Tritium R&D at AECL
Selected Topics

Tritium Focus Group Meeting, Savannah River Site

2014 April 22-24

Hugh Boniface

Chalk River Laboratories, Ontario, CANADA

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Outline of Presentation

- Introduction & Background
- Tritium Facilities: Laboratories, old and new
- Tritium Separations: CECE process
- Tritium Properties: Materials
- Tritium Exploitation: Batteries, Helium-3
- Other work: Education, environment, biology, fusion, hydrogen

Background

- CANDU reactor: Heavy water moderated, high neutron flux (1.9×10^{14} $cm^{-2}.s^{-1}$), typically 6 Ci/kg per year
- Each unit has ~250,000 kg in-core, so 19 Canadian units produce about 28 MCi (~3 kg) each year.
- Ontario's Darlington TRF processes about 2000 Mg D_2O per year for 18 reactors, capturing about 2 kg T_2
- OPG stores tritium as pure T_2 in 0.5 MCi containers
- AECL dispenses tritium from these containers

AECL Tritium Facility

- Set up before 1980
- One-of-a-kind in Canada
  - Commercial and R&D Operations
- Licensed to handle up to 1 MCi at any time
- R&D Labs in an old building
  - High Level
  - Low Level
- Tritium Vault (2.5 MCi)
- Handle mainly T_2 and HTO

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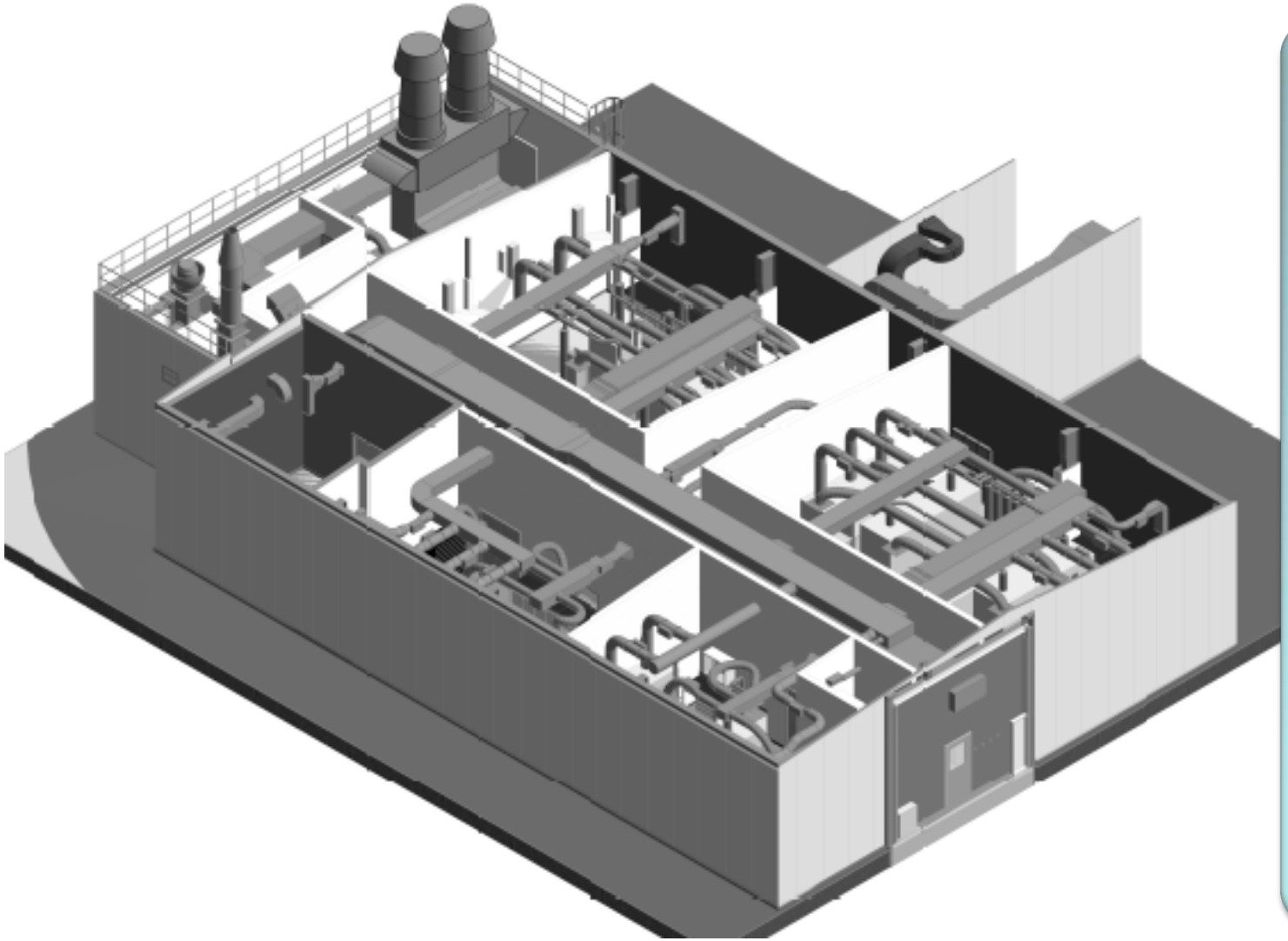
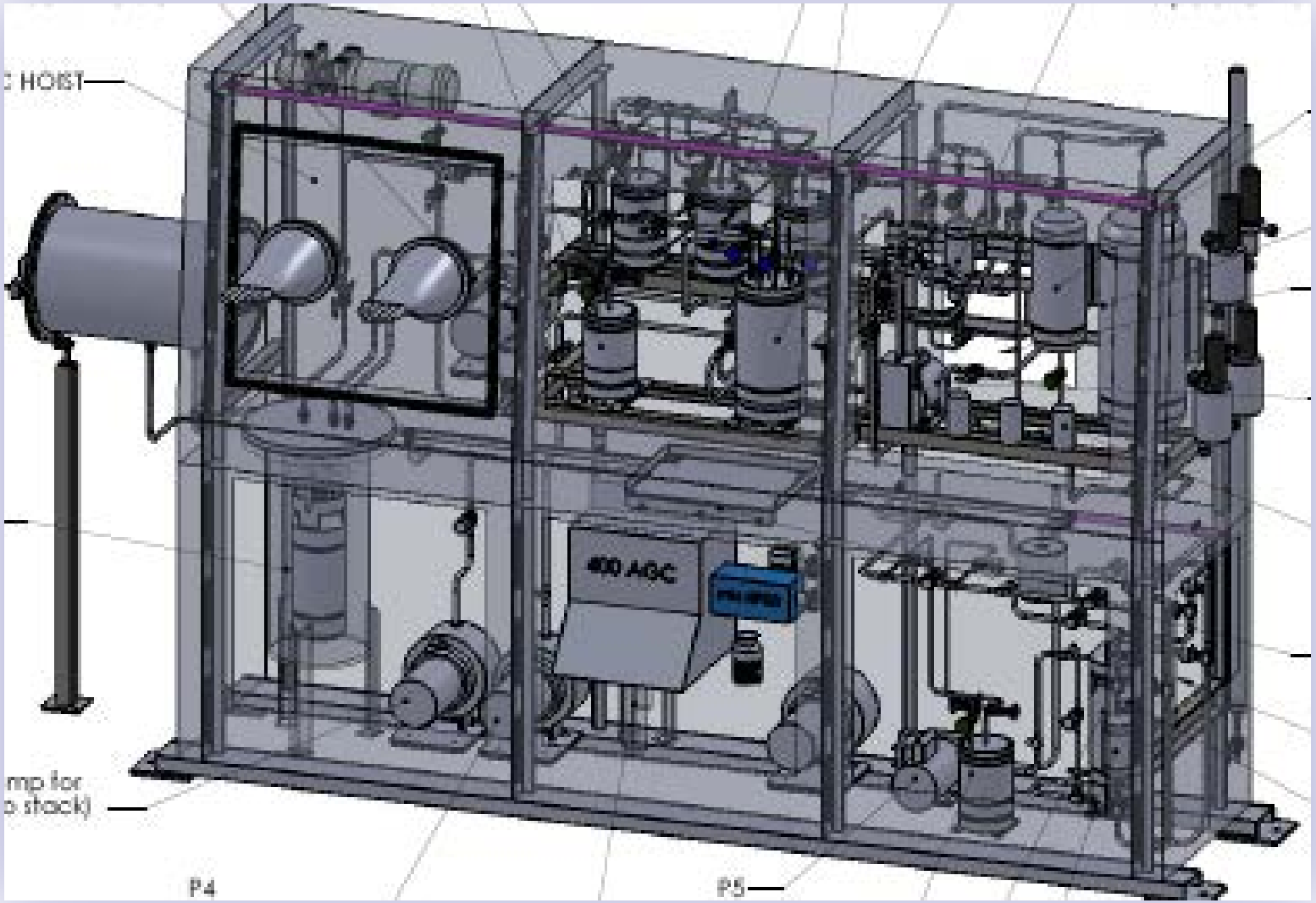
New Tritium Facility



