From: Tai, Tom
Sent: Thursday, November 03, 2011 1:08 PM
To: Spicher, Terri
Cc: STPCOL; Huang, Jason; Dixon-Herrity, Jennifer
Subject: FW: FMCRD
Attachments: STP 3&4 Process Flow Diagram.pdf; ECS-SE-000097%20Rev.1[1].pdf

Terri,

Attached for your use is NINA's proposed approach to address RAI 03.09.04-1 (eRAI 5870) to resolve the load information (or lack of) in FMCRD and HCU specifications. This includes a process flow diagram that STP Units 3 & 4 adopt to complete the specifications.

Please review these and be prepared to discuss in our Wednesday's telephone conference (November 9, 2011). I'll send a meeting request and an agenda later for this telephone conference later.

Regards

Tom Tai
DNRL/NRO
(301) 415-8484
Tom.Tai@NRC.GOV

From: Scheide, Richard [mailto:rhscheide@STPEGS.COM]
Sent: Thursday, November 03, 2011 1:03 PM
To: Tai, Tom
Cc: 'James Fisicaro'; Daley, Thomas J
Subject: FMCRD

Tom,

Attached for your review is a copy of the Draft revision to the FMCRD Design Specification as well as a Flowchart depicting the certification process for the specification/design report. The flowchart depicts at which point in the process particular load values are determined and included in the specification.

After your reviewers have completed their review of these documents, we can schedule a call to discuss any questions they may have. We can also determine if any additional actions are required at that time. If you have any questions in the interim, please call me.

Thanks,

Dick Scheide
Office: 361-972-7336
Cell: 479-970-9026

Hearing Identifier: SouthTexas34Public_EX
Email Number: 3173

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Sent Date: 11/3/2011 1:07:59 PM
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From: Tai, Tom

Created By: Tom.Tai@nrc.gov

Recipients:
"STPCOL" <STP.COL@nrc.gov>
Tracking Status: None
"Huang, Jason" <Jason.Huang@nrc.gov>
Tracking Status: None
"Dixon-Herrity, Jennifer" <Jennifer.Dixon-Herrity@nrc.gov>
Tracking Status: None
"Spicher, Terri" <Terri.Spicher@nrc.gov>
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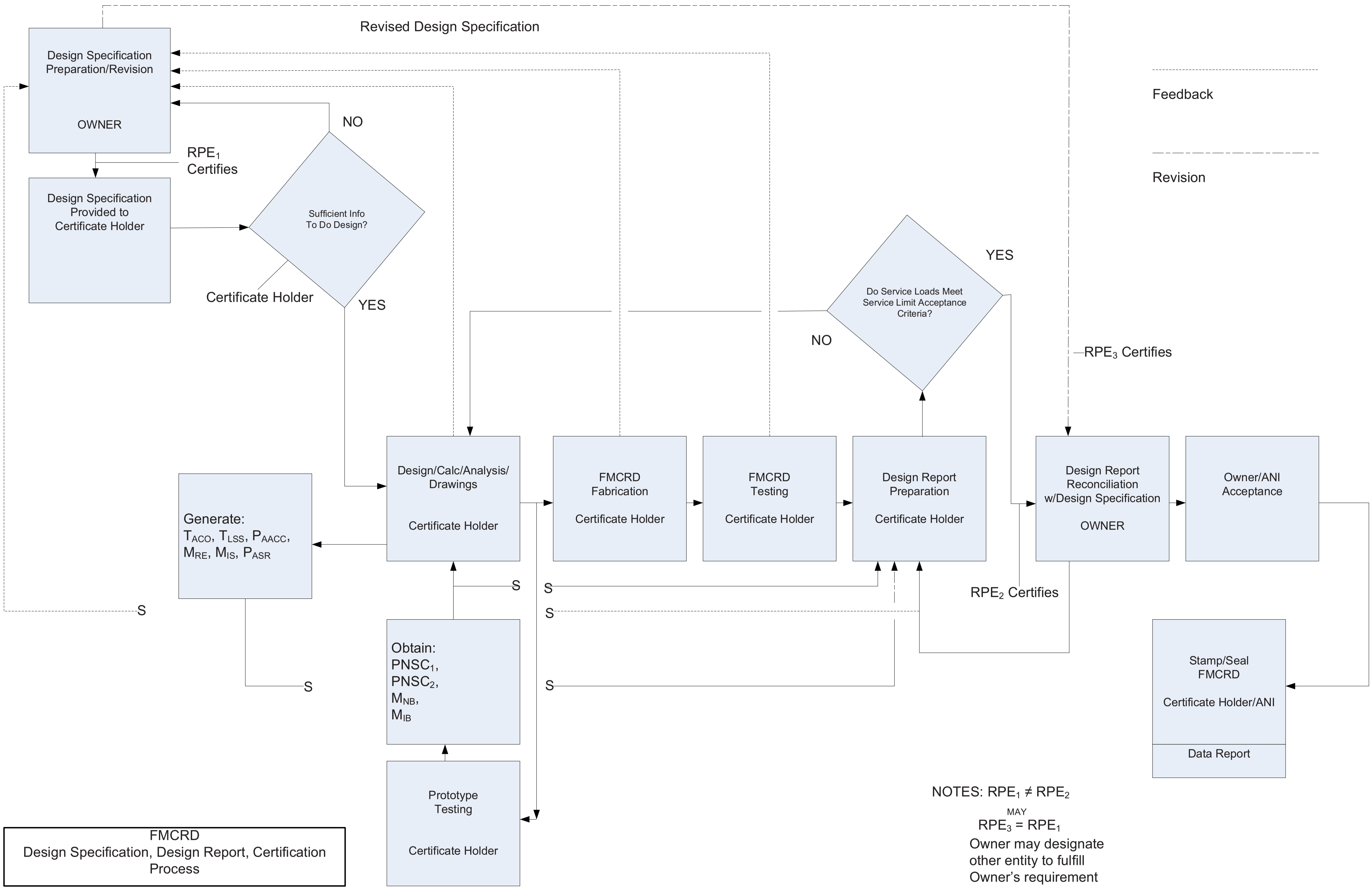
Recipients Received:



Revised Design Specification
Design Specification Preparation/Revision
OWNER
RPE_1 Certifies
Design Specification Provided to Certificate Holder
Sufficient Info To Do Design?
Certificate Holder
NO
YES
Design/Calc/Analysis/ Drawings
Certificate Holder
Generate:
T_{ACO}, T_{LSS}, P_{AACC}, M_{RE}, M_{IS}, P_{ASR}
Obtain:
$PNSC_1$,
$PNSC_2$,
M_{NB},
M_{IB}
Prototype Testing
Certificate Holder
FMCRD Fabrication
Certificate Holder
FMCRD Testing
Certificate Holder
Design Report Preparation
Certificate Holder
Do Service Loads Meet Service Limit Acceptance Criteria?
YES
NO
RPE_2 Certifies
RPE_3 Certifies
Design Report Reconciliation w/Design Specification
OWNER
Owner/ANI Acceptance
Stamp/Seal FMCRD
Certificate Holder/ANI
Data Report
Feedback
Revision
S
S
S
S
S
S
S
NOTES: $RPE_1 \neq RPE_2$
MAY
$RPE_3 = RPE_1$
Owner may designate other entity to fulfill Owner's requirement
FMCRD
Design Specification, Design Report, Certification Process

技　術　連　絡　票

ENGINEERING COMMUNICATION SHEET

Proprietary Class 2

宛先 TO	NINA, S&L, TANE		ECS-SE-000097 Rev.1
プラント名 PROJECT	STP-34	機器名 EQ/SYS	CRD
題　目 SUBJECT	Sending FMCRD Equipment Requirement Specification Rev.4 Draft incorporating discussion Nov.1,2011	製造/見積番号 JOB/QUOT.NO.	
□承認用 FOR APPROVAL □検討用 FOR REVIEW □確認用 FOR CONFIRMATION	■参考用 FOR INFORMATION □指示用 FOR NOTICE	回　答 REPLY □要　REQUIRED ■不要　NOT REQUIRED	回答希望日 DUEDATE

Toshiba sends FMCRD ERS Rev.4 Draft incorporating result of discussion held on Nov.1,2011 at S&L Chicago office (Attached Document).　The Draft is only for information to review.

Marked by pink; Changed part incorporating result of discussion on Nov.1,2011.

Marked by green; Changed part incorporating result of discussion on Oct.30,2011.

Marked by blue; Changed part of shown by ECS-SE-000082 Rev.0 Attachment 2 from FMCRD ERS Rev.3

[Attached Document]

FMCRD_ERS_Rev.4_Draft_20111102

改訂番号 REV No.	改訂内容 REVISED CONTENTS	承　認 APPROVED BY	調　査 CHECKED BY	担　当 PREPARED BY
1	Hydraulic Vertical Spectra numbers are added to the Attached Document (page 35).	K. Sekiguchi Nov 3, 2011	K. Sekiguchi Nov 3, 2011	M.Omiya Nov.3,2011

配布先 DISTRIBUTION					承　認 APPROVED BY	調　査 CHECKED BY	担　当 PREPARED BY
					K,Sekiguchi Nov.2,2011	K.Sekiguchi Nov.2,2011	M. Omiya Nov.2,2011

株式会社東芝 TOSHIBA CORPORATION　原子力事業部 NUCLEAR ENERGY SYSTEMS & SERVICES DIVISION

担当課　ISSUED BY
Control Rod Drive & Service System Engineering Group
SYSTEM DESIGN & ENGINEERING DEPT.

