RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

APR1400 Design Certification

Korea Electric Power Corporation / Korea Hydro & Nuclear Power Co., LTD

Docket No. 52-046

RAI No.:	**341-8410**
SRP Section:	**05.04.01.01 – Pump Flywheel Integrity (PWR)**
Application Section:	**5.4.1.1**
Date of RAI Issue:	**12/18/2015**

Question No. 05.04.01.01-1

Appendix A of 10 CFR Part 50, "General Design Criteria for Nuclear Power Plants," provides General Design Criteria (GDC) which establish minimum requirements for the principal design criteria for water-cooled nuclear power plants. Criterion 1, "Quality standards and records," and 10 CFR Part 50.55a(a)(1) require that SSCs important to safety shall be designed, fabricated, erected and tested to quality standards which shall be identified and evaluated to determine their applicability, adequacy, and sufficiency to assure a quality product in keeping with the required safety function. Because reactor coolant pump flywheels have large masses and rotate at speeds of 900 revolutions per minute (rpm) or 1200 rpm during normal reactor operation, a loss of flywheel integrity could result in high energy missiles and excessive vibration of the reactor coolant pump assembly. The safety consequences could be significant because of possible damage to the reactor coolant system, the containment, or the engineered safety features. Reactor coolant pump flywheel failure can result in reduction or loss of forced coolant flow. In following the standard review plan, NUREG-0800, section 5.4.1.1, "Pump Flywheel Integrity (PWR)," staff has determined that it must receive and review responses to the following requests for additional information before it can make its safety determination on the flywheel design.

APR1400 FSAR Section 5.4.1.1.2, "Fracture Toughness," states that:

KIC of the flywheel material at the normal operating temperature of the flywheel is greater than 165 MPa√m (150 ksi√in). Conformance is demonstrated by an indirect test. Justification is provided to establish the equivalence of fracture toughness in the proposed flywheel material and certain steels (ASME SA-533-B Class 1, ASME SA-508 Class 2, ASME SA-508 Class 3, and ASME SA-516 Grade 65). The RTNDT of the flywheel materials is determined in accordance with NB-2320 and NB-2330 of the ASME Section III.

The NRC requests the following:

a. Provide the method used to determine the fracture toughness.
b. Provide the justification that the flywheel material, 26NiCrMoV14-5, is equivalent to the steels specified above so that an indirect method of determining fracture toughness can be used. Otherwise, a direct method should be used, since this is the preferred method as stated in SRP 5.4.1.1, paragraph II.2, “SRP Acceptance Criteria.”
c. Provide the RTNDT of the flywheel material.
d. Provide operating experience of the flywheel material, 26NiCrMoV14-5.

Response

U. S. NRC Regulatory Guide 1.14 and Standard Review Plan (SRP) 5.4.1.1 recommend that the requirements of ASME Section III NB-2330 be used to establish reference temperature (RTNDT) values for flywheel material. The SRP states that the minimum KIC should be 165 MPa√m (150 ksi√in). Instead of attempting to justify by showing similarity between 26NiCrMoV14-5 (the flywheel and hub material) and the ASME materials listed in U. S. NRC Regulatory Guide 1.14 and Standard Review Plan (SRP) 5.4.1.1, a different approach will be used to show conformance of the minimum KIC of 165 MPa√m.

ASME Code Case N-631 allows the use of RTT0 as an alternative reference temperature for toughness curves in Appendix G of ASME Code Section III. Per N-631, RTT0 (°F) = [T0 + 35] (°F), or RTT0 (°C) = [T0 + 19.4] (°C).

The reference temperature, T0, will be determined in accordance with ASTM E 1921 - 15. The Charpy V-notch specimen location and orientation will be determined in accordance with NB-2322. Then, the KIC is calculated using the formula in ASME Section III G-2110 (and ASME Section XI A-4200), and RTNDT is replaced with RTT0:
KIC [MPa√m] = 36.5 + 22.783 exp[0.036 (T - RTT0)]

[ ]^{TS} is the lowest ambient temperature for the reactor coolant pump motor. This will be the “worst case” operating temperature. Per U.S. NRC Regulatory Guide 1.14, RTNDT is determined per ASME Section III, NB-2331(a), and must be at least 50°C below the lowest operating temperature. RTNDT or RTT0 = [ ]^{TS}

This is based only on the minimum operating temperature and guidance from U. S. NRC Regulatory Guide 1.14. The actual RTT0 will be determined and confirmed with test data. Assuming the RTNDT or RTT0 of [ ]^{TS} and the aforementioned formula for KIC, the lower bound KIC at [ ]^{TS} is 174 MPa√m, which is higher than the more limiting minimum KIC of [ ]^{TS} specified in the FSAR and in SRP 5.4.1.1. Therefore, the analyses performed in the technical report, APR1400-A-M-NR-14001-P, Rev. 0, “KHNP APR1400 Flywheel Integrity Report”, using KIC = [ ]^{TS} is conservative.

