Office for Nuclear Regulation

New Reactors Programme

GDA close-out for the AP1000 reactor

GDA Issue GI-AP1000-ME-01 – Squib valve concept and design substantiation

Assessment Report: ONR-NR-AR-16-014
Revision 0
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EXECUTIVE SUMMARY

Westinghouse is the reactor design company for the **AP1000®** reactor. Westinghouse completed Generic Design Assessment (GDA) Step 4 in 2011 and paused the regulatory process. It achieved an Interim Design Acceptance Confirmation which had 51 GDA issues attached to it. These issues require resolution prior to award of a Design Acceptance Confirmation and before any nuclear safety-related construction can begin on site. Westinghouse re-entered GDA in 2014 to close the 51 issues.

This report is the Office for Nuclear Regulation's (ONR's) assessment of the Westinghouse **AP1000** reactor design in the area of mechanical engineering. Specifically, this report addresses the GDA issue concerning the squib valve concept and design substantiation.

The **AP1000** plant uses three designs of squib valves. In total there are 12 squib valves within the plant. Each design is of a similar basis with regard to its functionality. The valves are of a predominantly stainless steel construction. A machined barrier known as a shear cap provides the isolation (duty) function during normal operations.

The valves are opened when a demand signal is generated causing an initiator to ignite, which subsequently ignites a secondary charge. This occurs within the pyrotechnic actuator. The resultant expanding gases drive a piston down onto the shear cap, which is designed to shear and opens to allow flow through the valve allowing depressurisation and to maintain cooling of the reactor core.

This GDA issue arose in Step 4 due to:

- the availability of adequate arguments and evidence for the selection, system incorporation and qualification of the squib valve designs had been limited; and so
- Westinghouse was required to issue appropriate, approved documentation providing adequate arguments and evidence for the squib valve selection, equipment design, and associated system design.

The GDA issue raised by ONR in Step 4 contained seven specific actions requiring Westinghouse to provide adequate arguments and evidence to close these out.

The Westinghouse GDA Issue Resolution Plan stated that its approach to closing the issues was to:

- provide an updated squib valve summary report to give evidence as to the squib valve selection, design qualification and identification of examination, inspection, maintenance and testing requirements;
- develop an independent safety case document for the **AP1000** plant squib valves. This document will contain the detailed claims, arguments and evidence for the squib valves implemented in the **AP1000** plant; and
- provide the necessary supporting documents (evidence) to allow ONR assessment.

My assessment conclusion is that:

- I judge that Westinghouse has provided adequate arguments and evidence to close the seven actions within the GDA issue; and
- Westinghouse has submitted appropriate, approved documentation that provides adequate arguments and evidence for its selection, equipment design, and associated system design for squib valves.

My judgement is based upon the following factors:

- Relevant good practice is met for substantiating the squib valve concept and detailed design.
- For GDA, risks are judged to be reduced so far as is reasonably practicable.
- Westinghouse has made commitments to address shortfalls with a licensee during site licensing and construction.
- The quality of submissions improved through a significant level of proactive engagement.

Assessment Findings

The following matters remain, which are for a future licensee to consider and take forward in its site-specific safety submissions. These matters do not undermine the generic safety submission and require licensee input / decision.

- Assessment Finding CP-AF-AP1000-ME-01 concerning the consideration of optioneering conducted in GDA and site-specific aspects to develop and implement an examination, inspection, maintenance and testing regime for squib valves.
- Assessment Finding CP-AF-AP1000-ME-02 concerning the undertaking of equipment qualification testing on the as-built actuator and components.
- Assessment Finding CP-AF-AP1000-ME-03 concerning monitoring of the actuators through-life environmental conditions.
- Assessment Finding CP-AF-AP1000-ME-04 concerning the production of methods and identification of equipment to be used for initiator continuity and resistance testing.
- Assessment Finding CP-AF-AP1000-ME-05 concerning the substantiation of reliability of the actuator and pyrotechnic components.
- Assessment Finding CP-AF-AP1000-ME-06 concerning provision of inspection and test arrangements to identify ageing and degradation of the initiators.

In summary, I am satisfied that the GDA issue concerning squib valve concept and design substantiation can be closed.

LIST OF ABBREVIATIONS

ADS	Automatic Depressurisation System
ALARP	As Low As Reasonably Practicable
ASME	American Society of Mechanical Engineers
BDB	Beyond Design Basis
C&I	Control and Instrumentation
CCF	Common Cause Failure
CDF	Core Damage Frequency
CIM	Cabinet Interface Module (or Component Interface Module)
CR	Containment Recirculation
DAC	Design Acceptance Confirmation
DAS	Diverse Actuation System
DBA	Design Basis Accident
EIMT	Examination, Inspection, Maintenance and Test
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
EQ	Equipment Qualification
EQSR	Equipment Qualification Summary Report
ER2104	Explosives Regulations 2014
ESD	Electrostatic Discharge
FAT	Factory Acceptance Testing
FME	Foreign Material Exclusion
FMEA	Failure Modes and Effects Analysis
GB	Great Britain
GDA	Generic Design Assessment
HLC	High Level Claim
HP	High Pressure
HSE	Health and Safety Executive
HSL	Health and Safety Laboratory
IAEA	International Atomic Energy Agency
IDAC	Interim Design Acceptance Confirmation
IRWST	In-containment Refuelling Water Storage Tank
JSP	Joint Services Publication
LAT	Lot Acceptance Testing
LOCA	Loss Of Coolant Accident
LP	Low Pressure
MDEP	Multinational Design Evaluation Programme
ONR	Office for Nuclear Regulation
OpEx	Operating Experience

PCSR	Pre-Construction Safety Report
PMS	Protection and Monitoring System
PPE	Personnel Protective Equipment
PSA	Probabilistic Safety Assessment
PSR	Preliminary Safety Report
PXS	Passive Core Cooling System
QA	Quality Assurance
RCS	Reactor Coolant System
RFI	Radio Frequency Interference
RGP	Relevant Good Practice
RP	Requesting Party
SAD	Safe Arm Device
SAPs	Safety Assessment Principles
SFAIRP	So Far As Is Reasonably Practicable
SFR	System Functional Requirement
SI	Structural Integrity
SSC	System, Structure (and) Component
SVSR	Squib Valve Summary Report
SVTU	Squib Valve Termination Unit
TAG	Technical Assessment Guide
TSC	Technical Support Contractor
US NRC	United States (of America) Nuclear Regulatory Commission

TABLE OF CONTENTS

Tables

Figures

Annexes

1 INTRODUCTION

1.1 Background

1. Westinghouse completed Generic Design Assessment (GDA) Step 4 in 2011 and paused the regulatory process. It achieved an Interim Design Acceptance Confirmation which had 51 GDA issues attached to it. These issues require resolution prior to award of a Design Acceptance Confirmation and before any nuclear safety related construction can begin on site. Westinghouse re-entered GDA in 2014 to close the 51 issues.

2. This report is the Office for Nuclear Regulation's (ONR's) assessment of the Westinghouse **AP1000** reactor design in the area of mechanical engineering. Specifically, this report addresses GDA Issue GI-AP1000-ME-01 – Squib valve concept and design substantiation.

3. The related GDA Step 4 report is published on our website (**www.onr.org.uk/new-reactors/ap1000/reports.htm**).

4. This provides the assessment underpinning the GDA issue. Further information on the GDA process in general is also available on our website (**www.onr.org.uk/new-reactors/index.htm**).

1.2 Definitions

5. The squib valve is a new concept within Great Britain's (GB's) nuclear industry. The following section defines a number of terms that are important to understanding the basis of the design, operation and assessment of the squib valves.

Phase 2 – This term is used to identify nuclear site licensing, detailed design and construction activities.

Normal business – This term is used where ONR has identified actions that a licensee will be required to undertake during Phase 2 of the regulatory process (licensing and construction). Due to its nature, ONR expects these actions to be performed as a matter of course within a licensee's design, construction and/or operational activities.

Poka yoke – This is a term used to describe a 'mistake proof' mechanism or feature on a design that highlights human errors as they occur, rather than enabling them to remain hidden. An example of such a feature is the use of shadow boards for the placement and accountability of tooling when not in use.

Initiator – An initiator is the first element in an explosive train. Upon receipt of the proper mechanical or electrical impulse, it produces a deflagration or detonation action. The deflagration or detonation action is transmitted to other elements in the train. A general term for an initiator is a squib.

Secondary charge – Also known as a booster charge, an explosive charge downstream of the first element of an explosive train that is used to increase the energy output to the end item.

Bridgewire – A resistance wire incorporated into the first element that converts electrical energy into heat to cause ignition of the explosive charge.

All-fire current – The lowest level of current which results in initiation of a first element within a specific reliability and confidence level as determined by test and analysis. Usually defined in the order of 0.999 reliability at 95% confidence.

No-fire current – The highest level of input energy to a first element at which initiation will not occur within a specific reliability and confidence level as determined by test and analysis. Usually defined in the order of 0.999 reliability at 95% confidence.

Safe Arm Device (SAD) – A mechanical or electromechanical device that enables remote safing or arming of an explosive train by means of a structural barrier in the train downstream of the first element.

6. A number of these definitions are taken from recognised standards with clarification provided to address the specific **AP1000** design.

1.3 Squib Valve Description

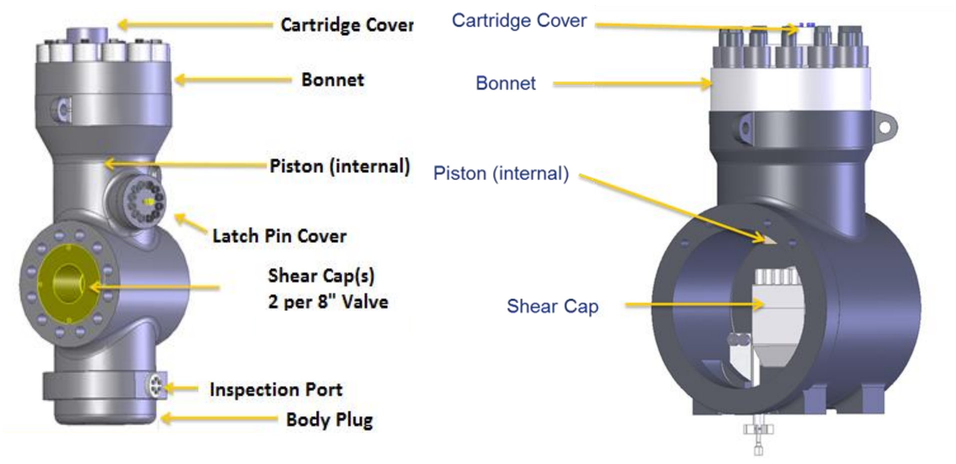
7. The **AP1000** plant uses three designs of squib valves. Each design is of a similar basis with regard to its functionality. They are either 8 inch (200 mm nominal bore) or 14 inch (350 mm nominal bore) valves of a predominantly stainless steel construction. A shear cap provides the isolation (duty) function during normal operations. This shear cap is a machined barrier providing a containment function.

8. During certain fault conditions, the squib valves may be called upon to open, allowing flow through the associated systems to maintain cooling of the reactor core. The opening function is designed to be provided in the following stages:

- A demand signal is generated which provides sufficient current to lead the bridgewire to heat up and the initiator to ignite. This causes the ignition of a secondary charge within the actuator assembly, producing rapidly expanding gases within the valve, above a piston.
- The gases produce sufficient force to fracture a [retaining] tension bolt holding the piston in a raised position, allowing the piston to drive vertically downwards onto the top of a shear cap, shearing this from the end of a pipe inside the valve, creating an opening. The shear cap is then retained within the valve.[*]
- This opening allows the fluid to flow through the valve.

9. Figure 1 below shows two different squib valves and identifies a number of the components.

[*] *The 14 inch ADS-4 valves have a single shear cap, and the 8 inch IRWST and containment recirculation (CR) valves have two shear caps within the valve. In each case, the piston is designed to shear the caps from the internal piping and the valve retains these post actuation. A position indicator provides a signal to the main control room, showing that the shear cap has opened.*



8 inch valve **14 inch valve**

Figure 1: Squib valve diagram (not to scale)

10. Within the **AP1000** design, there are 12 squib valves, made up of the following types:

- Four 14 inch squib valves within stage four of the automatic depressurisation system (ADS Stage 4 or ADS-4);
- Six 8 inch, high pressure (HP) squib valves – four within the in-containment refuelling water storage tank (IRWST) injection line and two within the containment recirculation (CR) line of the passive core cooling system (PXS); and
- Two 8 inch, low pressure (LP) squib valves within the CR line of the PXS.

1.4 Scope

11. The scope of my assessment is detailed in assessment plan ONR-GDA-AP-14-010 (Ref. 1).

12. My assessment focused on the seven actions identified within GDA Issue GI-AP1000-ME-01, following the GDA Step 4 assessment. The GDA issue identifies the following broad areas where further substantiation, including evidence, is required:

- Optioneering (including the assessment of risk) of the valve selection and the adequacy of the design process.
- Justification that squib valve component designs are able to achieve their safety function and are appropriately integrated into their interfacing systems.
- Justification that an adequate examination, inspection, maintenance and testing (EIMT) regime has been specified, that this can be appropriately implemented throughout the design life and covers all identified gaps noted during Step 4.
- A number of specific mechanical engineering and pyrotechnic-related gaps in the safety justification.

13. The scope of my assessment is appropriate for GDA because the ONR Step 4 assessment raised a number of concerns with the then, largely conceptual design of the squib valves. Since Step 4, Westinghouse has undertaken design development,

manufacture, testing and qualification to the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel design code. As a result, Westinghouse is now at an appropriate stage of design to provide the substantiation necessary at the GDA phase for the squib valve designs. Consequently, I have made my assessment of Westinghouse's safety case and design substantiation for the squib valves considering all actions within the GDA issue raised at Step 4.

14. However, I have targeted a number of areas for more detailed assessment, where I believe the greatest risk in achieving the safety case requirements and the highest consequences of failure lie.

These areas were:

- The adequacy of the equipment qualification (EQ) process undertaken for the pyrotechnic actuators: ie does the process provide adequate data on which to base future EIMT requirements, and to justify reliability throughout the design life of the actuators?
- EIMT of the valves throughout their design life: for example, what means are available to assess whether the valves continue to be capable of reliably providing their safety function during their 60-year design life? Can the valves be accessed without unnecessary risk and is the EIMT regime justified as suitable and sufficient?
- Spurious actuation of the squib valves: the valve actuating when not required to do so – the worst case potentially being at full system pressure. Have the risks and consequences of spurious actuation been adequately assessed and shown to be as low as reasonably practicable (ALARP)?

1.5 Method

15. This assessment complies with internal guidance on the mechanics of assessment within ONR (Ref. 2).

1.5.1 Sampling Strategy

16. It is rarely possible or necessary to assess a safety submission in its entirety, and therefore ONR adopts an assessment strategy of sampling. The sampling strategy for this assessment was firstly to assess whether Westinghouse's two key submissions provide adequate arguments and evidence to support closure of the seven actions within the GDA issue. I identify and discuss these in Sections 3 and 4 of my assessment report.

17. Where the key submissions identified supporting arguments or evidence, I sampled these to a level that provided me with confidence that the GDA issue was addressed.

18. As identified in paragraph 14 above, I targeted three specific areas of the GDA issue resolutions as I judged these to pose the most significant risk to the GDA design. Therefore, my sampling strategy largely targeted these areas.

19. My sampling strategy necessitated the involvement of human factors, probabilistic safety assessment (PSA), internal hazards, control and instrumentation (C&I) and structural integrity inspectors.

2 ASSESSMENT STRATEGY

2.1 Pre-Construction Safety Report (PCSR)

20. ONR's GDA Guidance to Requesting Parties (www.onr.org.uk/new-reactors/ngn03.pdf) states that the information required for GDA may be in the form of a PCSR, and Technical Assessment Guide (TAG) NS-TAST-GD-051 sets out regulatory expectations for a PCSR (www.onr.org.uk/operational/tech asst guides/ns-tast-gd-051.pdf).

21. At the end of Step 4, ONR and the Environment Agency raised GDA Issue GI-AP1000-CC-02 (www.onr.org.uk/new-reactors/reports/step-four/westinghouse-gda-issues/gi-ap1000-cc-02.pdf) requiring that Westinghouse submit a consolidated PCSR and associated references to provide the claims, arguments and evidence to substantiate the adequacy of the **AP1000** design reference point.

22. A separate regulatory assessment report is provided to consider the adequacy of the PCSR and closure of GDA Issue GI-AP1000-CC-02, and therefore this report does not discuss the mechanical engineering aspects of the PCSR. This assessment focused on the supporting documents and evidence specific to GDA Issue GI-AP1000-ME-01.

2.2 Standards and Criteria

23. The standards and criteria adopted within this assessment are principally the Safety Assessment Principles (SAPs) (Ref. 3), internal TAGs (Ref. 4), relevant national and international standards and relevant good practice (RGP) informed from existing practices adopted on nuclear licensed sites within GB and high hazard industries.

2.2.1 Safety Assessment Principles

24. The key SAPs applied within the assessment are included within Table 1.

Table 1: Key safety assessment principles applied within the mechanical engineering assessment of GI-AP1000-ME-01

SAP reference	Title
EKP	Key engineering principles
ECS	Safety classification and standards
ECM	Commissioning
EDR	Design and reliability
EMT	Maintenance, inspection and testing
ELO	Layout

SAP reference	Title
EMC	Integrity of metal components and structures
ECV	Containment and ventilation
EQU	Equipment qualification
EHF	Human factors
FA	Fault analysis
ERL	Reliability claims
MS	Leadership and management for safety
SC	Safety cases
AV	Assurance of validity of data and models
EAD	Ageing and degradation
EHA	External and internal hazards
ESS	Safety systems

2.2.2 Technical Assessment Guides

25. The TAGs that have been used as part of this assessment are set out in Table 2.

Table 2: Technical assessment guides used in the mechanical engineering assessment of GI-AP1000-ME-01

TAG number and revision		Title
NS-TAST-GD-003	Rev 7	Safety Systems
NS-TAST-GD-005	Rev 7	Guidance on the Demonstration of ALARP
NS-TAST-GD-009	Rev 3	Examination, Inspection, Maintenance and Testing of Items Important to Safety
NS-TAST-GD-016	Rev 4	Integrity of Metal Components and Structures
NS-TAST-GD-036	Rev 3	Diversity, Redundancy, Segregation and Layout of Mechanical Plant

TAG number and revision	Title
NS-TAST-GD-049 Rev 5	Licensee Core and Intelligent Customer Capabilities
NS-TAST-GD-056 Rev 3	Nuclear Lifting Operations
NS-TAST-GD-057 Rev 3	Design Safety Assurance
NS-TAST-GD-077 Rev 3	Supply Chain Management Arrangements for the Procurement of Nuclear Safety Related Items or Services
NS-TAST-GD-98 Rev 0	Asset Management

2.2.3 National and International Standards and Guidance

26. The international standards and guidance that have been used as part of this assessment are set out in Table 3.

Table 3: International standards and guidance used within the mechanical engineering assessment of GI-AP1000-ME-01

Standard / guidance reference	Title
IAEA Safety Standards Series No. SSR-2/1 (Rev. 1)	Safety of Nuclear Power Plants: Design
IAEA Safety Standards Series No. NS-G-2.12	Ageing Management for Nuclear Power Plants

27. I use the SAPs, TAGs and international standards or guidance as references to RGP to inform my judgement of Westinghouse's design and substantiation.

