

NUCLEAR DIRECTORATE

GENERIC DESIGN ASSESSMENT – NEW CIVIL REACTOR BUILD

STEP 3 MECHANICAL ENGINEERING ASSESSMENT OF THE WESTINGHOUSE AP1000

DIVISION 6 ASSESSMENT REPORT NO. AR09/015-P

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EXECUTIVE SUMMARY

This report presents the findings of the mechanical engineering assessment of the Westinghouse AP1000 Pre-Construction Safety Report (PCSR) undertaken as part of Step 3 of the Health and Safety Executive's (HSE) Generic Design Assessment (GDA) process.

The Step 3 assessment process consists of examining the arguments and identifying the evidence in the Westinghouse submission relating to the mechanical engineering aspects, and assessing them against the expectations and requirements of the Safety Assessment Principles (SAPs), legislation, good engineering practice, internal Nuclear Directorate (ND) guidance and relevant information from external bodies, i.e. The Western European Nuclear Regulators' Association (WENRA) reference levels and The International Atomic Energy Agency (IAEA) standards and guidance.

The Step 3 aim for the mechanical engineering assessment is to:

- Review the level of design completeness.
- Assess relevant aspects of the safety case.
- Assess the scope and extent of claims and arguments presented.
- Consider whether the mechanical design aspects are likely to meet regulatory expectations.
- Consider overseas regulators' knowledge of the designs.
- Consider the scope of, and plan for, further assessments.
- Liaise with the Environment Agency to aid their public consultation process.

Mechanical engineering covers a broad range of equipment types, and the assessment approach up to and including Step 3 has been to review selected equipment based on our regulatory expectations in terms of their safety functions. The results of this assessment approach are reported in this Step 3 report. This assessment approach considers, and challenges, the safety function categorisation and equipment classification philosophies adopted by Westinghouse and draws conclusions as appropriate.

The assessment is to consider the Structures Systems and Components (SSCs) for their:

- Design completeness.
- Safety categorisation and classification.
- Design and reliability claims.
- Equipment Qualification and integrity to deliver their functionality.
- Capability to satisfy their safety functions in normal operations and in fault scenarios.
- Layouts, access, ingress and egress to enable: operations, inspections, testing, maintenance and equipment replacement to be carried out.
- Interfaces with other assessment topic areas.

At this stage of the GDA process good progress is being made in terms of reviewing the Westinghouse submission, and identifying issues and areas for more detailed review and discussion.

A number of Technical Queries have been raised, and responses received, which have been reviewed as part of the assessment process. Two technical meetings have been held at the Westinghouse offices in Pittsburgh, and further direct interactions have taken place via telephone conferences and technical meetings.

At this stage of the overall GDA process, the following three Regulatory Observations have been raised associated with this Westinghouse Submission:

- Regulatory Observation - RO-AP1000-036 - Squib Valve Concept and Design Substantiation, July 2009.
- Regulatory Observation - RO-AP1000-038 – Metrication of the AP1000 for the UK, July 2009.
- Regulatory Observation - RO-AP1000-043 – Nuclear Ventilation, September 2009.

The Regulatory Observation in respect of the Squib Valve Concept and Design Substantiation represents a particularly significant assessment finding at this time. I have significant concern regarding the present state of design and development, and programme for future work, in respect of this Squib Valve concept, used as part of the Passive Core Cooling System. I consider that Westinghouse needs to apply significant resource and attention to this area.

The Regulatory Observation in respect of Metrication is of interest across most assessment disciplines. I am generally satisfied with progress made to date regarding this issue from a mechanical engineering perspective, but will continue to review progress and draw conclusions as appropriate.

The Regulatory Observation in respect of Nuclear Ventilation has been raised recently, and has been developed in close consultation with the Environment Agency. I consider that Westinghouse needs to apply significant attention to this area, since nuclear ventilation systems and associated filtration arrangements play a fundamental part in protecting people, society, and the environment from the hazards of radiation.

The Westinghouse methodology of safety categorisation and classification is not in line with the UK Regulatory SAPs, which are principles that UK Regulators use to make regulatory judgements and provide fundamental guidance to carrying out an effective assessment.

At this stage the current Westinghouse methodology has proved to be an obstacle in carrying out an effective assessment.

Westinghouse is currently aligning the allocation of safety categorisation and classification to the UK SAPs. I consider this exercise requires expediting and completion on an urgent basis otherwise it will significantly impact the effectiveness of the GDA. Westinghouse has advised the updated documentation will be approved and issued in November 2009.

I consider the understanding and definition of the installation sequence of the RCS pump (chosen as an example due to its size, mass and location) to be at an early stage and a significant amount of design definition work may be required to be carried out to enable the regulatory expectations to be achieved.

However, a degree of confidence has been gained in the design process applied by Westinghouse. Sampled areas that provided this confidence included the:

- RCS pump, which included review of Westinghouse's supply chain and the visible evidence of a satisfactorily level of Quality Assurance.
- CRDMs and the development tasks that are being undertaken.
- Valve selection process, where documents assessed captured both operational experience and standardisation.

At this stage of the overall GDA process, no Regulatory Issues have been identified associated with the Westinghouse submission.

FOREWORD

Mechanical Engineering

In carrying out this assessment, the term 'mechanical engineering' encompasses structures, systems and components (SSCs) that generally contain dynamic elements and interfaces. This is to distinguish it from the discipline of structural integrity, which is concerned with SSCs which are static in nature, primarily focussing on containment pressure boundaries. Notwithstanding this definition, a number of static components will also be of interest to the mechanical engineering discipline, and subject to appropriate assessment.

Examples of dynamic components that are considered to be of interest include:

- Control Rod Drive Mechanisms.
- Pumps.
- Valves, (check valves, motor operated valves, squib valves, safety relief valves and containment isolation valves).
- Cranes.
- Mechanical handling systems.
- Nuclear Ventilation (HVAC).
- Diesel generators.

Examples of static components that are considered to be of interest include:

- Heat exchangers.
- Gloveboxes, cabinets.
- Transport packages.
- Stillages.
- Seals.
- Strainers.
- Component support structures.

Structural integrity aspects with reference to the containment pressure boundaries and containment vessel internals are not specifically considered or assessed under the mechanical engineering discipline. These aspects are the subject of assessment under the discipline of Structural Integrity and reported the in the assessment report covering that topic.

LIST OF ABBREVIATIONS

ALARP	As Low As Reasonably Practicable
BMS	(Nuclear Directorate) Business Management System
CRDM	Control Rod Drive Mechanism
EA	The Environment Agency
FEMA	Failure Modes and Effects Analysis
FWS	Feed Water System
GDA	Generic Design Assessment
HEPA	High Efficiency Particulate Air
HSE	The Health and Safety Executive
IAEA	The International Atomic Energy Agency
ILRT	Integrated Leak Rate Testing
IRWST	In-containment Refuelling Water Storage Tank
MDEP	Multi-national Design Evaluation Programme
MSLB	Main Steam Line Break
ND	The (HSE) Nuclear Directorate
NPP	Nuclear Power Plant
PCCS	Passive Core Cooling System
PCER	Pre-Construction Environment Report
PCSR	Pre-Construction Safety Report
P&ID	Piping and Instrumentation Diagram
RCP	Reactor Coolant Pump
RCS	Reactor Coolant System
RI	Regulatory Issue
RIA	Regulatory Issue Action
RNS	Normal Residual Heat Removal System
RO	Regulatory Observation
ROA	Regulatory Observation Action
RP	Requesting Party
RPV	Reactor Pressure Vessel
SAP	Safety Assessment Principle
SSCs	Structures, Systems and Components
TAG	(Nuclear Directorate) Technical Assessment Guide
TQ	Technical Query
WEC	Westinghouse Electric Company LLC
WENRA	The Western European Nuclear Regulators' Association

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Table 1 Summary of determination of the Westinghouse safety case in respect of mechanical equipment

Annex 1: Mechanical Engineering – Status of Regulatory Issues and Observations

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1 INTRODUCTION

1 This report presents the findings of the mechanical engineering assessment of the Westinghouse AP1000 Pre-Construction Safety Report (PCSR) (Ref. 1) undertaken as part of Step 3 of the HSE Generic Design Assessment (GDA) process. This assessment has been undertaken in line with the requirements of the Business Management System (BMS) document AST/001 (Ref. 2) and its associated guidance document G/AST/001 (Ref. 3). AST/001 sets down the process of assessment within the Nuclear Directorate (ND) and explains the process associated with sampling of safety case documentation. The Safety Assessment Principles (SAPs) (Ref. 4) have been used as the basis for the assessment of the PCSR associated with the Requesting Party (RP) submission. The SAPs set the regulatory expectation that all credible hazards on a nuclear power plant or nuclear chemical plant site are identified and considered in safety assessments. Ultimately, the purpose of assessment is to reach an independent and informed judgment on the adequacy of a nuclear safety case and associated design.

1.1 Assessment Scope

2 In carrying out this assessment, the term mechanical engineering encompasses structures, systems and components (SSCs) that generally contain dynamic elements and interfaces. This is to distinguish it from the discipline of structural integrity, which is concerned with SSCs which are static in nature, primarily focussed on containment of the relevant pressure circuit boundaries. Notwithstanding this definition, a number of static components will also be of interest to the mechanical engineering discipline, and have been assessed as appropriate.

