

## Improvements to Coke Oven Gas (COG) Refining Systems Using MU Mixing Elements

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Coke oven gas (COG) is a useful gas generated in the process of producing coke, which is made by baking coal and is needed by steel mills as a reducing agent.

So that it can be used, COG must be cooled and refined to remove dust, sulfur, cyanogen, ammonia, and other substances. These refining processes use refining towers containing various internals.

Below, we describe how refining systems can be dramatically improved by employing MU Company's "MU-SSPW (MU-Static Spiral Perforated Wings)" for these internals.

Using the MU-SSPW not only does away with the need for maintenance thanks to its non-fouling, non-clogging construction, which is its chief advantage, but it also yields synergies in the form of lower initial costs and running costs.

Among the many causes of clogging are dust, deposition of naphthalene, and formation of polymers, and eliminating the problem of clogging has long been a challenge regardless of the efficiency of the internals used.

We hope that you will choose to experience for yourself the contribution that the benefits of using the MU-SSPW explained below can make to long-running, outstanding plant performance.

### **Introduction**

The MU-SSPW represented a breakthrough in tower internals when it was brought to market 33 years ago, since when it has been put to a wide range of uses—including mixing, absorption, desorption, reaction, cooling, dispersion, distillation, and extraction—wherever liquids, gases, and powders are handled.

During that time, it has acquired an enviable reputation for its proven high performance, maintenance-free operation, energy efficiency, and space-saving (reduction of construction cost) characteristics. The MU-SSPW, which is a component of the MU Mixing Element, has

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drawn interest in recent years as a solution to the environmental challenges posed by emissions of exhaust gas and wastewater and the need to conserve energy.

## 1. About the MU-SSPW

1-1 The MU-SSPW consists of a cylindrical element, as shown in **Figure 1**. This comprises two types of agitator “wing”—one twisting clockwise and the other counterclockwise—that ensure high-performance gas-liquid contact efficiency. These wings are perforated to allow liquid and gas to pass through.

Liquid and gas are thoroughly mixed by the element through a process of repeated division, merging, inversion, and shearing. The idea of effecting dynamic motion in the radial and axial directions was inspired by the flow of a waterfall, surging downward like a cloudy white wave, and is the outcome of the pursuit of the ultimate matter and heat transfer between different fluids.

