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WASTEWATER RECOVERY OF AIR CONDITIONING FOR INDOOR CANNABIS PRODUCTION

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ABSTRACT

This research studies an optimal process of wastewater recovery from air conditioning for indoor cannabis production. The thermal selection working fluid, computational fluid dynamics (CFD), and microcontroller techniques are used to design a wastewater recovery system. Indoor cannabis room at a sizing of 2.4 m × 3.4 m × 2.5 m is used to contain five lighting sets at each sizing of 1.0 m × 1.0 m × 1.8 m, which consists of one-violet light emitting diodes (LED) at a power of 300 W_e and two-daylight LEDs at each power of 100 W_e. A commercial of R-32 air conditioning at a cooling capacity of 12,300 BTU/h (3.6 kW) is selected from the optimal thermal behavior. The CFD simulation also supports the thermal result in terms of airflow pattern, pressure drop, and temperature at an air flow rate of 0.182 m^3/s, an average pressure of 101.322 kPa, and an average room temperature of 25.41 °C, respectively. Wastewater recovery at a volume of 18 L/day is supplied to 20 cannabis plants by using Arduino board, solenoid value, and drip emitter. These controlled systems can produce a harvest time of approximately 4 months, which is lower than a greenhouse system of approximately 6 months.

Keywords: Wastewater recovery; Air conditioning; Cannabis production; Computational fluid dynamics

1. Introduction

Smart farming topic is a popular technology and a hot issue in Thailand, especially for the high-value medicinal plant. Internet of things (IOT) is used to control and monitoring the optimal conditions for plant propagation and cultivation such as air temperature, relative humidity, lighting, and fertilizer. Cannabis is promoted for using in the medical process. Indoor greenhouse is general technique for cannabis cultivation. The advantage of this method is low-investment cost, low-operating cost from solar energy, and low-maintenance cost. However, the disadvantage in terms of the uncontrollable of air temperature and relative humidity, light intensity, wind speed, and harvest time. Thus, a new concept of wastewater recovery from indoor cannabis cultivation is presented in this study.

Various research works of design, simulation, and construction of indoor cultivation technologies were presented such us Vanhove et al. [1] reported a computational fluid dynamics (CFD) method to evaluate the suitable condition for indoor planting, which was corresponded with Zhang et al. [2], Niam et al. [3], and Lim and Kim [4]. The CFD is used to analyze the air contribution and uniform, sizing and position of air conditioning, and reducing harvest time. In addition, Yongson et al. [5] used the CFD technique to design the optimal condition of operating cost for plant cultivation. In the topic of air conditioning simulation, Chaiyat and Kiatsiriroat [6] compared thermal performance of R-32 and R-410a air conditioning units by testing process under the controlled conditions. R-32 refrigerant revealed a higher thermal behavior of approximately 5%. Taira et al. [7] presented heat pump performance by using the mixed refrigerants of R-32:R-125:R-1234yf (67%:7%:26% by weight) and R-32:R-1234ze(E) (70%:30% by weight) to compare with the pure refrigerants of R-410a and R-32. Both mixed fluids could replace instead of R-410a and R-32 at a lower energy efficiency ratio (EER) compared with R-32 working fluid. Dalkilic and Wongwises [8] simulated mixed refrigerants of R-152a, R-32, R-290, R-1290, R-1270, R-600, and R-600a to replace instead of the banned refrigerant of R-12 and R-22. It found that R-290:R-600a at a mass ratio of 40%:60% could be used in the R-12 vapor compression air conditioning, and R-290:R-1270 at a mass ratio of 20%:80% could be replaced in the R-22 unit.

From the above study works, it could be found that the CFD and thermal simulation techniques were popularly used in the optimization process of air conditioning. These methods were not represented for indoor cannabis production. Thus, the objective of this study is to investigate the optimal conditions for cannabis cultivation by using the CFD and thermal simulation methods. In addition, a new conceptual design of the control and monitoring systems are also developed for automatic plant watering system from wastewater of air conditioning.

2. Conceptual framework

Figure 1 shows a schematic diagram of wastewater recovery system from air conditioning. Cooling load (Q_E) from cannabis production in the insulator room releases heat into an evaporator of air conditioning (fan coil unit). After that heat from the returned air transfers to refrigerant, which changes phase from the mixture (liquid and vapor) to be the pure vapor. This fluid is increased pressure and temperature by a compressor ($W_{Comp,e}$), which is driven from electricity. Then, the high-temperature fluid rejects heat to the ambient temperature at a condenser (condensing unit, Q_C). The vapor refrigerant is condensed to be the pure liquid refrigerant, and sent through an expansion value to be the mixture fluid. After that the new cycle of air conditioning is restarted. At the evaporator, in the transfer heat between the moist air and refrigerant, the condensed water is found as wastewater from air conditioning. A wastewater tank is used to storage the condensed water, and supplied through a plant watering system for cannabis production. An air ventilation system in the cannabis room is controlled by blower of the evaporator, and rejects a part of moist air by a releasing air blower. In this study, this waste fluid is considered by using the thermal simulation and CFD techniques to select the suitable refrigerant for indoor cannabis process. The cooling efficiency of air conditioning unit in terms of EER_{AC} can be defined as shown follows:

