ISSN: 0974-5823 Vol. 6 No. 3 October-December, 2021

International Journal of Mechanical Engineering

Development of Smart Assembly Type Water Purifier Considering Function

Doo-Sung Baik*

Professor, Mechanical Engineering, Daejin University, Pocheon, Korea,
dsbaik@daejin.ac.kr

Abstract—

A water purifier is a device that removes impurities by filtering raw water through a filter. These water purification systems, with various functions such as large-capacity and home use, are being redeveloped and reengineered. Due to consumers demands in recent years, many products related to water purifiers and various types of water purifiers have been released. In general, large capacity purifiers are needed in schools, government offices, and workplaces, but for home use, not only are functions important but also exterior design is important, so it plays an important role in the development of the electronic product. On the other hand, looking at the world's water supply and demand, the demand is gradually increasing in areas where water supply is depleting, and the quality of water is getting worse. Therefore, the bottled water industry is increasing, but the use of self-filtering water purifiers is also increasing and rapidly. Water purifiers play a very important role in terms of environment and health. In current water purifier management systems, filter replacement is mainly done by visiting technicians. However, in the busy modern society, a door-to-door management service is inconvenient for water purifier managers and consumers; both waiting for and meeting technicians and representatives. The aforementioned problems can be overcome if the water purifier system manages itself or at least provides information related to the water purifier system so that the consumers can manage and maintain the system independently. In this study, in order to secure the efficiency of the water purifier management service, a modular water purifier was developed that allows the consumer to directly manage the filter by delivering the filter in a timely manner so that the consumer can manage the system directly.

Keywords— Water purifier, Filter, Cooling Technology, Compressor, Bacterial Reproduction

1. INTRODUCTION

A water purifier is a liquid filtration device manufactured to meet the water quality standards of drinking water through physical, chemical and biological processes or a combination thereof. It can be defined as an appliance with the function of reducing contaminants contained in influent water.

Water purifiers are sold for home use after technological developments allowed for smaller sized filtration systems. In addition, water purifiers are divided into Ultra Filtration water purifiers and Reverse osmosis water purifiers according to the level of removal of impurities in the applied filter. In addition, according to the function, they can be divided into cold and hot water purifiers, cold water purifiers, and general water purifiers. And since 2000, ice and cold and hot water purifiers have been developed and sold by applying ice-making and defrosting functions.

There are direct-water type purifiers that are directly connected to the faucet and storage type purifiers that put water into a container and pass it through a filter. The storage type water purifier includes a water tank that stores water purified through the filtration system. Depending on the function of the product, it is stored in cold or hot water tanks and is maintained at a constant temperature through a cooling or a heating device, so that a large amount of water can be used at once. However, since the purified water is stored a period of time, there is a risk of watering, bacterial growth, etc., so regular management is required. However, direct-water type water purifiers receive water from raw water connected without a storage tank, purify water through a filter, and then connect directly to the water intake port, thereby reducing the risk of contamination and saving energy because there is no need to maintain the filtered cold and hot water at a constant temperature. However, there is a disadvantage in that the amount of cold or hot water is may be insufficient [1].

Many technologies applied to water purifiers, such as cold water, hot water and ice making, have reached maturity. However, applying this technology to consumer products had a great response from customers in the market, and as a result the development of miniaturized water purifiers and complex water purifier products that are integrated with other home appliances are gradually increasing. According to the function, they can be divided into ice water purifiers, functional water (carbonated water, hydrogen water, etc.) purifier, refrigerator built-in water purifiers, portable water purifiers, etc. Further, multifunctional fusion products that can generate functional water are increasing. Smart home construction through IoT technology is in full swing, and the function of the water purifier is remotely controlled through a smartphone app, and filter orders, A/S requests, and warning notifications are provided through monitoring of water quality, internal contamination level, filter replacement cycle, etc. of the water purifier. It is expected that such products will be launched.