3 Examples of dynamic components that are considered to be of interest include:

- Control Rod Drive Mechanisms.
- Pumps.
- Valves, (check valves, motor operated valves, squib valves, safety relief valves and containment isolation valves).
- Cranes.
- Mechanical handling systems.
- Nuclear Ventilation (HVAC).
- Diesel generators.

4 Examples of static components that are considered to be of interest include:

- Heat exchangers.
- Gloveboxes, cabinets.
- Transport packages.
- Stillages.
- Seals.
- Strainers.
- Component support structures.

5 Structural integrity aspects with reference to the containment pressure boundaries and containment vessel internals are not specifically considered or assessed under the mechanical engineering discipline. These aspects are the subject of assessment under the discipline of Structural Integrity (Ref. 6).

- 6 This assessment report formally records the mechanical engineering progress statement in support of the Generic Design Assessment (GDA) Step 3 against the Westinghouse Electric Corporation LLC AP1000 Design submission (Ref. 1).
- 7 It should be noted that the mechanical engineering topic was not specifically assessed during Step 2, and other disciplines did not raise any issues specifically related to the mechanical aspects during their Step 2 assessment work.
- 8 The objective of Step 3 is to move from examination of the fundamentals in terms of the claims made by Westinghouse, to assessing the engineering design, principally at the system level. This Step 3 assessment has been guided by analysis of Westinghouse supporting arguments to underpin their claims, and then moving into the identification of supporting evidence contained within the Westinghouse submission.
- 9 The Step 3 assessment process consists of examining the arguments and identifying the evidence in the Westinghouse submission relating to the mechanical engineering aspects, and assessing them against the expectations and requirements of the Safety Assessment Principles (SAPs) (Ref. 4), legislation, good engineering practice, internal ND guidance and relevant information from external bodies, i.e. WENRA reference levels (Ref. 7) and IAEA standards and guidance (Ref. 8).
- 10 The Step 3 aim for the mechanical engineering assessment is to:
- Review the level of design completeness.
 - Assess relevant aspects of the safety case.
 - Assess the scope and extent of claims and arguments presented.
 - Consider whether the mechanical design aspects are likely to meet regulatory expectations.
 - Consider overseas regulators' knowledge of the designs.
 - Consider the scope of, and plan for, further assessments.
 - Liaise with the Environment Agency to aid their public consultation process.
- 11 The principal deliverable from the mechanical engineering Step 3 assessment is a progress statement and further definition of the assessment scope going forward.
- 12 Site specific aspects and commissioning are excluded from the assessment during this Phase. This includes any aspects specifically associated with construction of the power station and site-specific operational matters; these aspects are to be considered during Phase 2.

2 NUCLEAR DIRECTORATE'S ASSESSMENT

2.1 Westinghouse Safety Case

- 13 A safety case is generally assessed by identifying the claims on structures, systems and components, and people, and then assessing the associated arguments and underpinning evidence. This assessment structure, which should be aligned to the safety case structure, is essentially a 'top down' approach and provides a logical framework to ensure that all hazards have been adequately identified and suitably addressed.
- 14 The nature of mechanical engineering, and associated mechanical engineering assessment, favours an alternative 'bottom up' type approach. In this case mechanical items important to safety are identified and then assessed on the basis of their safety function, categorised in functional terms as associated with either cooling, reactivity control, or containment.

- 15 Mechanical engineering covers a broad range of equipment types, and the assessment approach up to and including Step 3 has been to review selected equipment based on our regulatory expectations in terms of their safety functions. The results of this assessment approach are reported in this Step 3 report. This assessment approach considers, and challenges, the safety function categorisation and equipment classification philosophies adopted by Westinghouse, and draws conclusions as appropriate.
- 16 This assessment approach will further interface with the approach adopted by other disciplines, including coordination with the areas of Fault Studies and Probabilistic Safety Assessment, as well as Human Factors as necessary, to provide a holistic assessment in terms of claims, arguments and evidence covering mechanical engineering items important to safety.
- 17 Based on the above approach, the following table provides a summary of my determination of the Westinghouse safety case in respect of mechanical equipment, which has guided my assessment.

Table 1 - Summary of determination of the Westinghouse safety case in respect of mechanical equipment

No.	Primary Safety Function	SSCs	Safety Aspect
1	Reactivity Control	Control Rod Drive Mechanism (CRDM)	<p>Reactivity control is achieved by the control rods and the soluble boric acid chemical composition within the primary coolant.</p> <p>The CRDMs are of a design that allows a fast response to reactivity changes.</p> <p>Slow changes such as fuel burn up are compensated by a combination of mechanical means (gray rods) and boron concentration changes. Typically, the day-to-day fuel burn up is compensated by the gray rods, and boron concentration changes are made weekly.</p>
2	Reactivity Control	Emergency Makeup and Boration	Emergency addition of boric acid provides a diverse method of shutting down the reactor.
3	Heat transfer / Residual heat removal	Passive Core Cooling System (PCCS)	<p>The PCCS provides emergency core cooling during events that involve increasing and lowering of secondary side heat removal and the lowering of the reactor coolant system inventory.</p> <p>The system manages reactor core decay heat removal, addition of Boron to the RCCS and acts as the safety injection system following a LOCA.</p> <p>The passive core cooling system uses four different sources of passive injection during a LOCA.</p> <ul style="list-style-type: none"> • Accumulators provide a very high flow for a limited duration of several minutes. • The Core Makeup Tanks provide a relatively high flow for a longer duration. • The In-containment Water Storage Tank provides a lower flow, but for a much longer time. • The Containment is the final long-term source

No.	Primary Safety Function	SSCs	Safety Aspect
			<p>of water, which becomes available following the injection of the other three sources and the flooding of the containment.</p> <p>Pressure Operated Relief Valves protect the tanks from overpressure.</p>
4	Heat transfer / Residual heat removal	Component Cooling Water System & Service Water System	<p>Provides support to the RNS in cooling down the reactor during the second cool down phase.</p> <p>Removes heat from various components during plant operation and removes core decay heat and heat during reactor cooling and shutdown.</p>
5	Heat transfer / Residual heat removal	Plant Gas System	<p>Nitrogen gas system is a safety system. Nitrogen is required to operate the accumulators.</p>
6	Heat transfer / Residual heat removal	Chemical & Volume control System	<p>Provides borated makeup to the reactor coolant system following accidents such as small loss-of-coolant accidents, steam generator tube rupture events, and small steam line breaks.</p> <p>Safety related isolation of the reactor coolant system upon receipt of a high steam generator level signal or a high pressuriser level signal.</p>
7	Heat transfer / Residual heat removal	Reactor Coolant System	<p>During normal operations the RCS transfers the heat generated in the reactor to the secondary loop system.</p> <p>Following a shutdown or a loss of power, the pump flywheel provides the inertia to ensure adequate heat transfer capability and aids the process to establish a natural circulation flow.</p>
8	Heat transfer / Residual heat removal	Feed Water System (FWS)	<p>FWS is to be able to remove decay heat from the steam generators in a reactor trip scenario.</p>
9	Containment of radioactive substances	Passive Containment Cooling System	<p>Reduce the containment temperature and pressure following a LOCA or Main Steam Line Break (MSLB) accident.</p> <p>Serves as the means of transferring heat to the safety related ultimate heat sink for other events resulting in a significant increase in containment pressure and temperature.</p> <p>Capable of removing sufficient thermal energy including subsequent decay heat from the containment atmosphere following a design basis event.</p> <p>The passive containment cooling system provides a source of makeup water to the spent fuel pool in the event of a prolonged loss of normal spent fuel pool cooling.</p>

No.	Primary Safety Function	SSCs	Safety Aspect
10	Containment of radioactive substances	Containment Isolation	<p>Upon failure of a main steam line, the steam generators are isolated as required to prevent excessive cool down of the reactor coolant system or over pressurisation of the containment.</p> <p>Provide isolation, containment barrier integrity for fluid and gas systems.</p>
11	Containment of radioactive substances	Containment Isolation	To prevent an explosive atmosphere (hydrogen) following a LOCA.
12	Containment of radioactive substances	<p>Ventilation</p> <p>Annex / Aux building Non radioactive HVAC system</p> <p>Ventilation – Nuclear non radioactive vent system (VBS)</p> <p>Ventilation (Controlled area vent). (VAS)</p>	<p>Prevents the build-up of hydrogen in non-Class 1E battery rooms.</p> <p>Provides a contained atmosphere to allow personnel to occupy the control room in the event of a design base accident. (Positive pressure).</p> <p>Monitors the main control room supply air for radioactive particulate and iodine concentrations</p> <p>Isolates the HVAC penetrations in the main control room boundary on high-high particulate or iodine concentrations in the main control room supply air, or on extended loss of ac power to support operation of the main control room emergency habitability system.</p> <p>Provides a system to manage airborne radioactivity in the access areas at safe levels for plant personnel.</p> <p>Maintains the overall airflow direction within the areas it serves from areas of lower potential airborne contamination to areas of higher potential contamination.</p> <p>Prevents the uncontrolled release of airborne radioactivity to the atmosphere or adjacent clean plant areas.</p> <p>Automatically isolates selected building areas from the outside environment by closing the supply and exhaust duct isolation dampers and starting the containment air filtration system when high airborne radioactivity in the exhaust air duct or high</p>

