Operation of a 2-Mg/Year Heavy-Water Detritiation Plant

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Summary

A Combined-Electrolysis Catalytic-Exchange (CECE) process is used to remove tritium from heavy water at NSSI.

- The CECE system has processed 1.3 metric tons of heavy water per month between January–June 2007.

- The activity of the processed water is below 0.2 MBq/kg (5 $\mu$Ci/kg).

- Plant throughput can be doubled with negligible cost.
Electrolysis, isotope separation, and the LPCE columns have been integrated to function as a CECE system.

- Facility design parameters
  - detritiation factor (DF) > $1 \times 10^6$
  - product activity <0.2 MBq/kg
  - maximum D$_2$ gas flow = 100 sLPM
  - G/L = 1.05
  - production rate: 2 metric tons/a
  - duty factor: 290 days

![Diagram showing the integration of electrolysis, isotope separation, and LPCE columns.]

Maximum electrolyte activity: 0.6 TBq/kg (15 Ci/kg)

- Column height vs. product (metric tons/a)
  - Design column height
  - Actual column height
  - DF = $10^7$
  - DF = $2 \times 10^7$
  - DF = $10^6$
The LPCE column detritiation factor exceeds
$2 \times 10^6$ with a $G/L = 1.05$
Columns, control systems, and recombiner are housed in separate ventilated enclosures for safety.

Three 8.3-m column sets are housed in an insulated and ventilated enclosure.

D₂/O₂ recombiner and cooling tanks are located in a separate enclosure above the roof line.

Electrolyzer behind wall in tritium lab.

LPCE and recombiner control systems.

Control systems sealed from hydrogen environment.
Heat removal limits the electrolysis system to 50% of its design throughput.

System design parameters:

- **D₂ production**
  - 100 sLPM (5.4 liters/h)
  - 45 to 140 psig
  - DP of ISS stream < –60°C
  - DP of LPCE stream <10°C

- **O₂ production**
  - DP of recombiner stream < –80°C

- **Electrolyte**
  - <15 Ci/kg

The current electrolyte activity is 13 Ci/kg.
H₂ oxidation at 95 sLPM in the recombiner has been demonstrated in steady state.
Trace DT is removed from the $D_2$ stream leaving the ISS in the LPCE columns

- Modes of operation on cryogenic mole sieve
  - stripping DT from $D_2$/DT mixtures (ppb to ppm)
  - volume reduction (ppm to 0.1%)
Operating in column set in total reflux yields a detritiation factor of $1 \times 10^7$ with $G/L = 1.05$.

![Diagram showing the process flow of recombiner, sample, tank, and D2O electrolysis.](image)

- **Electrolyte activity**: $\sim 4$ Ci/kg
- **System inventory**: $\sim 200$ kg
- **Product activity**: ($\mu$Ci/kg) vs. D2O electrolyzed (metric tons)
- **Design target**: Dotted line on the graph.
The plant is maturing toward the design throughput.

Recombiner and electrolyzer cooling power limit the plant capacity factor to 50%.

Plant availability = operating hours/duty factor
Capacity factor = quantity processed/design limit
Optimizing facility operations can increase the production rate above 2 metric tons/a

• DF degradation with increased product draw is tolerable
  – increase G/L from 1.05 to 1.1 to double the production rate

• The CECE throughput is tailored to meet the ISS throughput
  – increasing the electrolyte activity improves ISS throughput
    - 15 to 20 Ci/kg improves production rate by 30%

• Increase the molar flux in the LPCE columns to increase production rate
  – operating value ~10 mol/m²-s but 40 mol/m²-s is acceptable
  – increasing molar flux improves LPCE performance
The strategy to increase production capability will be staged: first optimize the process, then evaluate the need for upgrades

- **Process optimization:** Staged *low-cost* efforts
  - increase G/L from 1.05 to 1.1
  - increase the electrolyte activity from 15 to 20 Ci/kg
    → 1.8 to 4.6 mt/a is achievable but contingent on ISS performance

- **Upgrade electrolyzer from 7 sm$^3$/h to 30 sm$^3$/h: *modest* cost effort
  - molar flux over LPCE catalyst ~60 mol/m$^2$/s
  
  But it requires
  - a larger recombiner
  - an ISS scale-up
  
  → 4.6 to 20 mt/a
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