Enclosure 6 to E-63736

Comparison of SAR among MX6 FFR series packages (Public Version)

Comparison of SAR among MX6 FFR series packages

Currently, two design approvals of MX6 FFR series packages are obtained in Japan.
Fist package is MX6 (1F6) and its certificate was issued on March 20, 2019.
Second package is MX6 (PWR) and its certificate was issued on March 11, 2021.
And, third package is MX6 (1F4&6) which is design modification from MX6 (1F6), and its certificate will be issued shortly.

The safety analysis reports of these three packages are similar because design of packaging are same and contents of them are fresh fuel as well.
On the other hand, there are differences due to difference of basket or condition of contents, and also NRA requirements or requests.

Comparing between MX6 (1F6) and MX6 (PWR), for example, additional evaluations are given to MX6 (PWR) in structural analysis and criticality analysis according to NRA requests during examination.
Therefore, these evaluations are considered and included in MX6 (1F4&6).

Comparing between MX6 (1F4&6) and MX6 (PWR) or MX6 (1F6), differences are mainly given by the following factors.
- New guideline of NRA
  Evaluation of aging of package materials is required in the new guideline (issued in Jan. 2021)
- Additional contents (1F4 fuels and fuel cans)
  1F4 fuels may contain rubble which may include nuclides of contamination.
  Fuel can is adopted to prevent dispersion of contamination inside packaging.

Specially, shielding analysis of MX6 (1F4&6) is different from others.
Because, source intensity derived from rubble is unknown. Therefore, measurement of dose equivalent rate on fuel assembly surface is performed at loading to confirm within an operational criteria.
In the shielding analysis, it is confirmed that regulatory criteria (e.g. 100 μSv/h at 1m) is always satisfied if the measured values are within the operational criteria.
It should be noted that the analysis results of MX6 (1F4&6) shows closed value to the regulatory criteria, however, this reason is that analysis is based on conservative assumption (the operational criteria). For information, according to sampling measurement of 1F4 fuels, the level of dose equivalent rate was very low.

Concerning each item of SAR, comparison among these three packages is detailed in Table-1.

Table-1 Comparison of SAR among MX6 FFR series packages (1/11)

Chapter	Section	Subsections / Items *1		Comparison of SAR (description or evaluation) *2			Remarks
				MX-6 (1F6)	MX-6P	**MX-6 (1F4&6)**	
Chapter-I Description of nuclear fuel package	I-A Purpose and conditions	5. Transport index		0.1 or less	0.2 or less	10 or less	Due to difference of shielding analysis
		12. Assumed ambient temperature		(No description)	-40°C ~ 38°C	-40°C ~ 38°C	
		13. Planned number of years for use		(No description)	(No description)	50 years	New requirement from NRA
		14. Planned number of usage of packaging		(No description)	(No description)	200 times	(Ditto)
		Table I-A.1 Specification of nuclear material containing in packaging	Weight of contents (kg)	(No description)		4150 or less	
			Weight of fuel assembly (kg)	4150 or less		3100 or less	
			Total activity (GBq)	3.10×10^{2} or less (Total major nuclides: 2.59×10^{2} or less)		1.15×10^{3} or less (Total major nuclides: 2.59×10^{2} or less)	Including activity of rubble containing nuclides of contamination
	I-B Type of package	–		Type AF		←	
	I-C Packaging	C-1 Design summary		MX6+BWR basket		←	
		C-2 Structure					
		C-3 Material					
		C-4 Dimensions					
		C-5 Weight	Weight of components	Table-I-C.4		←	
			Note 1) contents weight	Fuel assemblies + packing materials		Fuel assembly (including channel boxes) + packing materials + fuel cans	
	I-D Contents of packaging	(1) Fuel assemblies	Type	(No description)		C-lattice fuel & D-lattice fuel	1F4 includes D-lattice fuels
			Contamination	(No description)		Contamination from spent fuel pool and Contamination from rubble containing nuclides of contamination	
		(2) Fuel can		(Not used)		Fuel assembly is loaded into fuel can	Stool is not used All fuels are loaded into fuel cans
		Table I-D.1 Fuel assembly type		(No description)		C-lattice and D-lattice	
		Table I-D.2 Channel box type		(No description)		Type 1, Type 2	
		Table I-D.3 Operational criterial		(No description)		Measurement of dose equivalent rate on surface of fuel assembly	Difference on loading operation
		Table I-D.4 Fuel can specifications		(No description)		Fuel can specifications (Table-I-D.4)	
		(3) Fuel composition specifications		U235, U238 and impurities specifications		←	
		(4) Quantity of radioactive material		Specific activity		←	
				Activity		←	
	Appendix-1	Causes of contamination		Spent fuel pool water		Spent fuel pool water + rubble	
		Measurement dose equivalent rate of surface of fuel assembly		(Not applied)		Comparison with the operational criteria	
		Maximum amount of activity		[ ] [^{60}Co TBq/package]		[ ] TBq/package [^{137}Cs and other nuclides(^{63}Ni, ^{134}Cs, ^{90}Sr, ^{137m}Ba, ^{90}Y)]	Calculated based on the operational criteria

