

Part III

Applications of MU-SSPW MU Mixing Elements

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The 21st century has been dubbed the century of the environment, and it was to help meet the growing need for environmental solutions that the “MU-SSPW” (MU-Static Spiral Perforated Wings) MU Mixing Element was developed. This element consists of multiple clockwise and counterclockwise twisted perforated blades with openings in the center, and papers on wet flue gas and wastewater treatment systems that incorporate MU Mixing Elements have been previously published.¹

The original inspiration for this technology is explained in an advertisement in *Nature*² and in “The Mayan Ruins and the Path to Technological Innovation.”³ (MU-SSPWs are components of the MU Mixing Element, and the MU Mixer consists of a stack of alternately arranged clockwise and counterclockwise twisting MU Mixing Elements. These are marketed under various names according to their specific form and application, including the “MU Scrubber,” “MU Reactor,” “MU Green Reactor,” “MU Aerator,” and “MU Eductor.”)

In this final part of our three-part series, we describe some examples of applications of the MU Mixing Element that have not previously been unpublished.

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Figure 1 Exterior of MR-40 Radon Stripper

“MU Reactor” radon stripper

The MR-40 Radon Stripper (**Figure 1**) is a modified second prototype used for the “Super-Kamiokande” (SK) neutrino observation system operated by the University of Tokyo’s Institute for Cosmic Ray Research in Kamioka Mine located in Kamioka-cho, Hida City, Gifu Prefecture, central Japan. Radon is stripped from the ultrapure water in the SK system’s tank by pure (radon-free) air and used to continuously measure the concentration of radon. In order to reduce background from the MU Reactor, its inner and outer surfaces are electro-polished to a surface roughness of not more than Ra 0.4 μm .

The MU Reactor contains a “MU Mixer” high-performance static fluid mixer. Ultrapure water in the SK system tank is supplied to the top of the reactor and pure air is supplied to the bottom in order to effect gas-liquid mixing in the MU Mixer. Radon in the ultrapure water is desorbed as radon gas, which is then fed to a radon measuring device. The high level of efficiency with which gas-liquid mixing and contact occurs allows the ultra-low concentrations (0.1-1.0 mBq/m^3) of radon present in ultrapure water to be desorbed at virtually vapor-liquid equilibrium.⁴

A MU Reactor is being used in a vacuum degasifier for removing radon and krypton from the pure oil used by a liquid scintillator in the KamLAND system for measuring neutrinos.⁵ The purpose of the degasifier is to purify pure oil in the system by removing radioactive noble gases such as radon and krypton present in the oil in order to lower

background and raise detection sensitivity⁶ (**Figure 2**). It has a desorption efficiency of 99% for radon and 99.9% for krypton.

A MU Reactor is also being used to enable continuous measurement of radon flux between the atmosphere and the ocean aboard *The Mirai* oceanographic research vessel,⁷ and it has played a particularly valuable role in enabling continuous measurement in the rough seas of the Antarctic Ocean. This is because the radon stripper's spiral 180°-twisted perforated blades ensure complete gas-liquid mixing with no gas short-passing even at a 30° incline, so desorption performance is unimpeded.

MU Reactors have one-sixth the diameter, one-fiftieth the volume (gas-liquid contact part), and three-hundredth the gas-liquid contact time of conventional packed tower systems (**Figure 3**).

The above products were supplied with the cooperation of the Institute for Cosmic Ray Research of the University of Tokyo, the Research Center for Neutrino Science of Tohoku University, Nagoya University, and Gifu University.

