Summary of major responses to the RFI (classified into items and categories) [Topic 1 : Accumulation of contaminated water]

Particularly-Requested Technologies for Contaminated Water Issues		Responses to the RFI			Trends of technical information in the responses	Expert Review Panel's comments
Items	Sub items	Categories	No.	key words		
(1) Requirements for the welded-type tanks	To accelerate the replacement of tanks, the term for delivery of parts and construction of each tank needs to be shortened compared to the current situation	Built in factory	558, 586, 620	Factory-built and installation-at-once large steel tank	Requirements for welded tanks are as follows. - The delivery of parts and construction of each tank need to be accelerated, - Leak prevention can be assured for more than 10 years without any need to inspect the inside and/or repair the tanks, - The tanks need to be effectively stored, - The tanks need to have seismic resistance (more than 0.36 G) and be able to contain water without leakage, - The tanks should be able to shield Bremsstrahlung X-rays which are produced inside the tanks, Factory built and installed at once on site, double shelled large steel tanks are proposed which satisfies all of these requirements. Also, many ideas are proposed for each requirement, and there is a room for discussion on the solution that combines these proposals. As for the acceleration of delivery, there is a proposal of steel tanks factory built & installed at once on site, and also of securing the supply chain from design to installation. As for the leak prevention assumable more than 10 years without any need to inspect the inside and/or repair the tanks, there are many proposals on coating inside the tanks with resins like epoxy, polyethylene or rubber. Also, there is a proposal of a method achieving the durability with titan lining on pre-casted concrete products. Corrosion proof by galvanic protection is also proposed. Moreover, technologies on maintenance of tanks, and leak prevention from connected pipes are presented. As proposals on effective storage, they are divided into an on-site-built concept and a factory-built concept. A water reservoir of 30,000t, the maximum capacity for the on-site-built, and a steel tank with a capacity of 2,000t for factory-built are proposed. As for the seismic resistance (more than 0.36 G), and the ability to contain water without leakage, an advice to cut-off the rigid pipe connection between tanks is suggested. A method of providing a deformation adaption function to the tank member joint is proposed. Methods of seismic isolation or damping of tanks are also proposed. As for the shielding of Bremsstrahlung X-rays, many ideas placed expectations on shielding X rays by tank body or installation of shielding materials. Inhibiting Bremsstrahlung X-rays itself by polymer material is also presented.	Many proposals are well considered and feasible. Double-shelled large steel tank seems to be a proposal which satisfies all technical specifications immediately. Resin liners for leak prevention need to be examined for their radiation-proof properties. As for the reduction of Bremsstrahlung X-rays by polymer materials, it will be better to research on its feasibility, and also to take it into account for the tank design. It should be kept in mind that enlargement of tanks will increase the storage efficiency, but on the other hand, it will also increase the risk in case of accident. Doubling the current capacity of the tank (2x1,000ton) seems to be allowable. There may be no problem on design and building of large tank itself. As for seismic resistance, making the connection of tanks flexible has been pointed out. Considering the risk of disasters by earthquakes, etc., this is an issue to be dealt with early by selecting any of the methods proposed. In the area of petroleum storage management, it is said that 10% of tanks are always kept empty and make them available for maintenance. As for the targeted tanks, however, contaminated water should not be replaced frequently, that said, this kind of know-how should be considered as a sort of technology. The operation of this kind is performed at foreign nuclear power facilities, and there should be related know-how in oil refineries or chemical plants.