*1: Subsections or items are based on the MX-6 for 1F4&6 SAR *2: Main differences (description or evaluation) from MX-6 (1F6) or MX-6P are explained in red color

Table-1 Comparison of SAR among MX6 FFR series packages (2/11)

Chapters	Sections	Subsections / Items *1	Comparison of SAR (description or evaluation) *2			Remarks
			MX-6 (1F6)	MX-6P	**MX-6 (1F4&6)**	
Chapter-II Safety analysis of nuclear fuel package	–	1. Structural analysis	Summary of structural analysis	← (Basically same but detailed)	←	
		2. Thermal analysis	Summary of thermal analysis	← (Basically same but detailed)	←	
		3. Containment analysis	Summary of containment analysis	← (Basically same but detailed)	←	
		4. Shielding analysis	Summary of shielding analysis	← (Basically same but detailed)	←	
		5. Criticality analysis	Summary of criticality analysis	← (Basically same but detailed)	←	
		6. Consideration of aging of nuclear fuel package	(No description)	(No description)	Summary of evaluation for aging of packaging	New description
		7. Evaluation of conformity to Regulation and Notification	Summary of evaluation to Regulation and Notification	←	←	
Chapter II-A Structural analysis	A.1 Structural design	A.1.1 Summary	Summary of structural design	←	←	
		A.1.2 Design criteria	Criteria for mechanical tests	←	←	
	A.2 Weight and center of gravity	–	Weight and position of center of gravity	← (except differences due to basket and contents)	← (same as 1F6)	
	A.3 Mechanical properties of materials	–	Mechanical properties of materials (Table II-A.4)	← (except basket)	← (same as 1F6)	
	A.4 Requirements for nuclear fuel package	A.4.1 Chemical and galvanic reactions	List of contact of different materials	← (Basically same but detailed)	←	
		A.4.2 Low temperature strength	Strength at -40°C	←	←	
		A.4.3 Containment system	Structure related to openings	←	←	
		A.4.4 Lifting devices	Stress and fatigue evaluation for trunnion and handling belts	← (appendix-6 is added)	←	
		A.4.5 Tie down devices	Stress evaluation for body supported by transport frame	← (Basically same)	← (same as 1F6)	
		A.4.6 Pressure	Results of thermal test	Temperature changes during transport are considered Results of displacement of opening in lid gasket part is added *	←	* Evaluation is shown in Appendix-7
		A.4.7 Vibration	Comparison between natural frequency and vibration given by transport means	Result with consideration of load amplification is added *	←	* Evaluation is shown in Appendix-8
	A.5 Normal conditions of transport					
	A.5.1 Thermal test	A.5.1.1 Summary of temperatures and pressures	Results of B.4	←	←	
		A.5.1.2 Thermal expansion	Evaluation for clearance between body and basket	Evaluation for consideration of temperature change is added Result of clearance between fuel and body is added *	←	* Evaluation is shown in Appendix-9
		A.5.1.3 Stress calculation	Evaluation for stresses of body components and for fatigue of lid tightening bolt	Results of displacement of opening in lid gasket part is added	←	* Evaluation is shown in Appendix-10
		A.5.1.4 Comparison with allowable stress	Conclusion of A.5.1.3	←	←	
	A.5.2 Water spray	_	Explanation for surface condition of cask against water spray	←	←	

