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Internal Cleaning Device for Closed Reactor based on Magnetic Force

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Abstract

In this paper, through the preliminary exploration of the process of the magnetic field generated by the energized solenoid to push the magnet to move, a non-disassembly cleaning method suitable for the instrument in which the components inside the closed cavity are arranged in parallel along the axis is proposed and a basic cleaning method based on this method is made. In the device model, the effective magnetic circuit length of the coil is reduced by adjusting the magnetic gap distance, and the remote control function is added to realize the non-dismountable cleaning of the inside of the closed reactor.

Keywords

Airtight Instrument; Magnetic Force; Cleaning Method; Remote Control.

1. Introduction

Whether in industry or in life, the internal cleaning of enclosed instruments often limits the development of such instruments. The stain deposition of the water treatment reaction instrument after working for a long time makes people have to consider the internal cleaning after the instrument has been used for a period of time. For example, the increasingly mature ultraviolet sterilization device is used in the treatment of ship's ballast water. The ultraviolet radiation dose is a key physical quantity to measure the ultraviolet sterilization ability. Only when the radiation dose distribution of the ultraviolet sterilizer is very uniform, In order to ensure that the sterilization effect can meet the requirements. The penetration ability of ultraviolet rays will be affected by the turbidity of the ballast water. In addition, the dirt of the tube sleeve of the ultraviolet lamp also causes the sterilization ability to decrease. Generally, the tube cover can be cleaned with alcohol-soaked gauze once every six months, or it can be scrubbed with polishing powder, but it is difficult to ensure that the UV sterilization device is always in good condition in the closed ballast water pipeline.In order to improve industrial efficiency and improve the quality of life, it is necessary to find a convenient and practical way to clean the inside of a closed instrument that does not need to be disassembled.

2. Current Status of Research on Internal Cleaning Technology of Airtight Containers

2.1 Ultrasonic cleaning

Ultrasonic cleaning technology is widely used in industry, medical equipment, chemical industry and other fields. The cleaning purpose is achieved through the use of ultrasonic cavitation. This technology has certain significant effects in terms of speed, accuracy and effect. Lu Li conducted research and analysis on the application of ultrasonic cleaning technology in the industrial field, optimized the sound field distribution, and affirmed the prospect of ultrasonic combined technology in the field of ultrasonic cleaning. Xiaosong Zhu designed and developed online automatic flaw

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detection equipment for the cleaning of bearing rings. Based on the current problems of ultrasonic cleaning technology, Huang Zhichao puts forward the development research recommendations of ultrasonic cleaning technology and the development direction of the device.

2.2 Hydraulic and mechanical cleaning.

Hydraulic and mechanical cleaning technology is more common in industry and life. Chun Liu analyzed the flow of cleaning fluid inside aviation pipe fittings, and provided an important reference for cleaning equipment design optimization and cleaning parameter settings. Tianlan Yu proposed a new spiral automatic cleaning technology for fluid dirt in the pipe. This technology is optimized in terms of angle, resistance, and pitch, but it is easy to wear and high maintenance costs.

2.3 Magnetic cleaning.

There are few reports about the application of magnetic force to cleaning technology.Gai Yang designed and invented an electromagnetic-driven energy-saving dual-axis motor shaft cleaning device, which improves the cleaning effect by contacting the shaft and the brush.

3. Design of automatic cleaning device driven by magnetic force

3.1 Fundamental principleg.

The magnetic cleaning device is composed of a control circuit, cleaning device and magnetic drive element. The control circuit is set outside the instrument and consists of a low-power DC stabilized power supply, a raspberry pie, and a motor drive. The cleaning deviceand which main body is a slider with magnetic poles is set on the inner shaft of the instrument. The magnetic drive element which the main body is a solenoid is installed on the outer shaft end of the container.

