§20. Tritium Balance in a DT Fusion Reactor

Nishikawa, M., Katayama, T., Tanabe, T. (Graduate School of Engineering Science, Kyushu Univ.),
Kozaki, Y., Yamada, H., Asakura, Y.

The ways to evaluate the required value for the tritium breeding ratio obtained from tritium balance, **$(TBR)_{BS}$ required**, to cover the tritium consumption in a fusion reactor and tritium requirement for preparation of the initial inventory of a next reactor and the attainable value of the tritium breeding ratio obtained from neutron balance in the blanket system, **$(TBR)_{BS}$ attainable**, are summarized in **Figure. 1**. First, the reactor base tritium breeding ratio, **$(TBR)_{R,Net}$ required** is obtained when the amount of tritium to be prepared for construction of next reactors and the time for preparation are decided.[1)]

$$(TBR)_{R,Net} = n_{total}/(T_{WT}\,f'_{Decay}), \quad (1)$$

Here, n_{total}, T_{WT} and f'_{Decay} are equivalent burning days corresponding to total inventory in a fusion reactor, tritium doubling time and correction factor for the beta decay with constant accumulation rate, respectively. Half-life of 12.2 years for tritium corresponds to the annual decay of 5.6% of the inventory.

Then, **$(TBR)_{BS}$ required** is evaluated from the tritium balance in a fusion reactor as follows.

$(TBR)_{BS}$ required

$$=(TBR)_{R,Net}\ \text{required}+(\delta_T)_{overall}/(\eta)_{overall}+(\theta_P)_{overall}/(\eta)_{overall}+(Q_T)_{Decay}/Tburn-\{(\delta_T)_{overall}/(\eta)_{overall}\}f'_{Decay}(\beta_{trap})_{VV}\ . \quad (2)$$

The required value for the tritium breeding ratio is obtained as follows when the recovery operation of tritium from co-deposits is not performed.

$(TBR)_{BS}$ required (no recovery operation)

$$= (TBR)_{R,Net}\ \text{required} + (\delta_T)_{overall}/(\eta)_{overall} + (\theta_P)_{overall}/(\eta)_{overall} + (Q_T)_{Decay}/Tburn. \quad (3)$$

The reactor base tritium breeding ratio during the burning operation, **$(TBR)_{Net}$ at operation**, is obtained from eq. (2) when the recovery efficiency from co-deposit is zero.

$$(TBR)_{R,Net}\ \text{at operation}=(TBR)_{R,Net}\ \text{required} -\{(\delta_T)_{overall}/(\eta)_{overall}\}f'_{Decay}\,(\beta_{trap})_{VV}\ . \quad (4)$$

This parameter is used as the index to check the tritium balance during the burning operation.

The attainable value of the breeding ratio in the blanket system, **$(TBR)_{BS}$ attainable**, is decided from the usage of neutron in the blanket system and the recovery efficiency of the bred tritium and **$(TBR)_{BS}$ attainable** must be larger than **$(TBR)_{BS}$ required**.[2]

Following conclusions are obtained in this discussion.

1. It is certified that recovery of tritium from the re-deposition layer is highly effective to ease the tritium balance when the trapping factor to the deposition layer is larger than 3×10^{-5}.
2. The burning plasma having an overall burning efficiency less than 0.5% is not preferable because the larger circulation rate of tritium in the fuel cycle through the plasma vessel makes the tritium loss larger as can be seen from Figure 2.
3. It is not easy to make the tritium inventory in the re-deposition layer smaller than 1% of the burning amount. Accordingly, it is recommended to discuss the limit of the site inventory in a power reactor scientifically, though limit of the site inventory is decided as 1 kg in the ITER operation.
4. A blanket system having the overall breeding ratio around 1.1 is preferable at early stage of the fusion era. Use of tritium from the outer tritium sources is helpful.

It is expected that such parameters as trapping properties to the first wall candidates which are required to evaluate the required values of tritium breeding ratio from tritium balance or such parameters as neutron usage in tritium breeding and recovery efficiency of bred tritium under the power plant condition are certified to make it possible to discuss the tritium balance of a power reactor in more precision.

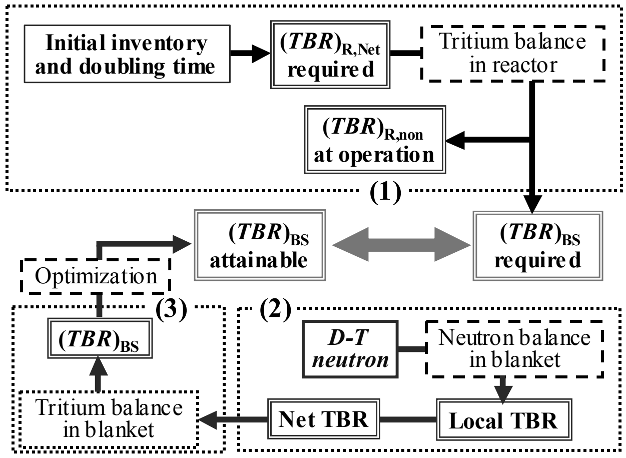

Fig. 1. Ways to estimate the required value for tritium breeding ratio and the attainable value

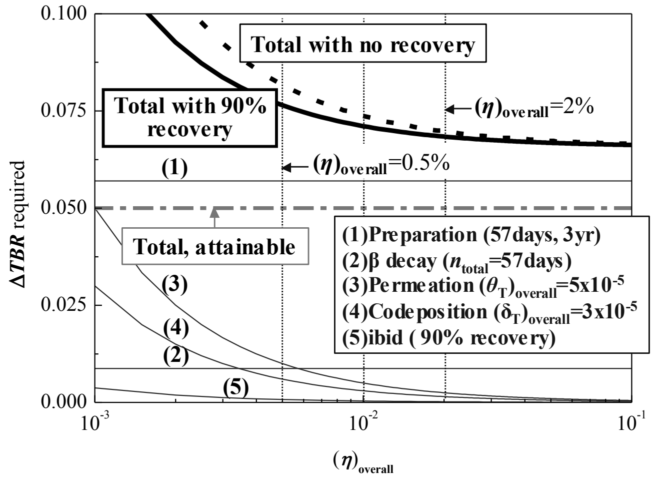

Fig. 2. Comparison of various factors composing the blanket system tritium breeding ratio required.

1) Nishikawa, M.,: Fusion Sci. Technol., **59** (2011) 350.
2) Nishikawa, M. ,: 9th Int. Tritium Conf., Nara, 2010.