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Table-1 Comparison of SAR among MX6 FFR series packages (3/11)

Chapters	Sections	Subsections / Items *1	Comparison of SAR (description or evaluation) *2			Remarks
			MX-6 (1F6)	MX-6P	**MX-6 (1F4&6)**	
Chapter II-A Structural analysis	A.5.3 Free drop	(1) Packaging body, SAC (2) Basket (3) Fuel cladding	Evaluation for plastic strain of packaging components, deformation of SAC, stress of lid tightening bolt and plastic strain of fuel cladding	← (except differences due to basket and contents)	← (same as 1F6)	
	A.5.4 Stacking test	(1) Vertical position (2) Horizontal position	Evaluation for stresses of packaging body under stacking test on vertical and horizontal positions	← (except differences due to basket and contents for horizontal position)	← (same as 1F6)	
				Evaluation for stacking test for SAC is added. Evaluation for displacement of opening in lid gasket part is added (appendix-11 is added)	←	
	A.5.5 Penetration	–	Evaluation for no penetration against external plate	Evaluation for no penetration against outer plate of SAC is added (appendix-12 is added)	←	
	A.5.6 Corner or edge drop	–	Not applicable	←	←	
	A.5.7 Summary of results and evaluation	(1) Thermal test	Conclusion of evaluation for stress and clearance	Conclusion of evaluation for displacement of opening in lid gasket part is added	←	
		(2) Water spray	Conclusion of water spray	←	←	
		(3) Free drop	Conclusion of evaluation for plastic strain and stress	Conclusion of evaluation for displacement of opening in lid gasket part is added	←	
		(4) Stacking test	Conclusion of evaluation for stress	Conclusion of evaluations for SAC outer plate and displacement of opening in lid gasket part is added	←	
		(5) Penetration	Conclusion of evaluation for external plate	Conclusion of evaluations for SAC outer plate is added	←	
	A.6 Accident condition of transport	–	Not applicable	←	←	
	A.7 Enhanced water immersion test	–	Not applicable	←	←	
	A.8 Radioactive contents	–	Conclusion of evaluation for fuel cladding in A.9 Package containing fissile material	←	←	
	A.9 Package containing fissile material	–	Purpose of this section is to evaluate damage condition assumed in criticality analysis	Purpose of this section is to evaluate change of shapes affecting criticality analysis	←	
	A.9.1 NCT for package containing fissile material	–	Summary of A.5.2 to A.5.5	← (slightly changed) *	←	* Conclusion is slightly changed (descriptions of influence to criticality analysis condition are moved to II-E)
	A.9.2 ACT for package containing fissile material	(1) 9m drop test	Evaluation for plastic strain of packaging components, deformation of SAC, stress of lid tightening bolt and plastic strain of fuel cladding	← (except differences due to basket and contents) *	← (same as 1F6) *	(Ditto)
		(2) 1m drop test	Evaluation for deformation of lid part, bottom part and shell part by mock-up test Evaluation for plastic strain of basket under horizontal drop by analysis	← (except differences due to basket) *	← (same as 1F6) *	(Ditto)

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Table-1 Comparison of SAR among MX6 FFR series packages (4/11)