The existing water purifier system was functionally divided into four system modules. Looking at the details, a water purification module, a cold water module, a hot water module, and joint parts connecting the modules have been developed. In addition, since the existing water purifier replaces the filter based on the usage time, rather than actual usage, the propeller type electricity water meter was also developed because if the filter is not properly managed, economic loss may occur and cause a sanitary risk. When using purified water, the digital water meter analyzes the blade rotation speed, and, according to the flow speed in the impeller method that meter informs the consumer with respect to the filter replacement time so that the filter can be replaced at a more appropriate time. Moreover, this water purifier was developed with an external control technology for the water purifier system that provides information on the operation status and management history of the water purifier by combining IOT and ICT technology. The external control technology of the water purifier includes a sensor unit that collects information on the water purifier, a control unit that analyzes the operating state, a memory unit that stores information, and a communication port that relays information transmission to an external inspection device. Through this, an intelligent water purifier system that can check and manage the water purifier quickly and conveniently has been developed by checking the current status of the water purifier and the contents of services and defects created by using the water purifier [2].

As such, various water purifiers are currently on the market, and there are many changes in the water purifier market. Water is recognized as an important source of health, and we are entering an era of new water purifiers on the market. It is true that the spread of such water purifiers is a generalized state, but there is still some distrust. Various studies are being conducted on filter technology, which is a core technology in water purifiers. Water purifier technology is getting smarter day by day. Water purifiers are advancing from small households using existing cooling technologies to large businesses. In addition, competition among water purifier manufacturers is intensifying. Entities from large companies to small and medium-sized enterprises, are targeting consumers with various water purifiers with a multitude of functions and sophisticated designs. However, technically, the core technologies of water purifiers are cooling technologies, hot water and water purification technologies, while the core of a water purification system is a filter. In terms of function, cooling technologies are related to cooler technology, and hot water is an existing technology that applies heat and is not an innovative technology [3].

Water purification is an environmental technology that is directly related to water quality, and it is a field that requires careful and continuous technology development because it is harmful to the human body if applied incorrectly. Moreover, as the earth suffers from serious problems due to global warming, Water is sometimes a life-threatening factor without drinking water even for a day [4-5]. Fortunately, Korea has good water quality compared to other countries, but Vietnam, China, the Middle East, Africa, Indonesia, and other places on the Earth have poor water quality or lack of water. According to TechSci Research [6-7], a global market research firm in 2018, the Vietnamese water purifier market value in 2017 was approximately $106 million. In addition, the Vietnamese water purifier market has grown at a compound annual growth rate (CAGR) of more than 12% since 2017 and is expected to exceed $221 million by 2023. These factors can be attributed to increased industrialization, improved living standards, and consumers' concerns about diseases related to water pollution. In particular, there is a trend of increasing consumer awareness due to environmental pollution and an aging water pipe management system in Vietnam. In 2019, Vietnam imported water purifiers worth about USD 124.48 million, and the major exporters of those water purifiers were Korea (33.84%), China (32.84%) and Japan (8.41%). Domestic water purifier companies are increasing their sales by entering and competing in the Southeast Asia markets. Comparing 2012 and 2018, Coway grew at an average annual rate of 40%. Exports of Cuckoo Homesys increased by 36%, and Malaysia's market share of Korean water purifier products in 2018 was about 50%. Currently, the penetration rate of water purifiers in Malaysia is less than 30%, which is significantly lower than the penetration rate of water purifiers in Korea, which is 60%. As such, there is still room for entry into the water purifier market in Malaysia. Coway entered the Malaysian market in 2007, Cuckoo Homesis in 2015, and Cheongho Nice in 2018 [8].

In Korea, the domestic water purifier market is showing a low growth rate of 2.2%, which is thought to be because a significant number of water purifier manufacturers have already been established and the number of bottled water manufacturers including Samdasoo has increased, making consumers less likely to feel the need to install a water purifier. Since the domestic water purifier market is experiencing such slow growth, in order to overcome the domestic market and expand the water purifier market, it is important not only to develop new technologies for water purifiers, but also to open up new markets overseas, which do not currently receive the benefits of water purifiers. This project aims to develop technologies that allows consumers to easily self-diagnose or manage water purifiers by reorganizing and analyzing the current water purifiers, focusing on the water purifier management system [9-10].

