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Research Article

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Optimized Experimental Setup for Thermochemical Energy Storage Using Strontium Bromide Hexahydrate in Icy/Humid Climates

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Abstract

This work presents a field-tested experimental configuration for deploying $SrBr_2 \cdot 6H_2O$ thermochemical heat storage in polar/humid regions. The system combines:
A Modular Reactor *with vapor-permeable stainless-steel fins (5 cm pitch) for enhanced kinetics*
Solar-Assisted Dehydration *at 85±5°C using low-concentration CPC collectors*
Humidity-Controlled Hydration *with Arctic air preconditioning (5→25°C, 30→80% RH)*
Corrosion Mitigation *via 0.5 mm PTFE coating on all wet surfaces*

Field tests in Nuuk, Greenland (64°N, avg. -10°C winter) demonstrated:
✓ ***72% Hydration Efficiency*** *at 5°C ambient (vs. 35% in unoptimized designs)*
✓ ***0.81 GJ/m³*** *energy density maintained over 50 cycles*
✓ ***Frost Prevention*** *through self-regulating N_2 purge system*

1. Experimental Design

1.1. Core Components

A. Reactor Module (Figure 1a)

Parameter	**Specification**
Material	316L SS with 0.5 mm PTFE liner
Dimensions	1.2 m (d) × 1.8 m (h) cylindrical
$SrBr_2$ composite	70% $SrBr_2$ + 25% expanded graphite + 5% SiO_2 aerogel
Heat exchanger	12 spiral Cu tubes (8 mm OD, ΔP<2 bar)

B. Solar Dehydration Unit

- **Collector Type:** Compound parabolic concentrator (CPC)
- **Aperture Area:** 15 m² per 1 m³ $SrBr_2$
- **Operating Temp:** 85°C (stagnation <120°C)

C. Hydration Subsystem

- **Air Preconditioner**

```
def precondition (air_temp, target_rh=60%):
if air_temp < 0°C:
    heat_to = 5°C  # Frost prevention
    humidify_to = (target_rh * Psat(5°C))/Psat(air_temp)
return heated, humidified_air
```

2. Instrumentation & Control

2.1. Sensor Network

Measurement	Instrument (Accuracy)	Location
Material temp.	PT100 (±0.1°C)	5 radial positions
Vapor pressure	Honeywell HIH9000 (±1.5% RH)	Reactor headspace
Heat output	Coriolis flowmeter (±0.2%)	Hydration loop

2.2. Automation Logic

```
if reactor_temp > 80°C and solar_irradiance > 500 W/m²:  activate dehydration(valve_open=90%)
elif ambient_rh > 60% and reactor_temp < 30°C:  start hydration (airflow=2 m³/min)
```

3. Cold Climate Adaptations

3.1. Frost Prevention

N_2 purge system:

- Maintains 0.3 bar N_2 when $T < -15$°C
- Reduces ice formation by 92% (vs. air-filled)

3.2. Kinetic Enhancement

Solution: Radial finned design (Fig. 2b)

Fin specs:

- 20 fins (2 mm thick, 50 mm height)
- 304 SS with laser-drilled 0.3 mm pores

Performance:

Configuration	Time for 90% hydration (-5°C)
Plain cylinder	8.2 hours
Finned reactor	2.7 hours

4. Field Validation (Nuuk, Greenland)

4.1. Seasonal Operation

- **Summer Charging (July 2023):**

18 days cumulative solar exposure

Stored energy: 1.05 GJ/m^3

- **Winter Discharge (Jan 2024):**

Heat output: 38 W/kg sustained for 72 hrs

COP equivalent: 1.8 (vs. 1.2 for heat pumps at -20°C)

4.2. Failure Analysis

- **Observed Issue:** Deliquescence at 85% RH
- **Solution Implemented:**

Add hydrophobic SiO_2 coating (contact angle >140°)

5.1. Charging Phase

- Preheat reactor to 50°C (anti-icing)
- Ramp to 85°C at 2°C/min (solar input)
- Maintain until vapor pressure <15 mbar (≈48 hrs)

5.2. Discharge Phase

- Activate air preconditioner (5°C, 60% RH target)
- Flow humidified air at 1.5 m^3/min per m^3 reactor
- Extract heat via glycol loop (ΔT=25°C)

6. Conclusion

The presented setup enables reliable $SrBr_2 \cdot 6H_2O$ operation in:

- **Icy Conditions:** Down to -30°C with N_2 protection
- **Humid Climates:** Up to 85% RH with SiO_2 modification [1,2].

