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Responsibility





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국민에게 신뢰받는 안전 최우선의 KINS





2021. 10. 28(목)

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개요

기기검증 환경에 따른 규제요건 및 기술기준

환경에서 따른 시험방법

맺음말



















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I. 개요

기기검증 정의



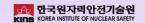
IEEE 323/KEPIC-END-1100

기기검증(Equipment Qualification)

기기가 정상 및 비정상 운전조건과 가상 설계기준사건 전, 동안 및 후에 계통 성능요건을 만족하기 위해 요구에 따라 운전이 가능함을 보증하기 위한 증거의 생성 및 유지

설계와 노화 관련 공통원인고장이 설계기준사건 전, 동안 및 후에 요구되는 기능을 수행하는 기기의 능력 손상이 기기의 다중계열에서 일어나지 않을 것이라는 합리적인 보증을 제공하는 것

기기검증 환경의 정의(1/2)



가혹한 환경

- · 설계기준사고 시 가상된 온도 및 압력 사용 조건
 - ✓ 격납건물 내부의 LOCA/HELB 사고
 - ✓ 격납건물 외부의 HELB 사고
 - ✓ 발전소의 특정 설계 조건에 따라 달라짐
- 방사선 환경
 - ✓ 기기의 방사선 문턱 값 이상에서 동작하도록 설계된 환경
 - ✓ 일반 전기기기의 감마선 문턱 값 : 10⁴ rads 이상
 - ✓ 마이크로프로세서 등 IC 전자부품의 문턱 값 : 10³ rads 이상

온화한 환경

- 정상 및 비정상 사용조건에서 형성된 환경
- 안전정지지진(SSE) : 유일한 설계기준사건(DBE)으로 간주
- 환경변수 대표 제한치(발전소 설계조건에 따라 달라질 수 있음)
 - ✓ 온도: ≤120 °F (50°C)
 - ✓ 압력: 대기압, 습도: 30~65%(typical), ≤95%(비정상)
 - \checkmark 방사선 : $\le 10^4 \text{ rads}$, 감마선 / $\le 10^3 \text{ rads}$, 감마선 (IC 전자부품, 마이크로프로세서)
 - ✓ 화학살수 및 침수: 영향 없음

기기검증 환경의 정의(2/2)



구 분	가혹한 환경 (Harsh Environment)	온확한 환경 (Mild Environment)
정 의	An environment resulting from a design basis event, i.e., loss-of-coolant accident (LOCA), high-energy line break (HELB), and main steam line break (MSLB) [IEEE Std. 323-2003]	An environment that would at no time be significantly more severe than the environment that would occur during normal plant operation, including anticipated operational occurrences. [10CFR 50.49(c)] An environment expected as a result of normal service conditions and extremes (abnormal) in service conditions where seismic is the only design basis event of consequence. [IEEE Std. 323-1983]
DBA	Seismic EventLOCA/HELB/MSLB	- Seismic Event

기기검증의 원칙 및 목적



구 분	가혹한 환경 (Harsh Environment)	온확한 환경 (Mild Environment)
원 칙	Efforts associated with developing explicit qualification programs for equipment in harsh environments	Implicit qualification associated with selection and procurement of equipment for mild environments
목적	For equipment located in a harsh environment, the primary objective of qualification is to demonstrate with reasonable assurance that electric equipment important to safety for which a qualified life has been established can perform its safety function(s) without experiencing common cause failures before, during, and after applicable design basis events.	For equipment located in a mild environment, it is sufficient to show that the equipment can meet its functional requirements during normal environmental conditions and anticipated operational occurrences as specified in the Design/Purchases specifications.