The following tables provides list of plants operating with flywheels made of 26NiCrMoV14-5 material without integrity issues.

Non-Proprietary

Siemens AG
Reference List RCPM Supplies with Fylwheel

Factory Number	Order Received	Connection to Grid (spare motors in brackets)	Country	Site	Customer	Owner	Reactor Type	Motor Power [kW]	Voltage [V]	Freqeuncy [Hz]	Speed [rpm]	Number of motors	Remarks
1301521	1968	1974	ARG	Atucha A		ENRE	KWU (HWR)	5500	6600	50	1490	2	
1301553	1969	1973	NDL	Borssele		EPZ	KWU (PWR)	7750	6000	50	1491	2	
1301563	**1970**	1972	GER	Biblis A		RWE	KWU (PWR)	8550	10000	50	1493	4	
1301569	**1971**	1977	GER	Brunsbüttel		Vattenfall	KWU (BWR)	2600	10000	50	1471	4	
1301575	**1971**	1974	GER	Biblis B		RWE	KWU (PWR)	8650	10000	50	1493	4	
1301578	**1972**	1978	GER	Unterweser		EON Kernkraft	KWU (PWR)	8650	10500	50	1485	4	
1301588	1974	(1968)	GER	Obrigheim (Spare)		EnBW Kraftwerk	KWU (PWR)	4220	6000	50	1500	1	
1301595	**1974**	(1974)	GER	Biblis B (Spare)		RWE	KWU (PWR)	8650	10000	50	1493	1	
1301589	**1974**	1979	SWZ	Gösgen 1		Atel	KWU (PWR)	9200	10000	50	1487	3	
1301599	**1975**	1984	GER	Grohnde		EON Kernkraft	KWU (PWR)	7350	10000	50	1483	4	
1301600	**1975**	1985	GER	Philipsburg		EnBW Kraftwerk	KWU (BWR)	7350	10000	50	1483	4	
1301613	**1976**	(1984)	GER	Original Project canceled, used for Grafenrheinfeld		EON Kernkraft	KWU (PWR)	7350	10000	50	1483	4	
131104	**1978**	1982	BRA	Angra 1	Areva / Eletronuclear , Angra dos Reis	Eletrobrás Termonuclear S.A.- Eletronuclear	Westinghouse	7500	13200	60	1183	4	
131105	**1978**	2000	BRA	Angra 2	Areva / Eletronuclear , Angra dos Reis	Eletrobrás Termonuclear S.A.- Eletronuclear	KWU (PWR)	7500	13200	60	1188	4	
1306007	**1979**	(1985)	GER	Grafenrheinfeld (Spare)		EON Kernkraft	KWU (PWR)	7350	10000	50	1483	1	
1306012	**1982**	1986	GER	Brokdorf		EON Kernkraft	KWU (PWR)	7350	10000	50	1485	4	
Factory Number	**Order Received**	**Connection to Grid (spare motors in brackets)**	**Country**	**Site**	**Customer**	**Owner**	**Reactor Type**	**Motor Power [kW]**	**Voltage [V]**	**Freqeuncy [Hz]**	**Speed [rpm]**	**Number of motors**	**Remarks**
1311012	**1982**	2008	BRA	Angra 2 (Spare)		Eletrobrás Termonuclear S.A.- Eletronuclear	KWU (PWR)	7500	13200	60	1188	1	
1306014	**1983**	1988	GER	Isar 1		EON Kernkraft	KWU (BWR)	7350	10000	50	1485	4	
1306018	**1983**	1988	GER	Isar 2		EON Kernkraft	KWU (PWR)	7350	10000	50	1485	5	
1306013	1983	plan: 2014	ARG	Atucha 2		ENRE	KWU (HWR)	12300	13200	50	1500	2	
1306019	**1984**	1988	GER	Emsland		RWE	KWU (PWR)	7350	10000	50	1485	4	
1306020	**1984**	1994	CHN	Qin Shan 1	KSB?	CNNC	CNNC	4500	6000	50	1489	2	
1301636	**1975**	(1985)	GER	Philipsburg (Spare)		EnBW Kraftwerk	KWU (BWR)	7350	10000	50	1483	1	
1306023	**1985**	(1986)	GER	Brokdorf (Spare)		EON Kernkraft	KWU (PWR)	7350	10000	50	1485	1	
1306021	**1985**	1989	GER	GKN Neckar- Westheim		EnBW Kraftwerk	KWU (PWR)	7350	10000	50	1485	4	
1311016 1311017	1988	1995/96	KOR	Yeonggwang 3/4 (Hanbit 3/4)	Westinghouse	KHNP (KEPCO)	System 80	6562	13200	60	1187	8	
1306031	1991	1998/99	KOR	Ulchin 3/4 (Hanul 3/4)	Westinghouse	KHNP (KEPCO)	KSNP	6562	13200	60	1187	8	
1301663	**1994**	(1972)	GER	Biblis A (Spare)		RWE	KWU (PWR)	8550	10000	50	1493	1	
1301665	1995	2002	KOR	Yeonggwang 5/6 (Hanbit 5/6)	Westinghouse	KHNP (KEPCO)	KSNP	6562	13200	60	1187	8	
1301668	1996	2004/05	KOR	Ulchin 5/6 (Hanul 5/6)	Westinghouse	KHNP (KEPCO)	KSNP	6562	13200	60	1187	8	
1301669	1997	N/A	USA	Teststand	Westinghouse	Westinghouse	OPR1000	6562	13200	60	1187	1	
1301674	1998	(1995/96)	KOR	Yeonggwang 3/4 (Hanbit 3/4) (Spare)	Westinghouse	KHNP (KEPCO)	KSNP	6562	13200	60	1187	1	
1301681	2001	Project cancelled (retrofit for spares)	KOR	(Sinpo 1/2)	Westinghouse	KHNP (KEPCO)	OPR1000	6562	13200	60	1187	0	