Chapters	Sections	Subsections / Items *1	Comparison of SAR (description or evaluation) *2			Remarks
			MX-6 (1F6)	MX-6P	**MX-6 (1F4&6)**	
Chapter II-A Structural analysis		(3) Thermal test (fire test)	Evaluation for plastic strain of packaging components and stress of lid tightening bolt Evaluation for clearance between body and basket due to thermal expansion Evaluation for stress of fuel cladding due to internal pressure	← (except differences due to basket and contents) *	← (same as 1F6) *	* Conclusion is slightly changed (descriptions of influence to criticality analysis condition are moved to II-E)
		(4) 0.9 m water immersion test	Not applicable	←	←	
	A.10 Appendix	A.10.1 Appendix-1 Design fatigue strength curves	Design fatigue strength curves of austenitic stainless steel and high strength bolt	←	←	
		A.10.2 Appendix-2 1/2 scale model drop test verification analysis	Comparison between drop tests and verification analyses Confirmation of applicability of the analysis conditions	←	←	
		A.10.3 Appendix-3 1/3 scale cut model drop test verification analysis	(Ditto)	←	←	
		A.10.4 Appendix-4 Strength of packaging body subjected to 15m water immersion test	Evaluation for stress of packaging body against external pressure on 15m water immersion test	←	←	
		A.10.5 Appendix-5 Strength of rear trunnions under horizontal lifting operation	Evaluation for stress of trunnions under horizontal lifting operation	←	←	
		A.10.6 Appendix-6 Strength of packaging body against lifting operation	(Not included)	Evaluation for stress of packaging body components under lifting operation	← (except differences due to basket) *	* Slightly different in case of horizontal lifting
		A.10.7 Appendix-7 Strength of packaging body against pressure/temperature changes	(Not included)	Evaluation for stress of packaging body and displacement of opening in lid gasket part due to pressure/temperature changes	←	
		A.10.8 Appendix-8 Effect of load amplification due to vibration during transport	(Not included)	Calculation of load amplification Evaluation for stress of lid and bottom during transport considering the load amplification	←	
		A.10.9 Appendix-9 Evaluation of thermal expansion in case of -40°C or 70°C reference	(Not included)	Evaluation for clearance between body and basket, between contents and packaging considering reference temperatures of -40°C or 70°C	← (except differences due to fuel can) *	* Clearance between fuel can and body, between fuel and fuel can are considered.
		A.10.10 Appendix-10 Displacement of opening during thermal test or free drop under NCT	(Not included)	Evaluation for displacement of opening in lid gasket part at thermal test and free drop under NTC	← (except differences due to basket) *	* Slightly different of free drop results due to different basket
		A.10.11 Appendix-11 Deformation and opening in shock absorbing covers during stacking test	(Not included)	Evaluation for deformation of SAC in case that load of stacking test is given to SACs. Evaluation for displacement of opening in lid gasket part	←	

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Table-1 Comparison of SAR among MX6 FFR series packages (5/11)

Chapters	Sections	Subsections / Items *1	Comparison of SAR (description or evaluation) *2			Remarks
			MX-6 (1F6)	MX-6P	**MX-6 (1F4&6)**	
Chapter II-A Structural analysis		A.10.12 Appendix-12 Evaluation for penetration to outer plate of shock absorbing cover	(Not included)	Evaluation for penetration to outer plate of SAC	←	
		A.10.13 Appendix-13 Fatigue evaluation on internal pressure change during transport	(Not included)	(Not included)	Evaluation for fatigue strength of packaging body components due to internal pressure change during transport	New evaluation
		A.10.14 Appendix-14 Selection of inclined angle for slap-down drop	(Not included)	(Not included)	Explanation for reason of selection of inclined angle applied to slap-down drop in A.9.2	New evaluation

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Chapters	Sections	Subsections / Items *1	Comparison of SAR (description or evaluation) *2			Remarks
			MX-6 (1F6)	MX-6P	**MX-6 (1F4&6)**	
Chapter II-B Thermal analysis	B.1 Summary	Thermal design features	Packaging design for heat transfer and counter measures for fire test	←	←	
		Table II-B.1 Analysis conditions and methods	Heat generation, ambient temperature, solar insolation, ambient emissivity and analysis code	←	←	
	B.2 Thermal properties of materials	–	Physical properties of materials (Table II-B.2)	← (except basket)	← (same as 1F6)	
	B.3 Technical specification of components	(1) Vinyl-ester resin (2) EPDM	Service temperature range	←	←	
	B.4 Normal condition of transport	–	Consideration for solar insolation	←	←	
	B.4.1 Thermal analysis model	–	Heat supply and heat dissipation	←	←	
		B.4.1.1 Analysis model	Shape of model Thermal condition (Table II-B.3)	←	←	
		B.4.1.2 Test model	Not applicable	←	←	
	B.4.2 Maximum temperature	–	Calculation of temperature of package surface by formula	←	←	
	B.4.3 Minimum temperature	–	Minimum temperature Embrittlement for packaging materials at the minimum temperature	←	←	
	B.4.4 Maximum internal pressure	–	Calculation of internal pressure considering saturated vapor pressure	←	←	
	B.4.5 Maximum thermal stresses	–	Result of thermal test	←	←	
	B.4.6 Summary of results and evaluation	–	Summary of B.4.2 to B.4.5	←	←	

