Going Maintenance Free with the MU Mixing Element and Its Incorporation into a Wet Dust Collector

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1. Introduction

MU Company released the “MU-SSPW” (MU-Static Spiral Perforated Wings) 34 years ago, since which time it has been used in a variety of fields to absorb, disperse, react, cool, separate, distill, and extract substances by mixing liquids with gases and other liquids. It has been employed at chemical plants, steel works, power stations, and other facilities where it has helped protect the global environment and reduce production costs. One of the MU-SSPW’s greatest strengths is that it requires no maintenance, and in this paper we explain what makes it maintenance free and its use in a wet dust collector.

2. Development background

Tray and packing technologies have long been used in distillation and absorption towers, and over the years manufacturers have come up with their own various innovations in constant pursuit of better performance.

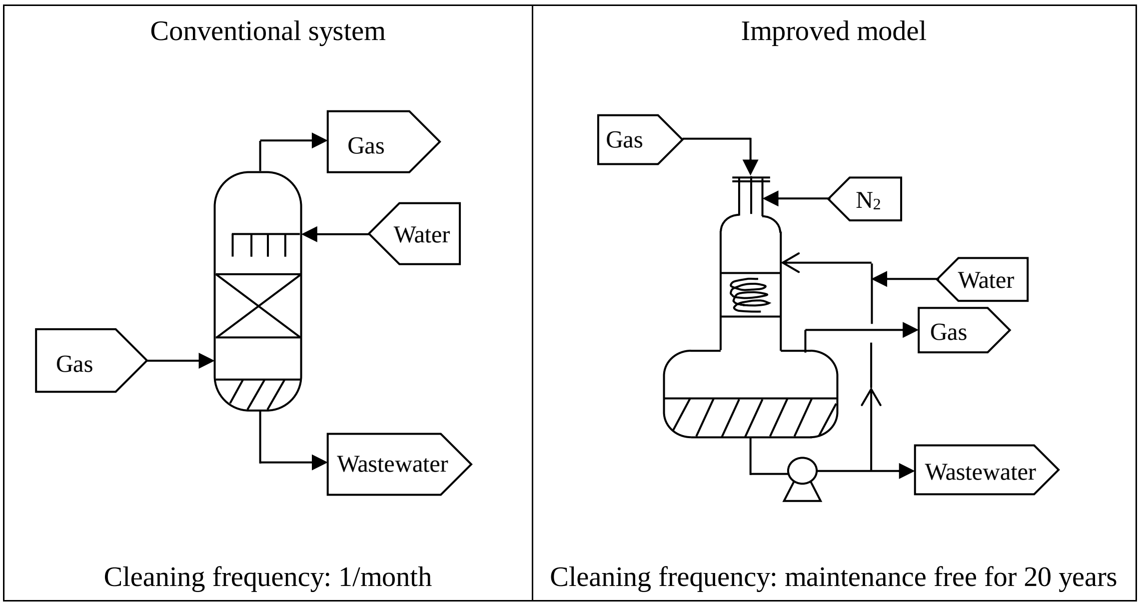
One drawback has remained, however: that of fouling. Trays become fouled from the dead-end and downcomer areas near the wall, where there is little movement, while packed towers become fouled from the distributor and the top of the packing. As fouling worsens, differential pressure in the tower rises, separation efficiency deteriorates, and flooding ultimately occurs.

Manufacturers have thus been unable to simultaneously improve efficiency and prevent clogging. In systems that are susceptible to fouling, use continues to be made of spray trays, donut rings, and expanding metal. The advantage of the MU-SSPW is that it is self-cleaning, as the system’s own liquid acts to thoroughly clean the system.

The superior performance of the MU-SSPW has been demonstrated in real-world use. For example, scrubbers that previously had to be switched over to a spare system once every three months due to fouling have now been operated without maintenance for 16 years following installation of MU-SSPWs. Similarly, semiconductor silane exhaust gas processing towers that used to be blocked by products and had to be stopped once a month for hazardous cleaning work to be performed have now been operating without maintenance for 20 years thanks to the use of MU-SSPWs (**Figure 1**). Due to its structure, the MU-SSPW is capable of functioning in both counter-current and co-current configurations.