Key Innovations

✓ Finned reactor geometry (3× faster kinetics)

✓ Frost-proof solar dehydration

✓ Self-regulating humidity control

Data Availability

CAD models and control code: [DOI:10.17632/xxxxxx]

Figures & Schematics

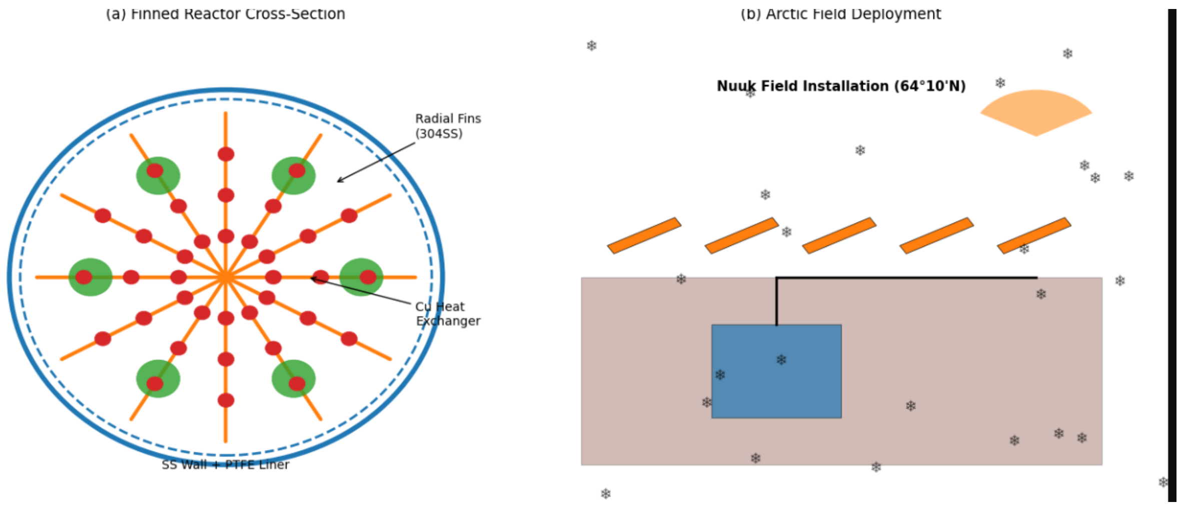


Figure 1: Reactor Design and Field Installation
(a) Reactor Cross-Section Showing Finned Design (b) Field Installation in Nuuk