ASME-CODE	US Safety Related
89 Edition excluding Addenda	

ECS-SE-000097 Rev.1 Attachment

Proprietary
Class 2

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Units 3 & 4	Specification	
	STPNOC Doc./Dwg. No.	Rev.
	U7-CRD-M-SPEC-FCRD-0001	E

South Texas Project - Nuclear Operating Company
STP Unit 3 & 4
Equipment Requirement Specification

DRAFT_20111102

Title **Fine Motion Control Rod Drive Equipment Requirement Specification**

Reviewed by Plant Materials Technology Group	Reviewed by Project Quality Assurance Group

Customer Name	STPNOC
Project Name	STP-34
Item Name	Control Rod Drive
Item Number	C12-D005
Job Number	B03974-05
Applicable Plant	STP Units 3&4

Rev.	Issue Date	Issued by	Approved by	Reviewed by	Prepared by	Summary
4					M.Omiya Nov.1,2011	

Rev.	Initial Issue Date 発行年月日	Issued by 発行部門	Approved by 承認	Reviewed by 調査	Prepared by 起草	Document filing No.
0	Dec. 26, 2008	Automatic Machine System Engineering Group, Mechanical Technology & Design Department	S. Ishizato Dec. 26, 2008	K. Sekiguchi Dec. 22, 2008	N. Nakamura Dec. 22, 2008	RS-5127642

TOSHIBA CORPORATION

Nuclear Energy Systems & Services Division

<table>
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<tr><td rowspan="3">0</td><td rowspan="3">See cover page</td><td rowspan="3">Initial Issue</td><td>Automatic Machine System Engineering Group, Mechanical Technology & Design Department</td><td>See cover page</td><td>See cover page</td><td>See cover page</td></tr>
<tr><td>Plant Materials Technology Group</td><td colspan="3">Noriyuki Chujo
Dec. 22, 2008</td></tr>
<tr><td>Project Quality Assurance Group</td><td colspan="3">Hiroyuki Nishiyama
Dec. 24, 2008</td></tr>
<tr><td rowspan="3">1</td><td rowspan="3">Feb.17, 2009</td><td rowspan="3">-(Para 1.1) Addition of unit number
-(Para 2) Correction of title
-(Para 2.1) Addition of paragraph
-(Para 2.2) Addition of sentence
-(Para 2.2.1 a) Addition of criterion
-(Para 2.2.2 e) Correction of applicable year
-(Para 4.1, 4.2) Correction of sentence
-(Para 4.3) Addition of sentences
-(Para 5.1.1, 5.1.3, 5.1.6, 5.1.8.4 i)
Correction of sentence
-(Para 5.1.9, 5.2.1.3) Addition of sentence
-(Para 5.2.2.1) Addition of paragraph number
-(Para 5.2.2.2, 5.2.2.4, 5.2.4.1.4, 5.2.4.1.5)
Correction of sentence
-(Para 5.2.7.1.2) Addition of ASME Subsection
-(Para 5.2.10) Correction of title
-(Para 5.2.10, 5.3.2.1) Correction of sentence
-(Para 5.2.11.7) Correction of unit
-(Para 5.3.4.3, 5.3.4.3.1)
Correction of paragraph number
-(Para 5.4.5) Addition of paragraph
-(Para 6.1.2.1 a, 6.1.2.2 a, 6.1.2.3, 6.1.6.2 Note)
Correction of unit
-(Para 6.1.2.4 b, 6.1.3) Correction of sentence
-(Para 6.1.6.2 a-e) Correction of design spec.
-(Para 6.2.2.2) Addition of paragraph number
-(Para 7.2.3) Addition of paragraph
-(Para 8.1.1, 8.3.1, 9.5)
Correction of paragraph number
-(Para 9.3) Addition of sentence
-(Para 12) Addition of chapter
-(Table 1, A) Correction of sentence
-(Table 1, B) Correction of paragraph number
-(Table 1, D, Table 2.1 Note 2,4)
Correction of sentence</td><td>Automatic Machine System Engineering Group, Mechanical Technology & Design Department</td><td>S.IshizatoFe b.17,2009</td><td>K.Sekiguchi Feb.17,2009</td><td>N.Nakamura Feb.17,2009</td></tr>
<tr><td>Plant Materials Technology Group</td><td colspan="3">S.TanakaFeb.17,2009</td></tr>
<tr><td>Project Quality Assurance Group</td><td colspan="3">H.NishiyamaFeb.17,2009</td></tr>
<tr><td rowspan="3">2</td><td rowspan="3">Jul.6, 2009</td><td rowspan="3">-(Para 2.2.1) Addition of criteria numbers
-(Para 2.2.4.2 c) Correction of applicable year
-(Para 2.2.4.3) Addition of Reg Guide
-(Para 2.2.4.6) Addition of document
-(Para 2.2.4.7) Addition of document
-(Para 3.1.1) Correction of document and addition of document number
-(Para 5.1.9) Correction of operability requirement</td><td>Automatic Machine System Engineering Group, Mechanical Technology & Design Department</td><td>S.IshizatoJul, 6,2009</td><td>K.Sekiguchi Jul,6,2009</td><td>N.Nakamura Jul,6,2009</td></tr>
<tr><td>Plant Materials Technology Group</td><td colspan="3">S.Tanaka Jul.6,2009</td></tr>
<tr><td>Project Quality Assurance Group</td><td colspan="3">R.Kudo Jul.6,2009</td></tr>
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3	See cover page	-(Para 2.2.3 a) Addition of applicable year -(Para 2.2.3 b) Addition of applicable year -(Para2.2.4.6) Correction of document number -(Para 5.2.11.6) Correction of unit -(Para 5.3.3.1 a) Correction of sentence -(Para 5.4.2) Addition of sentence -(Para 6.2.2.3.a) Correction of unit -(Para6.2.3.a) Correction of unit -(Table 7) Correction of spelling -(Figure 1) Correction of Figure	Automatic Machine System Engineering Group, Mechanical Technology & Design Department	S.Ishizato Aug.8,2009	K.Sekiguchi Aug,6,2009	N.Nakamura AUg,6,2009
			Plant Materials Technology Group	S.Tanaka Aug.6,2009		
			Project Quality Assurance Group	R.Kudo Aug.7,2009		
4	See cover page		Control Rod Drive & Service System Engineering Group, System Design and Engineering Department	See cover page	See cover page	See cover page
			Plant Materials Technology Group	See cover page		
			Project Quality Assurance Group	See cover page		

TABLE OF CONTENTS

ATTACHMENT

LIST OF TABLES

1. SCOPE

1.1 This document defines the design requirements for the Fine Motion Control Rod Drive (FMCRD) for "South Texas Project – Nuclear Operating Company, STP Unit 3&4.

1.2 This specification defines the requirements for the drive mechanism, bayonet coupling, spool piece, drive motor, brake, position indicators (synchro, scram probe) separation probes, connectors, attachment bolts, O-rings and spacer plate. The electric signal and power cables and connectors and hydraulic control lines are not covered by this specification.

2. UNITS, APPLICABLE LAWS, CODES AND STANDARDS

2.1 SI units shall be used in design, fabrication, inspection and submittal documents with the customary U.S. units attached in parentheses for any parameter that has an interface with the balance of the design being prepared in the U.S.. Physical interface between equipments designed in SI units and designed in U.S. English units shall conform to each other in English units.

2.2 Codes and Standards

The following codes and standards are applicable to CRD to the extent specified herein.
When edition of Codes and Standards referenced in ASME Code are different from that of in this section, the difference shall be reviewed to ensure that all technical requirements of the Code are satisfied.

2.2.1 Nuclear Regulatory Commission (NRC) Regulations Title 10, Code of Federal Regulations Part 50 (10 CFR 50)

a. Appendix A, General Design Criteria for Nuclear Power Plants (Criterion 1, 2, 4, 14, 23, 25, 26, 27, 28, 29)
b. Appendix B, Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants

2.2.2 American Society of Mechanical Engineers (ASME) Section III Code Items

a. ASME Boiler and Pressure Vessel Code Section III, Rules for Construction of Nuclear Facility Components – 1989 Edition excluding Addenda
    1. Subsection NB, Class 1 Components
b. ASME Boiler and Pressure Vessel Code Section II, Materials – 1989 Edition excluding Addenda
    1. Part A - Ferrous Material Specifications
    2. Part B - Non-Ferrous Material Specifications
    3. Part C - Specifications for Welding Rods, Electrodes and Filler Metals
c. ASME Boiler and Pressure Vessel Code Section IX, Welding and Brazing Qualifications – 1989 Edition excluding Addenda
d. ASME Boiler and Pressure Vessel Code Section V, Nondestructive Examination – 1989 Edition excluding Addenda
e. ASME Boiler and Pressure Vessel Code Section XI, Rules for Inservice Inspection of Nuclear Power Plant Components – 2004 Edition

2.2.3 Non-Code Items (Items which ASME Code SectionⅢ is not applicable)

a. ASME B1.1, Unified Inch Screw Threads (UN and UNR Thread Form) - 2003 Edition

b. ASME B1.13M, Metric Screw Threads - M profile – 2005 Edition

2.2.4 General (for both Code and Non-Code Items)

2.2.4.1 American Society for Testing and Materials (ASTM) Standards, Latest Edition

a. ASTM D2000, Standard Classification System for Rubber Products in Automotive Applications

2.2.4.2 Institute of Electrical and Electronics Engineers (IEEE)

a. IEEE-323-1974, Standard for Qualifying Class 1E Equipment for Nuclear Power Generating Stations
b. IEEE-344-1987, Recommended Practice for Seismic Qualification of Class 1E Equipment for Nuclear Power Generating Stations
c. IEEE-384-1992, Standard Criteria for Independence of Class 1E Equipment and Circuits.

2.2.4.3 Nuclear Regulatory Commission (NRC) Regulatory Guides (Reg Guide)

a. Reg Guide 1.54 Rev. 0, Quality Assurance Requirements for Protective Coatings Applied to Water - Cooled Nuclear Power Plants.
b. Reg Guide 1.89 Rev. 1, Environmental Qualification of Certain Electric Equipment Important to Safety for Nuclear Power Plants
c. Reg Guide 1.100 Rev. 2, Seismic Qualification of Electric Equipment for Nuclear Power Plants.
d. Reg Guide 1.31 Rev.3 , Control of Ferrite Content in Stainless Steel Weld Metal
e. Reg Guide 1.37 Rev.0 , Quality Assurance Requirements for Cleaning of Fluid Systems and Associated Components of Water-Cooled Nuclear Power Plants
f. Reg Guide 1.44 Rev.0 , Control of Use of Sensitized Stainless Steel

2.2.4.4 American National Standards Institute (ANSI)

a. ANSI N101.2; Protective Coatings (paints) For Light Water Nuclear Reactor Containment Facility – 1972 Edition

2.2.4.5 Military Specifications

a. MIL-D-3464E - Desiccants, Activated, Bagged, Packaging, Use and static Dehumidification.

2.2.4.6 STP 3&4 Master EPC Agreement Exhibit A ETS U7-PROJ-G-SPEC-ETS-001 Rev. 0

2.2.4.7 STP Units 3 & 4 COLA Rev.2

3. REFERENCE DOCUMENTS

3.1 The following documents form a part of this specification to the extent specified herein.

3.1.1 Supporting Documents

	Document Title	MPL No.
a.	FMCRD Design Specification Drawing	7C12-D005-3102-01 Rev.1
b.	Project Requirement Document Materials and Process Controls	7A10-0301-0021 Rev.1
c.	Process Flow Diagram Control Rod Drive System	Later
d.	FMCRD Design Acceptance Test Specification	Later
e.	FMCRD Production Test Specification	Later
f.	FMCRD Installation Requirements Specification	Later
g.	Rod Server Module Equipment Requirements Specification	Later
h.	Rod Brake Module Equipment Requirements Specification	Later
i.	Fine Motion Control Rod Drive Motor Equipment Requirement Specification	7C12-D005-3001-02 Rev.0
j.	Design Specification Drawing RPV Nozzles Cycles (Sh1-10)	7B11-D003-1111-02-01 Rev.4 7B11-D003-1111-02-02～10 Rev.3
k.	Hydraulic Control Unit Equipment Requirement Specification	7C12-D004-3001-01 Rev.3
l.	Control Rod Drive System Design Description	7C12-1001-0001Rev.2
m.	Control Rod Guide Tube Stress Analysis	Later
n.	Design Specification Drawing Control Rod Guide Tube	7B11-D010-3102-01 Rev.1
o.	Design Specification Drawing Reactor Cycles (SH 1-3)	7B11-D003-1111-01-01 Rev.4 7B11-D003-1111-01-02,03 Rev.3
p.	Water Chemistry Requirements	A24-0501-0001 Rev.0
q.	Applicable Unit Metric and Conversion Rule	7A10-0301-0003 Rev.1
r.	Calculation / Analysis Report STP3&4 Seismic and Reactor Building Vibration Response Spectra Report	7A25-0501-00015, Rev.1

4. EQUIPMENT FUNCTION

4.1 The FMCRD controls and detects the position of the attached control rod within the reactor core during normal operation and provides rapid insertion of control rods into the core (scram) during certain reactor transients. This is required in response to control rod drive system and reactor protection system command signals.