While the design gas superficial velocity in a counter-current packing tower is 1 m/s, the MU-SSPW permits stable operation at even 3 m/sec. Co-current systems can be operated at even greater velocities of 5 m/s or higher, thus allowing major reductions in size. Co-current MU-SSPW towers are particularly widely used for direct cleaning and reaction applications. Below, we explain the resistance to fouling and clogging that make the MU-SSPW so special.

Figure 1



3. Structure and features

3-1. Structure

The MU-SSPW's resistance to fouling and clogging derives from its structure, which causes the liquid itself to spiral downward (see **Photo 1**).

The liquid revolves dynamically downward under gravity along the stationary spiral perforated wings, and the gas mainly passes through the perforations in the wings. Contact between gas and liquid occurs in the gaps between the wings, which means there is no dead-end space. The exhaust gas forms a turbulent spiral consisting of a spiral flow that flows along the spiral wings, a direct flow that flows along the central portion of the wings, and a divided flow that flows through the perforations of the wings. The liquid constantly cleans the entire element as it rotates repeatedly clockwise and counter-clockwise in a downward spiral. This cleaning action prevents fouling and clogging (blockages).

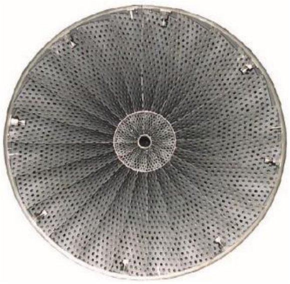


Photo 1

MU-SSPW structure

3-2. Advantages

We next describe two cases in which towers that normally experience severe fouling have been rendered maintenance free by using MU-SSPWs.

(1) Use by a semiconductor manufacturer to treat silane gases ($SiCl_4$, SiF_4, $SiHCl_3$, SiH_3Cl, SiH_2Cl_2, etc.)

The packing and gas feed nozzle were becoming frequently blocked by SiO2 and other isomers generated by a tower designed to hydrolytically react exhaust gas or absorb and remove dust (see **Photos 2 and 3**). The risk of explosion made this cleaning work hazardous.

The following three improvements were made to the tower:

(i) The irregular packing that had been used was replaced with an MU-SSPW.

(ii) The flow of gas and liquid was changed from counter-current to co-current flow.

(iii) The gas feed nozzle was replaced with one that had no dead end.

Gases such as N_2, H_2, air, and He are fed to a double- or triple-tube gas feed line, and the problem of clogging caused by SiO_2 and other products of hydrolysis has been ameliorated.

The frequent need for hazardous cleaning work to be performed has thus been eliminated and a high level of safety assured. This case illustrates the experiences of numerous repeat customers, both in Japan and other countries.