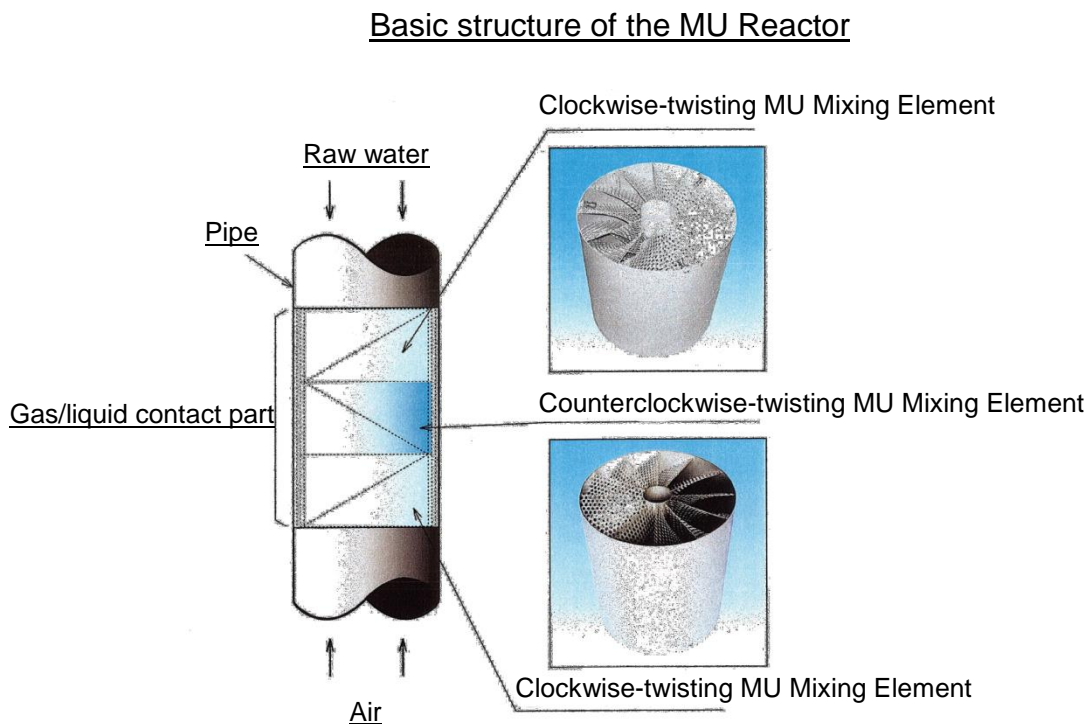


Figure 1 Basic structure of the MU-SSPW

1-2 **Figure 2** shows a comparison with the packing and trays that form the internals of conventional systems. Packing makes it easier for fluids to descend along the wall of a column and, conversely, for gases to blow through the center where resistance is lower.

