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LIST OF ABBREVIATIONS AND ACRONYMS

ALARP	as low as reasonably practicable
ANSI	American National Standards Institute
ASME	American Society of Mechanical Engineers
CMT	core makeup tank
CMTR	certified material test reports
CSR	Component Safety Report
CV	containment vessel
DVI	direct vessel injection
FMEA	failure modes and effects analysis
GDA	generic design assessment
HAZ	heat affected zone
ID	inside diameter
ISI	in-service inspection
LOCA	loss-of-coolant accident
NDE	nondestructive examination
PWHT	post-weld heat treatment
PXS	passive core cooling system
RCS	reactor coolant system
RT_{NDT}	reference temperature nil ductility transition
SFR	safety functional requirement
SSC	system, structure, or component
UK	United Kingdom
US	United States

APPENDIX 20H
CORE MAKEUP TANK COMPONENT SAFETY REPORT

20H.1 Introduction

This is the component safety report (CSR) for the core makeup tank (CMT) as introduced in Section 20.2.The safety argument herein substantiates the structural integrity of the CMT to a degree of rigour commensurate with the consequences of gross structural failure. The safety argument is supported by a suite of documentation outlined in Section 20H.5 that supports the design, manufacture, installation, and operation of the CMT.

20H.1.1 Scope

This report presents arguments to support the claim that the nuclear and radiological risks potentially arising from gross structural failure of the CMT are tolerably low for the design lifetime objective of 60 years. Conventional hazards to personnel safety are outside the scope of this Appendix 20H.

20H.1.2 Objectives

The objective of this report is to establish that the AP1000 plant risk remains both tolerable and as low as reasonably practicable (ALARP) for the design lifetime. This claim is substantiated by satisfying structural integrity safety design bases for all safety-significant AP1000 systems, structures, or components (SSCs). The safety design bases, applied across the operational, process and lifecycle scope of the safety case, embody the technical scope of the safety case: if these can be maintained at all times, the plant will be acceptably safe. Specific safety functional requirements (SFRs) for each particular component are developed from the structural integrity safety design bases, and correspond to the functions that need to be maintained to provide assurance of nuclear and radiological safety. The SFRs applicable to the CMT are identified in Section 20H.2.1.

20H.1.3 Interface with Other Safety Case Documents

This report provides a safety argument to support the nuclear safety case claims relevant to the CMT. The safety argument presented in this report is supported by a dossier of technical specifications and analyses. These are listed in the Technical Index (Section 20H.5) and each is specifically identified in the relevant section of the structured safety argument.

20H.1.4 Core Makeup Tank Description

20H.1.4.1 Overview

The CMTs (two), as shown in Figure 20H-1, are components of the passive core cooling system (PXS). They are located inside the containment above the direct vessel injection (DVI) line connections. The basic function of the CMT is to provide reactor coolant system (RCS) makeup and boration during events when the normal makeup system is unavailable or insufficient. Upon receipt of a safeguards actuation signal, valves open to provide makeup water to the RCS.

20H.1.4.2 Description

Details of the CMT design can be found in the CMT design specification (Reference 20H.2). The two CMTs are vertical cylindrical tanks with hemispherical upper and lower heads. They are located inside the containment (on the 102.3-m floor elevation) (i.e., 7'2" above grade) above the DVI line connections to the reactor vessel, which are at an elevation near the bottom of the hot leg (Figure 20H-2).

The CMT is made of carbon steel with stainless-steel clad on the internal surface with hemispherical upper and lower heads supported on columns. The tank has an inlet diffuser welded to the inside of the upper head in the centre. A manway is provided for access to the inside of the tank. There are eight level taps to insert level instrumentation. There are six thermowell penetrations, two level/sample taps, and one fill tap. In addition, three lifting lugs are welded to the upper head. The CMT is designed with a linear-type support having a flanged interface for bolting the CMT to the building structure. The CMT is designed in accordance with the requirements of American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code (Code) Section III, Subsection NB (Reference 20H.3). The CMT supports are qualified to the criteria of subsection NF of the ASME Code. Inside the containment, the secondary shield wall serves as a barrier between the reactor coolant loops and the CMTs.

20H.1.4.2.1 Materials

Materials used in the manufacture of the CMT subcomponents are shown in Table 20H-1. The cylinder and heads are made of low-alloy carbon steel and are clad on the internal surfaces with stainless steel for corrosion resistance. The nominal cladding thickness will be 5.6 mm (0.22 inch). Machining of as-deposited cladding is not required if the surface finish is suitable for required nondestructive examination (NDE) inspections. All clad surfaces including nozzles and manway will be 100 percent ultrasonically inspected for both bond and defects by the straight beam method. Materials in contact with the reactor coolant fluid are fabricated with corrosion resistant materials or are cladded. The cladding and stainless steel is carried through the rest of the tank features which include a manway, various small nozzles (level indicators, thermowells, pressure taps, and sample taps), and larger inlet/outlet nozzles. The cobalt content of materials used in the construction of component surfaces which come into contact with the primary coolant, including screws, bolts, washers, weld cladding and locking cups, has been specified to be no greater than 0.05 percent weight, integrated average. The cobalt content of all other welding materials is excluded from this requirement.

20H.1.4.2.2 Design Temperature and Pressure

The structural design of the CMT is based on the maximum steady state internal design pressure and design temperature values of 17.13 MPa gauge (2485 psig) and 343°C (650°F), respectively. These values are to be used in conjunction with the appropriate values of external pressure and temperature defined in the Design Specification (Reference 20H.2).

During normal operation, the CMTs are completely full of borated water (with a boron concentration of about 3500 ppm). The temperature of the borated water in the CMTs is generally about the same as that of the containment at a nominal operating temperature of 10°C to 48.89°C (50° to 120°F), since the tanks are not insulated or heated. Normally, the CMT outlet is isolated from the RCS and the cold leg pressure balance line is open, which keeps the tank at a pressure generally equal to the RCS.

20H.1.4.2.3 Total Volume/Flowrate

The free internal volume for the CMT is approximately 70.792 m^3 (2500 ft^3).

