

“Development of Containment Vessels Repair Method”

TOSHIBA CORPORATION
Hitachi-GE Nuclear Energy Co., Ltd.
Mitsubishi Heavy Industries, Ltd.

1. Purpose of Research & Development

①

If the boundary functions of Reactor Pressure Vessel (RPV) and Primary Containment Vessel (PCV) are lost, we must repair PCV to reconstruct the boundary, and fill PCV inside and RPV with water to take out core fuel.

The vicinity of PCV is under high dose and has narrow spaces. Moreover, PCV lower part (suppression chamber) is flooded. The technology to repair the damaged area under such environments has not been established.

We must develop the equipment and the technique to repair PCV under the high dose, narrow spaces and underwater environments.

2. Details of Research & Development

②

1. Development of Repair method

- Survey existing technologies required to repair the leakage of the containment vessel under the environment such as high dose, narrow and underwater / air, and develop optimal repair method.

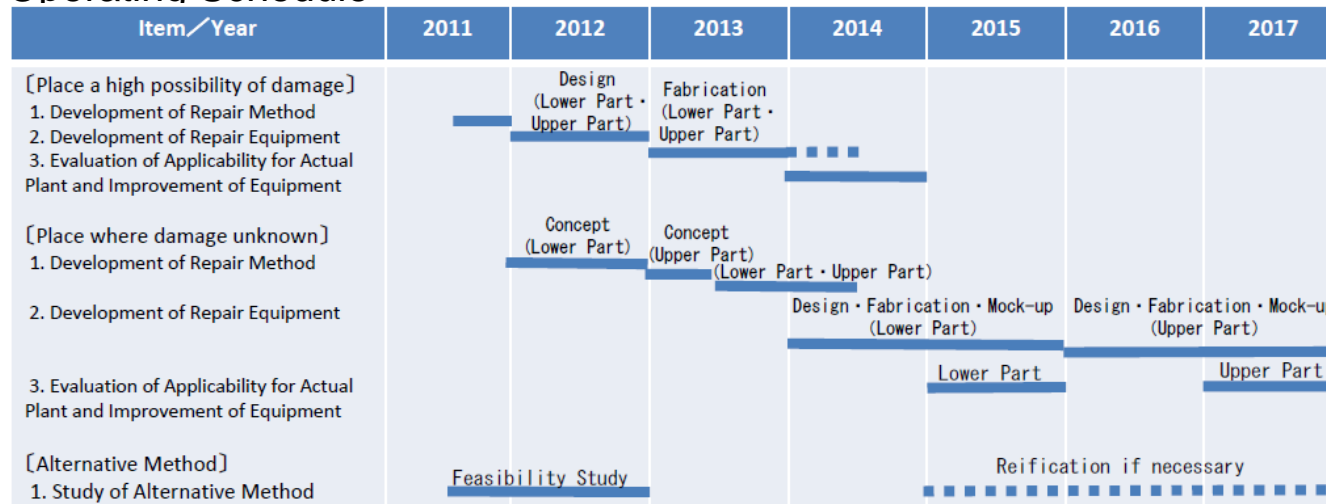
2. Development of Repair equipment

- Develop the elemental technologies and remote control technology necessary for repair containment in the environment, such as water / air, narrow, high-dose, based on the developed repair method, design and fabricate the repair equipments in combination with existing technology, and conduct mock-up testing.