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Table-1 Comparison of SAR among MX6 FFR series packages (6/11)

Chapters	Sections	Subsections / Items *1	Comparison of SAR (description or evaluation) *2			Remarks
			MX-6 (1F6)	MX-6P	**MX-6 (1F4&6)**	
Chapter II-B Thermal analysis	B.5 Accident condition of transport	–	Analysis code	←	←	
	B.5.1 Thermal analysis model	–				
		.5.1.1 Analysis model	Shapes and dimensions of analysis models and thermal conditions	← (except basket)	← (same as 1F6)	
		5.1.2 Test model	Not applicable	←	←	
	B.5.2 Evaluation conditions of nuclear fuel package	(1) Damage condition of package	Summary of deformation at 9m drop and 1m drop	← (except differences due to basket)	← (same as 1F6)	
		(2) Impact on thermal performance	Consideration of damages on thermal analysis	←	←	
	B.5.3 Temperature of nuclear fuel package	–	Maximum temperature of each part (Table II-B.5)	← (except differences due to basket)	← (same as 1F6)	
	B.5.4 Maximum internal pressure	–	Calculation of internal pressure considering saturated vapor pressure	← (except differences due to basket)	← (same as 1F6)	
	B.5.5 Maximum thermal stresses	–	Result of thermal test	← (except differences due to basket)	← (same as 1F6)	
	B.4.6 Summary of results and evaluation	–	Summary of B.5.3 to B.5.5	← (except differences due to basket)	← (same as 1F6)	

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Chapters	Sections	Subsections / Items *1	Comparison of SAR (description or evaluation) *2			Remarks
			MX-6 (1F6)	MX-6P	**MX-6 (1F4&6)**	
Chapter II-C Containment analysis	C.1 Summary		Leaktightness of package	←	←	
	C.2 Containment system	C.2.1 Containment system	Components consisting of containment system and summary of II-A and II-B	←	←	
		C.2.2 Penetrations of containment system	Parts of penetration and referred figures	←	←	
		C.2.3 Gaskets and welds of containment system	Temperature condition and maintenance for gaskets	←	←	
		C.2.3.1 Gasket				
		C.2.3.2 Welding area	Inspections applied to welds	←	←	
		C.2.4 Lid	Structure and integrity of lid part components	←	← (a description * is added)	* Summary of the results for displacement of opening in lid gasket part
	C.3 Normal condition of transport	–	Conclusion of containment performance under normal condition of transport	←	← (a description * is added)	(Ditto)
		C.3.1 Leakage of radioactive material	Conclusion of NTC	←	←	
		C.3.2 Pressurization of containment system	Maximum internal pressure and its impact	←	← (a description * is added)	(Ditto)
		C.3.3 Contamination of coolant	Not applicable	←	←	
		C.3.4 Loss of coolant	(Ditto)	←	←	
	C.4 Accident conditions of transport	–	(Ditto)	←	←	
	C.5 Summary of results and evaluation	–	Refer to C.2 and C.3 and conclusion for compliance to the Regulation	←	←	

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Table-1 Comparison of SAR among MX6 FFR series packages (7/11)