The discharge line from each CMT contains a flow-tuning orifice that provides a mechanism for the field adjustment of the injection line resistance. The orifice is used to establish the required flow rates assumed in the CMT design. The CMTs provide injection for an extended time after CMT actuation. The duration of injection will be much longer when the CMTs operate in the water recirculation mode as compared to the steam condensation mode.

20H.1.4.2.4 Manway

The CMT has an access manway in the shell of the tank to permit access for inspection and maintenance. The manway cover bolting is designed to facilitate the use of remotely operated stud tensioning and de-tensioning devices. The manway cover assembly is provided with design features to facilitate installation and removal of the cover away from the manway.

20H.1.4.2.5 Nozzles

The mechanical characteristics of the CMT nozzles are shown in Table 20H-2. All nozzles terminate in stainless steel material for compatibility with the interfacing piping material. The stainless steel safe ends are of sufficient length to prevent damage to the transition weld on the nozzle during field welding. Nozzles are buttered prior to final post-weld heat treatment (PWHT). In this way, the heat affected zone (HAZ) of the nozzle receives a PWHT. After final PWHT, the stainless-steel ends are welded to the buttered vessel nozzles. By following this procedure, sensitisation of the stainless steel ends is prevented.

20H.1.4.2.6 Lifting Lugs

The lifting lugs are designed in accordance with the criteria specified in American National Standards Institute (ANSI) N14.6-1993 (Reference 20H.5).

20H.1.4.2.7 Chemistry

The reactor coolant inside the CMT is controlled in accordance with the Electric Power Research Institute pressurised water reactor primary water chemistry guidelines (Reference 20H.6) as discussed in Chapter 21. The CMT water may contain dissolved oxygen at a concentration equal to saturation at atmospheric pressure. Samples from the CMTs are taken periodically to check the boron concentration. Connections are provided for remotely adjusting (if required) the boron concentration in the CMT during normal plant operation. Makeup water for the CMT is provided by the chemical and volume control system.

20H.1.4.2.8 Pressurisation

Overpressure protection of the CMT and RCS is provided by the use of ASME Code, Section III, Class 1 pressure safety valves which are located in the RCS piping.

20H.1.5 Core Makeup Tank Function

The basic function of the CMT is to provide RCS makeup and boration during events when the normal makeup system is unavailable or insufficient. Full details of the functional requirements are given in the AP1000 Core Makeup Tank Functional Specification (Reference 20H.7). CMT level and inlet and outlet line temperatures are monitored by indicators and alarms. The operator can take action (as required) to meet the technical specification requirements for CMT operability.

Each CMT is connected to the RCS through an outlet line that has normally closed isolation valves. Upon receipt of a safeguards actuation signal, these valves open to align the CMT to the RCS. The outlet line from each CMT is connected to one of the two DVI lines, which provides an injection path for the water supplied by the CMT. When the cold legs are filled, the CMTs operate in a water-recirculation mode driven by the density difference between the hot inlet line and the cold CMT. This mode of operation provides RCS water makeup and effective boration appropriate for non-loss-of-coolant accident (LOCA) events.

When the cold legs are voided, the CMTs operate in a steam-displacement (or steam-compensated injection) mode driven by the density difference between the cold leg steam and the cold water in the CMT. This mode provides greater injection rates than the water recirculation mode, which is appropriate for LOCA events. The CMT flow is based on limiting CMT and RCS temperatures and pressures to ensure that the CMTs can provide injection for a minimum of approximately 20 minutes after CMT actuation and the initial steam condensation transient. For non-LOCA events, the duration of injection will be much longer. Each CMTs inlet has an inlet diffuser designed to reduce steam velocities into the cold CMT water, thereby minimising potential water hammer and reducing the amount of mixing that occurs during initial CMT operation.

20H.1.6 Core Makeup Tank Boundaries

The physical boundaries of the CMT are defined in Reference 20H.2, as summarised below.

The equipment boundary of ASME Code jurisdiction includes all components in Figure 20H-3 and Figure 20H-4.

Figure 20H-3 shows the ASME Code jurisdictional boundaries of CMT, which include all pressure retaining materials up to the circumferential welds between the piping and nozzle safe ends or nozzle and piping (nozzle to pipe weld is not in the CMT jurisdictional boundary). The manway cover (including bolts), tank supports, shear block and shear block weld are ASME Code qualified components. As depicted in Figure 20H-4, the anchor bolts and associated hardware, slide and embedment plates are not ASME components.

The CMT is supported by eight columns. Each column support will have an individual base plate at the bottom. This serves as an interface for attaching the CMT to the embedded plate on the building floor. Auxiliary pipe connections including the quantity and size for the nozzles are specified in Reference 20H.2.

20H.2 Safety Case Requirements

The main focus of this report is to provide a structured safety argument, supported by suitable and sufficient evidence, to substantiate a structural reliability commensurate with the requirements of a Standard Class 1 component, as outlined in Section 20H.2.2 of this report. To achieve this, the safety argument is presented as three key elements, as follows:

Claim 1: **Quality of Build: High quality is achieved through good design and manufacture (Section 20H.3.1).**

Objective: Provides evidence of good design and manufacture based on established design and manufacturing processes and use of proven materials. It provides a keystone for a demonstration of high reliability and embodies the code and plant operating experience with the objective of achieving quality of build and the avoidance of defects.

Claim 2: **Good Design: Good design is achieved through compliance with ASME (Section 20H.3.2).**

Objective: Incorporates the build experience as embodied in the design codes.

Claim 3: **Mitigation and Management of In-Service Degradation: Components are tolerant to through-life degradation over the design life of the plant (Section 20H.3.3).**

Objective: Provides an assessment of through-life degradation mechanisms and shows that such mechanisms will not threaten integrity over a specific interval.

The three elements of the safety argument are provided in Section 20H.3 and the strength of the argument is discussed in Section 20H.4.

20H.2.1 Safety Functional Requirements

Chapter 20 identifies structural integrity safety design bases for the SSCs. These are requirements of plant systems, some duty and some accident response, which must be maintained at all times to provide assurance of plant nuclear and radiological safety. Identification of the SFRs for the CMT follows from the performance and safety functional requirements outlined in Reference 20H.7, as follows:

The CMT is a large tank containing borated water (at RCS pressure) that drains into the RCS during certain plant transients and accidents. Based on this, the following SFRs have been identified that reflect the overall role of the component in plant safety:

- **SFR 20.7.1** The CMT pressure boundary must remain intact during standby, normal operation, and under design basis faulted conditions for the design life of the plant.