4.2 The FMCRD is operated by both mechanical and hydraulic means. A motor driven spindle and ball nut drive the control rod for normal positioning operations while scram is achieved with hydraulic pressure. The control rod is connected to a hollow piston by a bayonet-type coupling. The hollow piston rests on the ball nut is not attached to it. Because of its weight, the control rod follows the motion of the ball nut

4.3 During the scram, the hollow piston separates from the ball nut as the control rod is driven into the core. Spring loaded latch fingers in the hollow piston expand and engage notches in the guide tube. The fingers support the hollow piston and the control rod until the ball nut can be driven up to support the hollow piston.

Stationary fingers on the ball-nut then cam the latches out of the slots and hold them in the retracted position. A scram action is complete when every FMCRD has reached their fully inserted position.

4.4 Rapid insertion (scram) of the control rod is accomplished by the application of a large differential pressure across the hollow piston. A high pressure accumulator provides the pressure and flow rate required for this mode of operation. A spring washer buffer assembly provides a controlled deceleration to the hollow piston at the end of its stroke by the effect of mechanical and hydraulic damping.

4.5 Control rod position indication is provided by magnetic switches in the position indicator probe and a drive shaft rotation counter called a synchro. Magnetic switches indicate when the drive is at 0, 10, 40, 60 and 100 percent of the stroke. The drive shaft rotation counter (or synchro) continuously monitors the drive position over its entire travel range, whenever the drive is being driven by the motor.

4.6 The insertion or withdrawal of the control rod is accomplished by pushing the appropriate buttons on the control panel. The control rod can be either inserted or withdrawn continuously or to a preset position.

5. DESIGN REQUIREMENTS

5.1 General

5.1.1 The FMCRD shall be designed to prevent the inadvertent withdrawal of the control rod under any normal reactor condition without restricting scram insertion.

5.1.2 The FMCRD shall be designed so that failure of a drive component will not impair the hydraulic rod insertion (scram) function whenever possible.

5.1.3 The FMCRD shall be designed to prevent uncontrolled withdrawal of a control rod under normal operation or accident conditions.

5.1.4 Reliability of the FMCRD with regard to satisfying its performance, design, and maintenance requirements shall be evaluated and/or demonstrated so that the FMCRD's effect on availability can be evaluated.

5.1.5 Interface compatibility shall be ensured or provided between the FMCRD and the following systems/components.

a. Reactor Vessel and Internals.
b. Control Rod Drive Housing Envelope and Attachment Bolt.
c. Control Rod Drive System, both Mechanically and Electronically.
d. Control Rod Coupling.
e. Fuel Lattice and Envelope.

f. CRD Installation/Removal Equipment.
g. Rod Control and Information System, both Mechanically and Electronically.
h. Hydraulic Control Unit
i. Control Rod Guide Tube

5.1.6 Seismic Design

The following FMCRD components shall be designed as seismic category I.

FMCRD Scram Related Components
- Hollow Piston
- Labyrinth Seal
- Ball Check Valve and Cage

Post Scram Holding
- Latches
- Brake Holding Function (brake and all parts which are utilized to couple the brake with the hollow piston, such as keys, couplings, shafts and ball nut)
- Ball Nut and Screw (Rod Holding after Scram)
- Guide Tube (Rod Holding)

Motor Casing and Bolting
Internal Blowout Support
FMCRD Separation Switch

5.1.7 All safety-related components shall be designed , purchased and manufactured in accordance with QA program which conforms to NRC 10CFR50 Appendix B.
QA program for ASME Section III components shall also conform to ASME Boiler and pressure Vessel Code Section III subsection NCA.

5.1.8 Structural

5.1.8.1 FMCRD parts, that form part of the reactor coolant pressure boundary shall be designed, fabricated, tested, and inspected in accordance with the ASME Boiler and Pressure Vessel Code, Section III.

5.1.8.2 All required stress analysis for FMCRD Code components defined herein shall be performed, reviewed and certified to show conformance with this specification and the ASME Boiler and pressure Vessel Code.

5.1.8.3 The components which are required for (a) integrity of the pressure boundary, (b) the ability to shut down and remain shut down, (c) the ability to prevent or mitigate the consequences of accidents that could result in potential off-site exposures exceeding allowable limits, shall be designated (for the purposes of this specification) as safety related. Safety related components shall meet the requirements of the applicable safety regulatory design guidelines.

5.1.8.4 Safety related components are:

a. Hollow piston.
b. Labyrinth seal.
c. Latches.
d. Guide tube.
e. Brake.
f. Check valve (active safety-related).
g. Check valve retainers.
h. Reactor Coolant Pressure Boundary components (see 5.3.3).
i. Internal Blowout Support (Includes Outer tube, Outer tube to middle flange weld and middle flange).
j. All parts (such as keys, couplings, shafts and ball nut) which are utilized to couple the brake with the hollow piston.
k. Separation Switches.

Reactor Coolant Pressure Boundary Components are categorized as Safety Class 1 and Quality Group A. Safety Class 3 components are categorized as Quality Group C.

5.1.9 Operability Requirements
The operability shall be verified during and after an earthquake of magnitude up to and including the SSE, and for all static and dynamic loads resulting from normal, anticipated operational occurrence and accident post-accident conditions. Analyses alone, without testing, will be acceptable as a basis for qualification only if it can be demonstrated that the necessary functional operability of the equipment will be ensured by its structural integrity alone.

5.2 Function

5.2.1 Pressure Boundary

5.2.1.1 FMCRD components identified in Paragraph 5.1.8.1 must be capable of maintaining pressure and avoiding loss of reactor inventory under any expected pressures.

5.2.1.2 Leakage through the seal housing shall be limited as such so that the temperatures of the non metallic parts (such as O-rings) do not exceed their recommended operating limit.

5.2.1.3 There are no requirements for overpressure protection.

5.2.2 Scram

5.2.2.1 The scram function shall be accomplished by translation of the hollow piston in response to differential hydraulic pressure as defined in the Process Flow Diagram (paragraph 3.1.1 c). The control rod insertion rate must satisfy Paragraph 6.1.2.2.

5.2.2.2 The FMCRD design shall provide a spring washer buffer assembly to mitigate the deceleration of the translating assembly at the end of stroke prior to impact with the end stop without adversely affecting drive function or control rod structural integrity.

5.2.2.3 The FMCRD design shall meet the performance requirements specified in 6.1.2 using the maximum control blade weight of 6.1.7.a.

5.2.2.4 The FMCRD shall be designed for all scrams with any degradation of the deceleration device (failed buffer) which cannot be detected by the failed buffer switch (Paragraph5.2.4.1.5). In addition, the FMCRD shall be designed to withstand the number of operational scrams with a detectable failed buffer condition defined in 6.1.4.h.

5.2.2.5 Scram capability shall be demonstrated under the most adverse conditions of misalignment (as defined in Table 3) and reactor operating conditions, including seismic events.

5.2.2.6 The FMCRD shall be designed to incorporate a non safety-related diverse means of shutdown at power operation that uses a different source other than hydraulic pressure, the function of which will not be impaired by failure of the primary system (i.e., scram accumulator). The diverse means of rod insertion shall have a rate of insertion as specified in Paragraph 6.1.1.e.

5.2.2.7 Latch

5.2.2.7.1 The FMCRD shall provide redundant latch mechanisms designed to support the control rod in position after a scram. The actuation of this latch shall be automatic in nature so that engagement with the guide tube occurs once the hollow piston departs from the ball nut.

5.2.2.7.2 The latch shall be designed so that its failure or interference shall not prevent the FMCRD from performing its scram function.

5.2.3 Control Rod Positioning

5.2.3.1 Rod position shall be maintained by the FMCRD during all reactor operation, including following a reactor scram, seismic event or loss of coolant accident.

5.2.3.2 Incremental positioning of the control rod shall be accomplished by the movement of a ball nut traversing a rotating spindle. The spindle is driven by a stepping motor capable of positioning the rod at increments or continuous drive operation. The incremental positioning shall meet the requirements of Paragraph 6.2.2.3.b to control rod positioning during normal reactor operation.

5.2.3.3 The FMCRD brake shall be capable of holding the control rod in position during any postulated accident, post-accident, and seismic condition.

5.2.3.4 During an Anticipated Transient Without Scram (ATWS), the FMCRD motor shall be capable of driving the rod full-in at rated speed. A seismic event need not be postulated in combination with ATWS.

5.2.4 Position Indication

5.2.4.1 Scram

5.2.4.1.1 The FMCRD shall have a position indicator probe designed to ensure that the scram performance of the CRD can be determined.

5.2.4.1.2 A continuous full-in indication device shall be designed to determine when the drive is at the top latched position or 100% position. The full-in indication device shall have the capability of providing the information required for continuous rod position display.

5.2.4.1.3 The position indicator mechanical design shall be capable of operation under loadings experienced during normal scram cycles. The number of scram cycles shall be equivalent to the design life of the FMCRD.

5.2.4.1.4 Failure of any position switch shall not affect the capability to read other position switches to allow determination that a fault exists.

5.2.4.1.5 A switch shall be provided to detect buffer failures.

5.2.4.1.6 The position indicator probe shall meet the electrical interface requirements of the Rod Server Module (Paragraph 3.1.1.g) and requirements of Paragraph 6.2.4.2.

5.2.4.1.7 A position switch shall be provided at the over travel out position for verification of CRD/control blade coupling in conjunction with Paragraph 5.2.8.2.

5.2.4.2 Fine Motion

5.2.4.2.1 The FMCRD shall be equipped with two synchros provided with redundant continuous detection and indication of the smallest increment motion over the entire range of positioning required including overtravel.

5.2.4.2.2 The synchro shall be installed within the space envelope provided by the control rod drive and shall be designed to function in the drywell environment as defined in Table 5 and Table 6.

