Abstract

Transport section of the Karlsruhe Tritium Neutrino experiment (KATRIN) must provide the dramatic reduction of tritium flow and gas density from the end of 10-m long windowless gaseous tritium source throughout a few stages of differential pumping system. The final stage of this section, cryogenic pumping section (CPS) based on pumping of cryogenic tritium on argon frost at 4.5 K should provide the flow ratio between inlet and outlet on the range of $10^5$. Cryosorbed tritium may decay emitting a few keV electrons, these electrons in their turn cause the electron stimulated desorption of cryosorbed argon and tritium, which re-distributed along CPS (migration process).

This effect was modelled with use of method of angular coefficients. The main result is that the tritium migration process does not affect the CPS performance at KATRIN for given inlet flow. Meanwhile the flow chosen larger the migration effect could be dominant.

Calculation of flow rate reduction factor

Two simultaneous processes were treated in the calculation model as two discrete processes happening in turn with each time interval $\Delta t$.

- **Gas injection**, when amount of tritium gas entered into the CPS during time between $t_k$ and $t_k+\Delta t$ is distributed following solution for $f$ from equation (**), that gives surface coverage distribution $\sigma$ and the number of decays during time $\Delta t$ on each ring.

- **Tritium decay and electron stimulated desorption**. Assuming that all decay happen simultaneously at the end of time period $t=t_k+\Delta t$ the number of molecules desorbed due to the tritium decay is calculated with formula (**). This gives a new desorption vector $d'$ for equation (*) and a new solution $f'$.

The number of molecules desorbed due to tritium decay during time $\Delta t$ for $i=1...N$:

$$d_i = \eta(s_i) \Gamma_i = \eta_{\text{max}} \alpha_i f_i \left(1 - \frac{1}{\alpha_i} \right)^{-1} \left(1 - \frac{i}{\alpha_i} \right)$$

**Conclusions:**

- An analytical model was developed for studying the tritium migration stimulated by its radioactive decay along the cryogenic tube with an argon frost. Calculations were performed for one straight part of CPS.
- The maximum electron stimulated desorption in the model was varied in wide range from the likely expected $10^3$ T$_2$/e$^-$ to maximum possible $10^5$ T$_2$/e$^-$ (dissipated power limit).
- The migration effect can be neglected for the calculation of CPS flow ratio for the inlet flow of $Q=10^{15}$ T$_2$/s (normal operation).
- The migration effect should be considered for the calculation of CPS flow ratio for the inlet flow of $Q=10^{16}$ T$_2$/s (case of failure of one turbo-molecular pump in an upstream differential pumping section) after 10 days of continuous injection.
- The migration effect may significantly affect the CPS flow ratio with the inlet flow of $Q=10^{16}$ T$_2$/s (accident case) after about 2 days of continuous injection.
- The main conclusion is that the migration process is insignificant in all operational regimes of CPS operation and allows using the available test particle Monte-Carlo programmes to model whole CPS.
- It was also shown that migration effect could be significant when significant amount of tritium sorbed at CPS.

**Results of calculations**

The gas flow trough the surface $i$:

$$Q_i = d_i = \alpha f_i$$

Hence, $f_j = \sum w_i d_i$ or $(E - W \cdot \text{diag}(1 - \alpha)) f = W \cdot d$. (*)

Unknown $f$ can be found from the equation for given $W$, $\alpha$ and $d$.