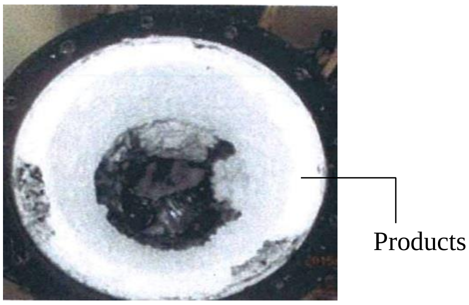


Photo 2

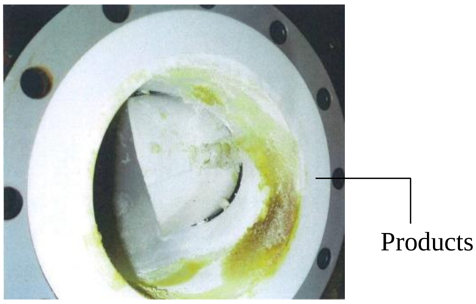


Photo 3

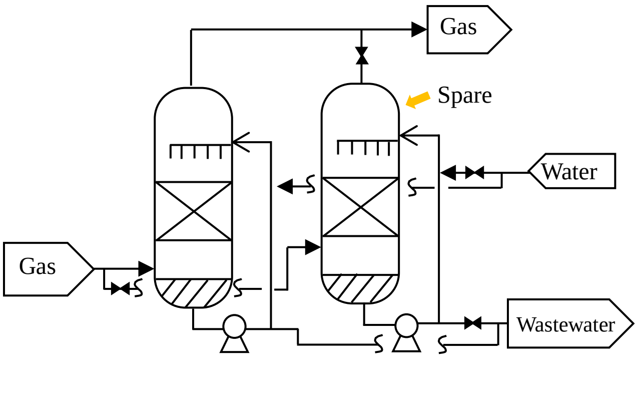
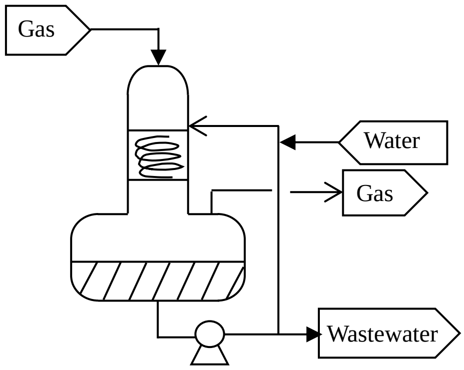
(2) Next, we describe the case of use of an MU-SSPW in an exhaust gas scrubbing tower at a petrochemical plant.

Exhaust gas used to be washed with water to remove the dust and VOCs that it contained. However, the irregular packing used would clog in three months and had to be replaced with spares. Although the SUS packing was incinerated and recycled each time, at least half had to be replaced with new material (see **Figure 2**).

Photo 4 shows an MU-SSPW being overhauled after 16 years in use. Although there is some discoloration of the wings, there is no clogging at all. A key aspect of this improvement is that use of the MU-SSPW allowed the direction of flow of the water and gas to be changed from counter-current to co-current, which meant that the tower could be made more compact.

As the purpose of the tower is reaction and dust removal, co-current flow is advantageous. The system was configured to remove dust at a gas superficial velocity of 5 m/s. Being able to create a co-current tower in this way is a major advantage of the MU-SSPW.

Figure 2

	Conventional system	Improved system
		
Cleaning frequency	Once every 3 months	Maintenance free for 16 years (since installation)
Gas superficial velocity	0.9 (m/sec)	5 (m/sec)
L/G L: water flow rate (l/hr) G: gas flow rate (m^3/hr)	2 (l/m^3)	6 (l/m^3)
Tower diameter	4.5 (m)	1.8 (m)
Differential pressure	10 (KPa)	< 100 (mmH_2O)
Composition Tower Element	 SUS304 SUS304	 FRP PVC

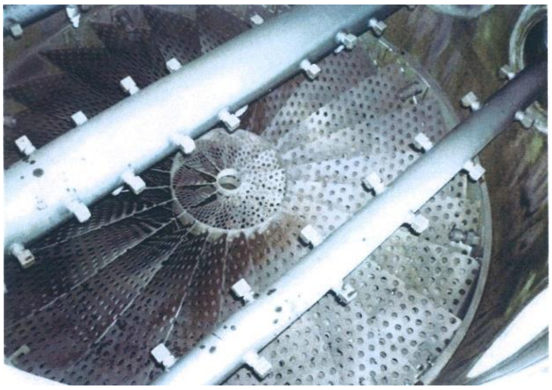


Photo 4

4. Actual application

In this section, we present one example of use of an MU-SSPW in a wet dust collector.

The dust-removing capabilities of a MU Scrubber (MU-SSPW) have already been described. A comparison with a bag filter (the typical conventional technology used) is shown in **Table 1**. In the comparison, the MU-SSPW and bag filter are used in an incinerator for disposing of radioactive waste.

While the only function of the bag filter is to collect dust, the MU-SSPW is capable of dust removal, gas absorption, and cooling. The critical particle diameter of the bag filter is 0.3 μm, and that of the MU-SSPW is 0.15 μm (depending on the substance). Gas velocity is 0.017-0.005 m/sec with the bag filter, and 5 m/sec with the MU-SSPW.