$$EER_{AC} = \frac{Q_E}{W_{Comp,e}}, \tag{1}$$

$$Q_E = \dot{m}_{da,E}(h_{a,E,i} - h_{a,E,o}) - \dot{m}_W h_{fg,W}, \tag{2}$$

$$\dot{m}_W = \dot{m}_{da,E}(\omega_{a,E,i} - \omega_{a,E,o}). \tag{3}$$

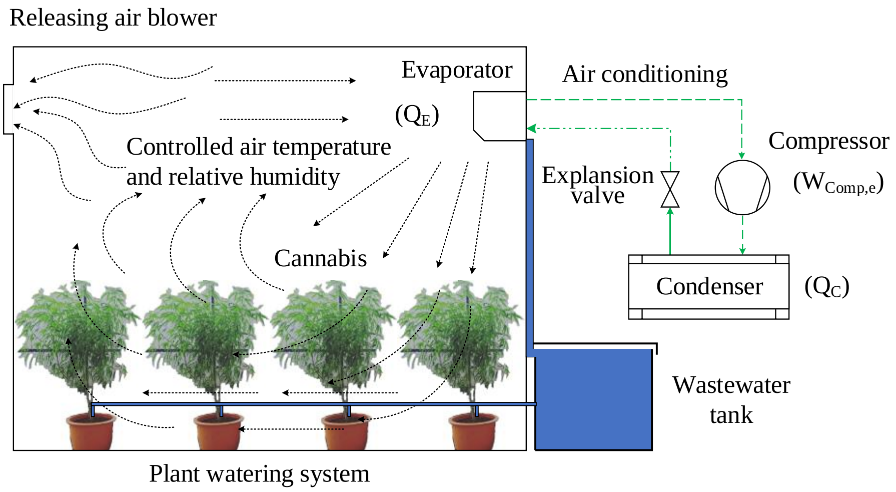

Figure 1 A schematic diagram of wastewater recovery system from air conditioning.

3. Methods and apparatus

The methods and apparatus of this study are as follows:

3.1 The indoor cannabis room and lighting set are designed by using a Solidworks program [9] in form of three dimensions (3D) model.

3.2 The air ventilation in the cannabis room is simulated by using the CFD technique from the Solidworks program (flow simulation). The airflow pattern, pressure drop, and temperature parameters in the controlled room are considered to select the suitable size of air conditioning. A Daikin R-32 commercial types are used to refer the specification data, as shown in Table 1. The CFD process is assumed under the initial conditions of a room temperature of approximately 25 °C and a relative humidity of 55%.

Table 1 Specifications of commercial air conditioning [10].

Cooling capacity (BTU/h)	Volume flow rate (m^3/s)
9,200	0.165
12,300	0.187
15,000	0.197
18,100	0.215

3.3 The thermal and CFD simulation results are used to design the microcontroller system of plant watering system.

3.4 The new design concept of indoor cannabis room, air conditioning, lighting set, and of plant watering system from the previous part are constructed and tested to evaluate the system performance.

4. Results and discussion

4.1 Conceptual design of indoor cannabis room

A 3D drawing of indoor cannabis room is illustrated in Figure 2. Cannabis room at a sizing of approximately 2.4 m × 3.4 m × 2.5 m is designed by using insulator from Isowall at a thickness of 2 inch. The optimal sizing chamber of cannabis room is designed for 1-unit small sprit type air conditioning unit at a sizing lower than 24,000 BTU/h. In addition, lighting set at a sizing of approximately 1.0 m × 1.0 m × 1.8 m is developed for using with four cannabis pots at each volume of approximately 12 L, which consists of one-violet light emitting diodes (LED) at a power of 300 W_e and two-daylight LEDs at each power of 100 W_e. The LED set is specially designed for generating a wavelength of approximately 600 nm, a spectral irradiance of approximately 200 mW/m^{2}□nm, and a photosynthetic photon flux density (PPFD) of approximately 100 μmol/m^{2}□s. Air conditioning is installed with the wall at a high of 2.0 m, which the suitable sizing of cooling unit will be optimized in the next part. The moist air is managed by a 6 inch-releasing air blower at a power of 16 W_e, that installed at the opposite of cooling unit.