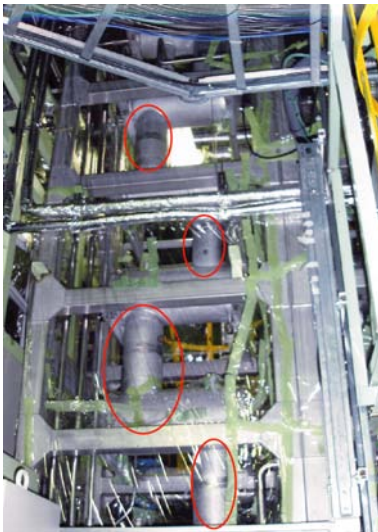
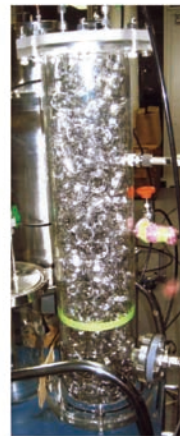


Figure 2 KamLAND vacuum degasifier



Gas-liquid contact part of MU Reactor system ($\phi 34 \times 600H$)



Gas-liquid contact part of packed tower system ($\phi 200 \times 700H$)

Figure 3 MU Reactor and packed tower system configurations compared

MU Reactor brine vacuum degasifier

A conventional brine degasifier requires the packed tower to be set at a water level height corresponding to the operating vacuum (approximately 11 m) (**Figure 4-(1)**). In contrast, a MU degasifier tower (MU Reactor) can be installed at ground level (shown

in **Figure 4-(2)**).

Brine throughput is 200-250 m³/h. The performance of this MU Reactor is shown in **Table 1**, and the design specifications of a packed tower system and a MU system are shown in **Table 2**.

This MU degasifier, which was installed jointly with Mitsubishi Chemical Engineering Corp. and has been in continuous, maintenance-free operation for eight years,

- (1) has a tower made of FRP and a MU Mixing element made of PP;
- (2) and requires no corrosion-resistant metal as its FRP construction is sufficient to maintain performance even under a vacuum of 25 Torr or less.

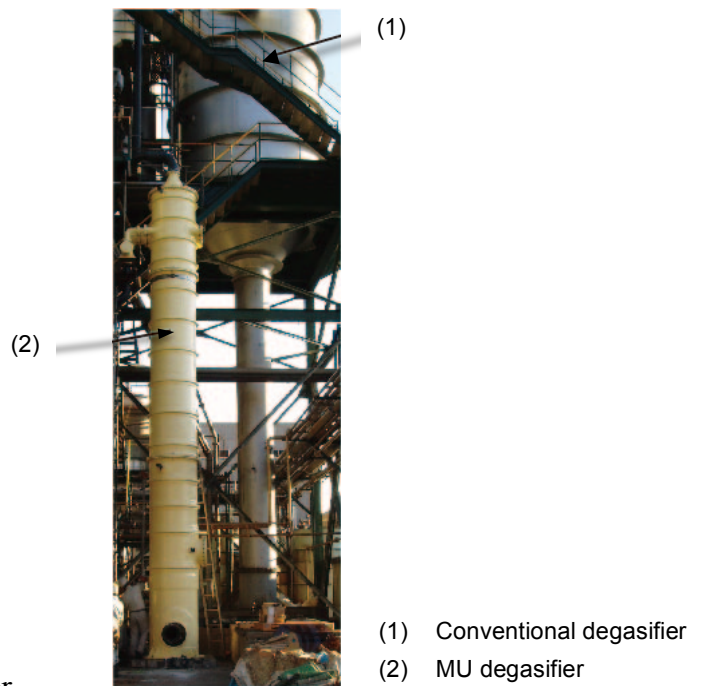


Figure 4 MU Reactor vacuum degasifier

Table 1 MU Reactor performance

Raw water		Treated water	
O ₂ concentration	8 ppm	O ₂ concentration	Max. 1 ppm
CO ₂ concentration	150 ppm	CO ₂ concentration	Max. 15 ppm
NaCl concentration	20 wt%	—	—

Table 2 Design specifications of packed tower system and MU system

	Packed tower system	MU system
1. Total height (m)	15	11
2. Packed section height (mm)	ø 1,600 x 6,800 H	ø 990 x 3,600 H
3. Packing	Raschig rings	MU Mixing Element
4. Tower material	Corrosion-resistant metal	FRP

MU Scrubber wet flue gas treatment system

The MU Scrubber invented by MU Company is steadily building up a proven track record. HCl, dust, and other emissions produced by incineration systems that burn waste oil, sludge, and garbage are rinsed in parallel flows by a MU Scrubber, downstream from which is installed an electrostatic precipitator.⁸ This system has been in continuous, maintenance-free operation for 13 years. HCl absorption efficiency is at least 99%. Parallel-flow rinsing of flue gas from cement kilns that contains SO_x, dust, and other matter has also been reported.⁹

These MU Scrubbers combine gas absorption and dust removal functions in a single tower. MU Scrubbers can also be installed in the flues of existing incinerators in order to improve dust removal efficiency, resulting in a dust removal efficiency of 98% and particulate emission concentration of not more than 0.003 g/Nm³ with little pressure loss (not more than 50 mmAq).