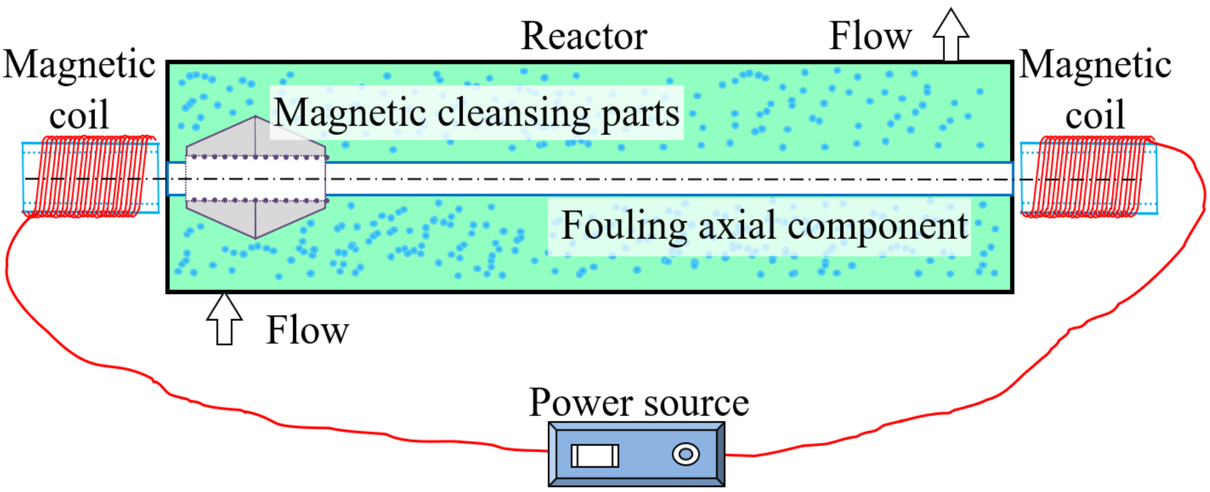

Fig. 1 Schematic diagram of magnetic cleaning device

The specific working principle is that the Raspberry Pi generates a logic signal and the motor drive board generates a current whose direction changes periodically and outputs it to the solenoids arranged at both ends of the enclosed instrument. The controllable magnetic field on the coil applies power to the cleaning device installed on the shaft to be cleaned, and the cleaning device moves along the shaft with the magnetic field for cleaning work.

3.2 Main component.

3.2.1 Magnetic cleaning device

The magnetic cleaning device is mainly composed of a permanent magnet inner core and a plastic shell adapted to the shape of the shaft part.

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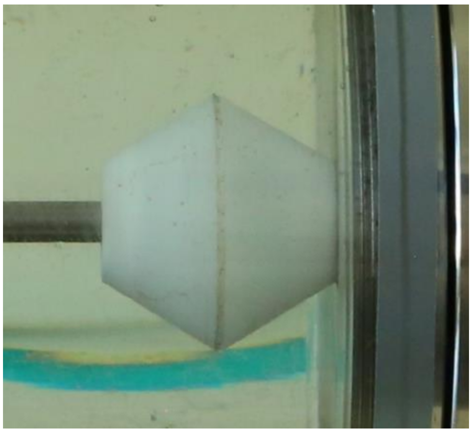

Fig. 2 Magnetic slider

3.2.2 Control circuit

The Raspberry Pi provides logic signals (PWM) for the 15A motor drive board. The 34V power supply powers the 15A motor drive and the motor drive board transmits the direction, size and cycle controllable current to the solenoid to generate a controllable magnetic field.

Fig. 3 Magnetic slider

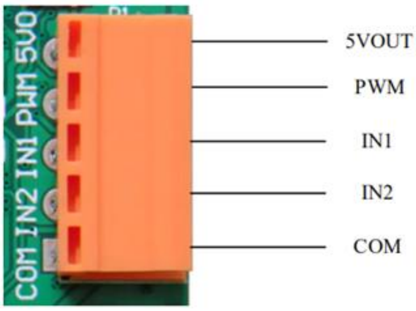

Fig. 4 Logic control part

Table 1. Output results corresponding to different logic controls

IN1	IN2	PWM	OUT
0	0	×	Stop pushing
1	1	×	Hang
1	0	1	Full-speed positive magnetic propulsion
0	1	1	Full speed reverse magnetic propulsion
1	0	PWM	Positive magnetic push
0	1	PWM	Reverse magnetic push

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3.3 Network layert.