New Tritium Lab

- Pure T_2 Handling
- T_2 Storage vault
- CECE closed-cycle (1 Ci/g)
- Materials exposure (1 Ci/g)
- Permeation at high-temp
- Standards prep.
- HTO decontam.
- Analysis (T/D/H)
- Scintillation counting

New T_2 Glove-box

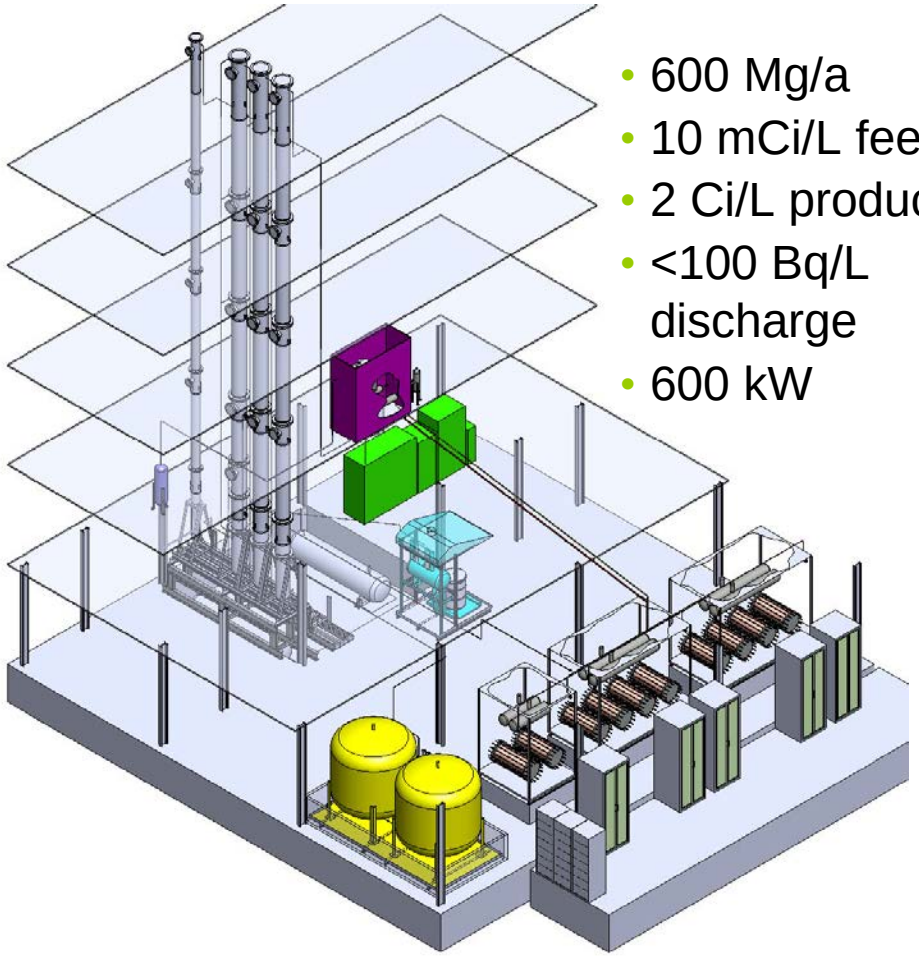


New High Activity Tritium Handling Apparatus & Glove box

Separation: CECE Applications

- Modest complexity
- High capacity factor
- Modest foot-print
- Reasonable price
- Proven technology

