Overview of AECL's Tritium Compatible Electrolyser Program

Tritium Focus Group Meeting, Idaho National Lab

2014 Sep 24-25

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Chalk River Laboratories, Ontario, CANADA

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Outline of Presentation

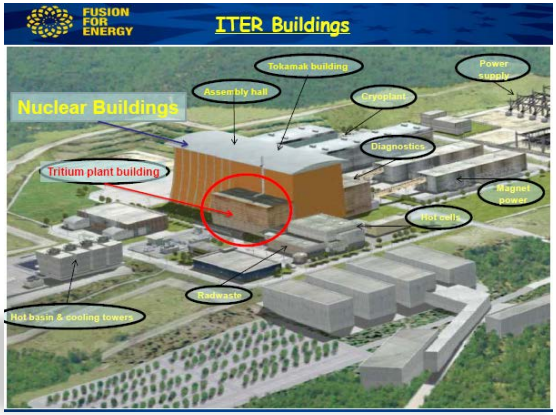
- Introduction & Background
- Electrolyser program overview
- Materials development (MEA)
- Testing
  - Part A: **Bench top scale**
  - Part B: **Small lab scale**
  - Part C: **Pilot scale**
- Summary

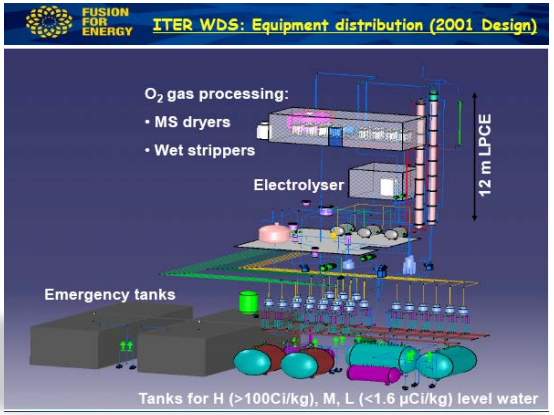
Introduction & Background

T in D_2O – Darlington

T in H_2O - Fukushima

T in Fusion - ITER





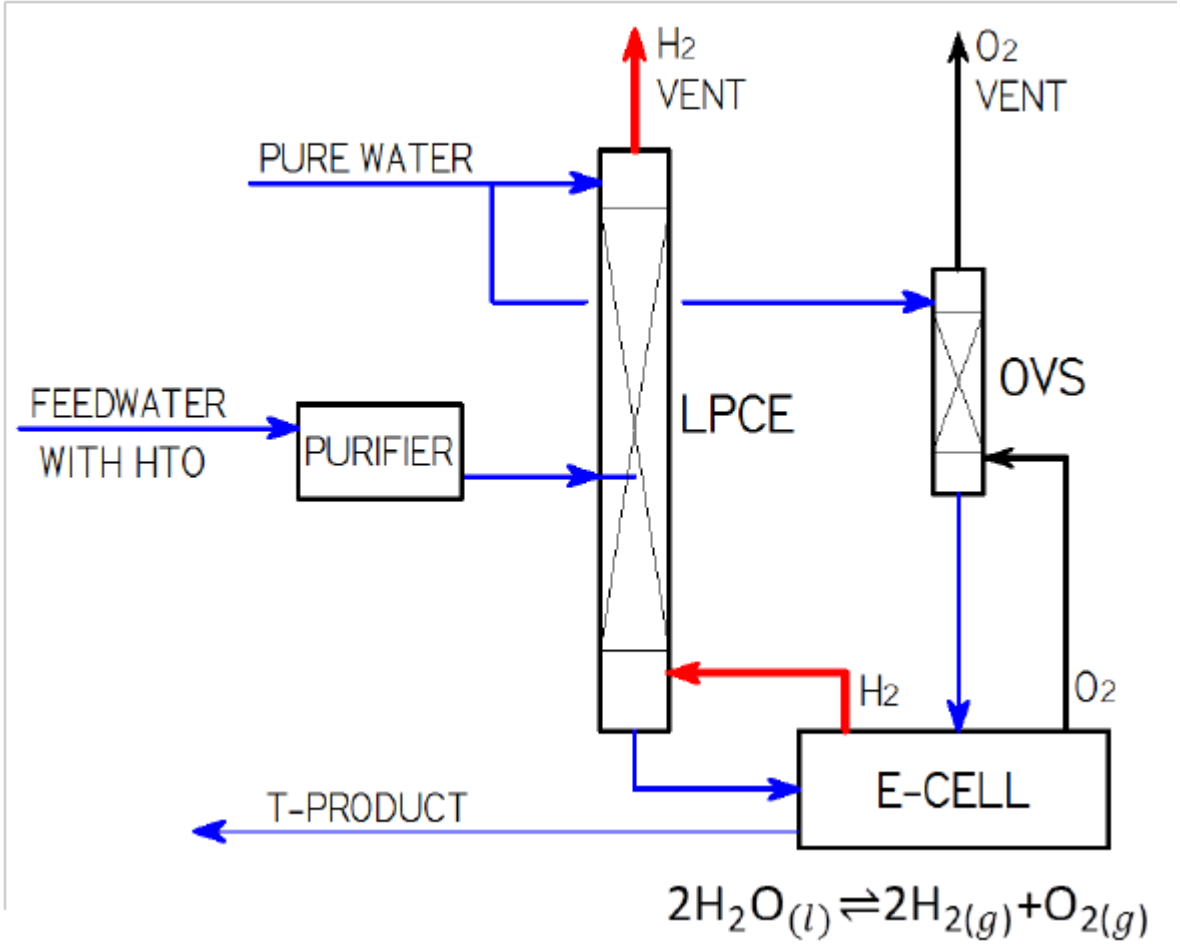
Introduction & Background

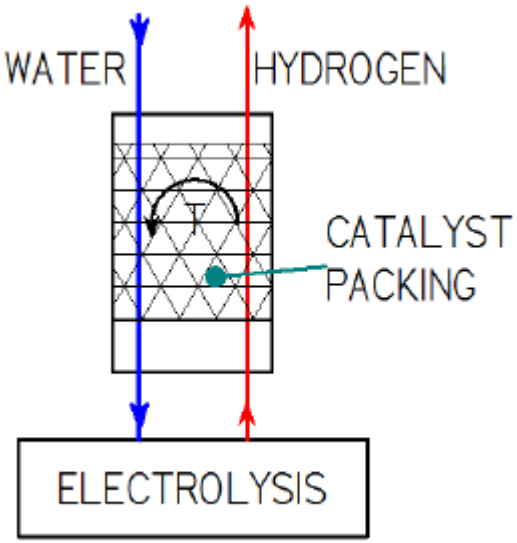
PCP – Hamilton, ON

CECEUD – Chalk River, ON

Introduction & Background
CECE Technology

$$HT_{(g)}+H_2O_{(l)} \rightleftharpoons H_{2(g)}+HTO_{(l)}$$



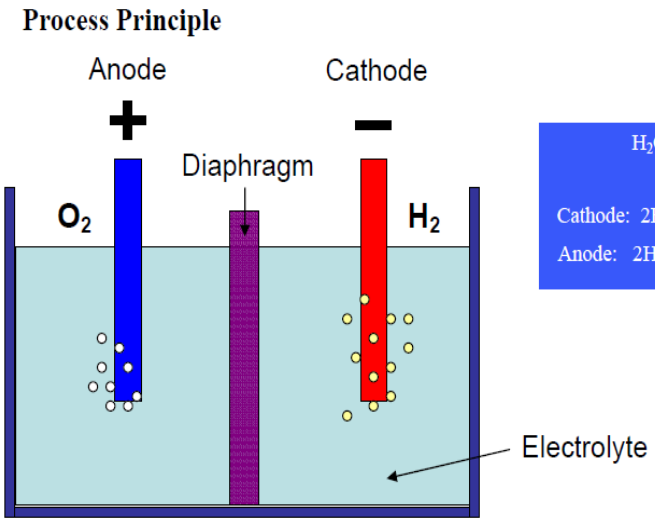


$$2H_2O_{(l)} \rightleftharpoons 2H_{2(g)}+O_{2(g)}$$

H. Boniface, *A Practical Process for Light Water Detritiation at Large Scales*, Pacific Basin Nuclear Conference, 2014

Program overview
Caustic vs PEM Electrolysers

Alkaline (Hydrogenics)