3. Evaluation of Applicability for actual plant and improvements of equipment

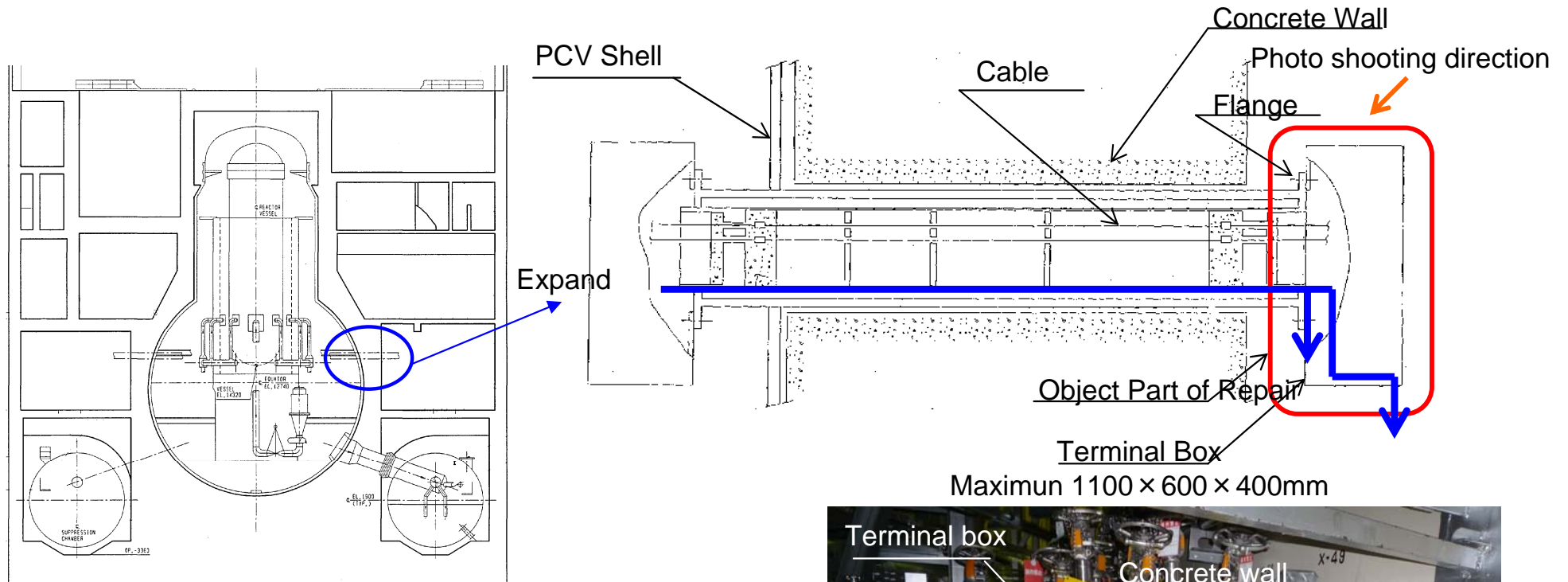
- Apply repair equipment to the actual plant and make sure that the equipment can repair in the environment, such as water / air, narrow and high dose.