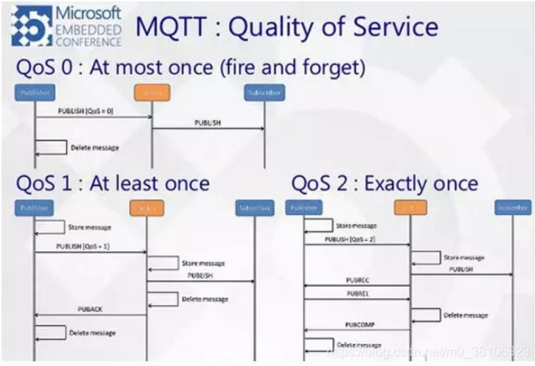

Fig. 5 Quality of Service

The communication layer is mainly responsible for the sending and receiving of client/server messages. The use of MQTT by WeChat applets is realized through the Websocket network layer.

The realization of the MQTT protocol requires the completion of the communication between the client and the server. In the communication process, there are three identities in the MQTT protocol: publisher, broker, and subscriber. Among them, the publisher and subscriber of the message are both clients, the message broker is the server, and the message publisher can be the subscriber at the same time.

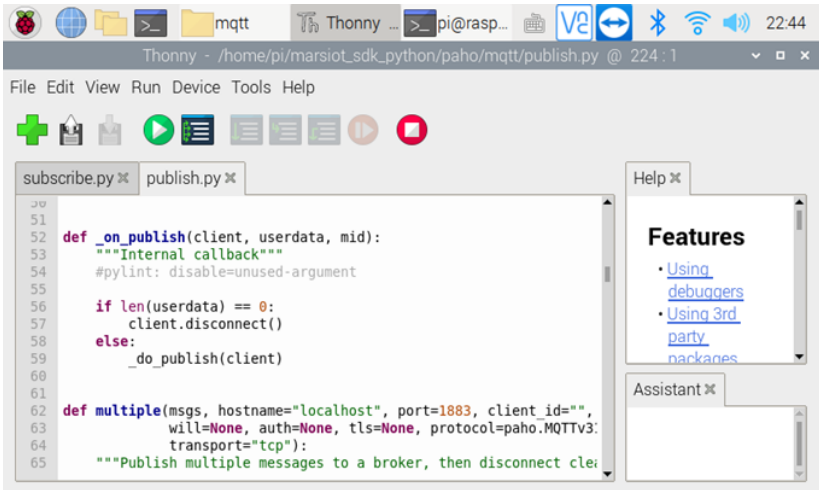

Fig. 6 MQTT publish

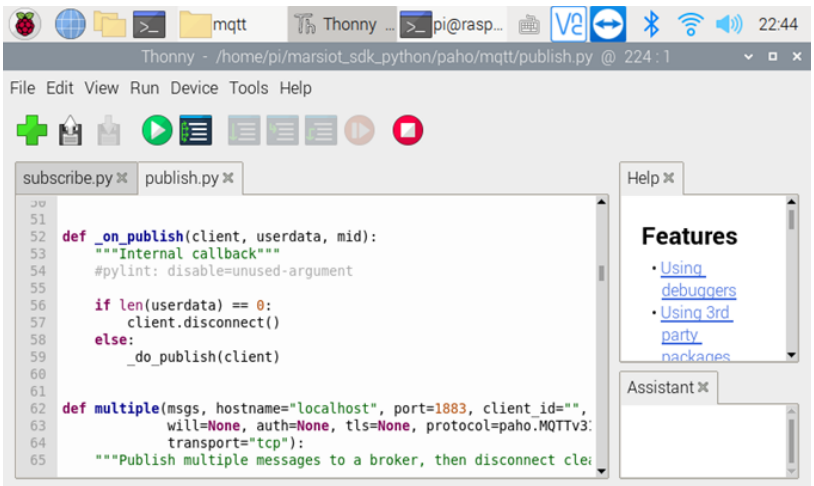

Fig. 7 MQTT subscribe

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3.4 Application layer.

We can publish instructions to the terminal and execute them on the cleaning device by clicking a button on the WeChat applet. As shown in the figure, we have buttons such as full speed, forward advance, reverse advance, and stop, which represent logical control signals composed of GPIO18, 23, and 23 on the Raspberry Pi. When we click the button, the server will publish instructions and be executed by the motor drive module.

