High-performance radioactive material adsorbent

AgX

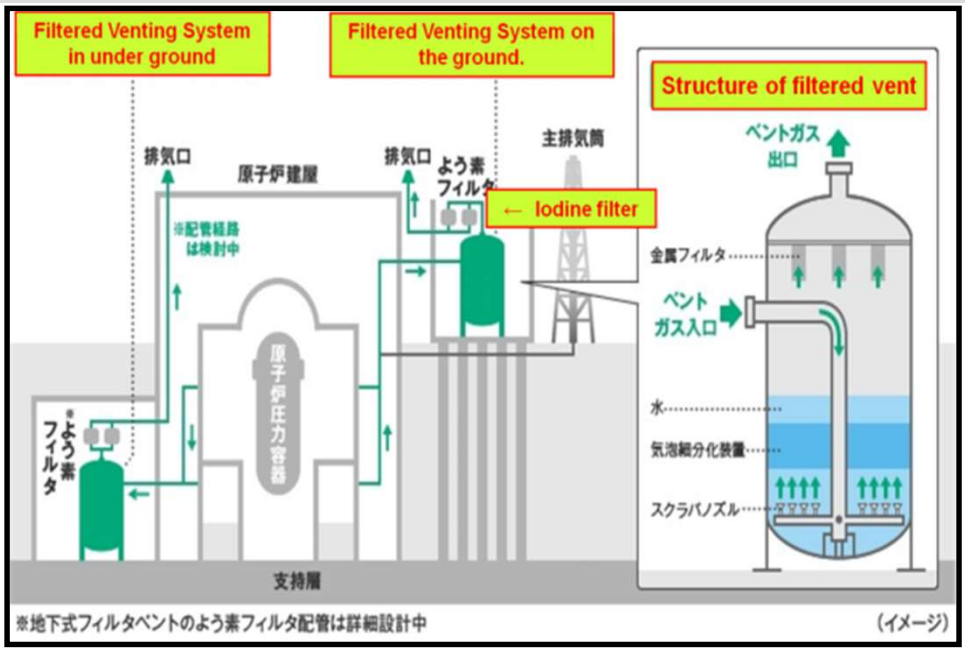
AgR

XeA

Rasa Industries, Ltd.

Preface

Rasa Industries, Ltd. has been providing silver zeolite (AgX) as a radioactive iodine adsorbent since 1980. AgX is a silver zeolite with the X-type selected to have the highest iodine adsorption performance among the synthetic zeolites originally considered. It has proven to be very efficient and durable in removing radioactive iodine, especially radioactive organic iodine (CH_3I), under severe conditions. Currently, AgX filters are being used at nuclear power plants in Japan as a countermeasure against radioactive iodine in filtered containment venting systems, and we already have a proven track record, including permits and approvals.



Tokyo Electric Power Co. Filtered containment venting system diagram

TEPCO's Kashiwazaki-Kariwa Unit 7. AgX filter to be brought in (Kashiwazaki Kariwa Nuclear Power Station Unit 7)

AgX **AgR** **AgX Filter**

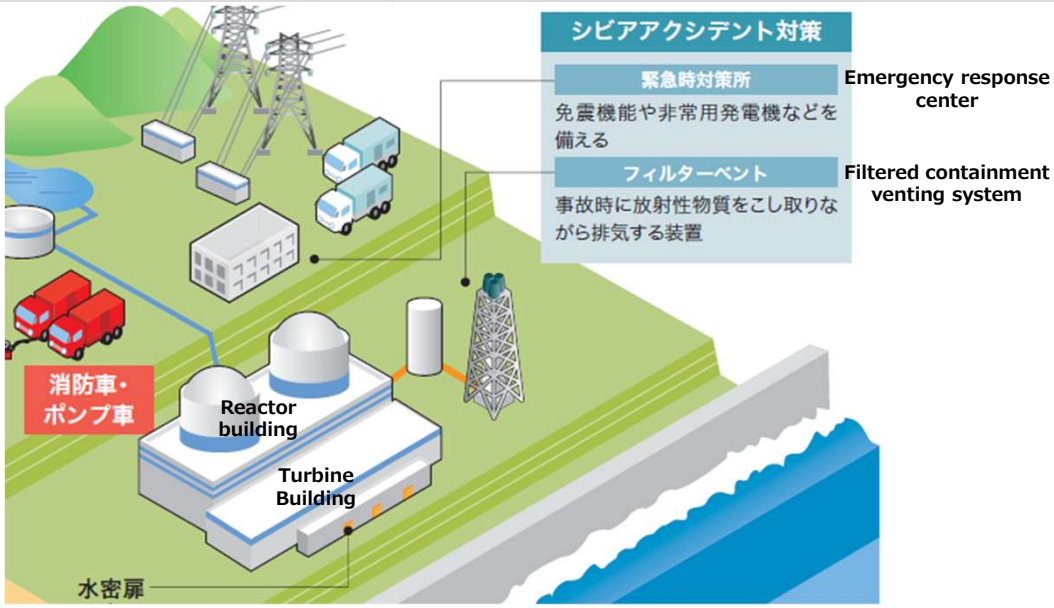
Normally, silver zeolite, like platinum (Pt) and palladium (Pd), has a hydrogen catalytic reaction to combine hydrogen and oxygen. AgR is a silver zeolite that has been developed based on the requirements of European electric power companies as a silver zeolite that reduces this hydrogen catalytic reaction to an extremely low level.