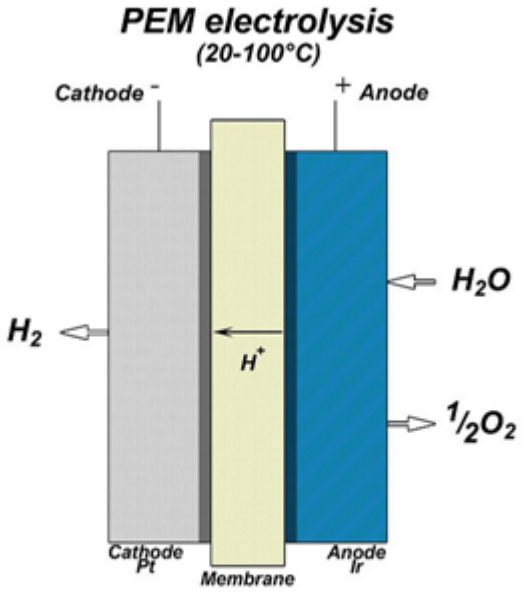


$$H_2O \Rightarrow H_2 + \tfrac{1}{2} O_2$$

Cathode: $2H_2O + 2e^- \Rightarrow H_2 + 2HO^-$

Anode: $2HO^- \Rightarrow \tfrac{1}{2} O_2 + H_2O + 2e^-$

PEM (HOGEN)

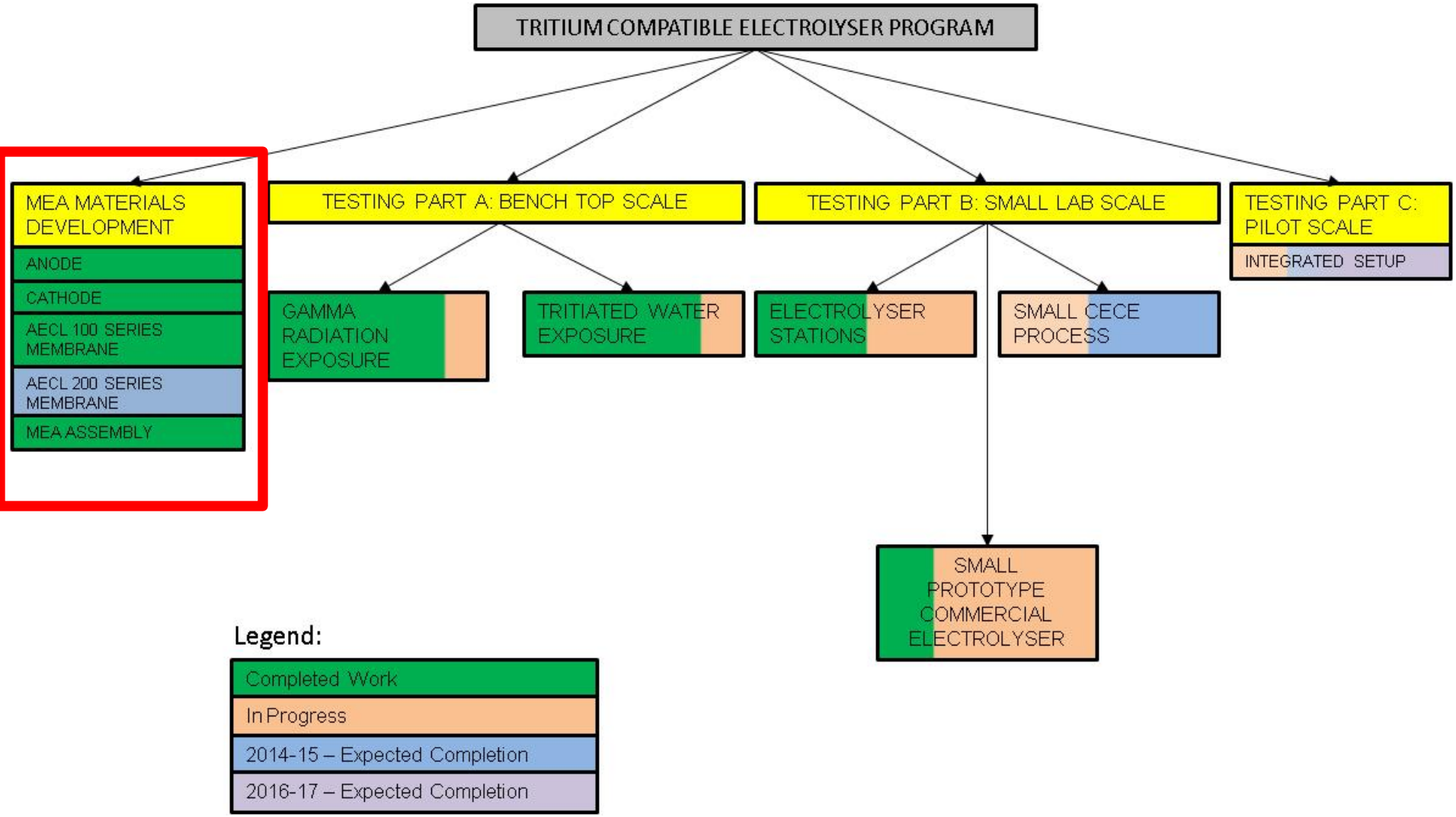


$$H_2O \longrightarrow 2H^+ + \tfrac{1}{2}O_2 + 2e^- \quad \text{Anode}$$

$$2H^+ + 2e^- \longrightarrow H_2 \quad \text{Cathode}$$

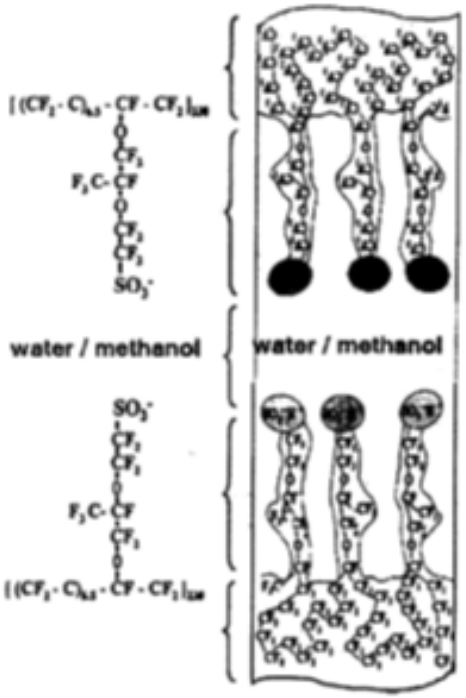
$$H_2O \longrightarrow H_2 + \tfrac{1}{2}O_2 \quad \text{Total Reaction}$$