Note that the volume reduction factor and decontamination factor sections are blank. These factors are also important for preventing endless circulation when disposing of radioactive waste.

A scanning electron microscope micrograph of oxide A captured in the circulation fluid of an MU-SSPW system is shown in **Photo 5**, and the relationship between particle size and particle distribution of oxide B is shown in the **attached graph**. From Photo 5, it can be seen that the particle size of oxide A does not exceed approximately 2 μm. The average particle size of oxide B is approximately 0.5 μm, and the minimum particle size is approximately 0.15μm. Extensive experience shows that installing MU-SSPWs in series in a multi-stage configuration of two or three towers raises dust collection efficiency further. This benefit of using MU-SSPWs is one that cannot be provided by a bag filter system. By increasing the hydrophilicity of the cleaning water, dust collection efficiency is raised still further.

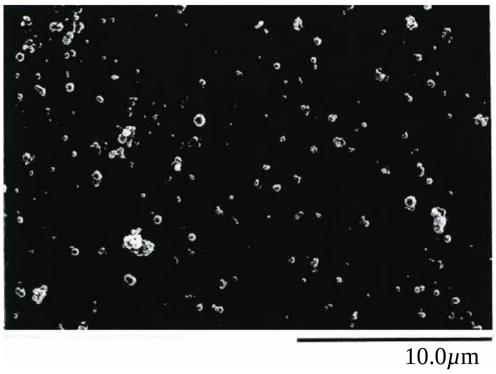


Photo 5

Attached Graph Particle size distribution of oxide B

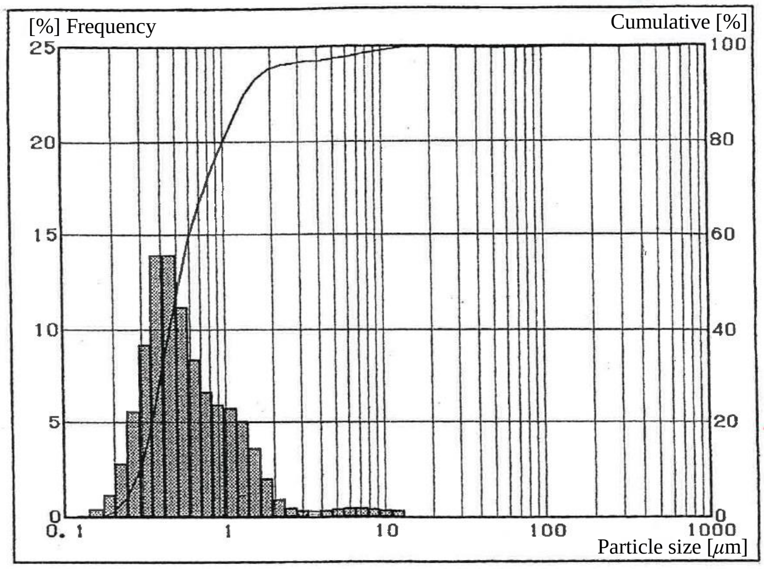


Table 1 Comparison of bag filter system and MU-SSPW system

	Bag filter system	MU-SSPW (MU Scrubber) system
Functions	Dust collection only	Dust removal Gas absorption Cooling
Principle/action	Captured by accumulation in filters	Captured in water solution through gas-liquid contact.
(1) Dust collection/removal efficiency	90% or higher	99.9% or higher (in 3-tower configuration)
(2) Critical particle diameter (μm)	0.3	Not more than 0.15
(3) Gas flow velocity (m/s)	0.017-0.005	5
(4) Pressure loss (KPa)	1-2	1.5-5
(5) Temperature	Up to 250 °C	Processable up to 1,200 °C
(6) Water content	Not suitable at high humidities	No issues
(7) Maintenance (times/year)	2-5 (depending on intake dust concentration)	Zero
(8) Cost of replacement of filter medium	High	Not used
(9) Form of radioactive waste	Solid (powder) / incinerated or solidified, buried, and stored.	Processing of solids made possible by magnetic