XeA is a special silver zeolite that can adsorb Xenon (Xe), the only radioactive noble gas that has been considered difficult to countermeasure in nuclear power. It has been confirmed that XeA is also effective against slightly generated Krypton (Kr).

New regulatory standard

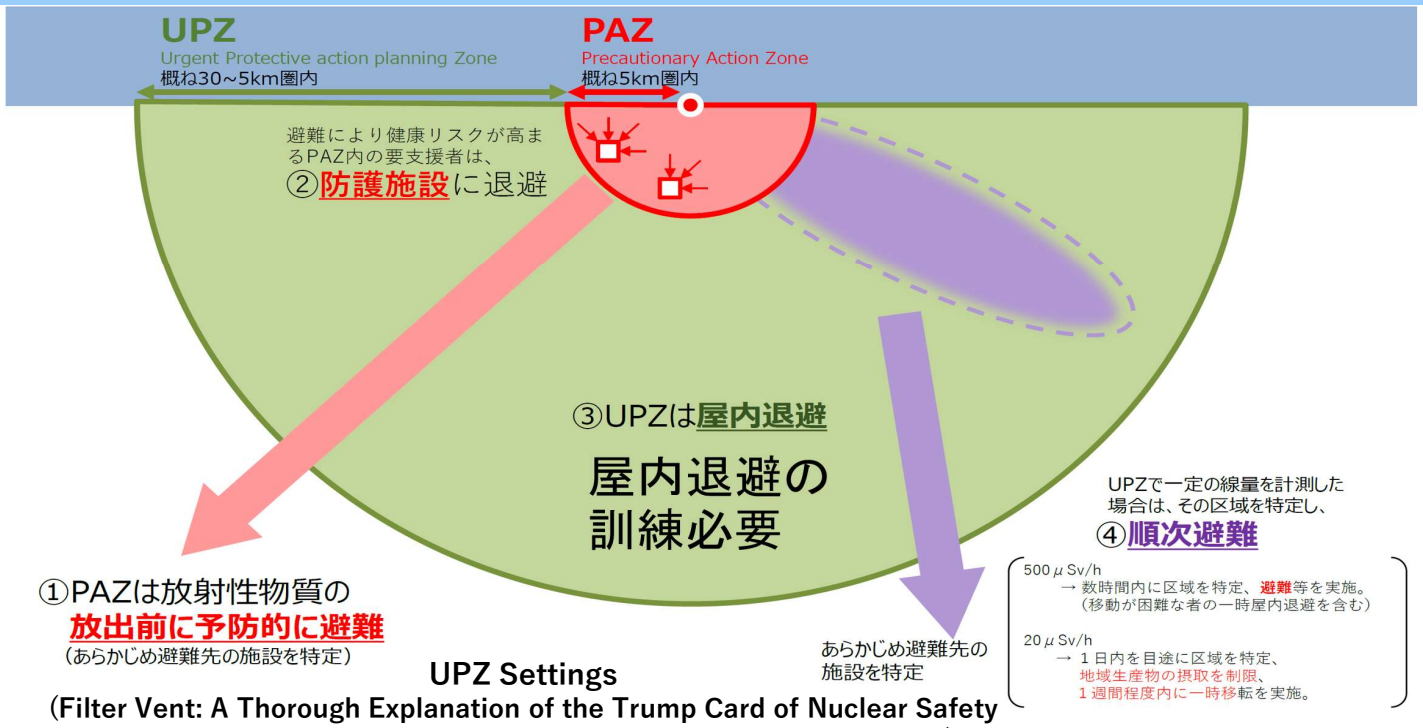
In Japan, new regulatory standards have been established based on the lessons learned from the accident at the Fukushima Daiichi Nuclear Power Plant, requiring the installation of filter vents (pressure relief devices) as a measure to prevent overpressurization damage to containment vessels.

This will greatly reduce the risk of accidents, enhance the safety and security of people in the area where the plant is located, and is very effective in promoting the restart of the plant. With the installation of filter vents, if there is no scattering of radioactive materials, people will be evacuated indoors within the UPZ zone (5 to 30 km).