Program overview

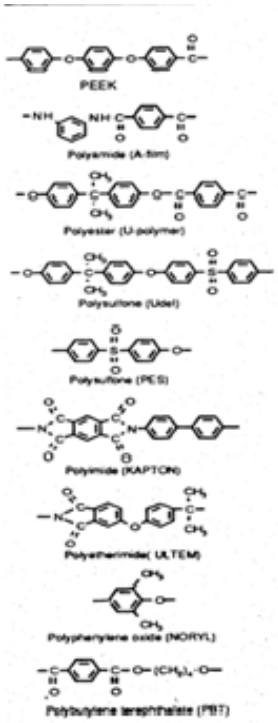


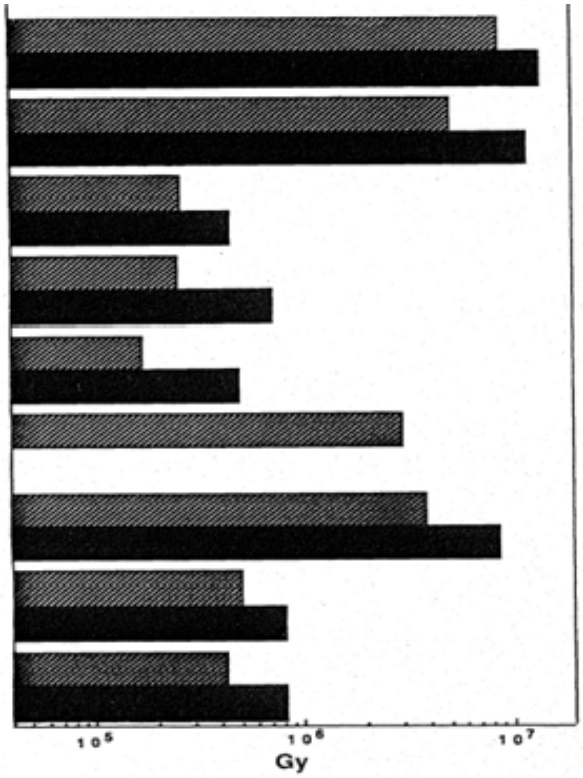
Materials development

Nafion® based type membranes



Radiation resistant polymers





D. W. Clegg and A. A. Collyer, *Irradiation Effects on Polymers,* Elsevier, 1991

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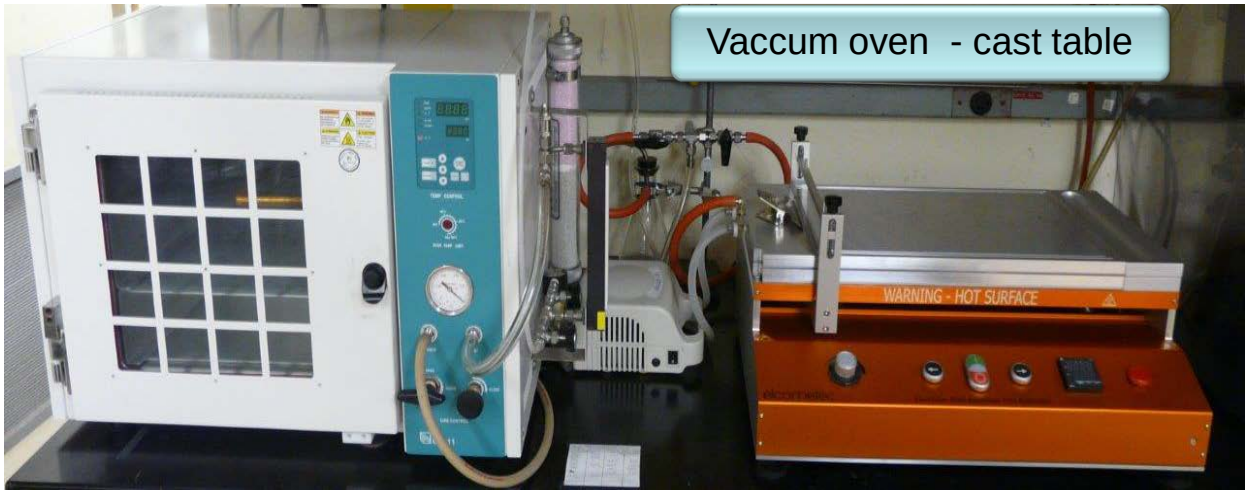
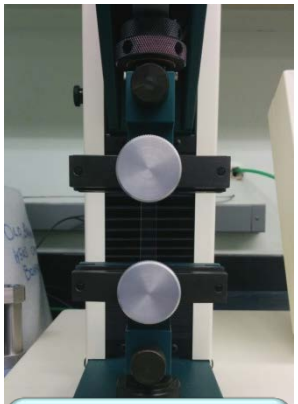
Materials development

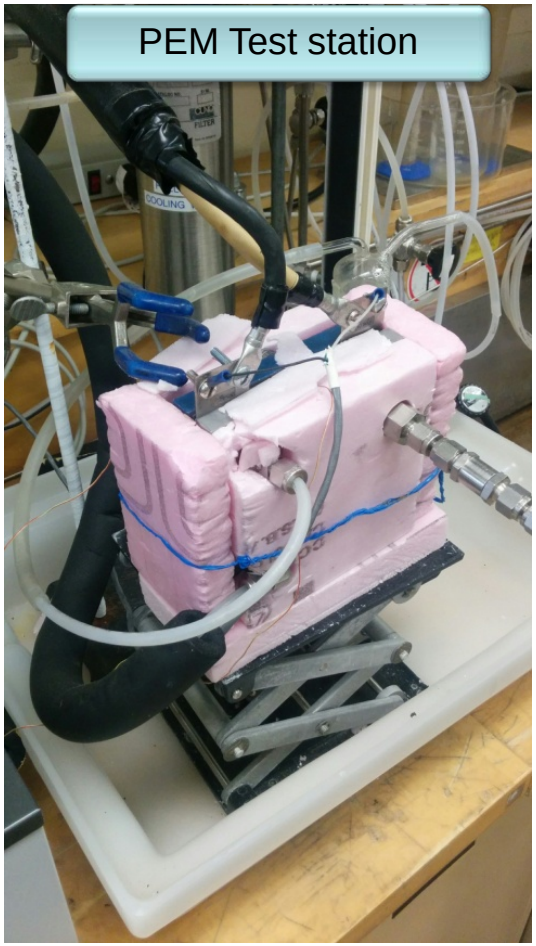


Vaccum oven - cast table

Spray machine



Tensile machine



PEM Test station

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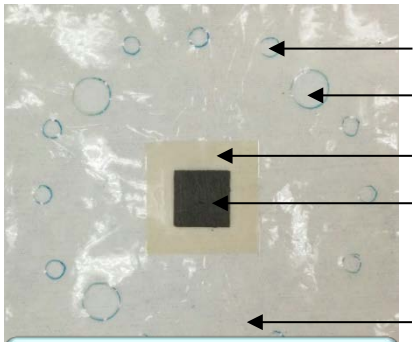
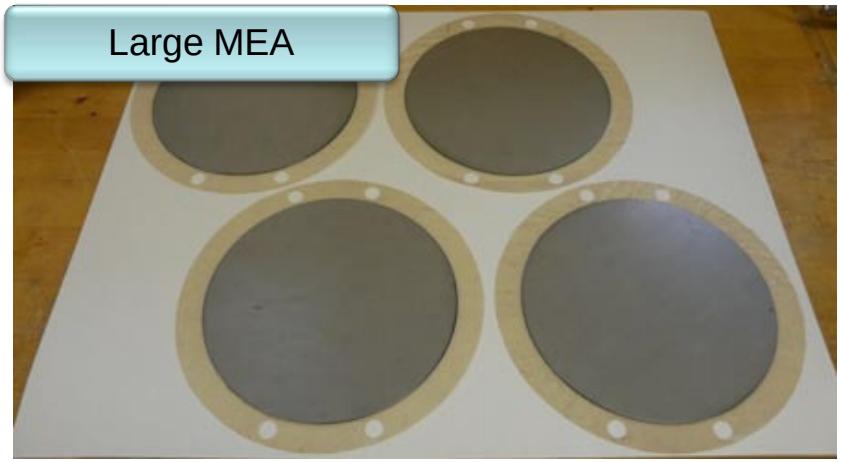
Materials development