	Proof against leakage can be assured for more than 10 years without any need to inspect the inside and/or repair the tanks	Lining	36	Titan sheet		
			86, 100, 286, 771	Epoxy liner		
			94	Low density polyethylene (LDPE) liner		
			136	No form 2		
			152	Plastic protection coating		
			176, 216	FRP liner		
			206	Leak prevention with impermeable sheet or air-borne resin inside tanks		
			219	Radiation-proof coating, High performance fiber		
			280	Lining with rubber suck		
			397	Radiation proof coating, Air-borne shielding material		
			433	Waterproofing work for the inside of tanks containing water		
			664	Installing a bag structure inside tanks		
		Corrosion prevention	373	Increase in longevity by galvanic protection		
		Double hull tank	102	Installing impermeable and radio-shielding material between the skins of double-hull tank		
			219, 558, 620	Double-hull		
		Maintenance of steel tank	400	Remote inspection, Steel thickness		
		Reinforcement of tank	174	Carbon fiber sheet wrapping		
		Leak prevention from joint pipe	603, 665	Backup, Connection pipes		
			687, 688	Retrofitting technology, Pipe connecting part		
	The tanks need to be effectively stored inside the limited site area. (Standard: cylindrical steel tanks with a volume of 1000 tons)	Enlargement of tank	58	Stainless distributing reservoir product of 10000 to 30000 t		
			147, 551	Tank made of large-diameter steel pipe		
			328	On-site build up of 9000t tank		
			334	1000t tank (stainless or glass fiber)		
			443	Oil tank		
			558	1000t steel tank built in factory		
			586	1500t steel tank built in factory		
			587	On-site-build of 5000t tank		
			620	2000t steel tank built in factory		
	The tanks need to be able to withstand considerable earthquakes (more than 0.36 G) and be able to contain water without leakage	Quake resistance of tank member	58, 72	Functional joint		
			152	Plastic protection coating		
			620	Double-hull steel tank		
		Isolation or damping	174	Seismic isolation of tank		
			361	Sloshing control device		
			692	viscoelastic damper		
		Others	28	Cutting off rigid pipe connection between tanks		
			669	seismic design		
	If possible, the tanks should be able to shield Bremsstrahlung X-rays which are produced inside the tanks	Shielding of Bremsstrahlung X-rays	36	Titan sheet		
			219	Installing lead between the skins of double-hull steel structure		
			549	No form 2		
			586	Shielding design		
			620	Double-hull		
		Reduction of Bremsstrahlung X-	274	Submerged Flexible Tanks, Epoxy coating		
		Others	698	Evaluation system		

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Particularly-Requested Technologies for Contaminated Water Issues: Items	Sub items	Responses to the RFI: Categories	No.	key words	Trends of technical information in the responses	Expert Review Panel's comments
(2) Other requirements for tanks	Long-term and stable storing of large amount of contaminated water	Storage on the ocean	13, 197, 273, 335, 395, 432, 457, 517	Crude oil carrier, Mega-float, etc.	As for long-term and stable accumulation of large amount of contaminated water, there are many proposals on storage of contaminated water in the ocean. Many proposals suggest utilization of tanker or mega-float, and some discuss various studies and suggestions from the experience of offshore petroleum storage, for example, utilization of tanker or container carrier, transshipment at intermediate port, and so on. As for storage in the harbor surrounded by a dyke, methods of storage in a floating body in the harbor, or storage directly in the harbor with water shielding materials installed inside it are proposed. As for underground tanks, a method of constructing a large underground tank in a short period of time, and an idea of utilizing a tanker as an underground tank are proposed. Many subsurface water reservoirs are proposed, and most of them are combination of bentonite barrier and impermeable liner. As for above-ground tanks, pre-stressed concrete tanks and large steel tanks usually employed for petroleum storage are proposed based on the past experience. An application of new materials for concrete tanks is proposed. Methods of using a number of small containers, and a method of stacking up relatively small tanks are also proposed. As for the method to cope with land subsidence, methods of foundation improvement, and an idea of adopting deformable joints between tank members are proposed. A lot of beneficial proposals are provided from Japan Society of Civil Engineering and Japanese Geotechnical Society, on the method of improvement of subsurface reservoir, improvement of foundation of tanks, including the item (1); Requirements for the welded tanks.	For the in-the-ocean storage of contaminated water, it is required that risks at the time of leak are considered. Even from the international point of view, there may not be any precedents, and will be difficult in technical reliability and reaching agreement with local stakeholders. In this point of view, floating storage in the harbor surrounded by embankments may be more feasible, but needs to consider countermeasures for Tsunami. Corrosion by chloride in seawater will be a problem for the in-the-ocean storage. It should be noted that underground tanks may take long in construction. Also, detection method of leak from underground must be considered. Considering that the accumulation of contaminated water is a very important issue at the site, it may be a good idea to keep the existing subsurface reservoir as a possibility up our sleeve. This type of reservoir had a leak accident in April 2013, but by increasing the thickness of the clay liner, the performance of water-tightness will greatly improve, and could be positioned as an emergency measure in case tanks have any defect in the future. It may be possible to compact a large amount of water by evaporation. In that case, we need to pay attention to the release of radionuclides such as tritium, and the concentration of nuclides and salt. In this time of RFI, ideas on in-the-ocean storage, underground large tanks, above-ground large tanks and subsurface reservoirs with clay barrier are proposed based on experiences of actual projects in the past. Hereafter, on examining the feasibility of these ideas, we need to investigate if it is possible to cope with the issues considering the risks like site conditions, priority, time constraint, and so on. At that time, it is important to think about the options to make against unexpected increase of contaminated water. As for land subsidence, design with accurate ground information seems to be important.
