

Overview of the NEK Equipment Qualification Programs



ÚJV Řež – May, 2019

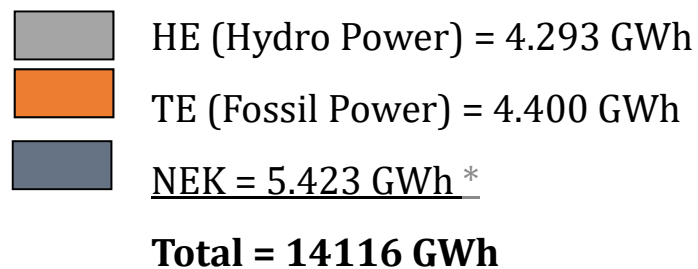
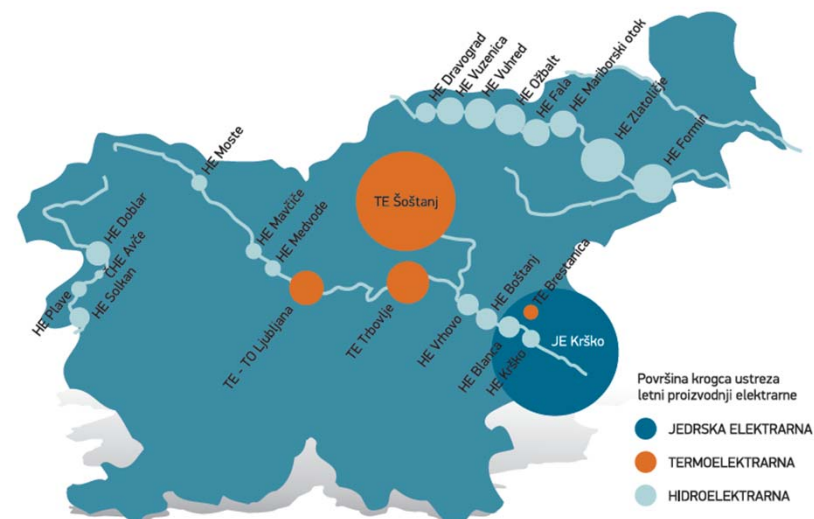
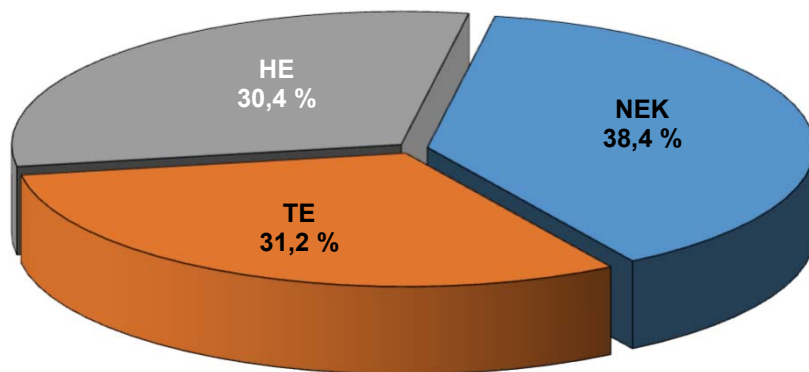


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- Owners: **GEN Energija 50% HEP 50%**
- Operator: **NEK**
- NSSS Supplier: **Westinghouse**
- Reactor Type: **PWR**
- Construction Permit: **1975**
- Commercial Operation: **1983**
- Operating Licence: **40-60 years**
- Gross Plant Output: **727 MW**

NEK share in Slovenia in production of electrical energy

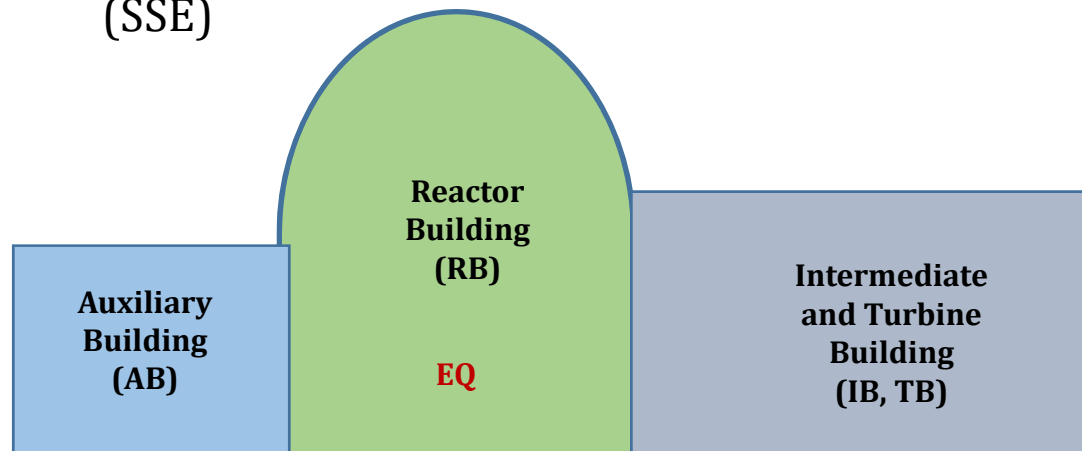


* Total Krško NPP Production

Source: ELES, Monthly Report on the Power System for December and year 2016, January 2017

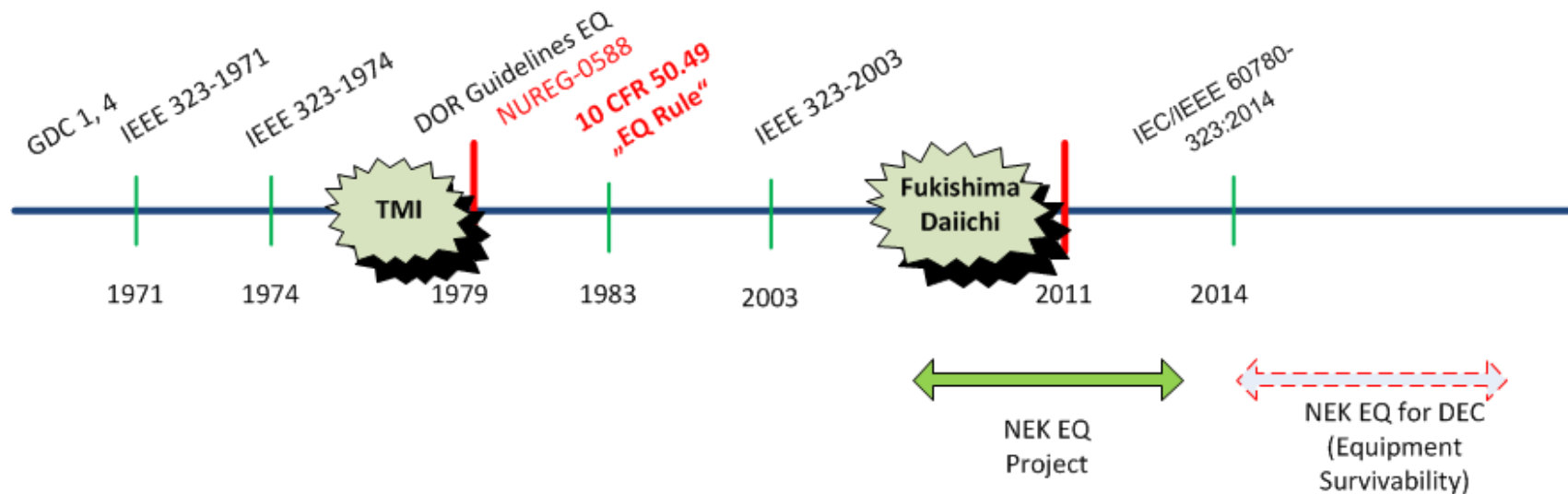
Construction design requirements:

