New Products

Compact Water Purification Unit

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1. Introduction

The act of preventing bacteria and viruses from multiplying is called inactivation. Inactivation by ultraviolet rays contained in sunlight has been used since ancient times, including sun-drying. Ultraviolet rays are classified into UV-A, UV-B, and UV-C according to their wavelengths. In particular, UV-C with a wavelength of 100 ~ 280 nm is called deep ultraviolet rays and have a particularly high inactivation capability (**Fig. 1**). Deep ultraviolet rays do not naturally exist on the earth because they are absorbed by the ozone layer before sunlight reaches the earth's surface. Deep ultraviolet rays are used for disnfection in various applications due to their inactivation effect.

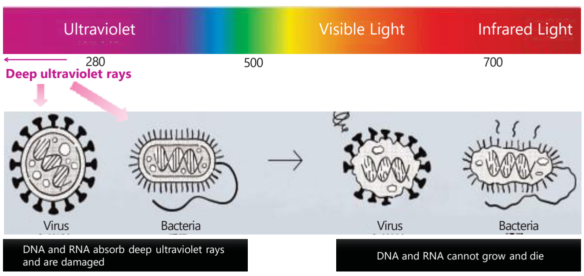


Fig. 1 Wavelength of light and inactivation effect

Water sterilization using mercury lamps is used for water treatment in large-scale facilities such as water purification plants and aquaculture farms. In recent years, as a result of increasing the output and efficiency of deep-UV LEDs, they have been installed in heat pump water heater for baths, which requires a small sterilization device that cannot be feasible with conventional mercury lamps. Toyoda Gosei has been mass-producing a water-cooled compact water purification unit (**Fig. 2)** using deep-UV LEDs since 2022.

We have developed an air-cooled compact water purification unit with high inactivation performance, a slim shape that can be easily accommodated in piping space, and continuous lighting with a small heat sink.

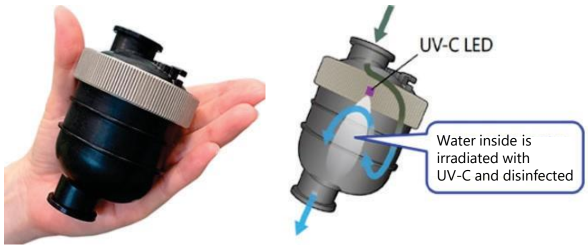
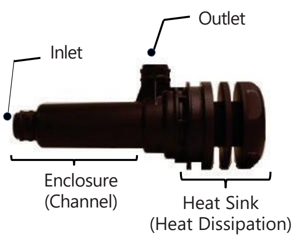


Fig. 2 Water-cooled water compact purification unit equipped with heat pump water heater for baths

2. Overview of the product

Fig. 3 shows the appearance of the product. Water flowing in from the inlet is irradiated with deep ultraviolet light to inactivate bacteria in the water and flows out from the outlet.



Item	Spec
Current Value	350mA
Flow Rate	0.5~2l/min.
Electric power	<3W
Escherichia coli inactivation rate (1 L/min)	99.999%
Size	120mm × Φ41mm
Joint	Rc1/8

Fig. 3 Product Specifications

Fig. 4 shows a schematic diagram of water flow and ultraviolet light irradiation. Light from a deep ultraviolet LED installed inside is irradiated in the direction of water flow. Heat generated by the LED is dissipated by a heat sink.

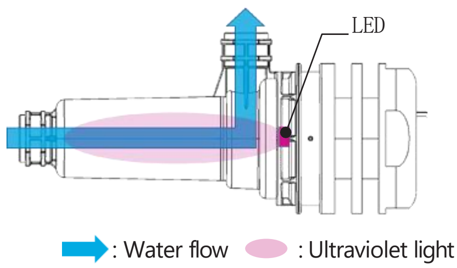


Fig. 4 Schematic diagram of water flow and ultraviolet irradiation

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This product can handle the flow rate from 0.5 L/min to 2.0 L/min and operates at a low power of less than 3 W. The inactivation performance is 99.999% for E. coli at a water flow rate of 1 L/min.

