AECL PAR Design: Performance & Requirements

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Presentation to U.S. Nuclear Regulatory Commission
Chalk River Laboratories
2004 July 20

AECL TECHNOLOGIES INC.

Outline of Presentation

- Introduction
- Test Facilities
- PAR Qualification Testing
- Conclusions from Qualification Testing
- PAR In-containment Testing
- Conclusions from In-containment Testing

Introduction

- **PARs are designed for mitigation of hydrogen that may accumulate inside containment following SA**
- **The AECL PAR development:**
  - **Largely in-house efforts to date**
  - **Selected for PWRs in Finland and France**

Hydrogen Control Strategy

- Hydrogen control can be achieved by:
  - Dilution (i.e., mixing) with containment air
  - Containment venting
  - Removal while the atmosphere is non-flammable using (thermal or catalytic) recombiners
  - Deliberate ignition
  - Combination of dilution, recombination and intentional ignition to achieve best solution for particular plant
- Hydrogen control strategy is highly specific to the particular plant design (containment strength, volume and configuration) and also to regulatory jurisdiction

Passive Catalytic Recombiners

- Remove hydrogen in non-flammable atmosphere
- Passive – do not require outside power or operator action
  - Self-starting in response to presence of hydrogen
  - Self-feeding (the heat of reaction produces strong natural convection flow which mixes the containment atmosphere)
- Safety-oriented
  - Supplement natural mixing process in containment
- Easy to engineer and install
- Improve safety margins for hydrogen

PAR Self-Start Threshold & Capacity

- Self-start threshold is defined in terms of temperature & H_2 concentration as follows:

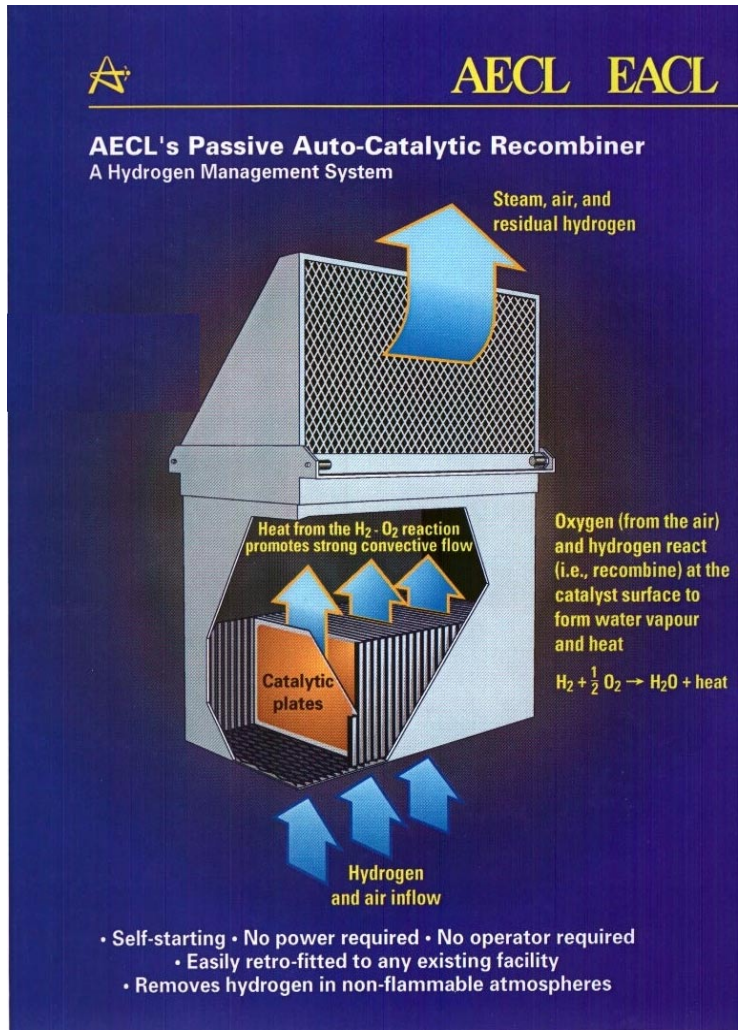
  Minimum hydrogen concentration to develop self-sustained flow through the recombiner at a given temperature