2. EXPERIMENT

2.1 EXPERIMENTAL APPROACH

The current water purifier management was performed by specific management personnel, but due to low professionalism, the reliability of water purifier management was inferior, and filters were replaced unnecessarily or only partial cleaning was performed. In order to efficiently manage such water purifiers, a modular water purifier that allows consumers to manage them has been developed, and replacement parts such as filters are delivered in a timely manner so that consumers can manage them directly. In order to allow consumers to directly manage the water purifier, it is necessary to develop a modular water purifier so that the existing water purifier structure system can be systematized and can be combined by functions such as water purification, hot water, and cold water. The water purifier system by function is as follows.

2.1.1. DIREST HOW WATER SYSTEM

In order to clean the sanitary piping due to foreign substances that may be caused by using the current hot water tank, a hot water system that provides hot water by instantaneous high-temperature heating only during use was applied.

2.1.2. DIREST COLD WATER SYSTEM

In order to remove contaminants in the cold water container that are generated by using the cold water container to store cold water, an instantaneous cooling system that provides cold water by instantaneous cooling only during use was applied.

2.1.3. PROPELLER TYPE ELECTRICITY WATER METER

Most water purifiers filters are replaced based on water usage time, not water usage. The most important part of water purifier management is filter management, and if the filter is not properly managed, it can cause economic loss and also cause sanitary risks. Therefore, it was necessary to develop a water meter that can check the replacement cycle in real time. When using purified water, the digital water meter uses a propeller method to analyze the rotation speed and flow speed of the propeller according to the amount of water and informs consumers of the filter replacement cycle in advance to enable replacement at an appropriate time.

2.1.4. DEVELOPMENT OF JOINT PARTS FOR EASY INFLOW AND OUT FLOW SYSTEM IN CONNECTION OF MODULES

In order to develop a prefabricated water purifier, it was necessary to develop a joint to connect each module. It was necessary to develop a convenient joint to open the purified water when installing the module and to block the purified water when disassembling the module so that the module can be attached and detached conveniently. A joint part capable of entering and exiting a water system that can withstand water pressure was developed. Fig. 1 demonstrates an interworking between modules and control.

2.1.5. SYSTEM FLOW CHART BY MODULES

The whole system consists of a water purification module, a cold water module, and a hot water module, Of course, the filter has a critical function in the water purification module. In the chilled water system, the cooling module through the compressor becomes an important function. On the other hand, in the hot water system, raw water is obtained as a heater and water heated by the heater is obtained through a solenoid valve. The sterilization system has a structure in which the hot water heated by a heater enters the hot water solenoid valve through the hot water module, sterilizes the cold water pipe and discharges it back to the solenoid valve [Fig.1].

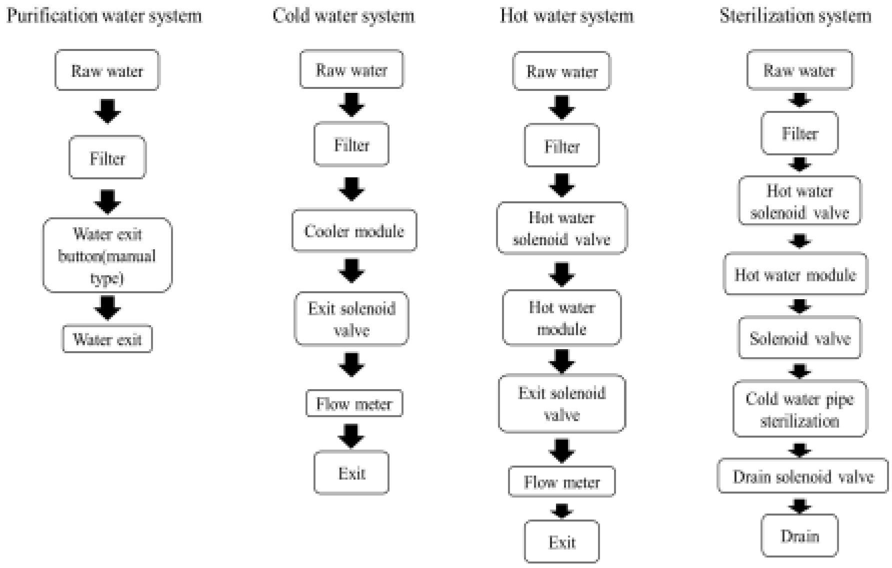

Fig. 1 Flow chart for systems

2.1.6. OVERALL FLOW CHART BY MODULES

Looking at the whole system, the water obtained from the raw water(tap water) passes through the filter of the water purifier, and each function. This includes a hot water, a cold water, and a sterilization module for each function. Therefore, temperature and flow control can be operated appropriately according to the user's request, and control is provided so that the consumer can self-manage the system.