2.2.4 Explosive / Pyrotechnic Codes and Standards

28. There are no UK nuclear-specific standards relating to the design, test and/or use of explosive or pyrotechnic components within a nuclear power plant. Therefore, I have considered the guidance given in the SAPs (ECS.3, ECS.4 and ECS.5).

29. Taking this into account I consider an approach may be adopted that is derived from codes and standards from other high hazard industries for similar equipment, in applications with similar safety significance. Westinghouse provides a justification for the use of specific US military / aerospace standards within its design process (see Section 4.2.6).

30. When addressing qualification of the actuator, I have considered a range of other standards that I consider to be RGP. I have included the standards identified by Westinghouse (see Section 4.2.6) but have also considered the following:

- Joint Services Publication (JSP) 520, Safety and Environmental Management of Ordnance, Munitions and Explosives over the Equipment Acquisition Cycle (Ref. 5)

- Health and Safety Executive (HSE)/Confederation of British Industry Explosives Industry Group, Guidance for Electrical Installation and Equipment within Explosives Manufacturing and Storage Facilities including Fireworks (Ref. 6)

2.2.5 Explosives Regulations 2014

31. The Explosives Regulations 2014 (ER2014) (Ref. 7) apply to the manufacture and storage of explosives within GB. The regulations do not directly apply to explosives that are 'in use', although the point at which an explosive becomes in use is not well defined. The **AP1000** plant actuator component has not yet been classified as an explosive article within the UK. However, it is likely that the ER2014 will apply to a number of the activities assessed within this report. Additionally, I consider the information provided in the ER2014 guidance document L150 (Ref. 8) to be a source of RGP for the use of explosives in cases where there is no nuclear industry-specific RGP.

32. Detailed compliance with ER2014 and other related regulations will be addressed in licensing; ONR is the ER2014 licensing authority for GB nuclear sites. I refer to ER2014 where appropriate.

2.3 Use of Technical Support Contractors (TSCs)

33. I have not required the support of a TSC within my mechanical engineering assessment of GDA Issue GI-AP1000-ME-01.

2.4 Integration with Other Assessment Topics

34. GDA requires the submission of an adequate, coherent and holistic generic safety case. Regulatory assessment cannot therefore be carried out in isolation, as there are often safety issues of a multi-topic or cross-cutting nature.

35. The following GDA issues are identified as having an interface with the closure of GDA Issue GI-AP1000-ME-01:

    - GI-AP1000-CI-01 Control and Instrumentation – Diverse Actuation System (DAS) adequacy of safety case, as the safety functions of the DAS have a direct impact on the actuation of squib valves;

    - GI-AP1000-CI-02 Control and Instrumentation – DAS adequacy of architecture, as the design of the DAS has a direct impact upon the ability of the squib valves to achieve their safety function;

    - GI-AP1000-CI-04 Control and Instrumentation – Protection and monitoring system (PMS) spurious actuation, as spurious actuation and consequences are regarded as a significant concern with respect to dose to operators and potentially the public;

- GI-AP1000-CI-08 Control and Instrumentation – PMS basis of safety case, as the adequacy of the PMS safety case has an impact upon the squib valves' ability to achieve their safety function;
- GI-AP1000-HF-01 Human Factors – Completeness of human factors safety case, as human error and human performance during installation, and EIMT of the squib valves will impact the reliability of the squib valves to achieve their safety functional requirements;
- GI-AP1000-IH-01 Internal Hazards – Internal fire, as this is presented within the squib valve safety case concerning spurious actuation;
- GI-AP1000-IH-02 Internal Hazards – Internal flood, as the 8 inch squib valves are claimed to actuate when submerged during reactor fault conditions;
- GI-AP1000-IH-05 Internal Hazards – Internal missiles, as the squib valves are claimed within the safety case to not cause internal missiles even when actuating at full pressure;
- GI-AP1000-PSA-01 Probabilistic Safety Assessment – Success criteria for the PSA, as the reliability of the squib valves to actuate on demand and their claimed frequency for spurious actuation have an impact upon the design safety assurance provided; and
- GI-AP1000-SI-06 Structural Integrity (SI) – SI categorisation and classification as this has a direct influence upon the design and design safety assurance provided by Westinghouse.

2.5 Out-of-Scope Items

36. Table 4 sets out the items outside the scope of my GDA assessment.

Table 4: Out-of-scope items for GDA Issue GI-AP1000-ME-01

Item	Justification
Assessment Findings	Assessment Findings are the responsibility of the future licensee to address during site licensing and construction. Closure of these is outside the scope of GDA.
Licensee specific activities or input	Activities or input required by a future licensee are not assessed in the closure of this GDA issue as they are not deemed 'generic' to the **AP1000** design.

3 REQUESTING PARTY'S SAFETY CASE

37. The Westinghouse safety case for GDA Issue GI-AP1000-ME-01 is documented in the following references:

- UKP-GW-GL-793 Revision 1, **AP1000** PCSR (Ref. 9)
- UKP-GW-GL-200 Revision 1, **AP1000** Squib Valve Safety Case (Ref. 10)
- APP-PV70-GER-002 Revision 2, Squib Valve Summary Report (Ref. 11)

38. The safety case for the **AP1000** squib valves is complex, with a number of technical interfaces. To ensure a targeted assessment, I specifically sampled the claims, arguments and evidence associated with the GDA issue actions, together with the documented evidence providing justification that the design reduces risk so far as is reasonably practicable (SFAIRP).

39. The squib valves must be reliable under both normal operations and fault conditions. Failure to perform their necessary safety function may result in a loss of coolant accident (LOCA), inadequate depressurisation or a delay in passive core cooling function.

40. Westinghouse assigns all squib valves within the **AP1000** design as Class 1 components forming a principal means of delivering a Category A safety function (in accordance with ONR SAPs ECS.1 and ECS.2).

3.1 Safety Functions

41. The **AP1000** PCSR (Ref. 9) identifies three safety functions (SFs) that the squib valves must deliver during normal operations and fault conditions.

- SF1: Preventing the release of radioactive material through the boundary of the RCS
- SF2: Removing decay heat from the reactor coolant during normal operation and accident conditions
- SF3: Maintaining reactor coolant inventory

42. Within Chapter 15 (engineering substantiation) of the PCSR, these SFs are identified against the following groups of squib valves:

- Four ADS Stage 4 squib valves:
  - Preventing the release of radioactive material through the boundary of the Reactor Coolant System (RCS) (SF1).
  - Removing decay heat from the reactor coolant during normal operation and accident conditions (SF2).
- Four IRWST injection squib valves:
  - Maintaining reactor coolant inventory (SF3).
  - Preventing the release of radioactive material through the boundary of the RCS (SF1).

- Four containment recirculation (CR) squib valves:
  - Maintaining reactor coolant inventory (SF3).

3.2 Safety Functional Requirements

43. Westinghouse identifies three safety functional requirements (SFRs) against the squib valves. These are identified within the squib valve safety case as:

- Maintain pressure boundary when a demand signal isn't generated to open the valve.
- Open when a demand signal is generated to provide the necessary flow path for cooling / depressurisation.
- Maintain their position based on demand.

44. The squib valve safety case (Ref. 10) also identifies four associated high-level claims (HLCs) in relation to delivering these three SFRs:

- HLC1: The squib valves will open when a demand signal is generated to serve their safety functional requirements.
- HLC2: The squib valves will maintain their interfacing pressure boundary to serve their safety functional requirements.
- HLC3: The squib valves' ability to perform their safety functional requirements will not be adversely impacted by their surrounding environments.
- HLC4: The squib valves provide a reliable means of performing their necessary safety functional requirements.

3.3 Engineering Substantiation (Arguments and Evidence)

45. Westinghouse provides the substantiation of the claims made against the three groups of squib valves within a number of technical and safety case documents. Two key references (Refs 10 and 11, identified in paragraph 37.) provide the link to the technical (evidential) supporting documents.

46. I have referenced those supporting documents that I have sampled, together with the reasons why, in my assessment of GDA Issue GI-AP1000-ME-01.

4 ONR ASSESSMENT OF GDA ISSUE GI-AP1000-ME-01

47. This assessment has been carried out in accordance with HOW2 guide NS-PER-GD-014, “Purpose and Scope of Permissioning” (Ref. 12).

4.1 Scope of Assessment Undertaken

48. The GDA Issue GI-AP1000-ME-01 (Ref. 13) identified seven actions (A1 to A7). Each of these was the result of ONR’s assessment of the generic **AP1000** design at the end of GDA Step 4 in November 2011 (see Ref. 14 for details). You can find details of these actions in the published GDA issue (Ref. 13) and I have summarised them below:

- GI-AP1000-ME-01.A1
  Westinghouse shall generate and issue appropriate approved documentation that provides adequate arguments and evidence for the squib valve selection.

- GI-AP1000-ME-01.A2
  Westinghouse shall generate and issue appropriate approved documentation to justify the squib valves detailed component designs are able to achieve the safety case requirements and assumptions.

- GI-AP1000-ME-01.A3
  Westinghouse shall generate and issue appropriate approved documentation to justify that the squib valves interfacing system designs are able to achieve the safety case requirements and assumptions.

- GI-AP1000-ME-01.A4
  Westinghouse shall generate and issue appropriate approved documentation to demonstrate the surveillance and EIMT regime is able to achieve the safety case requirements and assumptions.

- GI-AP1000-ME-01.A5
  Westinghouse shall address a number of points, which have been identified as gaps in the safety justification of the squib valve designs as a result of undertaking the GDA from a mechanical engineering perspective.

- GI-AP1000-ME-01.A6
  Westinghouse shall address a number of points, which have been identified as gaps in the safety justification of the squib valve designs as a result of undertaking the GDA from a pyrotechnics perspective.

- GI-AP1000-ME-01.A7
  Westinghouse shall address a number of further points, which have been identified as gaps in the safety justification of the squib valve designs as a result of undertaking the GDA from a surveillance and EIMT perspective.

49. Westinghouse’s Resolution Plan (Ref. 15) for these seven actions has formed the scope of my mechanical engineering assessment for closure of GDA Issue GI-AP1000-ME-01.

4.2 Assessment

50. Westinghouse’s resolution plan identifies a number of submissions intended to provide the arguments and evidence that support both the claims made against the squib valves and the adequacy that the design meets all of the items ONR raised in the GDA issue.

51. In my assessment, I have concentrated upon the arguments and evidence in the squib valve summary report (Ref. 11), the squib valve safety case (Ref. 10) and those supporting evidential documents identified by Westinghouse within these. However, in some cases (identified within Section 1.4, paragraph 14) I have undertaken a more targeted assessment due to the potential consequences of failure.

52. The sections below detail the key aspects of my assessment.

4.2.1 GI-AP1000-ME-01 Action 1

53. Action 1 of the GDA issue was for Westinghouse to:

“Generate and issue appropriate approved documentation that provides adequate arguments and evidence for the squib valve selection.

“ONR considers a GDA can not be completed without the design being finalised and the availability of auditable and approved design documentation that demonstrates the valve selection at the concept stage is ALARP.

“ONR’s expectation is for Westinghouse to finalise their designs and provide the formal Summary Report, which is to include the appropriate arguments and evidence to demonstrate the squib valve selection is ALARP, with sufficient evidence of optioneering, and the design has followed a robust design process.”

54. Within the squib valve summary report, Section 2 presents the process by which Westinghouse selected squib valves as the most appropriate option to deliver the SFs.

55. Sections 3, 4, 5 and 6 of the squib valve summary report continue to present the design process undertaken from concept through to design finalisation and verification.

56. I have concentrated my assessment on these sections of the squib valve summary report and included, where I judge it necessary, supporting references.

<u>Assessment</u>

57. The action requires that Westinghouse demonstrates that its valve selection and design process satisfies RGP, ie:

- it satisfies ALARP principles, including the assessment of options; and
- it has followed a robust design process.

Assessment of options

58. In line with guidance provided within ONR TAG NS-TAST-GD-005, Guidance on the demonstration of ALARP (see Ref. 4), my assessment has considered whether Westinghouse's submission demonstrates:

- the rationale for the evolution of the design, using its forerunners as a baseline, looking at why certain features were selected and others rejected and how this process has resulted in an improved design from a safety perspective; and
- whether the justification addresses the question "what more could be done?" and provides an argument of "why they can't do it" ie why is it not reasonably practicable?

59. Within the squib valve summary report (Ref. 11) Westinghouse presents the options considered together with the reasoning behind the deselection or selection.

60. Westinghouse initially considered eight types of valve including solenoid, pneumatic ball and gate valves, motor-operated ball, gate and globe valves, and squib valves. It considered three options for further optioneering: a motor-operated gate valve, an air-operated gate valve and a squib valve. The company also considered a range of variables including reliability, development risk, cost and expectations for in-service testing and maintenance.

61. My assessment of this found that Westinghouse has considered an appropriate range of options in line with guidance provided within the ONR TAG (see Ref. 4).

Design assurance

62. ONR TAG NS-TAST-GD-057, Design safety assurance (see Ref. 4) includes guidance on what is to be expected when assessing the adequacy of a design process. At this phase (GDA), aspects of the process may not have been addressed; however, I expect that the process shall cover a number of these with a greater degree of evidence. These are linked to the assessment of risk across all stages, risk mitigation where practicable within the design, assurance that the design has been adequately verified and validated at appropriate stages and that corrective action has been adequately recorded and undertaken.

63. I have included details supporting my assessment of Westinghouse's design processes in an assessment note (Ref. 16).

64. During my assessment I have sampled:

a. the squib valve design specifications (Refs 17 and 18).
I found that Westinghouse has identified the SFRs from the safety case;

b. the prototype / conceptual test documentation (Ref. 19) and the equipment qualification summary report (EQSR) for the 8 inch squib valves (Ref. 20).
The test and qualification documentation identify a series of tests that demonstrate that the components meet the requirements set out in (a) the specifications and (b) within the test requirements; and

c. two examples of corrective actions discussed within Ref. 21.
The corrective action examples provide evidence that a robust process has been undertaken to detail the issues identified, present the options for corrective action, argue the appropriate action to take and record that corrective actions have been completed.

65. I consider that Westinghouse's design process:

- utilises a similar process to that used within the aerospace industry to develop squib valves, which is in line with guidance provided in ONR SAPs MS.4 and ECS.5; and

- has undertaken adequate verification and validation of the design at appropriate stages throughout the project and incorporated corrective actions where deemed necessary. This is in line with guidance in the ONR TAG.

Judgement

66. I judge that Westinghouse has provided adequate arguments and evidence for the squib valve selection and that it has followed a suitably robust design process.

67. Therefore, I judge that GI-AP1000-ME-01 Action 1 is closed.

4.2.2 GI-AP1000-ME-01 Action 2

68. Action 2 of the GDA issue was for Westinghouse to:

"Generate and issue appropriate approved documentation to justify the squib valve detailed component designs are able to achieve the safety case requirements and assumptions.

"ONR considers a GDA can not be completed, without the designs being finalised and the availability of approved design documentation that demonstrates the valve detailed component designs meets the safety case requirements.

"ONR's expectation is for Westinghouse to finalise their designs and provide the formal approved design justification, which includes the appropriate arguments and evidence that the valves' detailed component designs meet the safety functional requirements."

69. Westinghouse identifies the SFRs for the squib valves within its squib valve safety case submission (Ref. 10).

70. Ref. 10 and the squib valve summary report (Ref. 11) provide claims, arguments and evidence relating to the design of specific key components within the squib valve designs.

71. Within the squib valve summary report, Table 4.3-1 lists a number of safeguards against failure of various components within the 8 inch squib valves. This identifies which components have a high, medium or low importance, primarily in regards to the diversity argument. I have used the safeguards section to inform my assessment[†].

72. As a basis of my assessment, I have sampled the following three key components:

- the actuator assembly – two SFRs, maintain pressure boundary and open on demand

- tension bolt – two SFRs, maintain pressure boundary and open on demand

[†] *Note that these safeguards identified for the 8 inch squib valves are, in most cases, directly transferrable to the 14 inch squib valve design, so I have only sampled the 8 inch design in this case.*

- shear cap – three SFRs, maintain pressure boundary, open on demand and maintain position

73. The engineering adequacy and performance of these components contributes significantly to the squib valve's achievement of its safety function during normal (duty) and fault conditions (see Section 3.2).

74. Equally, the engineering, examination, inspection and testing undertaken during design and manufacture of the valves and their components provides additional confidence that the valve will meet its claimed reliability target (probability of failure on demand) of 5.8 x10^{-4} pfd (claimed in Ref. 11).

Assessment

75. My expectation is that Westinghouse:

- provides a clear set of design and SFRs for each of the squib valve components in line with guidance within ONR SAP EKP.4;
- provides evidence that the overall squib valve design is inherently safe (in line with ONR SAP EKP.1); and
- provides evidence that there has been an assessment to demonstrate that the design is not sensitive to reasonably foreseeable faults. The design should also demonstrate that Westinghouse has considered the principle of defence-in-depth (ONR SAP EKP.3).

76. I have provided details supporting my assessment in Ref. 16, and have summarised the main points below.

Actuator assembly

77. The assembly comprises the following key components:

a. initiators – containing a hot bridgewire and primary propellant

b. booster charge – consisting of two sequential charges of secondary propellant

c. bursting discs

d. casing

78. Westinghouse's squib valve safety case identifies that:

- the primary propellant is designed to generate sufficient output to cause the first booster charge to ignite;
- the first booster charge is separated from the second booster charge by a bursting disc, which is designed to open once the correct pressure has been generated; and
- the second booster charge is then ignited which generates further gas causing the outer bursting disc (known as a closure disc) to open.

79. The ignition of both parts of the booster charge is required to generate sufficient gas pressure to fracture the machined portion of the tension bolt and drive the piston towards the shear cap. Achieving this satisfies the SFR to transfer open and relies upon the initiator successfully operating along with adequate progression through the pyrotechnic chain.

80. The squib valve safety case (Ref. 10) provides evidence of Bruceton testing[‡] that Westinghouse uses to identify:

- the all-fire current
- the no-fire current
- the initiator output

81. The actuator assembly must reliably produce sufficient gas pressure to ensure that the tension bolt fails and the piston is driven down its intended path to the shear cap. The squib valve safety case details the testing carried out to demonstrate the reliability of the actuators.

82. There is a second requirement that the actuator will not fire when a demand is not placed upon it, addressed by its SFR to maintain pressure boundary. Westinghouse identifies that spurious actuation may be generated by:

a. the C&I system itself (PMS or DAS);

b. Electromagnetic Interference (EMI) / Electromagnetic Compatibility (EMC) / Radio Frequency Interference (RFI) induced currents within the cabling connected to the initiator;

c. internal fire causing temperatures within the actuator to reach and/or exceed the auto-ignition temperature of the pyrotechnic; or

d. EIMT induced faults eg human error.

83. Argument 2.1.2 within the squib valve safety case presents the system level protections and the valve specific design protections to ensure that the valves do not actuate without a demand.

84. The most significant system level protections are provided in the form of the arm / fire logic and the C&I blocker device (the adequacy of which is assessed within GDA Issue GI-AP1000-CI-04).

85. One further system level protection claimed in the squib valve safety case is that PMS ground fault monitoring is not used in the squib valve C&I system. I assess this further in Section 4.2.6.

86. The reliability of the actuator has a direct influence upon the overall valve reliability claimed. Westinghouse's argument identifies these valve-specific design protections as:

- the use of a high no-fire current;
- the protection against electrostatic discharge (ESD);
- the protection against EMI or RFI;
- the assessed risk of auto-ignition due to fire; and
- administrative controls in place.