5.2.4.2.3 The synchro signals shall meet the requirements of Paragraph 6.2.4.4.

5.2.4.2.4 The synchro shall provide redundant indicated position for the sensor to the cable interface over the range specified by Paragraph 6.1.1.

5.2.4.2.5 Reliability shall be demonstrated by evaluation and verification.

5.2.4.3 Rod Separation

5.2.4.3.1 The device for detecting rod separation shall:

a. Be redundant.
b. Be electrically and physically separated to the maximum extent practicable from each other and from other, non-essential, electrical functions.
c. Meet electrical interface requirements of Paragraph 6.2.4.3.
d. Be qualified to demonstrate operability and/or it shall not fail in a manner detrimental to plant safety or accidental mitigation over the specified environmental conditions shown in Table 6.

5.2.5 Brake

5.2.5.1 The FMCRD motor shall be provided with a brake to protect against rod ejection. The brake shall be designed so that its failure or interference does not prevent scram.

5.2.5.2 The brake shall be designed to prevent rod ejection for a pressure boundary failure in the insert line at normal operating pressure.

5.2.5.3 The brake mechanism shall be normally locked, that is, locked when deenergized.

5.2.5.4 The brake mechanism shall be qualified to demonstrate operability and/or shall demonstrate that it will not fail in a manner detrimental to plant safety or accidental mitigation over the specified environmental conditions shown in Table 6.

5.2.5.5 The brake shall be normally locked and prevent rod ejection in a passive state. In addition, the brake shall be testable to confirm acceptable brake performance characteristics. This special brake testing shall be used for initial installation and annual inspection testing of the FMCRD brakes.

5.2.6 Check Valve

5.2.6.1 A check valve shall be provided to protect against rod ejection with the rupture of an insert line. The check valve shall be designed so that its failure or interference does not prevent rod insertion.

5.2.6.2 The check valve is considered an active component. Its function to prevent rod ejection is classified as active safety related. It shall be designed to be testable at every refueling outage.

5.2.6.3 The check valve shall be qualified to demonstrate operability and/or shall demonstrate that it will not fail in a manner detrimental to plant safety.

5.2.6.4 Upon rupture of an insert line, the check valve leakage shall be limited a such so that the rod ejection rate is less than 0.1 m/s (19.7 ft/min) at normal operating pressures.

5.2.7 Bolting and Fasteners

5.2.7.1 Pressure-Retaining joint Bolts

5.2.7.1.1 The bolt threads and heads shall be in accordance with the interface requirements specified on FMCRD Design Specification drawing (paragraph 3.1.1.a).

5.2.7.1.2 Bolt material shall conform to the requirements of ASME Code Section III, Subsection NB.

5.2.7.1.3 Positive means shall be implemented to prevent water accumulation in the bolt holes. One acceptable method for accomplishing this is using split washers under the fastener heads to provide channels for water drainage from the bolt holes.

5.2.7.2 Other Bolts and Fasteners
Internal bolts, nuts, and studs shall be positively locked. Design and arrangements of bolts, fasteners, and connectors shall be such that disassembly and maintenance can be accomplished quickly and easily in congested, high radiation areas.

5.2.8 Coupling with the Control Rod

5.2.8.1 The FMCRD shall be capable of coupling, operating, and uncoupling under worst case misalignment conditions as defined in Table 3 without damage to the FMCRD, Control Rod, or Control Rod Guide Tube. The design shall provide for removal and replacement of the FMCRD without necessitating removal of the reactor vessel head and shall assure minimum reactor water leakage down through the FMCRD during its removal or replacement, or while performing the coupling and uncoupling of the control rod. The FMCRD shall allow removal and replacement of the control rod from above the reactor vessel with the reactor vessel head removed and without the removal of the FMCRD.

5.2.8.2 A means of remotely determining positive coupling verification shall be provided (i.e., an uncoupling check).

5.2.8.3 The coupling shall meet the interface requirements of FMCRD Design Specification Drawing (paragraph 3.1.1.a).

5.2.9 Purge Flow

5.2.9.1 The FMCRD shall be designed so that the applied purge flow will limit the entrance of wear particles that could cause, or lead to, degradation of life and performance of mating or interfacing components.

5.2.9.2 The FMCRD shall be designed so that the applied purge flow will limit the normal steady-state temperature of all components whose service life may be restricted by prolonged operation at high temperature.

5.2.9.3 The design shall allow purge water flow as defined in the Process Flow Diagram (paragraph 3.1.1.c). through the drive at all positions including the fully withdrawn operating position.

5.2.10 Internal Blowout

The drive shall be attached to the control rod guide tube base and shall be designed to withstand loads due to blowout and the pressure loading imposed by a sudden housing break at its attachment weld, or a circumferential break in the CRD housing, or sudden and simultaneous break of all eight main reactor coolant pressure boundary bolts at the FMCRD housing flange.

In the event of a CRD housing break, the FMCRD shall be designed to withstand the blowout loads that occur upon closure of the gap between the FMCRD and the Control Rod Guide Tube (CRGT) base in the as-installed condition. The magnitude of the gap is limited by the stresses in the CRGT base as determined in the stress analysis report (paragraph 3.1.1.m). The total gap is composed of two components: (a) the gap at the interface of the FMCRD and the CRGT base, i.e., the gap between the faces of the FMCRD upper portion hub bayonet (or lug) and the CRGT base hub bayonet, and (b) the gap in the slot between the FMCRD outer tube and the key that connects the outer tube to the FMCRD upper portion. The first component of the total gap can be determined by performing a tolerance stack-up calculation using the CRGT assembly drawing (paragraph 3.1.1.n) and the FMCRD design drawings. The second component of the total gap represents the capability of FMCRD to adjust to accommodate the length of the as-built CRD housings.

5.2.11 Other

5.2.11.1 The FMCRD components shall be designed to assure adequate functional capability during loadings and combinations specified in Attachment 1 and Table 2.

5.2.11.2 As a minimum, the functional adequacy of the components shown in Table 6 shall be demonstrated as defined in the FMCRD Design Acceptance Test Specification (paragraph 3.1.1.e).

5.2.11.3 All non-metallic materials (O-rings, gland packing, vacuum grease, lubricants, etc.) shall conform to the requirements pertaining to such materials found in the applicable specification (Later).

5.2.11.4 Loads of the FMCRD imposed on the CRD housing and control rod shall not exceed those on FMCRD Design Specification drawing (paragraph 3.1.1.a). Loads to be considered shall include: scram, failed buffer, seismic, dead weight, motor torque*

*Note; Loads will be added to the drawing (paragraph 3.1.1a) later.

5.2.11.5 The maximum control rod drop speed when coupled with the hollow piston shall be limited to 0.7 m/sec (137.8 ft/min), although such an event is not expected to occur as the result of other design features (separation switches and positive coupling).

5.2.11.6 The spool piece shaft seal packing shall be selected such that the starting torque and the running torque does not exceed 44.13N-m (32.54 ft-lb).

5.2.11.7 The leakage from the assembled spool piece shaft seal packing, shall not exceed the equivalent 6 cm^3/min (0.4 in^3/min) at 7.48 MPa[gage] (1085 psi[gage]) when the shaft is rotated or stationed when performing spool piece leak test after inspection/assembly. All FMCRD leakage shall be directed through the leak detection system described in Control Rod Drive System Design Description (Paragraph 3.1.1.l).

5.3 Structure

Structural adequacy of the FMCRD shall be demonstrated by analysis for the loads shown in Attachment 1. Testing may be used to show structural adequacy for some non-pressure boundary components.

5.3.1 Analysis

5.3.1.1 General

5.3.1.1.1 Analysis shall be done to show adequacy of Reactor Coolant Pressure Boundary parts of the FMCRD. Analysis shall also be used to demonstrate adequacy of the remaining FMCRD components that are not Reactor Coolant Pressure Boundary parts and which cannot be adequately demonstrated by test (such as paragraph 6.1.2.4).

5.3.1.1.2 Material allowable value used for calculating stresses shall be those specified by ASME Code for all "Code" component analysis. Material allowable value for non code component analysis shall be based on a recognized reference.

5.3.2 Testing

5.3.2.1 Testing should conform and fulfill the requirements of Section 8.

5.3.2.2 Test procedures and specific points of adequacy to be shown by the test shall be established prior to testing to avoid insufficient demonstration of adequacy.

5.3.3 Reactor Coolant Pressure Boundary

5.3.3.1 Parts of the FMCRD which are required to maintain the Reactor Coolant Pressure Boundary include (Refer to Figure 1):

a. The middle flange between the flange faces, including the weld of the outer tube to the middle flange.
b. The spool piece housing.

c. The eight bolts used to maintain pressure integrity of the bolted flange connection of the drive to the CRD housing.
d. The seal housing.
e. The threaded nut which is attached to the seal housing.

5.3.3.2 The seals, bushings wipers, seal shaft and bearings which aid in maintaining the pressure boundary, are not classed as part of the primary pressure boundary because their failure would not lead to deleterious loss of vessel inventory.

5.3.3.3 The loads in Attachment 1 and the load combinations in Table 2 shall be used for the analysis.

5.3.3.4 Reports shall conform to the appropriate Codes and Standards.

5.3.4 Non-Pressure Boundary Component

5.3.4.1 The acceptability of these components shall be demonstrated by functional testing or analysis under the loads and load combinations in Attachment 1 and Table 2.

5.3.4.2 Components such as springs, locking devices, and seal rings shall be designed according to the acceptable industry standards or empirical data based on field experience or testing.

5.3.4.3 Analysis on non-pressure boundary components may use the Codes and Standards (Paragraph 2.2) as a guideline or the following method.

5.3.4.3.1 The "stress intensity" defined by the Codes and Standards (Paragraph 2.2) may be replaced by a combined stress calculation using the maximum distortion energy theory :

$$s = \left[\frac{(\theta_1 - \theta_2)^2 + (\theta_2 - \theta_3)^2 + (\theta_3 - \theta_1)^2}{2} \right]^{1/2}$$

where θ_1, θ_2 and θ_3 are the principal stresses calculated on an elastic basis.

The concept of stress differences shall apply to determine the maximum stress range for primary plus secondary stress for all loading conditions.

5.3.4.3.2 The stresses calculated by the preceding equation, including special stresses defined in the Codes and Standards (Paragraph 2.2), shall be limited to the allowable stresses specified in Table 4.

5.4 Materials

5.4.1 Material selection shall be made for individual FMCRD components based on the application (i.e., Code, Noncode), the applicable design duty cycle, the local environment, and the required service life.

5.4.2 Consideration shall be given to material applications that could introduce significant wear particles to the system. Cobalt content of all materials shall be limited to applications where an acceptable alternate cannot be found. The target value of cobalt content is 0.05 wt percent and this is not specification.