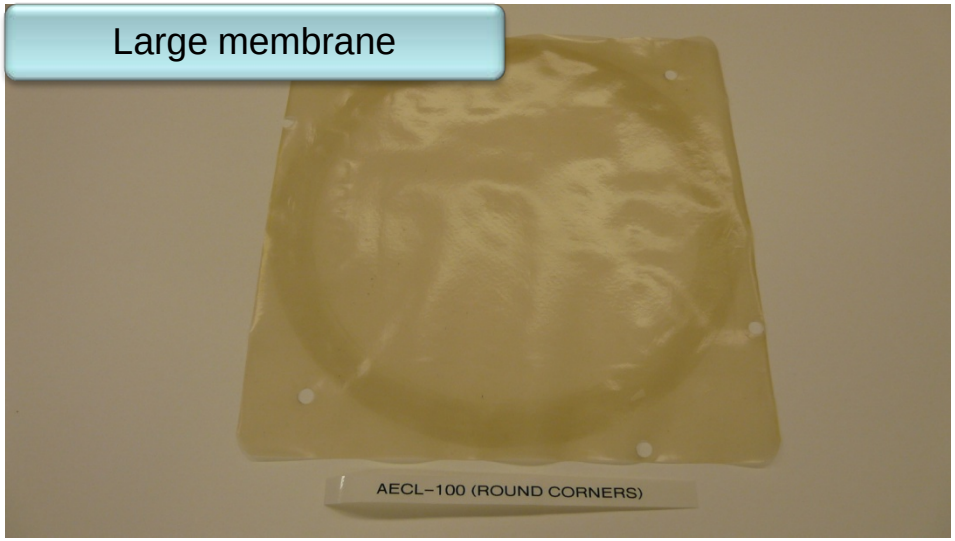


Small MEA

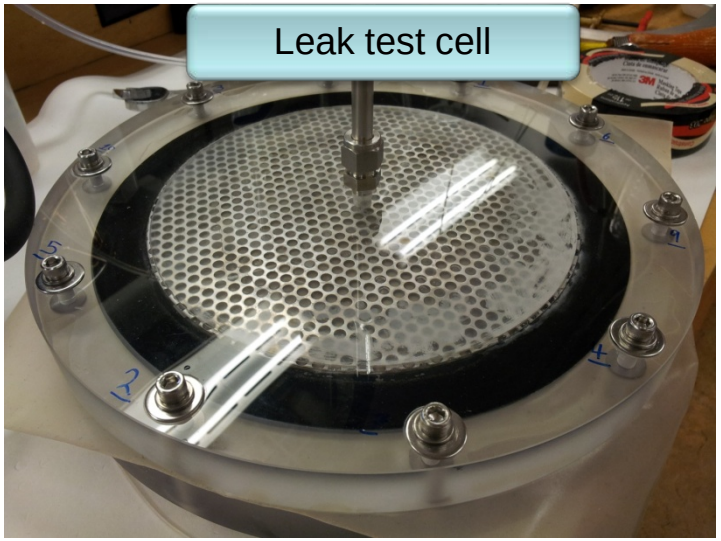
Large MEA



Large membrane



Leak test cell



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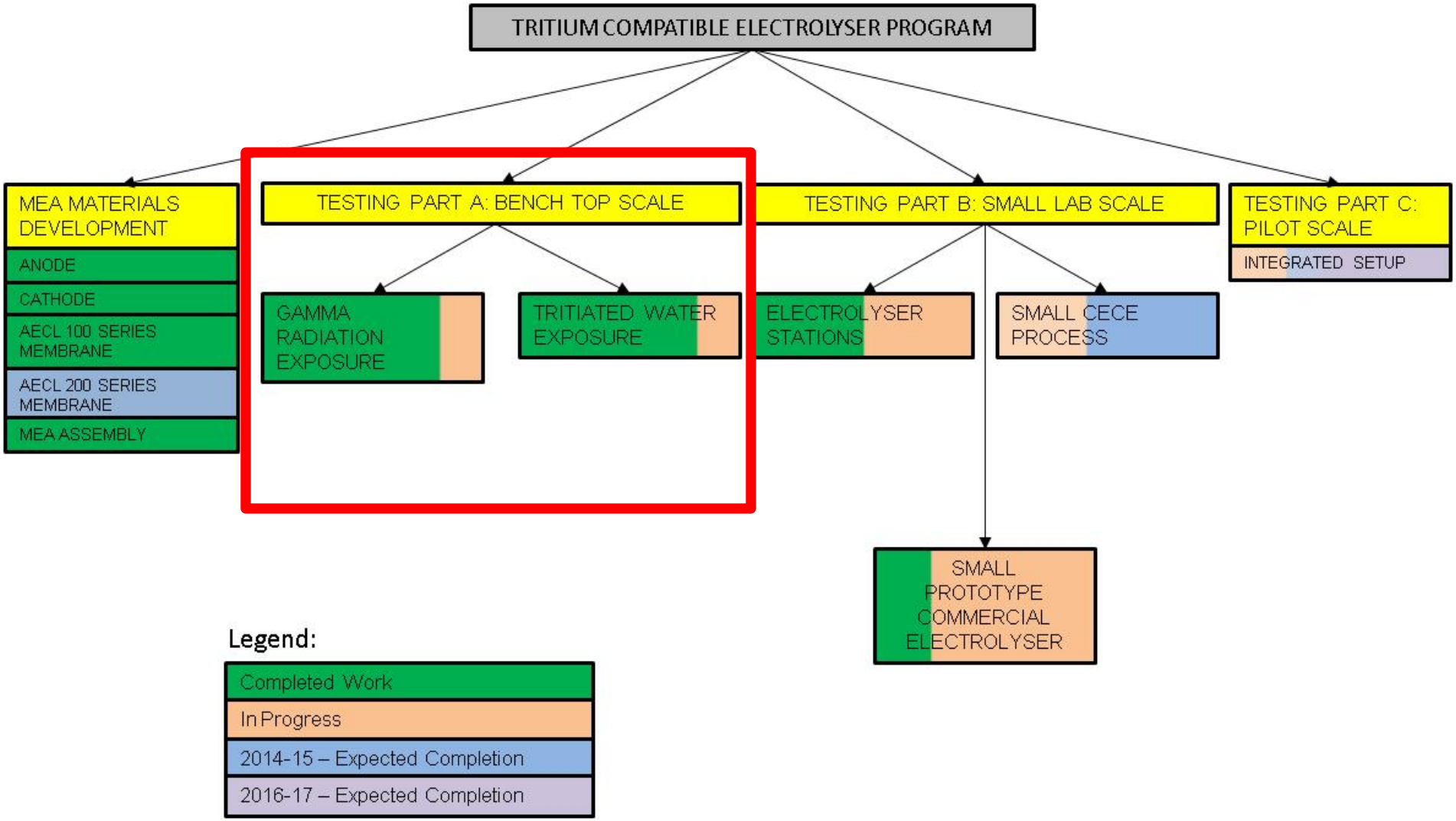
Program overview