NRC, Thomas Koshy 발표자료 참조

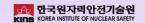
기기검증 환경의 한계

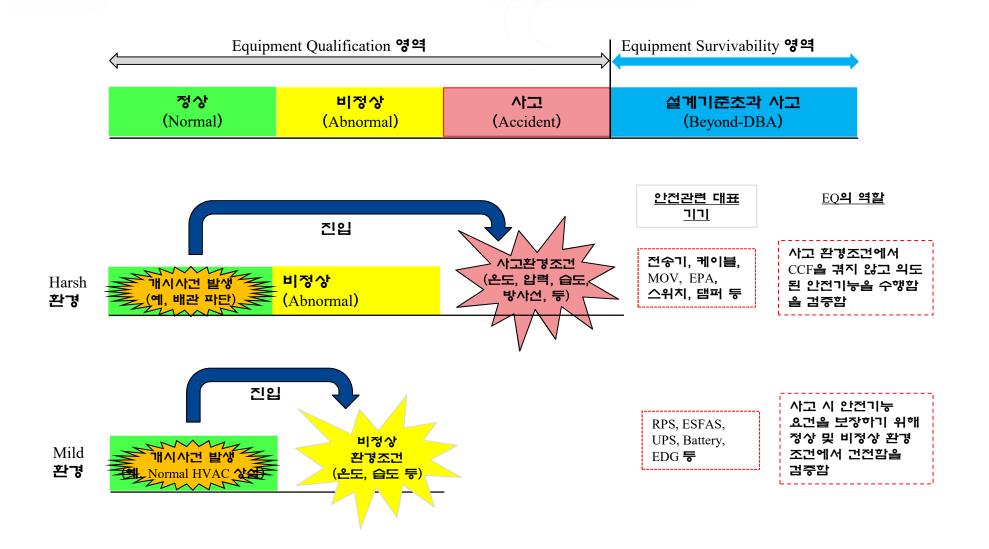


구 분	가혹한 환경 (Harsh Environment)	은확한 환경 (Mild Environment)
설정 근거	Harsh environment limits are based on the plant-specific consequences analyzed.	Mild environment limits are based on recognized equipment and material capabilities and the possible existence of concurrent high levels of individual environmental stresses(e.g., temperature, pressure, humidity, radiation, etc.)
정상/비정상 한계 (대표적인 수치)	 온도: > 120 °F 압력: > 대기압 방사선: > 10⁴ rads (전기기기) > 10³ rads (전자기기) 	 온도: < 120 °F 압력: 대기압 방사선: < 10⁴ rads (전기기기) < 10³ rads (전자기기)
비고	 For convenience, at or below these plant-specific limits, normal equipment operation is treated as in a mild environment. Above these limits, equipment is conservatively treated as harsh environment equipment even if its environment is not significantly affected by a design basis accident. 	

NRC, Thomas Koshy 발표자료 참조

정상, 비정상 및 사고조건별 구분













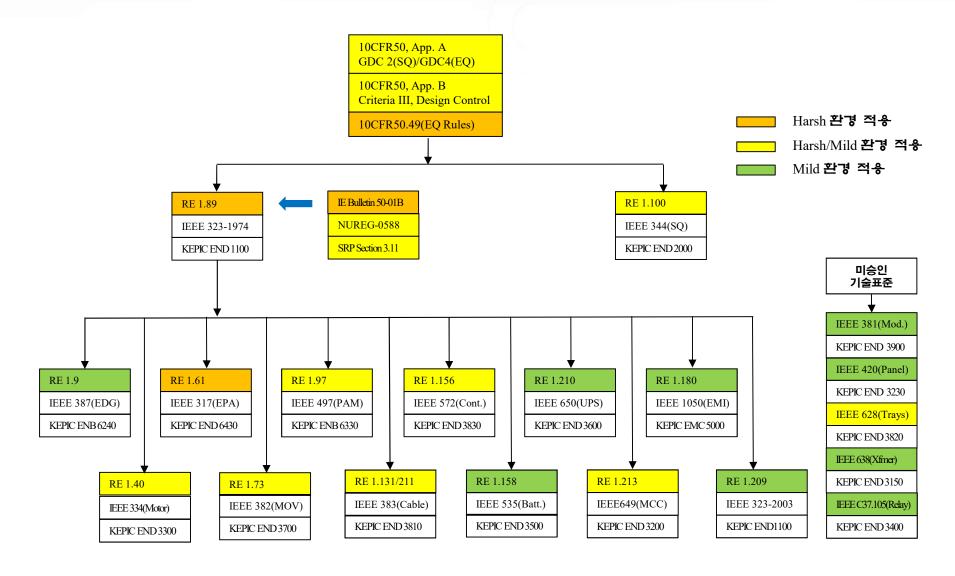


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Ⅱ. 기기검증 환경에 따른 규제요건 및 기술기준

기기검증 법규 및 규제지침의 체계





기기검증 관련 규제문서 및 기술기준 적용(1/4)