			39	Study of on the ocean storage based on petroleum stockpiling project		
			493	Study on cost and delivery of on the ocean storage in comparison with aboveground tanks		
			503	Steel cube		
			555	Harbor storage by mega-float		
		Storage in the harbor	421	Flexible container		
			550	Moat		
			668	Storage of contaminated water directly in the harbor surrounded by storm surge barriers with impermeable structures installed		
			697	Contaminated water tank, Processing plant , Processed water tank, Floating facility		
		Underground tank and storage	192	Utilization of underground ducts		
			367	Deep underground		
			557	Embedded tank using a crude oil carrier		
			574	High-speed construction of 0.5million t underground tank		
		Subsurface reservoir in trench shape	103, 382, 478, 554, 647, 666, 667, 702	Modification of structure and materials, General advice, Utilization		
		Aboveground tank (Such as Concrete tank)	36, 71, 146, 360, 565, 691, 699	Concrete tank		
			217	Storage in large-diameter long hoses		
			454	Aramid fiber, Reinforcement		
			619	On-site assembly		
			663	Leak back-up		
		Use of small tank	54, 106	Plastic tank		
			223	Three-dimensional stationary of small stack tank		
			257, 371, 719	Flexible bag		
			502, 651	Drink can technology		
	Techniques coping with the land subsidence		58	Functional joint		
			578	Foundation improvement by grouting		
(3) Technologies for detection of minor leaks	Improvement in the detection ability of beta rays on patrol	β detection under high-γ environment	83	Flexible shielding material	A method of β-rays monitoring by shielding γ-rays with flexible shielding material is proposed. Many detection methods of β-rays are proposed. However, most of them are under development. A method with thin plastic scintillator is also on the research stage, but a proposal states that it is near to practical utilization. There is a proposal of on realizes β-ray measurement by existing probes with a certain usage. As for weight reduction of measuring equipment, proposals on improvement of shielding material and probes are provided. Improvement of probes is on the research stage. As for visual detection of leaks of contaminated water, application of existing dye products is proposed. These products are for foods or medical use, and they are harmless to human body, but the impact on decontamination, the way of discoloring, and the effect on environment are issues to be solved hereafter. A method of detection utilizing the property that organic dyes are dissolved by β-rays is under study.	As the site is in severe condition in terms of radiation dose and the weather, precise work is difficult. Considering that 95% of errors in monitoring is generally caused at the time of sampling, simplifying the on-site work is important. In case we detect the leak by β-ray monitoring, the work shall be done very close to the tanks. On the other hand, in case we detect the leak by dyes, the work can be done at a certain distance away from the tanks. Therefore, there is a benefit in terms of reducing radiation exposure. A foreign organization has already developed a handy-type β monitor. The possibility of plastic scintillator in practical use seems high. We should confirm the manufacturers about their state of application to investigate their applicability to Fukushima site. As for the leak detection of beta nuclide, it may be feasible to count the scintillation of the smear sample in liquid scintillation vial. We deem it an effective method. Along with β-ray monitor and plastic scintillator, all these methods should be investigated including the efficiency in the actual operation. It may be feasible to detect the β-rays, not to measure, by utilizing the difference in material permeability between β-rays and γ-rays, for example, attaching some filter on the existing survey meter. As organic dyes will be dissolved by β-rays, it is necessary to assess the dose of the site, and select adequate dye usable in that condition. On the other hand, it may be feasible to detect minor leak of contaminated water utilizing this phenomenon. For the method with additives into contaminated water, the impact on water processing must be considered.