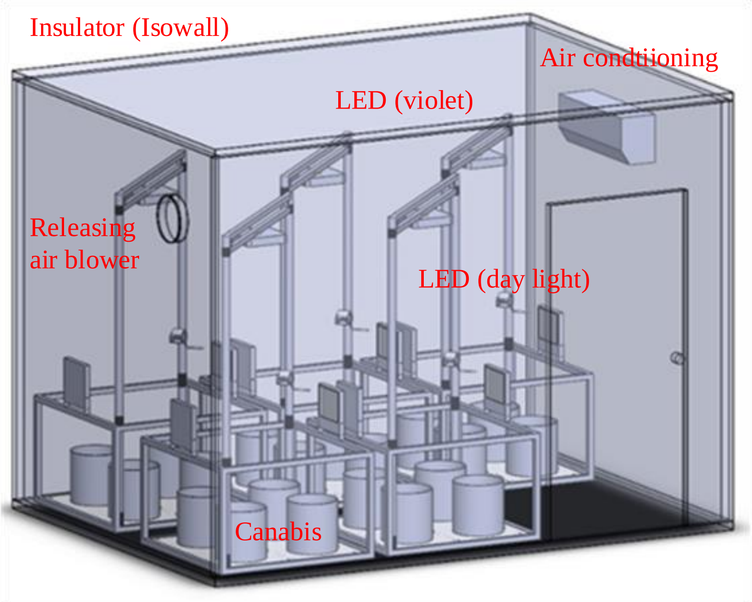

Figure 2 A 3D drawing of indoor cannabis room.

4.2 CFD

Four Daikin commercial air conditioning models are used to investigate the suitable sizing cooling unit, as shown in Figures 3-6. An air conditioning of 9,200 BTU/h reveals a low-air ventilation and nonuniformly. In the cases of air conditionings at the cooling capacity of 15,000 BTU/h and 18,100 BTU/h, the results imply that a high-air ventilation (nonuniformly) is found from the over size of both air conditioning units. Thus, the optimal size of air conditioning in this study is a 12,300 BTU/h model, as presented in Figure 4. The air flow rate of approximately 0.212 m^3/s or 0.19 m/s is suitable for the indoor cannabis room of 2.4 m × 3.4 m × 2.5 m.

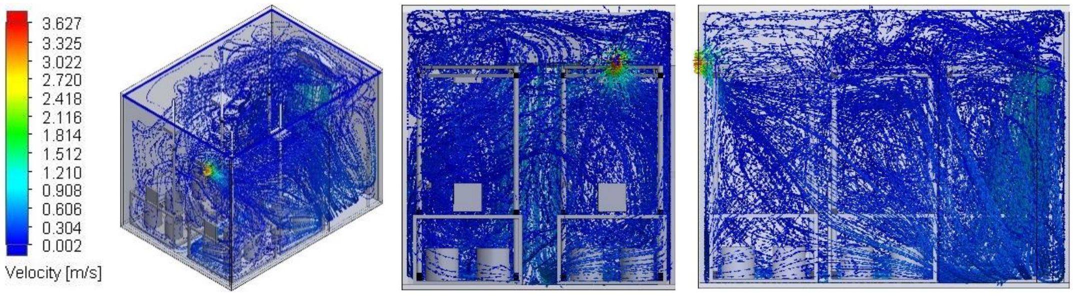

Figure 3 An air ventilation of 9,200 BTU/h-air conditioning.

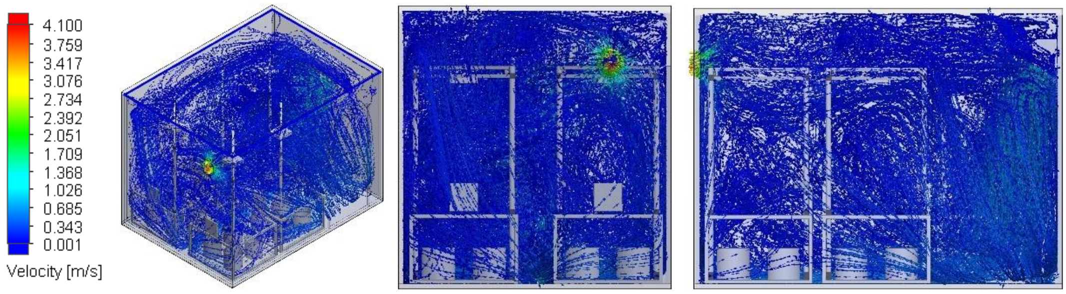

Figure 4 An air ventilation of 12,300 BTU/h-air conditioning.