[‡] *Bruceton testing is a statistical method of determining the all-fire and no-fire input energy levels using a stepped approach and analysis of results.*

87. Details supporting my assessment of high no-fire current and protection against ESD are contained in Ref. 16.

88. I have assessed the remaining three aspects in Section 4.2.6 of my assessment report, as they are included in GDA issue Action 6.

89. The use of lot acceptance testing (LAT) and levels taken from IEC (now EN) 61000-4-2-2008 (Ref. 22) and MIL-HDBK-1512 (Ref. 23) relating to ESD, is in line with my expectations as they use the most onerous conditions from both standards.

90. In Ref. 10, Westinghouse states that ESD has been analysed and tested to industry standards (EN 61000-4-2 and MIL-HDBK-1512), which I deem to be conservative given Westinghouse's requirements for appropriate personnel protective equipment (PPE) and other protective measures.

91. Therefore, I judge that the conditions are adequately assessed and specified. I expect this to be reassessed as appropriate during detailed design and for site-specific conditions as part of **normal business** in Phase 2 (site licensing and construction).

Tension bolt

92. This component is designed to securely hold the piston in the raised position within the valve when the valve is not required for use. It is secured in position during assembly (initial assembly and then during EIMT throughout the valve's design life).

93. When the actuator provides the specified minimum explosive pressure, the tension bolt is designed to fracture. This allows the piston to be driven vertically down towards the shear cap. The tension bolt is therefore significant in achieving the SF to open on demand and the SFR to transfer open. If the tension bolt is incorrectly fitted, or the piston is not at its fully raised position before actuation, this may affect the valve's ability to function when a demand is made.

94. In demonstrating the adequacy tension bolt design, Westinghouse provided information in Sections 5 and 6 of the squib valve summary report (Ref. 11), and I have discussed this with Westinghouse. It has provided adequate evidence that the tension bolt design has been appropriately tested and qualified in line with guidance in ONR SAPs ECS.5, EQU.1 and EMT.3. I have also discussed the quality assurance (QA) programme Westinghouse has in place concerning the traceability of materials throughout the supply and manufacturing processes.

95. I consider Westinghouse's arrangements to be in line with my expectations, informed by ONR guidance in NS-TAST-GD-057 (see Ref. 4).

Shear cap

96. This component is a machined cap designed to shear under a specified force as the piston strikes its top. In the case of the 8 inch squib valves, the piston strikes two shear caps, whereas for the 14 inch squib valve there is a single shear cap. In both cases, the design is such that the shear caps are retained within the valve body.

97. The shear cap design is significant in achieving the SF of:

   a. maintaining pressure boundary (when the valve is not actuated);

   b. opening on demand (once the valve is actuated); and

   c. providing adequate core cooling and depressurisation once actuated by ensuring that a sufficiently large opening is made after the cap is sheared.

98. The shear caps for the squib valves are specified within the design specification (Ref. 17) to:

- be a one-piece design (reducing the likelihood of failure);
- be a pressure boundary component; and
- require provisions to be made so shear caps with different part numbers cannot be interchanged.

(a) One-piece design

99. Westinghouse provided copies of its design specification (Ref. 17) along with a number of drawings showing the shear cap. This gave confidence that the shear cap is designed as a one-piece component.

(b) Pressure retaining part

100. My expectation therefore is that this component is subjected to adequate design analysis and testing in line with its requirements for other pressure boundary components.

101. During my assessment of the qualification requirements, I identified that the squib valve body is tested in accordance with ASME Boiler and Pressure Vessel Code, Section III, Class 1 NB3531.1 and ASME B16.34 whereas the shear cap is tested in accordance with NB3531.2. Westinghouse has provided its justification of this within its submission, which ONR's structural integrity inspectors and I consider to be adequate.

102. ONR structural integrity inspectors raised queries concerning the design and testing of the shear cap. In particular, they queried the analysis and testing of the machined groove (ligament section) of the shear cap and its behaviour under pressure. The structural integrity assessment of this is in an Assessment Note (Ref. 24).

(c) Provisions to avoid incorrect assembly of similar components

103. I judge that Westinghouse has achieved this requirement by implementing a poka yoke feature on the mating flange with the valve body. The bolt hole circle diameter is different for each of the shear cap designs (14 inch, 8 inch HP and 8 inch LP) so prevents incorrect assembly.

Judgement

104. I judge that Westinghouse has provided adequate arguments and evidence to justify that the squib valve detailed component designs can achieve the safety case requirements and assumptions.

105. The structural integrity inspector judges (Ref. 24) that Westinghouse's evidence to demonstrate the structural integrity of the shear cap as part of the pressure boundary is adequate.

106. Therefore, I judge that GDA Issue GI-AP1000-ME-01 Action 2 is closed.

4.2.3 GI-AP1000-ME-01 Action 3

107. Action 3 of the GDA issue was for Westinghouse to:

"Generate and issue appropriate approved documentation to justify that the squib valve interfacing system designs (e.g. supports, interfacing pipework etc) are able to achieve the safety case requirements and assumptions.

"ONR considers that GDA can not be completed, without the designs being finalised and the availability of approved design documentation that demonstrates each valve is integrated into its associated system, and meets the safety case requirements.

"ONR's expectation is for Westinghouse to finalise their designs and provide the formal approved design justification, which includes the appropriate arguments and evidence that each valve is integrated into its associated system, and meets the safety functional requirements."

108. Chapter 15 of the PCSR identifies the squib valves as a Class 1 system, structure or component (SSC) and that these are seismic category 1 valves. Therefore, in order to meet the requirements of the safety case the interfaces shall also be Class 1. This requirement is identified in Chapter 5 of the PSCR (Ref. 9).

109. Westinghouse submitted its squib valve safety case (Ref. 10), which contains its arguments and evidence supporting the claim that the surrounding SSCs will not limit the valves' ability to perform their safety function (sub-claim 3.1).

Assessment

110. Regarding interfacing systems, I expect the design of the systems in which the valves are located to consider:

- the impact of mechanical interfaces (eg piping);
- the impact of C&I interfaces (eg cabling connections); and
- the impact of civil and structural interfaces (eg supports).

111. While it is my opinion that the **detailed** design of piping, cabling and supports is outside the scope of GDA, I have assessed whether or not Westinghouse has considered these elements within the overall design of the systems in which the squib valves are located. This provided me with confidence that the interfacing system designs are suitable and sufficient to achieve their SFs (preventing release of radioactive material [SF1], removing decay heat [SF2] and maintaining reactor coolant inventory [SF3]).

112. The design of the interfacing SSCs should consider both normal (duty) and fault conditions, and justify that these SSCs are appropriately categorised and classified (ONR SAPs ECS.1 and ECS.2).

Normal (duty) operating conditions

113. Argument 3.1.1 (in Ref. 10) presents the arguments and evidence that Westinghouse claims provide justification for the adequacy of the connecting pipework to provide its SFR (maintain pressure boundary) before and after actuation of the valves.

114. Key to its claim are three piping stress and analysis reports (APP-PXS-PLR-030 (Ref. 25), APP-PXS-PLR-010 (Ref. 26) and APP-PXS-PLR-020 (Ref. 27)) which I sampled to determine whether analysis conditions appeared to be in line with my expectations concerning loads applied to the piping. These documents provide evidence that the forces generated by the pipe loading and by actuation forces are included in the assessment of the system designs.

115. The 14 inch and 8 inch HP valves are subjected to full system pressure under normal (duty) conditions – ie when the squib valves are closed. Here, their SFR is to remain closed to maintain the pressure boundary. I have assessed the adequacy of the shear cap in ensuring this SFR in Section 4.2.2. I consider the shear cap to be the final barrier for maintaining the pressure boundary within the squib valve design.

116. Westinghouse has analysed the loads imparted upon the piping during normal (duty) condition in the pipe stress and analysis reports I sampled.

117. The valves are designed to actuate at the operating pressures and temperatures identified within the valve design data sheets (see Ref. 28). Westinghouse also identifies that the valves and piping are subject to operational transients, which are included within the analyses.

118. It identifies that the results of these analyses are fed into the design and qualification of the supporting SSCs eg cable connectors and piping. Westinghouse presents arguments and evidence within Ref. 10 that the piping analyses (Refs 25, 26 and 27) and the qualification of cable connectors (which are part of the actuator assembly) justify their ability to operate under their intended conditions.

119. Westinghouse's arguments (within Ref. 10) identify that it has also assessed the integrity of the valves and connecting pipework at full system pressure actuation, which it claims is a beyond design basis (BDB) event.

120. This analysis is in line with my expectations from a mechanical engineering perspective (ONR SAP ECS.5).

Fault condition (spurious actuation)

121. The squib valve safety case (Ref. 10) also argues that the system designs in which the squib valves are located are such that interactions with other SSCs are minimised and that these SSCs are seismically qualified to appropriate levels. Ref. 10 also provides evidence to support this argument. This, I judge, to be in line with my expectations from a mechanical engineering perspective (ONR SAP ELO.1) in minimising adverse interactions.

122. The Westinghouse assessment of spurious actuation at full system pressure (Ref. 21) identifies that:

- RCS pipe deformation does occur but that this does not significantly impact the venting performance (ADS Stage 4 squib valves);
- due to uncertainty in movement post spurious actuation it is reasonable to assume the second ADS Stage 4 valve is inoperable eg cables are torn from the valve;
- SSCs credited with safe control of plant post actuation are not impacted by jet impingement due to ADS Stage 4 spurious actuation;
- the core makeup tank supply line B (CMT-B) is assumed to fail (conservative assumption) due to the ADS Stage 4 spurious actuation; and
- The IRWST check valves (located in line with the squib valves) are assumed to seize closed, following an assessment by the manufacturer, preventing opening of the valves when the RCS pressure later drops in an accident progression.

123. Westinghouse has provided appropriate arguments and evidence in Ref. 21 to support its claim that spurious actuation of a single squib valve, or a combination of

two valves, does not impact the plant's ability to safely shut down post spurious actuation.

Categorisation and classification

124. The valve data sheets (Ref. 28) identify that:

- the valves are Class 1 and seismic category 1; and
- the cable connections are seismic category 1 (PMS) and 2 (DAS) – diverse means of initiation.

125. Westinghouse also claims that the valve supports are seismically qualified and designed to withstand the forces and motion generated during actuation. As the PCSR identifies in Chapter 5, the interfacing components with Class 1 systems shall be equally classified. Westinghouse has provided further evidence of this requirement within piping support specification Ref. 29 and drawing Ref. 30.

126. This is in line with my expectations concerning classification of SSCs (ONR SAP ECS.2) in that the valve forms a principal means of fulfilling the Category A safety function of maintaining containment and so do the connecting pipework, supports and cable connections.

Judgement

127. For the GDA design basis, I consider that Westinghouse has provided appropriate arguments and evidence to demonstrate that the interfacing SSC designs can achieve the safety case requirements and assumptions.

128. Westinghouse claims that spurious actuation at full system pressure is a BDB event. Via an expert panel assessment, it demonstrates that the consequences of spurious actuation are bounded by other loss of coolant incidents considered within the design basis. Westinghouse identifies that supports and cabling may be impacted by this event, but argues that the plant can be brought to a safe shutdown state despite this. I judge that for the purposes of GDA, the arguments and evidence are adequate.

129. For site licensing, I expect that the future licensee shall continue to assess the interfaces between the squib valves and other SSCs along with the consequences of spurious actuation as the design develops. I consider this to be **normal business**.

130. On the basis of the above, I judge that GDA Issue GI-AP1000-ME-01 Action 3 is closed.

4.2.4 GI-AP1000-ME-01 Action 4

131. Action 4 of the GDA issue was for Westinghouse to:

*"Generate and issue appropriate approved documentation to demonstrate the surveillance and EIMT regime is able to achieve the safety case requirements and assumptions. Given the 60 year design life of the **AP1000** plant, and the inability to stroke the squib valves during in-service inspections, ONR considers that Westinghouse needs to specify a robust surveillance regime to ensure that the squib valve designs are capable of delivering their safety functions in accordance with the requirements of the safety case.*

"ONR's expectation is for Westinghouse to finalise their designs and provide the formal approved design justification, which is to include an adequate

*surveillance and EIMT regime specification that is commensurate to the **AP1000** NPP safety case and the safety role of each squib valve type."*

132. The EIMT regime (which includes surveillance) can be split into a number of aspects:

a) EIMT regarding the mechanical valve and its internal components.

b) EIMT regarding the pyrotechnic actuator and its components.

c) EIMT regarding the connected C&I systems (PMS and DAS).

d) Accessibility to the valves in order to carry out EIMT and the identification, assessment and demonstration that risks are ALARP.

e) Adequate system design to allow risk reduction related to removal and EIMT on the valves to be ALARP.

f) Identification and details of any remaining risk within the GDA design concerning EIMT that a licensee can reasonably be expected to consider in Phase 2 (site licensing and construction).

133. I have addressed specific EIMT of the pyrotechnic actuator and its components in Action 7 (Section 4.2.7) of my assessment report. I have, though, included assessment of the accessibility of the valves for actuator removal in this section.

134. EIMT regarding the connected C&I systems is outside the scope of this mechanical engineering GDA issue. I have, however, assessed the adequacy of design and analysis of the cable connectors which are the C&I interface with the actuator. My assessment of these is in Section 4.2.3.

Assessment

135. This action was one that I assessed in more depth due to the importance placed on maintenance of these valves in the PCSR. Chapter 10 of the PCSR (Ref. 9) identifies that common cause failure (CCF) of the squib valves is a significant contributor to the core damage frequency (CDF), so maintaining the reliability of these valves is important. Adequate identification of failure mechanisms, EQ, acceptance testing and EIMT are important to providing assurance.

136. My assessment has targeted Westinghouse's arguments and evidence within the squib valve safety case and squib valve summary report (Refs 10 and 11). In particular, I have assessed whether Westinghouse has:

- identified appropriate standards and RGP for EIMT (ONR SAPs ECS.3 and ECS.4) and demonstrated that operating experience (OpEx) from other projects is or will be used to inform EIMT (ONR SAP ECS.5);

- provided evidence that it has assessed the risk of CCF from EIMT activities and that it can be reduced SFAIRP (ONR SAP EDR.3);

- provided evidence that it has addressed EIMT requirements in line with ONR SAPs EMT.1, EMT.2, EMT.3, EMT.4 and EMT.6;

- provided evidence that it has considered access to the valves in line with guidance in ONR SAP ELO.1; and

- provided evidence that it has assessed human performance during EIMT and that planned EIMT can be performed in line with ONR SAPs EHF.3, EHF.5 and EHF.6.

Appropriate standards for EIMT of squib valves and use of OpEx

137. Concerning appropriate standards and RGP for EIMT on the squib valves, Westinghouse states that its EIMT regime is based upon two sources:

- ASME Boiler and Pressure Vessel Code (ASME BPV Code), Section XI; and
- ASME Operation and Maintenance of Nuclear Power Plants Code (ASME OM Code).

138. These two design codes are widely considered to be RGP, and are nuclear-specific design codes. However, their applicability to explosively actuated valves has less provenance.

139. The ASME BPV Code Section XI requirements are a generic set of requirements for all ASME Class 1 valves, with nothing specific to explosively actuated valves. The ASME OM Code was updated to include a number of specific requirements for explosively actuated valves.

140. While I judge that ASME requirements for standard valves within a nuclear facility are adequate for Class 1 valves, I have considered the new requirements (see below) in the ASME OM Code as part of my assessment.

141. Concerning the squib valves, the ASME OM Code[§] identifies that:

- the service life of any valve shall not exceed 10 years;
- the service life of each valve shall be reviewed at least every two years;
- at least once every two years, each valve shall undergo a visual examination of external and internal parts;
- this examination shall include verification of the initial operating position of the internal actuating mechanism;
- proper operation of remote position indicators shall be confirmed;
- at least once every two years one valve of each size (14 and 8 inch) shall be disassembled for internal examination of the valve and actuator; and
- all valves shall be disassembled for internal examination every 10 years.

142. In addition to the ASME requirements, Westinghouse identifies what it terms as “recommended” EIMT to be undertaken during planned inspections (Refs 10 and 11). This includes ultrasonic and liquid penetrant inspection, which I judge to be an appropriately conservative approach given the limited OpEx with such valves.

143. I expect the future licensee to sequence the valve EIMT to reduce risk SFAIRP – ie different valves within the same system are examined during outages whereby an assumption of equal condition may be made for the remaining valve(s) in that system. I expect this to occur as part of **normal business** for the licensee when considering its maintenance schedule.

144. Within its squib valve safety case (Ref. 10), Westinghouse has committed to developing EIMT arrangements with the licensee. This will include the incorporation of OpEx and learning from both the US and China projects, which I judge to be an

[§] *The ASME OM Code refers to squib valves as “explosively actuated” valves.*

appropriate measure and in line with guidance and expectations (ONR SAP MS.4). I believe that this too shall be part of **normal business** for the licensee and appropriately beyond the scope of GDA.

145. It is my opinion that Westinghouse's arguments and evidence are in line with regulatory guidance and expectations (ONR SAPs ECS.3, ECS.4 and ECS.5).

CCF within the mechanical valve design

146. CCF is where multiple, often identical, components fail due to the same cause. It is an important contributor to CDF within the PCSR (Ref. 9). Thus, assurance of the valve reliability is an important factor. This includes both the mechanical components and the pyrotechnic actuator.

147. Westinghouse's submission (Ref. 10) identified that:

- three out of four 14 inch ADS Stage 4 valves are required to actuate to adequately perform the safety functional requirements of depressurisation; and
- at least one of the PXS trains is open. This means that:
    - one out of four 8 inch IRWST valves is required to actuate; and
    - one out of four 8 inch CR valves is required to actuate to provide adequate passive safety injection.

148. ONR SAP EDR.3 identifies that CCF should be addressed explicitly where an SSC employs redundant or diverse components, measures or actions to provide high reliability.

149. Westinghouse claims its design has redundancy built into the systems – ie more than the number of valves required as a minimum – and within the valve designs themselves – ie more than one C&I system to actuate the valves and more than one method of actuating the valves. The level of redundancy is limited concerning the number of 14 inch valves; however, the addition of a third initiator within the actuator design has led to improvements in reliability. Additionally, Westinghouse claims a degree of diversity of the 8 inch valve designs, although I consider this is somewhat limited.

150. I consider that significant areas for the introduction of CCF during EIMT are:

- pre-service inspection and testing; and
- human performance during EIMT.

151. These two aspects are common in that not only might similar valves be undergoing EIMT during a planned outage, the same team(s) of maintenance engineers may be conducting EIMT on all valves sequentially.

(a) Pre-service inspection and testing

152. EIMT of the squib valves is proposed during planned outages of the **AP1000** plant. These are likely to be at either 18- or 24-month periods. At each outage, as required by the ASME OM code, at least one valve of each size will be removed for complete inspection. Each valve will also be inspected (visually). In addition, 20% of the actuators installed within the plant are to be removed and tested at each outage. Concerning the pre-service testing of the valves, continuity testing for the C&I

systems is undertaken as functional testing of the valves is not possible while installed. The actuator testing is discussed in Section 4.2.7.

153. Over a 10-year period, there is likely to be a maximum of six outages (assuming an 18-month operational period). This will align with two valves to be removed at each outage (there are 12 squib valves in the **AP1000** design). Due to there only being four 14 inch valves, at some stage, two 8 inch valves may be removed for inspection at the same time.

154. Westinghouse does not specify the valve removal arrangements. However, development of appropriate arrangements for EIMT will be activities undertaken by the licensee as **normal business** during Phase 2. The sequencing of valve removal will need to form part of its arrangements.