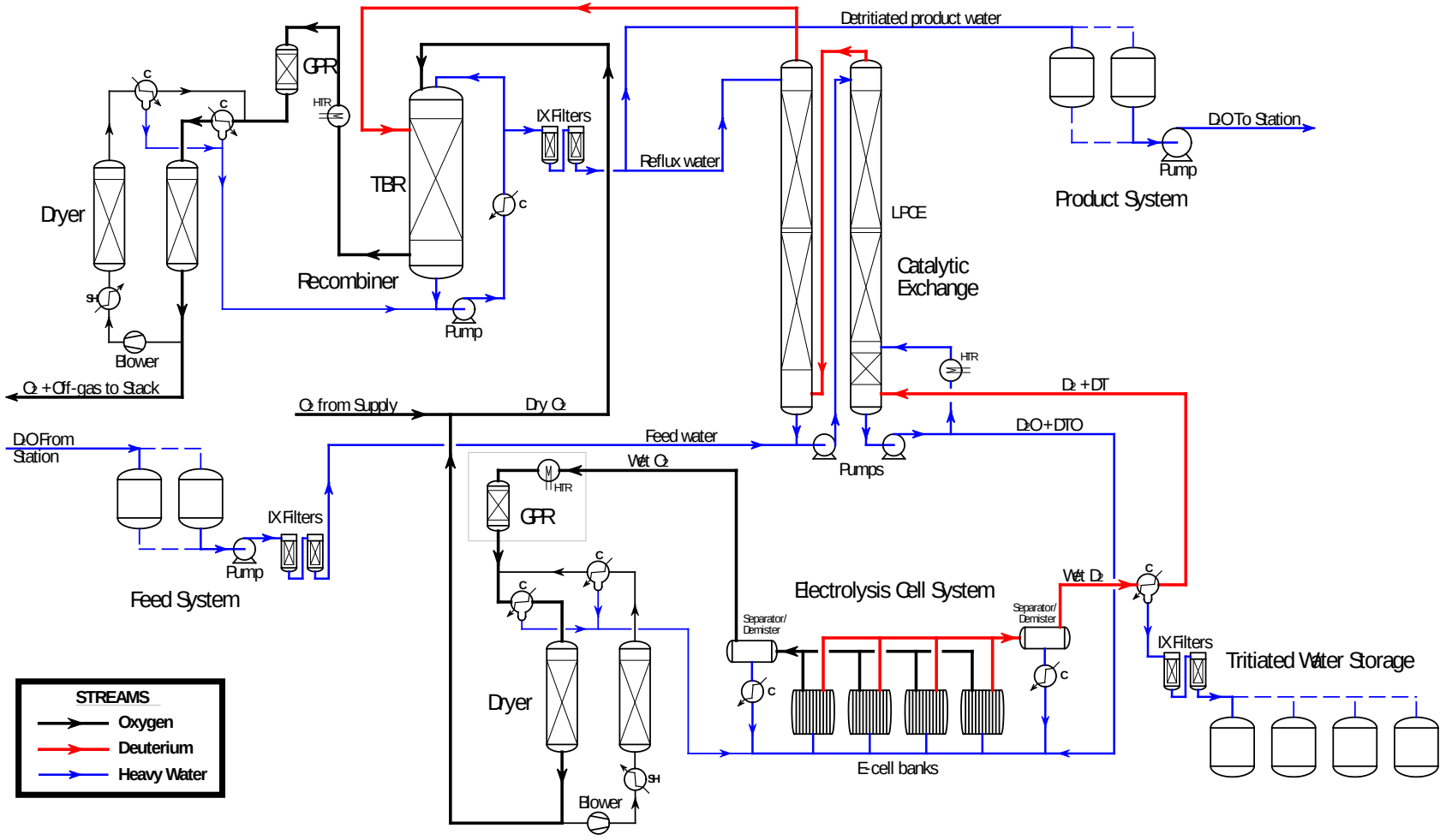
CECE Detritiation Process Demonstrated (CECEUD Facility)



- 600 Mg/a
- 10 mCi/L feed
- 2 Ci/L product
- <100 Bq/L discharge
- 600 kW

Light Water CECE Detritiation Process Designed for Chalk River

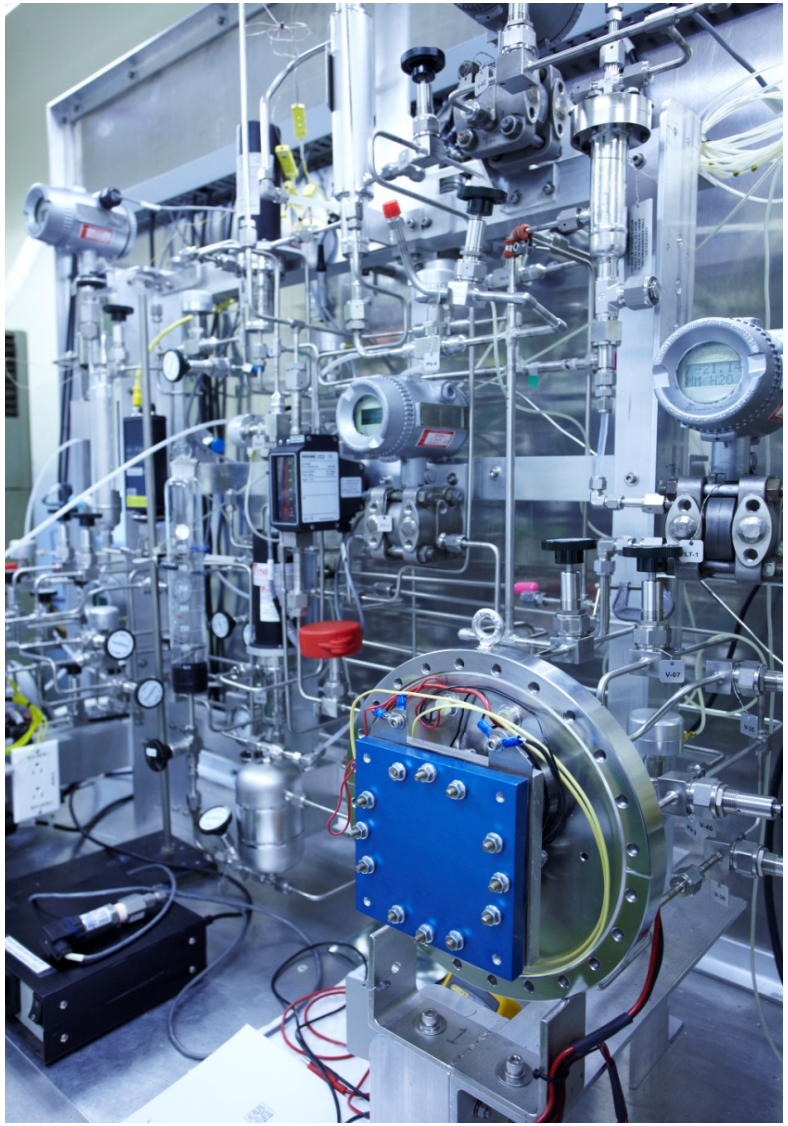
Separation: CECE Applications



CECE-Store:
Proposed for CANDU detritiation

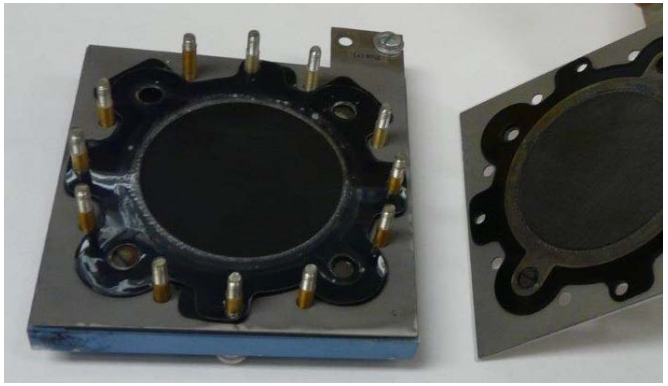
Separation: CECE Process
H_2-H_2O Exchange, Recombination, Electrolysis