			304	Non-destructive remote monitoring		
			320, 622, 725	Plastic scintillator sheet		
			376, 485	Improvement of the probe		
			472	Gas flow type survey meter		
			559	Pre-enrichment process, Adsorbent		
			621	β surface monitor, Shield using narrow window		
			623	Online water monitoring, Sr90 monitoring		
		Weight reduction of the monitoring equipment	83	Flexible shielding material		
			472	Gas-flow-type survey meter		
			485	Modification of probe		
	Improvement in visibility of leaks from tanks	Dyes	15, 552	Application of dyes		
			69	Application of commercial dye products		
			191	Utilizing of food coloring, White painting for a part of tank		
			225, 354	Fluorochrome		
			379	No form 2		
			720	Lignin		
		Discoloring by irradiance	532	Hue change by irradiance level		
			570	Detection paint, Gel		
			612	Investigation of discoloring of pigment by β ray		

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(3) Technologies for detection of minor leaks	Detection of leakage	Water level gauge	111	Remote monitoring system	Many methods of leak detection by water level monitoring are also proposed. Differential-pressure-type leakage monitoring method has already been used in petroleum storages and U.S. military. A method of detecting leaks by monitoring the change of pressure on the joint part of tanks, and a method of monitoring the surface of tanks by a spectroscope are also proposed. A method of modifying the structure of tanks, making it possible to be accessed by humans to the bottom of the tank to see the bottom plate or leakage itself is also suggested.	As a detection method of leak of water itself, differential-pressure-type monitoring method is an outstanding technology already applied in petroleum, military and nuclear site. It is a dominant technology for underground tank where the environment is stable, but the measuring condition needs to be confirmed when it is used for aboveground tank. Double shell steel tank has a benefit of performing leakage monitoring between two skins.
			176	Level meter, Beanie light		
			331	Sensing by differential pressure		
			498	High-accuracy liquid level gauge		
		Leak detection	58	Functional joint		
			121	Jellification, Visualization		
			638, 645	Laser spectroscope, Remote identification		
		Leak monitoring	214	Foundation structure with drains		
			215	Tank with visible baseplate and its relocation method		
(4) Facilitating removal of the bolted-type tanks	Speeding-up of decontamination during removal work Reduction of dose rate at decontamination work	Decontamination technology	132	Super-high-pressure liquid nitrogen decontamination technology	Various technologies for decontamination and remote operation are proposed. As methods of decontamination, high-pressure projection of liquid nitrogen, steel ball, and water; laser surface vaporization; electrolysis inside tanks utilizing the tank as an electrode are proposed. A remote recovering of sludge after decontamination by a movable long nozzle is also presented. Remote operation of gas-cutting technology and remote dismantling method already applied in oil mines or the nuclear industry are suggested. Streamlining of decontamination by strippable paint is also proposed. As for the treatment of decontamination waste, disposal methods of discharged water from decontamination, solidifying agents for waste, compaction by melting in furnace, and reuse of steels as a waste container are suggested. Also, know-how on decontamination and dismantling, and examination of decontamination procedure on CAD simulation are proposed.	To select an adequate decontamination measure, it is necessary to consider the condition of contamination, acceptable decontamination period, and so on. Also, disposition of secondary wastes should be considered. Methods that are too high in performance are not necessary, and we should consider that there was a case where decontamination with only the flushing water was effective enough. Liquid nitrogen projection method and fiber laser method need to be sufficiently examined on the speed of decontamination and the efficiency of decontamination on planer area. Some of the extracted technologies are already applied or considered to be applied in other countries. Other than the above proposals, dry-ice or ice blasting methods are applicable decontamination technologies. Remote operation technology has already been applied in many industries including the nuclear industry. Reuse of tank materials is a good point of view. It is worth examining including the possibility of installation of furnace in the site.