  Self-start threshold could change with exposure to reactor containment
- Capacity - rate of hydrogen recombination by PAR (kg/h)

PAR Description

- Capacity: 0.8 kg_{H2}/h at 4% H_2 in saturated air at 25°C and 1 bar
- Self-start (as new)*: 2% H_2, saturated air at 20°C

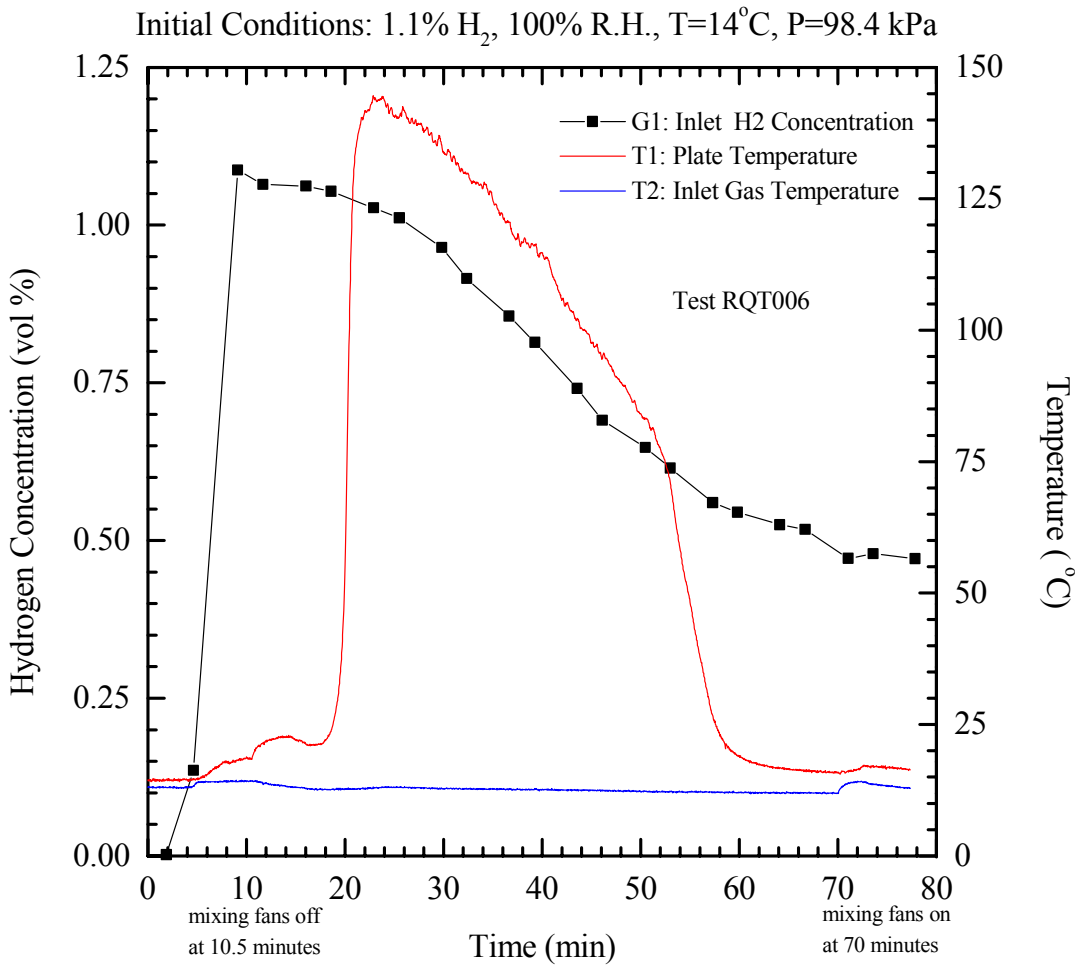
*Based on laboratory tests. Self-start at <100°C may increase after prolonged exposure to some contaminants which may be present in containment environment