- Environmental Qualification of Electrical and I&C (EQ) Reactor Building
DBA equipment shall be qualified to IEEE 323-1971 and IEEE 323-1974 –
NO FORMAL PROGRAM
- Seismic Design – Seismic Category I mechanical and electrical
equipment for the KRSKO Nuclear Power Plant shall meet seismic
performance requirements during and following the OPERATING
BASIS EARTHQUAKE (OBE), SAFE SHUTDOWN EARTHQUAKE
(SSE)



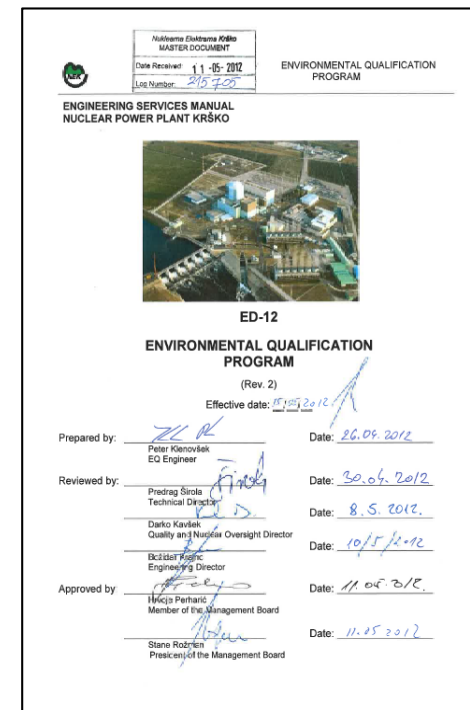
NEK Environmental Qualification program for Electrical and I&C equipment:

- First Periodic Safety Review (PSR1) – 2005 action plan
- Slovenian Nuclear Regulatory Body rule JV5 „ Rules on radiation and nuclear safety factors“



NEK EQ Program document:

1. ED-12 consistent with 10 CFR 50.49
2. ED-12 defines methodology and criteria for EQ conditions determination (EQ zones)
3. ED-12 methodology and criteria for EQMEL in EQSEL lists
4. Program defines qualification process:
 - Methods for qualification and documentation
 - Process control (design changes, maintenance, purchasing)



NEK DBA EQ conditions:

Environmental conditions during and after DBA:

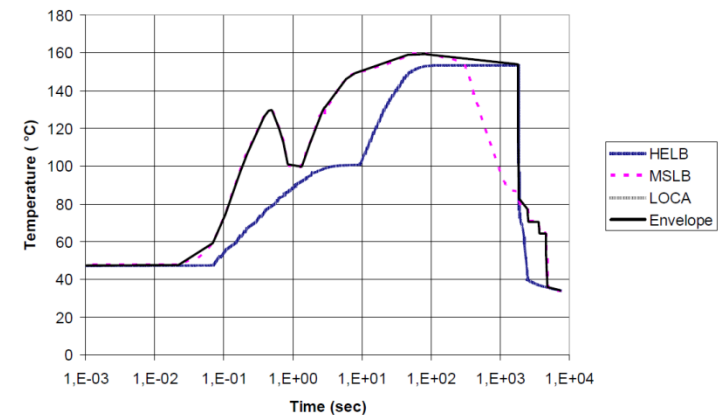
- LOCA
- MSLB (Main Steam Line Break)
- HELB (High Energy Line Breaks): $T > 93.3^{\circ}\text{C}$ or $p > 2.0 \text{ MPa}$
(for example CVCS letdown, SG BD)

Analyses:

- T/H: RB, IB, AB: T, p and RH
- Dose rates and TIDs: RB, AB (for example RH sump recirculation), IB

Harsh conditions significantly more severe than normal operating conditions:

- Temperature: $8,3^{\circ}\text{C}$ (15°F) above normal/design T
- Pressure: 10% above normal/design (10kPa – 1,47psi)
- RH: 100%RH with condensation
- Chemical Spray - exposure
- Submergence – exposure
- Radiation TID $> 100\text{Gy}$; $> 10\text{Gy}$ for electronics



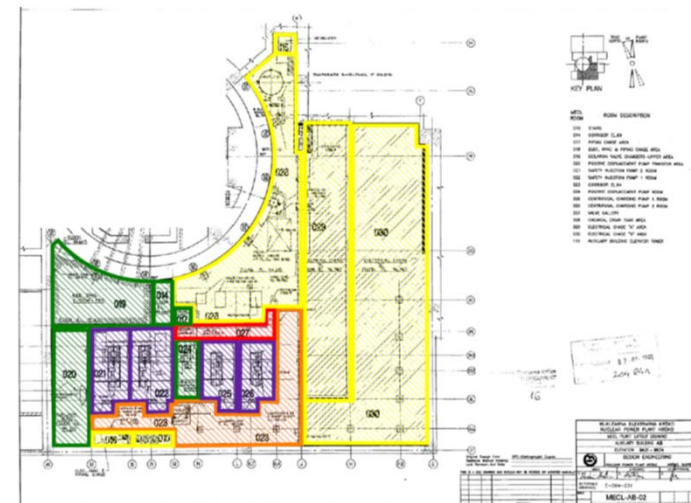
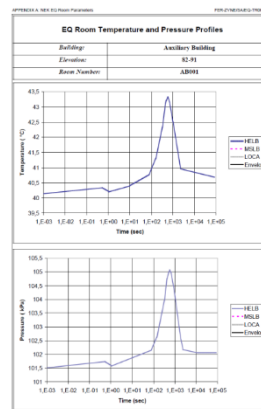
EQ Zone Maps document

- Defined Harsh/Mild locations end corresponding enveloping EQ zone:

BUILDING	ELEVATION	LOCATION	ENVIRONMENT	ZONE
Auxiliary building	82-91	AB001	MILD	AB-M-02
Auxiliary building	82-91	AB002	HARSH	AB-H-05
Auxiliary building	82-91	AB003	HARSH	AB-H-05
Auxiliary building	82-91	AB004	HARSH	AB-H-05

- EQ conditions defined for every evaluated room:

EQ Room Parameters				
Building		Auxiliary Building		
Elevation		82-91		
Room Number		AB001		
NORMAL OPERATING CONDITION	PARAMETER	ACCIDENT CONDITION	Notes/Ref.	
	40	Peak Temperature (°C)	LOCA: 40.0 MSELB: 40.0 HELB: 43.3	HR-EG-04/12/REF/32
101.3	Peak Pressure (bPa)	LOCA: 101.3 MSELB: 101.3 HELB: 105.1	HR-EG-04/12/REF/32	
	60	Minimum Humidity (%)	LOCA: 60 MSELB: 60 HELB: 65	HR-EG-04/12/REF/32
N/A	Chemical Spray	LOCA: N/A MSELB: N/A		
		LOCA: N/A MSELB: N/A		
N/A	Flood Level (m)	LOCA: N/A MSELB: N/A		
		HELB: N/A	HR-EG-04/12/REF/32	
E-04E-00	40 Year Dose Gamma (Sv)	E-04E-00	800% N/A	
N/A	Accident Dose Gamma (Sv)	E-04E-00	800% N/A	
N/A	Accident Dose Beta (Sv)	E-04E-00	800% N/A	
N/A	Resonance Dose Gamma (Sv)	E-04E-00	800% N/A	
N/A	Rad Beta (Sv)(1+0.55α)	E-04E-00	800% N/A	
ZONE		AB-M-02	MILD	

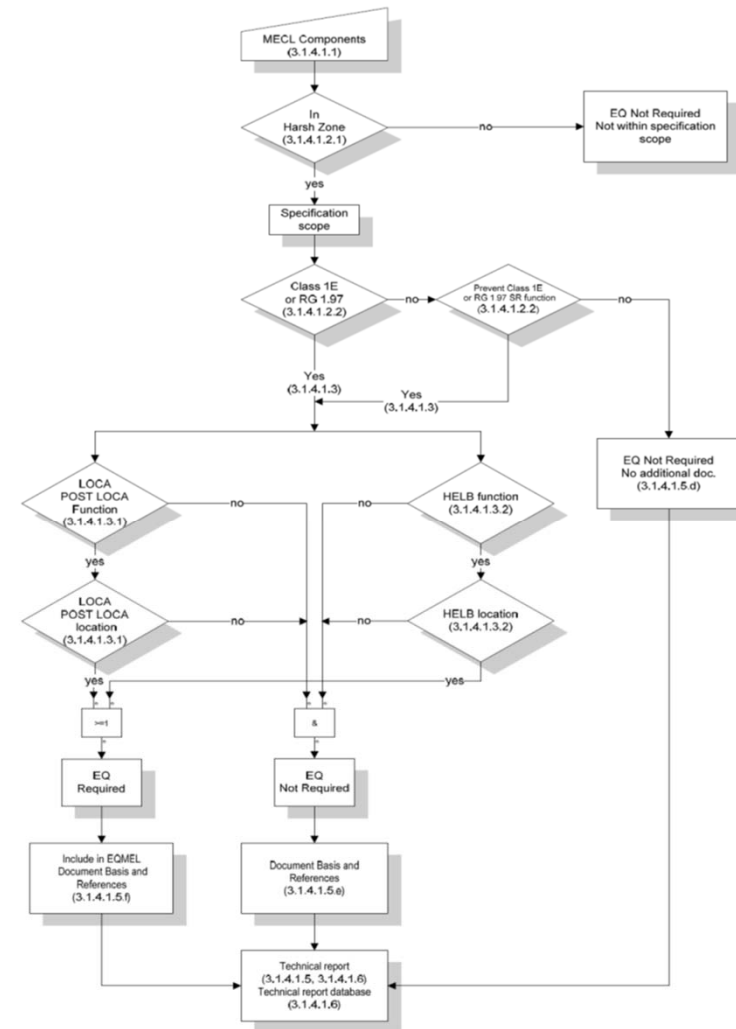


EQ equipment list

EQ Master Equipment List (EQMEL) components:

- Electrical and I&C equipment:
 - Safety-related;
 - Non-safety-related that affects safety-related;
 - Certain post-accident monitoring (RG 1.97 Category 1 in 2)
- Located in Harsh environment and perform DBA safety function

Equipment			
Equip no:	TE858	System:	RH
Status:	ACTIVE		
Func Desc:	REL LOCP #2 HK RETURN RTD		
Type:	E	Dscpt:	I
Cat:	ELE	Sub Cat:	
Parent:		Parent Equip System:	SPIN:
Vendor information			
Model:	/	Serial No:	N31733
Vendor Id:	ROUND ROCK, TX		
PO Vendor site:	4163, ULTRA ELECTRONICS, ROUND ROCK, TX (707 JEFFERY WAY, ROUND ROCK, ZDA)		
MFG Id:	UN51		- 0
Manufacturer:	ULTRA ELECTRONICS-UN51-0 - ULTRA ELECTRONICS NUCLEAR SENSORS&PROCESS INSTR.		
SQDR:		PART No:	612-1B-C-4-C-17.25-0-0
		P.O.No:	3120944
		Instl. Year:	21.03.2013
		Instl. Rev:	
Determinants			
ANSI:	N/A	SR:	N
ASME:		P/S:	P
IEEE:	N1E	Seismic:	N
Elec train:	X	BOP/NSSS:	N
Append 'R':	N	AMP:	N
		EQ Zone:	N
		EQ:	Y
		Q-List:	Y
		Saf. Func:	A
		RWP:	Y
Location			
Building:	AB	Room:	055
		Equip Elev:	103.85



EQMEL equipment list (typical):

- Pumps electric motors ,
- VA fan coolers electric motors
- MOVs
- Limit switches
- Electrical penetrations
- Pressure transmitters (LT, PT, FT)
- RTDs, TCs
- Pressure switches
- RM detectors/monitors
- Solenoid valves
- MCCDs
- H2 recombiners (replaced with PARs)
- Transformers,
- Selector switches



EQ Supporting Equipment List (EQSEL)
- entire functional loop shall be qualified

Typical supporting equipment:

- Cables – BIW, Rockbestos, Okonite, General Cable
- Wires – FWIII SIS, FLAMETROL
- Heat-shrink in-line cable splices - TYCO/RAYCHEM
- Terminal blocks – MARATHON
- Sealing Tapes – Graphoil, Locktite
- Connectors – EGS Qualtech, Conax
- Sealing Compounds – DOW CORNING, NAMCO

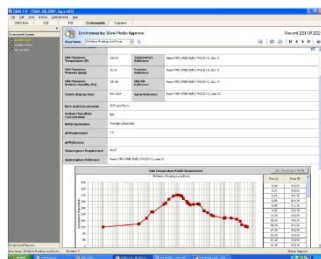
QualTech QDC connector



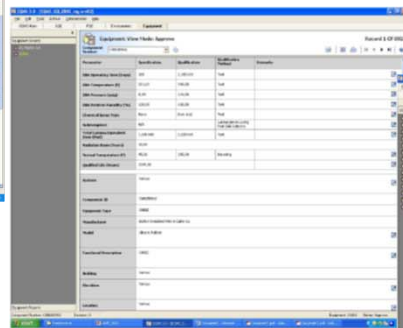
Qualification documentation – EQMS

- Test reports (Environmental Qualification Report)
- NEK Qualification evaluations - EPRI EQ management Software (EQMS):

