

Definition of the Q-PETE Experiment for Investigation of Hydrogen Isotopes Permeation through the Metal Structures of a DEMO HCPB Breeder

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Objectives and rationale of the Q-PETE experiment

In the HCPB, bred tritium is **purged** by a flow to the tritium extraction system. Tritium **permeates** into/through structures (cooling plates, pipes).

→ The Q-PETE (Hydrogen Permeation and Transport Experiment) was designed as a "purged permeation setup" with morphology, materials, temperatures and hydrogen partial pressures relevant for the HCPB:

1. To produce relevant **benchmark data for codes** to predict the tritium losses in purged scenarios (application for safety and tritium budget).
2. To directly derive **material properties** (Diffusivity, Sieverts constant).

Experimental setup and procedure

The Q-PETE/D2 experiment al setup is composed of

1. A temperature controlled permeator setup enclosed in a vacuum vessel:
 - a. The "**retentate chamber**" (formed by a stainless steel flange) is flooded and continuously supplied with hydrogen containing feed gas (Argon + Deuterium),
 - b. The "**membrane**" (1.2 mm Eurofer disk), through which the hydrogen permeates (time dependent flux $j_{QO}^M(t)$),
 - c. the "**permeate chamber**" receives the permeated hydrogen from the membrane.
2. A pure argon sweep flow collects the permeated hydrogen from the permeate chamber and transports it to a **quadrupole mass spectrometer** for time resolved quantitative detection.
3. The setup is completed with a **vacuum system**, controlled **purge gas supply** and a **temperature control** system (200-600°C).

Characterization of mass spectroscopy method

Low noise and low background level of the mass spectrometer are **key properties for successful experiments**, because this allows sufficiently high purge gas flow rates to minimize residence time induced signal distortions.

- The **noise level** was characterized dependent on the deuterium concentration, spectrometer dwell time and secondary electron multiplier (SEM) voltage (selected value 1400 V). We envisage signal levels of 0.5 – 20 ppm and sampling times 0.1 – 2 s.
- The **background level** at $m/z=4$ (D_2 , He) was systematically optimized:
 1. A needle valve was installed at the spectrometer outlet to **keep the system pressure near 0.4 bar (g) over atmospheric pressure** (to antagonize possible (helium) leaks in the valves of the inlet system).
 2. The unused part of the spectrometer inlet system are **continuously evacuated** by a membrane pump or turbomolecular pump to avoid any leakage into the measurement.

→ The background is well suppressed and significantly lower than the corresponding **limit of detection LOD 43 ppm** of the GAM300. (See diagrams)

Summary and Conclusions

- Q-PETE/D2 was designed and optimized for HCPB-relevant D_2 permeation through metal membranes at 200 - 600 °C for code validation.
 - Time resolved measurements will be performed with mass spectroscopy. The method was optimized to suppress the background to ~ 5 – 20 ppb (below limit of quantification!).
 - The limit of detection is 43 ppb and limit of quantification 141 ppb are well suited for measuring the expected signals with levels of 0.5 - 20 ppm (D_2).
- **The Q-PETE experiment is assessed to be fit for its purpose and is currently under construction.**