Operating Schedule



Outside Drywell repair Robot: Application Area —Electrical Penetration—

③

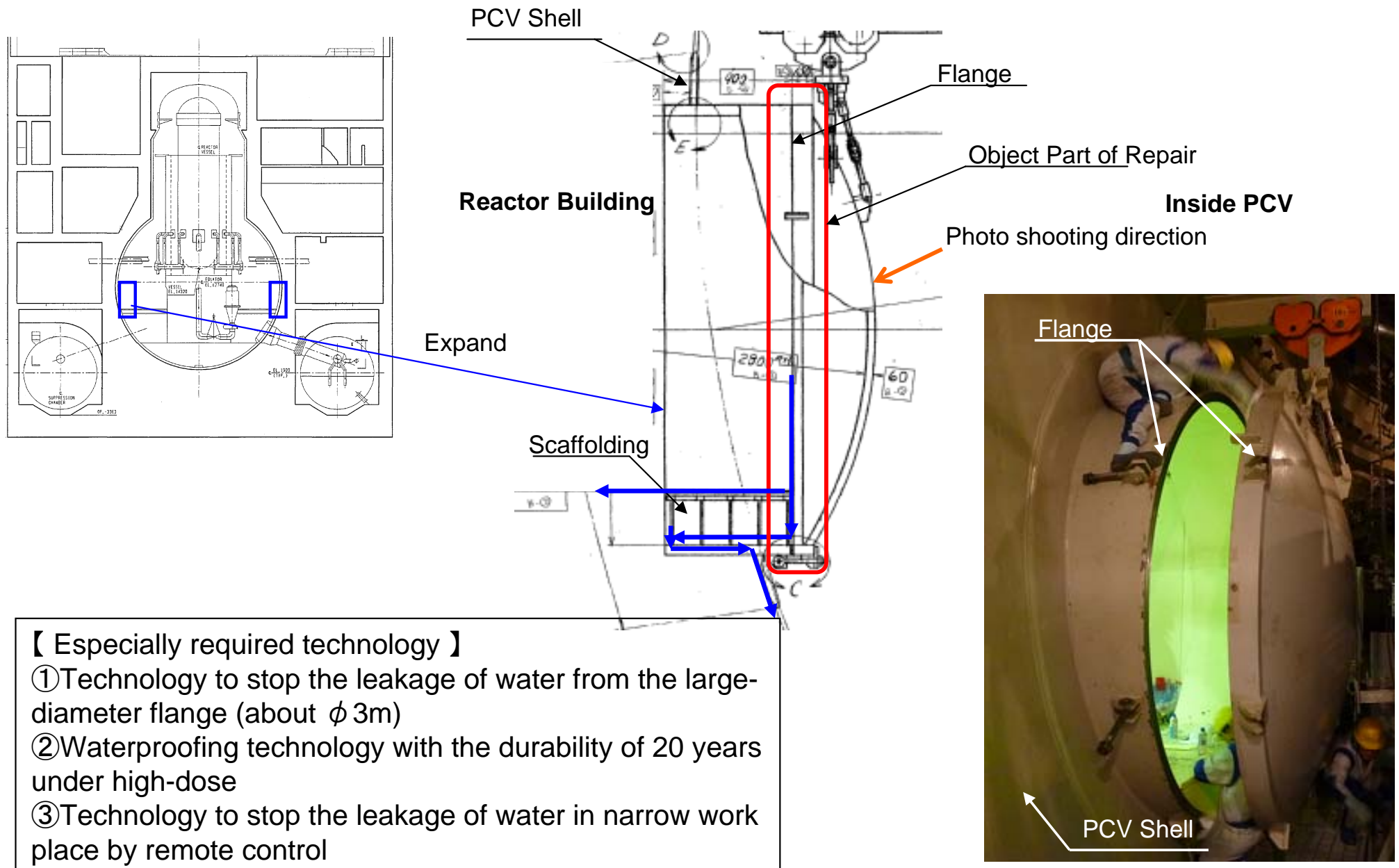


【Especially required technology】

- ① Technology to stop the leakage of water from the objects of complex shapes
- ② Water sealing technology with the durability of 20 years under high-dose
- ③ Technology to stop the leakage of water in narrow work place by remote control



Outside Drywell Repair Robot: Application Area—Equipment hatch— ④



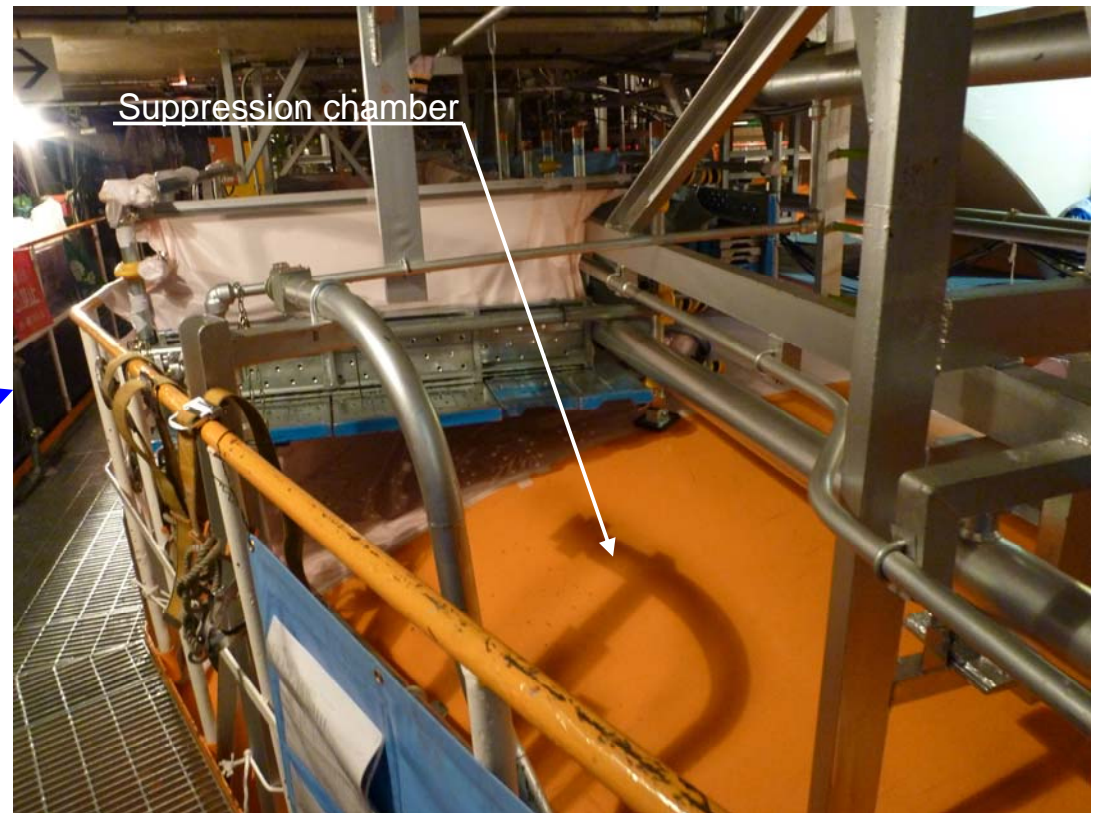
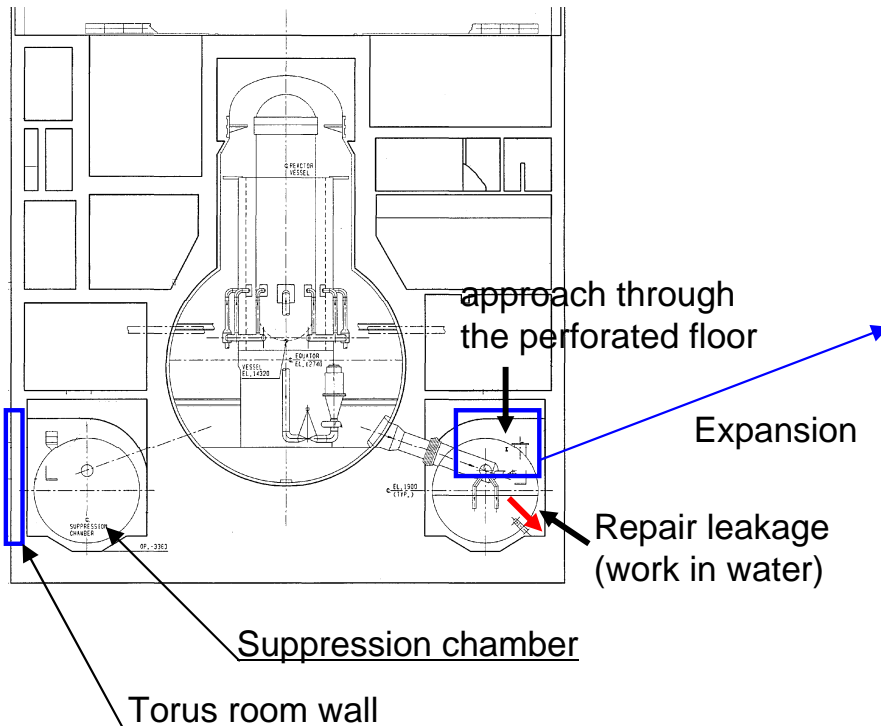
【 Especially required technology 】