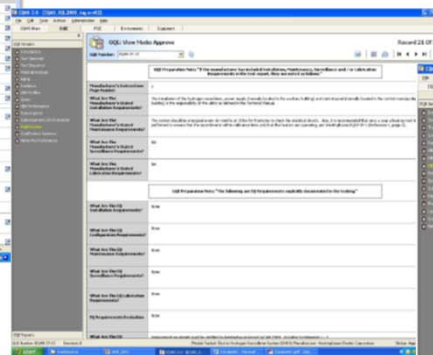
EQ Enviroments



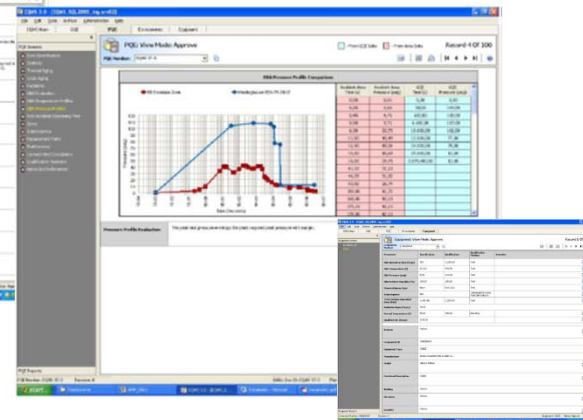
EQMEL



GOE



PQE + SCEW

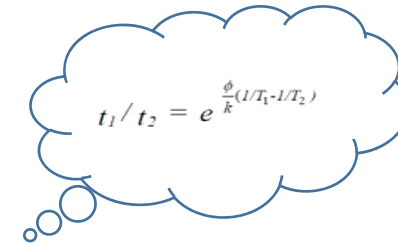


Qualification documentation – EQMS Plant Qualification Evaluation Module (PQE):

Thermal Aging – qualified life calculation:

Thermal Aging Qualified Life Calculation

Normal Area Name	Ambient Temp (F)	Basis	Temp Rise (F)	% Energized	Aging Time (Hr)	Aging Temp (C)	Activation Energy (eV)	Notes	Qualified Life (Y)
IB-H-06 Zone	114.80	Bounding	0.00	100.00	3.072.00	98.61	0.7800		19.40
RB-H-01 Zone	120.20	Bounding	0.00	100.00	3.072.00	98.61	0.7800		14.90
Plant Temperature Monitoring	98.42	T measurement RB el. 96.04: EQAR 30-3-TR-1	0.00	100.00	3.072.00	98.61	0.7800	See Reference 20.	44.60
Plant Temperature Monitoring	108.32	T measurement RB el. 100.30: EQAR 30-3-TR-1	0.00	100.00	3.072.00	98.61	0.7800	See Reference 20.	26.81
Plant Temperature Monitoring	104.00	T measurement RB el. 107.06: EQAR 30-3-TR-1	0.00	100.00	3.072.00	98.61	0.7800	See Reference 20.	33.40
Plant Temperature Monitoring	112.46	T measurement RB el. 115.55: EQAR 30-3-TR-1	0.00	100.00	3.072.00	98.61	0.7800	See Reference 20.	21.78



PAOT profiles area comparison – margin calculation:

Post Accident Operating Time Chart



PAOT Calculation Results

Accident Area Result (days)	GQE Result (days)	Percentage Difference
6.32E+02	1.58E+03	149.24

PAOT Calculation Input Values

Reference Temperature (F)	Start Time (s)	Activation Energy (eV)
120.38	0.10	0.7800

Accident Area Temperature Profile Name

Plant Envelope (without AB048) Zone

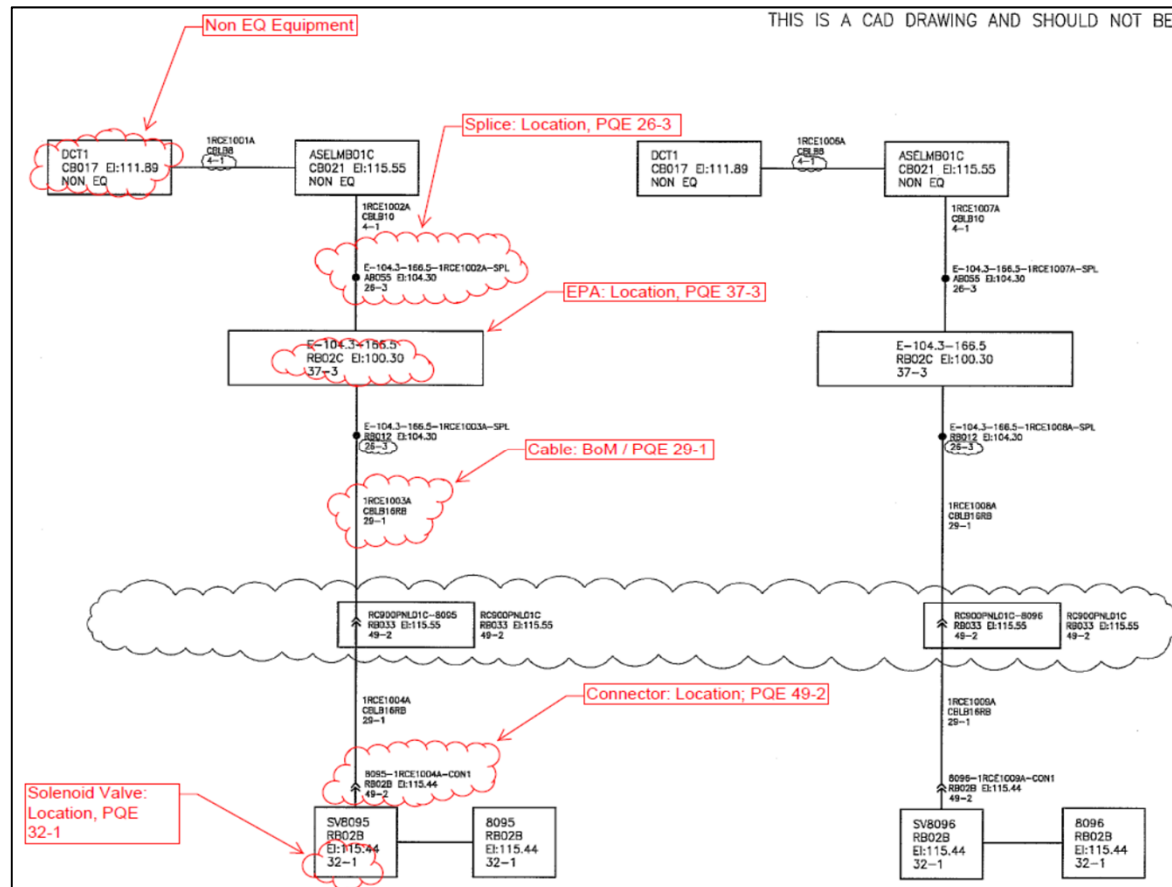
GQE Temperature Profile Name

Rosemount D2013003 Rev.B

Accident Area Time (s)	Accident Area Temp (F)	Plant Comp Temp Rise (F)	Plant Comp Total Temp (F)	GQE Time (s)	GQE Temp (F)	Specimen Temp Rise (F)	Specimen Total Temp (F)
0.00	122.00	0.00	122.00	0.10	120.00	0.00	120.00
0.01	174.20	0.00	174.20	10.00	360.00	0.00	360.00
0.05	222.08	0.00	222.08	60.00	435.00	0.00	435.00
0.15	309.20	0.00	309.20	180.00	435.00	0.00	435.00
2.00	312.80	0.00	312.80	240.00	365.00	0.00	365.00
3.00	318.20	0.00	318.20	600.00	365.00	0.00	365.00
33.90	318.56	0.00	318.56	660.00	320.00	0.00	320.00