Wetproofed catalysts for H_2 isotope exchange



H_2-O_2 recombiner catalyst

Electrolyzers



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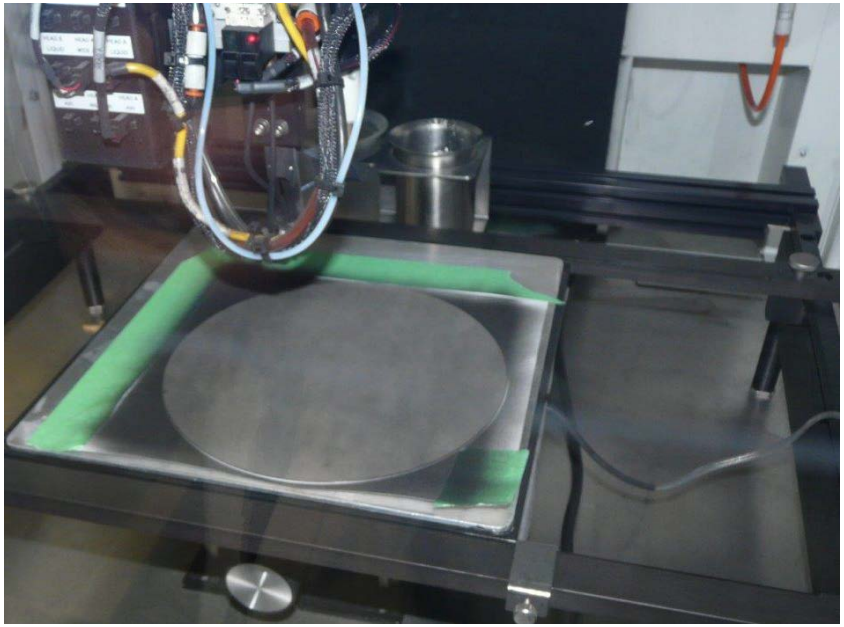
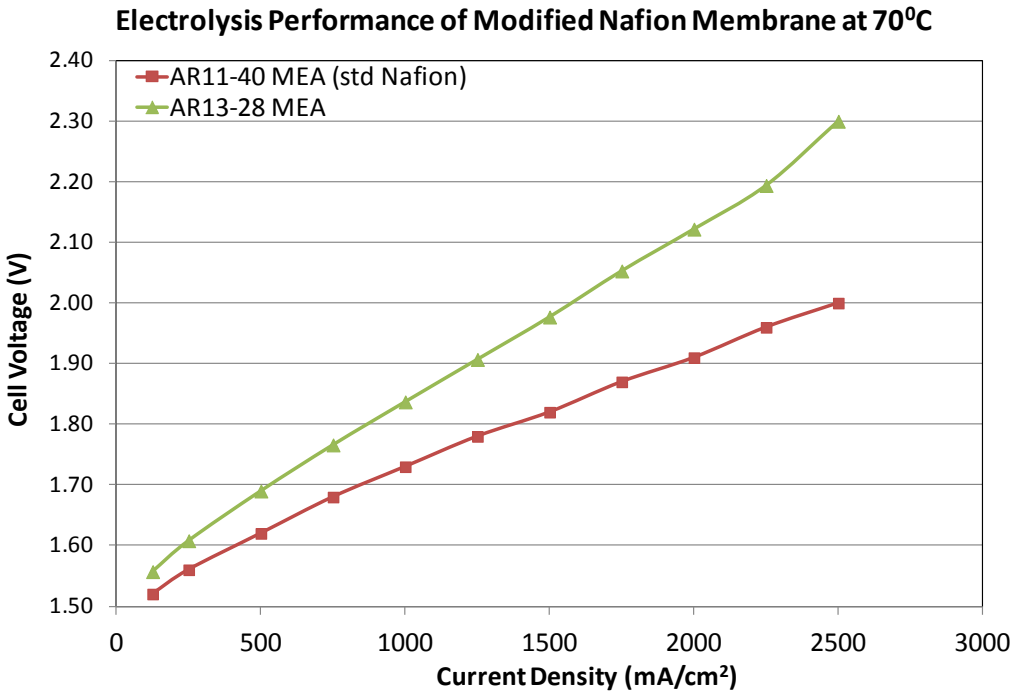
Separation: CECE Process
PEM Electrolysis – T-resistant Membrane development





Preparing proton-exchange membrane materials for testing:
- Nafion® reference membrane
- Catalyst spray on gas diffusion layer
- Hot-press MEA

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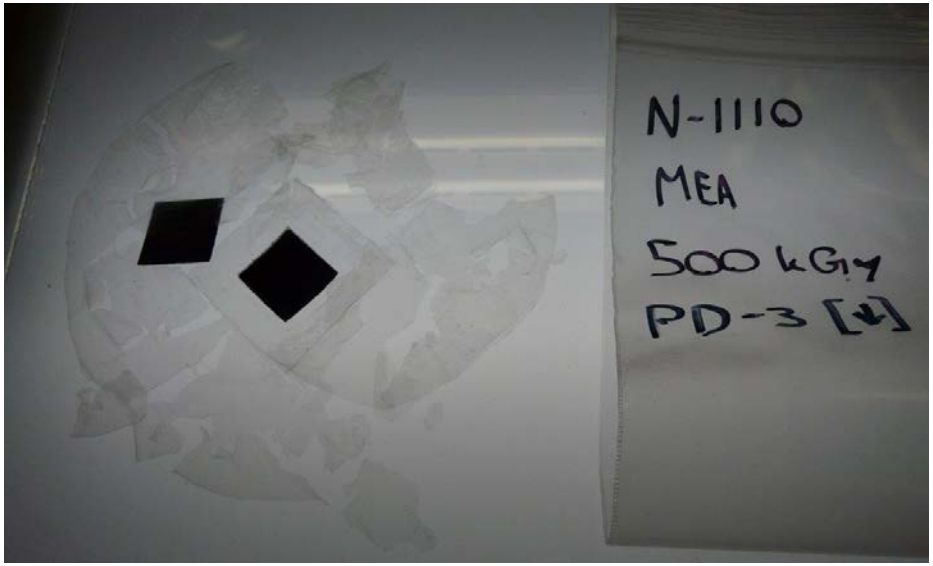
Separation: CECE Process
PEM Electrolysis – T-resistant Membrane development



Preparing proton-exchange membrane materials and exposing to radiation:
- Membrane spraying/casting in-house (extrusion by external collaboration)
- Gamma-irradiation (Gamma-cell 220)