Research and development work is currently being carried out on removing Hg, which is likely to become subject to tighter limits in the future, using an O₃ generator and MU Scrubber system.^{10,11} Companies are also planning and developing industrial applications.¹²

Hydrogen recovery unit

H₂ is used as a carrier gas for exhaust gas emitted from reactors. Recovering and recycling this H₂ is essential to reducing production costs and ensuring the stable supply of hydrogen gas.

Where exhaust gas contains a high concentration of HCl (50-500 kg/h) and silane-based compounds (5-50 kg/h), for example, it has conventionally been extremely difficult to

attain an HCl concentration of not more than 5 vol.-ppm and a dust concentration of not more than 0.1 mg/Nm³ after processing using water as the absorber. Working with one manufacturer, we have succeeded in achieving these values using three MU Scrubber towers (in a parallel flow + parallel flow + counter flow arrangement) (**Figure 5**).

Presently, hydrogen gas is recovered at a rate of 3,000-4,000 Nm³/h and reused. This technology is also being applied to processing gases containing high concentrations of NH₃, SO₂, and CO₂ through absorption by chemical reaction, and TiCl₄, SiCl₄, SiH₂Cl₂, Al(CH₃)₃, Al(CH₃)₂Cl, Ga(CH₃)₃ through hydrolysis reaction. It has been in continuous, maintenance-free operation for 17 years at one major manufacturer's synthetic silica plant, where it is used to process exhaust gas containing high concentrations of HCl and SiO₂ with a variation in outlet pressure from the MU Scrubber of ±3 mmH₂O.

Highly concentrated HCl gas is almost completely physically absorbed at vapor-liquid equilibrium. Where TiCl₄ gas is physically absorbed, the system has a removal efficiency of at least 99%. It has raised the efficiency of recovery of TiO₂ and slashed consumption of NaOH by downstream processes.

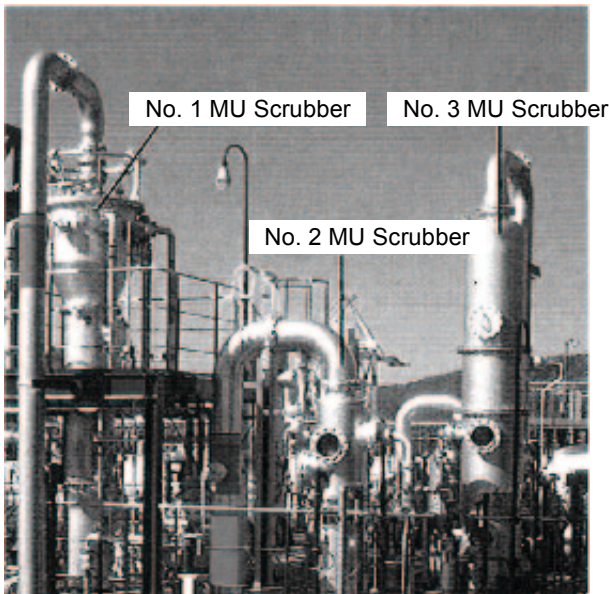


Figure 5 Hydrogen recovery unit

Wet deodorizing system

The MU Scrubber is in use as a wet deodorizing system that uses a combination of

sulfuric acid and alkaline washing to remove malodorous constituents (such as ammonia, hydrogen sulfide, trimethylamine, methyl sulfide, methyl disulfide, and methylmercaptan) from the gas discharged from rendering plants (**Figure 6**).