- ① Technology to stop the leakage of water from the large-diameter flange (about $\phi 3\text{m}$)
- ② Waterproofing technology with the durability of 20 years under high-dose
- ③ Technology to stop the leakage of water in narrow work place by remote control

Suppression Chamber repair Robot, Torus Room Wall Repair Robot and Perforating Robot: Application Area

⑤

Application Area



【Especially required technology】

- ① Technology to perforate the steel plate (20mm thick) and concrete floor (500mm thick) in the remote
- ② Technology to perforate exactly by remote control in the space where many pipes, frames are exist

【Especially required technology】

- ① Technology to stop the leakage of water in turbid water by remote control
- ② Water sealing technology with the durability of 20 years under high-dose

Development of Containment Vessels Repair Method

Required specifications for the Equipment

⑥

Object equipment	Operating environment	Operating temperature	Radiation resistance
Outside Drywell Repair Robot	In air	80°C or less	Atmosphere: 3 (Sv/h) or more Accumulation: 100 Gy or more*
Suppression chamber Repair Robot Torus Room Wall Repair Robot	In air / Underwater	80°C or less	Atmosphere: 3 (Sv/h) or more Accumulation: 100 Gy or more*
Perforating Robot	In air / Underwater	80°C or less	Atmosphere: 3 (Sv/h) or more Accumulation: 100 Gy or more*

*: Consider the possibility of component replacement.

Development of Containment Vessels Repair Method Required Technology

⑦

Object equipment	Especially required Technology
Outside drywell repair robot	<ul style="list-style-type: none">① Technology to stop the leakage of water from the objects of complex shapes② Technology to stop the leakage of water from the large-diameter flange (about ϕ 3m)③ Water sealing technology with the durability of 20 years under high-dose④ Technology to stop the leakage of water in narrow work place by remote control
Perforating robot	<ul style="list-style-type: none">① Technology to perforate the steel plate (20mm thick) and concrete floor (500mm thick) in the remote② Technology to perforate exactly by remote control in the space where many pipes, frames are exist
Suppression chamber repair robot Torus room wall repair robot	<ul style="list-style-type: none">① Technology to stop the leakage of water in turbid water by remote control② Water sealing technology with the durability of 20 years under high-dose

Technical catalog Vendors list(Development of Containment Vessels Repair Method)