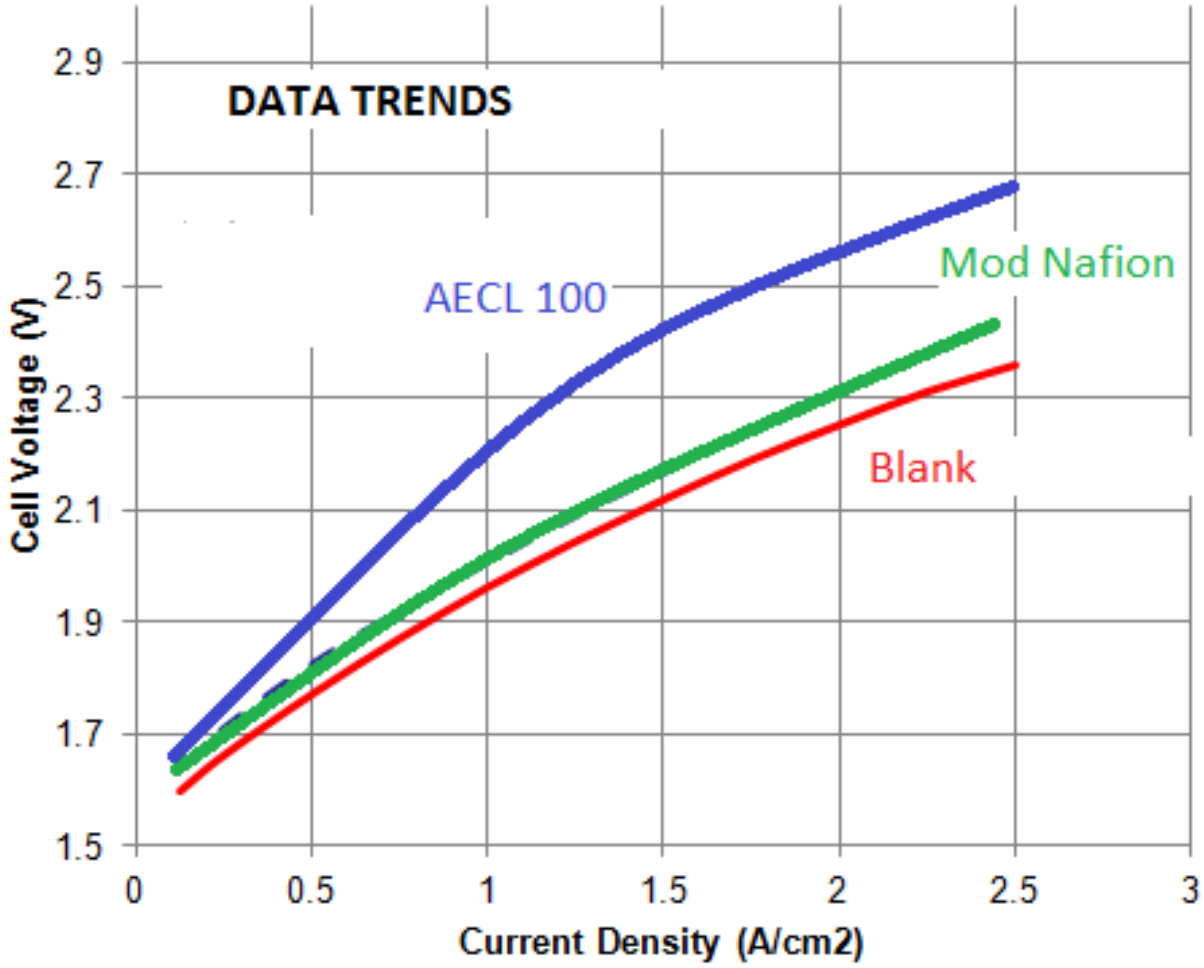


Testing Part A: Bench top scale
Study 1A: Gamma radiation exposure

Membrane	"Stiffness" – Modulus [MPa]		"Permanent deformation" - Offset Stress [MPa]		"Ductility" - Break Strain [cm/cm]	
	Blank	Exposed	Blank	Exposed	Blank	Exposed
Mod N-1110 (1000 kGy)	~200	1 to 3%	~10	5 to 10%	~2.5	-70%
AECL -100 (1000 kGy)	~450	-20 to 22%	~30	-25 to -30%	~0.4	-20 to -25%

1,000 kGy of Gamma (wet) gamma exposure

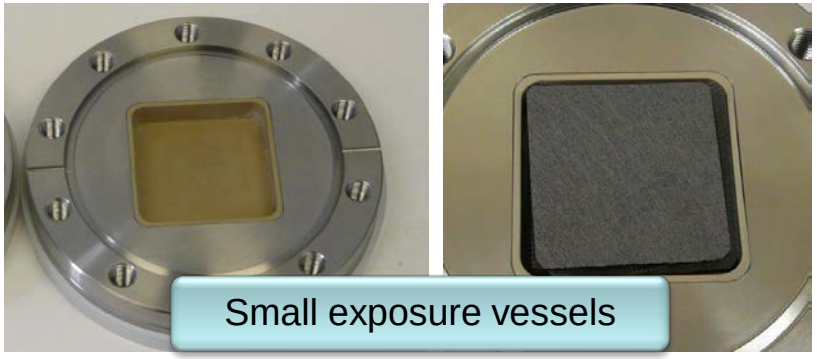
Testing Part A: Bench top scale
Study 1A: Gamma radiation exposure



1,000 kGy of Gamma (wet) gamma exposure

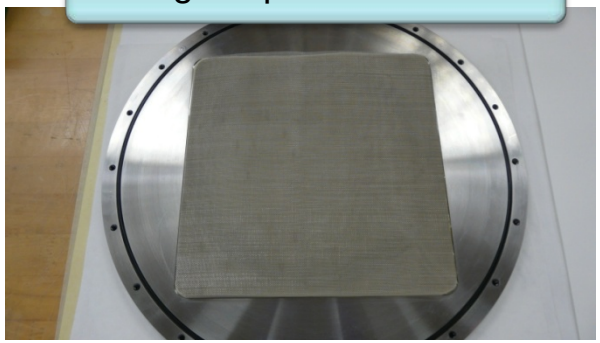
S. Lalonde, et al. *Charoacterization of Commercial Proton Exchange Membrane (PEM) Materials After Exposure to Beta and Gamma Radiation* ,10th Int. Conf. Tritium Sci. Tech. Nice, 2013

Testing Part A: Bench top scale
Study 2A: Tritiated water exposure



Small exposure vessels

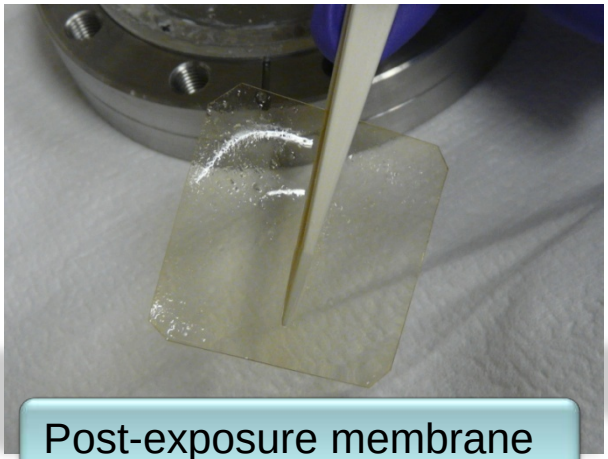
Large exposure vessels



1,000 Ci/L (37 TBq/L) tritiated D_2O

C. Muirhead, et al. *Production of Tritiated Water for Tritium Exposure Studies*, 10th Int. Conf. Tritium Sci. Tech. Nice, 2013

Testing Part A: Bench top scale
Study 2A: Tritiated water exposure



Post-exposure membrane

~2,000 Bq/ml in leachate relate to 4.5 x10^6 Bq/g in membrane

	Week of Decontam (*Method*)	**Leachate Concentration (Bq/mL)**	Week of Decontam (*Method*)	**Leachate Concentration (Bq/mL)**
Nafion 1110	1 (A)	**450**	42 (C)	**60**
Nafion 1110	1 (B)	**1200**	17 (C)	**310**
AECL 100	1(B)	**1300**	16 (C)	**530**

Help?