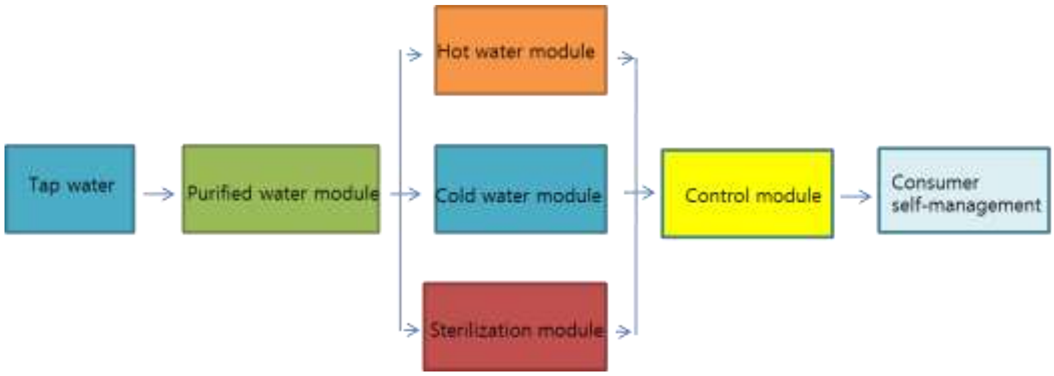

Fig. 2 Interworking between modules and control module

2.1.7. MANAGEMENT PROGRAM CONFIGURATION

The entire control system was configured using Raspberry PI3. The system configuration consisted of a Firebase-based cloud function, a real time database, serverless AWS Dynamo database, web hosting, or a structure in which the server communicated directly according to its own protocol. A remote control server was built for remote control, and databases (device, log, user, group) linked to Google Fire base and AWS Dynamo database were created for real-time data synchronization and control. The remote control server is composed of the types of transmission/reception data, service contents, and definitions of access rights for each user. Firebase is a service provided by Google and uses a cloud database. Firebase can respond quickly and to slight changes to real-time data, so it can respond sensitively to changes in the values of sensors, and service is possible in a serverless form and therefore, even when registering and controlling tens of hundreds of set-top boxes, it is possible to operate without failure without additional personnel, and without server optimization. The entire operating system was made of Raspbian.

2.2. MODULE TEST

2.2.1. WATER PURIFICATION TEST

The time was measured when tap water(raw water) with a water pressure of 1kgf/cm^2 passed through the water purifier filter and 150cc purified water was discharged.

2.2.2 COLD WATER MODULE TEST

At 1kgf/cm^2 water pressure, 12°C tap water inlet temperature and 400W external power of a compressor, the time required to discharge 10°C cold water and temperature change according to continuous water output were both measured [Fig.3].

Fig. 3 Cold water module test

2.2.3 HOT WATER MODULE TEST

The amount of power required to discharge 150cc hot water at 85 degrees at a water pressure of $1kgf/cm^2$ was measured [Fig.4].

Fig. 4 Hot water module test

2.2.4 COLD WATER MODULE AND CONTROL PART INTERWORKING TEST

The time required for the compressor to operate and lower the temperature of purified water from 9℃ to 7℃ was measured, and after the compressor stopped at 7℃, the change in the temperature of cold water inside the cooling system was measured [Fig.5].

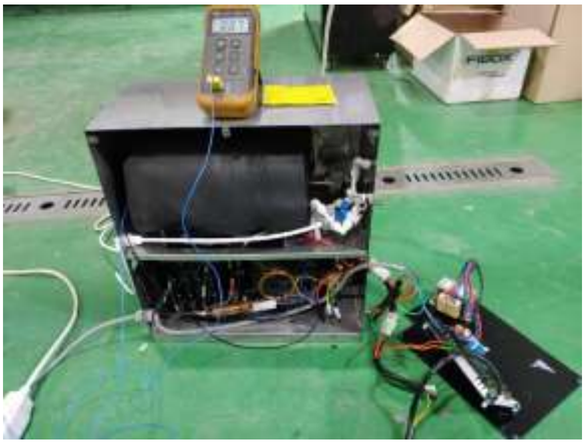

Fig. 5 Cooler module and control module test

2.2.5 HOT WATER MODULE AND CONTROL PART INTERWORKING TEST

The power consumption, water flow rate, and water outlet temperature required to raise 12°C tap water to 85°C hot water were measured, and a test was conducted to check whether 85°C hot water could be discharged at 400cc per minute [Fig.6].