Outline of New Regulation Standards
(Supervised by Dr. Tadashi Narabayashi, The Denki Shimbun)

- Before the Fukushima Daiichi Nuclear Power Plant accident, the scope to consider disaster prevention measures such as evacuation of residents was within 10 km prefecture from nuclear facilities, but the scope was expanded to 30 km prefecture, and the concept of non-man, such as immediate evacuation and indoor evacuation, was organized according to the distance from the nuclear facilities.
- In addition, the government has established a framework to support the development of evacuation plans, rather than leaving it up to local governments.



UPZ Settings
(Filter Vent: A Thorough Explanation of the Trump Card of Nuclear Safety p222-223 published by the Japan Society of Mechanical Engineers)

AgX

Radioactive iodine adsorbent

Feature

- AgX has a very high adsorption capacity for radioactive iodine and does not need to be replaced as a substitute for activated carbon, for example.
- The adsorption is chemisorption, which is characterized by the ability to remove specific substances with almost no inhibiting substances, and can selectively supplement organic iodine and other substances at high adsorption rates during severe accidents. **[Table 1] [Table 2]**
- It shows a high adsorption rate even in the room temperature range, which is usually considered difficult for silver zeolites to adsorb. **[Table 3]**

Table 1 Methyl iodide adsorption performance at high temperature and high humidity

Contact time [sec.]	Methyl iodide adsorption rate [%]				
	99°C (DPD 0K)	101°C (DPD 2K)	104°C (DPD 5K)	109°C (DPD 10K)	114°C (DPD 15K)
0.16	99.860	99.922	99.913	99.964	99.990
0.24	99.988	99.995	99.974	99.990	99.998
0.32	99.997	99.999	99.989	99.999	99.999

*Test results with radioactive methyl iodide by TUV (German evaluation agency)
DPD (Dew Point Distance) 0K: 99°C, 100% relative humidity
Normal silver zeolite is limited to use at DPD 10K or higher.

Table 2 Methyl iodide adsorption performance at high temperature and pressure

Contact time [sec.]	Methyl iodide adsorption rate [%]
0.246	99.967
0.369	> 99.999
0.492	> 99.999

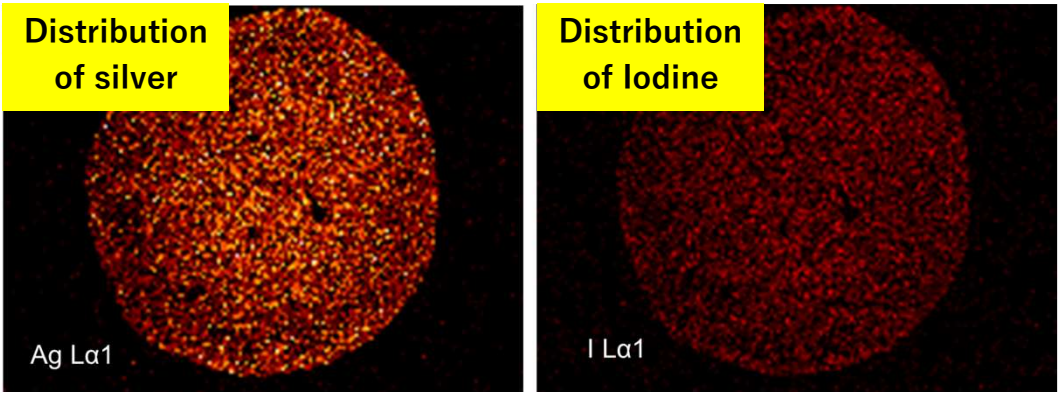
*Test results by NUCON using radioactive methyl iodide (equivalent to DPD2K) Test conditions: 130°C, 399 kPa

Table 3 Methyl iodide adsorption performance at room temperature and high humidity

Contact Time [sec.]	Methyl iodide adsorption rate [%]			
	Relative humidity 95%			Relative humidity 70%
	30° C	60° C	90° C	66° C
0.250	98.738	99.685	99.970	> 99.999
0.375	99.850	99.950	99.983	> 99.999
0.500	99.960	99.987	99.995	> 99.999

*Results of tests using radioactive methyl iodide by NUCON
Nuclear activated carbon should remove humidity.

Iodine adsorption on AgX (uniformly adsorbed to the inside of AgX)



SEM-EDX measurement of AgX adsorbed with methyl iodide (Tohoku Univ.)
Iodine is present at the same position as silver, confirming uniform adsorption of iodine

- AgX has excellent durability with almost no degradation over time. No degradation of performance occurs even in high temperature environments (500°C), 100% humidity conditions, or after immersion in water. It has been confirmed that activated carbon and other materials used in nuclear power generation are affected by water molecules.
- PAR is a device that utilizes the hydrogen catalytic reaction of platinum (Pt) and palladium (Pd), but there are concerns that radioactive iodine and moisture may reduce the catalytic reaction during severe accidents, so PAR is expected to play a supplementary role in PWR applications. However, there is concern that the catalytic reaction may be reduced by radioactive iodine or moisture during a severe accident, and PAR is expected to assist this function.
- Hydrogen catalysis has been observed under high humidity and in the presence of iodine. [**Table 4] [Table 5]**
- Almost no effect of gases generated during severe accidents. The effects of hydrogen gas, carbon monoxide, carbon dioxide, nitrogen, oxygen, hydrogen chloride, and other gases have been confirmed to be almost non-existent. [**Table 6]**
- It is nonflammable and does not present a fire or other hazard.
- The reaction time with radioactive iodine is fast, and drying facilities are not required, making it possible to downsize the facility.