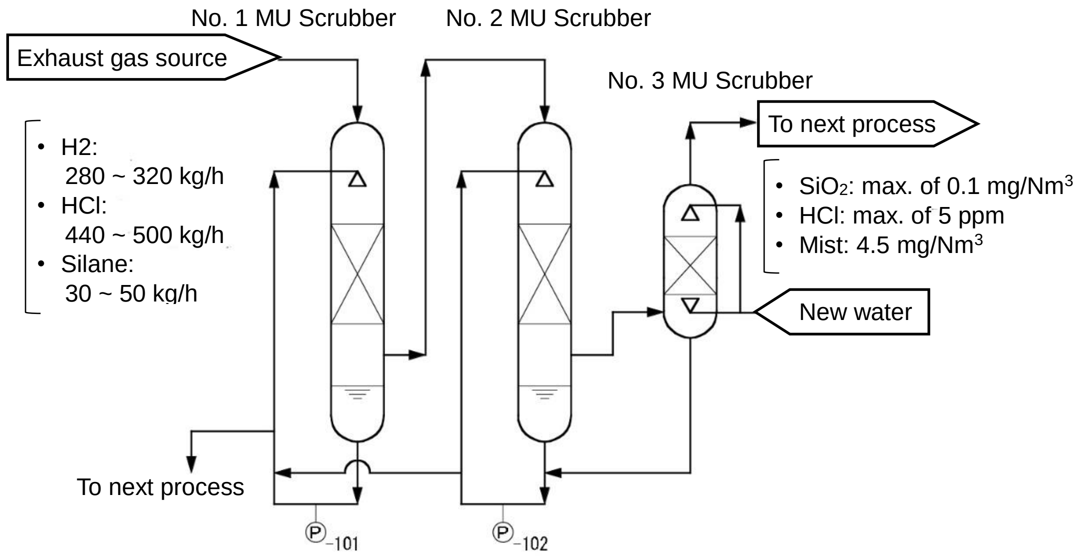
	If filter/filter media are incinerated, several reprocessing cycles are required.	processing of wash solution. Asphalt solidification / not susceptible to elution in water. Disposed of by storage.
(10) Installation footprint Area ratio (filter medium area: tower diameter)	Large 100	Very small 0.1-0.3
(11) Treatment of captured dust	Hard. Dust scatters into the surrounding environment when the filter is changed or shaken down, or shaken down dust is removed from the system.	Easy. Present in wash solution.
(12) Volume reduction /contamination factors	—	—

5. Example

5-1.

The MU-SSPW is used for hydrogen gas recovery and refining processes. **Figure 3** shows the flow sheet for an H_2 gas recovery and refining system. Exhaust gas consisting of 280-320 kg/h of hydrogen gas, 440-500 kg/h of HCl gas, and 30-50 kg/h of silane gas and cleaning water are supplied from the top of the No. 1 and No. 2 MU Scrubbers in a gas-liquid co-current configuration. SiO_2 and HCl are generated by hydrolytic reaction, and are captured and absorbed on the liquid side. The No. 3 MU Scrubber is provided to further raise the efficiency of capture of SiO_2 and to separate mist. Ultimately, refined gas containing a maximum of 0.1 mg/Nm^3 of SiO_2, 5 ppm of HCl and 4.5 mg/Nm^3 of mist is supplied to the next process.

Figure 3



H_2 gas recovery and refining system flow sheet

5-2.

The contribution to production costs of H_2 gas recovery and refinement may be calculated as follows. Assuming H_2 gas consumption to be 280-320 kg/h, the price of H_2 gas to be ¥1,000/kg, and annual operating time to be 8,000 hours, then

280-320 kg/h x ¥1,000/kg H_2 x 8,000 h/y = ¥2.24-2.56 billion

The MU-SSPW thus contributes to a cost reduction of ¥2.24-2.56 billion per annum.

5-3.