5.4.3 Material (except non-metallic materials) selections shall be made using the Materials and Processes Controls Specification (reference Paragraph 3.1.1.b) as a guidance in satisfying the requirements of Paragraph 5.4.1 where applicable.

5.4.4 Materials used in constructing FMCRD portions which provide safety related function, or are in contact with the process water, shall be selected on the basis of suitability for the service, the requirements of the applicable codes and standards, and a history of satisfactory service in BWR applications.

5.4.5 There is no requirements for impact test on pressure retaining material (austenitic stainless steel) of FMCRD Class 1 components (exception of ASME SecⅢ Subsection NB-2311 (a) (6) is applied).

5.4.6 The materials used shall conform to the requirements listed in Table 7.

5.5 Maintenance

5.5.1 Installation procedures and equipment shall be compatible with the FMCRD Design Specification drawing (Paragraph 3.1.1.a).

5.5.2 Time required to inspect, disassemble, and reassemble the FMCRD shall be limited, so that operations which may involve significant personnel exposure will be limited.

5.5.3 Special tooling required for the assembly or disassembly of the FMCRD shall be designed in accordance with the requirements of commercial tools, to limit personnel exposure.

6. SPECIFICATION DATA

6.1 Drive Mechanism

6.1.1 Rod Positioning.

The FMCRD shall be designed to satisfy the following rod positioning travel requirements:

a. Active stroke (full-out to full-in) 3660 mm (144 inch).
b. Ball screw pitch 12 mm (0.472 inch).
c. Over travel: 50 mm (1.97 inch) max (insert direction during scram).
d. Over travel: 60 mm (2.36 inch) max beyond backseat of rod to guide tube base.
e. Insert/Withdraw rate: 30 mm/s (1.18 inch/s) ±10 percent (through pitch defined in 6.1.1.b when combined with the balance of the positioning system).

6.1.2 Scram Times

The FMCRD shall be designed to insert the control rod rapidly into the core (i.e., scram) within the following limits. All times are from Loss of Signal (LOS) to the HCU. Start of Motion (SOM) is the time from LOS to drop out of the 0% insertion switch.

6.1.2.1 Limits for system conditions are:

a. The minimum hydraulic and nitrogen pressures (12.75 MPa[gage] (1849 psi[gage]) gauge with the accumulator piston bottomed).
b. The maximum line losses (2.11MPa (306 psi) at 473 liter (125 Gallon)/min from inside the accumulator to the CRD Housing flange face).
c. The maximum allowed misalignment (of Table 3).
d. The maximum blade weight (6.1.7.a).
e. Water and nitrogen volumes as specified in the Hydraulic Control Unit Equipment Requirements Spec.

6.1.2.2 The required scram times are:

a. For a vessel bottom head pressure of 7.48 MPa[gage] (1085 psi[gage])

start of motion	≦0.20 s
10% insertion	≦0.42 s
40% insertion	≦1.00 s
60% insertion	≦1.44 s
100% insertion	≦2.80 s

b. For a vessel bottom head pressure as shown in Table 1.1 (Later)

Start of motion	Later
10% insertion	
40% insertion	
60% insertion	
100% insertion	

c. For a vessel bottom head pressure as shown in Table 1.2 (Later)

Start of motion	Later
10% insertion	
40% insertion	
60% insertion	
100% insertion	

6.1.2.3 Acceptance Criteria

a. For vessel pressure equal to or larger than the normal operation, (i.e., 7.48 MPa[gage] (1085 psi[gage]) at the vessel bottom head, the scram times of Paragraph 6.1.2.2.a must be met under the system conditions defined in Paragraph 6.1.2.1.

b. For vessel pressure equal to or larger than the pressure transient of Table 1.1 (full load rejection without bypass) the scram times of Paragraph 6.1.2.2.b must be met under the system conditions defined in Paragraph 6.1.2.1.

c. For vessel pressure equal to or larger than the pressure transient of Table 1.2. (Safety Relief Valve Sizing) the scram times of Paragraph 6.1.2.2.c must be met under the system conditions defined in Paragraph 6.1.2.1.

6.1.2.4 Seismic Scram Performance

a. The Scram Performance (Scrammability) of the FMCRD under dynamic load condition of Table 1.1, 1.2 and Table 2 shall be demonstrated by bounding test and or analysis which simulate the friction between the control rod and a deflected fuel channel during the dynamic loads event. Use of previous test and analysis is acceptable.

b. Under a 41mm (1.61 inch) channel deflection, the FMCRD shall be tested and the scram curves recorded.

6.1.3 Buffer

The device used to dissipate the scram energy (i.e., buffer) shall stop the translating assembly from the maximum terminal velocity without exceeding applicable stress limits with a maximum weight blade (6.1.7 a). With this device inoperative, the FMCRD components shall be evaluated and must satisfy the requirements of Paragraph 5.2.2.4, as applicable, when subjected to maximum terminal velocities.

6.1.4 Design Life Duty Cycles

The FMCRD shall be designed for the following 60-year life duty cycle:

	Design Basis Cycles
a. Hydrostatic Test	90
b. Reactor start-up	260
c. Operational scrams	272
d. Reactor shutdown	252
e. Step/notch/short stroke continuous cycles	180,000/Drive
f. Travel distance	23,800 m (780,840ft)/drive
g. Drive cycles (full stroke, in and out)	1,000
h. Failed buffer scram (1 at zero vessel pressure)	20

6.1.5 Design Life

a. The drive internals shall be designed for a 60 year service life.

b. The lower seal housing package shall be designed for at least a 10 year service life.

c. The motor, brake, synchros, and probes shall be designed for at least a 10 year service life.

6.1.6 Environment

6.1.6.1 The FMCRD components shall be designed to the requirements of environmental and dynamic design to operate in the environment (external to the primary system) specified in Table 5.

6.1.6.2 Design parameters for FMCRD components which are part of the primary boundary or are enclosed within the primary boundary are:

a.	ASME Design Pressure	22.56 MPa[gage] (3272 psi[gage])
b.	ASME Design Temperature	66℃ (151°F)
c.	Maximum Operating Pressure	22.56 MPa[gage] (3272 psi[gage])
d.	Normal Operating Pressure	7.48 MPa[gage] (1085 psi[gage])
e.	Maximum Operating Temperature	302℃ (576°F, non-ASME Code parts)
f.	Water Quality (Design Basis) The Water Chemistry Requirements are identified in 3.1.1.p	

NOTE The pressures and temperatures for design of specific parts shall be determined in the stress analysis report ~~and shall be based on a minimum hydraulic control unit supply pressure of 12.75 MPa[gage] (1849 psi[gage]) at temperatures specified on the Process Flow Diagram (Paragraph 3.1.1.e).~~ Ambient temperature ranges are shown on Table 5. Temperatures and pressures inside the vessel are given by the Reactor Cycle Diagram and RPV Nozzle Thermal Cycles (Paragraph 3.1.1.j). Water hammer effects shall be considered.

6.1.7 Control Blade

The drive shall be structurally adequate and perform all of its intended functions with

a.	Maximum control blade weight	104kg (230 pound)
b.	Minimum control blade weight	75kg (165 pound)

6.1.8 Latches

Latching positions shall be at intervals of less than or equal to 210 mm (8.27 inch) throughout the full FMCRD stroke. Reliability of this latch must be demonstrated under the most adverse reactor conditions as defined herein. With a single failure of one of its latches, the hollow piston shall be capable of latching in position intervals of less than or equal to 420 mm (16.5 inch).

6.2 Electrical

6.2.1 General

6.2.1.1 Environmental conditions applicable to the FMCRD electrical components located at the under vessel area are defined in Table 5.

6.2.2 Motor

6.2.2.1 General

The FMCRD drive motor shall be designed to meet the requirements of this specification for the events shown in Table 6 and the applicable environments of Table 5.

6.2.2.1.1 Motor power shall be electrically and physically separated to the maximum extent practical from control and instrumentation cables.

6.2.2.1.2 Motor Specifications

a. Type — 3 phase, permanent magnet
b. Insulation — Class F
c. Time rating — 10 min
d. The motor shall be capable of satisfactory operation for 60 years with planned maintenance and replacement in the environment listed in Table 5.

6.2.2.2 Input.

The input requirements to the motor shall be consistent with the Stepping Motor Driver Module (paragraph 3.1.1 i).

a. Method of variable speed control — Equivalent to constant volts/Hz

6.2.2.3 Output

a. Motor torque characteristics shall result in meeting the performance requirements of this document. The motor torque shall have sufficient margin above the FMCRD starting and running resistance torque to prevent stalling and failure to start under conditions of Table 6.

Rated Motor Torque	44.2N-m (32.6 ft-lb) Note 1
Normal Pull-Out Torque	≥68.7N-m (50.7 ft-lb) Note 1
Normal Starting Torque	≥63.8N-m (47.1 ft-lb) Note 1
Abnormal Voltage Pull-Out Torque	≥44.2N-m (32.6 ft-lb) Note 2
Holding Torque	≥3.0N-m (2.3 ft-lb)

Note 1: This is required torque under conditions of normal (i.e. rated) input voltage to the stepping Motor Driver Module associated with each FMCRD motor.

Note 2: This is the required pull-out torque capability during short term transient drops of the input voltage down to 85% of rated input voltage for the stepping Motor Driver Module associated with each FMCRD motor.

b. Minimum step at ball nut through pitch (defined by 6.1.1.b) — 18.3 mm ±9 mm (0.720 inch ±0.354 inch)

c. Rated Motor speed — 150 RPM nominal

d. Rated motor speed variation — See 6.1.1.e

e. Starting characteristics (for notch and continuous movement)

Maximum time from start of motor movement to full speed	1.0 sec
Maximum distance traveled from start of motor movement to full speed	1 step per Paragraph 6.2.2.3.b

f. Deceleration characteristics (for notch and continuous movement)

Maximum time from full speed to minimum speed for stopping	1.0 sec
Maximum distance traveled from full speed to minimum speed for stopping	1 step per Paragraph 6.2.2.3.b

g. Maximum time to accomplish the step movement — 3.2 sec

6.2.3 Brake

a. Minimum holding torque	49 N-m (37 ft-lb) (includes margin)
b. Insulation	Class F
c. Maximum release time from power application to full mechanical release	0.4 sec
d. Maximum engagement time from loss of power to mechanical engagement	0.4 sec

6.2.4 Probes

6.2.4.1 General

The following requirements apply to the separation and position indicator probes.

6.2.4.1.1 The probes shall be designed for the environmental conditions of Table 5 and Table 6.

6.2.4.1.2 Pin to pin series resistance, with the respective reed switch closed, shall not exceed 50 ohms at 5 mA after application of a maximum of 5 VDC.

6.2.4.1.3 The design of the switches within the probes shall consider the cumulative effect of the surrounding drives, the internal components of a drive and other structures in the under vessel area on the magnetic fields of each drive.