No.	Primary Safety Function	SSCs	Safety Aspect
		<p>Radwaste Building HVAC system</p> <p>Diesel Generator Building Heating and Vent System</p> <p>Ventilation (Hot machine shop). (VHS)</p>	<p>auxiliary, or annex buildings to maintain these areas at a slightly negative pressure with respect to the adjacent areas when the radiologically controlled area ventilation system detects high airborne radioactivity or high pressure differential.</p> <p>Provides conditioned air to work areas to maintain acceptable temperatures for equipment and personnel.</p> <p>Provides confidence that air movement is from clean to potentially contaminated areas to minimize the spread of airborne contaminants. Collects the vented discharges from potentially contaminated equipment.</p> <p>Provides for radiation monitoring of exhaust air prior to release to the environment.</p> <p>Maintains the radwaste building at a negative pressure with respect to ambient to prevent unmonitored releases.</p> <p>Provides sufficient quantities of ventilation air to maintain acceptable temperatures within the generator rooms for equipment operation and reliability during periods of diesel generator operation in order for the onsite standby power system to perform its defence in depth functions. Provides suitable environmental conditions for equipment operation in each diesel generator electrical equipment service module under the various modes of diesel generator operation.</p> <p>Prevents the accumulation of combustible vapours and dissipate their concentration in the fuel oil day tank vault.</p> <p>Provides adequate heating and ventilation to maintain acceptable temperature within the diesel oil transfer module enclosures.</p> <p>Provides air movement from clean to potentially contaminated areas to minimize the spread of airborne contaminants.</p> <p>Collects the vented discharges from potentially contaminated equipment in the area.</p> <p>Provides for exhaust from welding booths, grinders and other miscellaneous equipment located in the hot machine shop.</p> <p>Provides for radiation monitoring of exhaust air</p>

No.	Primary Safety Function	SSCs	Safety Aspect
		<p>Habitability Systems (VBS & VES)</p>	<p>prior to release to the environment.</p> <p>Maintains the access control area and hot machine shop at a slight negative pressure with respect to outdoors and the clean areas of the annex building to prevent unmonitored releases of radioactive contaminants.</p> <p>Prevent uncontrolled release of airborne radioactivity to the atmosphere or adjacent clean plant areas.</p> <p>The habitability systems are capable of maintaining the main control room environment suitable for prolonged occupancy throughout the duration of the postulated accidents.</p> <p>A maximum main control room occupancy of up to 11 persons can be accommodated.</p> <p>The emergency habitability system maintains CO2 concentration to less than 0.5 percent for up to 11 main control room occupants.</p> <p>The habitability systems provide the capability to detect and protect main control room personnel from external fire, smoke, and airborne radioactivity.</p> <p>Automatic actuation of the individual systems that perform a habitability systems function is provided. Smoke detectors, radiation detectors, and associated control equipment are installed at various plant locations as necessary to provide the appropriate operation of the systems.</p>
13	Containment of radioactive substances	Component Cooling Water System	<p>Provide a barrier against leakage of fluid from primary containment and reactor systems.</p>
14	Containment of radioactive substances	Reactor Coolant System (RCS)	<p>During normal operations the RCS transfers the heat generated in the reactor to the secondary loop system.</p> <p>The RCS acts as the second containment barrier of defence following the fuel cladding.</p> <p>The Reactor Pressure Vessel (RPV) seal arrangement provides a containment barrier.</p> <p>The Pressure Operated Relief Valves limit the pressure within the RCS and minimise the possibility of high pressure transient during normal operations and cold over pressurisation transients during cold shut down conditions.</p>

2.2 Standards and Criteria

- 18 The approach is to carry out this assessment in accordance with :
- ND standards;
 - applicable SAPs;
 - guidance of the Technical Assessment Guides (TAGs).
- 19 This approach ensures the assessment provides a targeted, consistent and transparent consideration on the adequacy of the Westinghouse design.
- 20 The mechanical engineering assessment is to be carried out with the aid of a number of applicable SAPs, which are principles against which regulatory judgements are made and provide fundamental guidance in scoping an assessment topic and in carrying out an effective assessment.
- 21 Generally SAPs capture the requirements of WENRA reference levels and the IAEA Standards Series requirements. If a requirement is not found to be covered by a SAP the assessor will include the requirement within the assessment (Ref. 5).
- 22 It is worth noting, the nature of the mechanical engineering discipline often drives the assessment down to component level. Assessment at this component level can be extremely wide ranging given the very large number of such components, with numerous interfaces, across various plant process systems and covering several disciplines. As a consequence, a wide range of SAPs and TAGs can be applicable to carrying out an effective assessment. The approach to carrying out an effective sampled assessment is to select the most appropriate SAPs and TAGs to a particular selected mechanical engineering aspect.
- 23 The assessment of mechanical engineering aspects is guided by this selection of relevant SAPs. In making a judgment on whether a SAP is applicable to a mechanical engineering aspect, consideration is given to the following factors:
- Key Principles.
 - Safety Categorisation, Classification and Standards.
 - Design and Reliability.
 - Maintenance, Inspection and Testing.
 - Layout.
 - Pressure Systems.
 - Integrity of metal Components and Structures.
 - Safety Systems.
 - Containment and Ventilation.
- 24 Annex 2 Table A2.1 lists and interprets the SAPs that are considered applicable to carrying out an effective mechanical engineering assessment.
- 25 Annex 2 Table A2.2 lists the TAGs that are considered applicable to carrying out an effective mechanical engineering assessment.

2.3 Assessment Methodology

- 26 The assessment methodology for executing the assessment was to carry out the assessment in accordance with the Project Implementation Document (Ref. 5).

- 27 The Assessment was carried out on a sampling basis, dictated by consideration of risk and hazard significance, in coordination with the other assessment disciplines and early mechanical engineering assessment findings. The assessment has focused on the primary safety functions identified from within the Westinghouse submission, as described in Table 1. The GDA sampling policy requires the whole design to be considered, and then assessment targeted on specific areas based on considerations of their hazard and risk.
- 28 The initial assessment was to briefly assess the 'Fundamental Safety Overview' and the claims being made within the Westinghouse submission.
- 29 With resource and programme constraints, the assessment policy focus on the primary safety functions that manage the:
- Reactivity control.
 - Heat transfer and removal.
 - Containment of radioactive substances.
- 30 The progress statement has been prepared from:
- Reading the appropriate chapters of the Westinghouse PCSR submission.
 - Holding the appropriate technical discussions with interfacing disciplines.
 - Consideration of international acceptable standards.
 - Consideration of operational data and findings.
 - Consideration of other regulators' findings.
 - Raising and issuing of Technical Queries, followed by assessment of Westinghouse responses.
 - Holding the necessary technical meetings to progress the identified lines of enquiry.
- 31 The assessment considered the Structures Systems and Components (SSCs) for their:
- Design completeness.
 - Safety categorisation and classification.
 - Design and reliability claims.
 - Equipment Qualification and integrity to deliver their functionality.
 - Capability to satisfy their safety functions in normal operations and in fault scenarios.
 - Layouts, access, ingress and egress to enable: operations, inspections, testing, maintenance and equipment replacement to be carried out.
 - Interfaces with other assessment topic areas.
- 32 The assessment was carried out in accordance with the ND standards against the applicable SAPs and with the guidance of the Technical Assessment Guides (TAGs).
- 33 The GDA of the Westinghouse submission has been undertaken across 15 key topic areas. As part of the coordination of the assessment process, discussion with the technical leads in each of the key areas has been undertaken as necessary.
- 34 The GDA has reviewed the overall safety of the design. The PSA has been undertaken to identify the reliability claims on each SSC and the Deterministic Safety Analysis (Fault Studies) has been undertaken to identify the equipment performance required by the safety case.

2.4 Design Status

- 35 As part of my assessment it was necessary to understand the design status of mechanical SSCs that are important to safety to enable an effective mechanical engineering assessment to be scheduled and carried out.
- 36 I identified the listed SSCs to be of a regulatory interest, due to their correlation with the primary safety functions (Table 1):
- Control Rod Drive System (CRDM).
 - Reactor Coolant System (RCS).
 - Compressed Air System.
 - Nuclear Island HVAC System.
 - Cranes and Handling Systems.
 - Transport Packages.
 - Building Layouts, provision of ingress and egress routes for the replacement of mechanical items that are important to safety.
- 37 The concept design for the above SSCs is complete. The areas of exception are as follows:
- Squib valve concept designs, which form an integral part of the RCS.
 - Functional testing of the RCS canned pump.
 - Transport packages.
- 38 My assessment of mechanical engineering aspects is recorded under individual specific SSCs. It is worth noting the lack of available design definition and qualification associated with the squib valve has significantly limited the assessment of the component. Regulatory Observation RO-AP1000-36, (Ref. 9), captures the shortfall in design substantiation that supports the squib valve concept.

2.5 Design Process

- 39 Westinghouse needs to demonstrate that mechanical items important to safety follow a robust design process. A robust design process provides the evidence and the auditable trail that items important to safety will achieve their design intent.
- 40 My assessment process has involved reading the Westinghouse submission, the issue of Technical Queries and undertaking technical meetings to inform a progress statement.
- 41 My assessment considers:
- The techniques and tools utilised to ensure the safety requirements are clearly identified, categorised, classified, cascaded and substantiated throughout the project life cycle with an adequate audit trail.
 - That good engineering practice is captured in the mechanical design from the generation of the concept and through the project life cycle.
 - The management of plant and equipment layout and interfaces.
- 42 As a specific example, I identified the valve design selection process as an area for more detailed assessment. Mechanical valves have important safety functions in Nuclear Power Plants and I therefore considered it appropriate to target my assessment in this area. This equipment is discussed later in this report.