- **SFR 20.7.2** The CMT is required to store cold borated water under reactor coolant system pressure for high-pressure reactor coolant makeup in accordance with the component performance requirements.

- **SFR 20.7.3** The CMT is required to deliver borated water to the RCS in the event of a LOCA or non-LOCA when the normal makeup system is unavailable or insufficient.

Postulated failure modes that result in a loss of these functional requirements lead to identification of structural reliability targets commensurate with the consequences of gross failure, as determined through the process of component classification as described in Section 20H.2.2.

20H.2.2 Core Makeup Tank Structural Integrity Classification

For the United Kingdom (UK) AP1000 plant, the structural integrity classification methodology (Reference 20H.1), has been applied with the aim of determining the required level of structural reliability for each of the major plant components based on an evaluation of the direct consequences (e.g., LOCA) and indirect consequences (e.g., missiles/pipe whip etc) of gross failure. The detail of the classification for the CMTs is presented in Reference 20H.1.

This concluded that the direct consequences of gross failure of the CMT is bounded by the more limiting DVI line failure which is shown not to lead to core damage and is within the design basis analysis of Section 9.6.5. Considering the indirect failure consequences, due to the proximity of the CMTs to the containment vessel (CV) it is possible that damage to the containment could occur. An analysis of the effectiveness of the containment cooling with damaged containment has been undertaken and results show that the CV pressure is reduced to and maintained near atmospheric pressure. Also, CMT failure cannot impact the containment below elevation (102.1 m), thus the mass loss from the CV does not deplete the water inventory inside the containment quickly. In summary, damage to the containment would not prevent the passive protection system from cooling the core but the release rate would be increased. There is also potential for damage to Category 1 control and instrumentation cables but this would not prevent the redundant train of the affected safety system from operating properly. On this basis, the CMT has been categorised as a Standard Class 1 component.

20H.3 Safety Case Arguments

As discussed in Section 20H.2.2, the CMT has been classified as a Class 1 component in accordance with Reference 20H.1. The structural integrity claim is, therefore, based on arguments which substantiate the claims listed in Section 20H.2. Consistency with the appropriate ASME III Code class provides the basic demonstration of fitness-for-purpose for the CMT.

Compliance with ASME Code, Section III rules for a Class 1 component provides the primary element in the safety case for the AP1000 CMTs.

20H.3.1 High Quality is Achieved through Good Design and Manufacture

In order to demonstrate that high quality is achieved through good design and manufacture, evidence to support the following claims is provided:

- The fabrication specification complies with ASME Code requirements for Class 1 components.
- Supplementary requirements are specified to avoid defects and to ensure quality.

The reliability of the CMT depends upon the equipment design quality. The design intent is translated into a manufacturing route which is controlled by a Quality Assurance Programme which complies with rigorous design codes including the ASME Boiler and Vessel Pressure Code (Reference 20H.3). Section 2.3 of the CMT Design Specification (Reference 20H.2) provides a comprehensive list of the industry codes, specifications and standards applied to the component.

The justification of the quality of build of the CMT and materials includes:

- **Processes used for manufacturing and fabrication** – Design and fabrication of the CMT is carried out in accordance with ASME Code, Section III, Class 1 requirements as defined in the Design Specification (Reference 20H.2).
- **Material Specifications** – The CMT materials specifications and testing requirements have been specified in accordance with the requirements of Section II of the ASME Code. Material specifications also include relevant Westinghouse Standards, ANSI/ASME/ASTM standards, United States (US) Code of Federal Regulations and US Nuclear Regulatory Commission Regulatory Guides as defined in Reference 20H.2. The primary coolant boundary will be fabricated from ASME plate and/or forging material. Charpy V-notch tests and drop weight fracture toughness tests are required. Nozzles will terminate in stainless steel material for compatibility with the interfacing piping material. The stainless-steel safe ends will be of sufficient length to prevent damage to the transition weld on the nozzle during field welding. Nozzles will be buttered prior to final PWHT. In this way, the HAZ of the nozzle will be receiving a PWHT. After final PWHT, the stainless steel ends will be welded to the buttered vessel nozzles. By following this procedure sensitisation of the stainless-steel ends is prevented.
- **Material Test Reports** – Materials for parts within the jurisdiction of the ASME Code will have certified material test reports (CMTR) clearly presenting the results of all ASME Code required testing. All other materials will be certified as required by the applicable material specifications, but as a minimum by a certificate of compliance.

- **Mechanical Testing** – Hydrostatic tests will be carried out in accordance with the requirements of the ASME Code, Section III, using working fluids meeting the appropriate water chemistry specifications. The hydrostatic test will be performed at a test pressure of 1.25 times the design pressure and at a test temperature safe from brittle fracture. The minimum hydrostatic test temperature will be 33.3°C (60°F) above the reference temperature nil-ductility temperature (RT_{NDT}).

- **In-Manufacture NDE** – The NDE of the CMT is conducted in accordance with ASME Code, Section III requirements using ultrasonic examination, liquid penetrant examination, magnetic particle examination, surface examination and weld examination. These provide confidence that the required weld quality is achieved during manufacture. All clad surfaces, including nozzle and manway will be 100% ultrasonically inspected for both bond and defects by the straight beam method. Clad thickness will be measured in accordance with approved procedures. No seams will pass through or interfere with nozzles, and they are designed for 100 percent inspectability where required by the code. Only personnel qualified and certified in accordance with ASME Section III will perform Section III examinations.

- **Pre-Service and In-Service Examination Requirements** – The pre-service and in-service examination and acceptance criteria for of the CMT will comply with the 1998 Edition with Addenda up through and including 2000 of ASME Code, Section XI, Subsection IWB for pressure boundary welds and Subsection IWF for all other welds. Inspection personnel qualified and certified in accordance with the requirements of ASME Code, Section XI, IWA-2300 will perform the pre-service examination.

- **Weld Qualifications** – All pressure boundary welding procedures and welders qualifications will be in accordance with the ASME Code, Section III and Section IX. All non pressure boundary welding procedures and welders qualifications will be in accordance with the ASME Code, Section IX or equivalent approved standards.