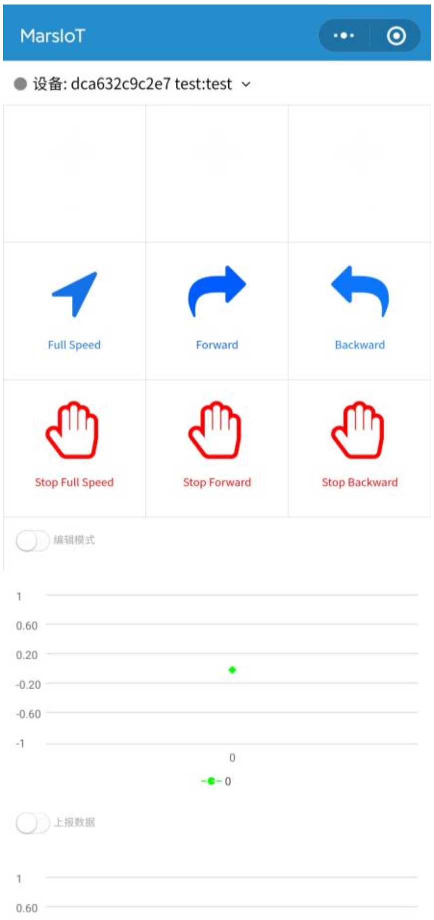

Fig. 8 WeChat applet interface

4. Theoretical Analysis of the Process of Magnetism

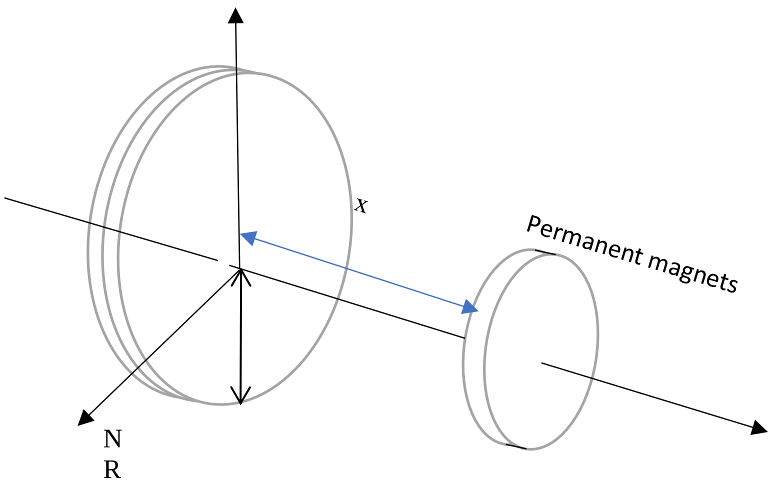

Fig. 8 Simplified schematic diagram of magnetic cleaning device

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If the superposition of the magnetic field is simplified, the magnetic field force received by the magnetic cleaning device is only regarded as the collection of all the magnetic charges in the unilateral magnetic pole by the magnetic field strength of the energized coil. The magnetic field generated by the energized solenoid is regarded as the superposition of the magnetic field generated by a large number of dense circular current-carrying wires. Under the above conditions:

$$F \propto \frac{R^2 IN}{2(R^2+x^2)^{\frac{3}{2}}} \tag{1}$$

In the formula, F is the force of the magnetic cleaning device, and the direction is away from the coil along the axis. R is the radius of the coil. I is the coil current. N is the number of turns of the coil. x is the distance between the magnetic pole face of the permanent magnet and the coil end face in the cleaning device.

Basic conclusion: The force of the cleaning device is positively correlated with the current and the number of turns of the coil, and negatively correlated with the distance between the end faces and the radius of the coil.

5. Experiments of the magnetic drive process

5.1 Design of the experimental model

In the experiment, the acrylic tube was used to simulate the water treatment reaction instrument, and the acrylic glass rod set in the center was cleaned. By constantly changing the relevant initial conditions of the experiment, determine the impact of changes in various conditions on the operation of the magnetic cleaning device.