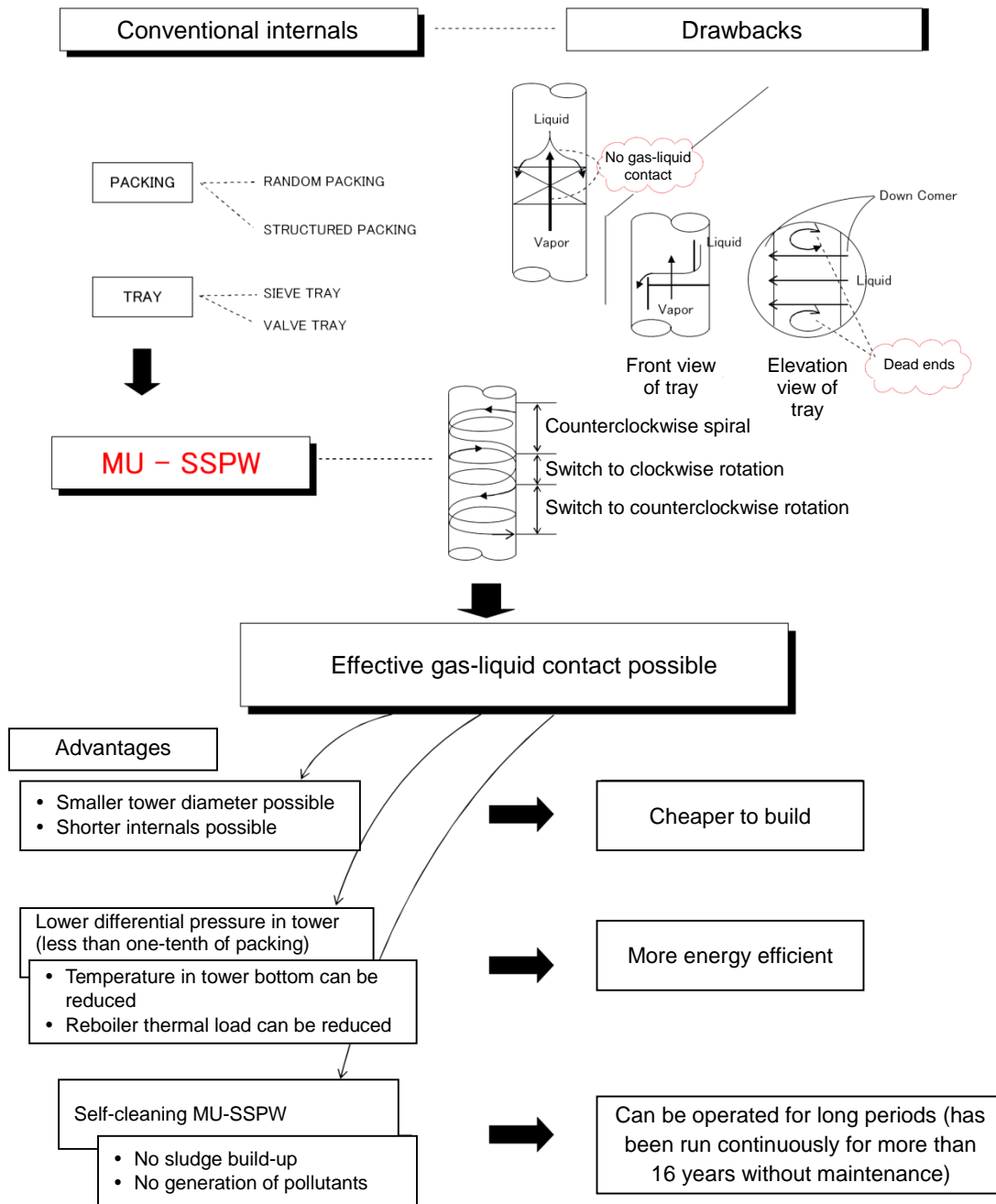


Figure 2 “MU-SSPW” M-Static Spiral Perforated Wings – a revolution in tower internals

Structurally, trays have dead ends that cause the flow of liquids to stagnate at each end of the tray floor. These require a downcomer part to change the direction of flow, and this reduces a tray’s effective area. Although manufacturers have tried various ways of ameliorating this problem, they have yet to find a definitive solution.

1-3 As explained in 1-1, the MU-SSPW is fundamentally different in concept from conventional internals.

## 2. Features of the MU-SSPW

The MU-SSPW offers especially outstanding performance in the following three respects.

- (1) Can be designed for gas superficial velocities of 2-6 m/s

This is considerably higher than with conventional internals, and is possible because of the low differential pressure and resistance to entrainment that result from the MU-SSPW's effective use of tower cross-section. It also has a high gas-liquid contact efficiency, which yields the following benefits.

Tower diameter can be halved or more compared with conventional internals, and the height of the internals can also be reduced. This allows the footprint as well as the column itself to be made more compact, and reduces the cost of construction.

- (2) **Figure 3** shows a comparison of pressure loss at low differential pressure.

These are the results obtained from tests on a water-air system. The MU-SSPW has a low differential pressure that is one-tenth that of packing, which means that the operating temperature at the bottom of a tower can be lowered. This helps save energy and prevent fouling.

- (3) The third and most well received aspect of installing a MU-SSPW is that it makes possible long-term stable operation.

As explained above, the MU-SSPW's structure ensures that liquid is repeatedly and dynamically inverted as it descends without creating any dead ends. The MU-SSPW is thus always automatically cleaning itself as it operates, as a consequence of which no sludge build-up or pollutants are generated and no blockages occur. Towers equipped with MU-SSPWs that have been repeatedly cleaned once every four months have been in continuous, maintenance-free operation for over 16 years.