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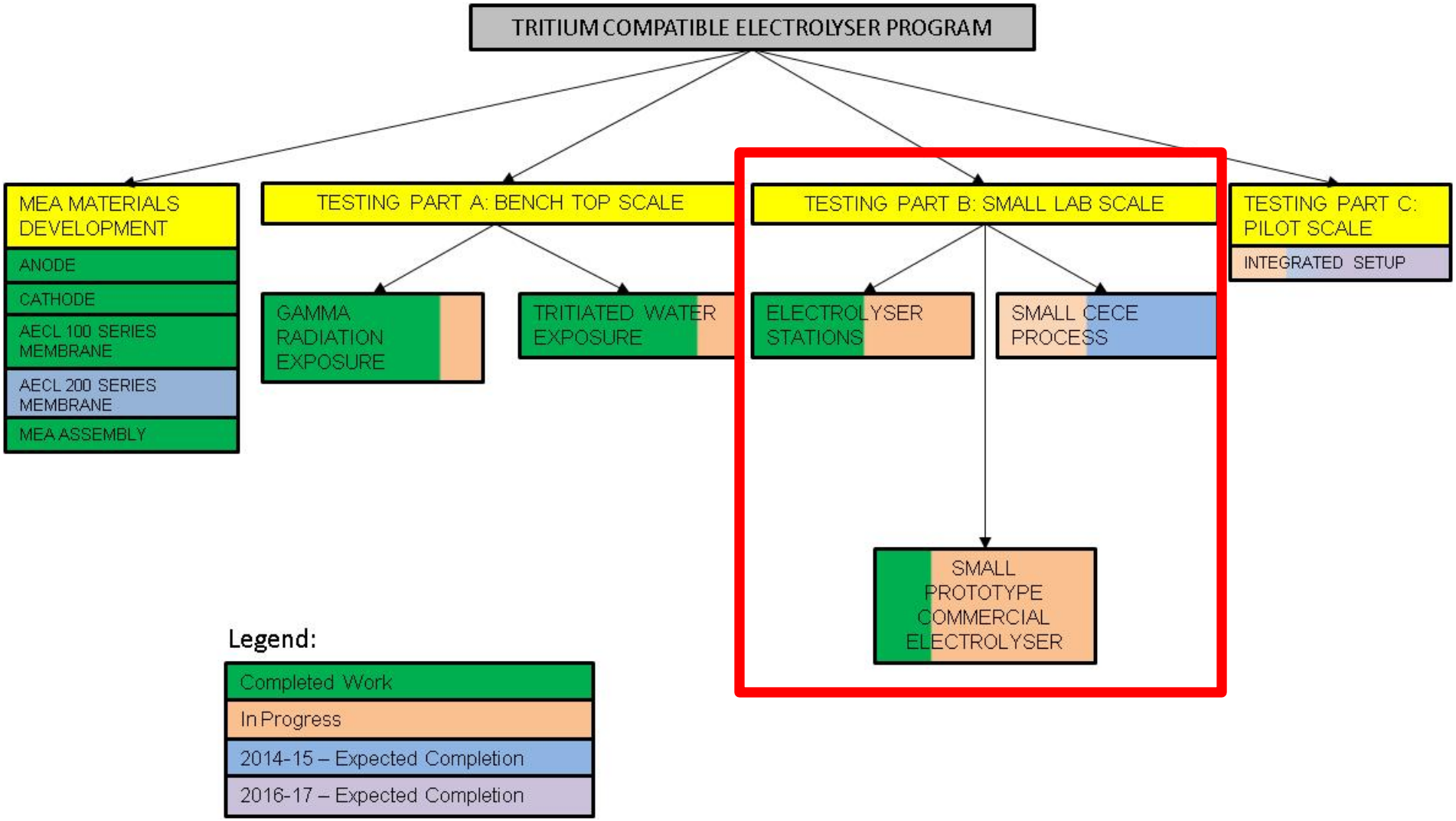
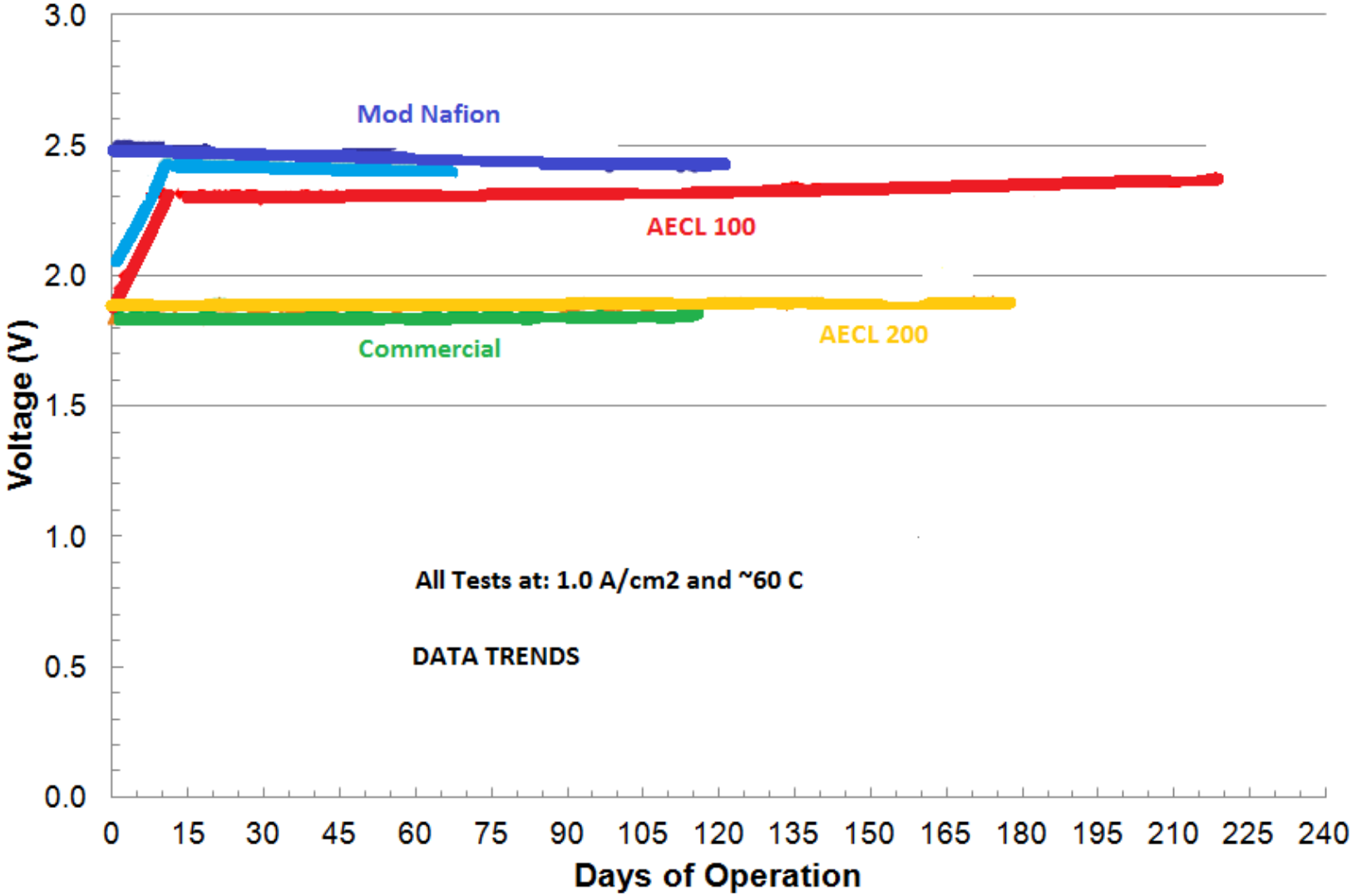
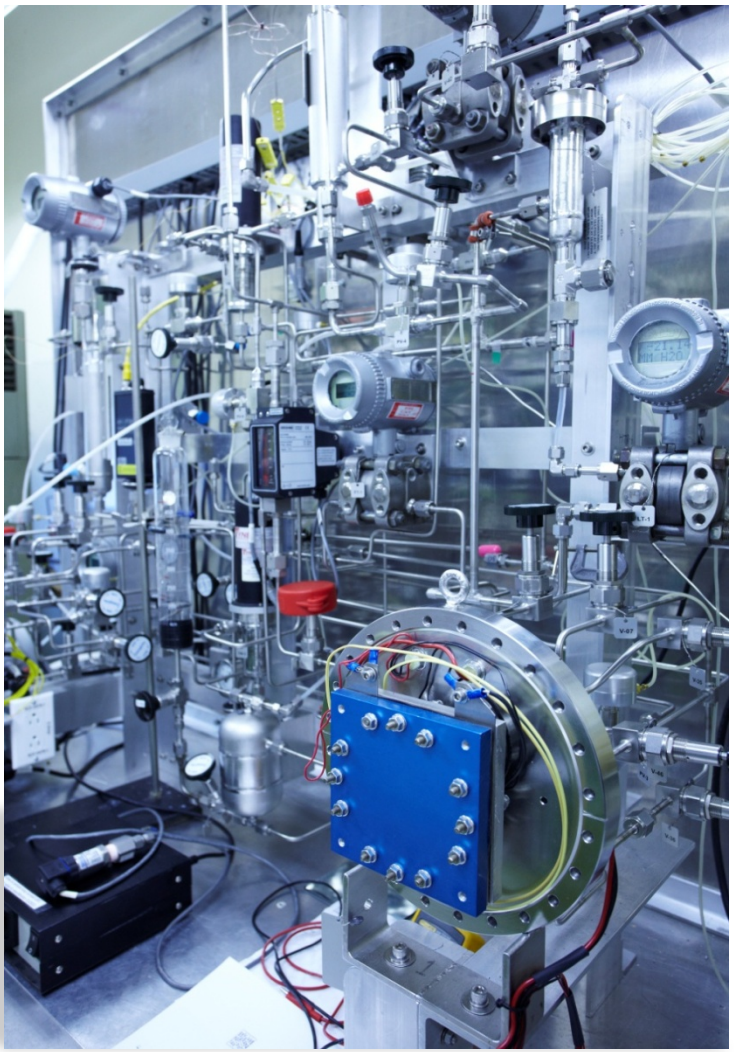
Program overview