Chapters	Sections	Subsections / Items *1	Comparison of SAR (description or evaluation) *2			Remarks
			MX-6 (1F6)	MX-6P	**MX-6 (1F4&6)**	
Chapter II-D Shielding analysis	D.1 Summary	–	Assumption for surface contamination Main shielding parts	←	Followings are added Consideration of contamination due to rubble Operational criteria applied to measurement of dose equivalent rate on surface of fuel assembly	
	D.2 Source specification	(1) Source derived from fuel composition	Fuel composition and source analysis specification (Table II-D.1)		←	
		(2) Surface contamination with pool water	Radioactive materials contained in poot water	←	(No description)	
		(2) Sources derived from fuel assembly surface contamination	(No description)	←	Nuclides of contamination contained in rubble Refer to Appendix-1	New description
	D.2.1 Gamma sources	(1) Source derived from fuel composition	Gamma source intensity related to fuel composition (Table II-D.2)		←	
		(2) Surface contamination with pool water	Assumption of activity in pool water and amount of pool water on assembly	← (except differences due to fuel assembly)	(No description)	
		(2) Sources derived from fuel assembly surface contamination	(No description)	←	Nuclides of contamination contained in rubble Source intensity based on the operational criteria	New description
	D.2.2 Neutron sources	–	Negligible	←	←	
	D.3 Model specification	D.3.1 Analysis model	Analysis model (Figure II-D.1 and D.2)		←	
			Modeling for components of packaging and fuel assembly		Following is added No consideration of fuel cans and channel boxes for shielding parts	
		D.3.2 Atomic number density in each region of analysis model	Atomic number density (Table II-D.4)		←	
	D.4 Shielding evaluation	(1) Shielding evaluation method (2) Calculation results	Analysis code Calculation results (Table II-D.5)	← (except value of dose equivalent rate in Table II-D.5)	←	
	D.5 Summary of results and evaluation	–	Conclusion of analysis Summary of results (Table II-D.6)	← (except value of dose equivalent rate in Table II-D-6)	←	
	D.6 Appendix	D.6.1 Appendix-1 Surface contamination of fuel assembly	(Not included)	(Not included)	Detail information and study concerning contamination of fuel assembly from rubble and pool water	New evaluation
		D.6.2 Appendix-2 Setting of source intensity for surface contamination of fuel assembly	(Not included)	(Not included)	Setting of source intensity by contamination and the operational criteria based on shielding calculation of a fuel assembly	New evaluation
		D.6.3 Appendix-3 Amounts of activity of nuclides of contamination per packaging	(Not included)	(Not included)	Maximum possible activity contained in package due to contamination and comparison with A_2 values	New evaluation
		D.6.4 Appendix-4 Conservativeness of shielding analysis model	(Not included)	(Not included)	Evaluation for conservativeness of analysis model of package	New evaluation

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Table-1 Comparison of SAR among MX6 FFR series packages (8/11)

Chapters	Sections	Subsections / Items *1	Comparison of SAR (description or evaluation) *2			Remarks
			MX-6 (1F6)	MX-6P	**MX-6 (1F4&6)**	
Chapter II-E Criticality analysis	E.1 Summary	–	Analysis code, Summary of damage conditions and modeling and analysis conditions, Conclusion	← (Basically same but simplified)	←	
	E.2 Analysis items	E.2.1 Contents	Major specification of fuel assembly (Table II-E.2) Assumption of modeling of fuel assembly		←	
		E.2.2 Packaging	Damage conditions of packaging	← (Appendix-1 for damages assumed in analyses is added)	←	
		E.2.3 Neutron poison	^{10}B content of stainless steel of basket material	←	←	
	E.3 Model specification	E.3.1 Analysis model	Shape of analysis model Components consisting of model Assumptions on modeling	← (except difference due to basket, Appendix-1 for damages assumed in analyses is added)	← [compare with 1F6] (Appendix-1 for damages assumed in analyses is added. Analysis model for D-lattice fuel is added)	
		E.3.2 Atomic number density in each region of analysis model	Atomic number density (Table II-E.3)	← (except difference due to basket and fuel assembly)	← (same as 1F6)	
	E.4 Subcriticality evaluation	E.4.1 Calculation conditions (1) Contents	Modeling for fuel rod pitch	←	← [compare with 1F6] (Both of C-lattice and D-lattice are considered)	
		(2) Packaging	Assumption for axial length and components ignored	←	←	
		(3) Neutron poison	Consumption of ^{10}B	←	← *	* Evaluation for consumption of ^{10}B is shown in Chapter II-F Appendix-3
		E.4.2 Leakage of water into nuclear fuel package	Assumption for leakage of water into package and boundary condition of outside of package	← (slightly different)	← [compare with 1F6] (Assumption for fuel can and packing materials is added) *	* Comparison between with and without packing materials is shown in Appendix-7
		E.4.3 Calculation method	System of analysis code applied (SCALE version 6.1)	← (except SCALE version (6.2.3))	← (same as 1F6)	
		E.4.4 Calculation results	Effective multiplication factors	← (value is different)	← [compare with 1F6] (value for D-lattice is added)	
	E.5 Bench mark test	–	Summary and conditions and results of bench mark test	← (except results due to SCALE version)	← (same as 1F6)	
	E.6 Summary of results and evaluation	–	Required conditions and conclusion	←	←	
	E.7 Appendix	E.7.1 Appendix-1 Damaged condition of packages and modeling for criticality analysis	(Not included)	Details of damaged condition of package and modeling and complementary explanation	← (except differences due to different package)	
		E.7.2 Appendix-2 Evaluation of effect of fuel rod pitch	(Appendix-3) Parameter calculation for fuel rod pitch	(Appendix-4) ← (except conditions and results due to different package)	← [compare with 1F6] (value for D-lattice is added)	Number of Appendix is different among 3 packages (the same hereinafter)
		E.7.3 Appendix-3 Evaluation of effect of water density in space inside/outside packaging	(Appendix-1) Parameter calculation for water density in space inside/outside packaging	(Appendix-2) ← (except conditions and results due to different package)	← [compare with 1F6] (model of D-lattice is used)	Model of D-lattice is used as representative. (the same hereinafter)

