Reliability Analysis Modeling of ITER Tritium Storage and Delivery System at Conceptual Design Stage

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1. Introduction

ITER tokamak uses tritium and deuterium as fuel for nuclear fusion reaction, and handles largest amount tritium ever. For this reason, RAMI analysis of tritium storage and delivery system (SDS) design is important to review the reliability and availability of the system and improve design balance.

The main purpose of SDS is to store and supply the gases needed for operation of ITER machine and to provide the necessary infrastructure for short and long term storage of large amounts of tritium. The SDS handles T2, D2(T), D2 and inactive gases in parallel independent to each gases.

In this paper the reliability modeling of conceptual design of ITER SDS and consists of functional breakdown of Tritium SDS, reliability data base of tritium component/system and reliability block diagram and analysis model.

2. Functional breakdown of Tritium SDS

The function of tritium SDS is to store and supply fuel gases according to the operation of ITER without affecting the operation of ITER machine. ITER SDS consists of mainly three independent fuel gas flows and an inactive gas flows. The fuel gases are tritium gas, the mixture of deuterium and tritium gas, and deuterium gas. Figure 1 shows the overall flow diagram of SDS with the ITER standard practice of node numbering.

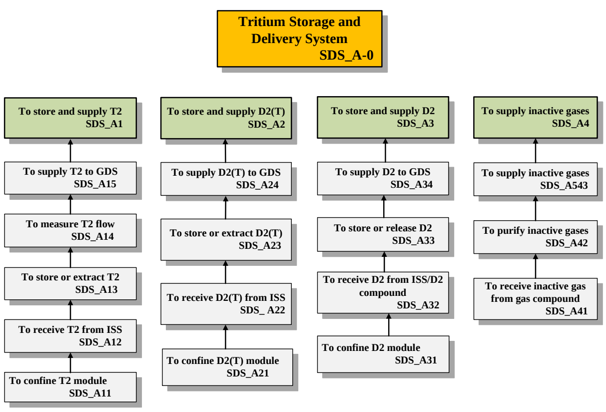


Figure 1. ITER Tritium SDS flow diagram

Some of the functional break downs are shown in Figures 2 to 4.