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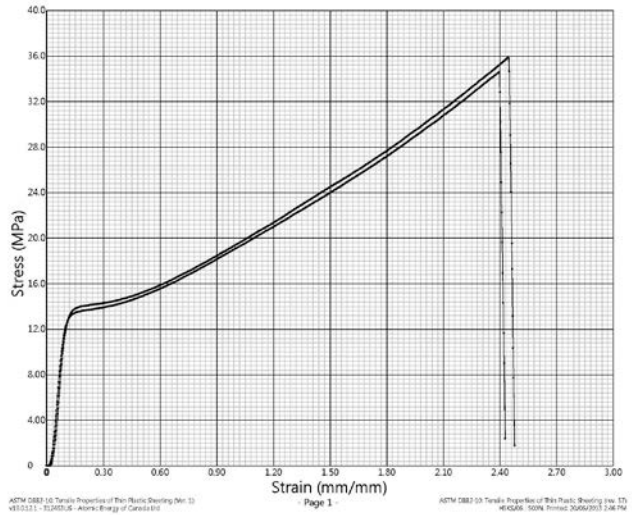
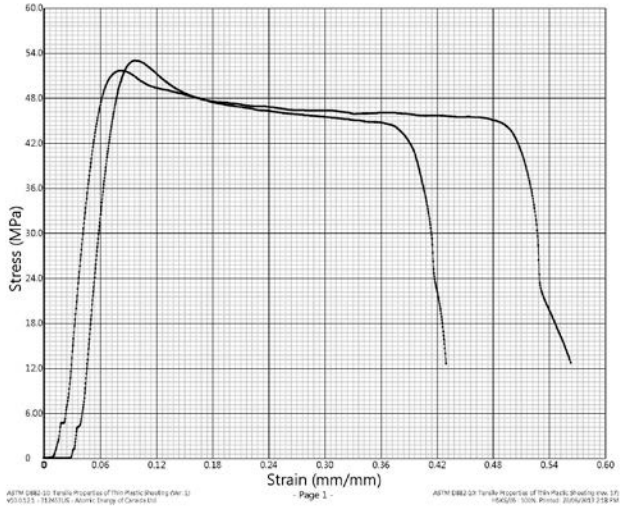
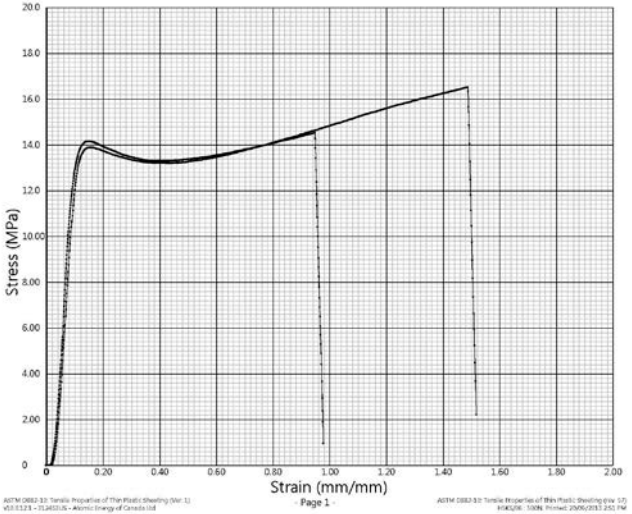
Separation: CECE Process
PEM Electrolysis – T-resistant Membrane development

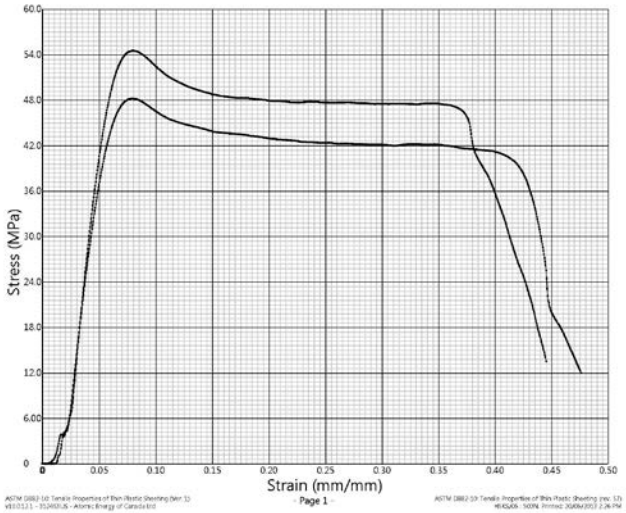


Reference:
←Nafion RT-53→





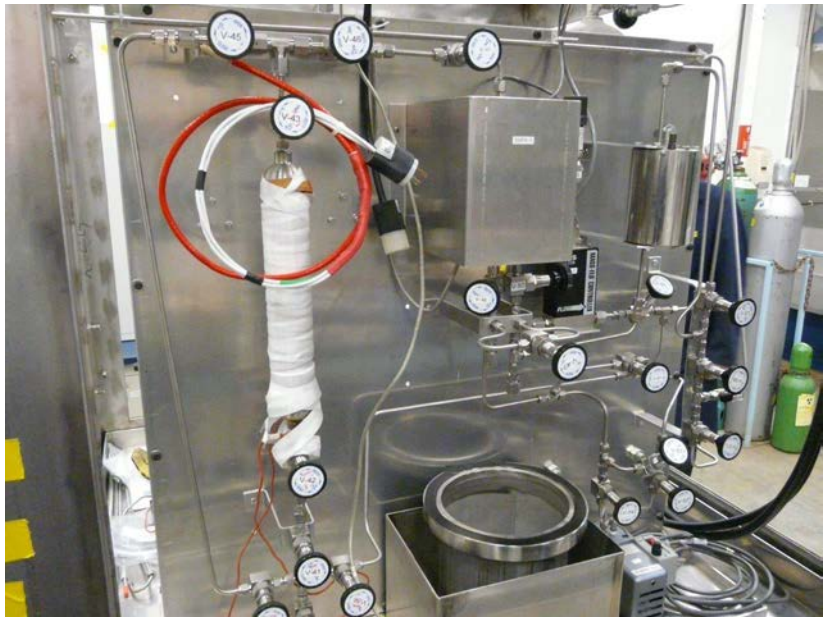
After 500 kGy:
←Nafion RT-53→

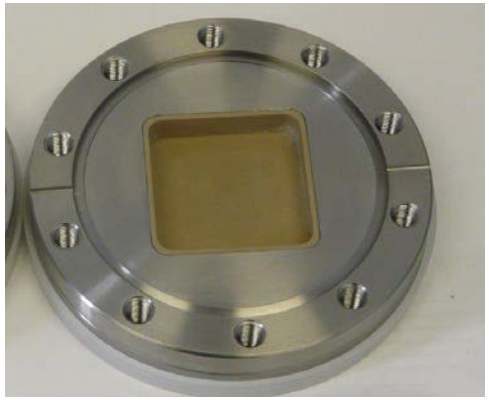


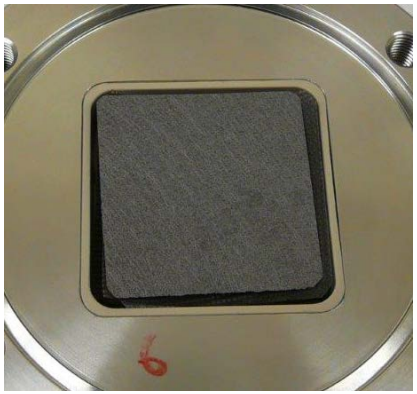
Tensile testing proton-exchange membrane materials after gamma-irradiation

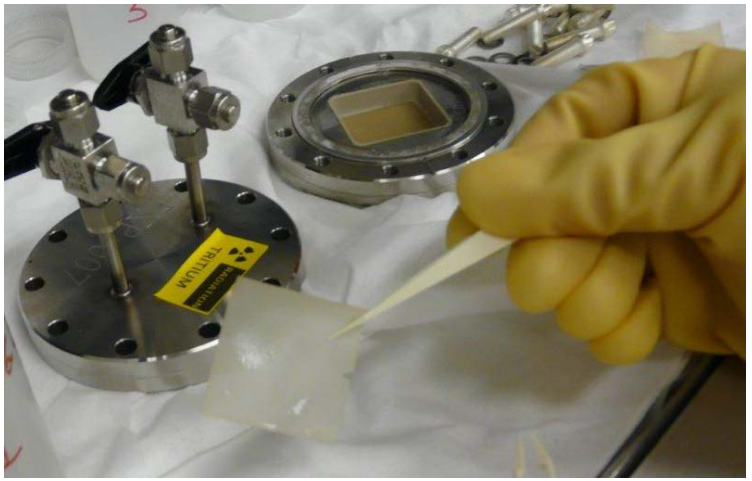
Separation: CECE Process

PEM Electrolysis – T-resistant Membrane development









Exposure of proton-exchange membrane materials to high tritium water (~1,000 Ci/L)