Factory Number	Order Received	Connection to Grid (spare motors in brackets)	Country	Site	Customer	Owner	Reactor Type	Motor Power [kW]	Voltage [V]	Freqeuncy [Hz]	Speed [rpm]	Number of motors	Remarks
2505015	2002	2011/12	KOR	Shin Kori 1/2	Westinghouse	KHNP (KEPCO)	OPR1000	6562	13200	60	1187	8	
2505016	2002	2014/15	KOR	Shin Wolsong 1/2	Westinghouse	KHNP (KEPCO)	OPR1000	6562	13200	60	1187	8	
15505023	2006	plan: 20015/16	KOR	Shin Kori 3/4	Westinghouse	KHNP (KEPCO)	APR1400	10068	13200	60	1188	8	
1505026	2007	(1998/99)	KOR	Ulchin 3/4 (Hanul 3/4) (Spare)	Siemens Energy	KHNP (KEPCO)	APR1400	6562	13200	60	1187	1	
1505034	2009	plan: 2016/17	KOR	Shin Hanul 1/2	Doosan	KHNP (KEPCO)	APR1400	10365	13200	60	1188	8	
2505044	2011	1979	SWZ	Gösgen 2 (Spare)		Atel	KWU (PWR)	9200	10000	50	1478	1	
1505042	2011	plan: 2017/18)	UAE	Barakah 1/2	Westinghouse	ENEC	APR1400	11186	13200	50	1488	8	
1505042	2012	plan: 2019/20	UAE	Barakah 3/4	Westinghouse	ENEC	APR1400	11186	13200	50	1488	8	
1885122	2012	(1998/99)	KOR	Ulchin 3/4 (Hanul 3/4) (Spare)	Westinghouse	KHNP (KEPCO)	OPR1000	6562	13200	60	1187	1	Retrofit of 1301681
1885123	2012	(1995/96)	KOR	Yeonggwang 3/4 (Hanbit 3/4) (Spare)	Westinghouse	KHNP (KEPCO)	OPR1000	6562	13200	60	1187	1	Retrofit of 1301681
1885124	2012	(2002)	KOR	Yeonggwang 5/6 (Spare)	Westinghouse	KHNP (KEPCO)	OPR1000	6562	13200	60	1187	1	Retrofit of 1301681
1885125	2012	(2002)	KOR	Yeonggwang 5/6 (Hanbit 5/6) (Spare)	Westinghouse	KHNP (KEPCO)	OPR1000	6562	13200	60	1187	1	Retrofit of 1301681
1885126	2012	(2004/05)	KOR	Ulchin 5/6 (Hanul 5/6) (Spare)	Westinghouse	KHNP (KEPCO)	OPR1000	6562	13200	60	1187	1	Retrofit of 1301681
1885127	2012	(2011/12)	KOR	Shin Kori 1/2 (Spare)	Westinghouse	KHNP (KEPCO)	OPR1000	6562	13200	60	1187	1	Retrofit of 1301681
1885128	2012	(2014)	KOR	Shin Wolsong 1/2 (Spare)	Westinghouse	KHNP (KEPCO)	OPR1000	6562	13200	60	1187	1	Retrofit of 1301681
1505052	2013	(2015/16)	KOR	Shin Kori 3/4 (Spare)	Westinghouse	KHNP (KEPCO)	APR1400	10068	13200	60	1188	1	
1505054	2014	plan: 2018/19	KOR	Shin Kori 5/6	Doosan	KHNP (KEPCO)	APR1400	10365	13200	60	1188	8	

Impact on DCD

There is no impact on the DCD.

Impact on PRA

There is no impact on the PRA.