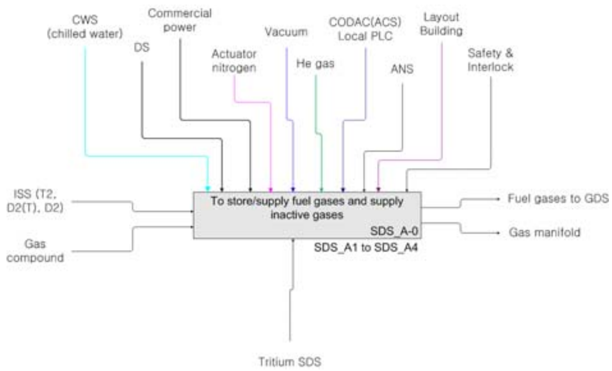


Figure 2. Level 0 functional breakdown of Tritium SDS

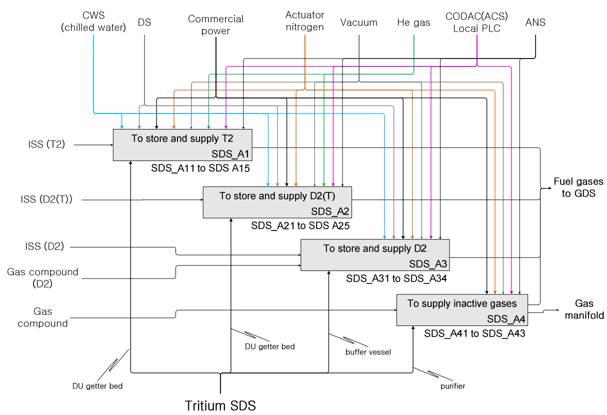


Figure 3. Level 1 functional breakdown of Tritium SDS

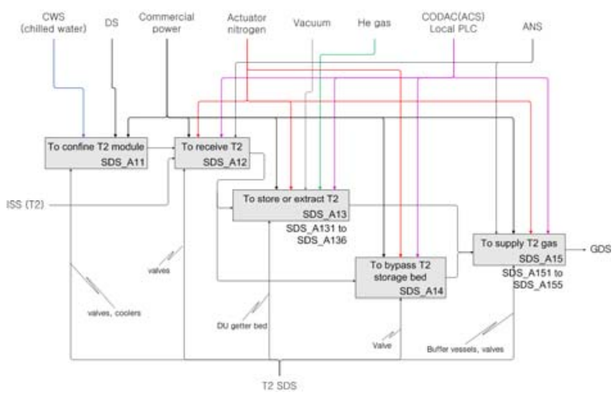


Figure 4. Level 2 functional breakdown of T2 storage and delivery

3. Tritium process component failure rate data

One of the hurdles for the Tritium system reliability analysis is obtaining failure rate data. Because there are no commercial systems based on tritium gases, the data available are limited and directed to just several sources from tritium research facilities.

All of the tritium process failure rate data are related to TSTA (Tritium System Test Assembly of US), JET (Joint European Torus of EU), TPL (Tritium Process Laboratory of Japan), and TLK (Tritium Laboratory Karlsruhe of Germany). Because of the scarcity of tritium process facility in the world, the failure rate data are somewhat scattered and covers limited number of components, see ref. 1. Among these failure data, data from JET is most applicable to ITER due to the fact that it was also a fusion machine as well as it was the most recently published data available.

Summary of components failure rates and sources are given in table 1, comparisons are also given in table 2.

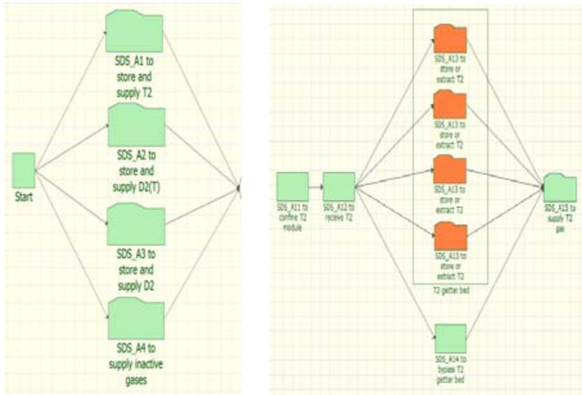
Table 1 SDS component failure rates used for the reliability analysis

Components	Failure rate (λ, /h)	Source	MTBF(h)
DU storage bed with heaters	8.04E-4	Ref. 1(2004), Table 1-1. All failure modes.	1.2438E+3
Valve	1.62E-6	Ref. 2(2010), Table 2-1. Sum of valve failure cases (fail to operate, leak external, leak internal)	6.1728E+5
Flow indicator	9.60E-7	Ref. 2(2010), Table 2-3. Erratic/ No output	1.0417E+6
Pressure Indicator	1.20E-6	Ref. 2(2010), Table 2-3. Erratic/ No output	8.3333E+5
Temperature sensor	2.40E-6	Ref. 2(2010), Table 2-3. Erratic/ No output	4.1667E+5
Buffer vessel	3.00E-10	Ref. 4(2007), Table 5-1. Gas piping failure data is used.	3.3333E+9
Glove box	1.67E-5	Ref. 3(1993), Table 3-3. Sum of glove box leakage and glove box glove breach values.	5.9880E+4
Purifier	2.396E-5	Ref.6 (2002) pp.457. Mechanical scrubber critical failure data is used.	4.1736E+4

It is note that glove box and DU bed is not a single component, rather it is a module that consists of many components. They are treated as single module to simplify modeling.

4. Reliability Block diagram of Tritium SDS

Idef0 functional breakdown and failure rate data is used to create BlockSim reliability analysis model. Figure 12 below show the reliability block diagram for use in the reliability analysis. For the reliability analysis of SDS, an exponential failure rate is assumed because the probability of most mechanical component failure can be represented by exponential function. Figure 5 shows a typical reliability block diagram of T2 flow.



(a) SDS_A0 (b) SDS_A1

Figure 5. T2 flow reliability block diagram

5. Conclusions

Three main part of ITER Tritium SDS reliability analysis modeling was carried out. The first was functional breakdown of ITER Tritium SDS that showed clear logic flow of the system and the second was collection of tritium process component failure rate data, and the last was to creating reliability block diagram. The reliability block diagram can be edited to accommodate system design changes later. Hence as the conceptual design progresses the reliability of the system can be compared to improve system performance.

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