It operates continuously with an air throughput of 1,500m³/min and gas flow rate of approximately 10 m/s. The no. 1 and no. 2 MU Scrubber towers are arranged in series. They each have a tower diameter of 1,800 mm and tower height of 6,600 mm, and wash and deodorize in parallel flows.

Their specifications are as shown in **Table 3**, and their MU-SSPWs have experienced no clogging in 14 years of continuous, maintenance-free operation (excluding mechanical working parts).

This deodorizing system was installed as a joint project in collaboration with Mitsubishi Nagasaki Machinery Mfg. Co., Ltd. and Osaka Resin Industry Co., Ltd.

Table 3 Specifications of wet deodorizing system

	Design values	Measured values
Inlet odor concentration	Max. 2,000	1,300
Outlet odor concentration	Max. 300	130



Figure 6 Wet deodorization system

Use of MU Eductor in large-capacity reaction tank

A MU Eductor® with built-in MU-SSPW is being used in one of the world's largest reaction tanks (4,000 m³) by a leading Taiwanese chemical manufacturer for organically reacting C₅-C₁₀ hydrocarbons.

The system flow is shown in **Figure 7**. Two MU Eductors are placed in a 4,000 m³ spherical tank measuring 20 m in diameter, and a feed of liquid concentrate C₅-C₁₀ hydrocarbons and circulating liquid is supplied at a rate of 500m³/h. The eductors accelerate chemical reaction and homogenize temperature and concentration, contributing to more uniform product quality and stable operation.

A comparison of a conventional eductor system and the MU Eductor system is shown in **Figure 8**. Compared with the conventional system, the MU system results in no more than one-twentieth the mixing-agitation reaction time, more stable quality, and greatly improved reaction yield.