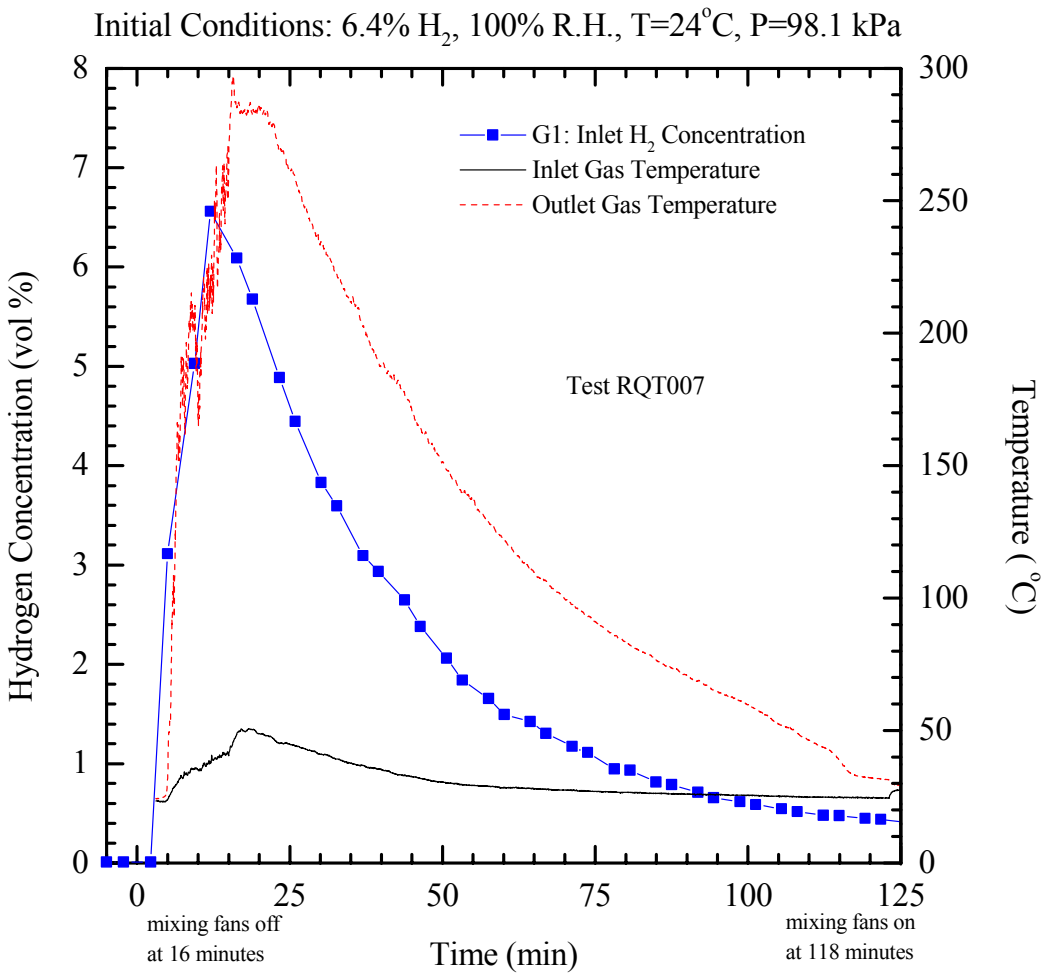
AECL's PAR

- All stainless steel 32 cm (L) x 62 cm (W) x 81 cm (H)
- Weight: ~30 kg
- 31 catalyst plates
- Hinged cover for easy access to plates

Typical Self-Start Test



Typical Capacity Test



PAR Qualification Testing (1)

- The AECL PAR catalysts were developed for hydrogen mitigation in demanding cold/humid environments – qualification aimed at typical CANDU SA environment
- CAN3-N286.2-86 - Design Quality Assurance for Nuclear Power Plants, Appendix D, Qualification Testing