3. Key points of development

3 - 1. Heat Dissipation Design for Continuous Operation

The first feature of this product is that continuous operation is possible by air cooling using a heat sink. **Table 1** compares water cooling and air cooling. The biggest advantage of the air cooling method is that it allows for dry-run operation, which enables ultraviolet treatment even when water is not flowing. It can reliably irradiate ultraviolet rays to water flowing irregularly or to applications with short water passing intervals.

Table 1 Comparison of cooling systems

Cooling system	Water cooling	Air cooling
Body size	Small	Larger than water cooling
Heat sink	Not required	Required
Empty heating operation	Not possible (several seconds)	Continuous operation possible

Heat dissipation using a heat sink requires efficient transfer of heat generated from LEDs to the heat sink and to air (**Fig. 5**). Although heat dissipation can be improved by installing a cooling fan, etc., there is a risk of failure. In order to realize natural air cooling without using a fan, an optimal shape was derived using thermal simulation. **Fig. 6** shows the results of heat dissipation simulation. It can be seen that the temperature of the heat sink is uniformly spread, and the heat dissipation effect is maximized. The slit shape, etc., was set in consideration of surrounding air convection, etc.

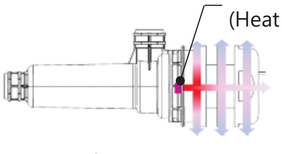

Fig. 5
Schematic of LED Heat Generation Cooling

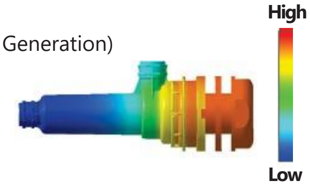

Fig. 6
Thermal Simulation Results

3 - 2. Improvement of Inactivation Performance

The UV irradiation dose (UV irradiation dose mJ/cm$^{2)}$ required to inactivate bacteria and viruses has been experimentally determined. In order to efficiently utilize UV light emitted from LEDs and to improve inactivation performance, it is necessary to uniformly irradiate light with uniform water flow and UV irradiation distribution.

The simulation results of water flow and UV radiation distribution are shown in **Figs. 7 and 8**, respectively. It can be confirmed that the water flow is uniform from the inlet to the outlet, and the UV radiation distribution is uniform in the channel.

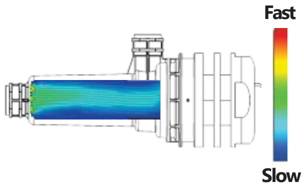

Fig. 7
Water flow distribution

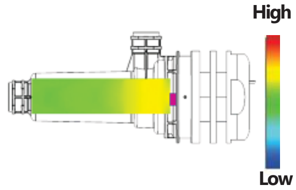

Fig. 8
UV Irradiation Distribution

As a result of the above study, a unit with high inactivation performance was realized. **Fig. 9** shows the evaluation results of the inactivation rate of this product at a flow rate of 1.0 L/min for Bacillus subtilis, Pseudomonas aeruginosa, and Escherichia coli.

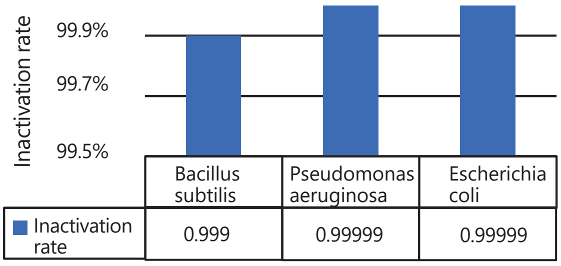

Fig. 9 Inactivation rate for each species

It was demonstrated that the inactivation rate was more than 99.9% for all bacteria. It is expected that UV irradiation can be applied to a wide range of products for various bacteria and viruses.

4. Summary

This compact water purification unit, which is capable of dry-run operation, can be installed in various types of equipment and is considered applicable to many water inactivation needs. By utilizing this technology, we will promote the development of smaller and more efficient products that meet the needs of society.

Acknowledgments

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We would like to express our sincere gratitude to everyone involved in the development and design of this product.

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