155. I consider this aspect should be addressed by the licensee regarding risk. Unnecessary removal of valves may have a consequence on their functional capability. As it does not undermine ONR's confidence in the safety of the generic design, impair ONR's ability to understand the risks associated with the generic design, require design modifications or require further substantiation to be undertaken, I shall raise this as a **minor shortfall** that ONR shall pursue during Phase 2.

Minor shortfall:
The licensee shall further consider the sequencing of squib valve removal, EIMT and replacement.

(b) Human performance

156. A significant aspect of CCF in EIMT is the analysis of human factors when generating instructions for operators to follow. Westinghouse, as part of GDA Issue GI-AP1000-HF-01, has assessed the tasks associated with maintenance of squib valves. The assessment and judgement of an ONR human factors specialist inspector is provided at the end of this section.

157. One other risk during maintenance, especially where multiple valves are operated on at the same time, is the mixing of similar components.

158. The squib valve designs incorporate measures to ensure that components of other squib valves cannot be mixed up and placed into the wrong valve. These are termed poka yoke features. I witnessed some of these features during a visit to the valve manufacturer's facility in September 2015 (Ref. 31).

159. The squib valve safety case (Ref. 10) identifies these features and provides, I judge, adequate arguments and evidence via drawings that these are sufficient to provide an engineered barrier against incorrect assembly of valves.

EIMT is in line with RGP and guidance

160. ONR guidance on EIMT is primarily found in ONR SAPs EMT.1 to EMT.8 (Ref. 3). For my assessment of Westinghouse's squib valve EIMT regime, I have concentrated on the guidance within EMT.1 to EMT.4 and EMT.6.

161. This covers:

- the identification of EIMT requirements;

- indication of the minimum frequency for such EIMT;
- the inclusion of type-testing within the design;
- the confirmation that EQ remains valid; and
- ensuring that the provision of EIMT is commensurate with the reliability claimed by the item.

162. Westinghouse's squib valve safety case (Ref. 10) substantiates that the EIMT regime is commensurate with that of a Class 1 component. It also substantiates that the valves will deliver their SFRs throughout their lifetime.

163. Prototype and developmental testing took place between 2006 and 2008. This enabled Westinghouse to develop the novel concept and prove it as a feasible solution to its functional requirements.

164. ONR SAPs paragraph 281 identifies that *"Novel approaches and features may be acceptable provided they are supported by appropriate research and development, are tested before coming into service to demonstrate the delivery of safety functions and are monitored during service."*

165. Westinghouse undertook a failure modes and effects analysis (FMEA), which ONR assessed during Step 4. Westinghouse has used this FMEA to inform its EIMT requirements. Westinghouse also identifies a number of *"critical valve components"* and *"critical dimensions"* within its squib valve safety case (Ref. 10) which has informed its inspection regime for the valves. Westinghouse's squib valve summary report (Ref. 11) discusses development of the EIMT regime for the squib valves and actuators.

166. The arguments and evidence to support Westinghouse's claim that *"EIMT requirements are defined and adequate for the squib valves, such that the Licensee can develop an adequate EIMT programme"* are identified in sub-claim 4.4.

167. Westinghouse's squib valve summary report presents arguments and evidence in regards to type-testing of the valves. This includes the ASME valve qualification testing carried out (ASME Qualification of Mechanical Equipment (QME-1)). Westinghouse has produced a qualification plan (Ref. 32) to support this testing and to ensure consistency of all future testing.

168. Of note, concerning the valve type-testing, the ASME QME-1 requirements cover all valves but do not specifically discuss explosively actuated valves. Westinghouse argues that the requirements for power-operated valves are appropriately robust for the mechanical elements of the valve. The actuators are tested to alternative standards (discussed in Section 4.2.6).

169. Westinghouse claims that the ASME-QME-1 testing requirements, when applied to the squib valves, are adequate. This is turn provides assurance that the safety case functional requirements will be adequately addressed by the squib valve design. After assessing the arguments and evidence, I consider that the test plan and discussion of the test results in Refs 10 and 11:

   a) demonstrate that the squib valve does not have any inherent design faults that could adversely affect its performance, life or reliability;

   b) have checked that the manufacturer's production processes, including testing, setting up and QA, are satisfactory;

c) establish the stability of the equipment when subjected to various influence factors such as vibration, radiation, temperature and humidity changes; and

d) provide evidence that it meets its specification and safety function.

170. I consider this to be in line with guidance within ONR SAP EMT.3.

171. The ASME BPV Code Section XI identifies the minimum requirements for Class 1 component maintenance and in-service inspection, together with a minimum periodicity. ASME OM Code identifies additional EIMT requirements for explosively actuated valves. These combined requirements form the basis of what Westinghouse argues to be an appropriate EIMT regime. Westinghouse uses nuclear codes and standards, part of which have been specifically developed for these components.

172. Westinghouse's development of its EIMT regime was aided by the revision to the ASME OM Code in 2012, which provided additional requirements, over and above those that Westinghouse was proposing. Input from manufacturers and regulators into the code update provides some confidence that the additional requirements resulted from operational experience and learning. I consider this to be in line with guidance within ONR SAPs ECS.3 and EMT.6 concerning the identification and application of appropriate standards for Class 1 equipment and their EIMT.

173. Table 4.4-1 in Ref. 10 provides squib valve specific recommendations for EIMT which are over and above the ASME requirements.

174. Westinghouse has also developed a maintenance manual for the squib valves which covers the mechanical valve and components (Ref. 33). It did this with the support of the valve and actuator manufacturers. The maintenance manual does not substantiate that the EIMT regime is appropriate. Nevertheless, it does provide evidence that Westinghouse has considered the scope and extent of maintenance. I recognise that the specific processes and procedures for carrying out EIMT will require a licensee's input and so expect these to be developed as part of **normal business** during Phase 2.

175. Based upon the submissions provided and Level 4 engagements with Westinghouse throughout GDA closure, I consider Westinghouse's justification that the EIMT regime for the mechanical valve is adequate to support the safety case requirements is in line with guidance provided within ONR SAP ECS.3 and EMT.1 to EMT.6.

Access to the valves is considered in line with regulatory guidance

176. I questioned Westinghouse on the ability of a licensee to remove and replace the squib valves from their locations to the areas proposed for maintenance operations.

177. The groups of 8 inch squib valves (2 x IRWST injection and 2 x CR valves) are in the same rooms within the **AP1000** plant. There are two rooms each containing four valves as above. The IRWST injection valves are directly above the CR valves.

178. I raised a concern, primarily over the complexity of the lifts involved in the removal of the lower CR valves. To remove a lower valve, the upper valves also have to be removed.

179. Recognising that, during EIMT, the systems in which the squib valves are located will be flushed and doses should be minimised thus reducing the hazard (radiation), the complexity of the lifts to remove the 8 inch valves introduces hazards which I did not judge to be ALARP. I therefore questioned the layout of the 8 inch valves. Westinghouse's assessment of this is contained within Argument 4.4.2 of Ref. 10.

180. Westinghouse claims that the relocation of valves would not be ALARP. This is based upon:

- the potential reduction in system performance;
- the amount of effort required to redesign and reanalyse systems; and
- the costs associated with this being disproportionate to the benefits gained.

181. A significant constraint is the design of the containment structures, which I consider to be acceptable. As a consequence of Westinghouse’s arguments concerning redesign, I requested Westinghouse to consider other options.

182. Westinghouse presented its assessment within two submissions (Refs 34 and 35). This provided an assessment of:

- the lifts required to remove the 8 inch and 14 inch squib valves;
- consideration of undertaking EIMT within the rooms;
- hazard reduction in regard to complex or significant lifts; and
- dose implications related to options for maintenance.

183. The outcome of Westinghouse’s assessment of options for EIMT is that:

- The original option for removing all valves to a dedicated maintenance area is still feasible, although this does involve a series of complicated lifts for the lower 8 inch valves and a complex lift through containment for the 14 inch valves.
- An option for conducting EIMT on one of the lower 8 inch valves within the valve room is considered feasible and will require the use of a maintenance cradle to set the valve during EIMT.
- An option for conducting EIMT on the 14 inch valves within the room in which it is located is also feasible. This too will require the use of maintenance cradles.
- Conventional safety risks have been assessed as part of the human factors assessment of EIMT for the valves (this is assessed in GDA closure report for GI-AP1000-HF-01).
- Indicative dose assessments have identified that temporary shielding can be introduced, where EIMT is conducted, within the valve rooms to reduce doses to operators.

184. I consider that this provides the licensee with additional options to consider during Phase 2 (licensing), rather than a single location for maintenance.

185. The identification of further ALARP options for squib valve maintenance will not alter the GDA design, nor does this impact on my ability to understand the risk. I consider it reasonable to allow the decision on exactly where EIMT is conducted based upon licensee choices, to detailed design and licensing.

186. Further information regarding doses to operators and choices of lifting equipment for valve removal is a factor that I judge appropriate for a licensee to consider.

187. Westinghouse has recommended, during licensing of the **AP1000** reactor**,** further development of the EIMT regime. This is to ensure that the process of maintaining the squib valves is such that both the complexity of valve removal and the dose to operators are reduced SFAIRP. Therefore, as this matter depends on licensee design choices and operator-specific choices, I have identified the following **Assessment Finding**:

Assessment Finding CP-AF-AP1000-ME-01

The licensee shall develop and implement an examination, inspection, maintenance and testing regime for squib valves using the options presented in the squib valve safety case (UKP-GW-GL-200) and considering site-specific aspects.

188. Closure of the **Assessment Finding** above should include, but not be limited to, consideration of the following:

- the dose implications of undertaking EIMT in each of the proposed locations;
- the complexity of lift involved and the potential for adverse interactions with other SSCs;
- dropped load assessment; and
- conventional health and safety risks.

189. Another important aspect to consider here is the EIMT requirements for the actuators. I assess this in Section 4.2.7.

Human factors during EIMT have been considered

190. Westinghouse has also undertaken a review of the human performance-related risks concerning EIMT of squib valves and actuators (Ref. 36). This is discussed in the squib valve safety case (Ref. 10) Argument 4.4.2.

191. I have discussed the human factors assessment of squib valve EIMT activities with a human factors specialist inspector, who has assessed this during the resolution of GDA Issue GI-AP1000-HF-01. I have presented below a summary of the human factors assessment and judgements. More information can be found in Ref. 38.

192. Following the optioneering study, Westinghouse modified the task-design to minimise lifting. The alternative method simply requires the valve to be moved axially to separate it from the associated connection. It is then lowered onto a maintenance cradle. The reduction and simplification of valve movement significantly reduce the risk of damaging neighbouring safety-critical SSCs.

193. The human error analysis provides convincing evidence that Westinghouse has recognised the risk of Type A[**] errors contributing to the latent, or unrevealed, failure of the valve. I consider that the analysis substantiates the associated human-based safety claim. It provides evidence that sub-tasks are credible, and contains sufficient detail on the sub-task failure modes and where recovery opportunities exist. The analysis also identifies the most important performance-shaping factors and makes sensible recommendations to further reduce risk SFAIRP.

[**] *Type A errors are defined as "pre-imitators", maintenance errors or sometimes "latent errors", as they only surface when the item fails on demand, some time after the error is made. These are also referred to as "unrevealed" failures.*

Judgement

194. I judge that Westinghouse has provided adequate arguments and evidence to justify the EIMT regime proposed in its squib valve safety case (Ref. 10), squib valve summary report (Ref. 11) and supporting documentation.

195. Westinghouse has provided an adequate level of evidence of the following:

- The adequate identification of appropriate EIMT.
- Valves are accessible in order to conduct EIMT, or risks related to the removal of valves are identified and mitigated where possible.
- Options are available to the licensee for EIMT location.
- Westinghouse identifies areas of risk that remain within the design, that are reasonable for a licensee to consider further in Phase 2.

196. I noted one Assessment Finding on the adequacy of EIMT arrangements to ensure risks are reduced SFAIRP. I judge it appropriate to allow this to be undertaken during site licensing and construction.

197. Therefore, I judge that GDA Issue GI-AP1000-ME-01 Action 4 is closed.

4.2.5 GI-AP1000-ME-01 Action 5

198. Action 5 of the GDA issue was for Westinghouse to:

"Address the listed points, which have been identified as gaps in the safety justification of the squib valve designs as a result of undertaking the GDA from a Mechanical Engineering perspective:

- *"Westinghouse shall demonstrate the FMEA for the final squib valve designs includes an independent technical reviewer.*
- *"Westinghouse shall generate and issue an ALARP justification that each squib valve type as proposed is adequate to achieve its safety functional requirements and its design intent, in terms of position indication during normal operation.*
- *"Westinghouse shall generate and issue an ALARP statement on how the bracket design achieves the design intent of a guard.*
- *"Westinghouse shall generate and issue an ALARP statement on how the 14 inch ADS squib valve design achieves its design intent without the requirement of a cover.*
- *"Westinghouse shall provide confirmatory evidence of the described poka yoke features within the 8 inch valve detailed drawings.*
- *"Westinghouse shall provide evidence that adequate arrangements are in place to control and manage the supply of the squib valves, and tolerances for the technical parameters of critical components.*
- *"Westinghouse shall provide evidence that the squib valve Equipment Qualification tests adequately demonstrate that each squib valve type is able to achieve its design intent."*

199. Justification for the closure of this action is presented within the safety case document (Ref. 10).

200. My assessment of Westinghouse's closure of this issue has assessed the arguments and evidence provided, against the ONR SAPs guidance.

Assessment

Independent review of the FMEA

201. Westinghouse provided a response to this item within Ref. 37 stating that:

"This response provides the evidence that the FMEA [Failure Modes and Effects Analysis] *was reviewed by <u>independent</u> technical reviewers as part of the Westinghouse design review process per Westinghouse Level II Procedure."*

202. I have assessed the evidence using guidance within ONR SAP SC.1 paragraph 93. This identifies that independence includes people who are independent of those involved in a document's production (in the SAPs case, this refers to a safety case).

203. Westinghouse submitted Ref. 37 providing extracts from its procedure for design reviews, and lists of attendees to the reviews. These include those used to generate the FMEA report (Ref. 39).

204. I have discussed the list of attendees with Westinghouse and it has confirmed that an independent review in line with ONR guidance has been conducted. Where significant revisions have been made to the report, Westinghouse states it has followed its own procedure for verification of the report, which includes an independent review. I consider this to be appropriate.

ALARP justification for [piston] position indication during normal operation

205. The ONR Step 4 report raised this in the GDA issue as a result of ONR concern that the operator had no means of determining whether or not the squib valves were available to operate on demand. ONR judged that an ALARP justification for not having position indication for the squib valve piston was required.

206. Safety significant valves often possess a means to indicate their position (open or closed) which is often linked to the stem position. In the case of squib valves, there is no valve stem that rotates to open or close the valve.

207. Westinghouse claims that adequate provisions are in place to provide confidence in the valve's ability to open when a demand signal is placed upon it. It also claims that when the valve fulfils its safety function during fault conditions, there is adequate indication of this for the operator.

208. Westinghouse presents its justification within an ALARP assessment in the squib valve safety case (Ref. 10).

209. Westinghouse has assessed RGP, undertaken optioneering and assessed risks for options considered in line with my expectations from NS-TAST-GD-005 (see Ref. 4). It concludes that:

- adding additional position indication to the piston would complicate the design and require significant retesting and qualification of components; and
- this only provides a means of monitoring the piston and does not **improve** the valve's ability to perform its safety function.

210. The assessment also considers conditions that may cause the piston to inadvertently change position. These are identified as:

- during EIMT operations; and
- following a seismic event, where the tension bolt may fail.

211. The ASME OM Code requires that the position of the valve internal actuating mechanism for all valves is verified every two years. Westinghouse anticipates this will occur during each outage. The ALARP assessment provides information on how the position of each piston can be verified by inspection.

212. Additional requirements, within the valve design specification (Ref. 17), are that:

- the tension bolt design undergoes prototype, lot and EQ testing; and
- a lock wire or locking technique is used such that the tension bolt remains in place.

213. I consider that these requirements provide additional confidence that the design is adequate and that the tension bolt remains in position.

214. The ALARP assessment concludes that the most likely cause of piston movement is a seismic event. Given the location of the squib valves within containment and the fact that the risk of the piston being in the wrong position is largely due to human error during assembly, inspection or maintenance, I consider this to be reasonable.

215. I expect a licensee to ensure that it has robust procedural requirements in place to confirm the piston position. I expect this to be undertaken as part of **normal business** when developing its EIMT arrangements.

216. Nevertheless, Westinghouse recommended improvements to the existing arrangements. The expert panel that Westinghouse convened to assess the design concluded that an additional inspection following a safe shutdown earthquake shall be undertaken to verify the integrity of the valve and components. I consider this to be in line with guidance within ONR SAP EMT.8.

217. In addition to Westinghouse’s submissions, I have also considered ONR SAP ESS.13 (safety systems) which identifies that *“there should be a direct means of confirming to operating personnel that the safety systems have operated (actuated) fully and correctly”*. I conclude that Westinghouse has demonstrated that it meets this guidance within the SAPs.

ALARP justification for bracket design achieving intent of a guard

218. Westinghouse presents its arguments and evidence to justify the bracket design for the 14 inch valve as this is larger and protrudes further causing Westinghouse to judge it as at more risk of accidental damage (personnel, ladders etc).

219. At GDA Step 4, this bracket supported the cabling that connects to the ‘valve open’ position indicator underneath the 14 inch valve. The bracket also served as a protective measure against inadvertent damage to the position indicator.

220. Subsequent to ONR’s Step 4 assessment (Ref. 14), Westinghouse states that the bracket design has been modified and explains that conduit cracking during ASME QME-1 testing revealed that the cause was the bracket clamp holding the cable in place. The component, referred to by Westinghouse as the bracket / guard assembly, now only acts only as a guard to mitigate the risk of inadvertent damage to the position indicator.

221. Westinghouse provides a number of diagrams within the squib valve summary report (Ref. 11) which give evidence as to the nature of the guard. It also provides evidence that the guard was qualified during ASME QME-1 testing.

222. Westinghouse's ALARP argument provides a brief review of RGP, identifies risks that have been subjected to an expert panel review by Westinghouse, and discusses other options for protecting the position indicator.

223. Westinghouse concludes that the current design:

- locates the position indication switch in the most appropriate position;
- is positioned so that the risk from damage by personnel is reduced SFAIRP;
- provides the added benefit of standardisation where OpEx and learning can be used from other **AP1000** plants;
- is equipment qualification (EQ) tested and demonstrates that the design meets the safety case requirements; and
- provides two open sides allowing access by personnel to perform EIMT without having to remove it, and aids in the convective cooling of the switch.

224. I consider that Westinghouse provides reasonable arguments and appropriate evidence of the current design, which are in line with my expectations based upon guidance within NS-TAST-GD-005 (see Ref. 4).

ALARP justification for 14 inch valve without requirement for a cover

225. The Westinghouse FMEA report (Ref. 39) identifies that foreign material inside the opening, and forming underneath the area where the shear cap would fall after opening, could cause a restriction of flow and reduce the venting capability. This capability is an important part of ensuring the depressurisation of the RCS system during fault conditions. During GDA closure, I have discussed with Westinghouse the use of a cover to protect the 14 inch valve opening against foreign material gathering inside.

226. In GDA Step 4, Westinghouse had not considered the use of a cover to protect the valve.

227. I discussed with Westinghouse the use of a cover during operation and EIMT. Westinghouse agreed to undertake an optioneering study to review options in a more structured manner and to identify risk concerning those options. Westinghouse presents this review in an Appendix to the squib valve safety case (Ref. 10).