Other qualification documents:

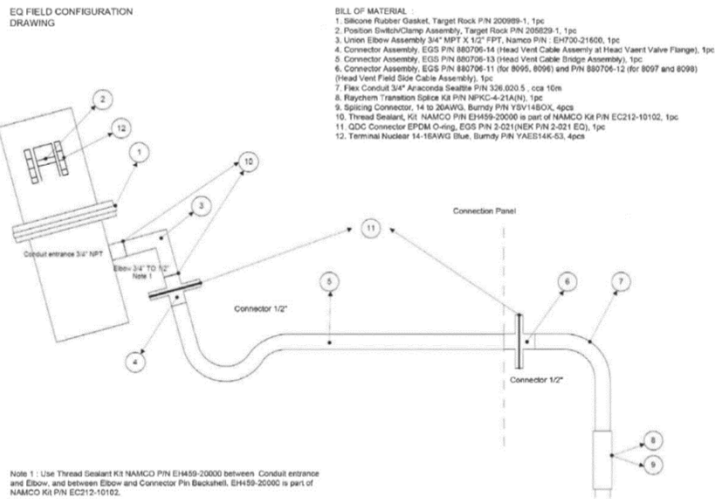
EQ block diagrams:



Other qualification documents:

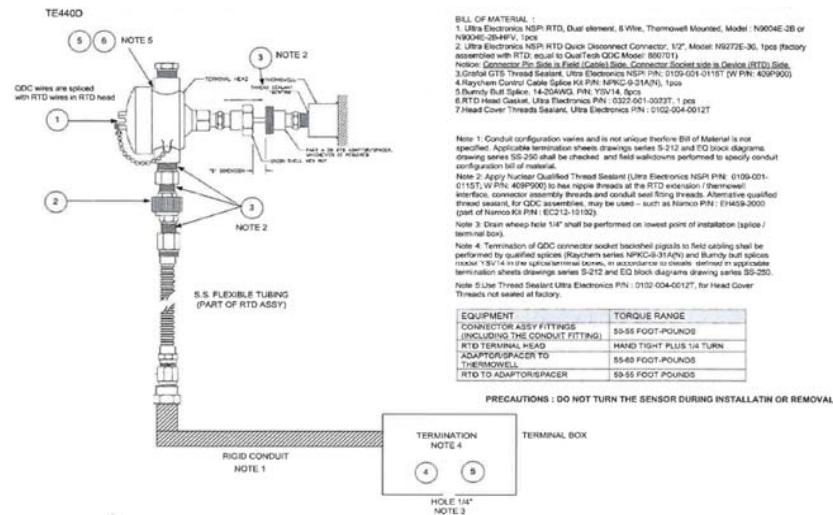
EQ Workmanship standard (EQWS):

EQ Field Configuration Drawings



EQ Field Configuration Parts List

EQ Field Installation Drawing Item:	Manufacturer/Vendor	Manufacturer P/N	Part description	DCM Drawing or Document No.	Drawing or Document Item	Replacement requirement	Safety Related	PQE purchasing requirement
1	Target Rock	200989-1	Silicone Rubber Gasket	79AB-008-1 Rev.G	32	Whenever solenoid valve cover removed	Yes	PQE 32-1
2	Target Rock	205829-1 (consisting of 205828-1 clamp, 205830-1 switches and 2058031-2 switches)	Position Switch Assembly including clamp and switches assembly	79AB-008-1 Rev.G	22, 23	12.69 years	Yes	PQE 32-1
3	Namco	EHT08-21600	Union Elbow Assembly 3/4" MPT X 1/2" FPT	Manufacturer Catalogues	No	No	Yes	Not applicable
4	QualTech NP/ Curtiss Wright	880706-14	1/2" QDC Connector Assembly	B-N-880706-14 Sh.1	All parts as one unit	No	Yes	PQE 49-2
5	QualTech NP/ Curtiss Wright	880706-13	1/2" QDC Cable Connector Assembly	B-N-880706-13 Sh.1	All parts as one unit	No	Yes	PQE 49-2
6	QualTech NP/ Curtiss Wright	880706-11 or 880706-12	1/2" QDC Cable Connector Assembly	B-N-880706-11 Sh.1 or B-N-880706-12 Sh.1	All parts as one unit	No	Yes	PQE 49-2
7	Anamet	32E.020.5	Anaconda Sealrite flex conduit	No	No	No	No	Not applicable
8	Tyco-Raychem	NPKC-4-21A(N)	Raychem Transition Splice Kit	Manufacturer Catalogues	No	No	Yes	PQE 26-5
9	Burndy	YSV1480X	Splicing connector 14-20AWG	Manufacturer Catalogues	No	No	Yes	PQE 5-1
10	Namco	EH459-20000 as part of kit EC212-10102	Thread Sealant Kit	Manufacturer Catalogues	No	No	Yes	PQE 38-4
11	QualTech NP/ Curtiss Wright	2-021; NEK P/N for EQ: 2-021 EQ	Nordel EPDM O-ring	Manufacturer Catalogues	No	Whenever connector is disconnected	Yes	PQE 49-2
12	Burndy	YAES14K-53	Terminal 12-16AWG, blue	Manufacturer Catalogues	No	No	Yes	PQE 5-1



EQ activities:

Hot spots determination:

- Temperature
- Gamma and neutron radiation



EQ labeling:



Control over plant processes:

- Design changes
- Preventive Maintenance
- Procurement

BI PROD Business Intelligence

11. EQ - Environmental Qualification Program

Equipment No. PGE No. Accident Purpose Qualification Base

EQ Zone DBA EQ Zone SA Building Name Room No. Owning Department Equipment Category System Code