Table 4 Methyl iodide adsorption performance under actual severe accident conditions

Elapsed time [min.]	Gas Composition [vol%]			AgX Temp. [° C]	Methyl iodide adsorption rate [%]*
	H	N	Water vapor		
0-3	28	60	12	22-70	> 99.6
3-6	28	60	12	70-75	> 99.6
6-9	28	60	12	75-75	> 99.6
15-18	23	53	24	105-115	> 99.6
35-38	5	12	83	140-145	> 99.8

*Evaluation reproduces actual gas conditions. Calculated from the lower limit of detection.
The AgX filter flows hot and humid gases at room temperature. Condensation does not degrade performance.

Table 5 Hydrogen Removal Performance

Test conditions				AgX Temp. [° C]	Results	
Moist air flow rate [ml/min.]	Hydrogen flow rate [ml/min.]	Contact hours. [sec.]	Approach side H concent [vol%]		Temp. rising [° C]	Exit side H concent [vol%]
6600	205	0.87	3.0	75	1	> 1.5
				120	15	< 0.5
				136	17	< 0.5

*Test results at Rasa Industries

Table 6 Methyl iodide adsorption performance under coexisting gas (CO, CO_2) conditions

Gas Concentration [vol%]						Adsorption rate (%)			
N	CO	CO_2	O	H	Water vapor	5 min.	15 min.	30 min.	60 min.
25.2	3.6	9.5	5.7	1.9	54.1	99.43	99.74	99.97	100.00

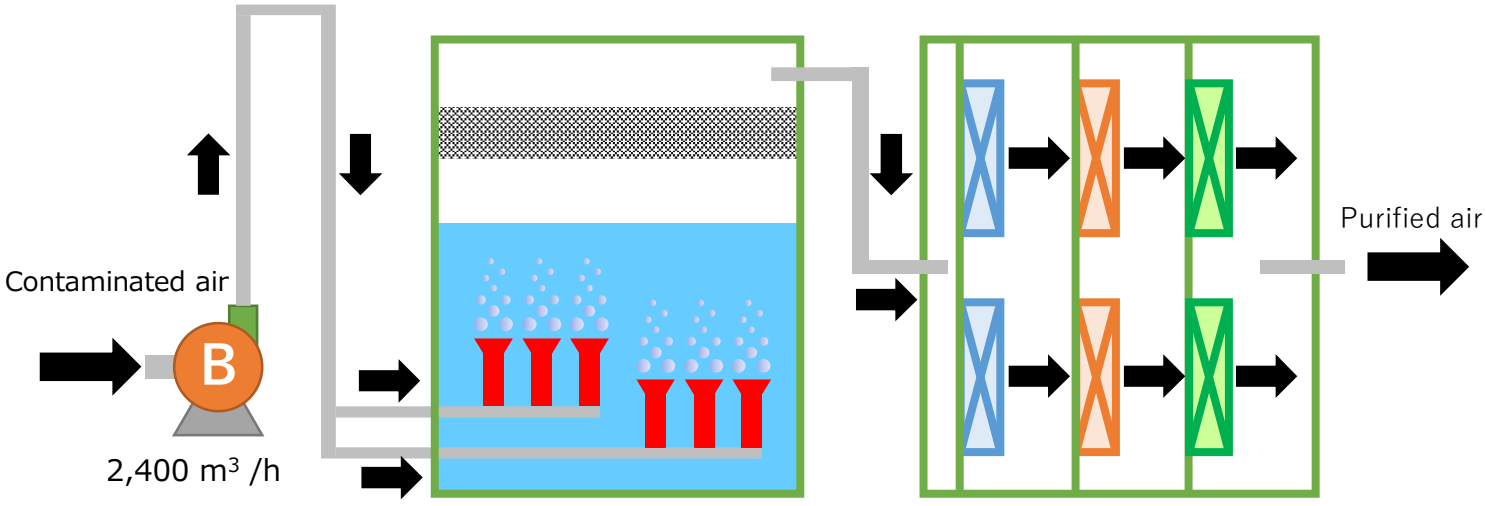
Test conditions: 140°C, 0.148 sec.