Fig. 6 Hot water and control module test

2.2.6 FLOW METER SENSOR TEST

To check the accuracy of the flow sensor, the flow rate passing at 3k water pressure and the flow meter display amount were compared [Fig.7].

Fig. 7 Flow meter sensor test

2.2.7 HIGH TEMPERATURE STERILIZATION TEST

To check the sterilizable temperature for sterilizing the contaminated pipe, the drain time and the cooling system temperature were measured when the 95 degree instant hot water was introduced [Fig.8].

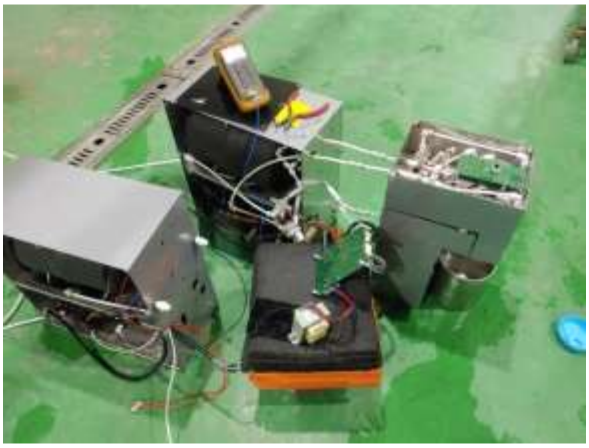

Fig. 8 High temperature sterilization module test

2.2.8 WATER PURIFIER OPERATION TEST

A modular water purifier was developed by assembling a water purifier, cold and hot water modules, and interworking tests were performed on the mechanical part and the control unit, and various tests were performed to secure the first grade in consumption efficiency of the water purifier [Fig.9].

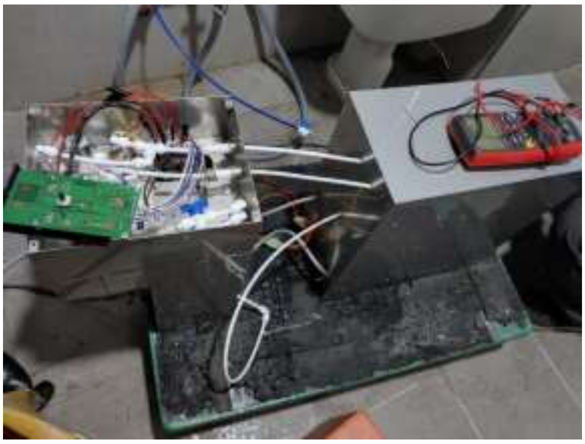

Fig. 9 Water purifier operation test

3. EXPERIMENTAL RESULT

3.1. WATER PURIFICATION MODULE TEST

At a water pressure of 1kgf/cm^2, tap water was supplied to the water purifier, passed through the filter, and then the time required to drain 150cc and 1000cc of purified water was measured [Table I]. It took 4 seconds to dispense 150cc of purified water, and it took 30, 26, and 27 seconds for each cycle to dispense 1000cc of purified water. Considering the test error, the average discharge flow rate is estimated to be approximately 38cc/sec.

Table I. Water purification module test

Number of Times	Output (cc)	Time (sec)	Water pressure(kgf/cm^2)
1	150	4	1
2	150	4	1
3	1000	30	1
4	1000	26	1
5	1000	28	1

3.2. COLD WATER MODULE TEST

The time required to lower the temperature of 14°C purified water to 10°C by operating a 300w compressor was measured according to the amount of water discharged. It took 10sec to dispense 150cc of cold water, and about 90sec to dispense 1000cc of cold water. In addition, based on the 150cc water output, the continuous water discharge volume of this system was 2500cc~3000cc, and the continuous water discharge range was 2800cc~3200cc based on the 1000cc water discharge volume [Table II].

