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Research Article

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Study on tritium safety for the tritium system of China TBM

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ABSTRACT

Tritium safety research on the tritium system of Test Blanket Module (TBM) was carried out. At first, according to safety conception of multiple containment systems, a possible layout of TBM tritium system was designed and analyzed. Secondly, according to safety analysis task and method of the tritium system, the research framework about tritium safety analysis was given. At last, in order to compare and assess safety grade about the tritium system among all kinds of nuclear facilities, calculation formula was given.

Keywords: Tritium Safety Analysis, Multiple Containment System, Tritium Monitoring, Nuclear Safety Class

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INTRODUCTION

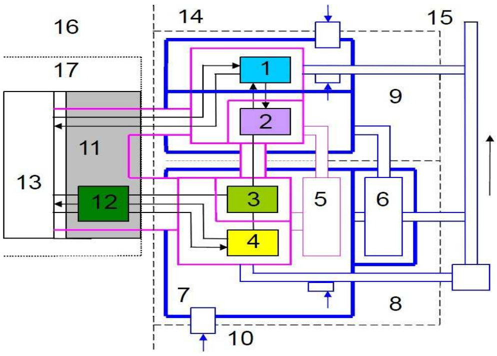
China tritium system is composed of three subsystems: tritium extraction system (TES), cooling purification system (CPS) and tritium measurement system (TMS). The three subsystems are all concerned with tritium safety. Before testing, TBM and its tritium system must submit the safety analysis report to ITER IO in order to get permission to test. Currently, China is carrying out the design and technology demonstration about TBM tritium system, taking tritium safety analysis as one of the important researches. In order to further improving tritium safety study, a tritium safety analysis was carried out in this paper.

2. LAYOUT DESIGN OF TRITIUM SYSTEM AND TRITIUM MONITORING

In ITER, TES will be placed in the tritium factory hall; and CPS belongs to tritium removal subsystem of Helium Cooling System (HCS), placed in the cooling water system (TCWS) hall; TMS will be placed in the channel for loading and unloading TBM. Drawing lessons from research experience about tritium technology and protection, a possible safety layout of TBM tritium system was designed, and its tritium protection concept is tritium multiple containment, as shown in figure 1.

Conveying pipeline and functional component, such as container, pump, valve, flange, temperature and pressure sensing element, constitute the primary containment system of tritium, housed in the glove box. Tritium primary containment system should have good sealing performance and resistance to tritium performance. The glove box and tritium cleaning system for tritium secondary containment system, are placed on the tritium closed operation room. The third containment system includes tritium operating room, ventilation system and emergency treatment system for tritium leakage.

Be based on considering tritium safety, ionization chamber will be used to monitor tritium concentration in the primary containment system, and it should have a low tritium menory effect. Proportional counter tube may be used to monitor tritium concentration in the glove box and the operating room. Mathematical calculating models about tritium concentration in glove box and operating room have been set up. In order to realize the on-line measure of tritium and improve the measuring accuracy, study on tritium sensors is very important now.



1-HCS, 2-CPS, 3-TMS, 4-TES, 5-detritiation system, 6-emergency system, 7-tritium operating room, 8-tritium plant, 9-hall for TCWS,10-ventilation installation, 11-Port Cell, 12-pretreatment system for output purge gas, 13- TBM, 14-building, 15-smokestack, 16-ITER hall, 17-ITER device.

Fig. 1. A possible layout of TBM tritium system.

If tritium removal is only by the ventilating way, mathematical model about the tritium removal process from the room can be described with the differential equation 1.

$$(Fx/RT)dt - qdt = -Vdx. \quad (1)$$

In Eq.1, x is the tritium content in the operating room, x_0 is the initial tritium content, x_t is the tritium content after ventilating for some time, 100%; F is the gas flow at 23℃, Pa·m^3/s; V is the air volume in the room at 1 atmosphere, m^3; q is tritium release rate from the glove box, mol/s. Eq.2 is the analytic expression of Eq.1.

$$e^{-\frac{F}{V}t} = (\frac{x_t}{RT} - \frac{q}{F})/(\frac{x_0}{RT} - \frac{q}{F}). \quad (2)$$

The tritium release rate from the glove box can be calculated with Eq. 3.

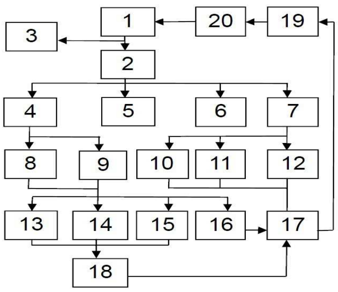
$$q = x_t F/(RT) \quad (3)$$

The tritium release rate from the first containment can be also calculated in this way.

3. THE PROCESS AND METHOD OF SAFETY ANALYSIS ON TBM TRITIUM SYSTEM

Safety analysis includes safety prediction, safety analysis and danger control, etc. According to the analysis result, a deterministic adjustment of the tritium system may be made, and the dangerous parts and weak section can be improved, so as to meet the safety requirements. The safety analysis research on ITER or attachment are inclined to adopt postulated initiating event analysis[1] and accidental sequence analysis[2] of the deterministic theory, as well as failure mode and effect analysis (FMEA)[3], etc.

This article applied Preliminary Hazard Analysis (PHA), FMEA, deterministic theory, probabilistic safety assessment (PSA), etc., to tritium safety analysis, making sure the type, cause and result of the accident or failure, as well as the logical relationship between different procedures of the safety analysis. By this means, the progress frame of safety analysis on TBM tritium system can be gained, demonstrated in Fig. 2.



1-FMEA, 2-excessive release of tritium, 3-analysis on other failures, 4-excessive tritium release in the abnormal state, 5-influence on the public and the environment, 6-harm to staff, 7-excessive release in normal operation, 8-safety research on materials, 9-research on leakage, 10-analysis on leakage rate, 11-research on permeation, 12-research on material damage, 13-analysis on technique and instrument, 14-analysis on human factor, 15-external influence analysis, 16-analysis with deterministic theory, 17-safety measures, 18-PSA, 19-TBM Tritium system, 20-PHA.

Fig. 2. Framework of tritium safety analysis for TBM tritium system.

4. EVALUATION METHOD ON SAFETY GRADE OF TRITIUM FACILITIES

In order to compare and evaluate the safety state of the new tritium facilities, the safety grade formula about the nuclear leakage or excessive release from the various nuclear facilities is put forward. If the external influential factors are taken into consideration, the comprehensive safety grade of nuclear facilities is as follows.

$$Z = K\times[(J\times G)/(L\times H\times Q)]\times W. \qquad (3)$$

In Eq.3, K is the safety coefficient; J is the technical level; G is the management level; L is the nuclear fuel amount; H is the damage ability to person of a unit radioactive nuclide; Q is the transportation ability of the radioactive nuclide; W is the external safety level of the nuclear facilities. The larger value of D and Z， the higher the safety grades of the nuclear facilities are. It is necessary to make sure the numerical value of each parameter for different nuclear facilities.

CONCLUSION

The current author made a preliminary research on tritium safety. The tritium layout design accords with the tritium operating experience and development trend; it is an efficient and reliable means for tritium safety. The primary task of tritium safety analysis is to put forward the analysis content and make the process frame. PHA and FMEA should be carried out during the design period. Deterministic theory and PSA are of good value in tritium safety analysis. The result of tritium damage should be analyzed through the operator, facilities, public and environment. Making use of the safety grade formula can derive the safety grade of various nuclear facilities, which has a good application prospect.

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