2.5.1 Safety Categorisation and Classification

- 43 In the Westinghouse submission, the Safety Classification of mechanical components is in accordance with the US NRC regulations methodology.
- 44 The Westinghouse methodology states that engineered safety systems are designed to establish and maintain safe shutdown conditions for the plant. Non-safety related systems are not required for safe shutdown of the plant. The application of this philosophy typically allocates a non-safety equipment classification to a mechanical SSC that requires an AC power supply to operate, or an SSC that has a supporting safety role.
- 45 The Westinghouse methodology is not in line with the UK Regulatory SAPs, which are principles that UK Regulators use to make regulatory judgements and provide fundamental guidance to carrying out an effective assessment.
- 46 At this stage the current Westinghouse methodology has proved to be an obstacle in carrying out an effective assessment.
- 47 Westinghouse is currently aligning the allocation of safety categorisation and classification to the UK SAPs. I consider this exercise requires expediting and completion on an urgent basis, otherwise it will significantly impact the effectiveness of the GDA. Westinghouse has advised the updated documentation will be approved and issued in November 2009.
- 48 Assessment of mechanical items' safety functional requirements are captured under individual mechanical items assessment areas, reported later in this document.
- 49 At this stage my assessment is on hold, further consideration will be given to:
- Assessment of the Safety Categorisation and Classification arrangements, once the methodology is in line with the UK SAPs.
 - i) The Safety Categorisation and Classification for the squib valve concept is captured under Regulatory Observation RO-AP1000-36, (Ref. 9).
- 50 At this stage of the overall GDA process, no other Regulatory Observations, or Regulatory Issues have been identified in this area.

2.5.2 Transfer of Safety Requirements through the Project Life Cycle

- 51 At the 1st mechanical engineering technical meeting Westinghouse presented how design requirements are captured and transferred through to the supply chain via their procurement design specifications.
- 52 I noted the design specifications:
- identify the component design and safety criteria;
 - are issued to the supply chain;
 - identify deliverables which provide Westinghouse an opportunity to review and endorse the design substantiation, and certify it achieves the design intent.
- 53 Safety functions are typically specified at an assembly level and are not broken down to the detailed component level.
- 54 I conclude the presentation demonstrated satisfactory arrangements in principle for transferring requirements to the supply chain.
- 55 Using the squib valve concept as a specific example, further consideration will given to the:
- Process for identifying safety functional requirements at the detailed level.

- Process for transferring the detailed safety functional requirements through the project life cycle.

56 Additional assessment findings are captured under individual component assessment areas.

2.5.3 Good Engineering Practice

57 At the 1st technical meeting, Westinghouse presented the process that is followed to verify and approve design specifications.

58 Evidence of the process being followed was noted with the availability of an approved design specification and supporting procedures (Refs 10 to 11).

59 My assessment of Mechanical Design Criteria, (Ref. 12), considered that a high level of standard criteria is implemented across the mechanical engineering equipment.

60 My assessment has identified that the Westinghouse AP1000 design is based on imperial units. This aspect has an impact on several assessment disciplines, and not just mechanical engineering. ND expects any AP1000 facility built in the UK to be of a design based on SI units. Regulatory Observation RO-AP1000-038, (Ref. 13), captures the shortfall of the design being based on imperial units.

61 Further consideration will be given to the understanding of the mechanical engineering items important to safety that will require redesigning and the items that will have their imperial units transformed to SI units.

62 Additional assessment findings against good engineering practice will also be captured under individual component assessment areas.

63 At this stage of the overall GDA process, no other Regulatory Observations, or Regulatory Issues have been identified in this area.

2.5.4 Layout / Interfaces

64 The layout of mechanical plant and equipment can affect the safety of plant. I have considered the adequacy of ingress and egress provision for carrying out inspection, maintenance, replacement and testing of mechanical items that are important to safety.

2.5.4.1 RCS Pump

65 Due to the RCS pump size, mass and location within the plant I selected the replacement sequence, as an area for initial review. The assessment process involved undertaking a technical meeting on the installation sequence of the RCS pump to inform the regulatory progress statement as part of the Step 3 review.

66 From the Westinghouse presentation of the installation sequence of the RCS pump, I consider the understanding and definition of the sequence to be at an early stage and a significant amount of design definition work may be required to be carried out to enable the regulatory expectations to be achieved.

67 In conclusion the assessment also considers:

- The manoeuvring of such a large, bulky and heavy component in the allocated space to be a significant undertaking.
- Conventional safety regulations are applicable and pertinent to this activity in the UK, (e.g. CDM, LOLER and the Confined Spaces Regulations).

2.5.4.2 3D Model

- 68 At the 1st technical meeting Westinghouse presented an overview of their computer 3D model, which is used to support their design process. The model, although not verified, is utilised to develop the NPP design, and to understand interfaces and space management aspects.
- 69 The presentation demonstrated a 3D model is a useful aid in support of developing NPP design concepts, understanding interfaces and space management aspects.
- 70 At this stage of the overall GDA process, no Regulatory Observations or Regulatory Issues have been identified in this area.

2.6 Specific Structures, Systems and Components

- 71 Based on the stated assessment methodology, assessment is being carried out on a sampling basis, dictated by consideration of risk and hazard significance. Table 1 identifies the SSCs that I consider support the primary safety functions of:
- Reactivity control.
 - Heat transfer and removal.
 - Containment of radioactive substances.
- 72 The following Structures, Systems and Components have therefore been identified for specific mechanical engineering assessment during Step 3, and this is reported as follows.

2.6.1 Control Rod Drive Mechanisms

- 73 Control Rod Drive Mechanisms (CRDMs) have an important safety function of controlling the core reactivity (Table 1) and are therefore an area of regulatory interest.
- 74 Against the background that CRDMs are of an established principle of design and with significant operational experience within NPPs around the world, my assessment philosophy is to focus on the:
- Safety design improvements, associated claims, arguments and evidence.
 - Safety categorisation and classification.
- 75 My assessment considered the CRDM latch assembly as being a particular item important to safety and should therefore be categorised and classified accordingly. Initial assessment of the safety documentation did not substantiate this aspect to my satisfaction.
- 76 The latch unit is located within the lower part of the pressure housing. It is the actual component, which converts the magnetic forces generated by the coils, located outside the pressure housing into sequences of mechanical motion. In principle, it consists of three armatures which alternatively engage two groups of latches into the grooves of the drive rod, thus holding the RCCA in position or moving it up or down to manage reactivity control.
- 77 At the 1st mechanical engineering technical meeting held 7th May 2009 Westinghouse presented an overview of the CRDM design, incorporated design improvements and the current design life testing programme. In addition discussions took place on the classification of the latch.
- 78 Westinghouse confirmed that a design change notice has been raised to allocate the appropriate Categorisation and classification to the latch mechanism.

- 79 I noted that several aspects of the CRDMs have been the subject of review, with the aim of improving the CRDM design and understanding the design life limits.
- 80 Examples of aspects under review include:
- Assessment of alternative materials to Stellite to reduce worker doses and discharges.
 - Design life functional tests and testing to failure to understand the limiting aspects of the design.
- 81 A CRDM test trial is in progress, and uses representative process parameters. The trial up to the 7th May 2009 has shown the CRDM to:
- complete 6.4 million cycle steps;
 - achieve a drop time significantly less than 150 milliseconds on 300 occasions.
- 82 The trial is now continuing until the CRDM fails. At the end of the test the CRDM assembly is to be dismantled, inspected, with the findings recorded in a formal report.
- 83 I also noted and considered from the presentation that:
- an acceptable design process is being followed in carrying out the research;
 - the CRDMs are of a established design;
 - reliability is underpinned from historical operational data and from carrying out the research trials;
 - design improvements are typically of a minor nature.
- 84 My assessment is ongoing, however, assessment to date has provided confidence that the CRDM is following a satisfactorily design process.

2.6.2 Valves

85 Several valves have important safety roles and functions in managing:

- Reactivity control.
- Heat transfer and removal.
- Containment of radioactive substances.

The types of valves supporting these roles include:

- containment isolation valves;
- check valves;
- motor operated isolation valves;
- squib valves;
- safety relief valves.

2.6.2.1 Valve Selection Process

86 I selected the Passive Core Cooling System as a system contains several valves, of various types, which are important to safety.

87 At the 1st. mechanical engineering technical meeting Westinghouse presented an overview of the process that is utilised for the selection of a particular valve type.

- 88 The Westinghouse valve selection process has evolved with time. Historically individual project design engineers selected a valve type based on their engineering judgement. For the development of the AP600 Nuclear Power Plant (NPP) design, Westinghouse generated a Valve Selection Guide (Ref. 14) with the purpose of introducing standardisation across future NPP designs, such as the AP1000, and to capture operational experience across existing NPPs.
- 89 In addition, Westinghouse presented a document covering the Mechanical Design Criteria, (Ref. 12). This document presents the high level design criteria that are considered by project design engineers during the development of a mechanical component design concept, and which includes valves.
- 90 My assessment is ongoing, currently awaiting the issue of a number of references to progress the subject area further. Initial assessment has provided confidence in a satisfactory principle for the selection of valve type, and documents assessed capture operational experience and standardisation aspects.
- 91 The selection process of the squib valve is captured under Regulatory Observation RO-AP1000-036, (Ref. 9), and is described later in this report.
- 92 At this stage of the overall GDA process, no other Regulatory Observations or Regulatory Issues have been identified in this area.