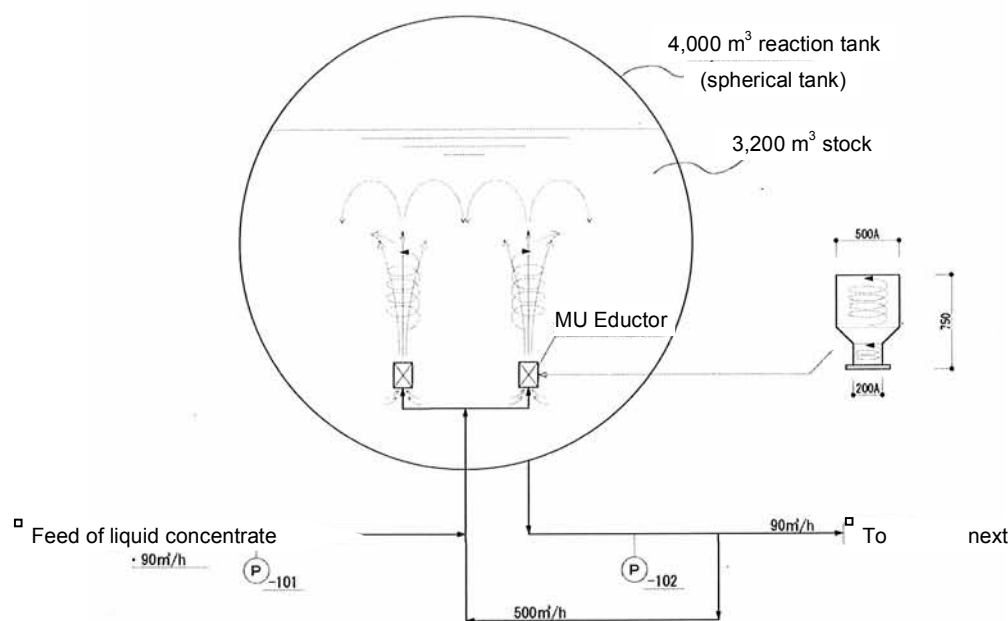


Figure 7 Large-capacity reaction tank with MU Eductors

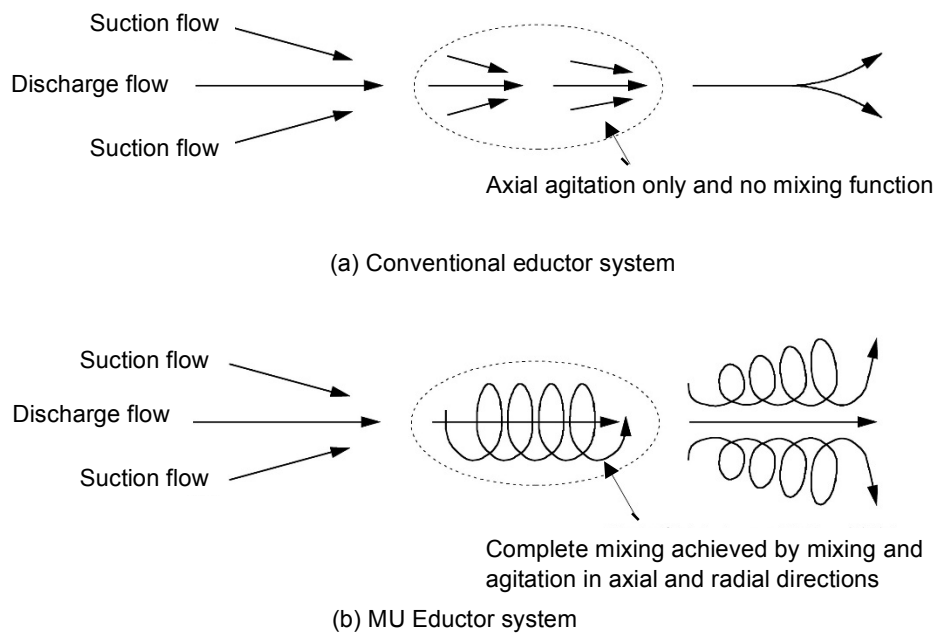


Figure 8 Comparison of conventional eductor system and MU Eductor system

Use in CO₂ absorption and desorption system

Large (10 m) diameter MU Mixing Elements can also be produced, enabling exhaust gas throughput of 1,400,000 m³/h at a tower gas velocity of 5 m/s, and throughput of 2,800,000 m³/h at a velocity of 10 m/s.

This system (**Figure 9**) consists of MU Mixing Elements with self-cleaning functionality installed in the gas-liquid contact parts of an exhaust gas scrubber, CO₂ absorption tower, and CO₂ desorption tower, and is characterized by its high performance, low cost, lack of need for maintenance, low pressure loss, energy efficiency, and small footprint.

Hg and dust in exhaust gas are removed in parallel flows in the first scrubber, and clogging caused by contamination by absorbent and dust are prevented in parallel flows in the second absorption tower to promote maintenance free and continuous operation. In the third desorption tower, rich CO₂ absorbent is supplied by counter flow from the top and water vapor is supplied from the bottom. CO₂ is desorbed in the gas-liquid contact section and discharged from the top of the tower as CO₂ gas.