Classification	Required technology	Technical description (needs)	Technology holding vendor	Remark
Outside D/W repair robot (flange, hatch, penetration etc.) 【Especially required technology】 ①Technology to stop the leakage of water from the objects of complex shapes ②Technology to stop the leakage of water from the large-diameter flange (about φ 3m) ③Water sealing technology with the durability of 20 years under high-dose ④Technology to stop the leakage of water in narrow work place by remote control	Travelling mechanism	・Equipment that can approach to the penetration and hatch outside D/W avoiding the obstacles ・Equipment that can approach to the hatch in narrow area (MS tunnel room etc.) avoiding the obstacles ・Equipment that can remote radio control travelling mechanism and working mechanism ・Control device to operate travelling mechanism and working device	Q.I Inc.	
			iXs Research Corp.	
			IHI Inspection & Instrumentation Co., Ltd.	
			TOPY Industries Ltd.	
			IHI AEROSPACE Co., Ltd.	
			Mitsubishi Electric TOKKI Systems Corporation	
			iRobot	
			Inuktun	
			AAI Japan Co. Ltd.	
			Adept Technology	
			BAB-HITACHI INDUSTRIAL Co.	
			Hitachi-GE Nuclear Energy, Ltd.	
			KOWA CORPORATION	
			Urakami Research & Development Co., Ltd.	
			SeaBotix	
			VideoRay	
			BL AUTOTEC, Ltd.	
			Futaba Corporation	
			Asahi Onkyo Corporation	
			HBC Radiomachic Japan	
			ROHM Co., Ltd.	
			OMRON Corporation	
			Mushin Systems	
			CONTEC CO., LTD.	
			Japan Radio Co., Ltd.	
			Xeline co.,ltd.	
			Panasonic Corporation	
			ADVANTEC Co.,LTD.	
			Techno CO., LTD.	
			KEYENCE CORPORATION.	
			DENSO CORPORATION	
			HIBOT CORP.	
			maxon motor	
TOSHIBA CORPORATION		catalog sample attachment 1		
Communication device	Included in travelling mechanism	—		
Control device	Included in travelling mechanism	—		

Technical catalog Vendors list(Development of Containment Vessels Repair Method)

Classification	Required technology	Technical description (needs)	Technology holding vendor	Remark
Outside D/W repair robot (flange, hatch, penetration etc.)	Working mechanism	Equipment that can avoid obstacles and bring working device to the penetration after approach to the penetration by travelling mechanism	Sugatsune Kogyo Co., Ltd.	
			ELGO JAPAN INC.,	
			Actua Systems	
			Geo Systems	
			MITSUBISHI HEAVY INDUSTRIES, LTD.	
			AAI Japan Co. Ltd.	
			Barrett Technology	
			Neuronics	
			Yamaha Motor Co., Ltd.	
			YASKAWA ELECTRIC CORPORATION	
			REVAST CO., LTD.	
			OC Robotics	
			Framatome	
			Kuraft Telerobotics	
			Cybernetix	
	TOSHIBA CORPORATION			
	TOSHIBA MACHINE CO.,LTD			
	Measuring device	Equipment that can monitor the operation by remote and teke pictures for long time under high dose (Radiation-resistant camera)	DIAKONT/MILS SYSTEMS CO.,LTD.	
			NUCRON Co., LTD	
			CENTRONIC Raditec	
			Thermo Fisher Scientific K.K.	
			OLYMPUS CORPORATION	
			Sound Metrics	
			BlueView Technologies	
			TOSHIBA TELI CORPORATION	
	Working device	Equipment that can stop water leakage by welding or injection	Nisco Co., Ltd.	
			AHLBERG ELECTRONICS AB	
			SysCom	
			HEISHIN Ltd.	
	Support equipment	<ul style="list-style-type: none"> •Equipment that can monitor operation overall widely •Support equipment that can lay cable long distance if it is wired equipment •Lifter with which repair equipment reaches the penetration at the high place above the floor 	BAB-HITACHI INDUSTRIAL Co.	
			MEIJI AIR COMPRESSOR MFG.CO.,LTD.	
			Shiro Industry Co.	
	Waterseal materials, Repair materials	Materian that can stop the leakage of water from hole or crack of Containment Vessel	Takami Manufacturing Co., Ltd.	
			TOSHIBA CORPORATION	
			Pingrout	
	Others	<ul style="list-style-type: none"> •Obstacle detection •Radiation shielding 	MAT Corporation	
			Ask Sanshin Engineering Corp.,Ltd	
			HOKUYO AUTOMATIC CO., LTD.	
			SICK.K.K.	
			mesa	
	Canesta			
Ask Sanshin Engineering Corp.,Ltd				

Technical catalog Vendors list(Development of Containment Vessels Repair Method)

Classification	Required technology	Technical description (needs)	Technology holding vendor	Remark
Perforating robot	Traversing Mechanism	<ul style="list-style-type: none"> *Small equipment that can move rapidly in narrow space and is controlled wired or wireless *Electronic devices shall operate correctly under high dose. *Equipment that can remote radio control travelling mechanism and working mechanism *Control device to operate travelling mechanism and working device 	Q.I Inc.	
			iXs Research Corp.	
			IHI Inspection & Instrumentation Co., Ltd.	
			ATEX co., Ltd.	
			CHIKUSUI CANYCOM, INC.	
			Komatsu Ltd.	
			YANMAR Co., Ltd.	
			KOBELCO CONSTRUCTION MACHINERY CO., LTD.	
			IHI Construction Machinery Limited	
			BAB-HITACHI INDUSTRIAL Co.	
			KOWA CORPORATION	
			Urakami Research & Development Co., Ltd.	
			SeaBotix	
			VideoRay	
			BL AUTOTEC, Ltd.	
			Futaba Corporation	
			Asahi Onkyo Corporation	
			HBC Radiomachic Japan	
			ROHM Co., Ltd.	
			OMRON Corporation	
			Mushin Systems	
			CONTEC CO., LTD.	
			Japan Radio Co., Ltd.	
			Xeline co.,Ltd.	
			Panasonic Corporation	
			ADVANTEC Co.,LTD.	
			Techno CO., LTD.	
			KEYENCE CORPORATION.	
			DENSO CORPORATION	
			HIBOT CORP.	
			maxon motor	
			MITSUBISHI HEAVY INDUSTRIES, LTD.	
			YASKAWA ELECTRIC CORPORATION	
TOSHIBA CORPORATION	catarog sample attachment 1			
	Communication device	Included in travelling mechanism	—	
	Control device	Included in travelling mechanism	—	