6.2.4.2 Position Indicator Probe

6.2.4.2.1 Detect scram positions of 0%, 10%, 40%, 60% and 100%.

6.2.4.2.2 Voltage

a.	Maximum supply voltage	48 VDC
b.	Minimum supply voltage	5 VDC

6.2.4.2.3 Maximum contact rating 10 W

6.2.4.2.4 Maximum switching current 0.5 A

6.2.4.3 Separation Probes

a.	Maximum supply voltage	48 VDC
b.	Minimum supply voltage	5 VDC

6.2.4.3.3 Maximum contact rating 10 W

6.2.4.3.4 Maximum switching current 0.5 A

6.2.4.4 The drive shaft rotation counter (synchro)

a.	Type	Speed-synchronizing signal generator
b.	Accuracy (Paragraph 6.1.1.b)	±5 mm (± 0.197 inch) through the ball screw pitch
c.	Output signal	180°Rotation angle shall correspond to 2048 mm (80.6 inch) through the ball screw pitch (Paragraph 6.1.1.b)

6.2.5 Connectors.
Connectors shall be located as designated on FMCRD Design Specification Drawing (Paragraph 3.1.1.a).

7. FABRICATION REQUIREMENTS

7.1 General Requirements

7.1.1 All fabrication shall be performed per fabrication drawings based on FMCRD Design Specification drawing, written fabrication, and test procedures.

7.1.2 Application of ASME Code welding shall be based on boundary jurisdiction of ASME SectionIII, NB-1130.

7.1.3 Fabrication of FMCRD parts shall meet the fabrication requirements stated in section 5 of the Materials and Process and Controls (Paragraph 3.1.1.b).

7.2 QC Requirements

7.2.1 The FMCRD shall be designed, manufactured, assembled, tested, and shipped in accordance with the quality requirements contained on the component drawings.

7.2.2 Documents shall be developed to specifically identify and define requirements outlined in the preceding paragraphs as applicable to each of the phase listed in the paragraphs.

7.2.3 Measuring and Test Equipment. Measuring and Test Equipment used for determining conformance to specified requirements shall be calibrated. Those Measuring and Test Equipment shall be traceable to the US National Institute for Standards and Technology (NIST) or to NIST through a Mutual Recognition Arrangement (MRA) or to US nationally recognized standards. If no nationally recognized standards exist, the bases for calibration shall be documented.

8. EXAMINATION AND TEST REQUIREMENTS

8.1 General Requirements

8.1.1 Material and part examinations (volumetric and surface) of the pressure boundary parts shall be performed in accordance with the requirements of the applicable Codes and Standards (Paragraph 2.2). Material and part examinations of the parts that are in contact with the reactor coolant (wetted) shall be performed in accordance with the requirements of the applicable Codes and Standards.

8.1.2 Test procedures shall be established to ensure applicability and completeness of tests performed.

8.1.3 The Supplier shall identify locations to be measured, tolerance for them and inspection method in the applicable dimensional inspection procedure and shall submit to the Purchaser for approval.

8.2 Hydrostatic Tests

8.2.1 After completion of fabrication, and while FMCRD is still in the shop (before shipment), either as a part of a control rod drive assembly or as a spare part, hydrostatic test primary pressure retaining parts in accordance with ASME Section III, Subarticle NB-6200.

8.2.1.1 Water used in hydrostatic tests and performance tests shall be demineralized water.

8.3 Production Testing

8.3.1 A production test shall be performed on each FMCRD prior to shipment to a reactor site in accordance with the Production Test Requirements (paragraph 3.1.1 e). This test shall ensure that all CRD functions are within normal acceptance limits.
In addition to the hydrotest (Paragraph 8.2), each drive shall:

a. Demonstrate capability to meet the scram times of Paragraph 6.1.2, at minimum accumulator charge and maximum line loss.
b. Demonstrate the capability to drive in and out.
c. Demonstrate margin over friction test criteria.
d. Demonstrate that leakage through the labyrinth is sufficiently low.

e. Demonstrate that the separation switches are functional (may be separate test, however, function of weighing platform shall be verified for each FMCRD).

9. CLEANING AND PAINTING

9.1 FMCRD cleanness shall be classified Cleanness Class C as defined in ASME NQA-1 Part II, Subpart 2.1.

9.2 All surfaces shall be thoroughly cleaned of all foreign material and shall have excellent cosmetic appearance. Stainless steel and other corrosion resistant surfaces shall not be painted. Sealing surfaces and fasteners regardless of material shall not be painted but shall be coated with a removable preservative for protection during shipping and storage.

9.3 All other surfaces shall be painted with a combination of zinc rich or epoxy primer followed by an epoxy finish coat. The finish color shall be 7.5GY 4.5/2.
Service level I coating (inside the reactor containment, safety-related) shall be applied in accordance with 2.2.4.3 a.

9.4 All paint and preservative shall be applied to clear surfaces following a written procedure based on the manufacturer's instructions.

9.5 Materials of construction, lubricants, cleaning solution residue, and all other materials which are contacted by process water shall be incapable of contaminating that water in excess of the limits (paragraph 3.1.1 p).

9.6 Cleanness shall be verified by visual inspection of the interior of components prior to final assembly.

10. PACKAGING AND TRANSPORTATION

Before packing, the drive shall be dried sufficiently to prevent corrosion. (Acceptable alternates to drying may be used to prevent corrosion.) Subcomponents should be protected to avoid damage during shipping. Several FMCRDs may be packed in one box for shipping.

10.1 FMCRD protection shall be classified as protection level B as defined in ASME NQA-1 Part II Subpart 2.2. and category B as defined in ASME NQA-1 Part Ⅱ Subpart 2.15.

10.2 The FMCRD shall be packed and packaged so that no degradation of any components will occur during normal transit to and storage at the reactor site.

10.3 A document shall be developed to identify specific packaging and shipment requirements for the FMCRD. This document shall address the following:

a. Materials for cleaning, packing, and packaging.

b. Support requirements.
c. Allowable external forces during transit.
d. Structural requirements for container.
e. Humidity control.

11. SPARE AND REPLACEMENT PARTS

List of Spare and Replacement Parts shall be submitted to the Purchaser.

12 SUBMITTAL DOCUMENTS

12.1 General

Submittal documents shall be issued in accordance with the requirements specified in this section and Quality Assurance Specification.

12.2 Submittal Documents

12.2.1 Fabrication Procedure:
The Fabrication Procedure shall be submitted for information prior to each fabrication.

12.2.2 Submittal documents list:
The submittal documents list shall be submitted for information and show all drawings, design reports, procedures, and material specifications required in section 11 and the dates when these item will be submitted prior to applicable material procurements or fabrication releases.

12.2.3 Equipment Drawing
The equipment drawings shall be submitted for approval prior to design analysis calculation performed before each fabrication release.

12.2.4 Certified Material Test Report
Certified Material Test Reports for ASME Section III code items shall conform to ASME Section III, Subsection NCA-3867 and submitted for approval. For other items, material test reports shall be submitted as required.

12.2.5 Design Report
The design report shall be submitted for approval and conform to ASME Code, Section III, Division 1, Appendix C.

12.2.6 Material Purchase Specification
Material purchase specifications for all ASME materials shall be submitted for approval prior to procurement of the materials.

Attachment 1. Loads Definition

This attachment summarizes the loads that should be considered in the design of the FMCRD. In those cases where specific load values have not been provided, the Certificate Holder is to determine the loads under which the FMCRD is to function from the information provided in this specification.

A. CRD Pressures

Scram.
For scram actuation, water pressure from the Hydraulic Control Unit (HCU) is applied to the CRD insert port while the displaced water is discharged through a labyrinth seal and into the reactor pressure vessel. The maximum insert line losses are specified in the Process Flow Diagram (Paragraph 3.1.1.c). The scram pressure peaks and other loads from scram events, including the peak scram pressure due to water hammer effects during normal (operative) buffer scram (P_{NSC1} and M_{NB}) and failed (inoperative) buffer scram (P_{NSC2} and M_{IB}), shall be determined in FMCRD scram testing.
The peak pressure during a normal HCU accumulator scram (waterhammer) with normal buffer (P_{NSC1}) shall not exceed the design pressure specified in Paragraph 6.1.6.2.a.

Abnormal Operations.
Postulated abnormal events such as a stuck control rod (P_{ASR}), or HCU accumulator overcharge (P_{AACC}) shall be considered in determining the pressure loads.

Vessel Pressures.
The vessel pressures for Level A(Normal) (P_{VA}), Level B(Upset) (P_{VB}), Level C(Emergency) (P_{VC}) and Level D(Faulted) (P_{VD}) conditions are specified in the Reactor Cycle Drawings (Paragraph 3.1.1.o).

B. Temperature

The following normal and postulated abnormal events describe the thermal boundary conditions for the CRD. The resulting thermal gradients shall be established by analysis or by approved engineering tests from which the thermal stresses can be determined.

Normal Operation (T_N).
Purge water for the CRD will be supplied to the insert line at flow rates, temperature and pressures specified in Process Flow Diagram (Paragraph 3.1.1.c).

Abnormal Operation
The following abnormal postulated events shall be considered:

a. Restricted or plugged purge water line (T_{ACO})
b. Leaking shaft seals or static O-rings (T_{LSS}).

C. Component Weight (W)

The CRD component weights combined with the applicable contained fluid weights shall be considered. The weight loads shall be combined with other forms of loadings described above.

D. Mechanical

Rod Ejection (M_{RE}).
This design condition assumes only the occurrence of a pressure boundary failure of scram line, which creates a differential pressure across the drive piston that tends to eject the rod.
Soundness of structure should be evaluated.

Normal Buffer.
This condition assumes normal CRD scram with operative buffer which stops the moving assembly as described in 6.1.3.

Inoperative Buffer (M_{IB}).
This condition assumes the occurrence of a CRD scram with the absence of the proper deceleration action due to an inoperative buffer. The detectable failed buffer scrams shall be considered to occur during operational scrams.

Internal Blowout (M_{IS})
Also referred to as Blowout loads (also described in Paragraph 5.2.10). This condition assumes the occurrence of a sudden housing break at its attachment weld, a circumferential break in the CRD housing, or sudden and simultaneous break of all eight main reactor coolant pressure boundary bolts at the FMCRD housing flange; and creates loads on outer tube, hollow piston, ball spindle, middle flange and bolts.

Drive Cycle.
The drive motor requirements to achieve the insert and withdraw rate of Paragraph 6.1.1.e are specified in 6.2.2.3. This load is defined as internal load so is not included in Table 2. These loads are considered as described in Paragraph 5.3.4.

E. Dynamic (Seismic, SRV, and Hydrodynamic)

The Dynamic Loads shall be the combination of the loads from the horizontal and the vertical dynamic inputs which are equivalent to the CRD housing dynamic loads (see Table 2).