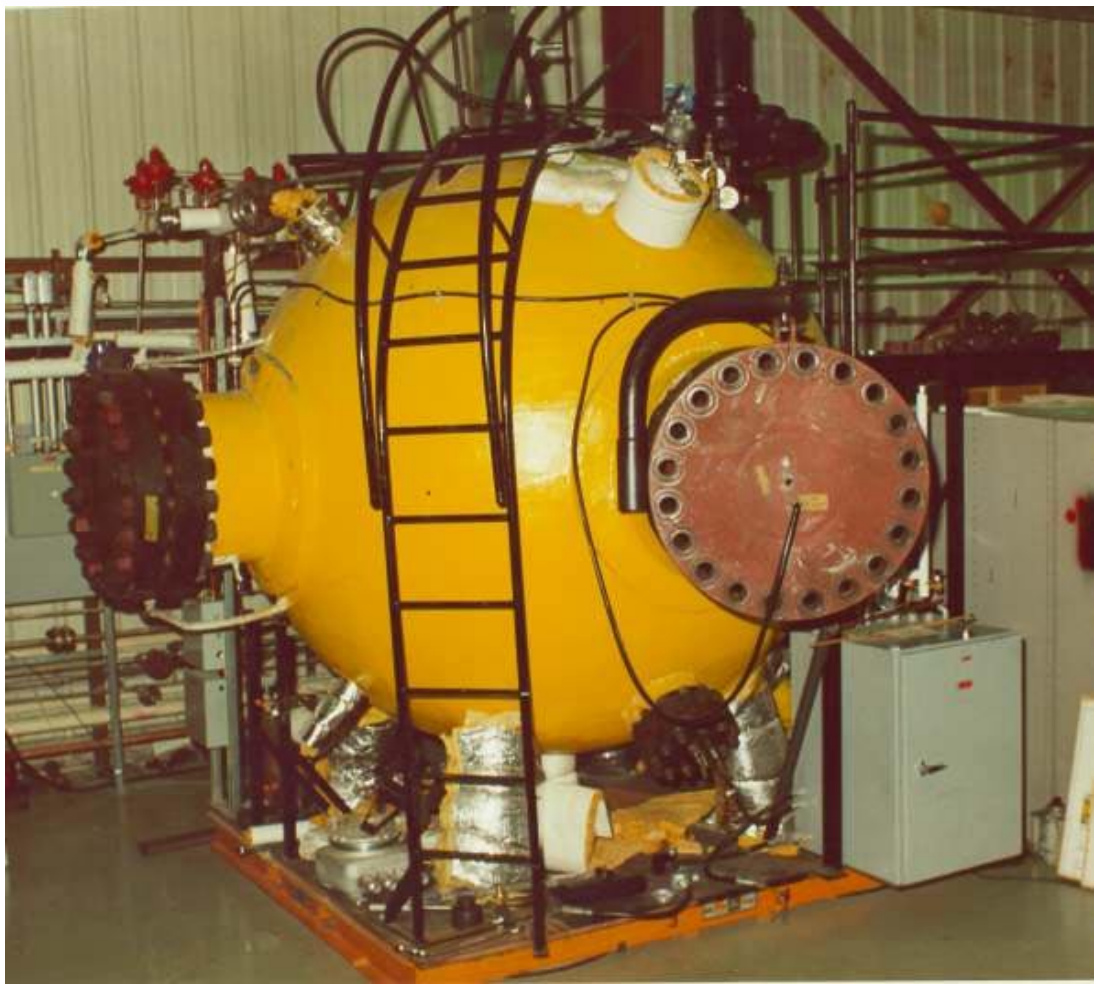
PAR Qualification Testing (2)