Together these provide a keystone for a demonstration that the CMT will achieve a high quality, will enter service free from structurally significant defects and that the effects of through-life degradation on material properties will not have a deleterious effect on the structural reliability of the vessel.

20H.3.2 Good Design is Achieved through Compliance with ASME

In order to demonstrate that good design is achieved through compliance with ASME, evidence to substantiate the following argument is provided:

- The design has been analysed and has been shown to comply with the requirements of ASME Code, Section III for Class 1 components.

  The AP1000 CMT has been designed in accordance with the requirements of the ASME Code, Section III, Div 1 – 1998 Edition with Addenda up through and including 2000. The CMT has been assessed against the limits specified in Subsection NB and the tank supports are assessed against Subsection NF. The assessment is reported in a suite of calculation notes, as listed in the Technical Index of this report. The subsection applicable to each sub-component is summarised below.

  The design transients used in the analysis are shown in Reference 20H.9. The load cases considered include normal, upset, emergency, and faulted conditions. The external load combinations on the CMT are specified in the CMT Design Specification (Reference 20H.2);

these include nozzle external loads, seismic loads and all other loads and loading combinations. The design of the CMT has, therefore, been designed against all design basis internal and external hazards.

Reference 20H.9 summarises an ASME sizing assessment of the critical locations of the CMT showing the minimum required thickness/minimum required areas compared to the actual thickness/actual area. Adequate thickness and/or actual area are provided for all locations.

Reference 20H.9 provides the results of a thermal and structural analysis which has been undertaken using established procedures to demonstrate that for the load cases analysed all the stresses and cumulative fatigue usage factors are satisfactory and meet the appropriate limits set forth in the ASME Code, Section III. This evaluation includes:

- A basic sizing and justification of the main parts and components of the CMT.
- A dynamic seismic analysis by the response spectrum method.
- Evaluation of stresses from internal pressure, earthquake effects, dead weight and externally applied loads at significant locations of the vessel shell, manway and nozzles.

Based on the results of the assessments presented in Reference 20H.9, it can be shown the design of the CMT meets all the applicable requirements of ASME Code, Section III.

20H.3.3 Mitigation and Management of In-Service Degradation

To demonstrate that the design has taken account of in-service degradation mechanisms, evidence to substantiate the following argument is provided:

- A structured process has been applied to identify in-service degradation mechanisms.
- The design has been optimised to mitigate against the risk from in-service degradation mechanisms.

20H.3.3.1 Identification of Degradation Mechanisms

Reference 20H.10 provides a failure modes and effects analysis (FMEA), which was carried out to identify design characteristics, potential hardware failures, or human errors associated with the design and operation of the CMT that could lead to a potentially hazardous condition such as injury, fatality, or loss of equipment and product.

The FMEA resulted in the identification of potential hazards or operational problems. Potential through-life degradation mechanisms considered were:

- Thermal cycling
- Fatigue
- Brittle fracture
- Corrosion
- Failure arising from manufacturing defect

The basis of the safety case argument is mitigation against corrosion, fatigue and manufacturing defects is essentially provided by compliance with ASME material specification, design and fabrication rules. The associated in-service inspection (ISI)

requirements and the operating experience embodied within the Code mitigate against these degradation mechanisms.

20H.3.3.2 **Avoidance of Non-Ductile Failure**

Reference 20H.9 presents the calculations performed for the CMT vessel shell, CMT inlet and outlet nozzles, and manway to provide confidence that the CMT is safeguarded against non-ductile failure during normal, upset, and test conditions, as required by ASME Code.

The non-ductile failure evaluation of the CMT was performed in accordance with Appendix G of the ASME Code. The ANSYS finite element analysis code was used to obtain the temperature and stresses. The FRMECH programme, Reference 20H.12, was used to obtain the stress intensity factors. Methods of evaluating non-ductile behaviour are based on linear elastic fracture mechanics of thick sections.

The postulated flaw is assumed to be perpendicular to the direction of maximum stress. The postulated flaw for the vessel shell is typically in the hoop direction and for the CMT inlet nozzle to be perpendicular to the direction of maximum stress, which is typically the hoop direction. The regions of the manway which may be susceptible to a non-ductile failure are the centre of the manway cover, the inside surface of the manway knuckle, and the inside surface of the shell

Calculated stress intensity factors (K_I) were compared with the allowable critical values (K_{IR}). The analysis is based on the general methodology set forth in Appendix G of the ASME Code and in WRC Bulletin No. 175 (Reference 20H.11). Safety coefficients have been applied to calculated stress intensity factors K_I in accordance with Appendix G, Articles G – 2215 and G – 2400.

The analysis presented demonstrates that the AP1000 CMT satisfies the structural requirements of Section III of the ASME Code for all loading conditions specified in Reference 20H.2.

20H.3.3.3 **In-Service Inspection**

ISI provides forewarning of degradation mechanisms and this forms an important element of the safety case argument. ISI will be carried out in accordance with Section XI of the ASME Code. An inspectability assessment of the CMT has been carried out. This assessment (Reference 20H.13) provides evidence that the design of the CMT has been optimised to permit ISI, including consideration of the examination requirements for the CMT using different techniques, the inspection coverage, limitations and access conditions at each location. A summary of the ISI requirements is shown in Table 20H-4.

20H.4 Strength of the Safety Case

The CMT is classified as a Standard Class 1 component. The safety argument in Section 20H.3 demonstrates how CMT structural integrity is established based on extensive quality assurance measures in design, manufacture, materials, testing, and qualified inspection. The strength of the safety case is based on achievement of integrity and that the CMT has been deterministically justified in accordance with ASME Code, Section III. The arguments presented are considered to provide a cogent basis to substantiate reliability claims commensurate with the Standard Class 1 classification of the CMT.

To substantiate this assertion this report provides a structured argument supported by suitable and sufficient evidence to achieve this, three key elements namely; Quality of Build,

Good Design and mitigation and management of in-service degradation have shown how this will be achieved.

Quality of Build has been demonstrated by compliance with ASME Code, Section III. Material specification control has been achieved in accordance with Section II of ASME Code, NDE in accordance with ASME Code, Section III with adequate fracture toughness demonstrated by compliance with the ASME Code.