			224, 588	Remote decontamination with steel blasting		
			305	Decontamination by fiber laser and remote processing		
			553	Laser decontamination, Gas cutting, Automatic technology		
			613	Electrochemistry, Ultrasonic		
			630	Decontamination with sand blasting		
			696	Water, HP water, Remote dismantling work		
		Remote collection technology	333	Waste collection by long reach arm		
			431	Sludge, Remote collection method		
		Remote dismantling work	553	Laser decontamination, Gas cutting, Automatic technology		
			164	Robot technology, Laser technology		
			167	Facilitating removal		
		Others	419	Decontamination of inside wall by peelable resin		
			729	Strippable paint to immobilize contamination and streamline decontamination		
	Treatment of decontamination waste	Treatment of waste fluid from decontamination	756	Electrochemical process, Removal of chloride, Oxidizes complexes		
		Solidification of waste	420	Solidifying agent for radioactive waste		
		Recycling of waste	556	Reuse of radioactive waste		
			644	Decontamination and recycle of steel		
	Others	Streamlining of decontamination work	188	Decontamination procedure		
			233, 336	General information on decontamination, Removal and dismantling		
			306	Optimization tool for decontamination procedure, CAD simulation		
			445	General decontamination technology (Decontamination, Compaction, Reuse)		

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Items	Sub items	Categories	No.	key words		
(5) Suggestions except for the tank body	Glauting, solidification, absorption of stored water	Gelation	64	Gelation agent	Besides the proposals of particularly-required technologies, gelation or solidification of accumulated water, and absorbable materials for water or nuclides are proposed. Construction of roofs on the tanks to prevent mixing of rain water and contaminated water is suggested. Proposal on reuse of tanks by lining the inside of bolted tanks after decontamination, or retrofitting the flange part by welding or resin are proposed. An idea for structure combining the storage facility with impermeable wall is presented. Also, ideas of placing sorbents around the tanks in case of leak; in-tank process of contaminated water; treatment method of accumulated water are proposed. Many foreign organizations presented their experiences on contaminated water issues.	The gelation or solidification of accumulated water may have many issues with the post-treatment. There may be possibilities if there is a technology to put it back to liquid, but we deem it difficult. Non-cement, non-polymer solidifying agents, which are the materials used for construction since the 60s, excel at absorbing substances. The post-solidification state is similar to concrete. It may be worth examining for application to other wok of recovery at Fukushima Daiichi. The proposals on reuse of bolted tanks with lining seem to have merits from the viewpoint of reducing waste volume, costs, and shielding Bremsstrahlung X-rays, but a supplemental measure for seismic resistance will be necessary. Further discussion is needed on improvement of storage effectiveness, reduction of exposure of workers, and quality control of retrofitting.
			121	Leak prevention by jellification		
		solidification	37	Solidifying agents, Stabilizing agents		
			42	Air hardening additives		
			161	Inorganic solidification agents		
			468	Non-cement non-polymer solidifying agents		
			471	Whole tank, Plaster		
		Absorption of nuclides or water	16	Biosafe, Nanocomposite polymer sorbents		
			130	Zeolite, Filling gaps of tanks, Collection of radioactive nuclides		
			171	Polymer water absorbents		
			365	Temperature-sensitive water absorbing resin		
	Protection against rain for tanks		25, 127, 196, 207	Roofs and gutters		
			124	Indoor tanks		
	Retrofitting of bolted tanks		202	Rubber injection		
			513, 689, 690, 693	Joint parts		
			630	Double-bottom structure, Rubber lining (containing lead), Overflow connection		
			722	Tanks and tank floating method		
	Underground tanks serving as impervious walls		96	Storing contaminated water inside the underground impervious wall		
			456	Precasted concrete members, Earth retaining work, Storing, Impervious structure		
	Processing of stored water in the tanks and at the time of leakage (such as additives, use of adsorbents, freezing, and transpiration)		43	Freezing, Condensation, Compaction		
			50	No form 2		
			55	Coagulating precipitation		
			73	Agricultural chemicals, Dissolution		
			115	Zeolite, Underground wall, Sr absorption		
			122	Water-storing shale		
			162	Ozone water, Separation		
			178	No form 2		
			247	Sr, Cs, Absorption process		
			277	Purification		
			285	Function of radioactivity elimination		
			504	Emergency countermeasures, Leak accidents		
			525	Contaminated water processing		
			534, 631	Water processing facility		
			715	Backup		
	Experience of working on contaminated water issues		142, 382, 445, 462, 539, 766	Overseas nuclear institutions, Power-related research institutes		

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