228. The assessment considered four options. Westinghouse presents, for each case, a discussion of the risks associated with each option, and a general discussion of RGP concerning foreign material exclusion (FME).

229. I consider that this ALARP assessment is in line with guidance and expectations ie NS-GD-TAST-005.

230. Westinghouse concludes that the use of a temporary FME cover provides the most benefit to plant safety. It also states that because of this, it has recommended a change to the EIMT programme that inspections of the 14 inch outlet will verify that the covers were removed and that the outlet of the valve is clear of foreign material.

231. I judge this to be a reasonable conclusion from the ALARP assessment.

Confirmatory evidence of poka yoke features

232. The purpose of poka yoke or 'mistake proof' features is to mitigate the risk of incorrect assembly of the squib valves (human error). Within the squib valve safety case, Westinghouse provides evidence in regard to the poka yoke features on the 8 inch and 14 inch squib valves.

233. These features include:

- tension bolt threads
- bonnet threads and mating rings
- body mating rings
- actuator dimensions
- shear cap bolt hole diameters
- flow arrows on the body of each valve

234. During a Level 4 engagement with Westinghouse in the US during September 2015, I visited the squib valve manufacturer's facility where I saw the features on the 8 inch squib valves (Ref. 31).

235. My assessment concludes that Westinghouse has provided adequate evidence of the poka yoke features on the squib valves.

Arrangements for control of supply of squib valves and technical parameters

236. The ONR Step 4 assessment (Ref. 14) identified that to manage and control the variables of the critical components; a number of arrangements need to be implemented during the procurement and manufacturing phase.

237. Westinghouse has now undertaken procurement of squib valves for its US and China projects. Westinghouse's squib valve safety case presents arguments and reference to evidence within Arguments 4.2.2 and 4.2.3.

238. I have previously assessed the adequacy of the design process and discussed the ASME NQA arrangements for quality control. I have found these to be in line with regulatory expectations and guidance concerning design assurance in NS-TAST-GD-057 (see Ref. 4). To control the supply of squib valves, Westinghouse uses a single supplier for the valves. This supplier has arrangements in place with a sub-supplier for the actuators.

239. The minimum critical characteristics are identified within the squib valve and actuator design specifications (Refs 17 and 18) recorded within the quality data package. These include, but are not limited to:

- valve end to end dimensions
- dimensions required for disassembly
- critical gasket/seal interface dimensions
- tension bolt critical dimensions
- shear cap critical dimensions

- cartridge interface critical dimensions
- initiator critical dimensions / characteristics
- cartridge critical dimensions / characteristics

240. Once confirmed, these characteristics are recorded within the quality data package for each valve and supplied to the purchaser (licensee).

241. Westinghouse also identifies that destructive testing as part of factory acceptance testing (FAT) is carried out, along with LAT of the tension bolts and shear caps.

242. Westinghouse states within Argument 4.2.2 (Ref. 10) that as part of its QA arrangements with the squib valve suppliers, it undertakes vendor oversight during design and manufacture. During my visit in September 2015, I met with the Westinghouse representative responsible for oversight of the valve supplier organisation.

243. I have sampled the design specifications for the squib valve and actuator (Refs 17 and 18). I consider the requirements to be in line with my expectations and those in the Step 4 report (Ref. 14).

EQ tests demonstrate squib valves achieve design intent

244. Guidance on this aspect in ONR SAPs is contained in EQU.1, which states:

“Qualification procedures should be applied to confirm that structures, systems and components will perform their allocated safety function(s) in all normal operational, fault and accident conditions identified in the safety case and for the duration of their operational lives.”

245. Paragraphs 174 to 176 provide supporting guidance:

“174. The qualification procedures should provide a level of confidence commensurate with the safety classification of the structure, system or component.

“175. The qualification procedures should address all relevant operational, environmental, fault and accident conditions (including severe accidents).

“176. The procedures should include a physical demonstration that individual items can perform their safety function(s) under the conditions, and within the time, substantiated in the facility’s safety case.”

246. Westinghouse document APP-PV70-VPH-001 (Ref. 32) presents the squib valve actuator and valve test plan. I have used this in my assessment of Westinghouse’s demonstration.

247. Westinghouse has tested each of the three squib valve designs. The valves were manufactured in accordance with the squib valve design specification (Ref. 17).

248. Each valve underwent the same sequence of testing. The tests built up consecutively on the same valve and components, completion of which was a functional test of the valve to provide evidence that it will meet its SFR to open on demand. The results of the EQ tests are presented within the equipment qualification summary report (EQSR) for each valve. In my assessment, I sampled the EQSR for the 14 inch squib valve (Ref. 40).

249. The EQ test plan and procedures have followed the requirements of ASME QME-1 and, where applicable, IEEE Std 382-1996 (Ref. 41) for seismic qualification. I consider these to be appropriate standards for Class 1 SSCs, in line with guidance in ONR SAP ECS.3.

250. The ASME QME-1 functional testing concentrates on the squib valve assembly. This test covers the following aspects:

- sealing capability
- valve fundamental frequency
- functional operation
- flow characteristics during a Design Basis Accident (DBA)

251. The EQSR (Ref. 40) identifies the environmental and operational conditions during normal, abnormal and fault conditions. The squib valves are required by the safety case to actuate during fault conditions.

252. Under normal conditions, the valves are required to maintain the pressure boundary. During a Direct Vessel Injection (DVI) line LOCA, the 8 inch squib valves are assumed to be submerged before actuation. The submergence test demonstrates operation of the valves under these conditions. The 8 inch valves are qualified to actuate following submergence for 72 hours. Westinghouse claims that the 14 inch valves are not at risk of submergence. Only the 14 inch position indicator is qualified to operate following submergence.

253. I conclude that the EQ results demonstrate that the squib valves meet their design intent.

Judgement

254. In considering Action 5 of the GDA issue, I have used ONR TAGs NS-TAST-GD-005 and 057. These provide guidance on assessment of ALARP justifications and design for safety. In summary, I judge that Westinghouse has:

- demonstrated the independence of attendees at reviews and verification of the FMEA document;
- provided an adequate ALARP justification for position indication and that indication of an actuated valve is suitable;
- presented an adequate ALARP justification for the position indicator bracket design achieving its design intent of a guard, protecting the position indicator from inadvertent damage;
- presented an adequate ALARP justification for the addition of a temporary FME cover for the 14 inch squib valve. This will provide engineered protection of the valve opening during operations involving access to the rooms in which the valves are located;
- provided adequate evidence of the poka yoke features on the squib valves;
- provided adequate evidence to support its arguments that critical characteristics are adequately verified during fabrication and assembly and that it employs adequate procedures to control the supply of those components; and

- demonstrated through EQ tests that squib valves meet their design intent. Note that this judgement is made on the qualification of the mechanical valve and components only. The actuator design substantiation is assessed in Sections 4.2.6 and 4.2.7.

255. Therefore, I judge that GDA Issue GI-AP1000-ME-01 Action 5 is closed.

4.2.6 GI-AP1000-ME-01 Action 6

256. Action 6[††] of the GDA issue was for Westinghouse to:

1. *issue document APP-PV70-GER-001.*
2. *generate and issue arguments and evidence to:*
    a. *justify the different rationales adopted to select the pyrotechnic substances for the initiator and booster;*
    b. *justify why good practice from aerospace is relevant within nuclear plants;*
    c. *justify the choice regarding the binder; notably, a comprehensive and well-argued analysis and supporting evidence requires to be provided;*
    d. *provide results of radiation exposure of the propellants, and the demonstration that reference environments used in the past are sufficiently similar to the environment expected within **AP1000** reactors; and*
    e. *justify the relevance of the Summary Report, Appendix C in substantiating the pyrotechnics aspects.*
3. *generate an argument that demonstrates that:*
    a. *test data from carrying out initiator tests by others provides suitable reliability evidence for use with the **AP1000** design given the variance in the **AP1000** initiator design and the use of a binder; and*
    b. *sufficient and relevant test evidence exists for the **AP1000** booster design to support its reliability claim.*
4. *clarify the relevance and purpose of Development Report 17399(01)DR to the ballistic analysis.*
5. *provide:*
    a. *a review of the advantages and disadvantages of each considered initiator concept;*
    b. *an explanation of the selection criterion for the initiator ignition concept; and*
    c. *the analysis to support the selection of each considered initiator concept.*

[††] The original Action 6 was not written in an alpha-numerical list; for ease of reference I have introduced it in my report.

6. *generate and issue justification that:*

    a. *cartridges will not be liable to react to any electromagnetic environments, with adequate consideration to resonant harmonics that they will be exposed to throughout their life cycle; and*

    b. *EIMT requirements for EMI protection is suitable and adequate.*

7. *generate and issue justification that all the relevant UK requirements for the design of cartridges and termination units have been adequately covered by the implementation of US standards and guidance.*

8. *generate and issue the following documentation:*

    a. *Finalised requirements regarding the propellant neutron testing, by justifying the energy, the intensity, and the duration of exposure.*

    b. *Qualification results, which includes the substantiation that actuators as proposed are adequate to achieve their safety functional requirements and their design intent.*

9. *provide the justification that C&I faults do not impact the properties of the initiator bridgewire.*

10. *generate and issue a further analysis to confirm that, in case of a fire in adjacent containment fire zones, the present design of cartridge peak temperature is maintained below the propellant auto-ignition temperature with an adequate margin – may be within evidence document or squib valve summary report (SVSR).*

11. *generate and issue comprehensive justification that:*

    a. *the safeguards that are provided within the termination units and cabinet interface modules (CIMs) are sufficient to reduce the spurious actuation probability at a level coherent with other potential sources of LOCA; and*

    b. *the absence of SADs within the pyrotechnic chain achieves the correct balance between the two competing demands of preventing spurious actuation of the squib valves, and yet ensuring they have a high reliability of actuation on demand to support the passive core cooling function.*

12. *provide, in respect of the electrical current values:*

    a. *a review of the advantages and disadvantages of each considered value;*

    b. *an explanation of the selection criterion for the electrical current value; and*

    c. *the analysis to support the selection of each considered option.*

13. *generate and issue the justification that each squib valve termination unit type and terminal block is designed adequately to achieve its safety functional requirements and its design intent. This justification shall include the:*

a. *comprehensive list of safety and functional requirements, including surveillance monitoring requirements;*

b. *detailed description of design solutions;*

c. *qualification programme and its results; and*

d. *description of EIMT provisions required to maintain safety functions.*

257. This action is related purely to the actuator (initiator and propellant charge) and the interface with the C&I systems that are part of the firing circuit.

258. The squib valve safety case submission (Ref. 10) together with the squib valve summary report (Ref. 11) provide claims, arguments and evidence relating to the majority of Action 6. The closure of some portions of the action is heavily reliant on assessments carried out by the C&I and PSA specialists, which are recorded in the relevant assessment reports.

259. I have addressed each action in turn within my assessment, and where the action is very specific I have limited my assessment to the closure of the action. More general actions – for example, areas where design changes have occurred since the GDA Step 4 report was completed – include:

- EQ – evidence supplied relating to reliability or safety;
- EIMT of the actuator and associated cabling; and
- a balance of risk argument relating to safe arm devices (SADs).

<u>Assessment</u>

Action 6-1: Provision of document APP-PV70-GER-001

260. The provision of the document APP-PV70-GER-001 (Ref. 42) was raised as an issue in Step 4. This was because the argument that the concept of using a linear-shaped charge had been reviewed and dismissed, for which the document was the main evidence.

261. Westinghouse issued and provided the document to ONR, and I assessed it as part of my review of the summary report (in which it is referenced). I raised a number of queries. Westinghouse supplied additional information and clarified a number of points.

262. I am content that the provision of the document and subsequent response met my expectations for closure of Action 6-1. I have considered ONR SAP SC.1 (Ref. 3) relating to safety case production in reaching this conclusion.

Action 6-2.a: Arguments and evidence to justify the different rationales adopted to select the pyrotechnic substances for the initiator and booster

263. This action was raised due to the rationale used to determine the choice of materials within the initiator and propellant charge, using different weightings for similar aspects. I discussed this approach to the design and historical optioneering with Westinghouse and its suppliers during an engagement in September 2015 (Ref. 43).

264. Westinghouse stated that the rationales used for selection of the pyrotechnic materials were in fact similarly weighted. The weighting had only been used as a selection tool and not as a justification of their suitability. Westinghouse provided

additional evidence to back up the choice of pyrotechnic materials within a development report (Ref. 44).

265. I am content that the arguments and evidence provided within the safety case and summary report meet the expectations for closure of Action 6-2.a. I have considered ONR SAP SC.1 relating to safety case production in reaching this conclusion.

Action 6-2.b: Arguments and evidence to demonstrate why good practice from aerospace is relevant within nuclear plants

266. The Step 4 report (Ref. 14) accepts that transposing good practice from the aerospace domain to the nuclear industry might be considered relevant. However, it notes that the environments within each industry differ significantly. I therefore considered this aspect of the issue to relate directly to the application of aerospace good practice within the nuclear industry, for example ensuring relevant test levels are selected.

267. The squib valve safety case (Ref. 10) references document DCP_DCP_007904 (Ref. 45) which specifically addresses the relevance of the standard, MIL-HDBK-83578 (Ref. 46), used to inform the design of the actuator. I assessed the document and consider that it addressed the intent of this aspect of the issue. The document addresses each section of the standard in turn. It provides justification as to whether they are applicable, plus references, as well as explanations when they are not applicable.

268. I noted the following key points during my assessment:

- Sections of the aerospace standard are only applicable to pyrotechnics of specific types and as such are justified as not applicable in this case.

- Sections of the aerospace standard are applicable to the C&I system directly and were justified as not applicable to the pyrotechnic systems. This aspect of the design is out of scope of my report, and the C&I interfacing systems are assessed separately.

- The document does not address aspects of the aerospace standard relating to the SAD, but in a separate SAD write-up document, which is now included within the squib valve safety case (Ref. 10) as Appendix A5. I have assessed this aspect of the design in detail under Action 6-11.b below.

- Where the aerospace standard refers to parts of the design where nuclear codes and standards do exist, such as the valve body, they are identified and refer to the relevant specifications.

- The test methods within the standard are, in some cases, replaced by nuclear-specific, ASME QME-1 tests with the associated quantities.

269. Where the document (Ref. 45) states that the aerospace standard does constitute RGP it references the appropriate section of the pyrotechnic actuator design specification (Ref. 18). The design specification provides the detail as to how the standard has been applied to the actuator design and qualification.

270. In the cases where the test methods have been replaced by nuclear-specific test methods, there may be discrepancies in the number of test items and methods used. This is due to the fact that nuclear methodology is based on mechanical and not pyrotechnic components. The aerospace standards tend to include a requirement for a higher number of test items or additional qualification evidence. I have assessed the specifics of the environmental qualification under Actions 6-3.b and 6-8.b.

271. I am content that Westinghouse has adequately demonstrated that the use of aerospace is appropriate and relevant. I have addressed the application of the standards with respect to SADs, as well as the use of standards within qualification, in later sections of this assessment.

272. I am content that Westinghouse has provided suitable arguments and evidence to meet the specific expectation that aerospace standards are relevant to nuclear plants as intended by Action 6-2.b.

273. I have considered ONR SAPs ECS.3, ECS.4 and ECS.5, which relate to codes and standards, within this assessment. I have specifically addressed the aspects relating to the combining of different codes and standards and absence of directly relevant established codes and standards.

Action 6-2.c: Arguments and evidence to justify the choice regarding the binder

274. The lack of a binder within the initiator pyrotechnic material was raised within the Step 4 GDA assessment (Ref. 14) due to lack of information relating to the choice. Westinghouse identified that although the historical basis of the initiator chosen included the use of a binder, the **AP1000** design had consciously decided not to use one from the start.

275. I assessed the squib valve safety case (Ref. 10, Argument 4.1.2), which provides an argument as to the history and reasoning behind the non-use of a binder. The argument is supported by a more recently produced position paper (Ref. 10, Appendix B), which reviews the general approach to the use of binders and the possible safety concerns of using them within a radiation environment.

276. The squib valve safety case also notes that safety / reliability of the initiator material has been demonstrated within the qualification process. I identified that a previous aerospace industry assessment (Ref. 47) of the removal of the binder from this type of initiator suggested that it may affect the ageing profile of the explosives. I have assessed the qualification results under Actions 6-3.b and 6-8.b below.

277. I am content that Westinghouse has provided suitable arguments and evidence to justify the choice regarding the binder as expected within Action 6-2.c.

278. I have considered ONR SAP SC.1 relating to safety case production in reaching this conclusion.

Action 6-2.d: Provision of results of radiation exposure of the propellants

279. The squib valve safety case (Ref. 10, Argument 3.2.1) identifies the testing carried out on the pyrotechnic components including the derivation of test criteria and levels. With respect to the radiation exposure levels, the safety case references document DCP_DCP_007869 (Ref. 48), which contains an analysis of the test level derivation and qualification levels achieved.

280. I assessed DCP_DCP_007869 from a mechanical perspective, concentrating on the test levels derived and those achieved during qualification. I noted the following important aspects of the document:

- The radiation dose was determined for each of the rooms in which squib valves are located.
- The most conservative case was taken as the baseline for all valves.

- The neutron radiation flux was determined as a function of energy for all locations and a bounding conservative case was taken for each energy level.
- Additional levels were calculated under DBA conditions.
- It was recognised that, due to the shielding imparted by the valve body, direct beta radiation was unlikely to impact the pyrotechnic components. Westinghouse carried out an assessment converting the beta dose into a resultant gamma dose for test purposes.
- An additional 10% margin was added to the values derived to take into account test variability.

281. The ONR radiation protection inspector reviewed the documentation relating to the approach to beta / gamma equivalence and neutron dose above. He advised me that he was content that the methodology was suitable and sufficient (Ref. 49).

282. I assessed the EQSRs for both the 8 inch (Ref. 20) and 14 inch (Ref. 40) valves. These contain the specifics of what was tested and the results of the testing. The summary reports stated that the same radiation test criteria were applied for all actuators. It stated that the levels of radiation testing carried out were for a 60-year exposure (intended valve design life) plus 72 hr accident condition, with respect to gamma radiation, and an eight-year exposure (intended actuator operational service life) with respect to neutron radiation. This meets the defined life of the actuators which is 12 years, consisting of four years' storage (no neutron exposure) and eight years' operational service.

283. The EQSRs identified that although the total neutron dose exceeded the test requirement, there was a small underdose in some cases. Ref. 48 addresses this and provides an argument that the underdose is acceptable, taking into account that the total dose exceeded the required level.

284. I have assessed the qualification programme as a whole within Actions 6-3.b and 6-8.b.

285. I am content that the approach taken to testing and the provision of the results meets the expectations of Action 6-2.d. I have considered ONR SAP EQU.1, relating to EQ, in reaching this conclusion.

Action 6-2.e: Arguments to the relevance of the summary report, Appendix C in substantiating the pyrotechnic aspects

286. The Step 4 GDA assessment raised this issue as the intention and benefit of the evidence supplied within Appendix C were unclear. The assessment asked that the appendix either be updated to provide additional evidence or identified clearly as not being used to substantiate the pyrotechnic aspects.

287. The squib valve summary report (Ref. 11) has been updated to identify that the information within Appendix C *"provides some examples of where squib valves have been utilized"* and has only been referenced within Section 3 of the report as supplementary information.

288. I am content that this update, which identifies that Appendix C is supplementary information only and not used as evidence in the safety case, meets the aim of Action 6-2.e.

