# §40. Modeling of Global Particle Balance and Plasma-Surface Interactions in TRIAM-1M

Hirooka, Y. (NIFS),
Sakamoto, M. (Kyushu Univ.)

Because Cadarache has been selected as the construction site for ITER (the International Thermonuclear Experimental Reactor), the magnetic fusion research community may be considered to have reached one of the milestones to be achieved for fusion power utilization. However, the execution of the 20 year long ITER program does not necessarily mean that all the technical issues will be resolved. On the contrary, issues to remain unresolved after ITER will be most critical in proceeding to the final step, i.e., the construction of a DEMO followed by commercial fusion power reactors. Among these post-ITER issues, particle control has recently been receiving considerable attention as being a key to sustain true steady state operation of fusion devices. Particle control can bring about multiple effects on the overall reactor performance as to core plasma density stability, tritium economy and radiation safety, and impurity generation and related lifetime of PFCs (plasma-facing components), etc.

Although ITER is planned to operate in the long pulse mode, the pulse duration is limited to ~500 seconds due to the OH capacity. Interestingly, recent operation experiences with the TRIAM-1M tokamak have demonstrated that it takes hours of continuous plasma interactions for wall components to reach their respective steady state temperatures [2]. Therefore, one predicts that the ITER pulse length is not long enough to address the steady state particle control issue. This means that the core plasma density will be affected by the gas desorption from PFCs during the course of discharge.

In the present work, the effect of gas desorption from PFCs on the core plasma density has been analyzed, using the zero-dimensional, 4-reservoir particle balance model [1]. This model is modified to take into account the effect of gas desorption from the limiter along with the temperature evolution shown in Fig. 1.

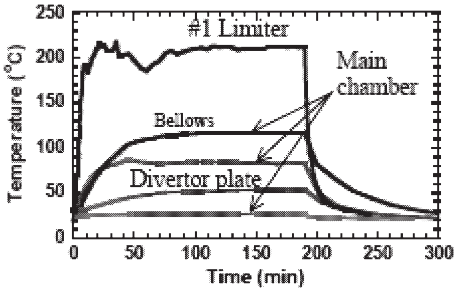

Fig. 1 Temperature evolutions of PFCs during the course of plasma discharge in TRIAM-1M [2].

Here, for simplicity, it is assumed that thermal desorption of hydrogen occurs exponentially along with the temperature evolutions. The thermally desorbed gas is taken as a secondary fueling source in such a way that:

$$\frac{dN_{core}}{dt}=-\frac{N_{core}}{\tau_{core}}+\alpha_1\frac{<\sigma v>_{cx1}}{2V_{gas}}N_{gas}N_{SOL}-\alpha_2\frac{<\sigma v>_{cx2}}{V_{gas}}N_{gas}N_{core}+(\frac{N_{SOL}}{\tau_{SOL}}$$
$$+\alpha_1\frac{<\sigma v>_{cx1}}{2V_{gas}}N_{gas}N_{SOL}+\alpha_2\frac{<\sigma v>_{cx2}}{V_{gas}}N_{gas}N_{core})(R_e{}^{re}f_{core}+R_{ef}{}^{ref}f_{core})+f_{core}(\Phi_{ext}+\Phi_{int}) \quad (1)$$

$$\frac{dN_{SOL}}{dt}=-\frac{N_{SOL}}{\tau_{SOL}}+\frac{N_{core}}{\tau_{core}}-\alpha_1\frac{<\sigma v>_{cx1}}{V_{gas}}N_{gas}N_{SOL}+\beta\frac{<\sigma v>_{ion}}{V_{SOL}}N_{gas}N_{SOL}+(\frac{N_{SOL}}{\tau_{SOL}}$$
$$+\alpha_1\frac{<\sigma v>_{cx1}}{2V_{gas}}N_{gas}N_{SOL}+\alpha_2\frac{<\sigma v>_{cx2}}{V_{gas}}N_{gas}N_{core})\{R_e{}^{re}f_{SOL}+R_{ef}(1-{}^{ref}f_{core})\}+f_{SOL}(\Phi_{ext}+\Phi_{int}) \quad (2)$$