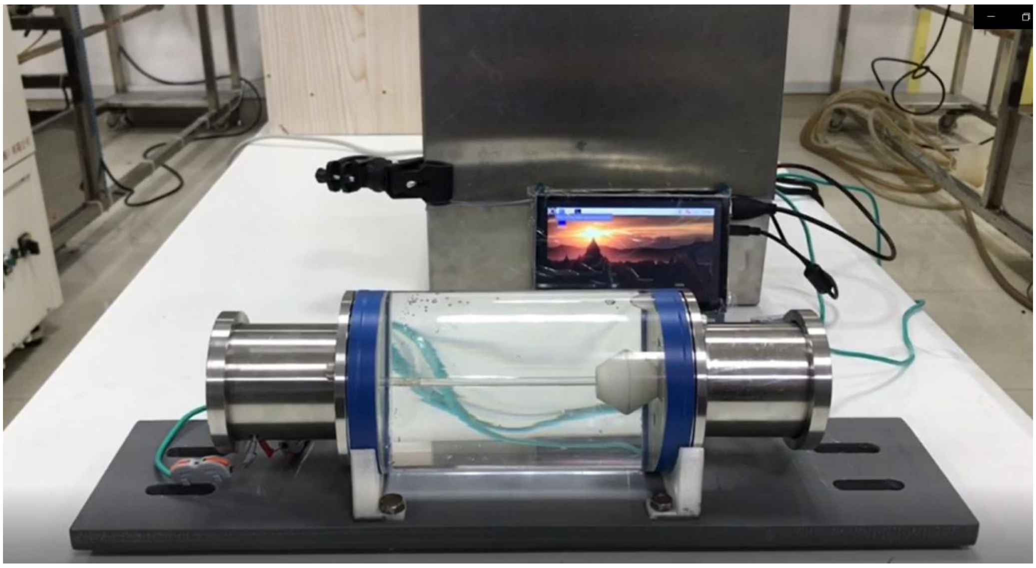

Fig. 8 Physical map of experimental model

5.2 Experimental performance and analysis (Change the magnet size experiment in the magnetic cleaning device)

According to the theoretical formula, when the magnetic field generated by the coils at both ends remains unchanged, the size of the magnet itself will affect the magnitude of the magnetic field force. In fact, the main resistance that the magnetic cleaning device overcomes when it moves is also related to its own size. In this experiment, other conditions will be fixed, the size of the magnet in the magnetic cleaning device will be changed, and the comparative experiment data will be recorded.

Experiment accessories: three-layer 1.08mm enameled wire spiral coil

Experimental conditions: 2.0cm apart, coils on both sides connected in series

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Table 2. Statistical table of experimental data for changing magnet size

Time(min)	Voltage (V)	Waiting current (A)	Operating current (A)	Temperature of coil 1 (℃)	Temperature of coil 2 (℃)
Magnet with a diameter of 50mm, a thickness of 10mm, and a hole diameter of 10mm					
0	9	9	8.9	21.5	21.5
1	9	8.7	8.5	34.8	36.4
2	9	8.6	8.5	39.6	41.2
3	9	8.5	8.1	41.9	43.3
4	9	8.4	8.2	43.9	45.3
5	9	8.4	8.2	45.8	47
6	9	8.3	8.1	47.9	49.3
7	9	8.2	8	50.3	51.5
8	9	8.2	8	51.8	53.3
9	9	8.1	7.9	53.5	54.8
10	9	8.1	7.9	55.9	57.2
Magnet with a diameter of 20mm, a thickness of 10mm, and a hole diameter of 10mm					
0	4.8	4.8	4.7	21.8	21.8
1	4.8	4.7	4.7	25.9	25.9
2	4.8	4.7	4.7	26.8	26.9
3	4.8	4.7	4.5	27.5	27.9
4	4.8	4.7	4.5	28.4	28.6
5	4.8	4.7	4.5	29	29.2
6	4.8	4.7	4.5	29.5	29.9
7	4.8	4.7	4.5	30.6	30.9
8	4.8	4.7	4.5	31	31.2
9	4.8	4.7	4.4	31.3	31.7
10	4.8	4.6	4.4	32	32.4
Magnet with a diameter of 20mm, a thickness of 5mm, and a hole diameter of 10mm					
0	4.2	4.2	4.1	22.8	22.8
1	4.2	4.2	4.1	25.9	26.1
2	4.2	4.2	4.1	26.9	27
3	4.2	4.1	4.1	27.3	27.6
4	4.2	4.2	4.1	27.7	27.9
5	4.2	4.1	4	28	28.2
6	4.2	4.1	4	28.5	28.7
7	4.2	4.1	4	29	29.4
8	4.2	4.1	4	29.5	29.7
9	4.2	4.1	4	29.7	30
10	4.2	4.1	3.9	30.1	30.4