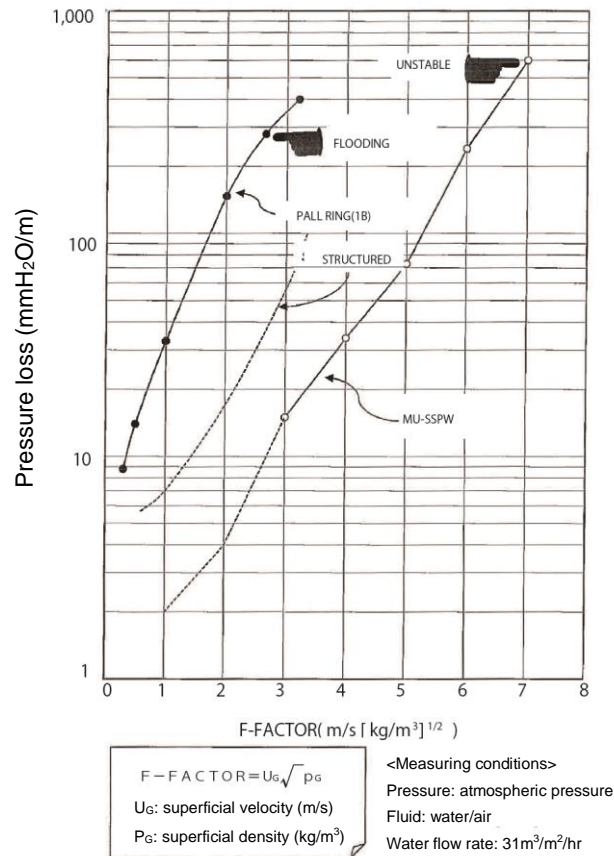
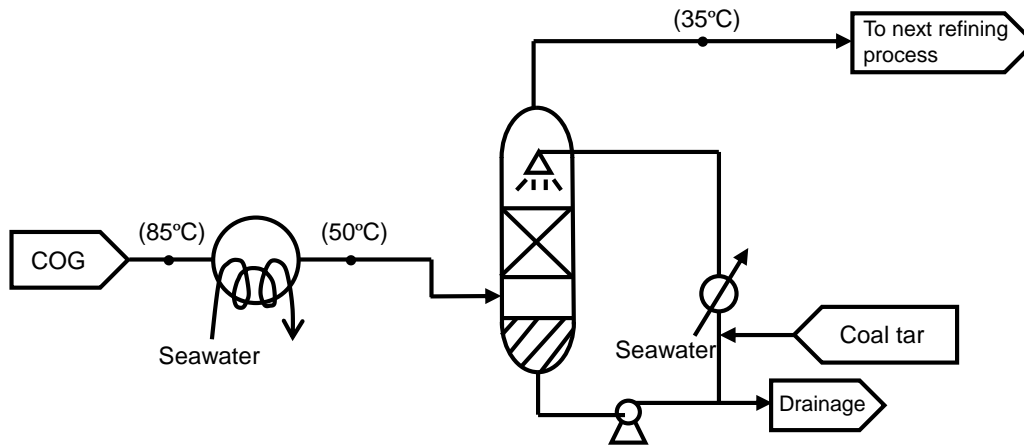


Figure 3 Pressure loss comparison (counter flow)

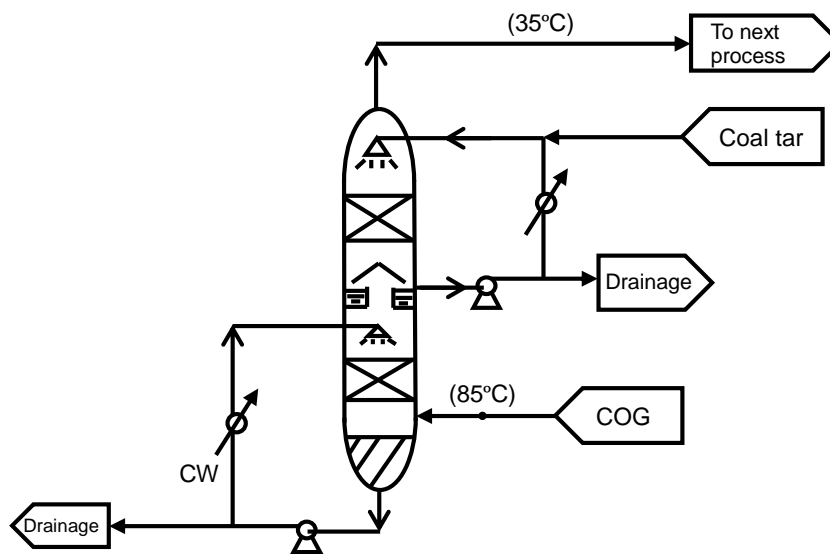
### Case studies

1. We begin by describing application of an MU-SSPW on a cooling, dust removal, and naphthalene removal line.
  - (1) Presently, 85°C COG is cooled to 35°C in two stages by combining an indirect cooler with a direct cooling tower. The naphthalene present in COG presents a particular problem, as it precipitates at 50°C and causes the indirect cooler to become clogged, making temperature control an important factor.



Although packing is used for the internals of the downstream direct cooling tower, its susceptibility to clogging by dust and naphthalene requires the tower to be modified into a spray tower or donut ring tower.

There also exist multi-systems that use only a direct cooling tower, and no indirect cooler, to cool and remove dust and naphthalene as follows.



All these systems employ the same packing and approach, making it hard to completely eliminate the impact of the dust and naphthalene that cause clogging. Due to their low gas-liquid contact efficiency, moreover, towers must have a large column diameter and deep packed bed, necessitating the use of large volumes of circulating fluid.