규제요건

구 분	가혹한 환경 (Harsh Environment)	온확한 환경 (Mild Environment)	비고
10CFR 50, App. A, GDC 4 "Environmental and Dynamic Effects Design Basis"	О	О	-
10CFR 50, App. B, Criterion III "Design Control"	О	О	-
10CFR 50, App. B, Criterion XI "Test Control"	О	О	-
10CFR 50, App. B, Criterion XVII "Quality Assurance Records"	О	О	-
10CFR 50.49, Environmental Qualification of Electric Equipment Important to Safety	О	X	가혹한 환경검증에 관한 특별법

기기검증 관련 규제문서 및 기술기준 적용(2/4)



규제지침

구 분	가혹한 환경 (Harsh Environment)	<mark>온화한 환경</mark> (Mild Environment)	비고
NUREG-0588 "Interim Staff Position on Environmental Qualification"	О	О	-
Reg. Guide 1.9, "IEEE Std. 387 사용 승인"	X	О	비상디젤발전기 (EDG)
Reg. Guide 1.40, "IEEE Std. 334 사용 숙인"	О	О	전동기
Reg. Guide 1.63, "IEEE Std. 317 사용 숙인"	О	X	전기관통부집합 체 (EPA)
Reg. Guide 1.73, "IEEE Std. 382 사용 승인"	О	О	MOV/AOV
Reg. Guide 1.97, "IEEE Std. 497 사용 승인 "	О	О	사고후계측설비 (PAM)
Reg. Guide 1.131/1.211, "IEEE Std. 383 사용 승인"	О	О	케이블

기기검증 관련 규제문서 및 기술기준 적용(3/4)



규제지침

구 분	가혹한 환경 (Harsh Environment)	<mark>온화한 환경</mark> (Mild Environment)	비고
Reg. Guide 1.156, "IEEE Std. 572 사용 승인"	О	О	전기콘넥터
Reg. Guide 1.158, "IEEE Std. 535 사용 승인"	X	О	축전지
Reg. Guide 1.210, "IEEE Std. 650 사용 승인"	X	О	UPS, 중전기 , 인버터 등
Reg. Guide 1.213, "IEEE Std. 649 사용 숙인"	О	О	전 동기제어센터 (MCC)
Reg. Guide 1.89, "IEEE Std. 323-1974 사용 승인"	О	X	가혹한 환경검증 에 관한 일반 지침
Reg. Guide 1.209, "IEEE Std. 323-2003 사용 승인"	X	О	온화한 환경검증 에 관한 일반 지침 (RTS, ESFAS, etc.)

기기검증 관련 규제문서 및 기술기준 적용(4/4)



미승인 기술기준

구 분	가혹한 환경 (Harsh Environment)	온화한 환경 (Mild Environment)	비고
IEEE Std. 381	X	О	I&C Modules
IEEE Std. 420	X	О	Control Board, Panel, Rack, etc.
IEEE Std. 638	X	О	변압기
IEEE Std. C37.105	X	О	보호계전기

기기검증 관련 규제문서 및 기술기준(1/3)



10CFR 50.49

- The 10CFR 50.49 requirements apply to the environmental qualification of electric equipment important to safety located in harsh environment.
- Requirements for (1) dynamic and seismic qualification of electric equipment important to safety, (2) protection of electric equipment important to safety against other natural phenomena and external events, and (3) environmental qualification of electric equipment important to safety located in a mild environment are not included within the scope of this section

III. Design Control

- The design control measures shall provide for verifying or checking the adequacy of design, such as by the performance of design reviews, by the use of alternate or simplified calculational methods, or by the performance of a suitable testing program.
- Where a test program is used to verify the adequacy of a specific design feature in lieu of other verifying or checking processes, it shall include suitable qualification testing of a prototype unit under the most adverse design conditions.