289. I have considered ONR SAP SC.1 relating to safety case production in reaching this conclusion.

Action 6-3.a: Demonstration that test data from carrying out initiator tests by others provides suitable reliability evidence for use with the AP1000 design

290. This action was raised during the Step 4 assessment as the evidence provided relating to reliability was based on an analysis of historical initiator and actuator designs. The issue relates to the fact that there were no details about the relevance of the historical evidence with respect to the current **AP1000** actuator design.

291. I have assessed both the squib valve safety case (Ref. 10) and the squib valve summary report (Ref. 11), which include arguments and evidence relating to the reliability of the actuators. The squib valve summary report refers to the same evidence provided as part of the Step 4 GDA assessment, with minimal changes to the arguments around the use of the evidence.

292. The squib valve safety case (Ref. 10, HLC 4) addresses the reliability of the squib valves in total. It refers to the historical evidence within sub-claim 4.1 which provides arguments that the concept of a squib valve is “proven technology”. I consider that although the concept of a squib operated valve has a historical basis, the specific design and inclusion as a nuclear Class 1 component are novel. The safety case then goes on to provide additional evidence as to the reliability of the actuator based on design concepts, margins, qualification and manufacture LAT. I assess these aspects later in this report.

293. The key point raised in the Step 4 report relating to this issue is that the larger the difference between the historical evidence and the current **AP1000** design, the less relevant the historical evidence is. I have identified a number of additional design changes (in Action 6-3.b) that have occurred since the Step 4 assessment. These increase the difference between the current design and the historical evidence, reducing the relevance of the historical evidence further.

294. Therefore, I consider that the historical reliability evidence within the squib valve safety case and summary reports are acceptable only as a baseline against which future reliability analysis can be assessed. Future licensees should ensure that reliability of the **AP1000** actuator is measured, recorded and used to update the safety case on a regular basis throughout operation. This should include any available data from other operating facilities and the manufacturer if available. I address aspects of reliability testing within Action 7-5 below.

295. I am content that the use of the historical evidence as part of optioneering studies, and as a reference baseline to the expected reliability, is acceptable and meets the expectation of Action 6-3.a. I have considered the following ONR SAPs during this assessment:

- SC.1, relating to safety case production
- ERL.1, relating to reliability claims
- AV.3, AV.7 and AV.8, relating to the use and collection of data and update of safety analysis

Action 6-3.b: Demonstration that sufficient and relevant test evidence exists for the AP1000 booster design to support its reliability claim

296. This action was raised during Step 4 (Ref. 14, Section 4.10.2.5.7) due to the lack of evidence provided regarding complete actuator reliability. The majority of evidence provided relates to the initiators only and is based on historical designs (see Action 6-

3.a). I consider this to be a significant aspect of this assessment and therefore targeted it for a more detailed assessment.

297. Due to the nature of the actuator, safety and reliability are closely linked; I have therefore recorded the details of my assessment of the qualification evidence in Ref. 16. I have provided the significant reliability and safety points here.

298. The reliability and safety of the actuator are dependent on a large number of factors (manufacture, storage, handling, ageing etc). It is important to take these factors into account during qualification (ONR SAP EQU.1). Due to the nature of the issue, I concentrated on the testing and evidence. In addition, I have identified aspects of the design and manufacturing process that are directly applicable to substantiation of reliability and safety. I do not address EIMT aspects of reliability within this section of the report, as they are covered in Action 7 below.

299. My assessment of the qualification evidence noted a number of areas that do not fully meet the requirements of RGP or my expectations. I have recorded the details of my assessment, along with specific observations, in Ref. 16. The key points are as follows:

- The number of complete actuators tested is not sufficient to provide the level of evidence required.
- The basis of the operational temperature used to define the qualification thermal ageing conditions is a theoretical calculation which is not validated against actual experience, experiment or tests.. A level of conservatism has been included within the test methodology, but margin depends on accuracy of initial calculation accuracy.
- The accelerated ageing methodology used to demonstrate service life has not been validated against real time aging conditions for this application.
- The number of initiators tested is not suitable or sufficient to provide the level of evidence required. The use of a mixture of manufactured lots and combination of results introduces additional confusion and uncertainty.
- The post-qualification change in design and manufacturing process of the initiators is considered significant with respect to the actuator reliability and safety. Further qualification evidence is required to address these aspects.

300. In addition to my observations relating to the qualification evidence, I have identified the following additional points. These impact on the validity of the qualification evidence:

- The supplier of the initiator identified that the pyrotechnic material used to fill the initiators has already been manufactured and is currently stored for future use. This means that an unknown but potentially significant amount of ageing of the initiator material will occur before manufacture.
- The current amount of pyrotechnic material manufactured and stored is unlikely to be enough to manufacture the initiators for the UK **AP1000** actuators. It is therefore likely that a new batch of raw materials will need to be sourced and manufactured for the UK **AP1000** plant.
- The manufacturing equipment for the pyrotechnic materials / components has been moved to a different facility.

301. Taking into account the points noted above, I consider that further EQ testing is required to meet ONR's expectations. Nevertheless, I am content that relevant test evidence has been provided that is sufficient to support the reliability claim at this stage of the design process and meets the intent of Action 6-3.b.

302. Due to the need for licensee involvement in defining the future procurement of actuators and specific requirements within GB, I identified the following **Assessment Finding**. This includes points identified within three residual matters in Action 6-6 relating to EMI and the residual matter in Action 7-4 relating to the impact of an actuator during handling:

Assessment Finding CP-AF-AP1000-ME-02:

The licensee shall provide adequate equipment qualification evidence to fully substantiate the as-built squib valve actuator and its components, taking into account site-specific characteristics.

303. Closure of the **Assessment Finding** above should include, but not be limited to, consideration of the following identified residual matters from this report:

- The number of test items should be consistent with RGP.
- Testing should be carried out on a single manufactured sample of components, having been manufactured in the same facility and using the same methods as the operational components.
- Sufficient real-time ageing should be used to supplement the accelerated ageing used to determine service life.
- Analysis of testing results should provide an output that can be directly compared with the safety case requirements.
- Confirmation of the all-fire and no-fire currents as a limit and condition for safe operation is required.
- Changes to design / manufacture / raw material need to be assessed against the qualification evidence and may invalidate previous results.
- There should be confirmation of the safety margin in induced current due to EMI, including resonant harmonics, as identified in Action 6-6 below.
- Definition of site-specific EMI environment is required, as well as substantiation that the actuator EMI qualification bounds the site-specific environment, as identified in Action 6-6 below.
- Impact effects on the actuator should be identified, as identified in Action 7-4 below.

304. I have also noted the need to validate the theoretical model that underpins the service life qualification of the actuators by in-service monitoring of the operational thermal environment. I consider that incorrect storage environment of actuators may introduce a CCF mode. I therefore identify the following **Assessment Finding**:

Assessment Finding CP-AF-AP1000-ME-03:

The licensee shall ensure that the environmental conditions of the actuators are monitored through-life, to verify assumptions that underpin the qualified service life.

305. Closure of the **Assessment Finding** above should include, but not be limited to, consideration of the following:

- adequate environmental monitoring (temperature, humidity, radiation) of the squib valve / actuator during operation;
- adequate temperature and humidity monitoring of the actuator during storage; and
- arrangements to ensure comparison of the monitored values against the assumed safety case and qualification environmental conditions. Specific consideration of all CCF modes should be included.

306. I have considered the following ONR SAPs in making this judgement:

- EQU.1, relating to qualification
- EKP.2, relating to fault tolerance
- ECS.3, 4 and 5, relating to codes and standards
- EDR.1 and 3, relating to design for reliability
- ERL.1 and 2, relating to reliability claims
- EAD.1, 2 and 4, relating to ageing and degradation

Action 6-4: Clarification of the relevance and purpose of development report 17399(01)DR to the ballistic analysis

307. This action was raised during Step 4 (Ref. 14) as the original squib valve summary report discussed it but provided no reference document or details of the aim of the document. Westinghouse provided the development report during the Step 4 assessment period but with a lack of explanation of the document's aim.

308. I have assessed both the squib valve summary report (Ref. 11) and the squib valve safety case (Ref. 10). Both refer to a ballistic report or analysis, but reference document APP-PV70-VDR-101 (Ref. 44). Westinghouse confirmed to me that this document is the same as previously discussed [17399(01)DR] but that it had been renumbered after being added to the Westinghouse document system.

309. The squib valve summary report (Ref. 11) describes the document as providing the completed development of the actuator design, including simulations, internal ballistic testing and initial propellant mass calculations and tests.

310. The squib valve safety case (Ref. 10) references APP-PV70-VDR-101 (Ref. 44) under Argument 1.1.2. to provide evidence that the actuator has been adequately designed and tested to provide sufficient force to open the valve.

311. I assessed the development report and consider that it provides an adequate record of early analysis and testing consistent with its use as evidence within the summary report and safety case.

312. The final sizing of the actuators has been refined since 2011, when the development report was produced. I have assessed this aspect of the safety case in Actions 6-3.b above and 6-8.b below.

313. I am content that the relevance and purpose of the development report, now referenced as APP-PV70-VDR-101 (Ref. 44), have been clarified and meet the expectation of Action 6-4.

314. I have considered ONR SAP SC.1 relating to safety case production.

Action 6-5: Provision of optioneering relating to, and the analysis supporting, the selection of initiator concepts

315. This action was raised in Step 4 to address the lack of evidence to demonstrate that suitable optioneering had been carried out in relation to the choice of initiator type.

316. I assessed the squib valve safety case (Ref. 10), which specifically addresses this in Appendix 3. This appendix includes background information on the current design and references other historical uses of squib valves. I assessed this aspect under Actions 6-2.e and 6-3.a above. The appendix identifies two primary risks for consideration: I understand these as being the criteria against which each potential option was assessed.

317. Appendix 3 provides a description of the process used to review a number of options for initiator methodology. This included local and remote mechanical systems and a number of electrical driven options. The conclusion of the appendix was that the electric hot bridgewire design chosen was on balance the best option. The bases for this decision were primarily reliability and low voltage / current operation requirements needed to meet the **AP1000** criteria.

318. The appendix also noted that *"with the proper mitigations"* this method can provide a high confidence that the valve will not spuriously actuate. I assess this aspect of the design in Actions 6-6, 6-8.b and 6-11 below.

319. I am content that Appendix 3 of the safety case provides suitable provision of optioneering, to support the selection of the initiator, to address Action 6-5. I have considered ONR SAP SC.1 relating to safety case production.

Action 6-6: Justification that the cartridges will not be liable to react to any electromagnetic environments and EIMT requirements relating to maintaining this protection

320. This action was raised in Step 4 (Ref. 14, Section 4.10.2.5.10) due to a lack of evidence that the actuator (specifically, the initiator) would not be liable to react to the electromagnetic environment. The issue was concerned about the following aspects:

- Identification of local electromagnetic environment, including mobile sources (eg radios, test and maintenance equipment).
- Justification that the actuators will not be liable to react to these electromagnetic environments – including any resonant harmonics.

- Identification of suitable EIMT for the cabling and other EMI protection.

321. I reviewed Argument 2.1.2 within the squib valve safety case (Ref. 10) which specifically addresses this. It notes that the design of the cabling takes into account guidance gained from MIL-HDBK-83575[‡‡]. I note that this standard includes specific reference to electroexplosive device circuits; as such, I am content that it represents RGP in this area.

322. I consider that the selection of shielded twisted pair cables is in accordance with the guidance given in MIL-HDBK-83575. I note that the guidance includes specific requirements on separation distances and shielding termination and grounding. I discussed the layout of cabling with the ONR electrical inspector and Westinghouse, who referenced a cable separation and segregation document (Ref. 50) that identifies the squib valve initiator cabling and its associated conduit and separation / segregation requirements.

323. I am content that this is sufficient to address the RGP requirements on separation and installation. The final installation of cabling should be in accordance with these requirements. I expect this to be undertaken by a future licensee as part of **normal business**.

324. The safety case describes the methodology for identifying the local electromagnetic environment and the test process to determine whether the actuator is susceptible to EMI. This process is defined in the EQ methodology document (Ref. 51) and the EMC program document (Ref. 52).

325. ONR's electrical inspector (Ref. 53) confirmed that this is the same process used for all EMI assessment within the **AP1000** design and that he is content with the generic approach. The local electromagnetic environment, as defined in the EMC program document, is based on frequencies of equipment and transmitters used in the US. I consider that this list needs to be updated and amended with GB site-specific information. This should then be used to determine if the actuator qualification still bounds the EMI environment. I consider that this should be included within the **Assessment Finding** identified in Action 6-3.b above.

326. The EMI testing consisted of a 14 inch single actuator, with initiator cables attached, being subjected to a series of electromagnetic environments, as described in the EQSR (Ref. 20). The test pass criteria were based on the following failures not being observed:

- bridgewire loss of continuity
- inability to function on final test
- inadvertent actuation during test

327. I reviewed the RGP justification document (Ref. 45) within Action 6-2.b above. I noted that Appendix D of the MIL-HDBK-83578, relating to EMI testing, was listed as being addressed by the use of ASME QME-1 qualification. The standards used within the EMC program do not address the specifics of pyrotechnic items; as such, the number of devices tested and the output from testing did not fully meet my expectations.

[‡‡] *It was noted that MIL-HDBK-83575 was not included within the safety case reference list, but was incorrectly attributed to reference 32 which is correctly referenced as MIL-HDBK-83578.*

328. I reviewed the guidance given in MIL-HDBK-83578 (Ref. 46) and MIL-HDBK-1512[§§] (Ref. 23); both consider that a larger number of test items are required. The exact number varies between the guidance documents, but is significantly larger than a single test sample.

329. In addition, both documents identify a minimum safety margin of 20 decibels (dB) between the maximum current generated by EMI and the no-fire current. Similarly, the ER2014 (Ref. 8) on electrical safety in explosive operations within Appendix 3 states, *"A margin of at least 12 decibels (dB) below the 'no fire hazard' threshold of the most sensitive device present should be maintained."*

330. The results from testing did not provide evidence of a margin; this does not meet my RGP expectations. I consider that this is a residual matter in the safety case. Due to the similarity in expectations, I consider that this should be included within the **Assessment Finding** identified in Action 6-3.b above.

331. The action identified the specific need to justify that the actuators will not be liable to react to these electromagnetic environments – including any resonant harmonics. There is no identification of the resonant frequency of the bridgewire design within the safety case or report. This aspect of the action requires further evidence to justify the safety of the design. I consider that this is a residual matter in the safety case. Due to the similarity in expectations, I consider that this should be included within the **Assessment Finding** identified in Action 6-3.b above.

332. The safety case refers to a theoretical calculation method (Ref. 54) which was originally provided as part of the Step 4 assessment. This calculation and the assumptions behind it were not considered sufficient to demonstrate that the initiator is not susceptible to EMI. I consider the conclusion drawn from this calculation has the potential to confuse a licensee and requires treating with caution.

333. The squib valve safety case (Ref. 10, Argument 2.1.2.) includes a schematic diagram of the cabling associated with the squib valves. Within this diagram there is a note that identifies that a length (approx. 6.7 m) of cable is coiled in a junction box before the valve. Westinghouse stated that the length is required to ensure each valve has the same resistance of cabling and so could not be removed. I consider that the detailed installation of this spare cable length needs to be assessed to ensure that it does not increase the susceptibility of the system to EMI. My expectation is that this is undertaken by a future licensee as part of **normal business**.

334. The proposed EIMT methodology for the valve, including the actuator and associated cabling, is detailed within the squib valve maintenance manual (Ref. 33). The internal cabling (known as electrical feedthroughs) are identified as a replaceable part at the same time as the actuator. The external electrical connections (known as the Mark 3 Connector) are identified as requiring inspection and replacement if they fail inspection. It is not clear whether they are required to be replaced at the same time as the actuators.

335. I consider that the squib valve maintenance manual gives suitable guidance on the inspection and replacement of cabling associated with the actuator, which is sufficient to address the expectation of this action. I note that the inspection and replacement schedule needs further justification and detail relating to the electrical connections. I address this aspect of EIMT in Action 7 below.

336. I am content that the evidence provided is sufficient to support the EMI susceptibility claim at this stage of the design process and meets the intent of Action 6-6. I have

[§§] *Westinghouse references MIL-HDBK-1512 as a document containing guidance on ESD testing criteria, but it also contains specific EMI testing guidance for initiators.*

considered ONR SAPS EQU.1, relating to EQ and EHA.10 relating to electromagnetic interference in reaching this conclusion.

Action 6-7: Justification that all relevant UK requirements for the design of cartridge and termination units have been adequately covered

337. This action was raised in Step 4 due to the concern that the design of the actuator and associated C&I systems to US standards may not ensure that they meet UK regulations. EMI test standards and the transport / storage and testing of actuators on a licensed site was raised as a specific concern.

338. I assess the interfacing C&I systems later in this report within Action 6-13 below; similarly, EMI testing has been assessed earlier in this report under Action 6-6.

339. The regulatory environment relating to the transport / storage and testing of explosive / pyrotechnic devices on nuclear power plants has changed since the Step 4 GDA assessment was written.

340. ONR is now the licensing authority under the ER2014 (Ref. 7) which superseded the Manufacture and Storage of Explosive Regulations 2005 extant at the time of Step 4 GDA. Despite this, the expectations of meeting UK regulations in this area remain and are similar to those raised during Step 4.

341. I reviewed sub-claim 4.5 of the squib valve safety case (Ref. 10) which includes Westinghouse's assessment of applicable regulations. It discussed the aspects of the actuator lifecycle (design, through qualification to handling and storage). For transport, handling and storage Westinghouse confirmed that the US regulations for packaging standards follow the same international approach as in the UK.

342. The final acceptance of the suitability of the actuator for importation and classification for transportation is the responsibility of the Health and Safety Laboratories (HSL) and HSE respectively. Any future licensee needs to recognise that the importation, transport and storage of these items will depend on the classification determined by HSE and any licence conditions set by ONR for on-site storage. My expectation is that this is undertaken by a future licensee as part of **normal business**.

343. The safety case identifies a number of UK 'regulations, standards and guidance' that are associated with aspects of the design. One document identified is JSP 482 (Ref. 55). This is a set of UK military regulations for the safe storage and processing of ordnance, munitions and explosives. This can be a useful document to address aspects that may not be covered by civil regulations, standards or guidance. However, I have identified the following concerns over the use of JSP 482 within the safety case:

- as a set of military regulations it has, within it, a number of exclusions and practices that are exclusive to the UK military that would not be suitable for civilian use. These are not easily identifiable and as such may be incorrectly applied; and
- the current edition (JSP 482, Edition 4) was published in January 2013 before the introduction of ER2014 and, as such, may be out of date with respect to UK law.

344. I consider that the identification of JSP 482 as demonstration of meeting UK regulations is not appropriate for civil nuclear use. Significant care must be taken by a licensee if referencing JSP482 guidance in any future safety case.

345. Future licensees should ensure that any use of JSP 482 is appropriate, especially where more applicable guidance is already available; I expect this to be addressed as **normal business**.

346. I am content that the application of UK regulations to the actuator design has been considered within the safety case to a suitable level for this stage of the project and meets the intent of Action 6-7.

347. I have considered ONR SAP, SC.1, relating to safety case production, in reaching this judgement.

Action 6-8.a: Issue documentation relating to the requirements for propellant neutron testing

348. This action was raised during Step 4 due to the use of gamma radiation equivalency during testing for neutron as well as beta radiation. The concern was that the effect of neutron radiation may not be suitably replicated by the use of gamma equivalency. Westinghouse identified that it would subject the actuators to neutron radiation, during qualification, but it provided no details of the test conditions during the Step 4 assessment.