(2) Using MU-SSPW for the packing instead offers the following benefits.

(2)-1 The self-cleaning action that is the MU-SSPW's chief advantage makes possible stable long-term operation without clogging.

It is thus no longer necessary to have a spare direct cooler. The cost of maintenance required for cleaning can also be reduced.

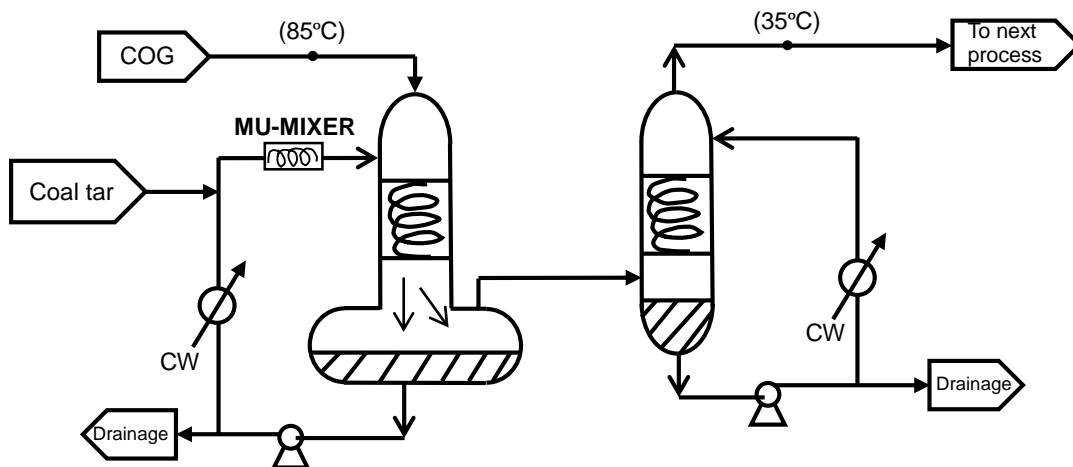
(2)-2 The tower can be made more compact.

Using an MU-SSPW is especially effective in the case of multi-systems.

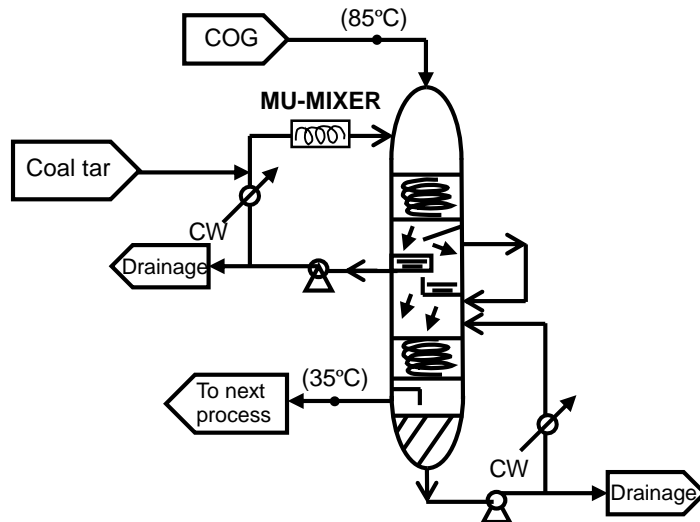
By also switching to a parallel-flow configuration (another advantage of the MU-SSPW), the problems caused by foaming and cladding are eliminated, and the diameter of the tower can be halved or more in comparison with conventional systems. This results in a more compact footprint and allows initial costs to be reduced.

Below we describe two examples of parallel-flow configurations.

Case 1 Combination of parallel flow and counter flow: Naphthalene and dust are removed from 50°C COG upstream, and the COG is then cooled to 35°C downstream.



Case 2 Combination of parallel flows only: Naphthalene and dust are removed from the COG at the upper stage, and COG is then cooled to 30°C at the lower stage. By combining solely parallel flows, foaming and cladding are completely eliminated, making it possible to operate at an in-tower gas velocity of at least 5 m/sec. The diameter of the entire tower can also be at least halved, making the system more compact.



(2)-3 More energy can be saved.