AECL – Tritium & Materials
Permeation and Degradation

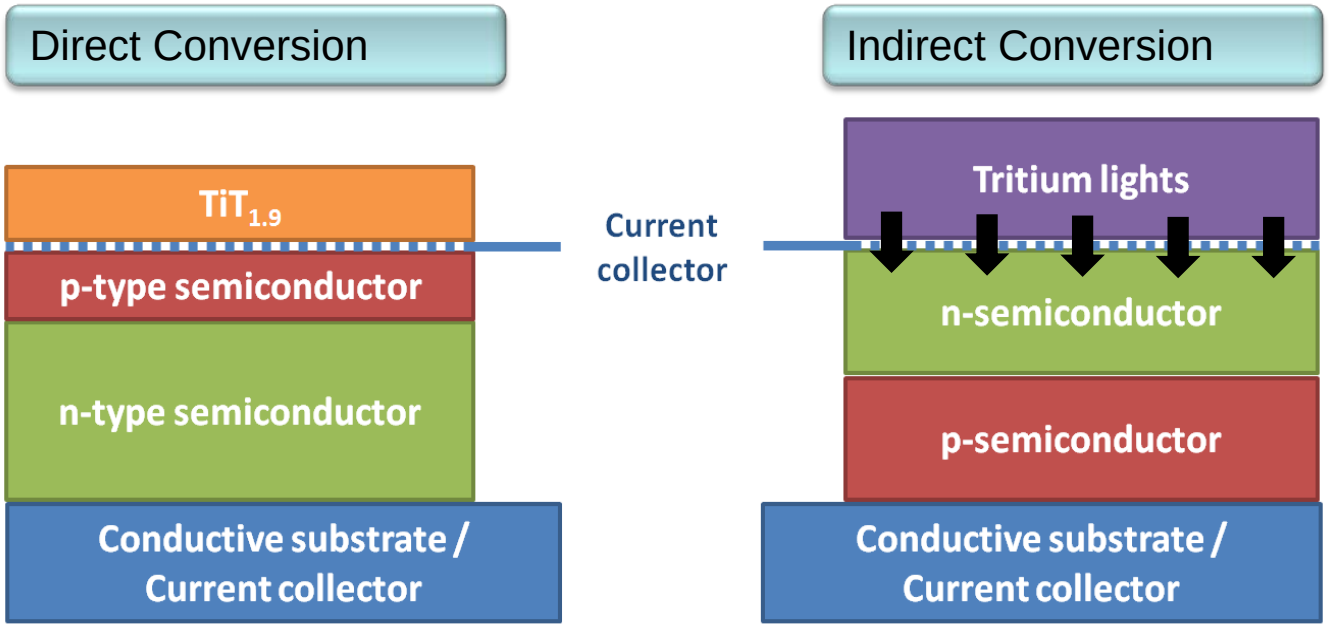
Tritium permeation setup

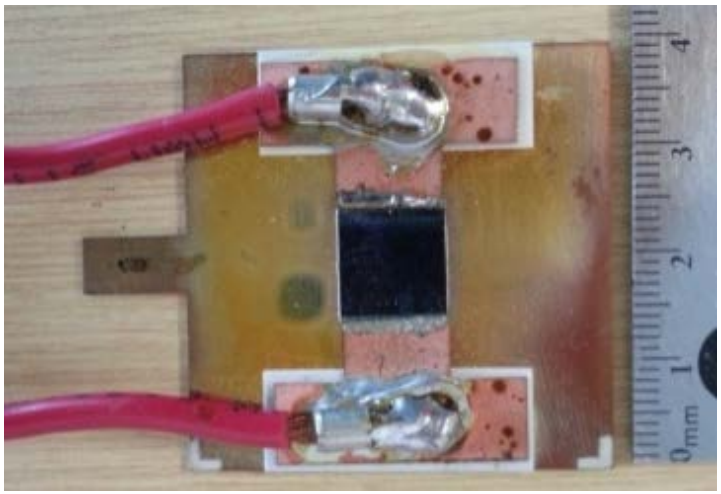
- Inductive heat to 1000ºC within 5ºC
- Sample:
  - 10 mm dia.
  - 50 mm lg.
- HT flow inner
- Swept annulus
- Measure and model tritium permeation