Impact on Technical Specifications

There is no impact on the Technical Specifications.

Impact on Technical/Topical/Environmental Reports

There is no impact on any Technical, Topical, or Environment Report.

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

APR1400 Design Certification

Korea Electric Power Corporation / Korea Hydro & Nuclear Power Co., LTD

Docket No. 52-046

RAI No.:	**341-8410**
SRP Section:	**05.04.01.01 – Pump Flywheel Integrity (PWR)**
Application Section:	**5.4.1.1**
Date of RAI Issue:	**12/18/2015**

Question No. 05.04.01.01-2

APR1400 Final Safety Analysis Report (FSAR) Section 5.4.1.1, "Pump Flywheel Integrity," states that the "flywheel uses a shrink fit design to couple it to a shaft." APR1400 FSAR Section 5.4.1.1.3, "Design," references the supporting RCP flywheel analysis summarized in technical report APR1400-A-M-NR-14001-P, "KHNP APR1400 Flywheel Integrity Report," Revision 0, dated November 2014, which details that the flywheel is shrink-fitted onto a hub, and this hub is shrink-fitted onto the shaft. Revise APR1400 FSAR Section 5.4.1.1 to be consistent with the flywheel design in the technical report.

Response

The description in technical report APR1400-A-M-NR-14001-P is correct. DCD Subsection 5.4.1.1 will be revised

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Impact on DCD

DCD Subsection 5.4.1.1 will be revised as indicated on the attached markup.

Impact on PRA

There is no impact on the PRA.

Impact on Technical Specifications

There is no impact on the Technical Specifications.

Impact on Technical/Topical/Environmental Reports

There is no impact on any Technical, Topical, or Environment Report.

5.4 Reactor Coolant System Component and Subsystem Design

5.4.1 Reactor Coolant Pumps

The reactor coolant pumps provide sufficient forced circulation flow through the reactor coolant system (RCS) to provide reasonable assurance of adequate heat removal from the reactor core during power operation. A low limit on reactor coolant pump flow rate (i.e., design flow) is established to provide reasonable assurance that specified acceptable fuel design limits (SAFDLs) are not exceeded. Design flow is derived on the basis of the thermal-hydraulic considerations presented in Subsection 4.4.4.5.1.

The reactor coolant pump and motor assembly in conjunction with the flywheel provide sufficient coastdown flow following loss of power to the pumps to provide reasonable assurance of adequate core cooling.

The reactor coolant pump pressure boundary is designed for the transients given in Table 3.9-1 so the ASME Section III (Reference 1) allowable stress limits are not exceeded for the specified number of cycles. Stress criteria concerning earthquake and pipe rupture conditions are presented in Subsection 3.9.3.

The design overspeed of the reactor coolant pump is 125 percent of normal speed.

5.4.1.1 Pump Flywheel Integrity

The RCP flywheel maintains the integrity to prevent the possibility of producing high-energy missiles and excessive vibration of the pump assembly under standstill, normal and anticipated operating condition consistent with the intent of General Design Criteria 1 and 4 (Reference 2) and Regulatory Guide 1.14 (Reference 3).

~~The flywheel uses a shrink fit design to couple it to a shaft.~~ The flywheel is constructed by a cylindrical shrink fit of the outer wheel to the hub, and then a conical shrink fit between the hub and the shaft. The stresses in the flywheel are a function of three attributes which are the material, the shrink fit, and the rotational speed.

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Application Section:	**5.4.1.1**
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Question No. 05.04.01.01-3

APR1400 FSAR Section 5.4.1.1 references the supporting RCP flywheel analysis summarized in technical report APR1400-A-M-NR-14001-P, "KHNP APR1400 Flywheel Integrity Report," Revision 0, dated November 2014. The NRC staff requests the following information concerning this technical report:

a. Paragraph 2.4, "Acceptance Criteria," of the technical report specifies that the total stress in the flywheel at standstill and normal operating speed does not exceed one-third of the ultimate tensile strength." In addition, paragraph 5.11 specifies that "the total stresses in the flywheel at standstill and normal operating speed shall not exceed one-third of the minimum specified yield strength" and that the "total stresses is 38,674 psi." Paragraphs 2.4 and 5.11 of the technical report are not consistent, and should state the total stresses should not exceed one-third of the minimum specified yield strength as stated in NRC Standard Review Plan (SRP) 5.4.1.1, paragraph II.4.a.

b. Section 5.11, "Evaluation of Stresses," of the technical report states that "one-third of the ultimate strength of 800/3 (N/mm2) = 38,677 psi." The NRC staff notes that one-third of the ultimate strength is actually 38,667 psi, and therefore, the calculated total stresses of the flywheel at normal operating speed of 38,674 psi exceeds 38,667 psi. Therefore, the calculated stresses do not meet the one-third of yield strength or one-third of ultimate tensile strength acceptance criteria. Therefore, the NRC staff requests that a flywheel design that meets the guidance and acceptance criteria of SRP 5.4.1.1 to be provided.