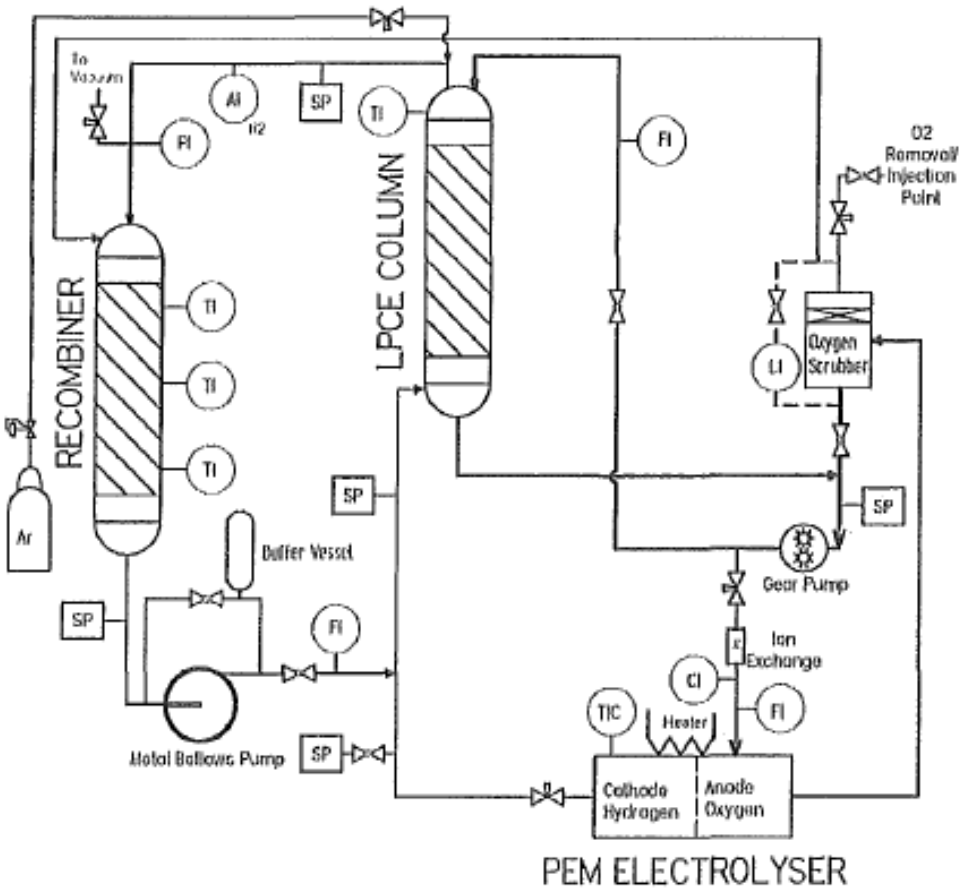


Testing Part B:
Study 1B: Electrolyser testing stations



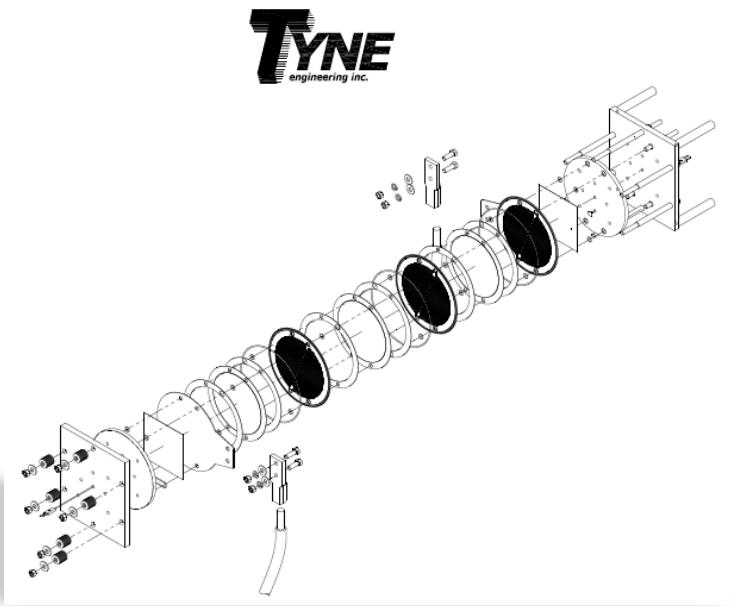
Testing Part B:
Study 2B: Small CECE Process