Good design has been demonstrated by providing evidence that design transients including normal, upset, emergency and faulted conditions have been analysed and loadings shown to be within the allowable limits of ASME Code, Section III, Div 1 – 1998 Edition with Addenda up through and including 2000.

The approach to mitigation and management of in-service degradation has been demonstrated by identifying all design characteristics, degradation mechanisms and potential hazards that could lead to injury, fatality or loss of operation of the CMT. ISI will also provide forewarning of degradation with inspection and maintenance carried out at appropriate intervals.

20H.5 Index of Technical Reports

Table 20H-5 provides a list of technical references supporting the safety case and the function of each document within the safety case.

20H.6 Review of Open Issues

There are no open issues for the CMT that affect the basis of the safety case arguments presented in support of generic design assessment (GDA).

20H.7 Conclusions

This report presents arguments that support the claim that the structural reliability of the CMT is commensurate with the consequences of gross failure. To evaluate this, the CMT has been classified in accordance with the procedure for structural integrity classification specified in Reference 20H.1.

The main element of the safety case argument is that the CMT has been designed in accordance with the high standards of the ASME Code as applicable to ASME Class 1 components. This includes tight controls on material properties, manufacturing processes, design, testing, inspection and installation such that there is a high level of confidence in the quality of the CMT and that it will enter service free from significant flaws that could affect the integrity of the CMT over its lifetime. Section 20H.5 of this report identifies the detailed specifications and analyses that provide the evidence to support this argument. In addition, an FMEA was performed to identify potential threats to the structural integrity of the CMT through its design life. Appropriate measures have been incorporated into the design and inspection requirements to mitigate against these threats.

Based on the arguments presented, together with the referenced supporting evidence, it is considered that the structural reliability of the CMT has been justified to a standard commensurate with the consequences of its gross failure.

20H.8 References

20H.1 Westinghouse Report UKP-GW-GLR-004, Rev. 3, "UK AP1000 Structural Integrity Classification," January 2017.

20H.2 Westinghouse Report APP-MT01-Z0-100, Rev. 9, "Design Specification for AP1000 Core Makeup Tank for System PXS," August 2016.

20H.3 ASME Boiler and Pressure Vessel Code Section III, Division 1, "Rules for Construction of Nuclear Power Plant Components," American Society of Mechanical Engineers, 1998 Edition with Addenda up through and including 2000.

20H.4 Not used.

20H.5 ANSI N14.6, "Special Lifting Devices for Shipping Containers Weighing 10,000 Pounds (4500 kg) or More," American National Standards Institute, 1993.

20H.6 Electric Power Research Institute (EPRI), 1014986, "Pressurized Water Reactor Primary Water Chemistry Guidelines – Revision 6," 2007.

20H.7 Westinghouse Report APP-MT01-Z0-001, Rev. 3, "AP1000 Core Makeup Tank Functional Specification," July 2011.

20H.8 Not used.

20H.9 Westinghouse Report APP-MT01-Z0R-001, Rev. 5, "AP1000 Core Makeup Tank ASME Generic Design Report," October 2016.

20H.10 Westinghouse Report APP-MT01-GRA-001, Rev. 0, "AP1000 Core Makeup Tank Failure Modes and Effects Analysis," November 2009.

20H.11 WRC Bulletin No. 175, "PVRC Recommendations on Toughness Requirements for Ferritic Materials," Welding Research Council, Inc., August 1975.

20H.12 Westinghouse Letter LTR-NCE-02-25, "Software Release Letter for FRMECH, Version 2.0, on the HP-UX 11.0 System State," September 11, 2002.

20H.13 Westinghouse Report APP-MT01-VMR-001, Rev. 1, "AP1000 Component ISI Inspectability Assessment: Core Makeup Tank," May 2012.

Table 20H-1. Core Makeup Tank Pressure Boundary Materials

Component	Material
Shell	SA-533 or SA-508
Upper/Lower Head	SA-533 or SA-508
Inlet/Outlet Nozzle	SA-508
Inlet/Outlet Nozzle Safe End	SA-336
Manway	SA-508
Manway Cover	SA-533
Manway Insert	SA-240
Manway Closure Stud Bolt	SA-193
Manway Closure Nut	SA-194
Manway Spherical Washer	SA-194
Support Column	SA-671
Inlet Nozzle Diffuser	SA-312
Lifting Lug	SA-516 or SA-533
Level Tap, Sample/Level Tap, Thermowell Penetration	SA-479
Fill Tap	Bimetallic SB-166 w/ SA-479 Safe End

Table 20H-2. Core Makeup Tank Nozzle Mechanical Characteristics

Duty Qty.	Qty.	Pipe Size		Material	Location	End Configuration
Inlet Nozzle from Cold Leg	1	DN 200 (NPS 8) Sch. 160		SA-508 with Cladding(1)	Top Head in the Centre	per design drawing
Outlet Nozzle	1	DN 200 (NPS 8) Sch. 160		SA-508 with Cladding(1)	Bottom Head in the Centre	per design drawing
Thermowell Penetration	6	DN 25 (NPS 1) Sch 80		SA-479	Top Head, Bottom Head and Shell	per design drawing
Level Tap	8	DN 25 (NPS 1) Sch 80		SA-479	Shell	1" 3000# Socket Weld Coupling
Sample Taps Level Taps	2	DN 25 (NPS 1) Sch 80		SA-479	Top and Bottom Head	1" 3000# Socket Weld Coupling
Fill Tap	1	DN 25 (NPS 1) Sch 80		SB-166 with SA-478 Safe End	Shell	1" 3000# Socket Weld Coupling

Notes:

1. Inlet & Outlet Safe End Material: SA-336

Table 20H-3. Not Used

Table 20H-4. Summary Core Makeup Tank ISI Requirements(1)

