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Neutron flux measurement using activation of Nickel during KSTAR operation

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1. Introduction

The KSTAR device is a superconducting fusion experiment device. The fusion reaction takes place inside the plasma. During plasma experiments, neutrons and other ionizing radiation are emitted and radioactive materials are generated by neutron nuclear reactions. In this paper, we introduce one of the methods for counting neutrons generated during operation. This method is a neutron measurement through the activation of Nickel.

2. Methods and Results

This section describes the structure for radiation shielding of KSTAR devices and the measurement method for checking the shielding performance.

2.1 Overview

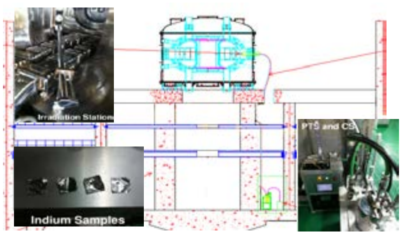
The source of KSTAR is the D (deuterium) -D (deuterium) reaction and the D (deuterium) -T (tritium) reaction. KSTAR tests the DD reaction during the fusion reaction, but the T and D Secondly, DT fusion reaction is also induced. [1]

(Primary fusion reaction)
D + D = 3He (0.82 MeV) + n (2.45 MeV)
D + D = T (1.01 MeV) + p (3.02 MeV)

(Secondary fusion reaction)
D + T = 4He (3.5 MeV) + n (14.06 MeV)
D + 3He = 4He (3.6MeV) + p (14.7MeV)

In the above equation, neutron 2.45 MeV and 14.06 MeV are important sources of radiation safety management in KSTAR operation, so special care is required.

A neutron activation system (NAS), one of the many neutron flux monitoring systems of ITER, is installed and operated in the KSTAR device. This system measures neutron flux using Indium's activation. However, since the half life of indium is short(In-115m, 4.48h), it is only possible to measure shot units.

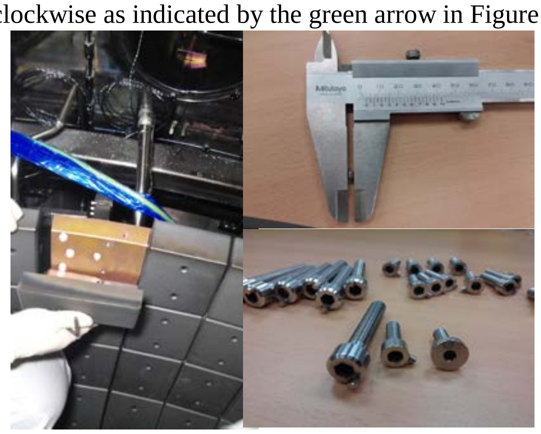


[Figure 1] neutron activation system (NAS)

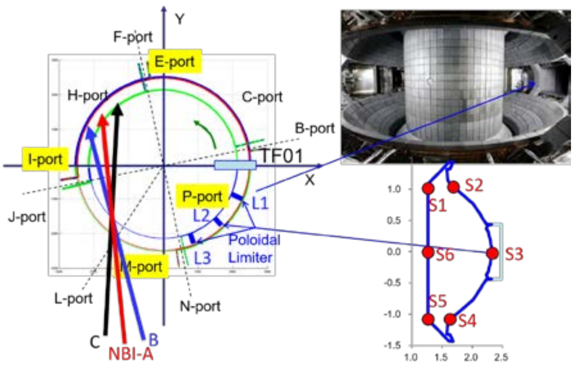
Nickel was used because Ni-58 in the Nickel isotope shifts to Fe-58 through Co-58 through (n, p) reaction. Since Co-58 has a half-life of 70.86 days, it is suitable for long-term measurement. The sample was attached to the plasma Facing Component (PFC) in the form of a cylinder (3mm * 3mm) to facilitate neutron irradiation. Sample preparation and attachment are shown below fig. 1. Their weight was about 0.2g. Sample is welded at bolt head fixing PFC to back-plate. After campaign, the gamma ray(811keV) of the activated sample is analysed by High Purity Germanium Detector[HPGe].

The locations of the specimens were placed at four locations with 90 degrees of toroidal distribution. The poloidal distribution was attached at three locations: the inbord limiter and the outbord limiter. Each attachment position is shown in the figure 1 below.

the samples were directly exposed to plasma at a radial location of r = 0.51 μm with a nominal plasma radius of 0.5 m. NB is injected into port L tangent to the direction of the plasma current and the beam armor is located at port H. The electron current is rotated clockwise as indicated by the green arrow in Figure 3.



[Figure 2] Nickel sample shape



[Figure 3] Nickel sample attachment position

The count value measured by HPGe was calculated as follows.

$$S_{\text{total}} = \eta t_3 N_a б \ \Sigma_{\text{shot\#}}^{\text{total}} \Phi \left[\mathrm{e}^{-\lambda t_{2N}} - \mathrm{e}^{-\lambda(t_N + t_{2N})} \right]$$

- Na : Atomic number, η : detection efficiency of detector

Table 1.Neutron Activation of Toroidal and Poloidal distribution

Port ($10^{17}/m^2$)	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**
In Vessel	**1.6**	**4.0**	**6.0**	**4.0**	**1.6**	**4.8**

The calculations show that the neutron in the vacuum vessel has a non-uniform distribution in the toroidal direction and the peak neutron flux is located around the fauroloid limiter, as shown in Table 1. The average flux inside the vessel was about 3.8 x 1017 / m 2 [2]

During the same period, the total neutron emission of NAS and Fission Counter was measured as 1.16E16 / m2. There is about a 20-fold difference between the two measurement systems. One of the reasons is that large amounts of sample are placed inside the vacuum vessel to perform measurements using Ni and only one point is measured for the NAS. And Ni is measured in an environment where long-term activation and corrosion are repeated. It is presumed that a difference has occurred in this property.

3. Conclusions

The KSTAR device is equipped with a variety of diagnostic and measuring devices as a fusion experiment device. Neutron diagnostics should also be applied in a variety of ways for the same reason. Currently, officially neutron flux measuring devices use NAS and Fission counters. However, measurement methods that can provide more convenient and objective measurement results will be developed. Nickel's radioactivity-based measurements can also be one way. However, a method that can effectively correct long-term investigation and repetition of damping should be studied.

REFERENCES

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