The Dynamic loads are defined by the Purchaser's dynamic model and response spectra (Paragraph 3.1.1 r and Table 2.2). The FMCRDs are installed in a stainless steel CRD housings which are assumed to be pinned to adjacent housings at the flanges and welded to the stub tubes in the RPV bottom head.

The applicable Response Spectra shall be taken from the Seismic Response Spectra Report (Paragraph 3.1.1 r) and shall be used in determining the resultant seismic, SRV, and hydrodynamic loads. The cut off frequency shall be set so that no more than 10% of the total energy is not included.

Table 1. Reactor Vessel Pressure Transient

TABLE 1.1. FULL LOAD REJECTION WITHOUT BYPASS PRESSURE TRANSIENT

Time (sec)	Pressure (MPa)	Event
0.0		Start of Event
0.2		FMCRD Start of Motion
1.9		Pressure Peak
2.3	Later	Start of Pressure Decay
3.6		
5.0		Pressure Decay Continues

TABLE 1.2. SAFETY VALVE SIZING PRESSURE TRANSIENT

Time (sec)	Pressure (MPa)	Event
0.0		Start of Event
1.1		Pressure Rise
2.2	Later	Initiate Scram
2.4		FMCRD Start of Motion
2.6		Pressure Peak
8.0		Pressure Decay Continues

*Linear interpolation

TABLE 2. LOAD COMBINATIONS

Operating Condition	Load Combinations
A	$P_{VA}+T_N+W$
B	$P_{VB}+T_N+W+P_{NSC1}+M_{NB}$ $P_{VB}+T_N+W+P_{NSC1}+M_{NB}+SRV_{NOC}$ $P_{VB}+T_N+W+P_{NSC1}+M_{NB}+SSE$* $P_{VB}+T_{ACO}+W+P_{NSC1}+M_{NB}$ $P_{VB}+T_{LSS}+W+P_{NSC1}+M_{NB}$
C	$P_{VC}+T_N+W+P_{NSC1}+M_{NB}$ $P_{VC}+T_N+W+P_{NSC1}+M_{NB}+SRV_{NOC}$ $P_{VC}+T_N+W+P_{NSC1}+M_{NB}+SRV_{LOCA}+CHUG$ $P_{VC}+T_N+W+P_{AACC}+M_{NB}$ $P_{VC}+T_N+W+P_{NSC2}+M_{IB}$
D	$P_{VD}+T_N+W+P_{NSC1}+M_{NB}$ $P_{VD}+T_N+W+P_{NSC1}+M_{NB}+SRV_{LOCA}+SSE+CHUG$ $P_{VD}+T_N+W+P_{NSC1}+M_{NB}+SRV_{LOCA}+SSE+CO$ $P_{VD}+T_N+W+P_{NSC1}+M_{NB}+SRV_{LOCA}+AP$ $P_{VD}+T_N+W$ ~~$+P_{NSC1}$~~ $+M_{RE}$ $P_{VD}+T_N+W+M_{IS}$ $P_{VD}+T_N+W+P_{ASR}$

*Fatigue evaluation

Table 2.1 Definition

Symbol	Description
P_V	The subscripts used with PV signify the vessel pressures during scrams at operating conditions A, B, C and D
P_{NSC1}	CRD pressures during a normal HCU accumulator scram (waterhammer) with normal buffer
P_{NSC2}	CRD pressures during a normal HCU accumulator scram (waterhammer) with failed buffer
P_{AACC}	CRD pressures during scram with over charged HCU accumulator pressures
P_{ASR}	CRD pressures during a normal HCU accumulator scram with stuck control rod
T_N	CRD temperature with normal purge water flow
T_{ACO}	CRD temperature with restricted or plugged purge water line
T_{LSS}	CRD temperature with leaking shaft seals or static O-rings
W	CRD component weights combined with applicable contained fluid weights
M_{RE}	Mechanical loading on CRD components during a control rod ejection event
M_{NB}	Mechanical loading on CRD components following a normal HCU accumulator scram (waterhammer) with normal buffer
M_{IB}	Mechanical loading on CRD components following a normal HCU accumulator scram (waterhammer) with failed buffer
M_{IS}	Mechanical loading on CRD components due to internal blowout (described in Paragraph 5.2.10 and Attachment 1)
~~SOT~~	~~System Operational Transient~~
SSE	RBV loads induced by safe shutdown earthquake.
~~SBL~~	~~Loads induced by small break LOCA.~~
~~IBL~~	~~Loads induced by intermediate break LOCA.~~
~~LBL~~	~~Loads induced by large break LOCA.~~
SRV	RBV loads induced by Safety/relief valve discharge of one or more vibration
SRV_{NOC}	SRV during normal condition
SRV_{LOCA}	SRV during LOCA condition
CHUG	Envelope of all symmetrical and asymmetrical chugging loads
CO	Envelope of all symmetrical condensation oscillation loads
AP	Envelope of all asymmetrical annulus pressurization loads

Dynamic Loads are defined in Seismic and Reactor Building Vibration Response Spectra Report (Paragraph 3.1.1 r).

Table 2.2 Response Spectra

a. Location

Inside RCCV, CRD Housing (Outside and Inside), STP Elevation 0'-1" (TMSL 1.655m)

b. Response Spectra

Load Case		Horizontal (Note 2)		Vertical (Note 3)	
		Node No. (Note.4)	Spectra No (Note 4).	Node No. (Note.4)	Spectra No. (Note 4).
Seismic	SSE	60	A1.27	38	A2.27
		66	A1.28	40	A2.28
Hydro-dynamic	AP	60	B1.27	-	-
		66	B1.28	-	-
	SRV LOCA	60	B2.27	38	B5.17
		66	B2.28	40	B5.18
	SRV NOC	60	B3.27	38	B6.17
		66	B3.28	40	B6.18
	CHUG	60	B4.27	38	B7.17
		66	B4.28	40	B7.18
	CO	-	-	38	B8.17
		-	-	40	B8.18

Notes:

1. Use the spectra at 3% damping.

2. For each load case, horizontal response spectra provided in the attachment are to be enveloped (the two nodes) prior to performing any load combinations. The resulting enveloped response spectra shall be used in the spectra combinations listed on TABLE 2 LOAD COMBINATIONS.

3. For each load case, vertical response spectra provided in the attachment are to be enveloped (the two nodes) prior to performing any load combinations. The resulting enveloped response spectra shall be used in the spectra combinations listed on TABLE 2 LOAD COMBINATIONS.

4. Node No. and Spectra No. are the same numbers used in reference document in Paragraph 3.1.1.r. The spectrum in the reference documents shall be used for the FMCRD analysis. Per Section 3.7 of ABWR Design Control Document (DCD), the cut-off frequency for dynamic analysis is 33 Hz for seismic loads and 60Hz for Hydrodynamic loads. The acceleration value at the cut-off frequency is considered to be applicable at all frequencies greater than the cut-off frequency.

TABLE 3. MAXIMUM ALLOWABLE COMMON PLANE MISALIGNMENT
(based on the stub tube as the zero reference)

	Reactor Vessel Temperature Condition	
	Ambient (Cold)	Operating (Hot)
Top Guide center of lattice	Later	
Orificed Fuel Support center line		
Top of stub tube center line		
CRD Housing Flange face center line		

TABLE 4. STRESS CRITERIA FOR NON-CODED COMPONENTS

Operating Conditions	Stress Classification (See Note 3)	Stress Limits	Note
Design	Pm P_L Pm (P_L) + P_b Special Stresses*	0.9 Sy, 0.5 Su 1.35 Sy, 0.75 Su 1.35 Sy, 0.75 Su *	1,4,5 1,4,5 1,4,5
Service Level A&B (Normal+Upset)	Pe Pm (P_L) + P_b + Pe + Q Pm (P_L) + P_b + Pe + Q + F Special Stresses*	2.7 Sy, Su 2.7 Sy, Su U < 1.0 *	1,4,5 1,4,5
Service Level B (Upset)	Pm P_L Pm (P_L) + P_b	Sy, 0.55 Su 1.49 Sy, 0.83 Su 1.49 Sy, 0.83 Su	1,4,5 1,4,5 1,4,5
Service Level C (Emergency)	Pm P_L Pm (P_L) + P_b Special Stresses*	1.08 Sy, 0.70 Su 1.62 Sy, Su 1.62 Sy, Su *120% of Special Stresses	1,4,5 1,4,5 1,4,5
Service Level D (Fault)	Pm P_L Pm (P_L) + P_b	2.16 Sy, 0.80 Su 2.16 Sy, 1.1 Su 2.16 Sy, 1.1 Su	1,4,5 1,4,5 1,4,5
*	Special Stresses	-	-
	-Pure Shear -Bearing -Progressive Distortion of Nonintegral Connections	0.6 Sy Sy + D_F /D_L (0.5 Sy) Sy	2,4 4,6 4

NOTES:
1. Use the smaller of the values specified.
2. Average pure shear stress limit for torsional shear, use 0.8 Sy shear stress other than these shall be included in other calculations.
3. Stress classification definitions are presented in ASME Boiler and Pressure Vessel Code Airticle NB-3000.
4. Yield strength values (Sy) taken at temperature.
5. Ultimate tensile strength (Su) taken at temperature.
6. The average bearing stress shall be limited to Sy + D_F / D_L (0.5 Sy) where D_F is the distance to a free edge and D_L is the distance over which the bearing load is applied.
The maximum distance ratio is limited to 1.0.

TABLE 5. FMCRD External Environment*

Plant Condition	Function Time***	Pressure kPaG (psig)	Temperature ℃ (F)	Humidity %	Load Definition
a. Normal	60 years	-3.43～13.73 (-0.4975～1.992)	57max (134.6) 10min (50.0)	90max 10min	**
b. Accidental Conditions	3h	-13.73～309.89 (-1.992～44.95)	171 (339.8)	steam	**
	6h	-13.73～309.89 (-1.992～44.95)	160 (320.0)	steam	**
	1day	0～172.60 (0～25.04)	121 (249.8)	100	**
	100days	0～138.27 (0～20.06)	93 (199.4)	100	**

*The primary containment atmosphere is nitrogen
**For testing of motor brake and switches, use response spectra at the CRD flange of the beam model for the various load combinations.
***Time defines the period after LOCA.

Plant Condition	Operating Dose Rate			Integrated Dose[1] and Neutron Fluence		
	Gamma (Gy/h)[2]	Beta (Gy/h)[3]	Neutron/cm^2-s	Gamma (Gy)	Beta (Gy)	Neutron /cm^2
Normal	0.15	Neg	1×10^4	8E+4	Neg	2×10^{13}

1. Integration time based upon 1.5 year cycles at 18 months operations at 95% availability over 60 years.
2. Operating dose rate at 100% rated power and 30 cm away from the radiation source.
3. Beta dose rates negligible (neg.), primarily due to Ar-41 and typically only in area between vessel and shield wall.

