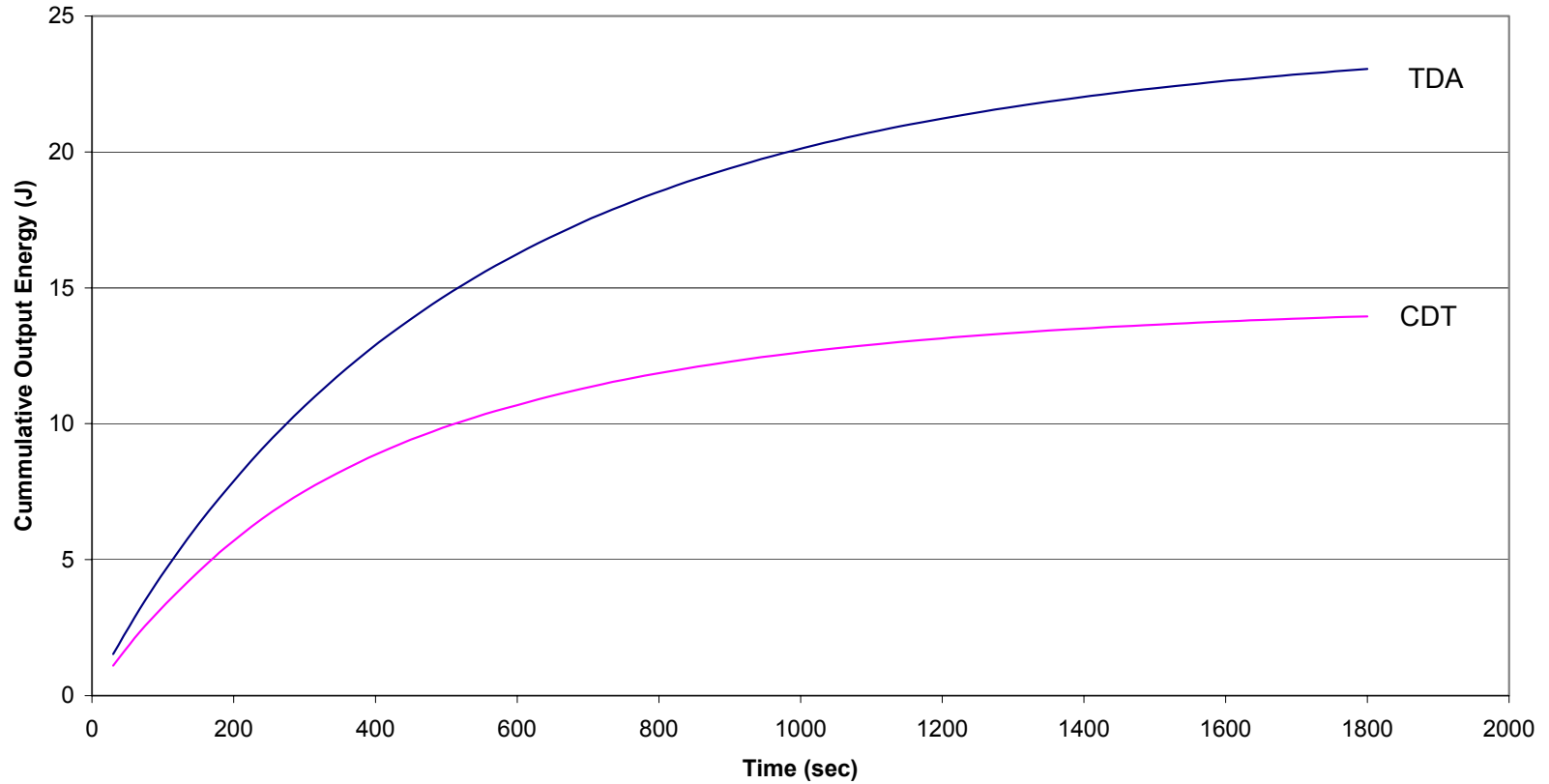
- Test long-term performance of electrodes
- 24 electrodes (12" x 6")

Typical Charge-Discharge Curve



Performance Comparison

Cumulative Discharge Energy



Summary of Results to Date

- **Comparison of TDA carbon electrodes with CDT carbon aerogel electrodes**
 - 45% increase in salt capacity
 - Factor of five decrease in materials cost
 - Factor of eight performance/cost increase

Commercialization

- **Applied for patent on new carbons**
- **Performing long-term studies using test bricks**
- **Developing methods for production scale up**