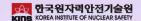
기기검증 관련 규제문서 및 기술기준(2/3)



NUREG-0588

구 분	가혹한 환경 (Harsh Environment)	온확한 환경 (Mild Environment)
격납건물 내부	1.1(1) The time-dependent temperature and pressure, established for the design of the containment structure and found acceptable by the staff, may be used for environmental qualification of equipment. 1.1(4) The test profile included in Appendix A to IEEE Std. 323-1974 should not be considered an acceptable alternative in lieu of using plant-specific containment temperature and pressure design profiles.	Not applicable
격납건물 외부	1.5(1) Equipment located outside containment that could be subjected to high-energy pipe breaks should be qualified to the conditions resulting from the accident for the duration required. The techniques to calculate the environmental parameters described in Sections 1.1 through 1.4 above should be applied.	1.5(2) Equipment located in general plant areas outside containment where equipment is not subjected to a design basis accident environment should be qualified to the normal and abnormal range of environmental conditions postulated to occur at the equipment location.

기기검증 관련 규제문서 및 기술기준(3/3)



IEEE Std. 323-2003

구 분	가 <u>촉한 환경</u> (Harsh Environment)	<mark>온확한 환경</mark> (Mild Environment)
4.1 검증 목적	 The primary objective of qualification is to demonstrate with reasonable assurance that Class 1E equipment for which a qualified life or condition has been established can perform its safety function(s) without experiencing common-cause failures before, during, and after applicable design basis events. Class 1E equipment, with its interfaces, must meet or exceed the equipment specification requirements. 	 For equipment located in a mild environment for meeting its functional requirements during normal environmental conditions and anticipated operational occurrences, the requirements shall be specified in the design/purchase specifications. A qualified life is not required for equipment located in a mild environment and which has no significant aging mechanisms. When seismic testing is used to qualify equipment located in a mild environment, pre-aging prior to the seismic tests is required only where significant aging mechanisms exist.











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Ⅲ. 환경에 따른 시험방법

환경에 따른 시험방법



가혹한 환경 (harsh environment)

정상 (Normal)

비정상 (Abnormal) 사고 (Accident)

Sig. Aging Mechanism (O)

- 기기/부품 검증수명 요구(O)
- 검증수명 동안 사전 노화처리(O)
 - 온도/방사선 노확
 - 운전 노확(operational cycles)

내진 시험 + LOCA/MSLB 시험

Sig. Aging Mechanism (X)

- 기기/부품 검증수명 요구(X)
- 검증수명 동안 사전 노화처리(X)

온확한 환경 (mild environment)

정상 (Normal)

비<mark>정상</mark> (Abnormal)

사고 (Accident)

Sig. Aging Mechanism (O)

- 기기/부품 검증수명 요구(O)
- 검증수명 동안 사전 노확처리(O)
 - 온도/방사선 노화
 - 운전 노확(operational cycles)
- 환경 시험(O)*