2.6.2.2 Containment, Isolation Valves

- 93 My assessment looked at the valve arrangement that provides the containment, and isolation requirements between the Reactor Coolant System and the Passive Core Cooling Safety Injection System process lines. The Piping and Instrumentation Diagram (Ref 1 Fig. 6.3-2) identifies the isolation and containment requirements being achieved by each of four branches incorporating two valves of different types, a squib valve and a check valve positioned in series. Each of these valves is assigned with a safety class 'A'.
- 94 The Piping and Instrumentation Diagram (P&ID) also identifies a test and drain line incorporated within the design, located between the two containment/isolation valves. Each test and drain line contains an isolation valve and a blank flange to achieve the containment / isolation requirements. Each of these valves is assigned with a safety class 'B'. With the components in question forming part of the reactor coolant system pressure boundary, my regulatory expectation is that the test and drain line components should also be assigned with an 'A' classification.
- 95 'A' classification is assigned to SSCs that forms part of the reactor coolant system pressure boundary. 'B' classification is a lower classification and is assigned to SSCs that limits the leakage of radioactive material from the containment following a design basis accident.
- 96 This topic was discussed at the 1st technical meeting and Westinghouse stated that their design process had identified the incorrect assignment of classification, and the necessary documentation is the subject of an update to capture the change.
- 97 At this stage of the overall GDA process, no Regulatory Observations or Regulatory Issues have been identified in this area.

2.6.2.3 Check Valves

- 98 My assessment identified the 'In-containment Refuelling Water Storage Tank' (IRWST) as containing check valves (PXS-PL-V124 A/B) assigned with an 'A' classification.

- 99 The assigned 'A' classification is in line with Westinghouse classification methodology i.e. where an item forms isolation of the RCS pressure boundary it is assigned an 'A' classification.
- 100 Westinghouse is currently aligning the allocation of safety categorisation and classification in line with the UK Regulator expectations.
- 101 Assessment to date has only seen safety functional requirements identified at an assembly level. I have not seen evidence of safety functional requirements specified at a detailed component level or evidence of how the safety function is achieved.
- 102 Operational experience of Sizewell "B" NPP has indicated non return valves are reliable at achieving their design criteria. When the passing of a valve is a potential issue, the design typically incorporates two non return valves in series. Experience has only found components being subject to excessive wear when the process flow fluctuates, which causes the valve seat to flap excessively throughout the process cycle.
- 103 At this stage of the overall GDA process, no Regulatory Observations or Regulatory Issues have been identified in this area.

2.6.2.4 Squib Valves

- 104 The primary purpose of the squib valves is to support the Passive Core Cooling System both during normal operations where their duty is to maintain the primary circuit pressure boundary, and during a fault scenario where their duty is to open on demand as part of the reactor core residual heat removal system.
- 105 The use of a squib valve concept is unusual for the nuclear industry and there is limited history of squib valves of this size.
- 106 As the squib valve principle is fundamental to the Westinghouse Passive Core Cooling Safety System, I consider the need to comprehensively understand and assess the principle in adequate depth to substantiate my assessment consideration.
- 107 My assessment to date of the squib valve design has identified insufficient design substantiation available to meet the UK Regulatory expectations. A Regulatory Observation with nine associated Regulatory Observation Actions has been issued (Ref. 9) to address the assessment finding.

The Regulatory Observation highlights the need for more evidence to be provided in the following areas:

- Safety Classification and Standards.
 - I expect Westinghouse to demonstrate a full understanding of the safety functions of each aspect of the valve, clearly defining the safety criteria for each function and provide the evidence that the safety criteria is achieved, when considered against the allocated Category and Classification.
- Reliability.
 - I expect Westinghouse to: demonstrate that the design has followed the necessary design process commensurate with its safety significance, that the failure modes and risks are fully understood and are either eliminated, mitigated or adequately managed; carry out adequate analysis both theoretical and physical to attain sufficient evidence that all aspects are able to achieve their reliability claims and to achieve the associated safety category and classification.

- Redundancy, Diversity & Common Cause Failure.
 - I expect Westinghouse to: demonstrate that the design has followed necessary design process, that the failure modes and risks are fully understood and are either eliminated, mitigated or adequately managed; carry out adequate analysis both theoretical and physical to attain sufficient evidence that all aspects are able to achieve their design intent, with satisfactory margins, redundancy, diversity and common cause failure considerations as necessary to attain the required safety category, classification of the component and subcomponents to achieve the safety function of the overall system.

- Margins.
 - I expect Westinghouse to: demonstrate a definitive understanding of the operational margins associate with each sequence and the component as a whole; provide the substantiation, arguments and evidence that underpins the evaluation.

- Design.
 - With the squib valve concept at present being at an early phase of development, there are several aspects that cannot be adequately assessed due to lack of design definition.
 - Several aspects will require to be considered for assessment once the design is at a significant level of maturity, such aspects include but not limited to:
 - That the design can sustain the design loads.
 - Material selection.
 - Integrity of sub components.
 - Material compatibility.
 - Standards and codes.
 - Availability of suppliers.
 - Design life.
 - Defence in depth.
 - Associated external and internal hazards.
 - I expect Westinghouse to provide the evidence that the above aspects achieve their design intent with sufficient margins, redundancy and diversity to attain the safety classification of the component and the associated system.

- Defence in Depth, Fault Tolerance.
 - I expect Westinghouse to demonstrate that the design has followed the necessary design process; the failure modes and risks are fully understood and are either eliminated, mitigated or adequately managed. The design substantiation is required to demonstrate how the design has evolved to be sufficient fault tolerant, incorporates adequate defence in depth and has been fully substantiated against each safety function to achieve its safety category and classification.

- Ageing, Degradation & Obsolescence.
 - I expect Westinghouse to demonstrate a full understanding, substantiated with sufficient evidence that shows the component is able to meet its design life with sufficient margins and describe an inspection regime that underpins the associated safety functions.

- Maintenance, Inspection and Testing.
 - I expect Westinghouse to demonstrate a full understanding and provide the substantiation of the examination, maintenance, inspection and testing requirements for the valve.
- Component Integrity.
 - I expect Westinghouse to demonstrate with sufficient evidence that the necessary level of integrity has been achieved for the bounding scenario, this should consider:
 - The use of sound design concepts and proven design features.
 - Detailed design loading specification covering normal operation, plant transients, faults and internal and external hazards.
 - Consideration of potential in-service degradation mechanisms.
 - Analysis of the potential failure modes for all conditions arising from design specification loadings.
 - Material substantiation.
 - Application of necessary high standards of manufacture, including manufacturing inspection and examination.
 - Necessary high standards of quality assurance.
 - Pre-service and in-service examination to detect and characterise defects at a stage before they could develop to cause gross failure.
 - Defined limits and conditions of operation to ensure the component is operated within the limits of the safety case. Where appropriate, limits and conditions of operation should be supported by protection systems.

108 As the squib valve design is an unusual and novel concept, and one that has not been utilised in previous NPP designs in such a role, the Multi-national Design Evaluation Programme (MDEP) has shown interest in it. I attended an MDEP meeting, which discussed the squib valve concept in September 2009.

109 At the MDEP meeting, a squib valve subgroup was formed with the aim of:

- Participating regulators providing an update of their assessment status and findings.
- Sharing knowledge and understanding of issues that are associated with the squib valve principle.
- Initiating, and developing a technical guideline of the design considerations when carrying out an assessment on an explosive actuated (squib) valve.

110 The technical guideline, although draft in status, is evolving with the following design considerations:

- Basis for use of squib valves versus alternative valve types.
- Identification of safety functions.
- Categorisation and classification of safety functions.
- Determination of Environmental parameters.
- Specification of Codes and Standards to be satisfied.
- Evaluation of design to deliver the safety functions through techniques such as a Failure Modes and Effects Analysis (FMEA).
- Establishment of qualification process to support the required reliability claims for the safety functions.
- Establishment of Qualified Life (operating hours, actuations, shelf life, and any post-accident life).

- Determination of Inspection/Testing/Maintenance Requirements.

- 111 I consider the MDEP forum reinforced my issues and expectations as described within my Regulatory Observation, RO-AP1000-36 (Ref. 9).
- 112 My assessment is in progress with the squib valve being of particularly high interest with its new nuclear application and design status.
- 113 The Regulatory Observation in respect of the Squib Valve Concept and Design Substantiation represents a particularly significant assessment finding at this time. I have significant concern regarding the present state of design and development, and programme for future work, in respect of this Squib Valve concept, used as part of the Passive Core Cooling System. I consider the Requesting Party needs to apply significant resource and attention to this area.
- 114 To date Westinghouse has not achieved any programme delivery dates associated with the RO actions. I consider there is a high risk that Westinghouse underestimates the depth of the issue, the resource and effort that is required to closeout the actions to my satisfaction. I also consider Westinghouse's ability to close out the squib valve actions during the GDA timeframe is now on the critical path.
- 115 Due to the significance of the issues raised, I will continue to carrying out assessment in this area with further consideration to the:
- Safety Categorisation and Classification, once the methodology is in line with the UK Regulatory expectations.
 - Progressing with evidence that supports the assessment and closing out Westinghouse RO actions.
 - Arguments and evidence that support the squib valve design and equipment classification.
 - MDEP findings and recommendations.
- 116 At this stage of the overall GDA process, one Regulatory Observation but no Regulatory Issues have been identified in this area.