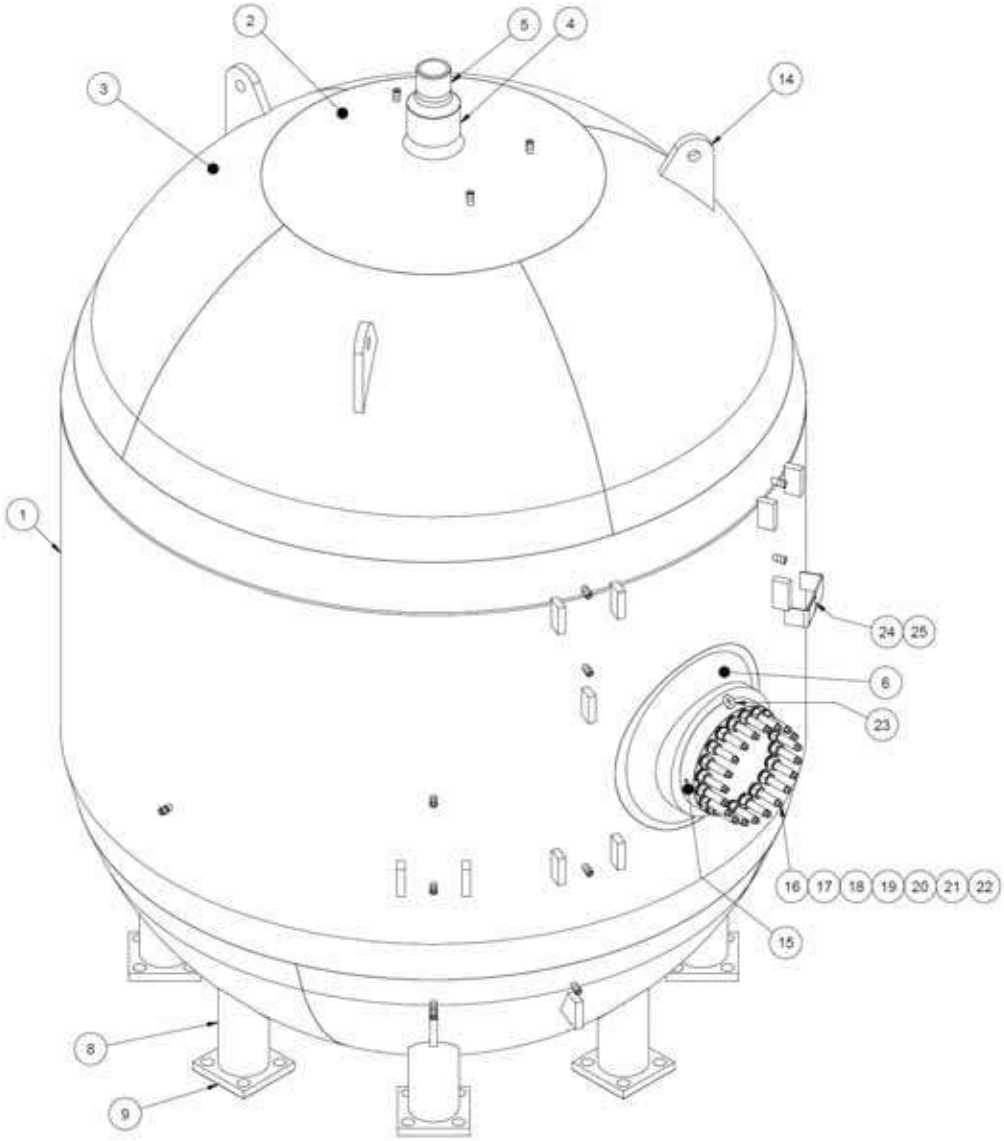
Description	Volumetric	Surface	Visual
Lower Head Transition Ring to Cylindrical Shell Circumferential Weld	X		
Upper Head Transition Ring to Cylindrical Shell Circumferential Weld	X		
Lower Head Dome to Head Transition Ring Circumferential Weld	X		
Upper Head Dome to Head Transition Ring Circumferential Weld	X		
Lower Head Transition Ring Meridional Welds(3)	X		
Upper Head Transition Ring Meridional Welds(3)	X		
Outlet Nozzle to Lower Head Dome Weld	X		
Inlet Nozzle to Lower Head Dome Weld	X		
Outlet Nozzle Inside Radius Region	[2]		[2]
Inlet Nozzle Inside Radius Region	[2]		[2]
Outlet Nozzle to Safe End Butt Weld	X	X	
Inlet Nozzle to Safe End Butt Weld	X	X	
Manway Bolts and Nuts			X
Welded Attachments (Support column to Lower Head)		X	
Pressure Retaining Boundary			X

Notes:

1. In-service inspection requirements for Class 1 tanks are not specifically designated in Table IWB-2500-1. Since the Core Makeup Tank is a Class 1 vessel the requirements identified for the pressuriser are assumed.
2. Provisions allowing for substitution of an enhanced magnification visual examination of the inside diameter (ID) surface in lieu of volumetric examination are applied.
3. Meridional welds, if applicable.

Table 20H-5. Core Makeup Tank Technical Index

Document Reference	Title	Description of Role in Safety Case
Report & Specifications		
APP-MT01-Z0-100	Design Specification for AP1000 Core Makeup Tank for System PXS	Defines the requirements for the design, materials, function, fabrication, examination, testing, cleaning, packaging, and shipping of the CMT to conform to the ASME Code, Section III.
APP-MT01-Z0-001	AP1000 Core Makeup Tank Functional Specification	Defines the functional performance and operational requirements for the CMT.
APP-MT01-Z0R-001	AP1000 Core Makeup Tank ASME Generic Design Report	Contains the detailed analyses required to demonstrate the adequacy of the structural design to sustain and meet in every respect the requirements of the Design Specification and of the ASME Code.
APP-GW-VW-001	AP1000 Design for Inspectability Program: ISI Requirements for Class 1 Components	Contains requirements and design guidance relative to ISI for ASME Class 1 components, specifically focused on the concept of design for inspectability, to ensure that adequate design and access provisions for meeting ASME Code, Section XI are considered in the overall plant design.
APP-MT01-VMR-001	AP1000 Component ISI Inspectability Assessment – Core Makeup Tank	Inspectability assessment relative to the ISI of the CMT.
APP-MT01-Z0-200	AP1000 Core Makeup Tank Fabrication Specification	Establishes the requirements for the fabrication, material, examination, testing, cleaning, packaging, preparation for shipment and quality assurance of the CMT.
APP-RCS-M1-001	Reactor Coolant System Design Transients	Defines the transients used to qualify the reactor coolant system to design requirement.
APP-GW-VLR-010	AP1000 Supplemental Fabrication and Inspection Requirements	Provides details of the AP1000 supplemental fabrication and inspection requirements.