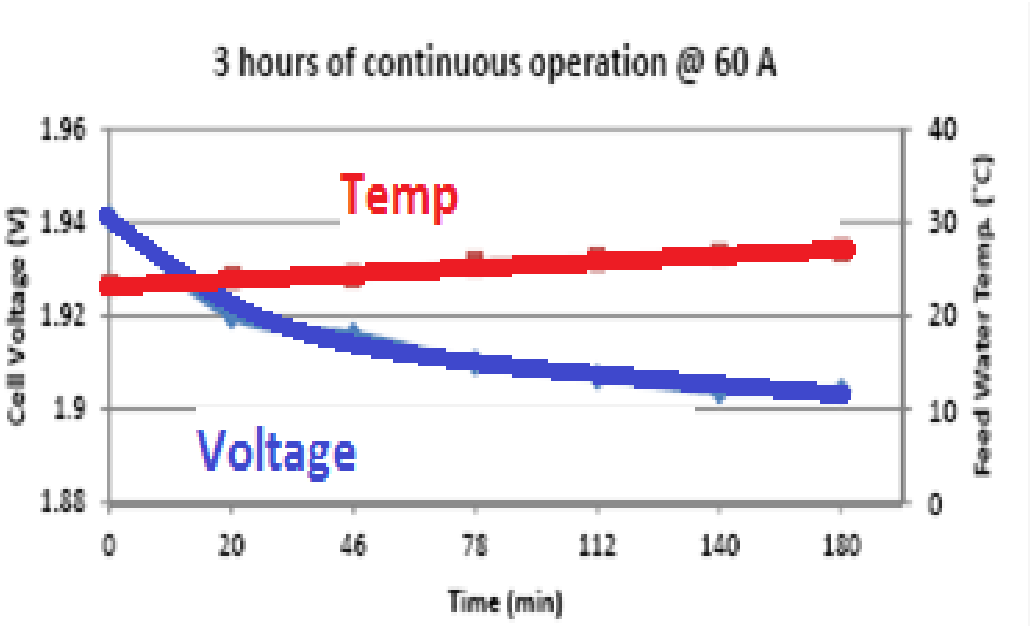




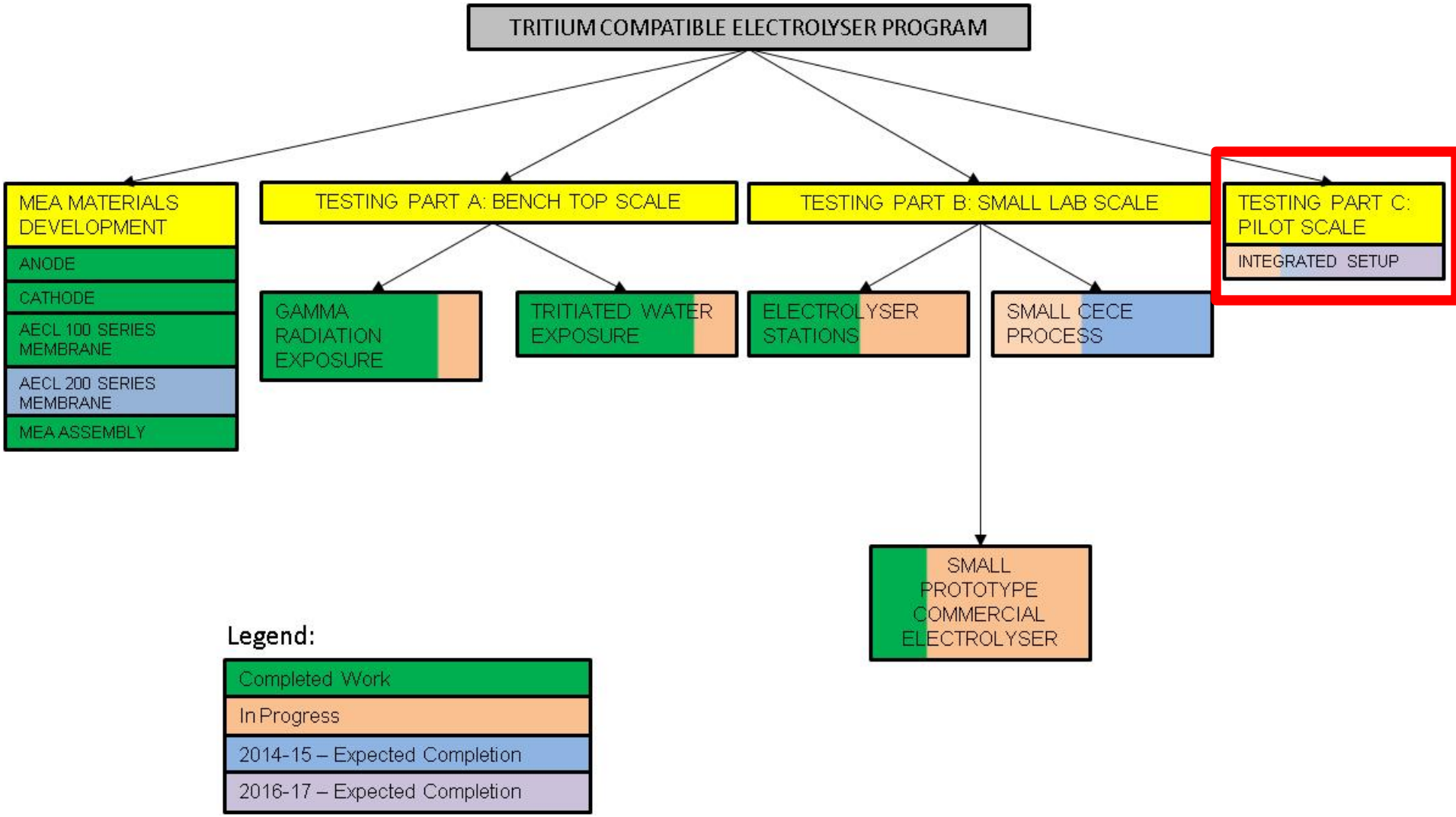
C. Muirhead, et al., *Advanced Combined Electrolysis & Catalytic Exchange (CECE) Process for Hydrogen Isotope Separation in Water Decontamination Applications,* 64th Canadian Chem. Eng. Conf.Niagara Falls, 2014

Testing Part B:
Study 3B: Small Commercial Electrolyser

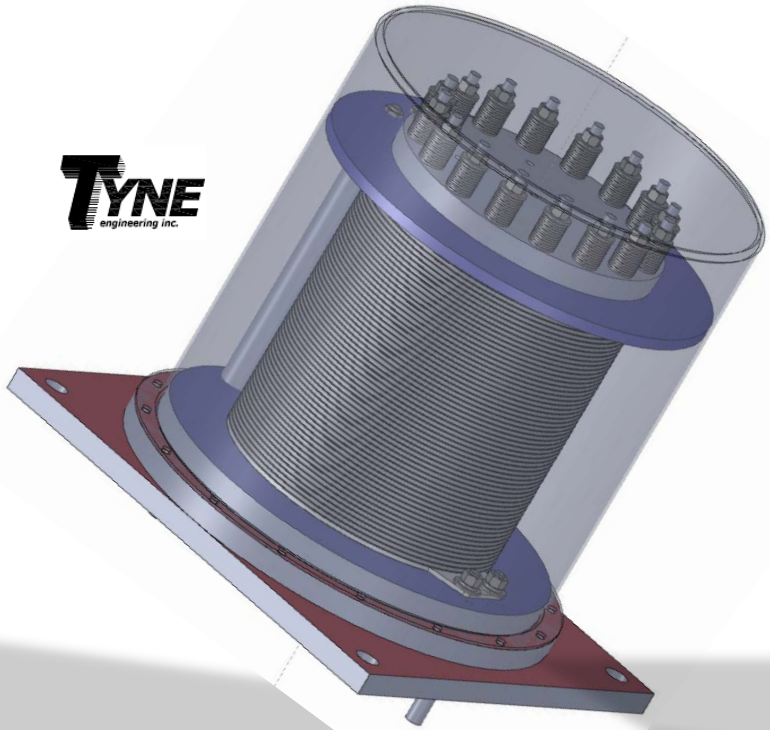




Program overview



Testing Part C:
Study 1C: Large Prototype Electrolyser



Summary

- AECL has developed new tritium compatible membranes and suitable electrodes for PEM-type cells
  - AECL 100 series – Good resistance
  - AECL 200 series – Good resistance at lower voltage
- AECL is collaborating with Tyne Engineering for commercial demonstration of tritium compatible electrolysers
- AECL's electrolyser program is ongoing

Collaborators

- S. Suppiah
- H. Boniface
- S. Thomson
- C. Muirhead
- H. Li
- R. Carson
- M. Byers
- F. Mattie
- K. McCrimmon
- A. Tripple
- N. Philippi
- K. Pilatzke
- Tyne Engineering Inc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