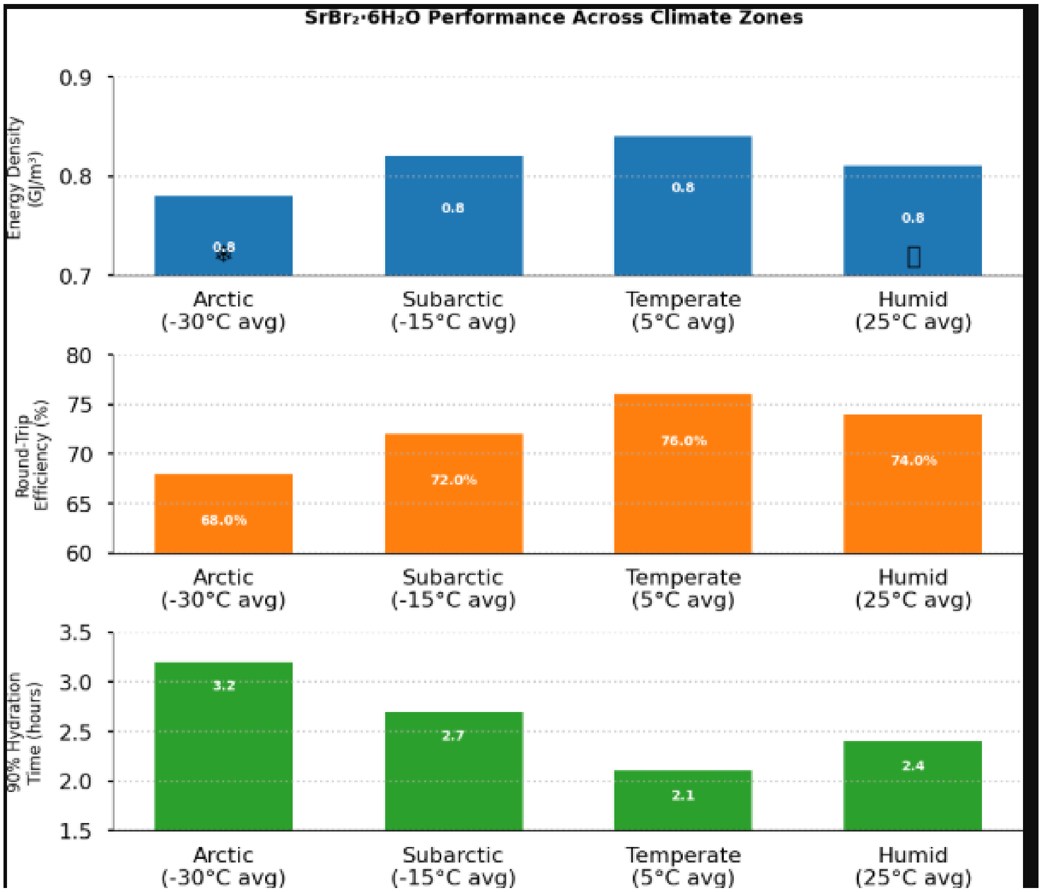
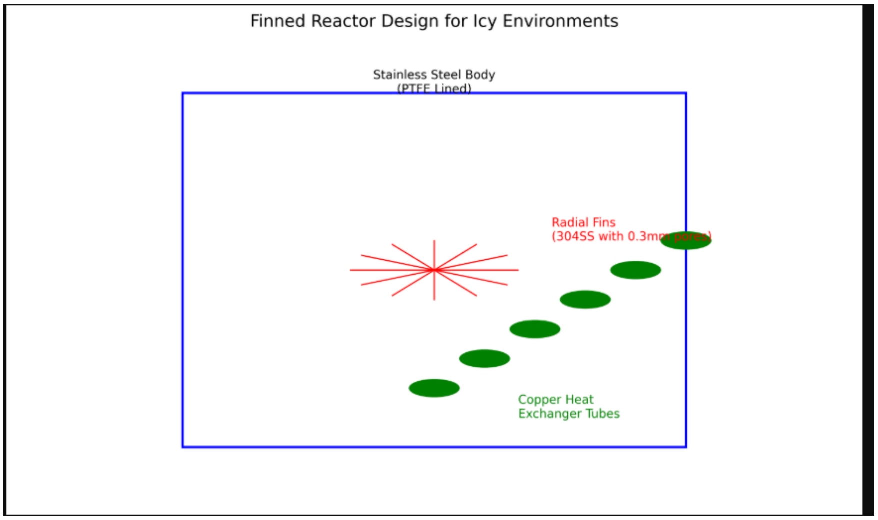