349. As Westinghouse combined the evidence for all radiation exposure testing into a single document, I have addressed this aspect of the issue in Action 6-2.d above.

350. I consider that the evidence provided and assessed in Action 6-2.d above meets the expectation of Action 6-8a.

Action 6-8.b: Issue documentation relating to qualification results that demonstrate the actuators achieve their safety function and design intent

351. This action was raised in Step 4 (Ref. 14) due to the limited level of evidence provided, as the qualification programme had not been completed.

352. Due to the nature of the actuator, safety and reliability are closely linked; I have therefore recorded the details of my assessment of the qualification evidence in Ref. 16 and assessed them within Action 6-3.b above.

353. I am content that the evidence provided and assessed within Action 6-3.b above, provides suitable justification of the actuators for this stage of the design, and meets the intent of Action 6-8b.

Action 6-9: Justification that C&I faults do not impact the properties of the initiator bridgewire

354. This aspect of the action was raised during Step 4 (Ref. 14) due to the concern that a C&I fault could result in a spurious current being generated at a level below the no-fire current but at a level that may affect the properties of the bridgewire that may impact reliability.

355. I assessed the squib valve safety case (Ref. 10), which states within Argument 2.1.2, that the use of ground fault monitoring has *"the potential to degrade the performance of the bridgewire"*. This process involves the C&I system sending a low current signal down the cable and waiting for a response.

356. I noted within the qualification report (Ref. 56) that the current required to fire an initiator was greater following an unsuccessful attempt to fire. The report does not identify the level of the initial current, but due to the testing methodology, it is between the no-fire and all-fire values.

357. Taking these points into account I consider that C&I faults may impact the properties of the initiator bridgewire.

358. Therefore, to address this aspect of the issue, Westinghouse argues that the sources of spurious current through the initiator have been reduced. This includes the EMI protection assessed in Action 6-6 and the C&I protection assessed in Action 6-11a. In addition, Westinghouse has stated that the CIM involved in the initiation of the actuators will not use the ground fault monitoring capability. I consider that this is an acceptable approach to removing this potentially damaging mechanism. I note that this aspect of the design will need to be identified as having this as a safety feature and be verified within licensing. My expectation is that this is undertaken by a future licensee as part of **normal business**.

359. The original Step 4 assessment report also queried the use of continuity checking with digital voltmeters; this is addressed in Action 7-3.c below.

360. Design changes that reduce the probability of the C&I system generating a spurious signal is addressed in Action 6-11.a below.

361. I consider that Westinghouse's approach to demonstrate the reduction in spurious currents within the bridgewire circuit meets the intent of Action 6-9.

362. I have considered ONR SAPs ERL.2, relating to measures to achieve reliability and EMT.4 for validity of EQ in reaching this judgement.

Action 6-10: Provision of suitable fire analysis to include surrounding rooms

363. This action was raised in Step 4 due to a concern that the full extent of fire effects on the actuators had not been considered.

364. I assessed Argument 2.1.2 within the squib valve safety case (Ref. 10). It identifies a reference (Ref. 57), which concludes that fires in adjacent fire zones would have minimal impact on the squib valves. It also argues that the rooms are large and contain very little combustible material, which limits the maximum temperature rise of the air due to fire.

365. I am content that the evidence provided in Ref. 57 and the associated argument in the safety case substantiates the claim that the squib valves will not be impacted by fire in adjacent rooms, as expected by Action 6-10.

366. I have considered ONR SAPs EHA.6, relating to hazard analysis, and EHA.16, relating to fire detection, when making this judgement.

Action 6-11.a: Justification that the safeguards provided within the termination units and cabinet interface modules are sufficient

367. This action was raised in Step 4 (Ref. 14) due to the design not being mature at the time of assessment. Although this action was raised within GI-AP1000-ME-01, it is similar in intent and wording to the C&I issues in GI-AP1000-CI-04 relating to the PMS spurious operation.

368. The assessment of GI-AP1000-CI-04 (Ref. 58) concluded that the inclusion of the blocking device reduced the risk of spurious arming of the squib valve termination unit (SVTU) due to software CCF of the PMS to beyond design basis. As the termination unit cannot generate an output current unless it is armed via the PMS then I consider that the inclusion of the blocker has met the expectation of this aspect of the issue.

369. The GI-AP1000-CI-04 assessment report identifies a single Assessment Finding (CP-AF-AP1000-CI-006) which requires a future licensee to further develop the safety case for the blocker and implement the identified safety plan. As noted in Action 6-11.b below, if any significant changes are made to the safety case the impact on the SAD should be considered. I consider that this does not affect my judgement below.

370. I am content that, the evidence provided and assessed within the GI-AP1000-CI-04 assessment report provides suitable justification that the safeguards within the PMS system as a whole are sufficient, as expected by Action 6-11a.

Action 6-11.b: Justification that the absence of SADs within the pyrotechnic chain achieves the correct balance of risk between reliability and prevention of spurious actuation

371. This action was raised in the Step 4 assessment report (Ref. 14) as the report considered that the inclusion of a SAD within the explosive train is reasonable. The action stated that the absence of a SAD within the design should be explicitly justified.

372. The inclusion of a SAD within the explosive chain would reduce the probability of a spurious actuation due to any initiating fault anywhere in the system up to and including the initiator. Conversely, it could reduce the reliability of the squib valves to operate on demand, as the reliability of the SAD would need to be included in the operating sequence.

373. I note that the original Step 4 assessment considered MIL-STD-1316E as RGP in this area. The current squib valve safety case references MIL-HDBK-83578 (Ref. 46); this contains the same expectation with respect to SADs as MIL-STD-1316E.

374. The justification of the absence of SADs was discussed during a Level 4 meeting with Westinghouse in September 2016 (Ref. 59). I advised Westinghouse that the justification should include a consideration of the following:

- RGP relating to SADs;
- consequences of a spurious actuation;
- potential increase in safety by inclusion of a SAD; and
- potential decrease in reliability due to inclusion of a SAD.

375. I advised Westinghouse that a balance of risk argument, in accordance with the ONR guidance on the Demonstration of ALARP NS-TAST-GD-005 (Ref. 4, paragraph 6.41), in conjunction with an assessment of the consequences would be suitable to address this aspect of the issue.

376. Appendix 5 of the squib valve safety case (Ref. 10) specifically addresses the applicability of RGP to SADs. It concludes that *"there is little that can be directly applied"*, and states that the approach is therefore via an ALARP argument.

377. I consider that the conclusion, that the RGP within MIL-HDBK-83578 is not directly applicable, is incorrect and that a SAD should be considered as a relevant safety feature for this type of device. This re-enforces the conclusion reached in Step 4, that the inclusion of a SAD is considered to be a reasonable expectation. This conclusion does not impact the approach taken by Westinghouse within the remainder of Appendix 5.

378. Appendix 5 also provides a discussion of the impact of a spurious actuation on the pipework, valves and other local SSCs. It concludes that the pipework would

withstand the forces generated by a spurious actuation, although they may move and deform. The pipes would retain sufficient flow area to ensure proper depressurisation and hence not challenge long-term core cooling. The associated non-return valves were assessed and the safety case stated that they would remain intact although they may remain closed due to the forces deforming the internals. An expert panel paper (Ref. 21) assessed the potential impact on other SSCs and determined that although some SSCs could be damaged there would be no impact on core cooling.

379. The ONR structural integrity inspector assessed, in Ref. 24, the claim relating to pipework, valves and SSCs and accepted the expert panel conclusion.

380. In addition to the above assessment, Westinghouse stated that a spurious actuation of squib valves was that the consequences were bounded by the current RCS leak and LOCA scenarios within the fault schedule. The ONR PSA inspector (Ref. 61concluded that the beyond design basis risk implications of a spurious squib valve actuation had been adequately explored within the GDA PSA. Two Assessment Findings were identified (CP-AF-AP1000-PSA01-39 and CP-AF-AP1000-PSA01-40) requiring the licensee to update the PSA to take into account a number of identified failure modes related to the squib valve spurious actuation.

381. Westinghouse also provided, within the squib valve safety case Appendix 5, a PSA analysis (Ref. 60) of the impact on core damage frequency (CDF) of introducing a SAD into the design. The analysis included the benefit to safety and detriment to reliability of the introduction of a SAD. A number of sensitivity runs were performed to assess different reliability and protection values. It also included the probability of EMI causing a spurious actuation. The analysis was based on the current PSA, with additional aspects added for the SAD and associated C&I. In addition, it included the benefit of the blocker device within the C&I protection as assessed in Action 6-11.a above.

382. The PSA analysis concluded that the introduction of a SAD into the system increased the CDF in almost all scenarios, with the only exception being if a SAD reliability to open was better than 1.0 $x10^{-5}$ per demand. Westinghouse concluded that this level of reliability in a mechanical system was unlikely to be achievable.

383. The ONR PSA assessment report (Ref. 61) concluded that the risk balance clearly shows that the safe-arm device is an overall risk detriment.

384. I am content that, on the current evidence provided, Westinghouse has provided a suitable and sufficient justification that the absence of a SAD achieves the correct balance of risk between reliability and prevention, as expected by Action 6-11b.

385. I note that the current justification is based on a number of assumptions, specifically that the C&I system reliability will meet a suitable level with respect to spurious actuation. I have also referenced Assessment Findings, made by the C&I and PSA inspectors, the resolution of which may have an impact on the justification. I expect that, as **normal business**, if there are changes to either of these aspects of the safety case, then the impact on the justification of the absence of SADs should be assessed.

386. In addition to NS-TAST-GD-005, the ONR guidance on the demonstration of ALARP (Ref. 4), I have considered the following SAPs when making this judgement:

- EKP.2, relating to fault tolerance
- EKP.3, relating to defence-in-depth
- EDR.1, relating to failure to safety

- EDR.4, relating to single failure criterion
- EHA.4, relating to frequency of initiating events

Action 6-12: Provision of optioneering of initiator electrical current values, selection criteria and analysis to support the selected option

387. This action was raised in Step 4 due to the lack of evidence provided to demonstrate that suitable optioneering had been carried out with respect to the initiator electrical current value. It specifically required Westinghouse to provide:

- a review of the advantages and disadvantages of each considered electrical current value;
- an explanation of the selection criteria for the electrical current value; and
- the analysis to support the final selection of each considered option.

388. The key concerned raised in Step 4 was that the electrical no-fire current value was low. The no-fire current for simple hot bridgewire systems, such as this, can be used as a guide to the sensitivity of the system to spurious actuation due to sensitivity to electrical currents.

389. I address the process of optioneering and final selection in this section of the report. I addressed the protection against currents generated by electromagnetic environments, C&I and EIMT activities in other sections. I further assess the qualification test results which include evidence of the actual initiator electrical current values in Actions 6-3.b and 6-8.b.

390. I assessed the squib valve safety case (Ref. 10), which specifically addresses this aspect of the issue within Appendix 4. This appendix includes background information on the relevant PMS C&I design and discussions on the properties of bridgewires and the interdependence of the no-fire and all-fire currents. The appendix identifies two primary risks (failure to open on demand and spurious actuation) which need to be considered. In addition, the control of the current and routing of the cables are identified. I consider these as the criteria against which each potential option was assessed.

391. Appendix 4 provides a description of three options considered:

- Increasing both no-fire and all-fire currents by modifying the bridgewire physical characteristics.
- Modifying the bridgewire material to increase the no-fire current without impacting the all-fire current.
- Retaining the current design.

392. The appendix addresses each of these in turn and provides a discussion on each option noting the reasons why the first two options were discounted and providing a rationale as to why the current design meets the criteria. The discussion of the current design references sub-claim 2.1 in the squib valve safety case relating to EMI protection and discusses prescription of EIMT test equipment current levels. I have raised specific concerns over the demonstration of EMI protection and EIMT test equipment selection in other sections of this assessment.

393. The conclusion of Appendix 4 is that the current design provides the best balance between the ability to actuate with a suitable level of protection from spurious current

generation. This is primarily driven by the ability of the C&I system to generate a suitable current.

394. I am content that Appendix 4 of the squib valve safety case provides suitable provision of optioneering, to support the selection of the initiator electrical current values, to address Action 6-12.

395. I considered ONR SAP SC.1, relating to safety case production process.

Action 6-13: Justification that each SVTU type and terminal block is designed adequately to achieve its SFRs and design intent

396. This action was raised in Step 4 due to a concern that the termination unit / terminal blocks within the firing circuit had not been assessed during Step 4 as they did not come under either the mechanical or C&I scopes of work.

397. Westinghouse did not address this aspect of the issue within either the safety case or summary report but provided a standalone reference (Ref. 62).

398. This reference identified the relevant specification and qualification documents for the termination units within the PMS system. The PMS system architecture and qualification is assessed within GDA Issue GI-AP1000-CI-08 which, while not specifically looking at these units, has assessed the processes behind the PMS specification and qualification. In addition, the ONR C&I inspector has produced an assessment note detailing his assessment of the C&I aspects of the PCSR, which includes the methodology used to design the C&I systems.

399. The DAS system architecture is currently being modified to meet UK requirements and, as such, the documentation for the DAS terminal blocks is not available. The DAS system has been assessed under GI-AP1000-CI-01 and GI-AP1000-CI-02 (Ref. 63), which has raised two Assessment Findings covering the following aspects:

- Full development and implementation of the DAS safety case.
- Demonstration of reliability of the DAS as-built system.

400. It is my expectation that the squib valve aspects of the DAS system, including the terminal blocks, will be included within the work undertaken to address these Assessment Findings.

401. I am content that the assessment of GDA Issue GI-AP1000-CI-08 and the C&I Aspects of the PCSR provides me suitable confidence for closure of Action 6-13.

402. I have considered SAPs ECS.1 and 2, relating to safety classification and categorisation, and ESS.2 and ESS.22, relating to safety systems, when making this assessment.

Judgement

403. I judge that from a mechanical engineering perspective Westinghouse has provided suitable arguments and evidence to justify the design, optioneering and interface with C&I systems as required by this action.

404. In the case of qualification evidence, in-service monitoring and electromagnetic environment, I have identified two **Assessment Findings** (**CP-AF-AP1000-ME-02 and CP-AF-AP1000-ME-03),** which require closure during licensing, but judge that the arguments and evidence provided within the current safety case are suitable for closure at this stage.

405. I have considered the arguments and evidence in conjunction with the guidance provided by the SAPs identified above and the following TAGs:

- NS-TAST-GD-003 – Safety Systems
- NS-TAST-GD-005 – Guidance on Demonstration of ALARP
- NS-TAST-GD-057 – Design Safety Assurance

406. Therefore, I judge that GI-AP1000-ME-01 Action 6 can be closed.

4.2.7 GI-AP1000-ME-01 Action 7

407. Action 7[***] of the GDA issue was for Westinghouse to provide:

1. *The detailed evidence that an adequate visual inspection can be carried out on the 8 inch squib valve design.*
2. *Within the consolidated PCSR, the requirement that if a cartridge taken out of a plant fails its test then all cartridges from that batch should be replaced.*
3. *The justification that electrical testing EIMT requirements result from a process which has considered and analysed each option, with a suitable selection rationale. The justification must also demonstrate the following:*
    a. *Testing every 24 months is sufficient to prove a high level of availability of the safety system using squib valves.*
    b. *Insulation testing does not reduce the risk of failure.*
    c. *Electrical currents supplied by digital voltmeters always stay lower than the threshold defined in the bridgewire resistance test.*
    d. *Reconnecting initiators to a circuit under voltage does not increase the risk.*
4. *Within the safety case, a safety requirement that every cartridge subjected to a significant mechanical shock loading during its lifetime must not be used. As part of this, Westinghouse shall also define the acceptance parameters in respect of this criterion.*
5. *Evidence of recommending an adequate surveillance and EIMT regime that is commensurate to the* ***AP1000*** *NPP safety case assumptions and the safety role of each squib valve type.*

408. This action is related mainly to the actuator (initiator and propellant charge), with the exception of Action 7-1 which relates to the 8 inch squib valve body.

409. The squib valve safety case submission (Ref. 10) together with the squib valve summary report (Ref. 11) provide claims, arguments and evidence relating to the majority of Action 7.

[***] *The original Action 7 was not written in an alpha-numerical list; for ease of reference this has been introduced in this report.*

410. I have addressed each point in turn within my assessment. Due to the specific nature of some aspects of this action, I have targeted the basis of my assessment towards the closure of the action.

Assessment

Action 7-1: Provision of detailed evidence that an adequate visual inspection can be carried out on the 8 inch squib valve design

411. This aspect of the GDA issue concerns itself with the ability of operators to visually examine the internal surfaces of the shear cap. The 8 inch squib valve contains an inspection port. Westinghouse stated within its squib valve safety case (Ref. 10) that the inspection port can be used to undertake the visual inspections referred to within the ASME OM Code (see Section 4.2.4 for further information).

412. Figure 2 identifies a number of 8 inch squib valve parts, including this inspection port.

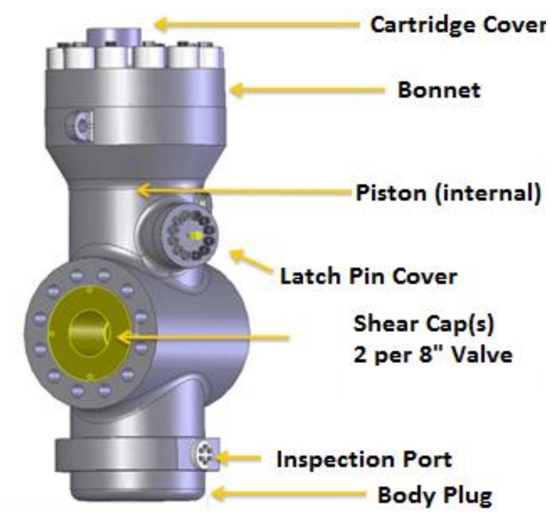


Figure 2: 8 inch squib valve parts

413. The inspection port is largely used to determine whether fluid is present in the area below the shear caps – indicating leakage. A concern, raised by ONR during Step 4, was related to inspection of the shear caps. The squib valve drawings for the 8 inch valves appear to show only a narrow area between the shear caps, which may result in difficulties in adequately inspecting the condition of the shear caps via the inspection port, for example using a probe. However, I judge that the removal and disassembly of at least two valves every two years should provide a licensee with the means to adequately inspect the condition of the shear caps at appropriate outages. The condition of those valves inspected should be used as indicators for the other valves within those systems.

414. In order to ensure that inspection arrangements for the shear caps are adequate, I expect a licensee to continually review its EIMT regime following each inspection of the squib valves as **normal business**.

415. Consequently, I am content that the current ASME OM Code requirements are sufficient to provide appropriate assurance of the 8 inch squib valve shear cap condition.

416. Therefore, I judge that GI-AP1000-ME-01 Action 7-1 can be closed.

Action 7-2: The requirement that if a cartridge taken out of a plant fails its test then all cartridges from that batch should be replaced should be included within the PCSR

417. This action was raised in Step 4 as the requirement was only identified in the summary report and not the safety case.

418. I have reviewed the recent PCSR and identified that this requirement is contained in Chapter 6.

419. I am content that the inclusion of the requirement within the PCSR meets the expectation of Action 7-2.

420. I have considered ONR SAP SC.1, relating to safety case production, in making this decision.

Action 7-3.a: Justification that testing every 24 months is sufficient to prove a high level of availability of the safety system using squib valves

421. This action was raised in Step 4 due to a concern that there could be a change in the squib valve system environment (including C&I system interfaces) during the 24-month period.