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Table-1 Comparison of SAR among MX6 FFR series packages (9/11)

Chapters	Sections	Subsections / Items *1	Comparison of SAR (description or evaluation) *2			Remarks
			MX-6 (1F6)	MX-6P	**MX-6 (1F4&6)**	
Chapter II-E Criticality analysis		E.7.4 Appendix-4 Effective multiplication factor with deformation of inner shell and aluminum spacer taken into account	(Not included)	(Appendix-5) Calculations by models considering deformations of inner shell and aluminum spacer due to 1m drop	← (except differences due to different package)	
		E.7.5 Appendix-5 Effective multiplication factor with inner shell expansion taken into account	(Appendix-2) Calculation by model considering deformation of inner shell with expansion of diameter	(Appendix-3) ← (except conditions and results due to different package)	← [compare with 1F6] (model of D-lattice is used)	
		E.7.6 Appendix-6 Consideration for additional shielding and tie rod in analysis model	(Not included)	(Not included)	Comparison calculation between with and without additional shielding and tie rod	New evaluation
		E.7.7 Appendix-7 Effect of packing materials on effective multiplication factor	(Not included)	(Appendix-6) Parameter calculation for packing material density	← (except differences due to different package)	

*1: Subsections or items are based on the MX-6 for 1F4&6 SAR *2: Main differences (description or evaluation) from MX-6 (1F6) or MX-6P are explained in red color

Chapters	Sections	Subsections / Items *1	Comparison of SAR (description or evaluation) *2		Remarks
			MX-6 (1F6) / MX-6P	**MX-6 (1F4&6)**	
Chapter II-F Consideration of aging of nuclear fuel package	F.1 Factors of aging to be considered	–	(Not included)	Condition of use Factors of aging to be considered Assuming duration of use and temperature and number of cyclic load	New chapter required by NRA guideline (Feb. 2020)
	F.2 Evaluation for necessity of consideration of aging on safety analysis	–	(Not included)	Materials to be evaluated Evaluation for necessary of consideration of aging	
	F.3 Considerations of aging on safety analysis	–	(Not included)	Conclusion of evaluation for necessary of consideration of aging	
	F.4 Appendix	F.4.1 Appendix-1 Neutron irradiation and loss ratio of boron	(Not included)	Calculation of neutron irradiation and loss ratio of ^{10}B in resin or borated stainless steel	
		F.4.2 Appendix-2 Weight loss of resin	(Not included)	Calculation of weight loss of resin against period of use	
		F.4.3 Appendix-3 Strength degradation of aluminum alloys	(Not included)	Calculation of strength degradation of aluminum alloys against period of use	
		F.4.4 Appendix-4 Fatigue strength of fuel can against variation of internal-external pressure difference during transport	(Not included)	Calculation of fatigue strength of fuel can against variation of internal-external pressure difference during transport	