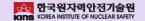
내진 시험

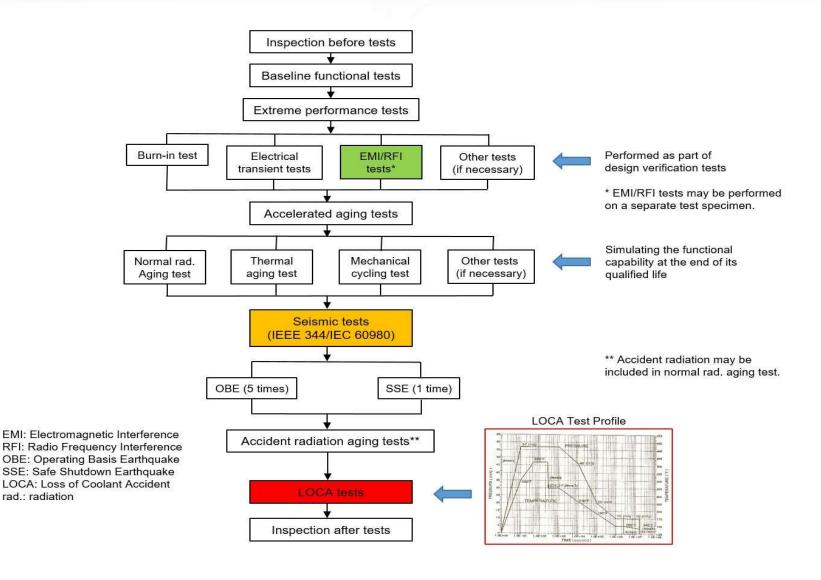
Sig. Aging Mechanism (X)

- 기기/부품 검증수명 요구(X)
- 검증수명 동안 사전 노확처리(X)
- 환경 시험(O)*

* Environmental tests are based on recognized equipment and material capabilities and the possible existence of concurrent high levels of individual environmental stresses (e.g., temperature, pressure, humidity, radiation, etc.)

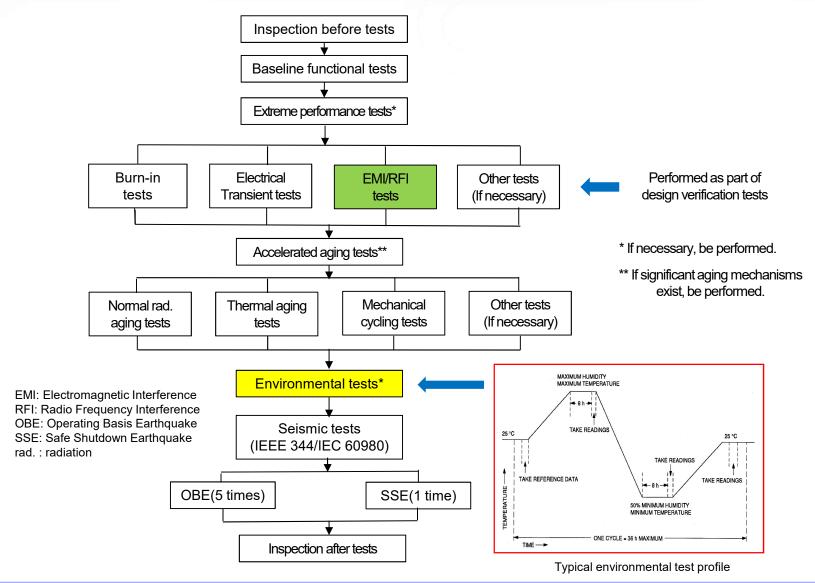
가혹한 환경에서의 노화 처리 및 DBE 시험





온화한 환경에서의 노화 처리 및 DBE 시험





온화한 환경에서의 노화 처리 및 환경 시험(1/4)



IEEE Std. 650-2006

IEEE Standard for Qualification of Class 1E Static Battery Chargers, Inverters, and Uninterruptible Power Supply Systems for Nuclear Power Generating Stations.

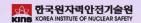
Sec. 5.3.1.1~5.3.1.2(노화처리)

- Components shall be analyzed and, where required, aged to their respective qualified life or the equipment qualified life.
- Because the battery charger, inverter, and UPS systems are located in an environment where only low levels (typically less than 1.0E + 03 rads, total integrated dose) of radiation are encountered. Documentation (analysis or testing) shall be provided to demonstrate that the ability of the equipment to perform its required function is unaffected by the radiation dose specified.

Sec. 5.3.1.6(Environmental Stress Test)

- To demonstrate that the equipment will meet its specified Class 1E performance characteristics under the specified service conditions (as required by IEEE 323-2003), refer to Figure 2 and perform the following stress test on the fully loaded equipment, or load condition that generates the maximum heat, in the test chamber.
- This test subjects the complete equipment to the <u>worst-case and nominal conditions</u> of temperature, humidity, input voltages, and output loads (input frequency variations have no impact on stressing the equipment).