AgX

Main applications

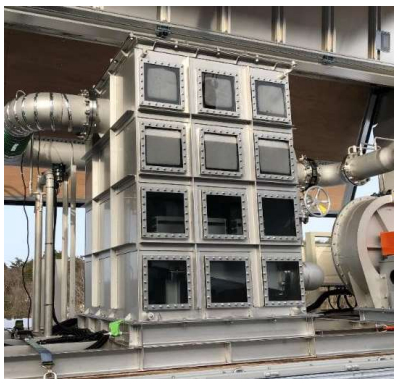
1	Radioactive iodine removal filter for filter vents (available for both WET and DRY systems)
2	Countermeasures against radioactive organic iodine in the final filter of filter vents
3	SGTS / Annulus activated carbon alternative
4	Air purification systems for emergency response stations
5	Municipal nuclear disaster prevention (no need to set in the event of an accident like activated carbon)
6	Air purification system for nuclear shelters
7	Auxiliary role of PAR in PWR containment
8	Prevention of hydrogen explosions and radioactive iodine adsorbents in SGTS and nuclear buildings of BWRs

◆Air purification system for emergency response stations For municipal nuclear disaster prevention (image)



Installed equipment that brings together various technologies in trucks

Air purification system (exterior view)



Scrubber Tank

Filter Unit

AgR

Radioiodine adsorbent with reduced hydrogen catalysis

Feature

- AgR has the feature of almost no hydrogen catalytic reaction that combines hydrogen and oxygen, so even if the hydrogen concentration becomes very high in PWR applications, no hydrogen catalytic reaction occurs, and radioactive iodine can be removed while preventing excessive temperature increases. Recombiner) can be used to help the hydrogen recombiner work by removing iodine, which inhibits the hydrogen-catalyzed reaction of the PAR (hydrogen recombiner). **[Table 7]**
- It has been shown to function under actual severe accident conditions and exhibits high adsorption rates under high temperature, high pressure, and high humidity conditions. **[Table 8]**
- Excellent durability with almost no degradation over time. No degradation of performance occurs even under high temperature (500°C), 100% humidity conditions, or after flooding. Normal silver zeolite has been shown to deteriorate and lose its adsorption function.
- It shows a high adsorption rate even under high humidity conditions, which is considered difficult for silver zeolite to adsorb. **[Table 9]**
- Non-flammable, so there is no risk of fire or other hazards.

Table 7 Methyl iodide adsorption performance in the presence of hydrogen

Elapsed time [min.]	Gas composition [vol%]				AgX Temp. [° C]	Methyl iodide adsorption rate [%] *
	H	N	Air	Water vapor		
0-2	10	13	24	53	26-122	99.9
7-9					101-105	> 99.9
15-17					126	> 99.9
30-32					124	> 99.9
60-62					120	> 99.9

*Test results by Rasa Industries, Ltd. (calculated from the lower limit of detection)

The AgR filter flows hot and humid gases at room temperature.

Condensation does not degrade performance.

It has been confirmed that the temperature does not increase even under conditions of high hydrogen concentration.

Table 8 Methyl iodide adsorption performance at high temperature and pressure

Contact time [sec.]	Methyl iodide adsorption rate [%]
0.125	99.998
0.187	99.912
0.250	> 99.999

*Test results by NUCON using radioactive methyl iodide (equivalent to DPD2K)

Test conditions: 130°C, 399 kPa

Table 9 Methyl iodide adsorption performance at high temperature and high humidity

Contact time [sec.]	Methyl iodide adsorption rate [%]			
	99° C (DPD 0K)	101° C (DPD 2K)	104° C (DPD 5K)	109° C (DPD 10K)
0.16	97.68	99.21	99.45	99.83
0.24	99.54	99.89	99.934	99.979
0.32	99.924	99.985	99.994	99.998

Results of test repentance using radioactive methyl iodide by TUV (German evaluation agency)

DPD0K: 99°C, 100% relative humidity

Normal silver zeolite is limited to use at DPD 10K or higher.

- Almost no influence of coexisting gases generated during severe accidents. The effects of hydrogen gas, carbon monoxide, carbon dioxide, nitrogen, oxygen, and hydrogen chloride have been confirmed to be almost non-existent. [**Table 10**]
- The reaction time with radioactive iodine is fast, and drying facilities are not required, making it possible to downsize facilities.
- Less silver is used, making it more economical than AgX.

