

Design Status of Safety Isolation Valve for the ITER Neutron Activation System

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1. Introduction

ITER neutron activation system (NAS) is designed to evaluate the total fusion power and the neutron fluence on the first wall through the activation of sample materials. A schematic layout of the ITER NAS is shown in Fig. 1 [1].

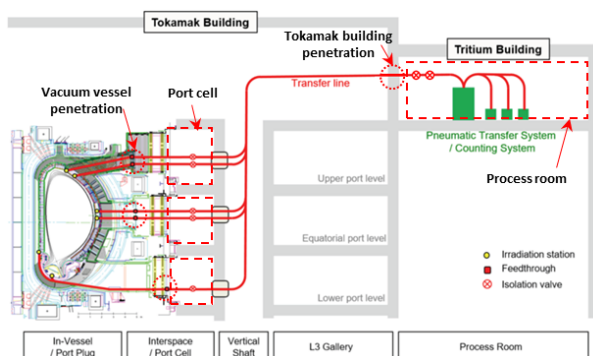


Fig. 1. Schematic layout of ITER NAS

The sample material, encapsulated within a capsule, is transferred via transfer lines that routed through the irradiation end and pneumatic transfer system. As illustrated schematically in Fig. 1, these transfer lines penetrate the vacuum vessel and the tokamak building, which constitute the first and second confinement barriers, respectively.

Following each confinement barrier penetration, safety isolation valves are installed in the tokamak building port cell and the tritium building process room to ensure confinement under all operational and accident conditions. In accordance with the safety requirements of the regulatory authority, two identical safety isolation valves are required for each transfer line at every penetration point.

2. Operational Conditions and Functional Requirements

The NAS is required to operate under three distinct regimes: normal operation, service vacuum system (SVS) operation and accident conditions.

During normal operation, nitrogen gas at a maximum pressure of 6 bar (gauge) is supplied for capsule transfer. The capsule, which contains the sample material, has an outer diameter of 8 mm and a length of 20 mm. Consequently, the applicable valve types for capsule transfer are limited to ball valves or gate valves.

For vacuum leak localization, the transfer lines are connected to the SVS, whose function is to identify leak locations. Any system connected to the SVS must comply with vacuum requirements [2]. Specifically, the required vacuum quality class (VQC) is VQC-3, under which only vacuum compatible materials are permitted [2]. In addition to material restrictions, components also satisfy requirements for baking, leak rate and outgassing rate associated with VQC-3 classification.

Under fire accident scenarios, the most severe accident, the temperature at the safety isolation valve location in the port cell may reach up to 805°C for a duration of two hours. Under these conditions, the safety isolation valves must meet prescribed safety leak rate requirements. The classification of safety isolation valves in both the port cell and the process room, based on operational conditions and functional requirements, is summarized in Table 1.

Classification	NAS safety valve in port cell (1 st confinement barrier penetration)	NAS safety valve in process room (2 nd confinement barrier penetration)
PIC/ Safety Importance Class (SIC)	PIC / SIC-1	PIC / SIC-2
Quality	QC-1	QC-1
Seismic	SC1-SF	SC1-SF
PED/ESPN	PED Cat.0	PED Cat.0
Vacuum	VQC-3A	VQC-3A
Remote handling (RH)	No RH	No RH
Hard core component (HCC)	N/A	HCC

Table 1. Classification of NAS safety isolation valves

3. Qualification process

In ITER, any component associated with a safety function is classified as a protection important component (PIC). For PICs, a formal qualification procedure is required to generate and maintain evidence that provides reasonable assurance of the component's capability to perform its designated safety function [3]. The NAS safety isolation valves, classified as PICs, will therefore be subject to this qualification procedure.

At present, no commercially available valve fully satisfies the aforementioned requirements. However, the

customized manufacture of new qualified valves is expected to impose significant budgetary demands. To address this, the commercial grade dedication (CGD) methodology [4] will be applied for the qualification of the NAS safety isolation valves. The CGD process forms an integral part of the PIC qualification procedure [3], particularly in relation to the manufacturing stage.

4. Candidate COTS Valves and Limitations

The initial step in applying the CGD methodology for PIC qualification is the selection of candidate commercial off-the shelf (COTS) valves. Although a commercial vacuum gate valve satisfying the vacuum requirements is available, its maximum operating pressure is limited to 2 bar (abs.), which is insufficient. For this reason, all candidate valves were selected from commercially available ball valves.

The most demanding operational condition for the valves is the fire scenario, in which the temperature may reach 805°C for two hours. While the valves are planned to be installed inside a valve box wrapped with fire-resistant insulation, high-temperature compatibility remains the foremost requirement. Four COTS ball valves were identified as potential candidates for this application: Swagelok S60P steam service, Swagelok T60M thermal service, Swagelok A60T fire series and Habonim Z47Q. Their maximum operating temperatures are 315°C, 454°C, 204°C and 650°C, respectively. In addition, the Swagelok A60T fire series compliant with API Standard 607, 6th edition.

Since these valves were not originally designed for vacuum service, a preliminary helium leak test was conducted on the Swagelok S60P series model to evaluate vacuum compatibility, following the guideline in Ref. [2]. The test result was satisfactory, demonstrating a helium leak rate below the required limit. The helium leak test of one candidate COTS valve is presented in Fig. 2.



Fig. 2. Helium leak test for one of candidate ball valve: Swagelok S60P steam service.

Nevertheless, all four candidate valves contain materials that are not approved for ITER vacuum conditions [2]. Specifically, the S60P series contains PEEK and Grafoil; T60M series contains Grafoil; the A60T series contains polyimide, PTFE, and Grafoil; and the Habonim Z47Q contains PEEK, graphite, and PTFE. Ongoing investigations are assessing whether these materials could be conditionally approved for use in

vacuum environments if they satisfy other requirements, such as leak rate and outgassing rate.

5. Ongoing Work: All-Metal Ball Valve Development and Interface Modification

As described in the previous section, the NAS operates under pressurized conditions during normal operation, but must also function under vacuum conditions during leak localization. To date, no commercially available gate valve or ball valve has been identified that satisfies both requirements simultaneously. To address this challenge, the development of a customized ball valve is under consideration. In this design, all fluid boundary components will be manufactured from vacuum-compatible materials to ensure compliance.

Since the primary role of the SVS is leak localization, the possibility is being investigated that the NAS itself could fulfill this function, particularly for localized applications within the NAS. If verified, the physical interface between the NAS and the SVS could potentially be eliminated. The requirements for leak localization, along with their feasibility within the NAS, are currently under evaluation.

REFERENCES

- [1] 55.B8 System Design Description (DDD), ITER_D_VLFJU4
- [2] ITER Vacuum Handbook, ITER_D_2EZ9UM
- [3] Procedure for Qualification of Protection Important Components (PIC), ITER_D_XB5ABP
- [4] Commercial Grade Dedication for ITER, ITER_D_6MKCJ6

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