The capacity of a wet dust collector with built-in MU-SSPW is shown in terms of SiO_2 concentration after treatment in **Photo 5-02**. Tests demonstrate that when exhaust gas containing 2,400 mg/Nm^3 of SiO_2 is fed into a test system and gas flow velocity, liquid-gas ratio (L/G), gas-liquid contact time, and other variables are changed, the concentration of SiO_2 is reduced to a maximum of 20 mg/Nm^3 and white smoke is barely visible. It has also been demonstrated that the concentration of dust emitted from a bag filter and electrostatic precipitator can be reduced from tens or hundreds of mg/Nm^3 to several mg/Nm^3 or less. To date, this technology has been used to process 100,000 m^3/h of exhaust gas from a gas throughput of 60 m^3/h, and 120 units of this kind have so far been installed. The concentric arrangement of the MU-SSPW's spiral blades in two, three, and *n* layers makes scaling up easy, and systems with diameters of up to 3,000 mm can currently be made. This makes it possible to process large volumes of exhaust gas (180,000-240,000 m^3/h), resulting in high performance, energy and space savings, and zero maintenance requirements.

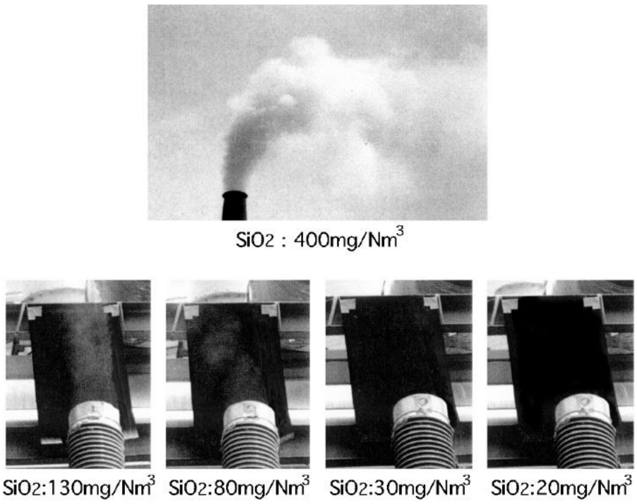


Photo 5-02 Capabilities of a MU Scrubber

6. Conclusion

The benefits of maintenance-free operation made possible by the MU-SSPW's unique self-cleaning action should be evident from the above, and we are confident that the MU-SSPW is the only element capable of combining high-efficiency gas-liquid contact with clogging prevention.

We conclude by considering two areas in which the MU-SSPW can contribute to industry and make the world a safer place for humankind. The first regards the fine radioactive particles carried by westerly winds to Japan. Measuring just 0.1 μm or less and invisible to the naked eye, these have emerged as a concern because even the ultra-low penetration air filters used in clean rooms are incapable of completely removing them from the air. This being so, it is impossible to eliminate the possibility that a single high energy radioactive fine particle might attach itself to an integrated circuit and so generate noise. The same problem exists in the field of ultrapure water production.

Fine particles measuring 2.5 μm or less in diameter, known as PM 2.5, also present an important and difficult challenge that will have to be tackled in order to minimize the impact on humans and the natural world in the 21st century. Guided by the principle of reaching ever higher and further, therefore, we are committed to pushing steadily ahead, step by step in spiral fashion, in pursuit of creative destruction through the further development and application of MU-SSPW technologies.

On a final note, the question we must now answer is: How can we manage risks in the near future and actively adopt cutting-edge technologies that would be rejected due to their lack of a proven track record? It is important to respect the ethics of the engineer, in other words, the ethics of human beings, and the scientific spirit, and this too appears to demand creative destruction.

Some clues as to how to proceed may perhaps lie concealed in the following words.

Time-being is time already in being, and all being in time.

Eihei Dōgen, *Shōbōgenzō* (“Uji”)

The cherry trees blossom

And we glow like will-o’-the-wisps,

Reflected upon still waters.

Michiko Ishimure, *Ten*

The petals fall, magnificent in their carefree demise …

The partyers, intoxicated by the cherry blossom, have gone,

But the petals continue their fall to the very end.

Choku Kanai, *Chiru Hi*

Working together with all our stakeholders, we are committed to surmounting all obstacles as we continue our quest to lower production costs and protect the global environment.

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