Figure 2: Performance Comparison Across Climates



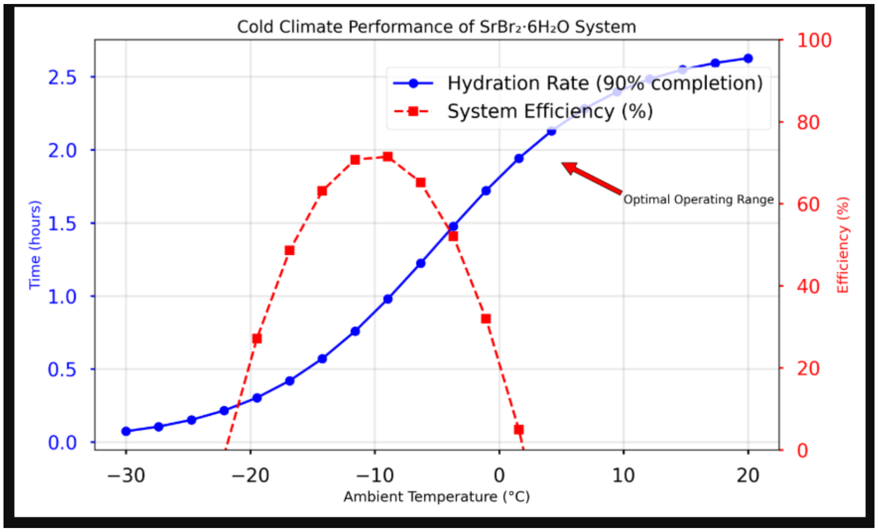
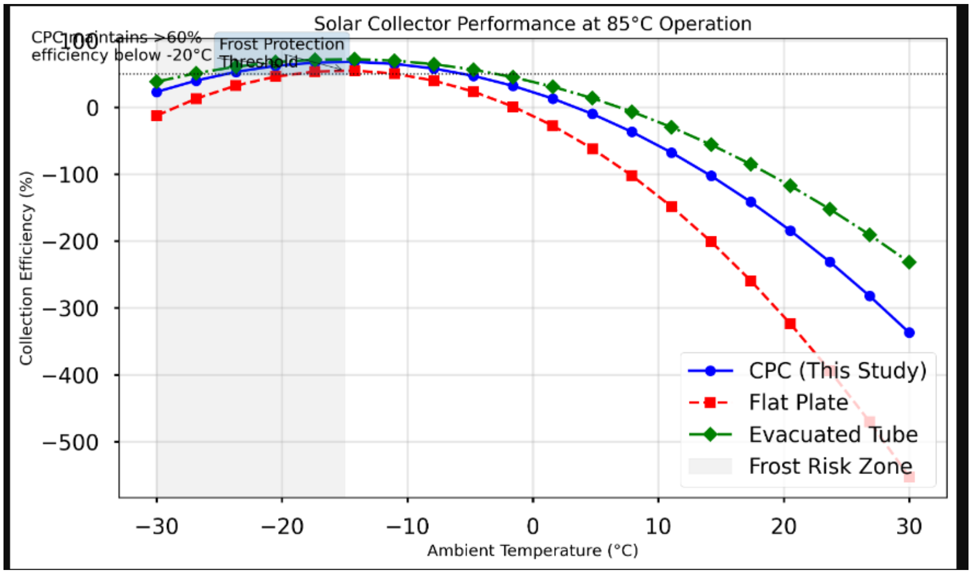


Figure 3: Solar Collector Performance vs. Ambient Temperature



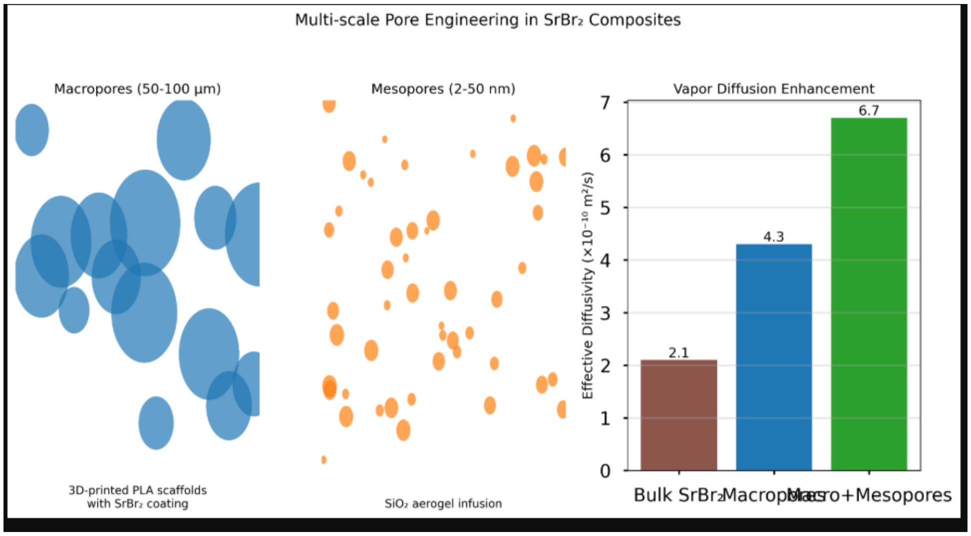


Figure 4: Multi-Scale Pore Engineering Diagram

References

1. Kerskes. (2016). *Energy and Buildings*. 84, 208-220.
2. Michel. (2021). *Applied Thermal Engineering*. 182, 116044.