- Environmental qualification testing
  - Performed in Large-Scale Vented Combustion Test Facility at WL
  - Determination of self-start threshold following sequential exposure to cumulative stressors for normal operation and post-accident conditions
  - Performed sequentially on the same set of plates in commercial size unit
- Additional functional tests
  - Performed on 1/6th and 1/10th scale units
  - In Containment Test Facility (6.6 m^3) at WL and IPSN, Cadarache, France
  - Effects of low oxygen, high pressure, fuel aerosols
- Small-scale tests on catalyst coupons
  - Effect of postulated SA chemicals
  - Effect of chemicals that may be present in the containment

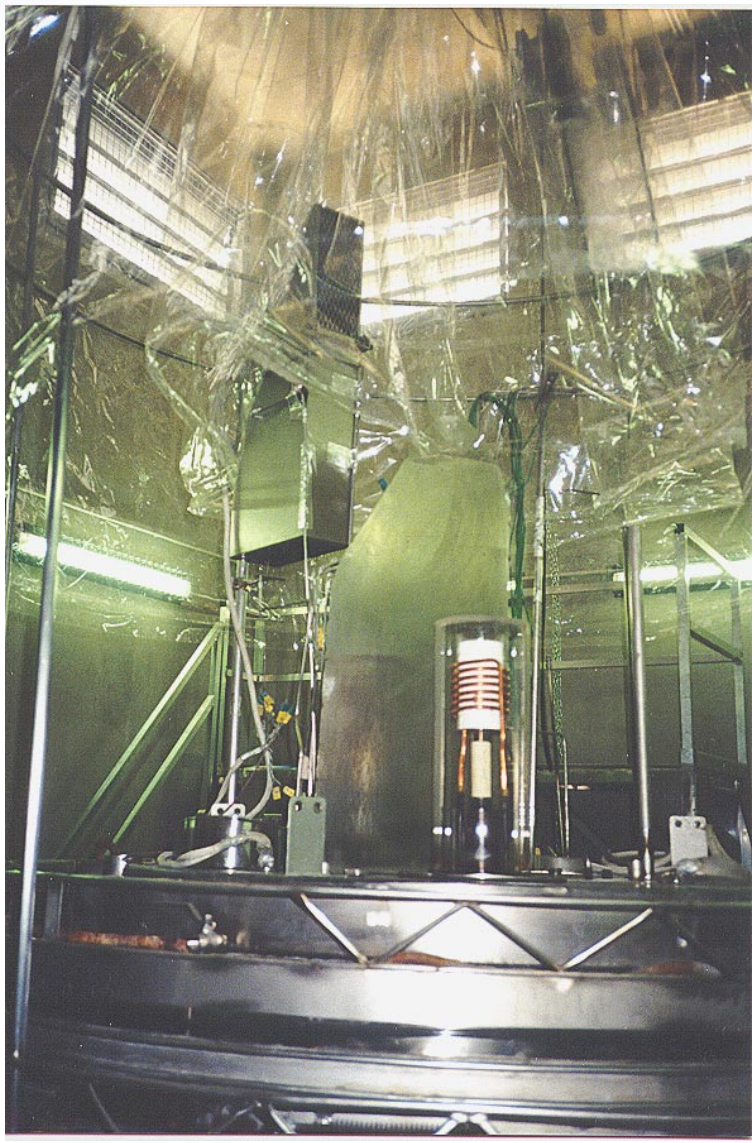
Large-Scale Vented Combustion Test Facility (LSVCTF)

PAR installed in the LSVCTF

6.6-m^3 Sphere at the Containment Test Facility (CTF)

