MDEP Common Position No AP1000-01

Related to : AP1000 Working Group activities

THE DESIGN AND USE OF EXPLOSIVE - ACTUATED (SQUIB) VALVES IN NUCLEAR POWER PLANTS

COMMON POSITION ON THE DESIGN AND USE OF EXPLOSIVE - ACTUATED (SQUIB) VALVES IN NUCLEAR POWER PLANTS

Multinational Design Evaluation Program

AP1000 Design Specific Working Group

Squib Valve Subgroup

Purpose

To communicate a common position among regulators reviewing squib valve designs in order to:

- Promote and understand each country's regulatory decision and its basis.

- Aid in the assessment of explosive-actuated valves (squib) valves that are used to perform a safety function within a nuclear power plant.

Background

The nuclear industry has a limited amount of experience with the use of squib valves. The available operating experience is typically from small squib valves in the standby liquid control system at boiling water reactor (BWR) nuclear power plants. The design, qualification, procurement, and in-service testing and inspection activities for squib valves to be used in new reactors represent a significant engineering challenge because of their risk and safety importance, large size range, and new design aspects.

A squib valve ensures zero leakage during normal operations by its sealed closure. Actuation occurs by a pyrotechnic process that is triggered by an electric control signal. Actuation of the squib valve results in the shearing of a pipe cap to allow fluid to flow through the valve. Squib valves can be used to depressurize plant systems, or to provide for coolant to flow to the reactor core or containment building. Actuation of a squib valve is a once-only sequence that requires refurbishment to return the valve to service.

Discussion

In the absence of regulatory experience with valves of this type, the regulators participating in the MDEP AP1000 working group (US NRC, UK NII, Canada CNSC, and China NNSA) developed design principles that they believe are required to be considered in the design, qualification, procurement and life management (examination, inspection, testing and maintenance) of a squib valve.

The principles consider: the design process; reliability; margins; integrity; redundancy; diversity; common cause failure; defence in depth; fault tolerance; aging; degradation; obsolescence; and the examination, maintenance, inspection and testing (EMIT) requirements.

The aim of issuing high-level technical guidance on novel aspects that are being introduced to new nuclear power plants, where there is likely to be limited regulatory experience, is to:

- promote a common approach to regulatory assessment and the harmonisation of regulatory standards;
- develop new power plants with the highest level of safety; and
- inform power plant design organisations of the regulators' expectations.

Position

Listed below are the principles that are expected to be considered in the design, qualification, procurement and in-service activities (such as examination, inspection, testing and maintenance) of a squib valve.

1. Evaluate the basis for use of squib valves versus alternative valve types.
2. Identify safety functions.
3. Categorise and classify safety functions.
4. Determine environmental parameters.
5. Specify codes and standards to be satisfied.
6. Evaluate design to perform the safety functions through techniques such as a Failure Modes and Effects Analysis (FMEA).
7. Establish qualification process to support the required reliability for the safety functions.
8. Establish qualified life (operating hours, actuations, shelf life, and any post-accident life).
9. Determine the examination/maintenance/inspection/testing requirements.

Below is a table of examples of information required to support the safety justification for the performance of squib valves to be used in nuclear power plants. The table also identifies, where applicable, design principles, aging/degradation, and EMIT activities relating to the design, qualification, and in-service surveillance, inspection/testing information items.

The table is not intended to provide a complete or exhaustive list of requirements as these can only be determined by the design authority

No.	Examples of Squib Valve Design, Qualification, and In-Service	Design Principles							
		Design process	Reliability	Margins	Integrity	Redundancy/ Diversity	Defence in Depth	Aging/ Degradation	EMIT
1	Design process satisfies applicable regulatory requirements	x							
2	Design achieves appropriate seismic categorisation and classification	x	x		x		x		
3	Design achieves appropriate I & C categorisation and classification	x	x		x		x		
4	Design achieves appropriate mechanical and integrity categorisation and classification, taking into account the harsh operating environment and the design life (60 years)	x	x	x	x		x	x	x
5	Safety functions have been identified (including number of explosive firings for which squib valve assembly will be qualified)	x							
6	Valve availability is consistent with its safety function throughout operational life for normal and accident conditions	x	x		x				
7	Valve leakage criteria is within safety limit and consequences adequately considered	x	x	x	x			x	x
8	Actuation logic satisfies safety analysis (including any need for direct actuation from control room)	x	x		x	x	x		
9	Positional indication (remote and local) achieves safety functional requirements,	x	x		x				
10	Design ensures 72 hour post accident life	x	x		x				