2.6.2.5 Safety Relief Valves

- 117 The safety relief valves used within the primary circuit and the secondary circuit are important areas for regulatory attention. In particular, the claims and arguments in respect of these safety relief valves are important in regard to the frequency of spurious opening, the reliability of operation on demand (expressed as a probability of failure on demand), and the reliability of re-seating following operation.
- 118 As part of the sampling process undertaken (which is intrinsic to the assessment process), I identified the following safety relief valves for initial consideration:
- the spring loaded safety relief valve design used on the primary circuit pressuriser;
 - the low temperature over pressure protection safety relief valve design used in the suction line of the normal residual heat removal system;
 - the safety relief valve design used in the main steam line on the secondary side.
- 119 Technical Queries (TQs) were raised in early July 2009 to seek arguments and evidence in relation to the recent operational experience of these valve types. The responses to these Technical Queries have been reviewed as part of the assessment process, and the following conclusions have been drawn appropriate to this stage of the overall GDA process:

- Westinghouse has provided a technical description and explanation of the operation and design of the spring-loaded safety relief valves used on the primary circuit pressuriser. They have stated that the safety relief valve design configuration has been used on most Westinghouse PWRs, and they have performed an Operational Experience Feedback (OEF) search on the Institute of Power Operations (INPO) database. They have only identified issues (within the last five years) relating to valve seat leakage, and set-point drift, (the pressure at which the valve rapidly opens). Westinghouse has explained that these issues are addressed as part of the Equipment Qualification arrangements applied to the valve supplier. Westinghouse has also stated that no issues relating to spurious actuation, reliability of opening on demand, and failure to re-seat after actuation were identified. I am satisfied with Westinghouse responses at this stage, and consider the identified issues with leakage and set point drift can be adequately addressed through a sufficient Equipment Qualification regime, and associated in service maintenance and testing.
- Westinghouse has provided a technical description and explanation of the spring-loaded safety relief valve used in the suction line of the normal residual heat removal system. They have stated that past operating experience has demonstrated that this valve type is adequate for the intended application. They have also performed an OEF search on the INPO database covering the past five years, and have identified no issues relating to spurious actuation, reliability of opening on demand, and failure to re-seat after actuation were identified. I am satisfied with Westinghouse responses at this stage.
- Westinghouse has provided a response in respect of the main steam safety relief valves, and has also performed an OEF search on the INPO database covering the past five years. This has identified issues in relation to set point drift. Westinghouse has explained that these issues are addressed as part of the Equipment Qualification arrangements applied to the valve supplier. They have also stated that the valve design must have significant operating experience in nuclear plants. I am satisfied with the Westinghouse response at this stage.

120 I have also requested a copy of the overpressure protection report which has been prepared according to Article NB-7300 of Section III of the ASME Code, which is referenced in the Requesting Party submission, and which has now been provided.

121 At this stage of the overall GDA process, no Regulatory Observations or Regulatory Issues have been identified in this area.

2.6.3 Reactor Coolant System Pump

122 The role of the reactor coolant pump (RCP) is important to safety for managing the primary safety functions of :

- Reactivity control.
- Heat transfer and removal.
- Containment of radioactive substances.

123 My assessment has taken into consideration responses to Technical Queries, discussions from technical meetings, information relating to operational experience and a visit to the pump manufacturer.

124 The pump is of a canned type design where the internals are contained within the pump casing. Westinghouse considers this design philosophy is a design improvement to a conventional seal type pump as it eliminates the pressure boundary seal and the supporting active seal injection system. The design therefore eliminates a potential LOCA at the seal. However, I consider access to carry out inspection and maintenance

is more demanding due to components being located within the canned containment housing. In addition, components that are located within the canned containment housing are subject to an increase in radioactive contamination, due to their direct contact with the RCS liquor.

- 125 The adoption of the canned pump design removes the pressure boundary seal and support systems, which is consistent with the Westinghouse 'Passive' safety philosophy.
- 126 From the presentation and the visit to the pump manufacture I consider that both organisations have a high level of confidence in the proposed design. The level of confidence is achieved from the:
- Manufacturer experience, designing and manufacturing similar type of pumps for over fifty years for nuclear applications.
 - Operational experience gained over the last fifty years.
 - Design criteria and constraints being within the existing design knowledge envelope.
- 127 I noted the over-speed flywheel tests have been successfully carried out, demonstrating the design is acceptable in this respect. I note that the change in the flywheel material from depleted Uranium to Tungsten was introduced on commercial grounds.
- 128 The pump manufacturer has constructed a dedicated test loop to functionally test and demonstrate the proposed AP1000 pump against represented process parameters. The testing programme is scheduled to be carried out over a 68 week period, with the latter 34 weeks assigned for incorporating any learning from experience from the initial functional tests.
- 129 A tour of the pump manufacturer has provided me with an initial satisfactory level of confidence in their competence and ability to deliver such a significant item that is important to safety.
- 130 Assessment of the RCP heat exchanger may be subject to separate assessment as considered appropriate during further assessment.
- 131 A canned pump has a number of advantages over a pump design that contains a seal system, although the principle introduces some disadvantages as noted above. However, I consider that a canned pump is an acceptable principle.
- 132 At this stage of the overall GDA process, no Regulatory Observations or Regulatory Issues have been identified in this area.

2.6.4 Cranes

- 133 The cranes utilised throughout the proposed nuclear facility are important areas for regulatory attention. A number of faults are worthy of consideration in respect of cranes which are used for nuclear use, which can challenge the safety functions of cooling, criticality control, and containment. For cranes which are located inside buildings, typical faults are associated with the load path (with the potential to lead to dropped or suspended loads), including double blocking, snagged loads, ledged loads, rope failures, gearbox and motor failures, failures associated with the braking systems and failures associated with the control and protection systems. A common feature for cranes required to undertake nuclear lifts, is that they are 'single failure proof', such that no single failure will result in loss of capability of the system to retain the load. Dual rope systems are also commonly employed as part of achieving this criterion, with energy absorbing systems incorporated into the designs as necessary. Furthermore, cranes are commonly de-rated against their industrial code capacity as a specific safeguard to minimise the probability of failure.

- 134 As part of the Step 3 assessment, I have asked a number of Technical Queries relating to cranes identified within the facility as having a significant nuclear use. Specifically queries have been asked in relation to the Refuelling Machine and Fuel Handling Machine (within the light load handling system), and the Polar Crane and the Cask Handling Crane (within the heavy load handling system).
- 135 The responses to these Technical Queries have been reviewed as part of the assessment process. I am satisfied at this stage with the response received in respect of the:
- Safety factors in the wire ropes used in the light load handling system.
 - Energy absorbing systems for the heavy load handling systems.
 - Braking systems for the re-fuelling machine, the fuel handling machine, the polar crane and the cask handling crane.
- 136 I note the response in respect of the re-fuelling machine and fuel handling machine being non-single failure proof. I may consider further assessment in this area.
- 137 I note the response in respect of control and protection for the re-fuelling machine, the fuel handling machine, the polar crane and the cask handling crane. I may consider further assessment in this area.
- 138 At this stage of the overall GDA process, no Regulatory Observations or Regulatory Issues have been identified in this area.

2.6.5 Nuclear Ventilation (HVAC)

- 139 Nuclear ventilation systems have an important nuclear safety function in terms of supporting containment of nuclear material, by ensuring that air movements and discharges are adequately directed and filtered to reduce doses to operators and the public under both normal and accident conditions. Nuclear ventilation systems commonly use HEPA (High Efficiency Particulate Air) filters on the discharge line to capture airborne particulate containing radioactivity, as a means of minimising discharges to meet statutory requirements including the ALARP principle. Ventilation also plays an important role in ensuring the habitability of the nuclear facility under normal and accident conditions, with a specific focus on the habitability of the Main Control Room under accident conditions. The principles of nuclear ventilation are well understood, and as a matter of principle, for dynamic containment, there should be a cascade of air flow from areas of lower to those of higher potential contamination, to control the spread of contamination throughout the facility, and to support the correct segregation of areas from a worker dose perspective.
- 140 As part of the Step 3 assessment process, I have raised Technical Queries associated with the following issues of nuclear safety significance:
- The general containment philosophy for the various ventilation systems, specifically in terms of utilisation of HEPA filtration.
 - The design and type of HEPA filters which are used within the design, noting that difficulties are often encountered with achieving an adequate seal within the filter housing. In addition, modern HEPA filters commonly use a safe change filter change system, using an integral bag system, to provide containment during the maintenance activity.
 - The habitability of the Main Control Room.
 - The nuclear safety evaluation associated with the various ventilation systems.
 - The ventilation system specifically associated with the spent fuel pool.

- The design criteria for the various ventilation systems, relating to the reasonably foreseeable rise in temperature over the ~ 60 year period to account for global warming.
- The durability of external features of the ventilation systems, accounting for the UK maritime climate likely to be experienced at the proposed UK reactor sites.