Table II. Cold water module test (cold water 10℃, water pressure 1kgf/cm^2)

Number of Times	Output (cc)	Time (sec)	Continuous Output (cc)
1	150	10	3000
2	150	10	2500
3	1000	12	3200
4	1000	90	2800
5	1000	90	3000

3.3. HOT WATER MODULE TEST

Table III shows the power consumption of the module test for heating tap water at 17 degrees to 85 degrees that was measured. There was a change in power consumption according to the applied water output and consumption time. The higher the power consumption, the higher the applied energy, so the time was shortened even if the amount of hot water was the same. As the amount of hot water increases, the energy consumption increases, so the time required becomes longer.

Table III. Hot water module test (Hot water 85℃)

Number of Times	Output (cc)	Time (sec)	Electric Power (W)	Water Pressure (kgf/cm^2)
1	150	40	500	1
2	150	25	1000	1
3	150	12	1500	1
4	1000	180	1000	1
5	1000	120	1500	1

3.4. COOLER MODULE AND CONTROL INTERWORKING TEST

For the cooler module interworking test, the set temperature of the cold water was set at 7 degrees, the operating temperature of the cooler system was set at 9 degrees, the raw water temperature was set at 12 degrees, and the water output per minute was set at 400cc. Table. IV shows that the water outlet temperature changes according to the water outlet volume while the compressor temperature was fixed to 4℃. The water output temperature was constant at 7°C until the water output of 200cc, but the temperature rose slightly to 8°C until the water output of 400cc. In addition, it was confirmed that when the amount of water output was increased to 1000cc, the temperature of the water output started to increase. Also, in the case of continuous water discharge, for example, when 2000cc of water was discharged, the cooler operating time increases rapidly to about 50 minutes, and in the case of 3000cc of water, the cooler operation time was 150 minutes. In addition, the temperature when the cooler was stopped inside the cooler system and the change in the temperature inside the cooling system after the cooler was stopped were measured. As a result, even though the cooler was stopped, it was confirmed that the internal temperature of the cooling system dropped by 4 to 5 degrees. This results from heat transfer by convection.

Table IV. Cooler module and control part interworking test

Number of Times	Output (cc)	Output Temperature (℃)	Cooler Temperature (℃)
1	100	7	7
2	200	7	7
3	300	8	7
4	400	8	7
5	1000	10	7

3.5. HOT WATER MODULE AND CONTROL INTERWORKING TEST

After setting the raw water temperature to 12 degrees and the temperature for hot water to 85 degrees, the change in the temperature of the water outlet was measured according to the amount of water discharged per minute. The test was repeated, and the water outlet temperature decreased as the water outlet volume increased. In order to maintain a water outlet temperature of 85°C, the water outlet rate was must be less than 400cc/min [Table V].

Table V. Hot water module and control part interworking test

Number of Times	Output (cc/min)	Output Temp.(℃)	Instant time (sec)
1	1000	40	1
2	700	60	1
3	500	75	1
4	400	85	1
5	200	60	1

3.6. FLOW METER SENSOR TEST

A real-time propeller-type flow sensor different from the conventional flow sensor concept was developed, and a test measured by the actual flow rate compared with the value displayed on the flow sensor dashboard at an input water pressure of 3kg/cm^2. This helps to inform the exact replacement time of the filter by calculating the exact flow rate rather than the number of times it passes through the filter in the existing type [Table VI].

Table VI. Flow meter sensor test

Number of Times	Actual volume flow rate (L/sec)	Flow meter display (L/sec)

1	100	100
2	100	96
3	100	98
4	100	100
5	100	100

3.7. HIGH TEMPERATURE STERILIZATION TEST

To check the sterilizable temperature for sterilizing the contaminated pipe, the cooling water drain time and the cooler temperature were measured when hot water was introduced at 95 degrees.

In order to regularly sterilize the contaminated pipe, the hot water was raised to 95 degrees and supplied for the purpose of cleaning the pipe, and the time required at this time was measured and the temperature change of the cooler was measured. The time required to clean the pipe with 95°C hot water was 165~175sec, and the temperature change of the instantaneous cooler at that time was about 69~75°C [Table VII].