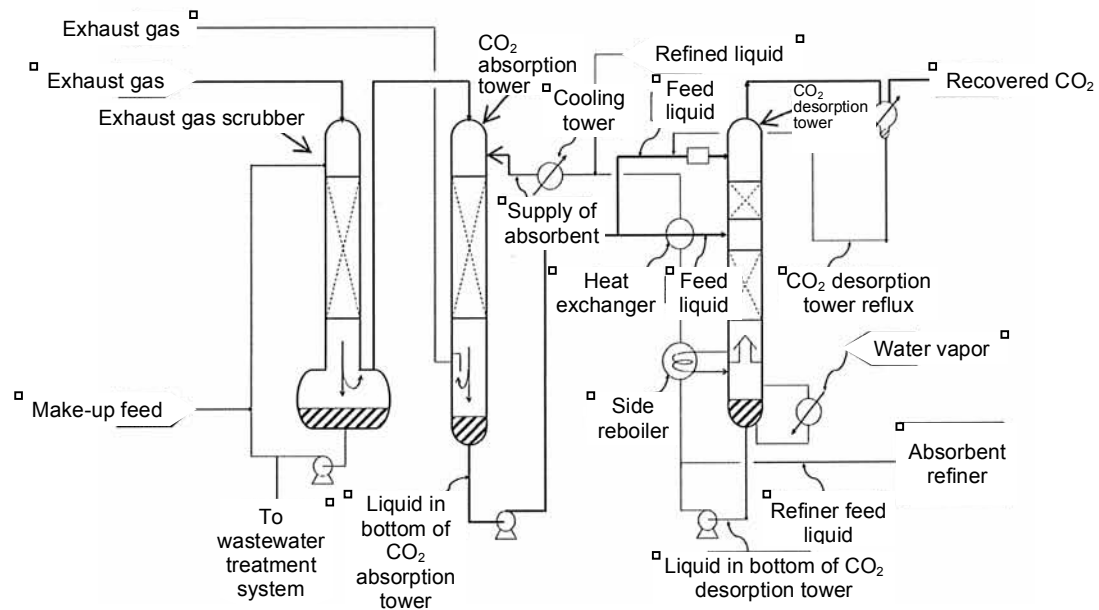


Figure 9 CO₂ gas absorption and desorption system

Use to treat vent gas containing radioactive substances

MU Mixing Elements can also be used to create wet waste gas treatment systems capable of processing radioactive vent gas emitted when an incident occurs at a nuclear reactor. As previously noted, installing a MU Mixing Element comprised of an MU-SSPW in a vent gas pipe offers a number of benefits, including (1) lack of need for maintenance, (2) high performance (at least 95% collection of submicron dust and gas absorption of at least 99%), (3) low pressure loss, and (4) space savings.

Other possible applications as means of separating and recovering radioactive material from wastewater include floatation using micro-bubbles and concentration and volume reduction by liquid-liquid extraction. Another possible use is as a backup treatment system to prevent breakdowns caused by microbes and particulate matter in filtration and adsorption processes.

Potential for scaling up MU Mixing Elements

For manufacturing and cost reasons, MU Mixing Elements have until now been limited in size to a diameter of 1,500 mm (**Figure 10**). By adopting a multi-layered structure of spiraling vanes arranged in concentric circles (**Figure 11**), however, it becomes possible

to make large-diameter MU Mixing Elements measuring 10 m or more in diameter.¹³

The resulting element is capable of gas absorption and dust removal with an air throughput of 2,800,000 m³/h. (For comparison, a 300,000 kW coal-fired thermal plant is estimated to produce 1,500,000 Nm³/h of exhaust gas. World atmospheric emissions of mercury are estimated to amount to 2,000 t/year (in 2005), 45% of which derive from coal combustion.)¹⁴ Another possible use of MU Mixing Elements consisting of spiral vanes (MU-SSPW) arranged in a multi-layered structure is in distillation columns.¹⁵

The above concludes our brief review of the actual performance and potential uses of MU Company's "MU-SSPW" MU-Static Spiral Perforated Wings in a wide range of applications.



Figure 10 Conventional MU Mixing Element

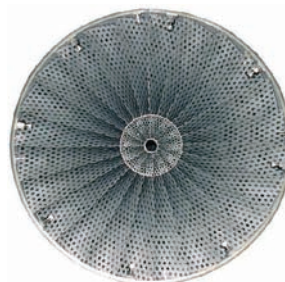


Figure 11 Modified MU Mixing Element

Conclusion

Being a new product, sales were poor to begin with. Since then, however, we have steadily built up a track record of success and recently celebrated our 31st anniversary, and we would like to take the opportunity in these pages to thank everyone we have worked with during that time for their cooperation, guidance, and assistance.

It seems strange to think that we have remained in business for the 31 years since our first encounter with that amazing thing, the "spiral." Not content to remain where we are now though, we will continue to reach ever higher and further. There will be diversions along the way, but step by step we will continue to innovate technologically and make the qualitative leap to applying "spiral" rather "linear" thinking to exploring a world where "emptiness is form and form is emptiness" as we pursue the true "MU."

The summer grasses –

For many brave warriors

The aftermath of dreams.

Matsuo Basho, *Oku no Hosomichi* (“Hiraizumi”)

Translation: Donald Keene, *Travelers of a Hundred Ages*, New York, 1999, p. 316

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