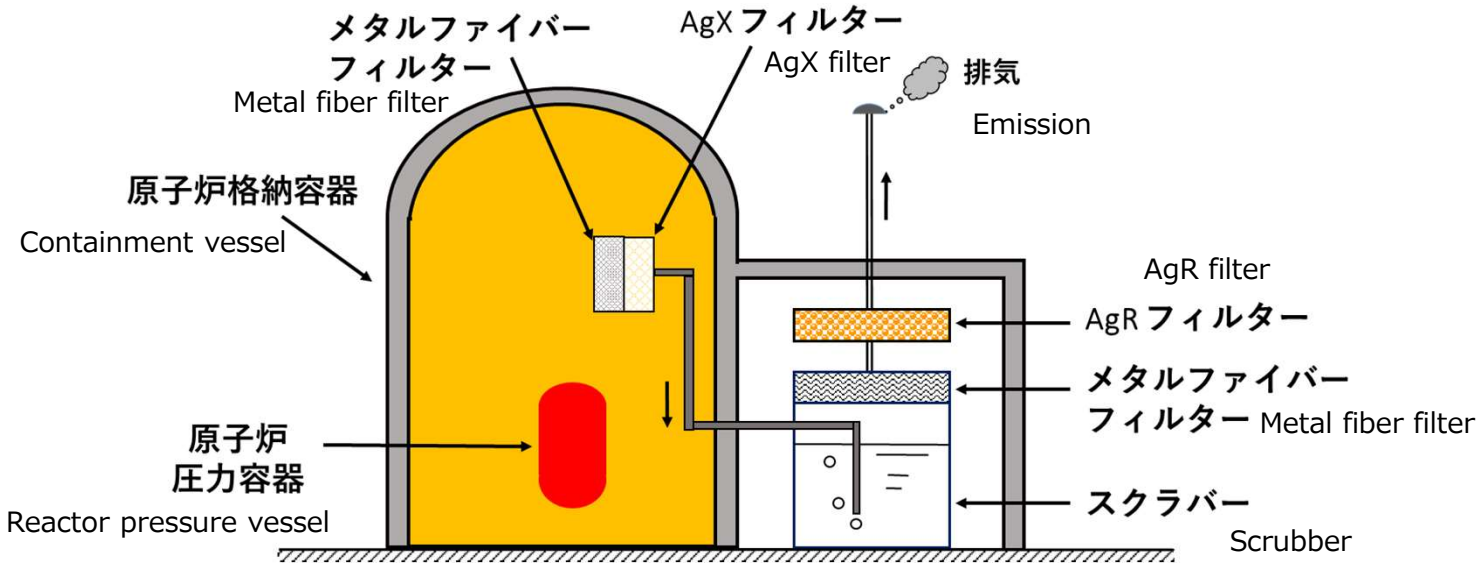
Table 10 Methyl iodide adsorption performance under coexisting gas (CO, CO_2) conditions

Gas Concentration [vol%]						Adsorption rate [%]			
N	CO	CO_2	O	H	Water vapor	5 min.	15 min.	30 min.	60 min.
19.1	3.7	9.8	4.9	9.8	52.7	98.64	99.57	99.72	99.59

Test conditions: 140°C, 0.156 sec.

Main applications

1. Radioactive iodine removal filter for filter vents (available for both WET and DRY systems)
2. Countermeasures against radioactive organic iodine in the final filter of filter vents
3. Iodine countermeasure for PAR (hydrogen recombiner) in containment vessel
4. Prevent false readings of hydrogen sensors in containment vessels



Proposed application of AgX and AgR to filter vent systems

XeA

Radioactive noble gas adsorbent

Feature

- XeA has a high adsorption and retention capacity for noble gases and is expected to be more compact than systems using activated carbon.
- In a dry atmosphere, the adsorption and retention capacity has been found to be 80 times greater than that of activated carbon. [**Figure 1**]
- Even in high humidity, it has been confirmed to have a high adsorption and retention function for rare gases. In the case of ordinary activated carbon for rare gases, a contact time of 4.5 seconds is required to achieve sufficient performance in a dry atmosphere. Under the conditions of 100% relative humidity, contact time of 1.53 seconds, and 30°C, xenon was adsorbed and retained for approximately 40 minutes. [**Figure 2**]
- It has been confirmed to have excellent adsorption and retention performance, especially for low concentrations of xenon. **[Figure 3]**
- Non-flammable, so there is no risk of fire.
- It is expected that by using the air purification system, almost all radioactive materials will be kept out of the emergency response station, eliminating the need for air cylinders and other equipment during an emergency.