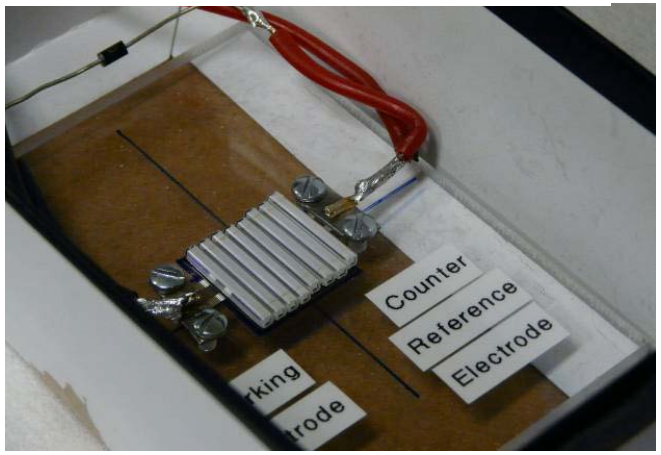
Tritium powered batteries

Direct Conversion

Indirect Conversion







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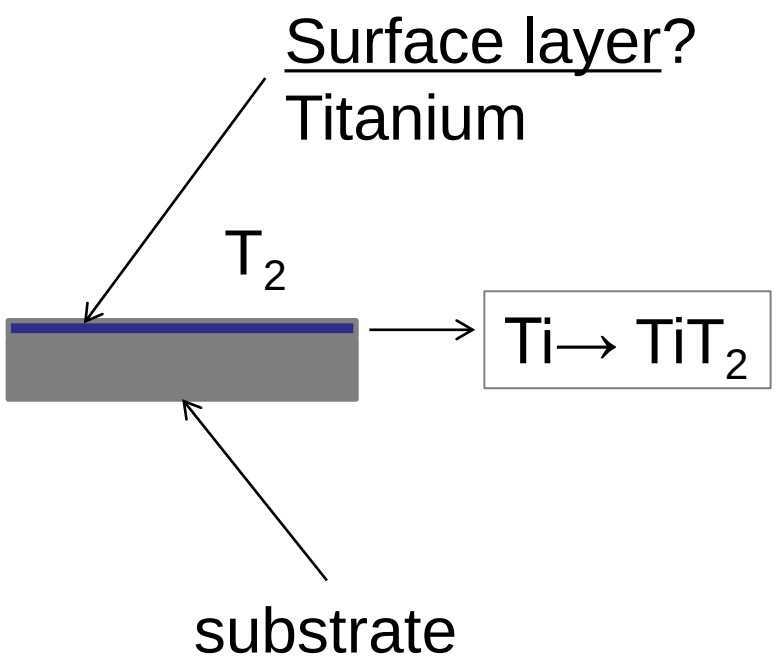
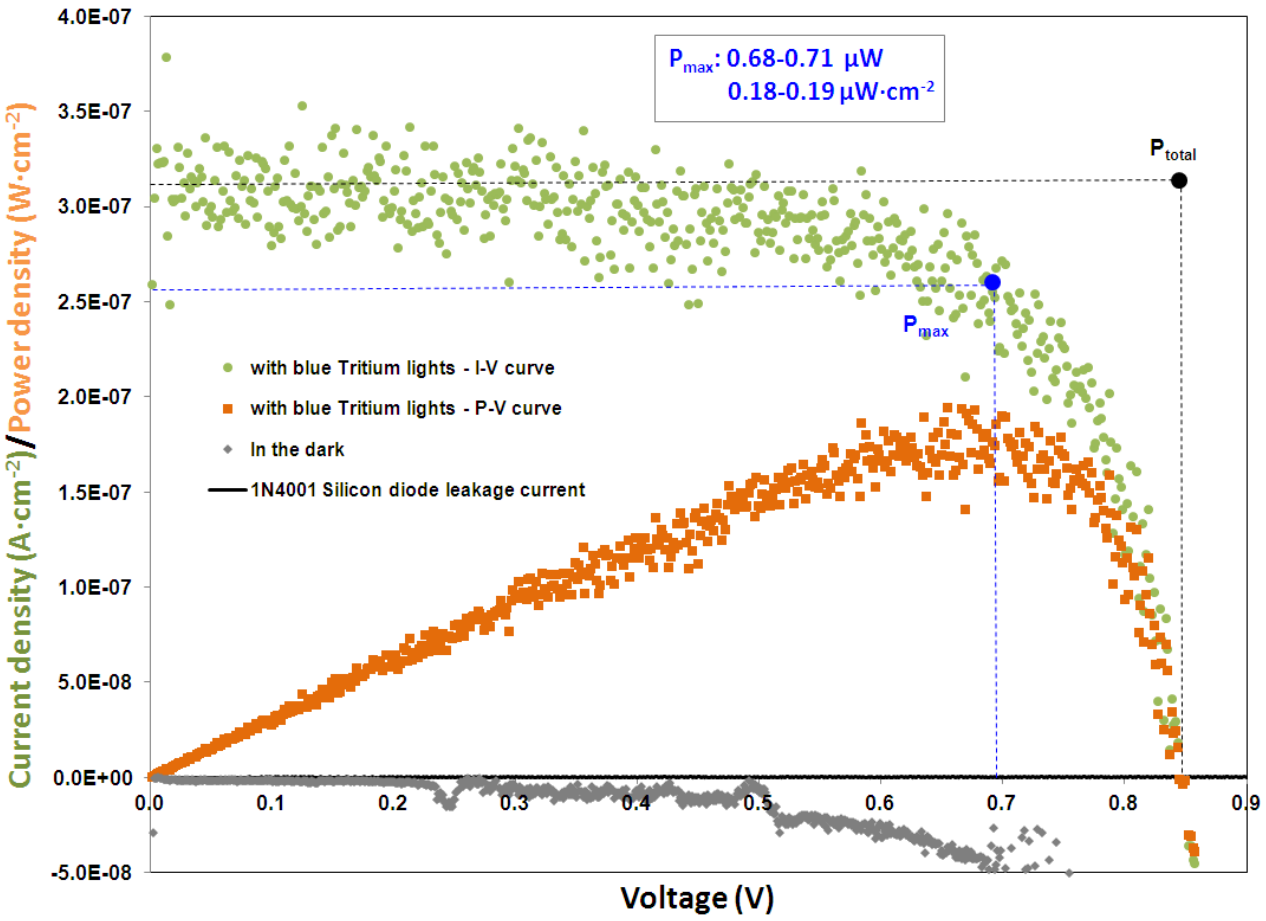
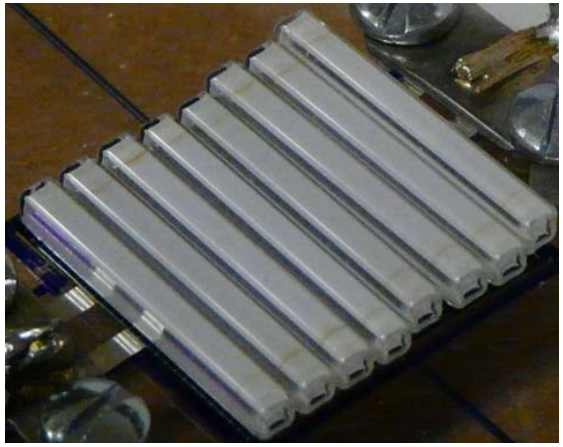
Direct Tritium battery
Immobilized Tritium Layers



Metal vapour deposition

Indirect Tritium battery
Set Voltage – Measure Current





Blue lights

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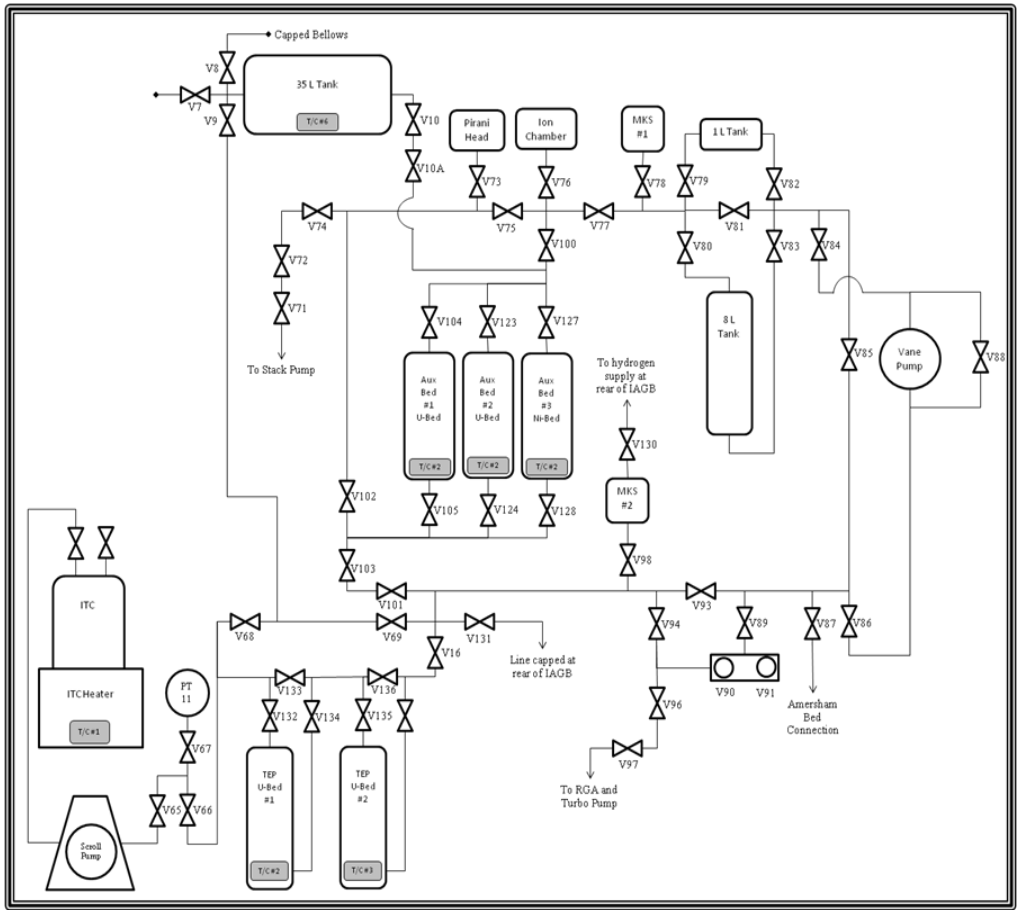
Helium-3 recovery



