# Steam Removal Phenomenon inside the Containment of Nuclear Power Plants using Silica Gel considering Initial Steam Partial Pressure Conditions up to a Design Limit

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## 1. Introduction

Several approaches like spray or cooling systems are considered and installed in nuclear power plants to mitigate an over-pressurization inside containments. The containment, a final barrier against releases of radioactive nuclide, should keep its integrity to minimize any impacts on surrounding environments especially during accident progressions. In this regard, a silica gel, one of famous options known to effectively remove moisture, can play a role to enhance the safety by adsorbing steam molecules on its surfaces. Considering its low cost, with rather easy maintenance, it would give big benefits toward the applications. To assess a preliminary applicability to the system, an effect of the amount of steam is considered on the performance in this study.

## 2. Methods and Results

A steam partial pressure condition considered in this study is 1, 2 and 3 bar (up to near a design limit condition of the containment when only the steam contributes to the pressurization). Based on the Di et al. [1]'s approach, a linear driving force equation is used to describe the diffusion process in the system, and a modified Dubinin-Astakhov equation [2] is considered to directly include the temperature effects.

$$\frac{dx}{dt} = D_{ads}\left[x(\infty) - x\right]$$

$$D_{ads} = (15 D_{diff} / D_p^2)\exp[-E_0 / (R(T_{silica} + 273.15))]$$

$$x(\infty)_{modified} = x_0 \exp\left\{-k\left(\frac{T_{silica}}{T_{sat}} - 1\right)^b\right\}$$

Di et al. [1] summarized an equation that describes a time-dependent adsorption ratio; in this study, changes of each terms with time in the equation have been further considered.

$$x(t_n) = x(\infty)_{t_n}\left[1 - \exp(-D_{ads}\Delta t)\right] + x(t_n - \Delta t)\exp(-D_{ads}\Delta t)$$

Related conditions and properties considered in this study are as follow (Table I).

Table I: Conditions and Properties

| | |
|---|---|
| $P_{steam}$ [bar] | 1, 2, 3 |
| $M_{silica}$ [ton] | 1000 |
| $V_{CTMT}$ [m$^3$] | 77240 |
| $E_0$ [J/mol] | 42000 |
| $D_p$ [μm] | 710 |
| $D_{diff}$ [m$^2$/s] | 0.000254 |
| $x_0$ | 0.346 |
| k | 5.6 |
| n | 1.6 |

### 2.1 Calculation Process

Steam partial pressure by remained steam molecules, at each time steps, are calculated with the amount of adsorption occurred in the previous time step; saturated conditions are assumed at each time steps. Temperatures of the silica gel bed are calculated with energy transfer from the adsorbed steam molecules.

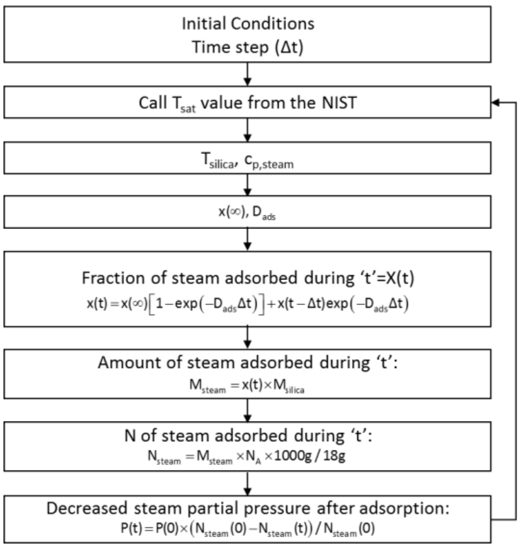


Fig. 1. Calculation flow of the depressurization process.

### 2.2 Steam partial pressure with time

Steam partial pressure radically decreases after the activation of the system. Beyond certain time periods, the phenomenon becomes saturated by the maximum capacity of the silica gel. As the initial steam partial pressure increases, final stable pressure conditions increases, but overall efficiencies increase.

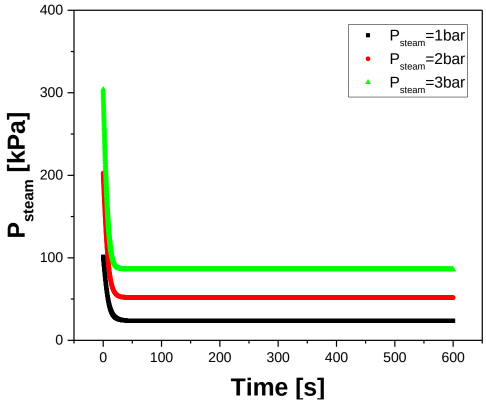


Fig. 2. Steam partial pressure with time (for initial values from 1 bar up to 3 bar).

### *2.3 Adsorption with time*

The amount of adsorption is described with adsorption ratio in this part. The adsorption process occurs in relatively short time periods as summarized in the previous section. Also, the ratios become saturated beyond certain time periods because of the maximum loading capacity, and they increases with initial steam partial pressure; absolute amount of adsorption increases.

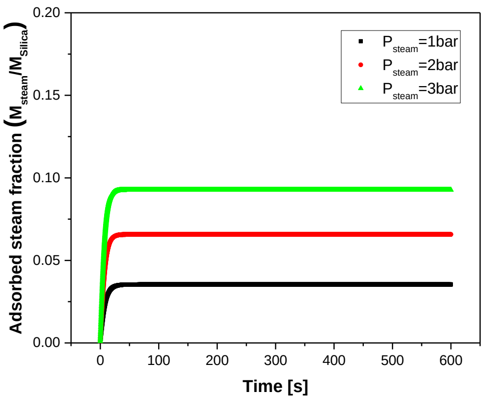


Fig. 3. Adsorbed steam fraction with time (for initial values from 1 bar up to 3 bar).

## 3. Conclusions

Silica gel is proposed for depressurization purpose inside the containments of nuclear power plants in this study. Considered initial steam partial pressure conditions are from 1 bar up to 3 bar, which stands for 2 bar to 4 bar of the containment when only steam contribution is considered. With its well-known characteristics, water molecules are rapidly adsorbed on the surfaces, which in turn, results in fast decrease of the system pressure. With increasing amount of the water molecules, absolute amounts of the adsorption increases with enhanced efficiency. With the system, rapid reduction of the pressure and protection against over-pressurization can be realized. Also, its low cost and rather easy maintenance would provide strong benefits toward the future applications.

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