422. I reviewed the squib valve safety case (Ref. 10) which addresses the EIMT requirements for the squib valves within sub-claim 4.4. The safety case states that the validation of the C&I systems is to be performed every 24 months or whenever the plant is shut down for refuelling outage. The 24-month test frequency for the squib valve is aligned with this frequency. The squib valve summary report (Ref. 11) states that a more frequent interval of testing is outweighed by the additional risk of inadvertent operation of the valve.

423. I consider it disproportionate to require the plant to be shut down more often to carry out checks specifically on the squib valves within containment. I also consider that the probability of damage to the cabling, trunking, cabinets or junctions within containment is very low.

424. The external portion of the control system consists of the squib valve cabinet, cabling to it from the C&I system (either DAS or PMS) and cables from it to containment penetration. I have previously noted (Action 6-9 above) that Westinghouse has removed the capability for the C&I system to operate the automatic ‘ground fault monitoring’ option, within this system. I have assessed the use of digital voltmeters in Action 7-3.c below.

425. I consider that an assessment of the balance of risk between the frequency of circuit testing required to ensure the system has not been damaged and the risk of damage to the initiators is required. This should include visual inspections of the out of containment portions of the system. I consider that this is a residual matter in the safety case. Due to the similarity in expectations, I consider that this should be included within the **Assessment Finding** raised in Action 7-3.c below.

426. I am content that the evidence provided within the safety case provides suitable justification that testing every 24 months is acceptable for the in-containment portions of the system. I consider that additional justification is required by the licensee regarding the out of containment portions and circuit continuity checks, as expected by Action 7-3.a.

427. I have considered the following SAPs, when making this judgement:

- EMT.1, relating to identification of EIMT requirements

- EMT.4, relating to validity of EQ
- EMT.7, relating to functional testing

Action 7-3.b: Justification that insulation testing does not reduce the risk of failure

428. This action was raised in Step 4 due to the concern that on connecting the cable to the initiator damage could occur to the pins causing a short circuit. The expectation was that there should be a suitable in-service test method to identify this or that it could be demonstrated that the short circuit would not occur by design.

429. The current in-service test methodology does not specifically identify this failure mode as one that is tested, although the resistance test may be failed on a low resistance which could indicate a short circuit. There is also no specific check of resistance between the pins and the body of the valve to identify a short circuit in that direction.

430. There is also no specific mention of this failure mode being excluded by design within the summary report or safety case.

431. I am not content that an insulation test to detect short circuits has been included or suitably designed out, as expected by this action. I consider that this is a residual matter in the safety case. Due to the similarity in expectations, I consider that this should be included within the **Assessment Finding** raised in Action 7-3.c below.

432. I am, however, content that as the level of risk is low and there is a need for the licensee to produce the detailed EIMT arrangements to address the **Assessment Finding**, Action 7-3.b can be closed.

433. I have considered the following SAPs when making this judgement.

- EMT.1, relating to identification of EIMT requirements
- EMT.5, relating to EIMT procedures
- EMT.6, relating to reliability claims

Action 7-3.c: Justification that electrical currents supplied by digital voltmeters always stay lower than the threshold defined in bridgewire resistance test

434. This action was raised in Step 4 (Ref. 14) due to the concern that there was no safety requirement relating to current production placed on any voltmeter used within the EIMT procedure.

435. The squib valve safety case (Ref. 10 – Argument 2.1.1 and Appendix 4) places a current generation limit of 0.5 Amps on any test equipment used to test continuity of the squib valve circuit. The bridgewire resistance test threshold as defined in the actuator design specification (Ref. 18) is limited to no more than 10 mAmps.

436. I have considered RGP in this area and note that MIL-HDBK-83578 (Ref. 46) also requires resistance check circuits to be at 10 mAmps and resonance measurements to be at 500 μAmps. I also consider that similar bridgewire circuits, for example in the aerospace or defence industries, have dedicated test equipment for initiators of similar type.

437. HSE has provided guidance to industry, in conjunction with the Confederation of British Industry (CBI), *"for electrical installation and equipment within explosives manufacturing and storage facilities"* (Ref. 6). This guidance specifically addresses electrical equipment for testing explosives and electroexplosive devices in its Section 17. The guidance includes the statement that:

"Equipment intended for testing EEDs and firing circuits fitted with live EEDs shall be designed such that:

a. *No single fault of any nature can result in initiation or the degradation of an EED.*
b. *Connection to the system under test will not degrade the EMC of the system within the specified environment.*
c. *Safety under test conditions shall not be solely dependent on procedures."*

438. The use of a dedicated piece of test equipment could potentially meet the expectations of Action 7-3.b above as this test could be incorporated into the device. A lower current test system could also benefit the balance of risk assessment identified within Action 7-3.a.

439. I am not content that the argument made within the safety case meets the expectations of this aspect of the issue. I also consider that the 0.5 Amps value specified by Westinghouse is not ALARP in this respect. Westinghouse has identified this within its safety case in the commitments section (Ref. 10 – Section 4) as an aspect of EIMT that should be addressed during licensing. I have raised the following **Assessment Finding** in respect to testing of the bridgewire, including the residual matters identified in Actions 7-3.a and 7-3.b above:

Assessment Finding CP-AF-AP1000-ME-04:

The licensee shall ensure that the methodology and equipment used to test the continuity and resistance of the initiators is in line with relevant good practice.

440. Closure of the **Assessment Finding** above should include, but not be limited to, consideration of the following identified residual matters from this report:

- reduction of circuit test currents to be reduced SFAIRP;
- the use of specialist electroexplosive device test equipment for the testing of continuity and resistance of the initiators, or other means to meet RGP;
- inclusion of a test for short circuit or grounding;
- assessment of the balance of risk between the amount of circuit testing required to ensure the system has not been damaged and the risk of reducing the reliability / spurious actuation of the initiators is required.

441. I am, however, content that as the level of risk is low and as there is a need for the licensee to produce the detailed EIMT arrangements to address the **Assessment Finding**, Action 7-3.c can be closed.

442. I have considered the following SAPs when making this judgement:

- EMT.4, relating to validity of EQ
- EAD.2, relating to lifetime margins

Action 7-3.d: Justification that reconnecting initiators to a circuit under voltage does not increase the risk

443. This action was raised in Step 4, as there was no specific line item within a referenced maintenance instruction to remove the multi-meter before reconnecting the cables to the initiator. I have not assessed the detailed maintenance instructions as I considered them to be outside of the GDA scope. The squib valve maintenance manual (Ref. 33) includes specific instructions to remove the multi-meter and replace the covers on electrical connections after testing.

444. I consider that the detailed maintenance instructions and associated justification of them is an aspect that will be assessed during the licensing phase, as **normal business**.

445. I am content that the squib valve maintenance manual provides suitable guidance on the dangers of reconnecting initiators to live circuits, as expected by Action 7-3.d.

446. I have considered ONR SAP SC.1, relating to safety case production, and EMT.7, relating to functional testing, when making this judgement.

Action 7-4: Inclusion within the safety case of a safety requirement that every cartridge subjected to a significant mechanical shock loading during its lifetime must not be used, including definition of acceptance parameters

447. This action was raised in Step 4 (Ref. 14) due to it being noted that no shock loading assessment was included within the qualification tests.

448. The squib valve safety case (Ref. 10) identifies that there is a requirement for any actuator that is dropped or damaged to be returned to the supplier for disposal. A drop is defined as *"an uncontrolled freefall of any distance greater than approximately one half of an inch".*

449. During the September 2015 Level 4 meeting (Ref. 43), I queried the basis of this height. Westinghouse has not been able to provide a suitable explanation for the drop height. It has therefore included an assessment of actuator drop heights as part of commitments and recommendations within the safety case (Ref. 10 – Section 4).

450. I consider that a number of aspects need to be addressed with respect to drop heights, specifically, but not exclusively:

- Determination of what drop height would potentially cause the actuator to initiate, or justification that this height exceeds the maximum potential drop height in the facility.
- Determination that drop height could potentially cause damage to the actuator, causing it to become unsafe or less reliable.
- Justification of safety measures within the EIMT process that protect the actuator from being exposed to drop heights approaching these values and that a suitable safety margin exists.
- Production of a procedure for handling and disposal of potentially damaged actuators.

451. I note that the ER2014 guidance (Ref. 8) on expectations when handling explosive articles includes impact loading.

452. I am content that the safety case (Ref. 9) includes a safety requirement that every cartridge subjected to a significant mechanical shock loading during its lifetime must not be used, as expected by this aspect of the issue. I consider that the acceptance parameters defined within the requirement are not suitable or sufficient, lacking in justification and detail, to meet the expectation of the issue.

453. I consider that this is a residual matter in the safety case. Due to the similarity in expectations, I consider that this should be included within the **Assessment Finding** raised in Action 6-3b above.

454. Additionally, I am content that the commitments and recommendations section of the squib valve safety case (Ref. 10) provides confidence that Westinghouse understands the expectations for future safety cases; therefore, Action 7-4 can be closed.

455. I have considered ONR SAPs FP.4 relating to safety assessment and EHA.12 and 13 relating to the use, storage and generation of hazardous materials and sources of harm when making this judgement.

Action 7-5: Evidence of recommending an adequate surveillance and EIMT regime that is commensurate to the AP1000 NPP safety case assumptions and the safety role of each squib valve type

456. This action was raised in Step 4 (Ref. 14) due to the justification of EIMT not meeting expectations. Due to the single shot nature of the valve and novelty of the design, I identified EIMT as an area for more detailed assessment (Section 1.4, paragraph 14 above). I address the actuator aspects of EIMT within this action, with the valve body EIMT having been assessed in GDA issue Action 4, Section 4.2.4.

457. The initial reliability and safety evidence originates from the manufacturing process and associated surveillance LAT regime. I have therefore included this within my assessment of this action; I assessed the regime in an order that follows the operational life of the actuator. I have recorded the details of my assessment along with specific observations in Ref. 16, and the following are the key points:

- The actuator manufacturing LAT sample sizes have not been justified using recognised standards to meet the reliability level defined in the safety case.
- There are no defined incoming receipt or in-storage inspection procedures for the actuators.
- There is no visual inspection guidance given for the actuators.
- The 20% replacement of actuators per outage has not been substantiated against the safety case reliability.
- The current EIMT testing process does not allow for identification of ageing and degradation of the initiator.

458. I consider that the inspections for receipt / in-storage and guidance on visual inspections are aspects that will be assessed during the licensing phase, as **normal business.**

459. I consider that the manufacturing lot acceptance and outage sample sizes to be residual matters, as they underpin the safety case reliability. Taking into account that they are related to the same aspect of safety and are cumulative in their effect, I consider that they should be consolidated into a single **Assessment Finding**:

Assessment Finding CP-AF-AP1000-ME-05:

The licensee shall ensure that the reliability of the actuator and pyrotechnic components meet the claims within the safety case.

460. Closure of the **Assessment Finding** above should include, but not be limited to, consideration of the following:

- Manufacturing LAT (initiator and actuator) sample sizes should be justified against recognised standards. The sample size should be based on the safety case requirements for reliability.
- Outage sample sizes for actuator removal, replacement and test should be justified. This should take into account the novelty of the component, local and international operational experience as well as the claims in the safety case.
- Variable sample size regimes, initially high sample sizes reducing on provision of an evidence-based case.

461. I consider the lack of EIMT procedure to identify ageing and degradation of the initiator to also be a residual matter, as the initiator has been shown to be the more age and degradation-sensitive component of the actuator. I have raised the following **Assessment Finding** in respect to testing the initiator.

Assessment Finding CP-AF-AP1000-ME-06:

The licensee shall establish EIMT arrangements that identify ageing and degradation of the initiators in line with the safety case claims.

462. Closure of the **Assessment Finding** above should include, but not be limited to, consideration of the following:

- removal and separate testing of initiators, from actuators removed during an outage; and
- separate test samples from storage and operational conditions.

463. In addition to those aspects that relate directly to the actuator reliability / safety, I have identified a number of aspects of explosives handling listed below:

- Impact damage to the actuators, dropping of the actuator has been assessed in Action 7-4 above, but other potential causes of impact damage to the actuators have not been assessed.
- PPE requirements are identified within the documentation, but future arrangements must identify that the PPE for actuator handling are different and in addition to the normal PPE for maintenance.
- The use of grounding straps needs further substantiation, specifically the design and EIMT of the installed grounding points within the facility.

464. I expect the PPE and grounding aspects identified to be addressed as part of **normal business**, noting that specific regulations within ER2014 are likely to be applicable to this aspect of the safety case.

465. I am content that the safety case and evidence have provided suitable justification of the EIMT and surveillance at the current stage of the project, to address the intent of Action 7-5.

466. I have considered the following SAPs when making this judgement:

- EMT.1, 2, 3, 5, 6 and 7, relating to EIMT
- EAD.2, 3 and 4, relating to ageing and degradation

Judgement

467. I judge that from a mechanical engineering perspective Westinghouse has provided suitable arguments and evidence to justify that valve visual inspection and PCSR links are provided as required by this action.

468. In the case of continuity testing and EIMT / through life asset management, I have identified three **Assessment Findings** (**CP-AF-AP1000-ME-04, CP-AF-AP1000-ME-05 and CP-AF-AP1000-ME-06),** which require closure during licensing, but judge that the arguments and evidence provided mean that the current squib valve safety case is suitable for closure of the action at this stage.

469. I have considered the arguments and evidence in conjunction with the guidance provided by the SAPs identified above and the following TAGs (see Ref. 4):

- NS-TAST-GD-005 Guidance on Demonstration of ALARP
- NS-TAST-GD-009 Examination, Inspection, Maintenance and Testing of Items Important to Safety
- NS-TAST-GD-057 Design Safety Assurance
- NS-TAST-GD-077 Procurement of Nuclear Safety Related Items or Services
- NS-TAST-GD-098 Asset Management

470. Therefore, I judge that GI-AP1000-ME-01 Action 7 can be closed.

4.3 Overseas Regulatory Interface

471. ONR has formal information exchange agreements with a number of international nuclear safety regulators, and collaborates through the work of the International Atomic Energy Agency (IAEA) and the Organisation for Economic Co-operation and Development Nuclear Energy Agency. This enables us to use overseas regulatory assessments of reactor technologies, where they are relevant to the UK. It also enables the sharing of regulatory Assessment Findings, which can expedite assessment and helps promote consistency.

472. ONR also represents the UK on the Multinational Design Evaluation Programme (MDEP), which is a group of nuclear safety regulators engaged in the technical review of reactor technologies. This helps to promote consistent assessment standards, and enables the sharing of information.

473. In this assessment, the following information from overseas regulators has been used.

474. I have held discussions with the United States Nuclear Regulatory Commission (US NRC) regarding a number of aspects of the squib valve design. These mainly concerned the pyrotechnic selection, manufacture, testing and qualification. In addition, I have discussed the adequacy of the hydrostatic testing conducted on the squib valves and their compliance with design code requirements.

475. Information provided by US NRC inspectors has informed my assessment of the **AP1000** squib valves in these areas, although the US NRC's acceptance of the squib valve design has not influenced my judgement of the adequacy of Westinghouse's design and safety case.

4.4 Assessment Findings

476. During my assessment, I identified six items for a future licensee to take forward in its site-specific safety submissions.

477. These Assessment Findings relate to:

- further consideration of identified EIMT options and reduction of risk SFAIRP;
- further EQ testing on actuators;
- monitoring of the actuator thermal and environmental conditions to verify assumptions in the safety case;
- the site-specific electromagnetic environment being bounded by the EQ conditions;
- the methodology and equipment used for testing of the initiators being in line with RGP; and
- arrangements for through-life EIMT and asset management being commensurate with the safety case requirements.

478. Details of these are contained in Annex 1.

479. These matters do not undermine the generic safety submission and are primarily concerned with the provision of site-specific safety case evidence, which usually becomes available as the project progresses through the detailed design, construction and commissioning stages.

480. Residual matters are recorded as Assessment Findings if one or more of the following apply:

- site-specific information is required to resolve this matter;
- the way to resolve this matter depends on licensee design choices;
- the matter raised is related to operator specific features / aspects / choices;
- the resolution of this matter requires licensee choices on organisational matters;

- to resolve this matter the plant needs to be at some stage of construction / commissioning.

4.5 Minor Shortfalls

481. During my assessment, I identified one item as a minor shortfall in the safety case. This shortfall relates to the sequence in which the squib valves are removed for inspection. Details of this are also contained in Annex 1.

482. Residual matters are recorded as a minor shortfall if it does not:

- undermine ONR’s confidence in the safety of the generic design;
- impair ONR’s ability to understand the risks associated with the generic design;
- require design modifications;
- require further substantiation to be undertaken.

4.6 ONR Assessment Rating

483. I have rated my assessment outcome as adequate. In concluding this I consider that Westinghouse has provided evidence that:

- RGP is met for substantiating the squib valve concept and detailed design;
- for GDA, risks are judged to be reduced SFAIRP;
- Westinghouse has made commitments to address shortfalls with a licensee during site licensing and construction; and
- the quality of submissions improved through a significant level of proactive engagement.

5 CONCLUSIONS

484. This report presents the findings of the assessment of GDA Issue GI-AP1000-ME-01, squib valve concept and design substantiation, relating to the **AP1000** GDA closure phase.

485. I have identified six Assessment Findings that will require adequate resolution by a licensee during site licensing and/or construction.

486. I judge that Westinghouse has provided adequate arguments and evidence to close the seven GDA issue actions. In my opinion, Westinghouse has submitted appropriate, approved documentation that provides adequate arguments and evidence for its selection, equipment design, and associated system design for squib valves.

487. In summary, subject to a licensee adequately resolving the Assessment Findings listed within Annex 1, I am content that GDA Issue GI-AP1000-ME-01 Squib Valve Concept and Design Substantiation is closed.

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Annex 1

Assessment Findings to be Addressed During the Forward Programme – Mechanical Engineering

Assessment Finding Number	Assessment Finding	Report Section Reference
CP-AF-AP1000-ME-01	The licensee shall develop and implement an examination, inspection, maintenance and testing regime for squib valves using the options presented in the squib valve safety case (UKP-GW-GL-200) and considering site-specific aspects.	4.2.4
CP-AF-AP1000-ME-02	The licensee shall provide adequate equipment qualification evidence to fully substantiate the as-built squib valve actuator and its components, taking into account site-specific characteristics.	4.2.6 – Action 6-3.b 4.2.6 – Action 6-6 4.2.7 – Action 7-4
CP-AF-AP1000-ME-03	The licensee shall ensure that the environmental conditions of the actuators are monitored through-life, to verify assumptions that underpin the qualified service life.	4.2.6 – Action 6-3.b
CP-AF-AP1000-ME-04	The licensee shall ensure that the methodology and equipment used to test the continuity and resistance of the initiators is in line with relevant good practice.	4.2.7 – Actions 7-3.a, 7-3.b and 7-3.c
CP-AF-AP1000-ME-05	The licensee shall ensure that the reliability of the actuator and pyrotechnic components meet the claims within the safety case.	4.2.7 – Action 7-5
CP-AF-AP1000-ME-06	The licensee shall establish EIMT arrangements that identify ageing and degradation of the initiators in line with the safety case claims.	4.2.7 – Action 7-5

Minor Shortfalls Identified within Assessment Report

Minor Shortfall details	Report Section Reference
The licensee shall further consider the sequencing of squib valve removal, EIMT and replacement.	4.2.4