c. Paragraph 5.15, "Fatigue Crack Growth," of the technical report describes the fatigue crack growth rate for the flywheel, but not for the hub. In addition, paragraph 5.15 of the technical report specifies that "the fatigue crack growth due to 6,000 cycles from standstill to normal operation can be predicted by the fatigue crack growth rates available in reference 5 [ASME Code, Section III, Division 1, Appendix A]." Revise the technical report to provide justification that the fatigue crack growth rates used apply to the flywheel

material. In addition, this analysis should also be done on the hub since it is a critical part that attaches the flywheel to the shaft, and a potential hub failure could release the flywheel as a missile.

d. Submit reference 6 (Siemens Document, 4D5.0170.83-575711F, Revision F, "Flywheel Calculation," May 30, 2011) from the technical report to support the staff's review of the APR1400 design.

Response

a. The technical report APR1400-A-M-NR-14001-P, "KHNP APR1400 Flywheel Integrity Report," Revision 0, dated November 2014, contains a typographical error. Section 5.11 of the report will be revised to read "…shall not exceed one-third of the minimum specified ultimate strength". As noted in the U.S. NRC comment, the limit in SRP 5.4.1.1 is one-third of yield. However, the justification of the exceptions to SRP 5.4.1.1 is provided here.

Specific criteria acceptable to meet the relevant requirements of the U.S. NRC's regulations are given in SRP 5.4.1.1. The SRP is not a substitute for the U.S. NRC's regulations. Compliance is not required because the SRP permits "alternative methods" to achieve the intent of the guidance provided therein and in the U. S. NRC Regulatory Guide 1.14. However, an applicant is required to identify differences between the design features, analytical techniques, and procedural measures proposed for its facility and the SRP acceptance criteria. Furthermore, the applicant is required to evaluate how the proposed alternatives to the SRP acceptance criteria provide acceptable methods of compliance with U.S. NRC regulations.

The stresses in the flywheel are typically a function of the flywheel material, the shrink fit, and the rotational speed. The Siemens flywheel design considers all three attributes in the material selection and specific manufacturing processes for compliance with the regulatory guidance. The design also factors in field experience gained from successfully operating flywheels of similar design in Germany and South Korea for more than four decades.

The design specification requires that no flywheel separation at speeds less than 150% of normal operation would occur for the APR1400 flywheel assembly. In order to maintain a shrink-fit stress that would meet this requirement, the criterion on combined stresses at normal operation was chosen to limit the maximum stress to one-third of the minimum ultimate strength, instead of one-third of the minimum yield strength. This exception, taken for the APR1400 flywheel design, still provides significant margin relative to the material yield strength, albeit not 33% as suggested by the SRP guidance. Stress analyses on the APR1400 RCP flywheel show that the maximum (von Mises) stress at normal operation of the flywheel (1,200 rpm) occurs at the interface between the hub and the outer wheel of the two-piece flywheel. The maximum stress at normal operation, which includes rotational stress and shrink-fit stress, is 38,674 psi. This result is 42% of the minimum yield stress of 92,825 psi and 33% of the minimum ultimate stress of 116,029 psi (800 MPa) at normal operating temperature. The judgment that 33% of the minimum ultimate stress is an acceptable criterion is supported by the observation that ASME Section II,

Mandatory Appendix 2, Paragraph 2-110 for assigning design stress intensity values is based on one-third ultimate stress.

b. Per ASME Section III Appendix AA, AA-3000, the conversion factor is 0.0068948 MPa/psi. Carrying out the decimals, 800/3 [MPa] / 0.0068948 [MPa/psi] = 38,676.5 [psi], round up to be 38,677 psi. The NRC staff used an approximate conversion factor of 1 MPa = 145 psi to arrive at the value of 800/3 MPa = 38,667 psi.

c. As stated in Section 5.13 of the technical report, the stress intensity factors (KI) are calculated at the highest tensile stress location, which is at the inner radius of the outer wheel. The fatigue crack growth evaluation bounds the hub as well. As discussed in the response to RAI 05.04.01.01-1, a through c, the lower bound KIC formula in ASME Section XI, A-4200 is applicable and conservative. Therefore, it is consistent to use the fatigue crack growth rate in the NRC approved, ASME Section XI, Appendix A, paragraph A-4300 .

d. Siemens Document, 4D5.0170.83-575711F, Revision F will be uploaded to ERR per the above request.

Impact on DCD

DCD Table 1.9-2 will be revised as indicated on the attached markup.

Impact on PRA

There is no impact on the PRA.

Impact on Technical Specifications

There is no impact on the Technical Specifications.

Impact on Technical/Topical/Environmental Reports

APR1400-A-M-NR-14001-P, “KHNP APR1400 Flywheel Integrity Report,” Revision 0 will be revised.

