§24. Tritium Balance in a DT Fusion Reactor

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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 reported by the present author. 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)]

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

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. The active inventory of tritium is inversely proportional to the overall burning efficiency though the inventory of inactive tritium is independent of the overall burning efficiency. Then, the tritium inventory of a D-T fusion reactor is shown by the following equation where the amount of tritium storage is considered to be the burning amount in 30days as shown in Fig. 1, where n represent the burning days of a reactor under the operation.

$$n_{total} = 18(0.001/(\eta)_{overall}) + 39 \qquad (2)$$

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

$(TBR)_{BS}$ **required**

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

The reactor base tritium breeding ratio during the burning operation, $(TBR)_{Net}$ **at operation**, is obtained from eq. (3) when the recovery efficiency from co-deposit is zero.

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

$$= (TBR)_{R,Net}\ \text{required} + (\delta_T)_{overall}/(\eta)_{overall} + (\theta_P)_{overall}/(\eta)_{overall} + (Q_T)_{Decay}/Tburn. \qquad (4)$$

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)]

Effect of the burning efficiency is discussed in this year and the following conclusions are obtained as summarized in Table 1.

1. It is certified that recovery of tritium from the re-deposition layer is highly effective to ease the tritium balance.
2. The overall burning efficiency should be larger than 5.5 % when the attainable tritium breeding ratio is 1.05 even when the trapping factor is $3\text{x}10^{-5}$ if the recovery operation of tritium from co-deposits is not performed.
3. It is necessary to know the burn-up in the core plasma corresponding to this overall burning efficiency.

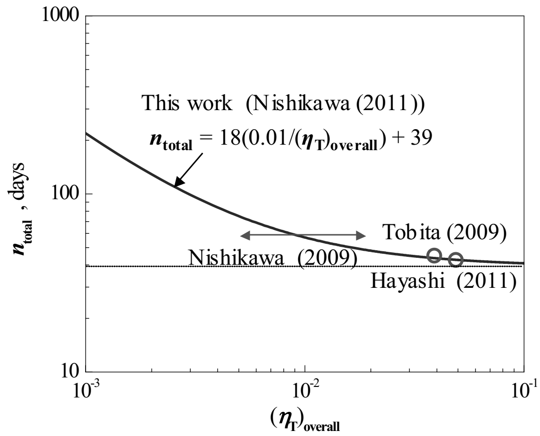

Fig. 1 Overall burning efficiency and tritium inventory.

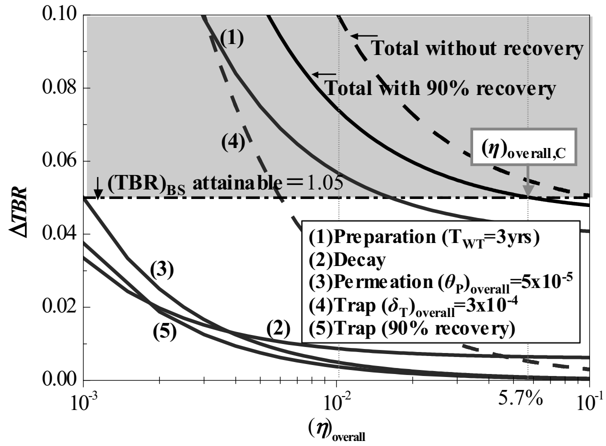

Fig. 2 Comparison of various factors composing the blanket system tritium breeding ratio required.

Table 1 Critical value of overall burning efficiency obtained from tritium balance

(1) 90% recovery from co-deposits in every year

	Trapping factor		
	$3\text{x}10^{-5}$	$3\text{x}10^{-4}$	$1.5\text{x}10^{-3}$
$(TBR)_{BS}$ attainable			
1.05	5.2 %	5.9 %	8.9
1.06	1.74	2.0	3.0
1.07	1.04	1.18	1.78

(2) No recovery from co-deposits

$(TBR)_{BS}$ attainable			
1.05	5.5 %	11.2 %	-
1.06	1.92	3.7	11.7
1.07	1.15	2.3	7.0

1) Nishikawa, M.,: Fusion Sci. Technol., **59** (2011) 350.
2) Nishikawa, M. , 21st International Toki Conference, 2011.