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Table-1 Comparison of SAR among MX6 FFR series packages (10/11)

Chapters	Sections	Subsections / Items *1	Comparison of SAR (description or evaluation) *2			Remarks *2
			MX-6 (1F6)	MX-6P	**MX-6 (1F4&6)**	
Chapter II-G Evaluation of compliance to the Ordinance and the Notification	–	Table II-G.1 Evaluation of compliance with the technical standards of the Ordinance and the Notification	Results of each analysis are summarized in a concise manner	Not only results but also outline of contents (condition and method) of each analysis are summarized	Summary of evaluation of Chapter II-F (Consideration of aging of nuclear fuel package) is added	According to NRA instruction, explanations of analyses are described in more detail than before.

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Chapters	Sections	Subsections / Items *1	Comparison of SAR (description or evaluation) *2		Remarks
			MX-6 (1F6) / MX-6P	**MX-6 (1F4&6)**	
Chapter III Maintenance of packaging and handling procedure of nuclear fuel package	III-A Handling procedure of nuclear fuel package A.1 Loading operation	(1) Preparation of the packaging and preliminary work	Sequence of operations on; - Fuel assembly - Lifting devices - Packaging	← (operation for fuel assembly is not included)	
		(2) Preparation of the contents and inspection	(Not included)	Sequence of operations on; - Fuel assembly	Operations for fuel assembly are separated.
		(3) Fuel loading operation	Sequence of operations on; - Packaging - Fuel assembly	← (operations for fuel can and fuel assembly are added)	
		(4) Installation of shock absorbing covers	Sequence of operations on; - Shock absorbing covers	←	
	A.2 Inspection before shipment	1. Visual inspection	Content of visual inspection	←	
		2. Dose rate inspection	Content of dose rate inspection	←	
		3. Subcriticality inspection	Content of subcriticality inspection	←	
		4. Lifting inspection	Content of lifting inspection	←	
		5. Weight inspection	Content of weight inspection	←	
		6. Contents inspection	Content of contents inspection	← (operations for fuel assembly are added)	
		7. Surface contamination inspection	Measurement of contamination of package	←	
	A3 Unloading method	(1) Preparation	Sequence of operations on; - Lifting devices - Packaging	←	
		(2) Fuel unloading	Sequence of operations on; - Packaging - Fuel assembly	← (operations for fuel can are added)	
	A.4 Preparation of empty packaging		Operations for checking integrity of packaging	← (operations for fusible plug, pressure regulation valve and bolts are added)	

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Table-1 Comparison of SAR among MX6 FFR series packages (11/11)

Chapters	Sections	Subsections / Items *1	Comparison of SAR (description or evaluation) *2		Remarks
			MX-6 (1F6) / MX-6P	**MX-6 (1F4&6)**	
Chapter III Maintenance of packaging and handling procedure of nuclear fuel package	III-B Maintenance conditions		Interval and contents of periodical inspections	←	
		B.1 Visual inspection	Content of visual inspection	←	
		B.2 Pressurized inspection	Content of pressurized inspection	←	
		B.3 Leak tightness inspection	Content of leak tightness inspection	←	
		B.4 Shielding inspection	Content of shielding inspection	←	
		B.5 Subcriticality inspection	Content of subcriticality inspection	←	
		B.6 Thermal test	(Not applicable)	←	
		B.7 Lifting inspection	Content of lifting inspection	←	
		B.8 Workability inspection	(Not applicable)	←	
		B.9 Maintenance of subsystem	(Not applicable)	←	
		B.10 Maintenance of valve and gasket of containment system	Content of maintenance of baskets	←	
		B.11 Storage of packaging	Content of storage of packaging	←	
		B.12 Storage of record	Content of storage of record	←	
		B.13 Miscellaneous	(Not applicable)	←	

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