Table 1.9-2 (9 of 33)

SRP Section/Title	Revision / Issue Date	Conformance or Summary Description of Deviation	DCD Tier 2 Section
5.3.3 – Reactor Vessel Integrity	Rev. 2 03/2007	The APR1400 conforms with this SRP.	5.3.3
5.4 – Reactor Coolant System Component and Subsystem Design	Rev. 2 03/2007	The APR1400 conforms with this SRP.	5.4
5.4.1.1 – Pump Flywheel Integrity (PWR)	Rev. 3 05/2010	The APR1400 conforms with this SRP with the following exception: • ~~Design stress criteria.~~	5.4.1.1
5.4.2.1 – Steam Generator Materials	Rev. 3 03/2007	The APR1400 conforms with this SRP.	5.4.2.1
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5.			
5.			
5.			
5.			
5.			
5.			
B C			

- Design stress criteria

The acceptance criterion for total stress in the flywheel at standstill and normal operating speed is 1/3 ultimate tensile strength, instead of the SRP 5.4.1.1 suggested 1/3 yield strength.

The stresses in the flywheel are typically a function of the flywheel material, the shrink fit, and the rotational speed. The Siemens flywheel design considers all three attributes in the material selection and specific manufacturing processes for compliance with the regulatory guidance. The design also factors in field experience gained from successfully operating flywheels of similar design in Germany and South Korea for more than four decades.

The flywheel design specification requires that no flywheel separation at speeds less than 150% of normal operation would occur for the APR1400 flywheel assembly. In order to maintain a shrink-fit stress that would meet this requirement, the criterion on combined stresses at normal operation was chosen to limit the maximum stress to 1/3 minimum Su, instead of 1/3 minimum Sy. This exception, taken for the APR1400 flywheel design, still provides significant margin relative to the material yield strength, albeit not 33% as suggested by the SRP guidance.

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Question No. 05.04.01.01-4

APR1400 FSAR Section 5.4.1.1.4.f, "Test and Inspection," states that, "Each flywheel receives a preservice baseline inspection that incorporates the methods defined above for an inservice inspection. Examination procedures and acceptance criteria are determined in accordance with ASME Section III."

Revise APR1400 FSAR Section 5.4.1.1.4.f to state the acceptance criteria that will be used for the inspection. In addition, specify in the FSAR whether the maximum flaw size used as the acceptance criteria for this inspection is bounded by the flaw size used in determining the critical flaw size in Technical Report APR14001-A-M-NR-14001-P, Rev. 0.

Response

Siemens indicates the minimum detectable flaw size is [ ]TS. The technical report determined the critical rotation speed and crack growth conservatively using a postulated flaw size of 0.5 inch. Therefore, the analysis in the technical report is conservative and bounds the minimum detectable flaw size. It would be acceptable to use 0.5 inch as the inspection acceptance criterion.

Impact on DCD

There is no impact on the DCD.

Impact on PRA

There is no impact on the PRA.

Impact on Technical Specifications

There is no impact on the Technical Specifications.

Impact on Technical/Topical/Environmental Reports

There is no impact on any Technical, Topical, or Environment Report.

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Date of RAI Issue:	**12/18/2015**

Question No. 05.04.01.01-5

Technical Report APR14001-A-M-NR-14001-P, “KHNP APR1400 Flywheel Integrity Report,” Revision 0, dated November 2014, Section 3.1, "Stresses and Radial Displacement Due to Shrink Fit of Sections of Flywheel," details that the flywheel is shrink-fitted onto a hub, and this hub is shrink-fitted onto the shaft. Therefore, since the hub can affect the integrity of the flywheel if it fails and releases the flywheel as a potential missile, the test and inspections proposed in APR1400 FSAR Section 5.4.1.1.4 for the flywheel should also apply to the hub.

Revise APR1400 FSAR Section 5.4.1.1.4 to specify that the tests and inspections proposed for the flywheel will also apply to the hub. Also, include whether the hub can be inspected without the removal of the flywheel from the pump.

Response

The technical report APR1400-A-M-NR-14001-P evaluated the flywheel, including the outer wheel and hub. The highest tensile stress located at the inner radius of the outer wheel was used to compute KI, therefore, the evaluation on the outer wheel bounds the hub. DCD Subsection 5.4.1.1.4 and Table 1.9-1 will be revised accordingly.

Impact on DCD

DCD Subsection 5.4.1.1.4 and Table 1.9-1 will be revised as indicated on the attached markup.

Impact on PRA

There is no impact on the PRA.

Impact on Technical Specifications

There is no impact on the Technical Specifications.

Impact on Technical/Topical/Environmental Reports

There is no impact on any Technical, Topical, or Environment Report.