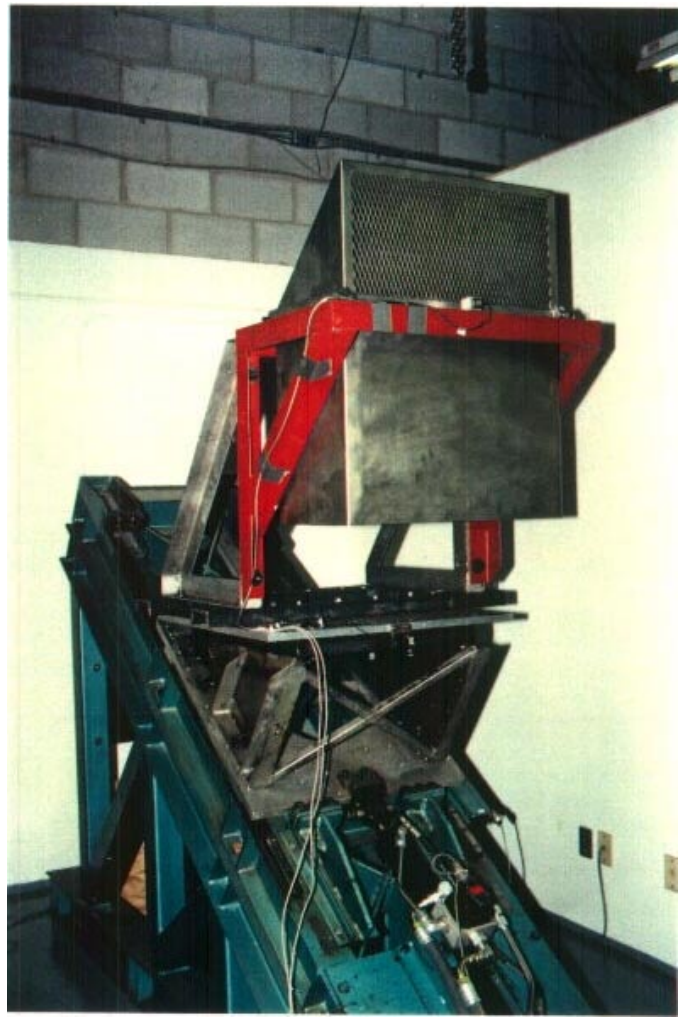


H2PAR Facility

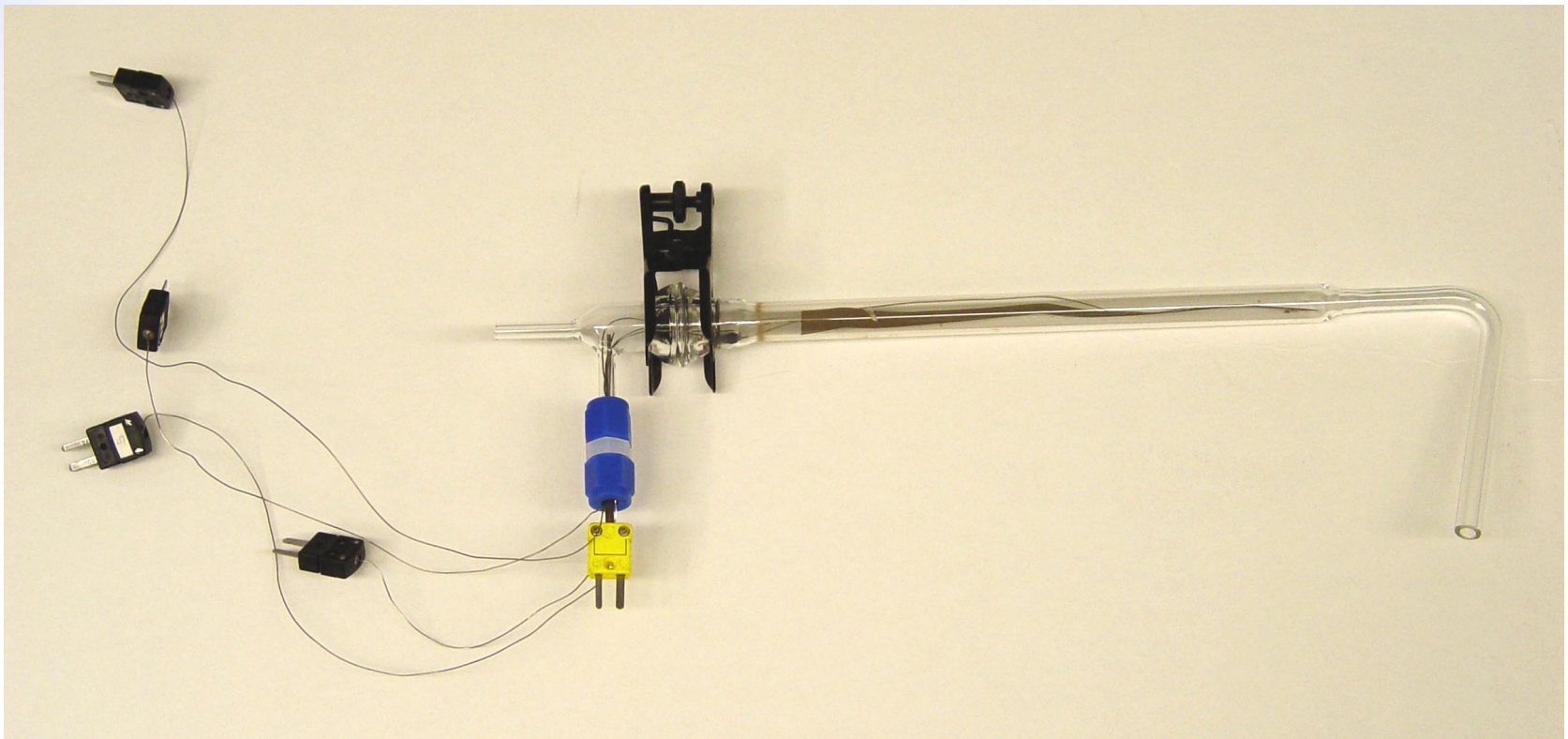


Seismic Qualification

- Testing performed on an inclined axis, biaxial shake table
- PAR mounted to the shake table using the floor mounting frame; repeated with wall mounting frame



Small-Scale Test Column with Catalyst Strip Installed



Conclusions from Qualification Testing

PAR maintains self-start threshold after exposure to stressors of

- **Accelerated thermal aging**
- **Accelerated radiation aging**
- **Seismic testing**
- **Exposure to a postulated 24-h post-accident H_2 transient**
- **Exposure to fuel aerosols**
- **With sprays containing CANDU water chemicals**

Conclusions from Small-Scale Testing

Small-scale testing on catalyst coupons shows that the catalyst remains operational after exposure to

- Iodine at a concentration 2 orders of magnitude higher than expected after SA
- Methyl iodide at a concentration 2 orders of magnitude higher than expected after SA
- Hydrazine
- Hydrochloric acid
- Chlorine

Other small-scale tests show that some volatile organic compounds can temporarily affect the self-start threshold compared to catalyst in as-new condition

- The self-start threshold is restored to as-new condition by heating in air
- In an operating plant the regeneration can be ensured by inspection and testing

Operating Experience

Objectives

- Expose PARs to containment environment
- Determine self-start threshold of the PAR catalyst after exposure to containment during outage, restart and normal operation
- Identify the factors affecting PAR catalyst performance in containment environment

In-containment PAR testing has been carried out in a PWR and in a CANDU, and more are underway or planned

Major Conclusions from Lab Qualification & Reactor Exposure Tests

- Analyses of containment air indicate the presence of a large number of volatile organic compounds
- High-temperature (>100°C) self-start threshold – unaffected
- Capacity – unaffected
- Low-temperature self-start threshold may be temporary affected requiring higher hydrogen concentration and/or higher temperature compared with as-new condition
  - Effect of ventilation (fresh air supply)
  - Effect of plant start-up
- Self-start leads to self-regeneration of catalyst
- Self-start threshold is restored to as-new condition by heating in air
- Inspection and testing of PAR will assure functional readiness of PAR

Whole Plate Tester

- Designed for in-service testing
- In-service testing to confirm that the self-start threshold of the installed PAR meets the requirements
- Measures temperature rise of a catalyst plate exposed to a 2% H_2-air mixture – and indicates "PASS" or "FAIL" for the plate to self-start at the required threshold

Whole Plate Tester (WPT)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