141 The responses to these Technical Queries have been reviewed as part of the assessment process, and the following conclusions have been drawn appropriate to this stage of the overall GDA process:

- Westinghouse has provided a response regarding containment philosophy for the various ventilation systems, and also the HEPA filters are described as using a 'bag-in/bag-out' system as part of the maintenance replacement arrangements. However, I note that the potentially contaminated areas do not utilise HEPA filtration for routine discharges, and hence there is a reliance on active systems to operate in the event of high airborne radiation being detected, in order to switch to HEPA filtration. Furthermore, for some systems, there is the requirement for operator action in the event of high radiation signals, to eliminate or reduce discharges. I have raised a Regulatory Observation, RO-AP1000-43 (Ref. 15), which covers this issue, and intend to follow this up during my further assessment.
- Westinghouse has provided a response regarding the safety evaluation philosophy in respect of ventilation systems. They have stated that a number of systems associated with containment of radioactive material do not require a nuclear safety evaluation, and I have incorporated this issue into my Regulatory Observation, RO-AP1000-43 (Ref. 15), where I am seeking an appropriate and adequate nuclear safety evaluation, for all ventilation systems which have the potential for significant airborne contamination under either normal or fault conditions.
- I note the response in respect of the ventilation system associated with the spent fuel pool, and the statement that the exhaust fans normally discharge to the plant vent without filtration. This issue has been captured by my Regulatory Observation, RO-AP1000-043 (Ref. 15).
- I am satisfied at this stage with the response in respect of the single failure tolerance of the Main Control Room Emergency Habitability System.
- I am satisfied at this stage with the response in respect of the design temperatures for the HVAC system, and their applicability to the UK.
- Westinghouse has stated they are considering a number of design changes to the ventilation system external features, to accommodate the marine climate/weather conditions likely to be experienced at UK facilities. I will consider reviewing the final decisions in respect of this as part of my further assessment, and their implementation through the design process.

142 I have raised a Regulatory Observation (Ref. 15) at this stage of the GDA process, in respect of the containment and filtration philosophy for areas of the facility subject to potential contamination during normal and fault conditions. This Regulatory Observation also covers the related issues of nuclear safety evaluation for ventilation systems, and equipment classification.

143 At this stage of the overall GDA process, one Regulatory Observation, but no Regulatory Issues have been identified in this area.

2.6.6 Gloveboxes / Cabinets

- 144 Gloveboxes and mechanical equipment cabinets as an area for limited regulatory interest as part of the assessment process. Interest in this area primarily relates to protection of the operator, although there is the potential that further derivative issues may arise through progression of the assessment activity.
- 145 As part of the Step 3 assessment activity, Westinghouse has been asked to identify the gloveboxes and cabinets within the facility design, identifying their safety functional requirements and associated ventilation systems, plus the standards used for their design and fabrication.
- 146 These responses will be reviewed in due course.
- 147 At this stage of the overall GDA process, no Regulatory Observations or Regulatory Issues have been identified in this area.

2.6.7 Heat Exchangers

- 148 Heat exchangers used within the facility have an important safety function in terms of cooling, and I have identified the following heat exchangers for assessment at this stage:
- Reactor Coolant Pump Heat Exchanger.
 - Passive Residual Heat Removal Heat Exchanger.
 - Normal Residual Heat Removal Heat Exchangers.
 - Spent Fuel Pool Heat Exchangers.
- 149 Specifically I have raised technical queries to clarify the arguments and evidence in relation to:
- The recent operational experience of the specific design of heat exchanger proposed within the design, which relates to the reliability of operation of these engineering features.
 - The selection of a single Residual Heat Removal Heat Exchanger as part of the passive core cooling arrangement.
 - The number of spent fuel pool heat exchangers, and associated maintenance requirements, which provide the important safety function of cooling the spent fuel pool pond.
- 150 I have reviewed the Westinghouse response in respect of the spent fuel pool heat exchangers and note that the final maintenance recommendations will be determined once a vendor is chosen. In respect of the number (two) of heat exchangers, Westinghouse has stated that a single heat exchanger will remove a sufficient amount of decay heat from the pool in an emergency. Furthermore, the spent fuel pool cooling system maintains the capability of aligning with the normal residual heat removal system. I am satisfied with this response at this stage of my assessment.
- 151 Further responses will be reviewed in due course.
- 152 At this stage of the overall GDA process, no Regulatory Observations or Regulatory Issues have been identified in this area.

2.6.8 Diesel Generators

- 153 Diesel generators are traditionally designated as part of a safety system. They typically provide a diverse means of providing AC power to support the operation of components

that are important to safety. They are accordingly assigned with the appropriate safety categorisation and classification.

154 My initial assessment line of enquiry was to determine the safety role of diesel generators within the Westinghouse AP1000 design.

155 My assessment focused on reading the Westinghouse submission to identify the safety functional requirements and claims associated with the diesel generators, and assessing the submission for adequate arguments and evidence to achieve the design intent, to a standard that meets the UK Regulatory expectations.

156 Westinghouse has not assigned a safety claim on any of the diesel generators. This is due to the Westinghouse claim on the Passive Safety System only requiring the support of a DC battery supply.

157 Further assessment of the diesel generators shall be given consideration, once the issue of safety categorisation and classification is satisfactorily resolved.

2.6.9 Spent Fuel Handling, Pond Stillages, Radioactive Waste Containers and Transportation Flasks

158 I have identified that the following mechanical items:

- Spent fuel handling equipment.
- Pond Stillages.
- Rad. Waste containers.
- Transportation flasks.

are important in supporting the primary safety functions of cooling, criticality control and containment, and are therefore areas of Regulatory interest.

159 However, my assessment to date has focused on the structures, systems and components that are directly associated with the main reactor island primary safety functions. This has resulted in limited progress being made in this assessment area.

160 The Westinghouse design process may limit the availability of information associated with radioactive containers and transportation flasks. This may limit the ability to carry out a significant depth of assessment under the GDA process in these areas, due to the available level of information.

3 CONCLUSIONS

161 At this stage of the GDA process good progress is being made in terms of reviewing the Requesting Party submission, and identifying issues and areas for more detailed review and discussion.

162 A number of Technical Queries have been raised, and responses received, which have been reviewed as part of the assessment process. Two technical meetings have been held at the Westinghouse offices in Pittsburgh, and further direct interactions have taken place via telephone conferences and technical meetings.

163 At this stage of the overall GDA process, the following three Regulatory Observations have been raised associated with this Westinghouse Submission:

- Regulatory Observation - RO-AP1000-036 - Squib Valve Concept and Design Substantiation, July 2009.
- Regulatory Observation - RO-AP1000-038 – Metrication of the AP1000 for the UK, July 2009.
- Regulatory Observation - RO-AP1000-043 – Nuclear Ventilation, September 2009.

These represent assessment findings that require further justification by, and/or discussion with, the Requesting Party and further assessment by the Regulators in the expectation that they can be resolved to the satisfaction of the Regulators. A Regulatory Observation that has not been satisfactorily resolved may, at the discretion of a Regulator, be converted to a Regulatory Issue.

164 The Regulatory Observation in respect of the Squib Valve Concept and Design Substantiation represents a particularly significant assessment finding at this time. I have significant concern regarding the present state of design and development, and programme for future work, in respect of this Squib Valve concept, used as part of the Passive Core Cooling System. I consider that Westinghouse needs to apply significant resource and attention to this area.

165 The Regulatory Observation in respect of Metrication is of interest across the assessment disciplines. I am generally satisfied with progress made to date regarding this issue from a mechanical engineering perspective, but will continue to review progress and draw conclusions as appropriate.

166 The Regulatory Observation in respect of Nuclear Ventilation has been raised recently, and has been developed in close consultation with the Environment Agency. I consider that Westinghouse needs to apply significant attention to this area, since nuclear ventilation systems and associated filtration arrangements play a fundamental part in protecting people, society, and the environment from the hazards of radiation.

167 The Westinghouse methodology of safety categorisation and classification is not in line with the UK Regulatory SAPs, which are principles that ND uses to make regulatory judgements and provide fundamental guidance to carrying out an effective assessment. At this stage the current Westinghouse methodology has proved to be an obstacle in carrying out an effective assessment. Westinghouse is currently aligning the allocation of safety categorisation and classification to the UK SAPs. I consider this exercise requires expediting and completion on an urgent basis otherwise it will significantly impact the effectiveness of the GDA. Westinghouse has advised the updated documentation will be approved and issued in November 2009.

168 I consider the understanding and definition of the installation sequence of the RCS pump (chosen as an example due to its size, mass and location) to be at an early stage and a significant amount of design definition work may be required to be carried out to enable the regulatory expectations to be achieved.

- 169 However, a degree of confidence has been gained in the design process applied by Westinghouse. Sampled areas that provided this confidence included the:
- RCS pump, which included review of Westinghouse's supply chain and the visible evidence of adequate Quality Assurance.
 - CRDMs and the development tasks that are being undertaken.
 - Valve selection process, where documents assessed captured both operational experience and standardisation aspects.
- 170 At this stage of the overall GDA process, no Regulatory Issues have been identified associated with the Westinghouse submission.