온화한 환경에서의 노화 처리 및 환경 시험(2/4)



IEEE Std. 535-2013

IEEE Standard for Qualification of Class 1E Vented Lead Acid Storage Batteries for Nuclear Power Generating Stations

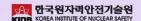
Sec. 8.3.2.e (노화처리)

- The accelerated aging temperature and duration values (based on the activation energy) in Table 1 are the default values for the plate construction types identified based on the predominant failure mode of positive grid corrosion.
- In all cases, the aging duration shall be no less than 10 days equivalent to 1 year and shall be in increments of 1 day for durations above 10 days.
- The maximum temperature shall be 71° C (160° F). The Arrhenius methodology shall be used to determine the accelerated aging factors, refer to IEEE Std. 323.

Environmental Test

Not applicable

온화한 환경에서의 노화 처리 및 환경 시험(3/4)



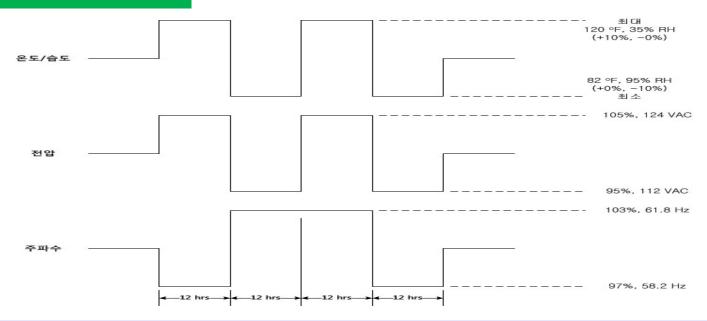
WCAP-8587

Environmental Qualification of Westinghouse NSSS Class 1E Equipment

Reg. Guide 1.209, C(1)(노화처리)

• The NRC does not consider the age conditioning because of the absence of significant aging mechanisms on microprocessor-based modules

Environmental Test Profile



온화한 환경에서의 노화 처리 및 환경 시험(4/4)



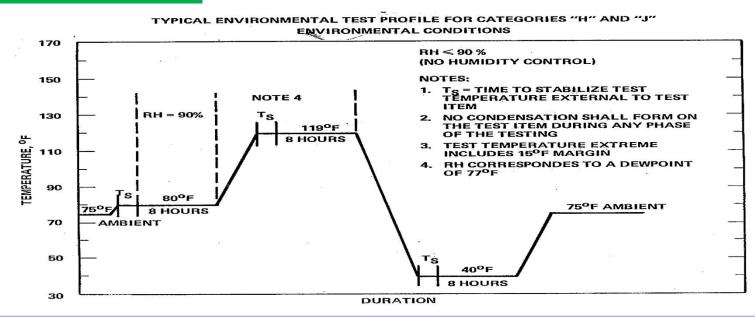
CENPD-255-A, Rev3

Qualification of Class 1E Electrical Equiment

Reg. Guide 1.209, C(1)(노화처리)

• The NRC does not consider the age conditioning because of the absence of significant aging mechanisms on microprocessor-based modules

Environmental Test Profile











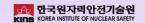




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IV. 맺음말

맺음말



기기검증의 역할

환경 또는 사용 조건으로 인한 공통원인고장이 발생하지 않음을 보증하는 수단

기기 검증의 규정

가혹한 환경의 기기는 10CFR 50.49의 법령에 따라 검증하고, 온화한 환경의 기기는 NUREG-0588, IEEE Std. 323의 규정에 따라 검증함.

검증수명 및 검증상태 수립

- 가혹한 환경의 기기이든, 온화한 환경의 기기이든 간에 노화분석을 통해 심각한 노화기구(Significant aging mechanism)가 확인되면
- 검증수명과 검증상태가 수립되고 설계기준사고 검증시험 이전에 검증수명 동안 사전 노화처리 (Pre-aging)를 수행함
- 또한 검증수명 동안 검증상태가 유지되도록 EQ 정비를 수행함.