Manufacturer Name Manufacturer Part No. Serial Number Item Number Purchase Order

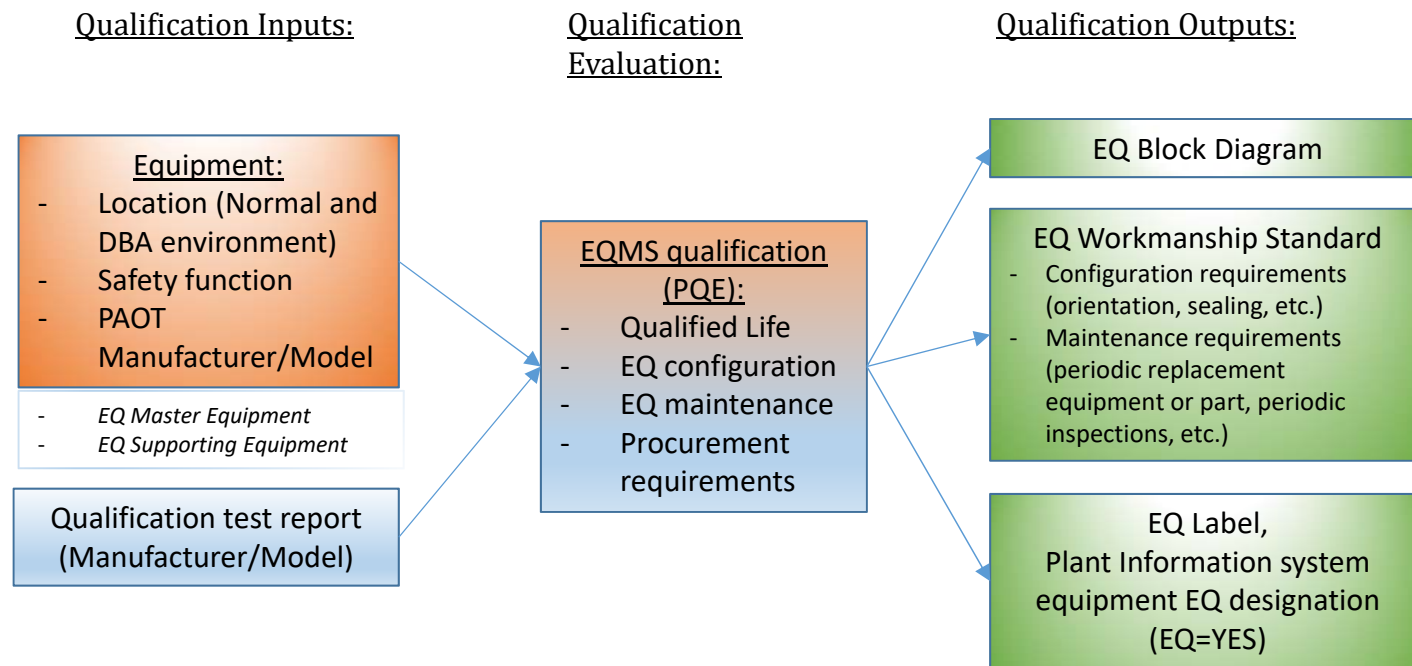
Installation Date

EQ Required Replacement Date

Assets

Equipment No.	Accident Purpose	Qualification Base	EQ Zone DBA	EQ Zone SA	Building	Room No.	System	Equipment Category	EQ Qualification Category	EQ Procurement Requirements	Owning Department	Installation Date	EQ Qualifier Life (Years)	EQ Replacement Date	EQ Workmanship Standard	EQ Maintenance Requirements Notes	PGE	QGE
F72714EC	(+) DBA	IEEE 323	RB-H-01	NA	RB	023	CC	XMT	NUREG 0588 Cat I	Replacement Rosemount Model No. 3154N Series Transmitters shall be certified to Rosemount Report No. 02013003 Rev. Rev B. Certify that the testing is in accordance with IEEE Standard 323-1974/1982/2003 and IEEE Standard 344-1975/1987/2004.	TD.VZIC	20.10.2016	21.8	03.08.2038	EQWS 30-12	Walkdown acceptable. Qualified life is based on Amplifier and Calibration Board qualified life. Replace the cover O-ring(s) if either the terminal cover or electronic cover is removed. Transmitter installed per WO 79566 (PT 16) an wired/unconnected per WO 104578 (PT 12).	PGE 30-12	QGE 30-12
F72715EC	(+) DBA	IEEE 323	RB-H-01	NA	RB	024	CC	XMT	NUREG 0588 Cat I	Replacement Rosemount Model No. 3154N Series Transmitters shall be certified to Rosemount Report No. 02013003 Rev. Rev B. Certify that the testing is in accordance with IEEE Standard 323-1974/1982/2003 and IEEE Standard 344-1975/1987/2004.	TD.VZIC	20.10.2016	21.8	03.08.2038	EQWS 30-12	Walkdown acceptable. Qualified life is based on Amplifier and Calibration Board qualified life. Replace the cover O-ring(s) if either the terminal cover or electronic cover is removed. Transmitter installed per WO 79566 (PT 16) and wired/unconnected per WO 104578 (PT 12).	PGE 30-12	QGE 30-12
F72019EC	(+) DBA	IEEE 323	IB-H-06	NA	IB	025	AF	XMT	NUREG 0588 Cat I	Replacement Rosemount Model No. 3154N Series Transmitters shall be certified to Rosemount Report No. 02013003 Rev. Rev B. Certify that the testing is in accordance with IEEE Standard 323-1974/1982/2003 and IEEE Standard 344-1975/1987/2004.	TD.VZIC	19.03.2018	25.0	01.05.2041	EQWS 30-12	Walkdown acceptable. Qualified life is based on Amplifier and Calibration Board qualified life. Replace the cover O-ring(s) if either the terminal cover or electronic cover is removed. Transmitter installed per WO 79566 (PT 16) and wired/unconnected per WO 104578 (PT 12).	PGE 30-12	QGE 30-12

EQ overall process



EQ group is involved whenever EQ equipment is affected:

- 1) Replaced,
- 2) Modified,
- 3) De-installed
- 4) New EQ equipment installed
- 5) Environmental conditions affected

Second Periodic Safety Review (PSR2):

1. Qualification to Severe Accidents – Equipment Survivability Program
2. Active Mechanical Equipment Environmental Qualification – Mechanical Qualification Program
3. Electromagnetic Compatibility Qualification – EMC Program

REGULATIONS:

Slovenian legislation:

„Rules on radiation and nuclear safety factors“ requires Equipment Survivability (ES) assessment to show that there is reasonable assurance that the equipment and instrumentation used to mitigate and monitor Design Extended Accident Conditions (DEC).

Act is in accordance with IAEA, WENRA requirements.

IAEA Safety Standard SSR-2/1 „Specific Safety Requirements“

Requirement 20 - Design extension conditions:

„These design extension conditions shall be used to identify the additional accident scenarios to be addressed in the design and to plan practicable provisions for the prevention of such accidents or mitigation of their consequences“.