【Especially required technology】
①Technology to perforate the steel plate (20mm thick) and concrete floor (500mm thick) in the remote
②Technology to perforate exactly by remote control in the space where many pipes, frames are exist

Technical catalog Vendors list(Development of Containment Vessels Repair Method)

Classification	Required technology	Technical description (needs)	Technology holding vendor	Remark
Perforating robot	Working mechanism	Equipment that can move working device in place in high dose	Sugatsune Kogyo Co., Ltd.	
			ELGO JAPAN INC.,	
			Actua Systems	
			Geo Systems	
			MITSUBISHI HEAVY INDUSTRIES, LTD.	
			AAI Japan Co. Ltd.	
			Barrett Technology	
			Neuronics	
			Yamaha Motor Co., Ltd.	
			REVAST CO., LTD.	
			OC Robotics	
			Framatome	
			Kuraft Telerobotics	
			Cybernetix	
			DIAKONT/MILS SYSTEMS CO.,LTD.	
	NUCRON Co., LTD			
	CENTRONIC Raditec			
	TOSHIBA CORPORATION			
	Measuring device	<ul style="list-style-type: none"> *Equipment that can identify psition of itself in the romm where many instruments exist near wall *Equipment that can monitor the operation by remote and teke pictures for long time under high dose (Radiation-resistant camera) 	Nikon Metrology	
			Furukawa Sangyo Kaisha,Ltd.	
			FARO	
			RIEGL JAPAN LTD.	
			Trimble	
			Thermo Fisher Scientific K.K.	
			OLYMPUS CORPORATION	
			Sound Metrics	
			BlueView Technologies	
SysCom				
HEISHIN Ltd.				
BAB-HITACHI INDUSTRIAL Co.				
MEIJI AIR COMPRESSOR MFG.CO.,LTD.				
TOSHIBA TELI CORPORATION				
Nisco Co., Ltd.				
AHLBERG ELECTRONICS AB				

Technical catalog Vendors list(Development of Containment Vessels Repair Method)

Classification	Required technology	Technical description (needs)	Technology holding vendor	Remark
Perforating robot	Working device	<ul style="list-style-type: none"> • Marking • Perforation of concrete slab • Perforation of PCV steel plate 	Spraying Systems	
			MIYANAGA Co., Ltd.	
			KOIKE SANSEI KOGYO CO., LTD.	
			Takashima & Co., Ltd.	
			DAI-ICHI CUTTER KOGYO K.K.	
			FLOW	
			Shibuya Company, Ltd.	
			CONSEC CORPORATION	
			DIAMOND	
			HILTY	
	Husqvarna			
	JR East Consultants Company, OYO Corporation, YBM Co.,Ltd.			
	TOHO CHIKAKOKI Co.,Ltd.			
	Others	<ul style="list-style-type: none"> • Obstacle detection • Radiation shielding • Cooling water supplying 	HOKUYO AUTOMATIC CO., LTD.	
			SICK.K.K.	
			mesa	
			Canesta	
			Ask Sanshin Engineering Corp.,Ltd	
			Shibuya Company, Ltd.	
			CONSEC CORPORATION	
HILTY				
Husqvarna				

Technical catalog Vendors list(Development of Containment Vessels Repair Method)