Table VII. High temperature sterilization test

Number of Times	Drainage Time (sec)	Cooler Temperature (°C)
1	170	70
2	175	69
3	165	75
4	170	74
5	170	73

3.8. WATER PURIFIER OPERATION TEST

In the water purifier operation test, the system was optimized to lower the power consumption by targeting the power consumption with the goal of the first grade in consumption efficiency. Table VIIII shows the measured values of power consumption for purified water, power consumption for cold water, power consumption for hot water, and power consumption for sterilization of the drain pipes according to the operation test of the water purifier. The power consumption of the water purification module alone was 12W, the power consumption of cold water is 90W, the power consumption of hot water was 2212W, and the power consumption required for sterilization was 2212W, confirming that the power consumption of hot water is relatively higher than the power consumption of cold water [Table VIII].

Table VIII. Power consumption for water purifier operation test

Number of Times	Water purification (W)	Cold water (W)	Hot water (W)	Sterilization (W)
1	12	90	2212	2212
2	12	90	2212	2212
3	12	90	2212	2212
4	12	90	2212	2212

4. CONCLUSIONS

In the existing rental management system of water purifiers, management comes from filter replacement. In a situation where consumers are requesting a non-face-to-face management system to project against corona or because of personal choice, the technology to reinforce the non-face-to-face management system is increasing. By analyzing the existing water purifier system, it was remanufactured by dividing it into four module systems, namely, a water purification system, a hot water system, a cold water system, and a sterilization system by function. And by controlling the flow rate and temperature through a control module, a system that can control the flow rate and temperature desired by the consumer was constructed. Also, to control the flow rate between modules, a solenoid valve was connected to form a link between each module. For the test of each module, the performance of each module was tested and the entire system was completed by attaching the modules. In addition, by combining IOT and ICT technology, we have developed a smart water purifier that enables remote control services such as collecting transmission/reception control types and utilizing service contents using a Rasbery PI3 to control the entire system. Therefore, through this study, the existing water purifier technology was checked and a technology to simplify the water purifier was developed so that consumers can easily access it. If an efficient management system is applied through an app-based management system, it is possible to reduce the overall rental cost by more than 40% by enabling consumers to easily replace or clean filters, etc.

REFERENCES

[1] Jeon Y. S., Park H. H., Lee J. S. and Kim Y. C. "Analytical Study on the Performance Characteristics of an Instant Cooling Type Water Purifier with the Design Parameters of the Cooling Tank." Korean J. of Air-conditioning and Refrigeration Engineering, 24.7 (2012):545-552.

[2] Park K. J., Lee Y. H., Jung D. S and Kim K. K. "Performance of G430A on refrigeration system of domestic water purifiers." Korean J. of Air-conditioning and Refrigeration Engineering, 21.2 (2009):109-117.

[3] Lee D. W. and Kim C. B. "Characteristic Analysis of the Cooling System Using Ice Slurry Type Heat Storage System." J. of Energy Engineering, 20.1 (2011):30-35.

[4] Jung J. W., Jung C. W., Kim S. S., Kang S. S. "Performance comparison between the conventional air cooled type condenser and the water cooled type condenser using drain water of the reverse osmosis type cold and hot water purifier." Proceedings of the SAREK Summer Annual Conference, pp.1165-1170.

[5] Kim K. B. "A design compact size direct feed water purifier through the redesign of cooling model part." Pusan National Univ., 2015, Thesis, pp 30-35.

[6] Lee J. H. "A study on factors of agitator of cooling module in direst water stream type of water purifier that influence continuous cooled water outlet temperature." Pusan National Univ., 2014, Thesis, pp. 50-55.

[7] Bong C. H. "A study on improvement of cold water performance for cooling water direct feed system purifier.", Pusan National Univ., 2018, Thesis, pp. 45-60.

[8] Vietnam water purifier trend, http://blog.naver.com/ggrimm/222181759481(2020.12.22).

[9] Vietnam water purifier trend, http:/blog.naver.com/kisulee7/222170192208(2020.12.15).

[10] Baik, D. S. "Development of Water Purifier for Energy Efficiency." J. of Green Engineering, 11:2 (2021): 1940-1950.