The design overspeed of flywheel is 125 percent of the synchronous speed of the RCP motor. The design overspeed is at least 10 percent greater than the highest anticipated overspeed of the pump. The highest anticipated overspeed is predicted for loss of coolant accident with the largest break size remaining after the application of leak before break, as described in Subsection 3.6.3. The largest break size remaining after the application of leak before break that may affect the maximum overspeed of the RCP is a 10.16 cm (4 in) pressurizer spray line.

The shaft and bearings supporting the flywheel are able to withstand any combination of the loads of normal operation, anticipated transients, loss of coolant accident with the largest mechanical pipe break remaining after application of leak before break as described in Subsection 3.6.3, and an SSE.

The flywheel is accessible for 100 percent in-place volumetric ultrasonic inspections. The flywheel-motor assembly is designed to allow such inspection with a minimum of motor disassembly.

5.4.1.1.4 Test and Inspection

a. Each flywheel [and hub] is tested at the design overspeed.

b. The flywheel ~~is~~ [and the hub are] subjected to a magnetic particle or liquid-penetrant examination per ASME Section III before final assembly. ~~The inspection is performed on areas of high stress concentrations.~~

c. Each finished flywheel [and its hub] is subjected to a 100 percent volumetric ultrasonic inspection from the flat surface as per ASME Section III. ~~This~~ [The flywheel] inspection is performed ~~on the flywheel~~ after final machining and the overspeed test. [The hub inspection is performed before final machining.]

d. The inservice inspection program includes ultrasonic examinations ~~of the areas of high stress concentration at the bore and keyway~~ [of the flywheel, excluding the hub,] at about three and one-third year intervals, during the refueling or maintenance shutdown coinciding with the inservice inspection schedule as required by ASME Section XI (Reference 5). Removal of the flywheel [or hub] is not required.

e. A surface examination of all exposed surfaces and a 100 percent volumetric examination by ultrasonic methods are conducted at approximately 10-year intervals during the plant shutdown coinciding with the inservice inspection schedule as required by ASME Section XI. This examination is limited to the flywheel, excluding the hub.

f. Each flywheel receives a preservice baseline inspection that incorporates the methods defined above for an inservice inspection. Examination procedures and acceptance criteria are determined in accordance with ASME Section III.

5.4.1.2 Description

Table 5.4.1-1 lists the principal parameters of the reactor coolant pumps, and Figure 5.4.1-1 depicts the arrangement of the pump and motor. Reactor coolant pump supports are described in Subsection 5.4.15. The flow diagram for the reactor coolant pump is given in Figure 5.1.2-2.

The four reactor coolant pumps are vertical, single stage, bottom suction, horizontal discharge, motor-driven centrifugal pumps. The pump impeller is splined and locked to its shaft. Pump shaft alignment is maintained by a water lubricated radial bearing within the pump and by radial and thrust bearings located in the motor stand. The pump and motor shafts are directly connected by a coupling.

The pump rotating assembly is mounted in a diffuser-type pump casing. The pump casing is a one-piece design in accordance with applicable sections of ASME Section III. The one-piece casing reduces the ASME Section XI examination requirements.

The pressure boundary materials used for the reactor coolant pump assembly are listed in Table 5.2-2, are compatible with the reactor coolant addressed in Subsection 5.2.3.2.1.

The shaft seal assembly consists of two face types, mechanical seals in series, with a controlled leakage bypass to provide the same pressure differential across each seal. The seal assembly is designed for the pressure differential of 175.8 kg/cm^2 (2,500 psi) and to reduce the leakage pressure from the RCS pressure to the volume control tank pressure. A third, face-type, low-pressure vapor seal at the top is designed to withstand system operating pressure when the pumps are not operating. The leakage past the second

Table 1.9-1 (2 of 38)

NRC Regulatory Guide		Revision / Issue Date	Conformance or Summary Description of Deviation	DCD Tier 2 Section
1.8	Qualification & Training of Personnel for Nuclear Power Plants	Rev. 3 05/2000	Not applicable (COL)	N/A
1.9	Application and Testing of Safety-Related Diesel Generators in Nuclear Power Plants	Rev. 4 03/2007	The APR1400 conforms with this NRC RG.	8.1.3.3, 8.3.1.2.2
1.11	Instrument Lines Penetrating Primary Reactor Containment	Rev. 1 03/2010	The APR1400 conforms with this NRC RG.	3.6.2.1.4.2, 6.2.4.1
1.12	Nuclear Power Plant Instrumentation for Earthquakes	Rev. 2 03/1997	The APR1400 conforms with this NRC RG.	3.7.4.1
1.13	Spent Fuel Storage Facility Design Basis	Rev. 2 03/2007	The APR1400 conforms with this NRC RG.	9.1.1.1, 9.1.1.3, 9.1.2.1, 9.1.3.3.3, 9.1.4.3, 9.1.5.2.1, 9.1.5.3, 9.4.2.1
1.14	Reactor Coolant Pump Flywheel Integrity	Rev. 1 08/1975	~~The APR1400 conforms with this NRC RG.~~	5.4.1.1
1.20	Comprehensive Vibration Assessment Program for Reactor Internals During Preoperational and Initial S	Rev. 3 03/2007	The APR1400 conforms with this NRC RG with the following exception:	3.9.2.4, 14.2.7.1.6
1.21	Measur Radioa Effluen			11.5, 12.3.4, TS Part 3, 5.0
1.22	Periodi Actuati			7.1.2.38, Table 7.1-1, 7.2.2.5, 7.2.3.3, 7.3.2.5, 7.3.3.5, 8.1.3.3
1.23	Meteorological Monitoring Programs for Nuclear Power Plants	Rev. 1 03/2007	Not applicable (COL)	N/A