1 Shell Barrel
2 Shell Head Crown
3 Shell Head Petal
4 Central Nozzle
5 Nozzle Safe End
6 Manway Pad
8 Support Column
9 Support Column Base
14 Vessel Lifting Lug
15 Manway Cover
16-22 Manway Closure Hardware
23 Eyebolt
24 Nameplate
25 Metallic Drive Screw

Figure 20H-1. Core Makeup Tank

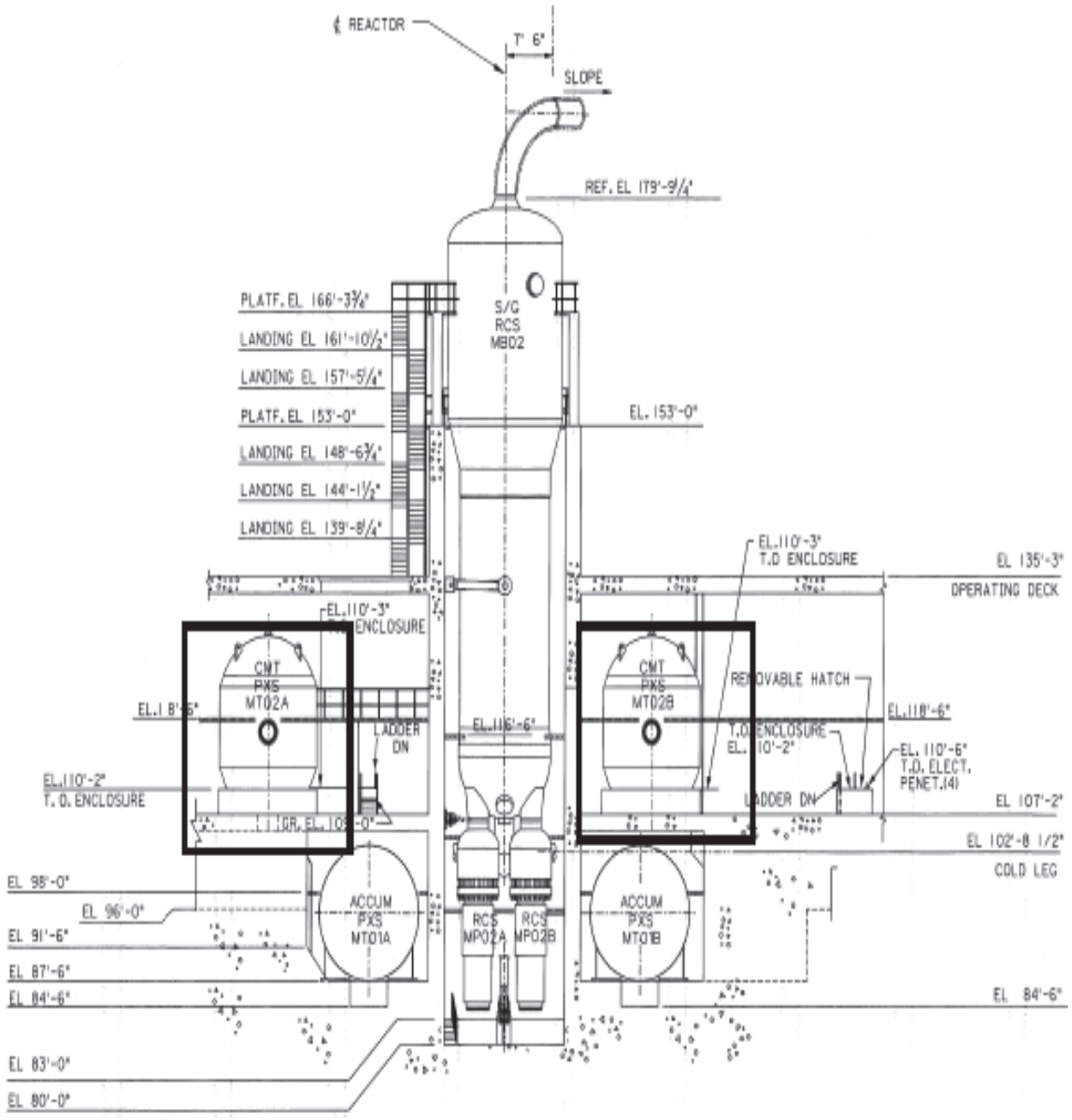


Figure 20H-2. Core Makeup Tank Elevation

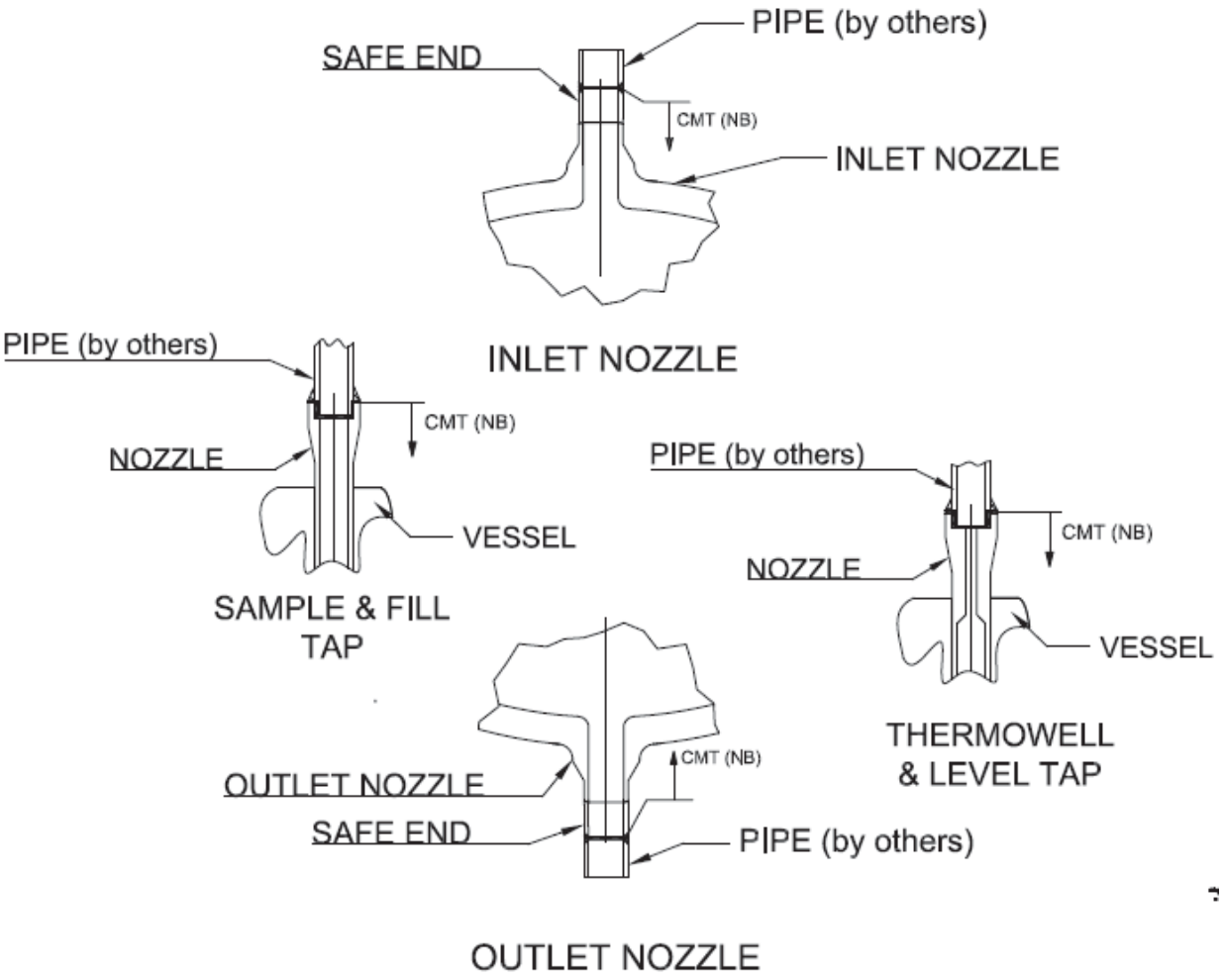


Figure 20H-3. Core Makeup Tank Nozzle Jurisdictional Boundary

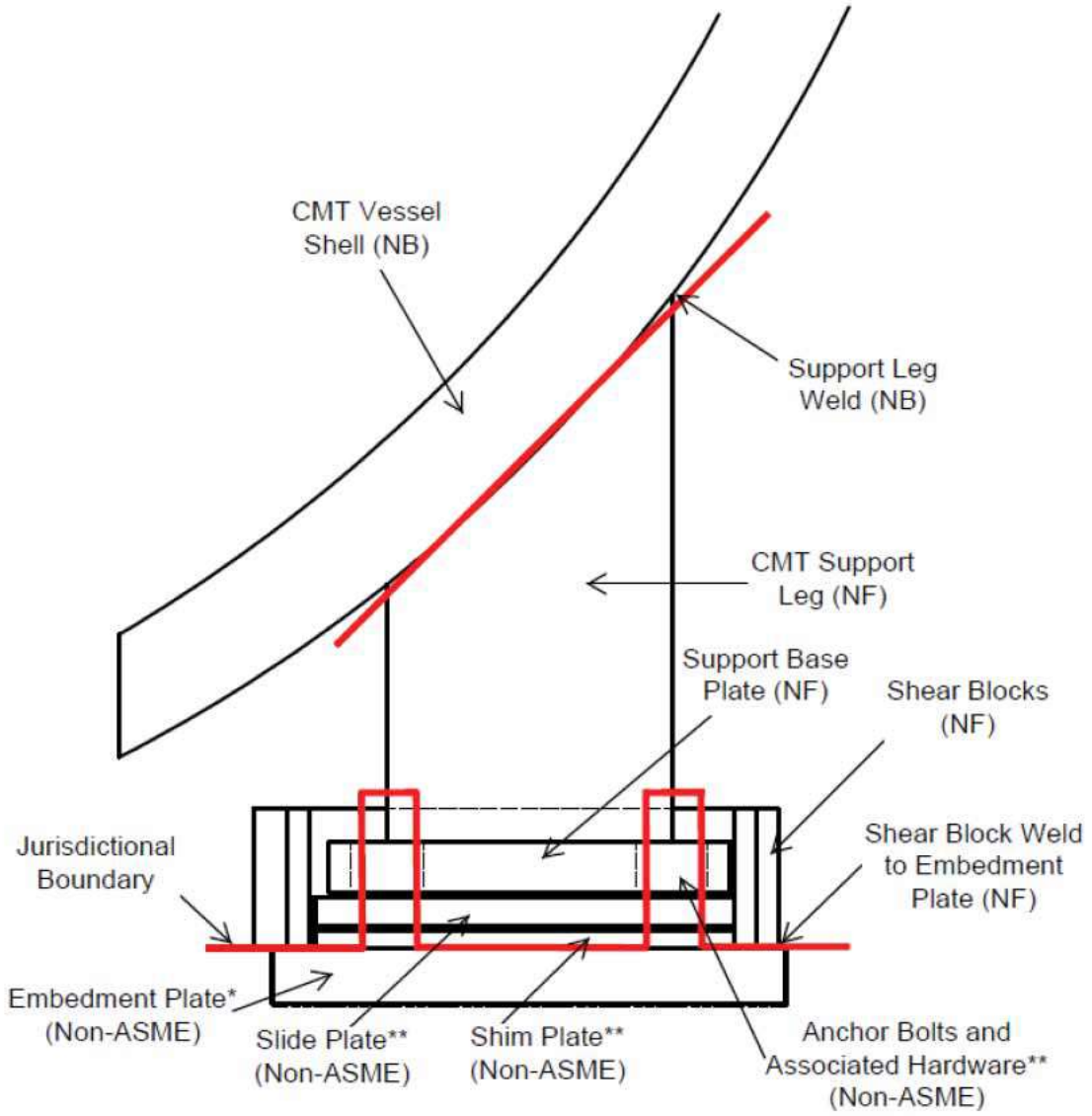


Figure 20H-4. Core Makeup Tank Support Jurisdictional Boundary