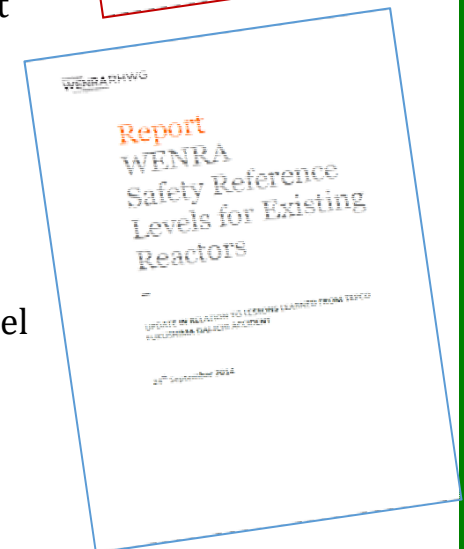
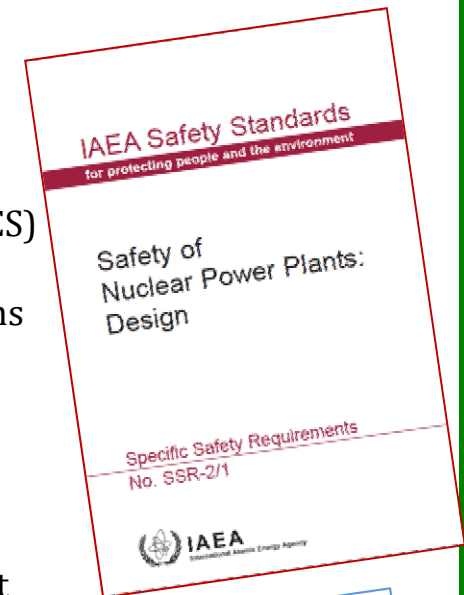
WENRA Safety Reference Levels for Existing Reactors (2014)

Issue F - Design Extension of Existing Reactors:

„There are two categories of DEC:

- DEC A for which prevention of severe fuel damage in the core or in the spent fuel storage can be achieved;
- DEC B with postulated severe fuel damage“.

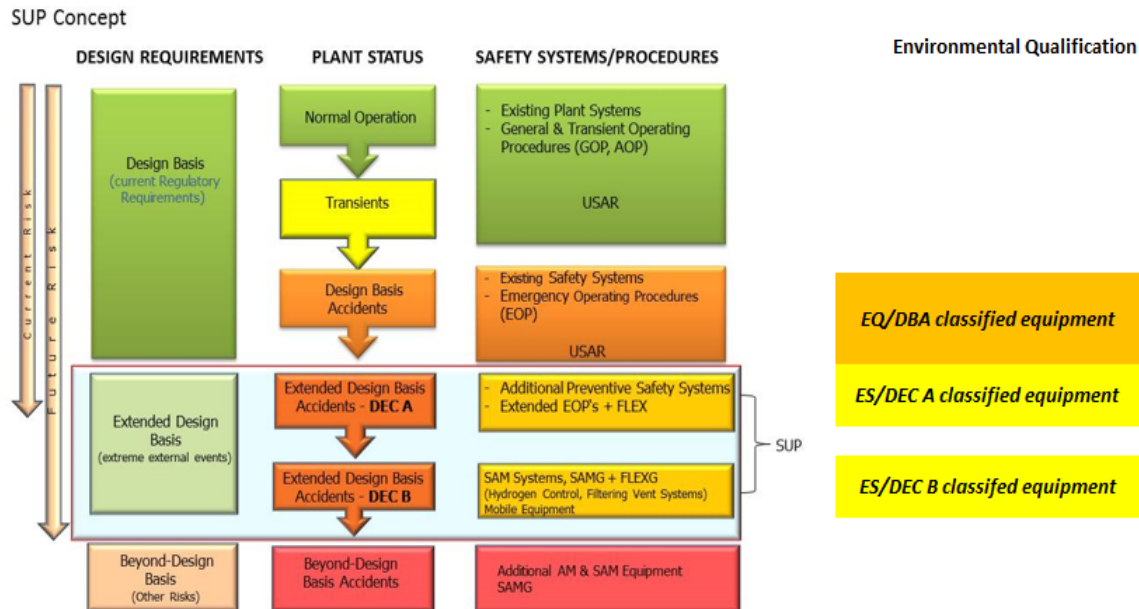
„... DEC have the capacity and capability and are adequately qualified to perform their relevant functions for the appropriate period of time ...“



NEK WENRA approach:

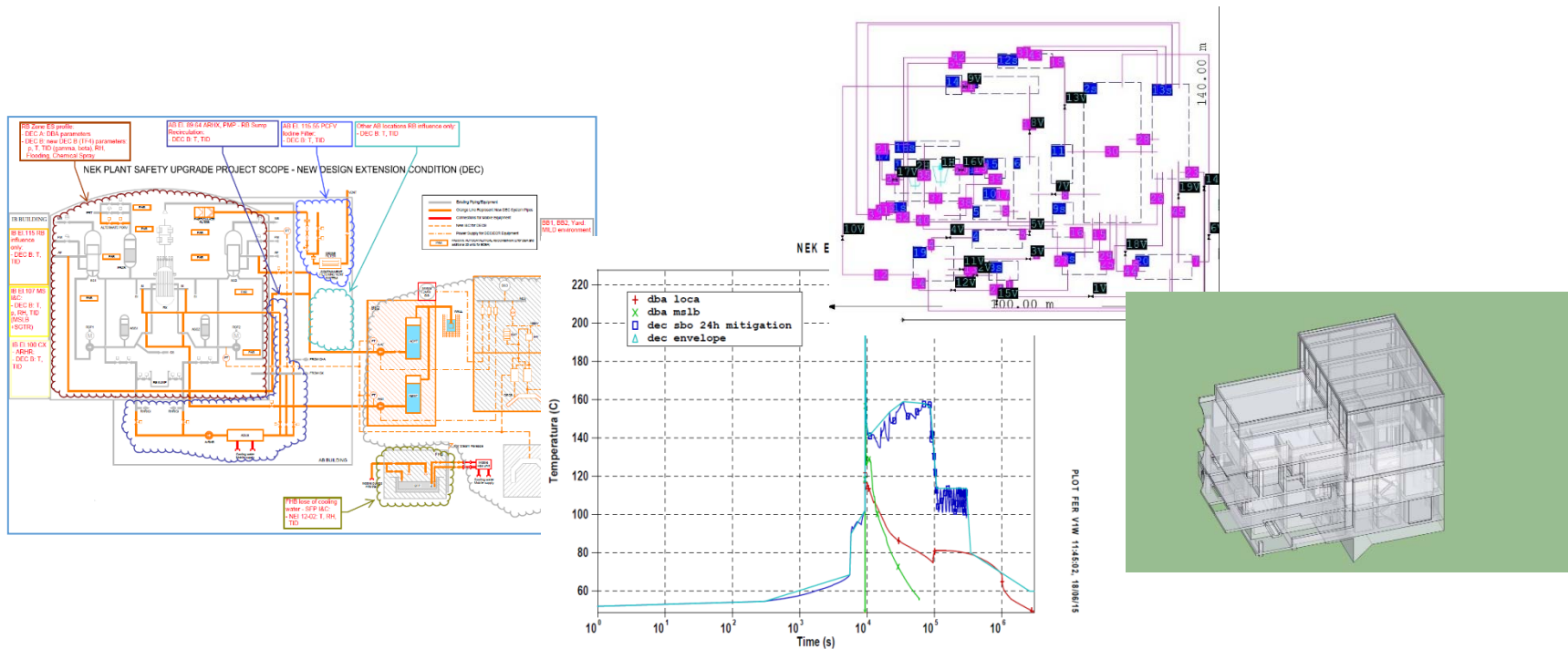
IAEA and WENRA plant states defines environmental qualification and equipment survivability → NEK Safety Upgrade Projects (SUP) requirements:

Operational States		Accident conditions	
Normal operation (NO)	Anticipated operational occurrences (AOO)	Design basis accidents (DBA)	Design extension conditions
			without significant fuel degradation



DESIGN EXTENSION CONDITIONS DEC B

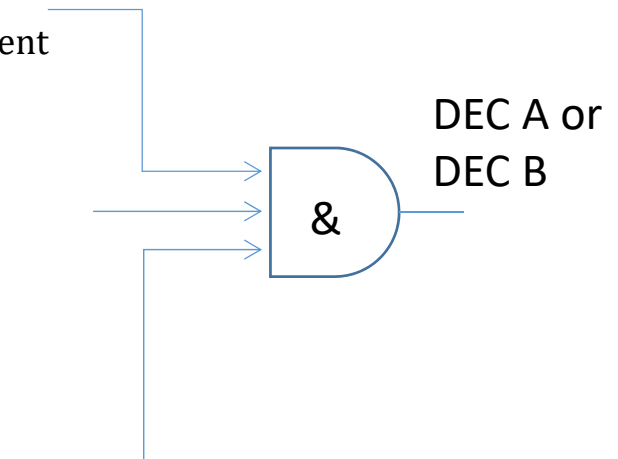
- 1) The limiting scenario is SBO sequence with PCFV, PAR actuation, mitigation actions at 24h: reactor core damage, Ex-Vessel core relocation; Accident mitigation scenario using AHX in severe accident (spray, recirculation from containment sump during ex-vessel event): conditions in AB, IB building at ARHR equipment /piping locations
- 2) SGTR: radioactive release to environment - conditions in BB1, BB2, Yard
- 3) SFP accident: scenario per Industry Guidance NEI 12-02 - conditions in FHB



Equipment Survivability Elements

Equipment Safety Function and Location Assessment DEC classification:

- Detailed safety function description - in which specific plant state equipment will be used (normal operation, abnormal operation, DBA, DEC) – If DEC than candidate for DEC classification
- Location of equipment – is equipment located in Harsh environment – If Yes than candidate for DEC classification
 - Temperature: 8,3⁰C (15⁰F) above normal/design T
 - Pressure: 10% above normal/design (10kPa – 1,47psi)
 - RH: 100%RH with condensation
 - Chemical Spray - exposure
 - Submergence – exposure
 - Radiation TID > 100Gy; > 10Gy for electronics



DEC PAOT timing is determined: 1hour, 1day, 1month, 1year

DEC Qualification standards:

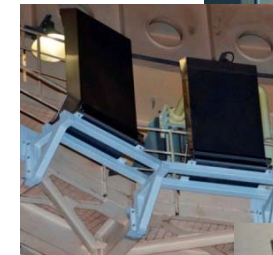
- Electrical and I&C: IEEE 323-1974 or later edition, IEEE EQ daughter standards (317, 334, 382, 383, ...)
- Mechanical: ASME QME-1, or qualification of non-metallic materials

DEC systems and qualification

Various post-Fukushima Safety Upgrade Projects under development:

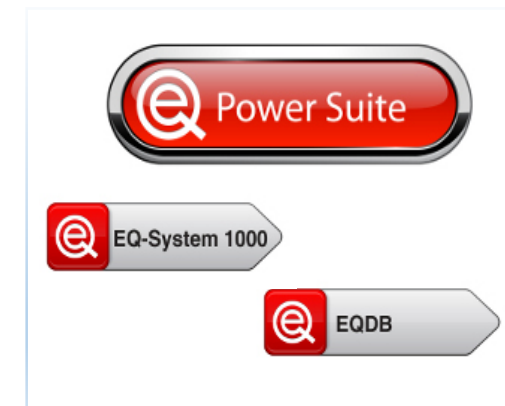
- Independent third DEC Diesel Generator additional to two 100% redundant DBA DGs – DEC B equipment
- Flood protection upgrade
- New Emergency Control Room in DEC Bunkered Building
- Passive Containment Filtering & Ventilation system (PCFV) – DEC B equipment
- Passive Autocatalytic System (PAR) – DEC B equipment
- Containment accident instrumentation - DEC A&B
- Various instruments located in systems in containment building (including new neutron flux instrumentation channels) – DEC A&B
- Independent system for the RCS pressure relief (alternate PORV) - DEC A system
- Reactor Coolant and Containment alternate cooling (ARH-ACI) system DEC A&B
- Alternate SI and AF (ASI, AAF) systems DEC A&B
- Alternate cooling of the SFP (Heat Exchangers, Spray System) – DEC A systems

Equipment Survivability (under development) performed to required level of conditions (DEC A or DEC B conditions).



Active Mechanical Equipment Qualification

- New qualification program based on:
 - EPRI EQ Reference Manual
 - EPRI NP-3877 Qualification of Active Mechanical Equipment for Nuclear Plants
 - NUREG 0800 Standard Review Plan Ch. 3.11
 - RG 1.100 Rev.3 (SEISMIC QUALIFICATION OF ELECTRICAL AND ACTIVE MECHANICAL EQUIPMENT AND FUNCTIONAL QUALIFICATION OF ACTIVE MECHANICAL EQUIPMENT FOR NUCLEAR POWER PLANTS) endorsing ASME QME-1 (Qualification of Active Mechanical Equipment Used in Nuclear Power Plants)
- MEQMEL development: DBA and DEC equipment; Safety function; PAOT; Location (Normal and Harsh environment conditions)
- Qualification assessment: Based on available qualification test reports or based on evaluation of non-metallic materials (EPRI reports and Curtiss Wright Power Suite EQ applications)
- Documentation packages (similar approach as EQ); corrective actions
- Preserving qualified status: control of maintenance, modifications and procurement processes



EMC Qualification Program

- New qualification program based on:
 - **USNRC Regulatory Guide 1.180**
 - Guidance applicable to all new safety related systems or modifications to existing safety related systems containing analog, digital or hybrid (combined) electronics equipment
 - **EPRI TR-102323**
 - Detailed technical report providing details from historical background to recommended generic EMI susceptibility and emissions test levels to be used in establishing equipment electromagnetic compatibility for nuclear power plant applications
- Provides definition of equipment under EMC scope:
 - EMC zones: high emissions (E); sensitive equipment (S) including exclusion zones
 - SR I&C equipment located in EMC zones
- Provides guidelines and practical examples for EMC-related documentation
- **Zone mapping** has been performed to **capture an emission profile of the selected area.**
- **Administrative measures** – defines exclusions area for welding, use of portable transceivers
- Implementation of **practical noise reduction design considerations**
- **Qualifications process** required and started for new equipment/systems (including SUP)



- EQ program / Plant Life Extension from 40 to 60 years (2023 to 2043)
 - Electrical Penetration Assemblies, Cables, Cable Splices and other commodities qualified life extension (Reanalysis per NUREG-1801, qualification testing for life extension)
 - Obsolete equipment – new qualifications
- To complete Equipment Survivability
- To complete MEQ program
- To complete EMC program
- PSR3???



Thank you!

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