Plant Condition	LOCA Dose Rate		Integrated Dose[1]	
	Gamma (Gy/h)	Beta (Gy/h)	Gamma (Gy)	Beta (Gy)
Accident Conditions	2E+5	2E+6	2E+6	2E+7

1. Integrated dose is summed over a six month period.

TABLE 6 Plant Conditions for Electrical Components

	Normal	All Non-Accidents	ATWS	LOCA	Submergence	Dynamic Loads
Drive Motor	X	X	X	N／A	N／A	N／A
Motor Position Synchro	X	X	X	N／A	N／A	N／A
Continuous Full-in Indication Switch(PIP)	X	X	X	N／A	N／A	N／A
Separation Switch(SIP)	X	X	N／A	N／A	N／A	N／A
Scram Position Switch (0%, 40%, 60%)	X	X	N／A	N／A	N／A	N／A
Brake	X	X	X	X	X	X

Key
X = Component required to function during this condition.
N／A = Not Applicable.

TABLE 7 Materials

Assembly	Parts	Applicable Codes	
		ASME	ASTM etc.
Spool Piece Assembly	Spool Piece Housing	ASME SA-182/182M Grade F304L, F304 * , F316L, F316 * or ASME SA-336/336M Grade F304L, F304*, F316L, F316 *	
	Seal Housing	ASME SA-182/182M Grade F304L, F304 *, F316L, F316 * or ASME SA-336/336M Grade F304L, F304*, F316L, F316 *.	
	Drive Shaft	ASME SA-479/479M Type 316*, 316L (Hard surfaced with Colmonoy No.6 or equivalent Nickel base alloy)	ASTM A479/479M Type 316*/**, 316L** (Hard surfaced with Colmonoy No.6 or equivalent Nickel base alloy)
	Ball Bearings (in water)		ASTM A756 Type 440C** or A276 Type 440C**
	Ball Bearings (in air)		AISI 52100**
	Gland Packing Spring		AMS 5699 Alloy N07750**(Alloy X-750)
	Separation Spring		AMS 5699 Alloy N07750**(Alloy X-750)
	Separation Magnet	Alnico No.5 and ASME SA-479/479M Type 316*, 316L	ASTM A479/479M Type 316*/**, 316L**
Ball Spindle	Ball Screw Shaft	ASME SA-564/564M Type 630 Condition H-1100	ASTM A-564/564M Type 630(17-4PH)** Condition H-1100
	Ball Nut	ASME SA-564/564M Type 630 Condition H-1100	ASTM A-564/564M Type 630(17-4PH)** Condition H-1100
	Balls		ASTM A756 Type 440C** or A580/580M Type 440C** or A276 Type 440C**
	Guide Roller		Stellite No.3, or nickel base alloy
	Guide Roller Pin	ASME SA-479/479M Type XM-19 (Nitrided)	ASTM A479/479M Type XM-19** (Nitrided) or equivalent ferrous base alloy
	Spindle Head Bolt		Stellite No. 6B**
	Spindle Head Bushing		Stellite No. 12**
Buffer Mechanism	Buffer Disk Spring	ASME SB-637 Alloy N07750 (Alloy X-750)	ASTM B 637 Alloy N07750** or AMS 5542 Alloy N07750** (Alloy X-750)
	Buffer Sleeve	ASME SA-479/479M Type 316*, 316L (Hard surfaced with Colmonoy No. 6)	ASTM A479/479M Type 316*/**, 316L** (Hard surfaced with Colmonoy No. 6)
	Guide Roller		Stellite No. 3, or nickel base alloy
	Guide Roller Pin	ASME SA-479/479M Type XM-19 (Nitrided)	ASTM A479/479M Type XM-19** (Nitrided) or equivalent ferrous base alloy
	Stop Piston	ASME SA-479/479M Type 316*, 316L (Hard surfaced with Stellite No. 6)	ASTM A479/479M Type 316*/**, 316L** (Hard surfaced with Stellite No. 6)
Hollow Piston	Piston Tube	ASME SA-312/312M Grade TPXM-19	ASTM A312/312M Grade TPXM-19
	Drive Piston	ASME SA-479/479M Type 316*, 316L (Hard surfaced with Stellite No. 6)	ASTM A479/479M Type 316*/**, 316L** (Hard surfaced with Stellite No. 6)
	Latch	ASME SB-637 Alloy N07750 (Alloy X-750)	ASTM B 637 Alloy N07750** (Alloy X-750)
	Latch Spring		AMS 5699 Alloy N07750** (Alloy X-750)
	Bayonet Coupling	ASME SB-637 Alloy N07750 (Alloy X-750)	ASTM B 637 Alloy N07750** (Alloy X-750)
Guide Tube	Guide Tube	ASME SA-312/312M Grade TP316*, TP316L	ASTM A312/312M Grade TP 316*/**, TP316L**
Outer Tube Assembly	Outer Tube	ASME SA-312/312M Grade TPXM-19	ASTM A312/312M Grade TPXM-19**
	Middle Flange	ASME SA-182/182M Grade F304L, F304*, F316L, F316 * or ASME SA-336/336M Grade F304L, F304*, F316L, F316*	
Miscellaneous Parts	Ball for Check Valve		Stellite No. 3, or equivalent cobalt base alloy
	O-Ring Seal (Between CRD Housing and CRD)		Type 321 stainless steel coated with a qualified material
	CRD Installation Bolts	ASME SA-193/193M Grade B7	

* The material shall be qualified to ensure that it is free from sensitization. Carbon content specified to be 0.020% maximum.

** Equivalent materials have been provided. Materials with similar chemical composition, mechanical properties, and operating experience are considered equivalent.

Note1: The bayonet coupling and latch are fabricated from Alloy X-750 in the high temperature (1093°C) solution heat treated condition, and aged 20 hours at 704°C to produce a tensile strength of 1034 MPa minimum, yield of 655 MPa minimum, and elongation of 20% minimum. The ball screw shaft and ballnut are ASTM A 564, Type 630 (17-4PH) (or its equivalent) in condition H-1100 (aged 4 hours at 593°C), with a tensile strength of 965 MPa minimum, yield strength of 795 MPa minimum, and elongation of 14% minimum.

Note2: The target value of cobalt content is 0.05 wt percent and this is not specification.

TABLE 7 MATERIALS (Continued)

Table 7B. Non Structural Materials Requirements for Use in Areas Where Replacement Occurs < 10 Years

Material	Use	Requirements
Aluminum	Gland Packing	Must have a 10 year minimum life.
Nylon*	Gear Coupling	Must not deteriorate in radiation fields of the lower dry well. Must have a 10 year min life.
For use in areas where replacement will not occur within 10 years.		
FKM	O-Ring coating	Must have a 60 year life with planned replacement.
Alnico	Position Magnets	None.

*Better materials are acceptable

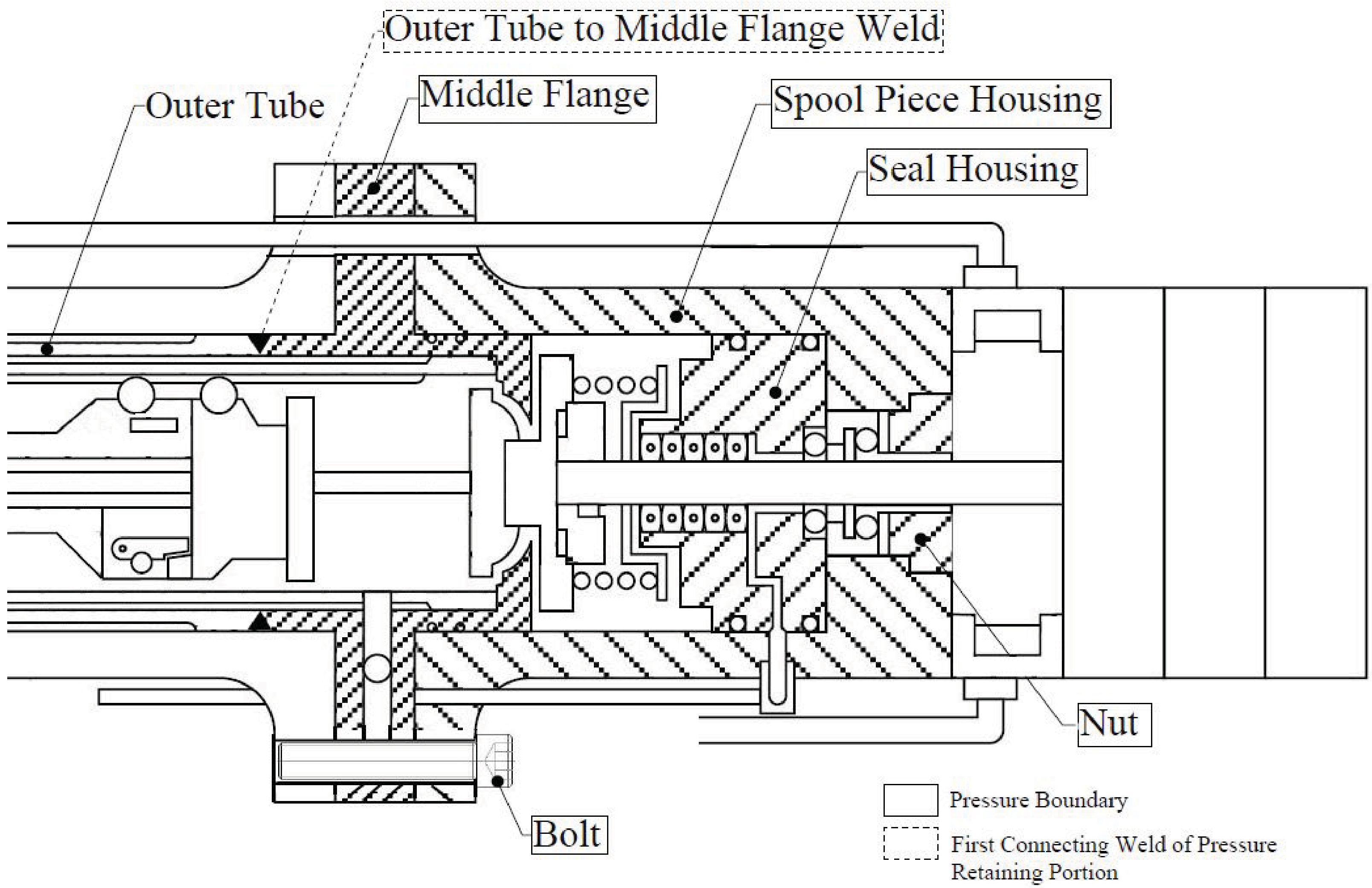
Outer Tube to Middle Flange Weld
Outer Tube
Middle Flange
Spool Piece Housing
Seal Housing
Nut
Bolt
Pressure Boundary
First Connecting Weld of Pressure Retaining Portion

Figure 1 Boundary of Components