- Heat ITCs to 720ºC
- Determine He-3 recovery as function of temperature
- Determine rrecovery as function of decay time
- Determine if a one-step purification is effective

Submitted to *AECL Nuclear Review* -
"Helium-3 Recovery from Immobilized Tritium Containers"

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Education – Tritium Handling Course

- Lectures
  - Tritium Interaction with Materials
  - Radioactive Materials Transport
  - Tritium Monitoring
  - Tritium Gas Chromatography
  - Tritium Waste Management
  - Tritium Accounting
  - Tritium Dosimetry
  - Detritiation (atmospheric & water)

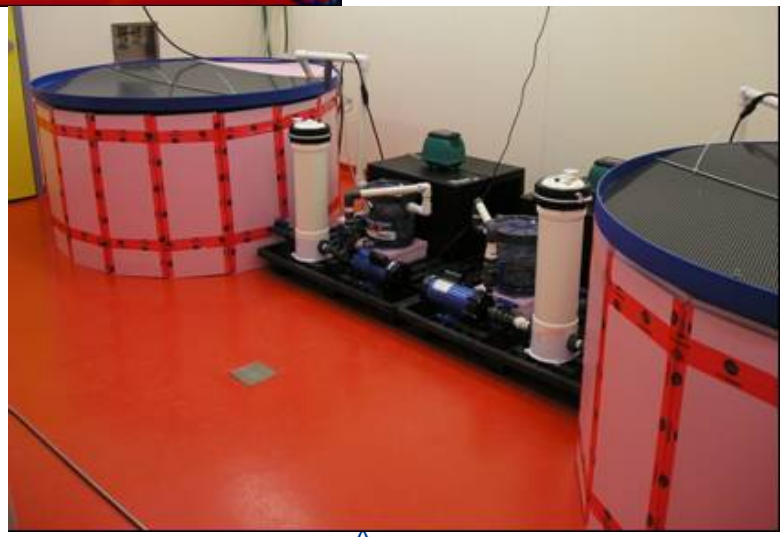
Course customized based on clients' needs

- Practical exercises
  - Tritium Handling
    - Desorbing gas from a uranium bed
    - Measurement of gas volume (P, V, T)
    - Analyse H/D/T by gas chromatography
    - Isotopic swamping of apparatus with H_2
  - Getter Bed Demonstration
    - Performance of a SAES St707 getter bed to remove tritium
  - Tritium Decontamination
    - Decontamination of metals
    - In-situ decontamination of a process ionization chamber

Biological Aspects of Tritium

- **Radiobiology**
  - Study the effects of low level beta irradiation on biological systems (cancer and non-cancer disease)
  - Eco-toxicological studies on animal species including fish, amphibians and birds
- **Biokinetics**
  - Pharmacokinetic and dosimetric mathematical models for dose estimation following radionuclide intake (incorporation into body tissues and fluids)
- **Radio-Ecological Research**
  - Evaluation of environmental data
  - Models to predict dispersion of tritium releases
  - Water remediation
- **Dosimetry**

Biological Research Lab



Aquaculture System

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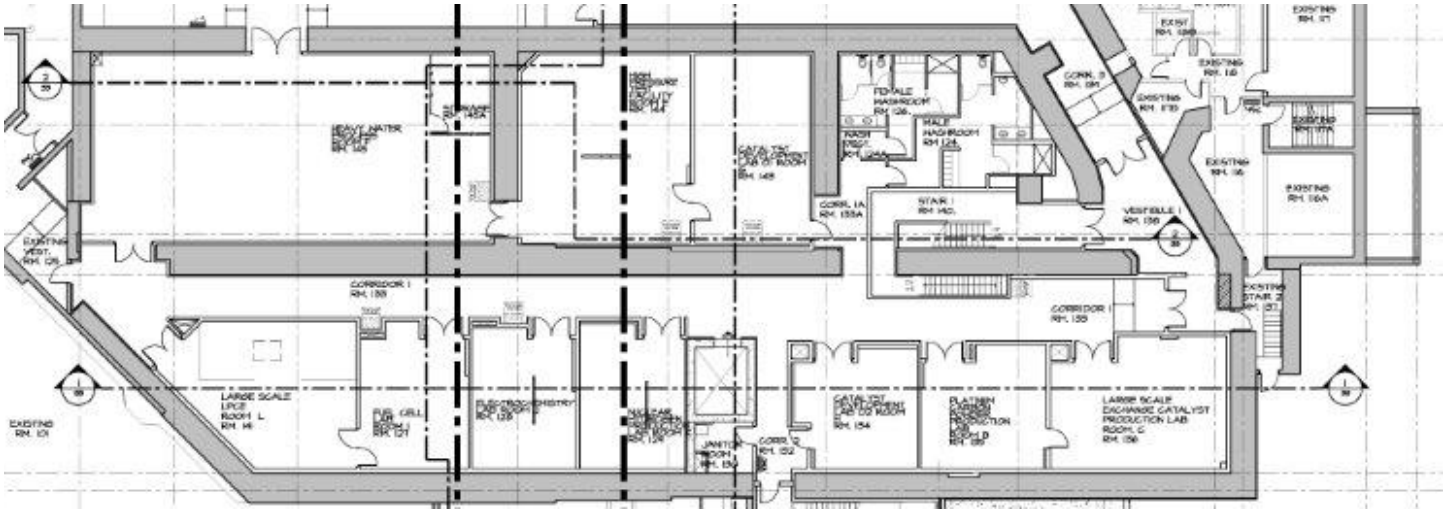
Hydrogen Work

- Heavy water processes (catalysts, cell technology, process models, isotope analysis)
- PEM Electrolysis – water, steam, copper-chlorine cycle
- Fuel cell catalysts and membranes
- Catalytic recombination (passive, stoichiometric)
- Non-active tritium work
- Energy storage – hydrogen, modelling, batteries

New Hydrogen Lab



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Summary

- Significant tritium capabilities exist in Canada
  - R&D and commercial activities
- Mature designs, technologies for water detritiation
- Advances in tritium handling technologies
  - Electrolysis
  - Catalysis
  - Materials
- Promotion of the use of tritium
  - Tritium-powered batteries
  - Helium-3 recovery
- Biological studies
- Support in new hydrogen facility


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