4 REFERENCES

- 1 *AP1000 Pre-construction Safety Report*. UKP-GW-GL-732, Revision 1, Westinghouse Electric Company LLC, March 2009.
- 2 *ND BMS, Assessment Process*. AST/001, Issue 2, HSE, February 2003.
- 3 *ND BMS, Guide: Assessment Process*. G/AST/001, Issue 2, HSE, February 2003.
- 4 *Safety Assessment Principles for Nuclear Facilities*. 2006 Edition, Revision 1, HSE, January 2008.
- 5 *New Reactor Build. Generic Design Assessment. Step 3 Mechanical Engineering*. ND Division 6 Assessment Report No. AR08/034 HSE December 2008 (Project Implementation Document) - TRIM ref. 2009/21999.
- 6 *Generic Design Assessment – New Civil Reactor Build. Step 3 Structural Integrity Assessment of the Westinghouse AP1000*. ND Division 6 Assessment Report No. AR09/013 HSE November 2009 – TRIM Ref. 2009/305953.
- 7 *Reactor Safety Reference Levels*. Issue O, Western European Nuclear Regulators' Association (WENRA), January 2008.
- 8 *Safety of Nuclear Power Plants: Design – Requirements*. IAEA Safety Standards Series No. NS-R-1, International Atomic Energy Agency (IAEA) Vienna 2000.
- 9 *Regulatory Observation - RO-AP1000-036 - Squib Valve Concept and Design Substantiation*. HSE-ND, July 2009. TRIM Ref. 2009/358257.
- 10 *AP1000 SSD Writer's Guide*, APP-GW-GEP-020 Revision 1, Westinghouse Electric Company LLC, April 2009.
- 11 *AP1000 System Specification Documents*, APP-GW-GAP-406 Revision 0, Westinghouse Electric Company LLC, December 2008.
- 12 *AP1000 Mechanical Design Criteria*. APP-GW-M1-001 Revision 0, Westinghouse Electric Company LLC.
- 13 *Regulatory Observation - RO-AP1000-038 – Metrication of the AP1000 for the UK*. HSE-ND, July 2009. TRIM Ref. 2009/358257.
- 14 *Valve Standardisation Selection Criteria*. GW-P1-020 Rev 0, Westinghouse Electric Company LLC. March 1996.
- 15 *Regulatory Observation - RO-AP1000-43 – Nuclear Ventilation*. HSE-ND, September 2009. TRIM Ref. 2009/358257.

Annex 1 – Mechanical Engineering – Status of Regulatory Issues and Observations

RI / RO Identifier	Date Raised	Title	Status	Required timescale (GDA Step 4 / Phase 2)
Regulatory Issues				
None.				
Regulatory Observations				
RO-AP1000-036	July 2009	Squib Valve Concept and Design Substantiation	To date Westinghouse has not achieved any programme delivery dates associated with the RO actions. I consider there is a high risk that Westinghouse underestimates the depth of the issue, and the resource and effort that is required to deliver and close out the actions to my satisfaction. I also consider Westinghouse's ability to close out the squib valve issue during the GDA timeframe is now on the critical path.	All actions are required to be satisfactorily closed out within the GDA Step 4 timeframe.
RO-AP1000-038	July 2009	Metrication of the AP1000 for the UK	RO formally issued and awaiting a formal response from Westinghouse to the actions.	All actions are required to be satisfactorily closed out within the GDA Step 4 timeframe
RO-AP1000-043	Sept 2009	Nuclear Ventilation	RO formally issued and awaiting a formal response from Westinghouse, and acceptance to the Regulatory Observation and actions.	All actions are required to be satisfactorily closed out within the GDA Step 4 timeframe

Annex 2 – Mechanical Engineering Tables – Applicable Safety Assessment Principles and Technical Assessment Guides

Table A2.1 lists and interprets the SAPs that are considered applicable to carrying out an effective mechanical engineering assessment. Noting mechanical engineering covers a wide range of components, not all SAPs are applicable to the assessment of each individual component. The policy is to select the applicable SAPs for the component that is being assessed.

The third column in Table A2.1 cross-references to the associated Technical Assessment Guide. The fourth column highlights the Step during which the assessment is initiated (Phase 1, Step 3). The fifth column highlights the associated reference to the WENRA reference levels and the sixth column highlights the associated reference to the IAEA safety standard series requirements (Ref. 5).

Table A2.1 - Mechanical Engineering Applicable Safety Assessment Principles

SAP Number	SAP Title	TAG	Assessed Category	WENRA Ref.	IAEA Ref.
EKP - Key Principles					
EKP.1	Inherent safety	T/AST/056	P1-S3	E2.1	2.9 – 2.11 3.2 3.3 3.6 -3.9 4.1 – 4.4
EKP.3	Defence in depth	T/AST/011 T/AST/021 T/AST/056 T/AST/011 T/AST/005	P1-S3	E2.1	2.9 – 2.11 3.2 3.3 3.6 -3.9 4.1 – 4.4
ECS	Safety Classification and standards				
ECS.1	Safety categorisation	T/AST/011 T/AST/056 T/AST/003 T/AST/016 T/AST/057	P1-S3	E3.1	5.1 - 5.3
ECS.2	Safety Classification of structures, systems and components	T/AST/009 T/AST/056 T/AST/016 T/AST/057	P1-S3	G1.1 G2.1	
ECS.3	Standards	T/AST/056 T/AST/003 T/AST/005 T/AST/016 T/AST/057	P1-S3	G2.2 G3.1	3.6
ECS.4	Codes & standards	T/AST/056 T/AST/005 T/AST/016 T/AST/057	P1-S3	C3.1 C3.6	3.6

SAP Number	SAP Title	TAG	Assessed Category	WENRA Ref.	IAEA Ref.
EDR - Design and Reliability					
EDR.1	Failure to safety	T/AST/056 T/AST/016	P1-S3	E9.1	
EDR.2	Redundancy, diversity and segregation	T/AST/036 T/AST/056 T/AST/011 T/AST/003 T/AST/016	P1-S3	E2.1 E9.4 E10.7	2.9 – 2.11
EDR.3	Common cause failure	T/AST/036 T/AST/056 T/AST/016	P1-S3	E10.7	2.9 – 2.11
EDR.4	Single failure criteria	T/AST/011 T/AST/056 T/AST/006	P1-S3	E10.7	2.9 – 2.11
EMT	Maintenance, inspection and testing				
EMT.1	Identification of requirements	T/AST/009 T/AST/056 T/AST/016	P1-S3	K1.1	5.42 6.50 6.81
ELO	Layout				
ELO.1	Access	T/AST/036 T/AST/021 T/AST/009 T/AST/056 T/AST/016	P1-S3		5.43 – 5.44 5.48 5.61 5.65
EPS	Pressure systems				
EPS.1	Removal closures	T/AST/016	P1-S3		
EPS.3	Pressure Relief	T/AST/016	P1-S3		
EPS.4	Overpressure protection	T/AST/016	P1-S3		
EMC - Integrity of metal components and structures					
EMC.5	Defects	T/AST/009 T/AST/016	P1-S3	G3.1	
EMC.7	Loadings	T/AST/016	P1-S3		
EMC.11	Failure Modes	T/AST/056 T/AST/016	P1-S3		
EMC.12	Brittle behaviour	T/AST/016	P1-S3	G3.1	
EMC.22	Material compatibility	T/AST/016	P1-S3	G4.1	
EMC.25	Leakage	T/AST/016	P1-S3		
EMC.26	Forewarning of failure	T/AST/016	P1-S3		

SAP Number	SAP Title	TAG	Assessed Category	WENRA Ref.	IAEA Ref.
EMC.29	Redundancy and diversity	T/AST/009 T/AST/016	P1-S3	E9.4 E10.7	
ECV - Containment and ventilation					6.92 – 6.95
ECV.1	Prevention of leakage	T/AST/021 T/AST/056 T/AST/041	P1-S3	E9.8	
ECV.2	Minimisation of releases	T/AST/056 T/AST/041	P1-S3	E9.8	
ECV.3	Means of confinement	T/AST/021	P1-S3	E9.8 S4.4 S4.5	
ECV.4	Provision of containment barriers	T/AST/021	P1-S3	E9.8 E9.9 E9.10	
ECV.5	Minimisation of personnel access	T/AST/021	P1-S3		
ECV.6	Monitoring devices	T/AST/021	P1-S3		
ECV.7	Leakage monitoring	T/AST/021	P1-S3		
ECV.8	Minimising of provisions	T/AST/021 T/AST/056	P1-S3		
ECV.9	Standards	T/AST/021 T/AST/056	P1-S3		
ECV.10	Safety standards	T/AST/022	P1-S3		

Table A2.2 – Applicable Mechanical Engineering Technical Assessment Guides

No.	Reference No.	Issue	Title
1	T/AST/057	1	Design Safety Assurance
2	T/AST/003	5	Safety Systems
3	T/AST/005	4	Demonstration of ALAEDF AND AREVA
4	T/AST/056	1	Nuclear Lifting Operations
5	T/AST/009	1	Maintenance, Inspection & Testing of Safety Systems, Safety Related Structures and Components
6	T/AST/036	2	Diversity, Redundancy, Segregation and Layout of Mechanical Plant
7	T/AST/022	1	Ventilation
8	T/AST/016	3	Integrity of Metal Components and Structures
9	T/AST/011	1	The Single Failure Criterion
10	T/AST/041	2	Criticality Safety
11	T/AST/021	1	Containment: Chemical Plants