The APR1400 conforms with this NRC RG with the following exception:

- The flywheel hub has small oil channels which prevents accurate ultrasonic test (UT) inspection. Due to this reason, the hub is only inspected before machining. Since the flywheel was analyzed using the maximum tensile stress at the outer wheel inner diameter surface, the hub is bounded. The outer wheel will be inspected after machining and during service as indicated in RG 1.14.

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

APR1400 Design Certification

Korea Electric Power Corporation / Korea Hydro & Nuclear Power Co., LTD

Docket No. 52-046

RAI No.:	**341-8410**
SRP Section:	**05.04.01.01 – Pump Flywheel Integrity (PWR)**
Application Section:	**5.4.1.1**
Date of RAI Issue:	**12/18/2015**

Question No. 05.04.01.01-6

APR1400 FSAR Section 5.4.1.1.4 specifies an inservice inspection program that includes ultrasonic examinations of the keyway in the flywheel. However, Technical report APR1400-AM-NR-14001-P, "KHNP APR1400 Flywheel Integrity Report," Revision 0, dated November 2014, does not show that the flywheel has a keyway, nor is one described. Therefore, provide a drawing of the flywheel design, so that NRC staff can confirm whether the flywheel has a keyway. Also, revise the Technical report APR1400-A-M-NR-14001-P, "KHNP APR1400 Flywheel Integrity Report," Revision 0, dated November 2014, and APR1400 FSAR Section 5.4.1.1.4, as necessary, to be consistent with the actual flywheel design.

Response

The flywheel design has no keyway. The technical report description of the flywheel design is correct. DCD Subsection 5.4.1.1.4 will be revised.

Impact on DCD

DCD Subsection 5.4.1.1.4 will be revised as indicated on the attached markup.

Impact on PRA

There is no impact on the PRA.

Impact on Technical Specifications

There is no impact on the Technical Specifications.

Impact on Technical/Topical/Environmental Reports

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a. Each flywheel and hub is tested at the design overspeed.

b. The flywheel and the hub are is subjected to a magnetic particle or liquid-penetrant examination per ASME Section III before final assembly. The inspection is performed on areas of high stress concentrations.

c. Each finished flywheel and its hub is subjected to a 100 percent volumetric ultrasonic inspection from the flat surface as per ASME Section III. The flywheel This inspection is performed on the flywheel after final machining and the overspeed test. The hub inspection is performed before final machining.

d. The inservice inspection program includes ultrasonic examinations of the areas of high stress concentration at the bore and keyway of the flywheel, excluding the hub, at about three and one-third year intervals, during the refueling or maintenance shutdown coinciding with the inservice inspection schedule as required by ASME Section XI (Reference 5). Removal of the flywheel or hub is not required.

e. A surface examination of all exposed surfaces and a 100 percent volumetric examination by ultrasonic methods are conducted at approximately 10-year intervals during the plant shutdown coinciding with the inservice inspection schedule as required by ASME Section XI. This examination is limited to the flywheel, excluding the hub.

f. Each flywheel receives a preservice baseline inspection that incorporates the methods defined above for an inservice inspection. Examination procedures and acceptance criteria are determined in accordance with ASME Section III.

5.4.1.2 Description

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The pump rotating assembly is mounted in a diffuser-type pump casing. The pump casing is a one-piece design in accordance with applicable sections of ASME Section III. The one-piece casing reduces the ASME Section XI examination requirements.

The pressure boundary materials used for the reactor coolant pump assembly are listed in Table 5.2-2, are compatible with the reactor coolant addressed in Subsection 5.2.3.2.1.

The shaft seal assembly consists of two face types, mechanical seals in series, with a controlled leakage bypass to provide the same pressure differential across each seal. The seal assembly is designed for the pressure differential of 175.8 kg/cm^2 (2,500 psi) and to reduce the leakage pressure from the RCS pressure to the volume control tank pressure. A third, face-type, low-pressure vapor seal at the top is designed to withstand system operating pressure when the pumps are not operating. The leakage past the second