The above measures allow the volume of circulating fluid used by two coolers to be reduced by one third.

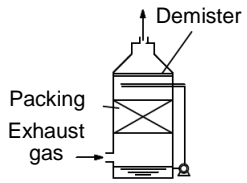
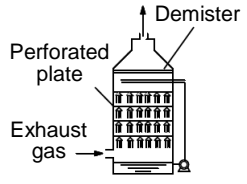
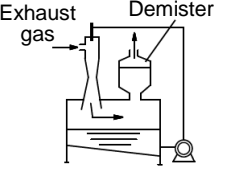
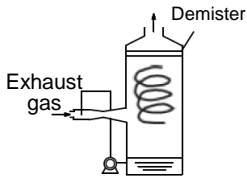
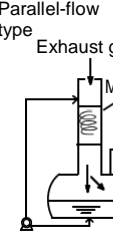
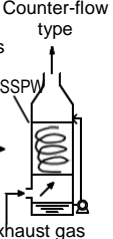
This makes it possible to use less cooling water and to cut power consumption by a large circulation pump by one third. This simultaneously allows the cooler and pump to be made more compact, and also contributes to the aforementioned reduction of initial costs.

2. Next, we suggest modifications to the desulfurization (reaction), decyanation (reaction), and deammoniation (absorption) processes that comprise the next stage of the COG refining process.

As the following comparative table shows, these processes conventionally use methods that offer poor gas-liquid contact efficiency. By using a parallel-flow MU-SSPW for the reaction stage and a counter-flow MU-SSPW for the absorption stage, it becomes possible to enjoy the same benefits as those described in 1 above.



Comparison of MU-SSPW and conventional internals

			Gas-liquid contact efficiency	Differential pressure	Tower diameter	Energy efficiency	Fouling and clogging	Remarks
Conventional types	Packed tower		Medium	Medium	Large	Low	High	Next commonly used type after spray towers, they are vulnerable to clogging.
	Perforated plate tower		Medium	Medium	Large	Low	High	
	Jet scrubber		Low	Low	Medium	Low	Medium	Performs almost as well as a spray tower and is resistant to fouling, but gas-liquid contact efficiency is poor.
	Venturi scrubber		Low	Low	Medium	Low	Medium	
MU scrubber	<div style="display: flex; justify-content: space-around;"> <div style="text-align: center;"> <p>Parallel-flow type</p>  </div> <div style="text-align: center;"> <p>Counter-flow type</p>  </div> </div> <p style="text-align: center;">Exhaust gas</p>	High	Low	Small	High	None (has run maintenance-free for 16 years)	Optimized by using parallel-flow and counter-flow types according to application (reaction or absorption).	

## Conclusion

While the focus of this paper was on explaining how the MU-SSPW can be used to improve the dust removal, cooling, reaction, and absorption functions of the COG refining systems used at steel mills. The MU-SSPW is used and offers proven superiority in a wide a range of other applications, including mixing, desorption, separation, distillation, and extraction.

Thirty-three years after our foundation, we are committed more than ever to taking on fresh challenges, one step at a time, in pursuit of further technological innovations.

In the steel industry, which has towered over other basic industries in importance to the state, there is a strong need for better performance, greater energy efficiency, smaller space requirements, lower carbon dioxide emissions, and other improvements in recent years in order to withstand international competition.

The MU-SSPW has an extensive track record as a means of removing sub-micron dust and treating the acid gas emitted by plants that produce silicon dioxide ( $\text{SiO}_2$ ), which is the main raw material used to make the semiconductors that in Japan have been dubbed the “rice of industry.” It is also used as a radon stripper that can desorb, at vapor-liquid equilibrium, the trace amounts of radon (Rn) present at a level of 0.1-10 mBq/m<sup>3</sup> in ultrapure water at the Super-Kamiokande neutrino observation system operated by the University of Tokyo’s Institute for Cosmic Ray Research.

Building on these achievements, we aim to expand our business with the steel industry while at the same time contributing to reducing production costs, protecting the global environment, and enhancing international competitiveness by creating innovative technologies out of conventional ones, all the while guided by the idea that “the great image has no form” (*da xiang wu xing*).