Classification	Required technology	Technical description (needs)	Technology holding vendor	Remark
Suppression chamber repair robot <div style="border: 1px solid black; padding: 5px; width: fit-content;"> <p>【Especially required Technology】 ①Technology to stop the leakage of water in turbid water by remote control ②Water sealing technology with the durability of 20 years under high-dose</p> </div>	Travering Mechanism	<ul style="list-style-type: none"> *Small equipment that can move rapidly in narrow space and is controlled wired or wireless *Electronic devices shall operate correctly under high dose. *Equipment that can remote radio control travelling mechanism and working mechanism *Control device to operate travelling mechanism and working device 	Q.I Inc.	
			iXs Research Corp.	
			IHI Inspection & Instrumentation Co., Ltd.	
			TOPY Industries Ltd.	
			IHI AEROSPACE Co., Ltd.	
			Mitsubishi Electric TOKKI Systems Corporation	
			iRobot	
			Inuktun	
			AAI Japan Co. Ltd.	
			Adept Technology	
			BAB-HITACHI INDUSTRIAL Co.	
			KOWA CORPORATION	
			Urakami Research & Development Co., Ltd.	
			SeaBotix	
			VideoRay	
			BL AUTOTEC, Ltd.	
			Futaba Corporation	
			Asahi Onkyo Corporation	
			HBC Radiomachic Japan	
			ROHM Co., Ltd.	
			OMRON Corporation	
			Mushin Systems	
			CONTEC CO., LTD.	
			Japan Radio Co., Ltd.	
			Xeline co.,ltd.	
			Panasonic Corporation	
			ADVANTEC Co.,LTD.	
			Techno CO., LTD.	
			KEYENCE CORPORATION.	
			DENSO CORPORATION	
	HIBOT CORP.			
	maxon motor			
	MITSUBISHI HEAVY INDUSTRIES, LTD.			
YASKAWA ELECTRIC CORPORATION				
			TOSHIBA CORPORATION	catalog sample attachment 1
	Communication device	Included in travelling mechanism	—	
	Control device	Included in travelling mechanism	—	

Technical catalog Vendors list(Development of Containment Vessels Repair Method)

Classification	Required technology	Technical description (needs)	Technology holding vendor	Remark
Suppression chamber repair robot	Working mechanism	Equipment that can move working device in place in high dose	Sugatsune Kogyo Co., Ltd.	
			ELGO JAPAN INC.,	
			Actua Systems	
			Geo Systems	
			MITSUBISHI HEAVY INDUSTRIES, LTD.	
			AAI Japan Co. Ltd.	
			Barrett Technology	
			Neuronics	
			Yamaha Motor Co., Ltd.	
			REVAST CO., LTD.	
			OC Robotics	
			Framatome	
			Kuraft Telerobotics	
			Cybernetix	
			DIAKONT/MILS SYSTEMS CO.,LTD.	
			NUCRON Co., LTD	
	CENTRONIC Raditec			
	TOSHIBA CORPORATION			
	TOSHIBA MACHINE CO.,LTD			
	Measuring device	*Equipment that can monitor the operation by remote and teke pictures for long time under high dose (Radiation-resistant camera)	Thermo Fisher Scientific K.K.	
			OLYMPUS CORPORATION	
			Sound Metrics	
			BlueView Technologies	
			SysCom	
			HEISHIN Ltd.	
			BAB-HITACHI INDUSTRIAL Co.	
			MEIJI AIR COMPRESSOR MFG.CO.,LTD.	
			TOSHIBA TELI CORPORATION	
			Nisco Co., Ltd.	
	AHLBERG ELECTRONICS AB			
	Working device	Equipment that can stop water leakage by welding or injection	IHI Corporation	
			SysCom	
			HEISHIN Ltd.	
BAB-HITACHI INDUSTRIAL Co.				
MEIJI AIR COMPRESSOR MFG.CO.,LTD.				
Waterseal materials, Repair materials and Filling materials	Materian that can stop the leakage of water from hole or crack of Containment Vessel	Kaiyo Doboku Co.,Ltd		
		PENTA-OCEAN CONSTRUCTION CO., LTD.		
		Hazama Corporation		
		Pingrout		
		MAT Corporation		
Ask Sanshin Engineering Corp.,Ltd				

Technical catalog Vendors list(Development of Containment Vessels Repair Method)

Classification	Required technology	Technical description (needs)	Technology holding vendor	Remark
Suppression chamber repair robot	Others	<ul style="list-style-type: none"> •Obstacle detection •Radiation shielding 	HOKUYO AUTOMATIC CO., LTD.	
			SICK.K.K.	
			mesa	
			Canesta	
			Ask Sanshin Engineering Corp.,Ltd	

Technical catalog Vendors list(Development of Containment Vessels Repair Method)