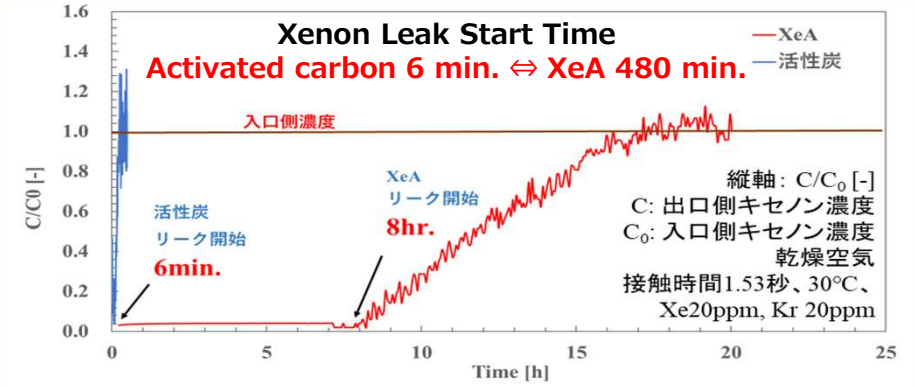


Figure 1 Xenon retention performance under dry air

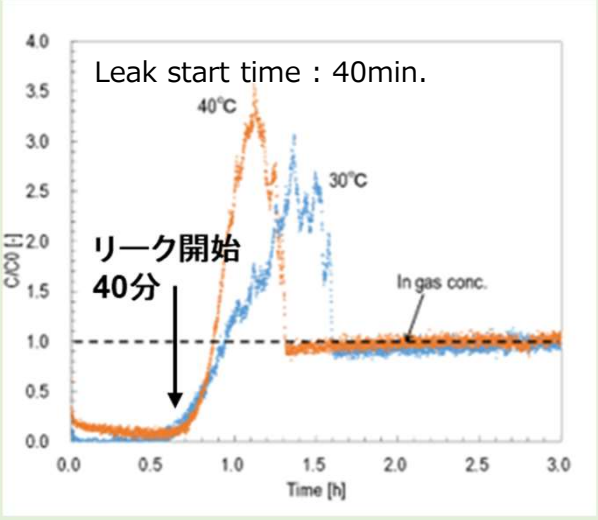


Figure 2 Xenon retention performance under humid air

Vertical axis: C/C_0 [-]
C: Concentration of xenon at outlet side
C_0: Inlet side xenon concentration Gas concentration:
Xenon 20ppm
Krypton 20ppm
Contact time: 1.53 sec.

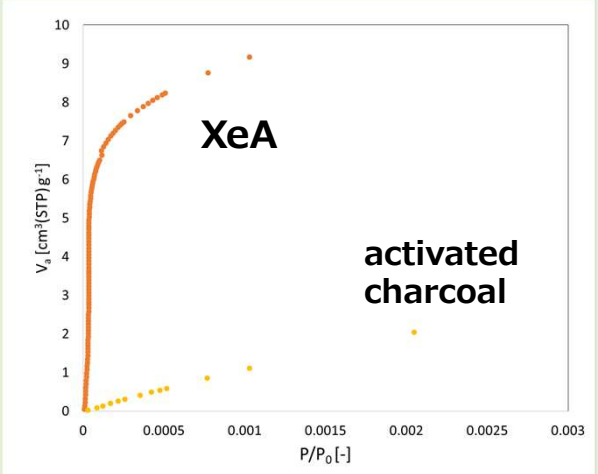


Figure 3 Xenon adsorption isotherm

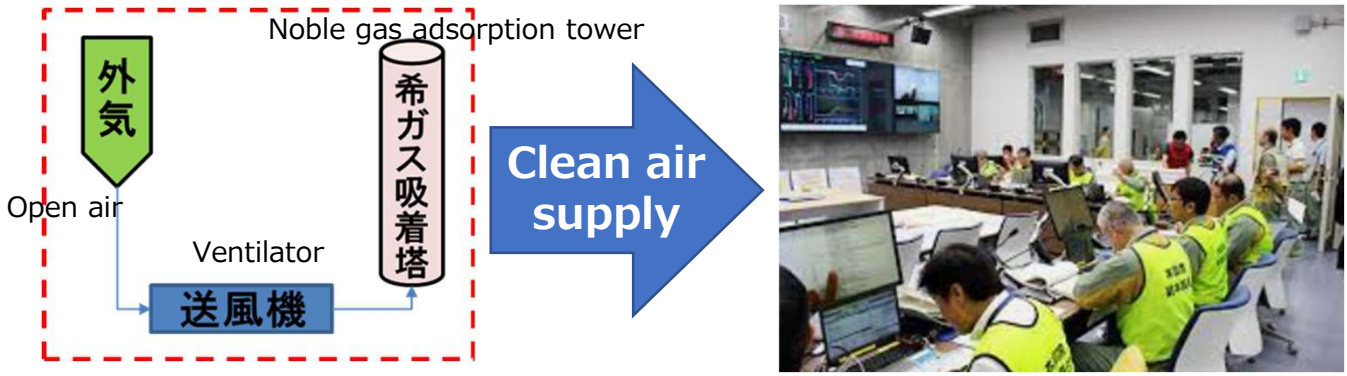
Vertical axis: Xenon adsorption V cm^3 /g
Horizontal axis: Relative pressure P/P0
P: Xenon partial pressure
P_0: 101.3kPa
Gas concentration: 100% xenon

XeA

Main applications

1	Air purification system at the emergency response station at the time of filter vent activation in the event of a severe accident (e.g., containment damage) (elimination of the need for a noble gas half-expected machine, elimination of the need for air cylinders during an emergency)
2	Replacement of activated carbon for noble gases in rare gas holdup systems
3	Incorporated into air purification systems and air conditioning of nuclear shelters
4	Rare gas capture agent for testing of hydrogen bombs, atomic bombs, etc.