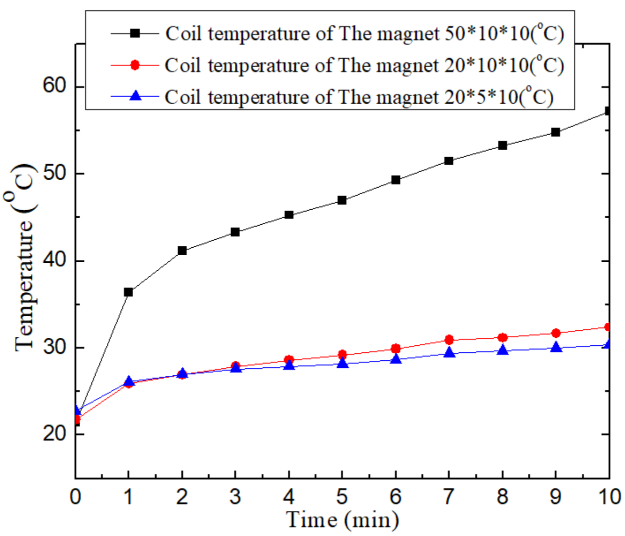

Fig. 9 Coil temperature change

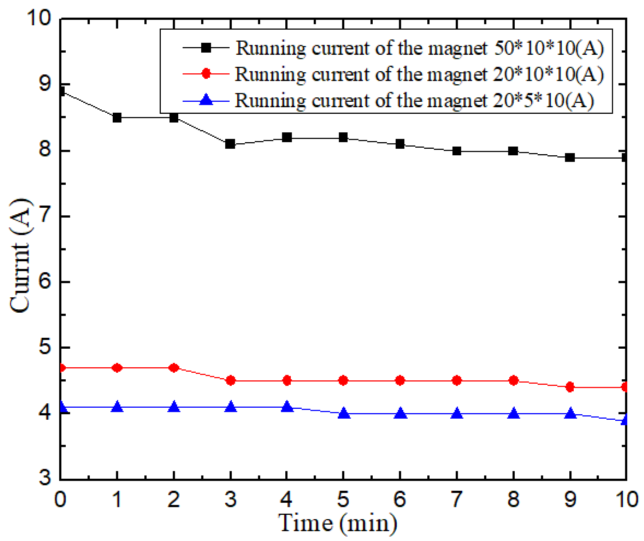

Fig. 10 Operating current changes

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Change magnet experiment data analysis:

For this experimental device, the input power is significantly reduced after reducing the magnet diameter from 50mm to 20mm, and the input power is also reduced after reducing the magnet thickness from 10mm to 5mm.The experiment can draw conclusions based on the theoretical formula of the force of the magnet in the magnetic field and the assumption of the resistance of the magnet to the movement. Under certain conditions, adjusting the size of the magnet has an important effect on the energy consumption of the cleaning device.

5.3 Experimental phenomena

Effect picture of the middle acrylic rod before and after cleaning:

Fig. 11 Before cleaning

Fig. 12 After cleaning

6. Conclusion

In this research, the magnetic drive cleaning device has realized remote control and intelligent control. The key optimization of the device is to think about how to use less energy to generate a stronger magnetic field and reduce the heat generated by the electromagnetic coil. The conclusions under some variable conditions are only limited to the simulated experimental device of this size specification. However, it is undeniable that many general scientific conclusions have been obtained through this research, and the model is suitable for multiple scenarios, such as cleaning of ultraviolet lamps in ship's ballast tanks and non-detachable cleaning of overflow UV lamps.

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