Classification	Required technology	Technical description (needs)	Technology holding vendor	Remark
Torus room repair robot	Traversing Mechanism	<ul style="list-style-type: none"> * Small equipment that can move rapidly in water and is controlled wired or wireless * Equipment to convey the unit that inject water seal materials to torus room from outside of torus room * Electronic devices shall operate correctly under high dose. * Equipment that can remote radio control travelling mechanism and working mechanism * Control device to operate travelling mechanism and working device 	Q.I Inc.	
			iXs Research Corp.	
			IHI Inspection & Instrumentation Co., Ltd.	
			TOPY Industries Ltd.	
			IHI AEROSPACE Co., Ltd.	
			Mitsubishi Electric TOKKI Systems Corporation	
			iRobot	
			Inuktun	
			AAI Japan Co. Ltd.	
			Adept Technology	
			BAB-HITACHI INDUSTRIAL Co.	
			KOWA CORPORATION	
			Urakami Research & Development Co., Ltd.	
			SeaBotix	
			VideoRay	
			BL AUTOTEC, Ltd.	
			Futaba Corporation	
			Asahi Onkyo Corporation	
			HBC Radiomachic Japan	
			ROHM Co., Ltd.	
			OMRON Corporation	
			Mushin Systems	
			CONTEC CO., LTD.	
			Japan Radio Co., Ltd.	
			Xeline co.,ltd.	
			Panasonic Corporation	
			ADVANTEC Co.,LTD.	
			Techno CO., LTD.	
			KEYENCE CORPORATION.	
			DENSO CORPORATION	
			HIBOT CORP.	
			maxon motor	
			TOSHIBA CORPORATION	
	Communication device	Included in travelling mechanism	—	
	Control device	Included in travelling mechanism	—	

【Especially required Technology】
①Technology to stop the leakage of water in turbid water by remote control
②Water sealing technology with the durability of 20 years under high-dose

Technical catalog Vendors list(Development of Containment Vessels Repair Method)

Classification	Required technology	Technical description (needs)	Technology holding vendor	Remark
Torus room repair robot	Working mechanism	Equipment that can move working device in place in high dose	Sugatsune Kogyo Co., Ltd.	
			ELGO JAPAN INC.,	
			Actua Systems	
			Geo Systems	
			MITSUBISHI HEAVY INDUSTRIES, LTD.	
			AAI Japan Co. Ltd.	
			Barrett Technology	
			Neuronics	
			Yamaha Motor Co., Ltd.	
			YASKAWA ELECTRIC CORPORATION	
			REVAST CO., LTD.	
			OC Robotics	
			Framatome	
			Kuraft Telerobotics	
			Cybernetix	
	TOSHIBA CORPORATION			
	Measuring device	<ul style="list-style-type: none"> •Equipment that can monitor the operation by remote and teke pictures for long time under high dose (Radiation-resistant camera) 	DIAKONT/MILS SYSTEMS CO.,LTD.	
			NUCRON Co., LTD	
			CENTRONIC Raditec	
			Thermo Fisher Scientific K.K.	
			OLYMPUS CORPORATION	
			Sound Metrics	
			BlueView Technologies	
			TOSHIBA TELI CORPORATION	
			Nisco Co., Ltd.	
	AHLBERG ELECTRONICS AB			
	Working device	Equipment that can stop water leakage by welding or injection	SysCom	
			HEISHIN Ltd.	
			BAB-HITACHI INDUSTRIAL Co.	
			MEIJI AIR COMPRESSOR MFG.CO.,LTD.	
	Waterseal materials	Materian that can stop the leakage of water from torus room wall	Pingrout	
MAT Corporation				
Ask Sanshin Engineering Corp.,Ltd				
Others	<ul style="list-style-type: none"> •Obstacle detection •Radiation shielding 	HOKUYO AUTOMATIC CO., LTD.		
		SICK.K.K.		
		mesa		
		Canesta		
		Ask Sanshin Engineering Corp.,Ltd		

Technical catalog

Classification	Travelling Mechanism
Title	Gamma Crawler
Proponent	TOSHIBA CORPORATION

1. Technical details (feature, specifications and performance)

Traveling mechanism with 2 crawler independently driven

- Dimensions: 910 × 440 × 290 mm (Excluding protrusion)
- Weight: 60kg.
- Travelling level difference: 130 mm (Performance)
- Travelling stairs degree: 41 degree (Performance)
- Allowable weight: 150 kg (Adjustable for intended purpose)
- Cable winding: 100 m (Wireless LAN available)
- Interface: Joystick
- Options: Cameras for travelling (2), Camera with LED lighting, Pan/Tilt function for inspection camera, Multi joint manipulator



Example mounting Gamma Camera

2. Experience (including the experience in domestic plants, foreign plants, and other industries)

This equipment has been used for inspection at the indoor or outdoor in Fukushima Dai-ichi Nuclear Power Station since May 2011.

3. Reasons to be considered applicable to Fukushima Dai-ichi Nuclear Power Station, and technical issues

Applicable issues	Applicability	Remark and Reason (quantitatively)
Use under radiation environment	Yes	This equipment has been used successfully for 1 hour in radiation 1Sv/h.
Use in a high temperature environment (60°C)	No	This equipment has been used successfully 40°C or less.
Provision in the first half of fiscal	Yes	Standard delivery time is 1.5 months
Correspondence to the disclosure of technical information and the remodeling	Yes	Customization according to the intended purpose is possible.
Dispatch of operation engineers	Yes	Dispatch to Fukushima Dai-ichi Nuclear Power Station is possible.

4. Technology to be developed (example)

5. Remarks