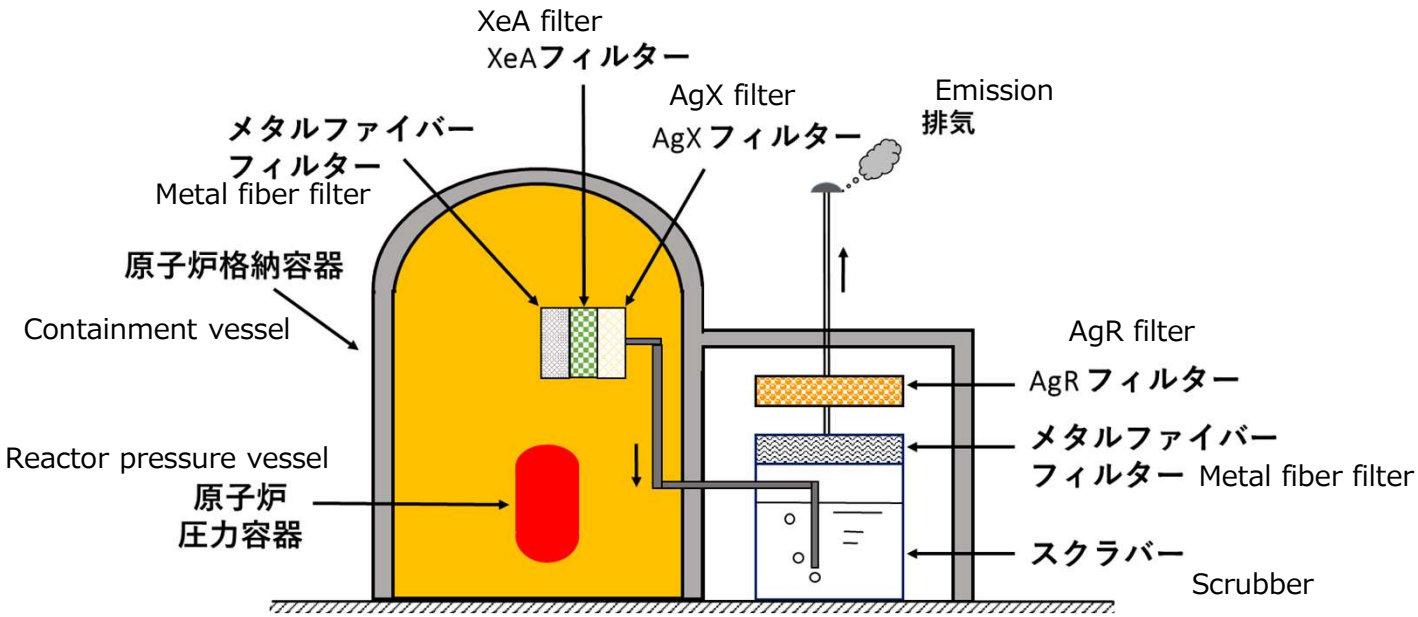
◆Application to air purification systems for emergency response centers, etc.



Air Purification System

Emergency Response Center, etc.

◆ Application of silver zeolite technology (AgX, AgR, XeA) to FCVS (image)



AgX, XeA in nuclear containment vessel
Reduces load on FCVS by removing iodine and noble gases

AgX Product Standards

No.	Item	Specifications	Remarks
1	Composition	Synthetic Zeolite	
2	Exchange metal cations	Silver (Ag)	
3	Silver component	≧ 36 %	Drying Standard
4	shape	Beads	
5	Size	10 x 20 mesh	JIS K 1474
6	Filling density	1.05 - 1.15 g/ml	ASTM D - 2854
7	Rotational strength	≦ 3.0 %	ASTM D - 4058
8	Moisture content	≦12 wt%	150 °C 3hr drying
9	Pressure loss	0.15 kPa	Thickness: 50 mm LV: 20 cm/sec.

AgR Product Standards

No.	Item	Specification	Remarks
1	Composition	Synthetic zeolite	
2	Exchange metal cations	Silver (Ag)	
3	Silver component	≧9.5 wt%	Drying standard
4	Shape	Pellet	
5	Size	≧98wt% (≧0.85mmΦ)	JIS K 1474
6	Filling density	0.80 - 0.90 g/ml	ASTM D - 2854
7	Rotational strength	≦ 3.5 wt%	ASTM D - 4058
8	Moisture content	≦ 10 wt%	150°C 3hr drying
9	Pressure loss	0.50 kPa	Thickness: 100 mm LV: 20 cm/sec.

Contact

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Rasa island

North latitude: 24 27' 57"'
East longitude: 131 11' 23"

2022.9