$$\frac{dN_{gas}}{dt}=-S_{pump}N_{gas}-\beta\frac{<\sigma v>_{ion}}{V_{SOL}}N_{gas}N_{SOL}+(\frac{N_{SOL}}{\tau_{SOL}}+\alpha_1\frac{<\sigma v>_{cx1}}{2V_{gas}}N_{gas}N_{SOL}$$
$$+\alpha_2\frac{<\sigma v>_{cx2}}{V_{gas}}N_{gas}N_{core})(R_e(1-{}^{re}f_{SOL}-{}^{re}f_{core})-\gamma(Y_{sput}\frac{N_{SOL}}{\tau_{SOL}}+Y_{sput-1}\alpha_1\frac{<\sigma v>_{cx1}}{2V_{gas}}N_{gas}N_{SOL}$$
$$+Y_{sput-2}\alpha_2\frac{<\sigma v>_{cx2}}{V_{gas}}N_{gas}N_{core})+(1-f_{core}-f_{SOL})(\Phi_{ext}+\Phi_{int}) \quad (3)$$

$$\frac{dN_{wall}}{dt}=(\frac{N_{SOL}}{\tau_{SOL}}+\alpha_1\frac{<\sigma v>_{cx1}}{2V_{gas}}N_{gas}N_{SOL}+\alpha_2\frac{<\sigma v>_{cx2}}{V_{gas}}N_{gas}N_{core})(1-R_e-R_{ef})$$
$$+\gamma(Y_{sput}\frac{N_{SOL}}{\tau_{SOL}}+Y_{sput-1}\alpha_1\frac{<\sigma v>_{cx1}}{2V_{gas}}N_{gas}N_{SOL}+Y_{sput-2}\alpha_2\frac{<\sigma v>_{cx2}}{V_{gas}}N_{gas}N_{core})-\Phi_{int} \quad (4)$$

,where $N_{core}$, $N_{SOL}$, $N_{gas}$, $N_{wall}$ are the particle inventories in the core, SOL, gas, and wall, respectively, $\alpha_1$, $\alpha_2$ , $\beta$, are adjusting parameters to express degrees of separation between the SOL and gas regions. All other symbols have their usual meanings. The secondary gas fueling is indicated by $\phi_{int}$ in red. Results obtained are in good agreement, as shown in Fig. 2, with the experimental data.

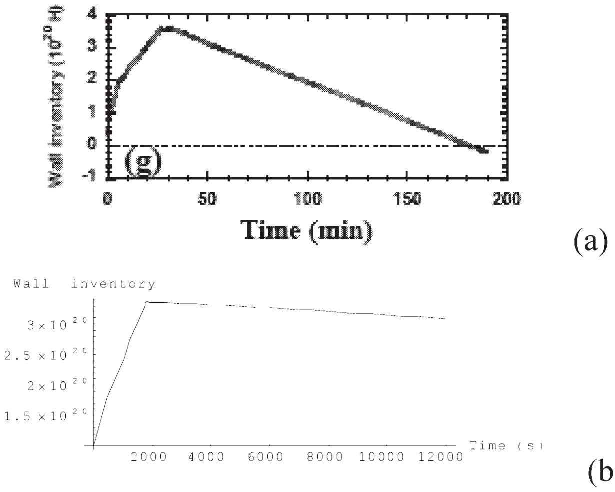

Fig. 2 A comparison between (a) the experimental data [2], and (b) the model prediction on the wall inventory.

## References

[1] Y. Hirooka et al., Nucl. Mater. 313-316(2006)588.
[2] M. Sakamoto et al., IAEA-FEC(2002), Exp4-07.