No.	Examples of Squib Valve Design, Qualification, and In-Service Inspection/Testing Information	Design Principles							
		Design process	Reliability	Margins	Integrity	Redundancy / Diversity	Defence in Depth	Aging/ Degradation	EMIT
11	Valve opens on demand with single actuation reliability and remains full open without interference	x	x						
12	Spurious opening probability is sufficiently low to satisfy the safety criteria	x	x		x				
13	Pressure retaining parts satisfy recognised nuclear design codes and standards such as ASME Code Section III	x			x				
14	Design considers output from FMEA, other analysis, and relevant experience with independent analysis review	x							
15	Design provides adequate level of diversity and redundancy during the actuation process	x	x			x	x		
16	Comprehensive understanding of the energy distribution during the actuation process and the transfer of energy through the different components or bypassed through the valve	x		x					
17	Comprehensive assessment of the assembled valve components, including tolerances, clearances and fits for the harsh operating environment	x	x	x	x			x	x
18	Comprehensive assessment of the process flow performance and characteristics (including potential water hammer effects), such that the valve adequately opens to achieve the required flow rate	x	x	x				x	x

No.	Examples of Squib Valve Design, Qualification, and In-Service Inspection/Testing Information	Design Principles							
		Design process	Reliability	Margins	Integrity	Redundancy/ Diversity	Defence in Depth	Aging/ Degradation	EMIT
19	The actuation loads (forces and moments) that are transferred to the attached piping system (including piping and component supports) are specified to the piping designer to allow consideration of those loads in piping analyses and support design to maintain system, valve, and pipe support integrity following valve actuation	x			x				
20	The as-qualified valve support structure and its anchorages are adequately reflected in the as-installed design	x			x				
21	The maximum loads (forces and moments) from the interfacing piping system onto the squib valve are specified to ensure that the valve's operability is not adversely impacted	x			x				
22	Material selection achieves design and safety intent, including consideration of potential temperature differential expansion e.g. tension bolt shears within a known range, and potential degradation due to boron crystals	x	x	x	x			x	x
23	Design avoids water and debris interfering with the actuation process	x	x						
24	Design allows removal of explosive charge for periodic inspection and replacement	x	x					x	x
25	Design evaluates effects of propellant blow-by into reactor coolant	x							

No.	Examples of Squib Valve Design, Qualification, and In-Service Inspection/Testing Information	Design Principles							
		Design process	Reliability	Margins	Integrity	Redundancy/ Diversity	Defence in Depth	Aging/ Degradation	EMIT
26	Establishment of a robust test-based equipment qualification process such as ASME QME-1-2007 and IEEE 323, 344, and 382 as addressed by NRC regulatory guides (that includes consideration of valve orientation and submergence, and performance of sensitivity analyses and testing to address uncertainties in valve design, manufacture, installation, actuator explosive charge, and in-service activities)	x	x	x	x	x	x	x	x
27	Demonstration of material capability: for example, tension bolts that break at necessary load (not prematurely or too high of a load)	x	x	x	x			x	x
28	Design includes adequate provision for installation of squib valve and its supports considering orientation, tolerances and periodic examination, maintenance, inspection and testing activities	x							x
29	Establishment of a robust quality assurance program (such as 10 CFR Part 50, Appendix B) for design, qualification, and in-service testing/inspection activities	x	x						x

No.	Examples of Squib Valve Design, Qualification, and In-Service Inspection/Testing Information	Design Principles							
		Design process	Reliability	Margins	Integrity	Redundancy /Diversity	Defence in Depth	Aging/ Degradation	EMIT
30	Development of a robust surveillance and Examination, Maintenance, Inspection and Testing (EMIT) program that considers ASME Code and other applicable codes as well as lessons learned from design, qualification, and operating experience; and takes into consideration new valve design to obtain sufficient initial performance data to support in-service inspection/testing and periodic in-service maintenance intervals (e.g., EMIT activities should consider periodic visual examination for presence of boron crystals and non-destructive examination for shear cap thinning)	x	x						x
31	Adequate consideration of the effects of aging (e.g. stress corrosive cracking of the shear cap, propellant, seals, valve body, etc) with establishment of applicable replacement intervals	x			x			x	x
32	Design process ensures proper component and parts control and valve replacement activities to prevent incorrect components and parts being installed in similar squib valves	x			x				x
33	Documentation is generated and maintained in an auditable manner describing the design, design development and qualification process, including the analyses and test results, issues identified during the design and qualification process, and corrective action taken to resolve those issues	x			x				