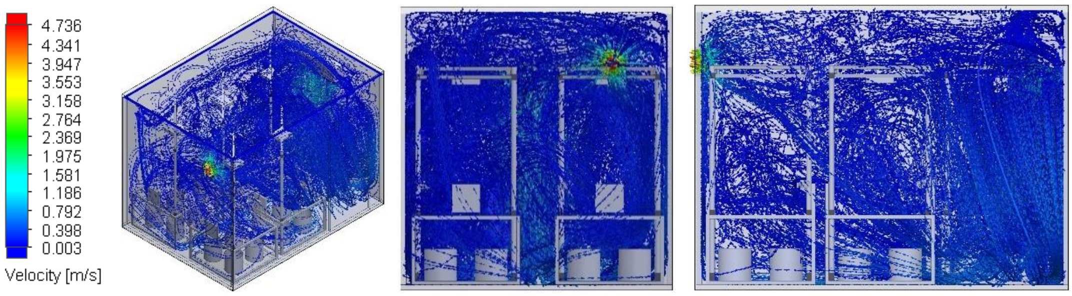

Figure 5 An air ventilation of 15,000 BTU/h-air conditioning.

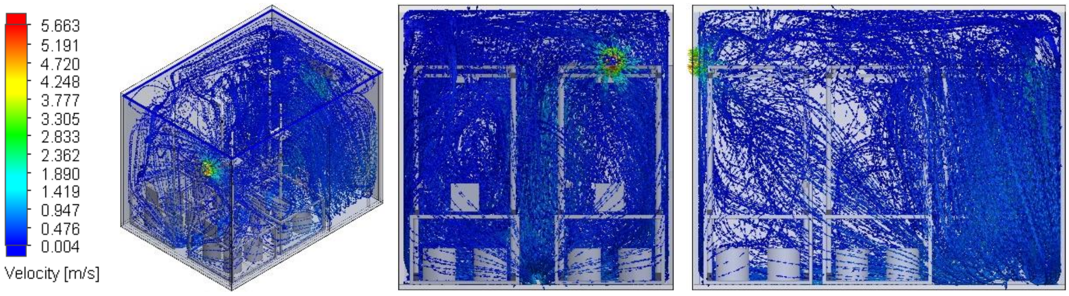

Figure 6 An air ventilation of 18,100 BTU/h-air conditioning.

The 12,300 BTU/h model also shows an average room pressure of 101.322 kPa, as shown in Figure 7, which is nearly with the environmental pressure of 101.325 kPa. In the temperature profile in cannabis room is found that a LED temperature is approximately 49.25 °C, while an average air temperature is approximately 25.41 °C, as shown in Figure 8.

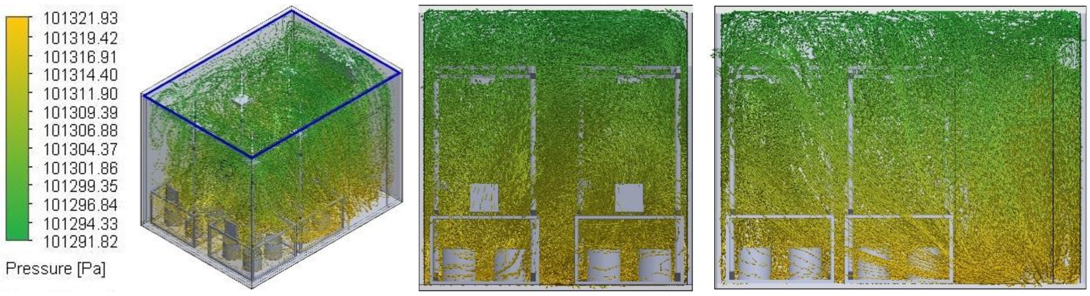

Figure 7 An average room pressure of 12,300 BTU/h-air conditioning.

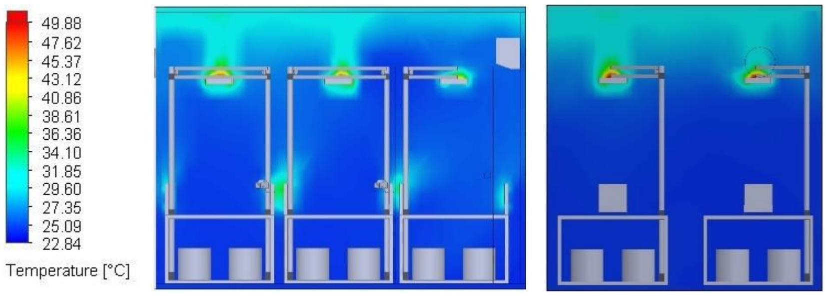

Figure 8 A temperature profile of 12,300 BTU/h-air conditioning.

4.3 Wastewater recovery of air conditioning

From the thermal simulation, wastewater from the 12,300 BTU/h air conditioning is approximately 18.302 L/day or 0.76 L/h. This volume of water can be used to supply for the 12 L-cannabis pot of 20 plants (5 lighting sets). Thus, the conceptual design of control part for plant watering system is set as three modes of 24 h, 48 h, and 72 h, respectively. These setting times are programed for various kinds of cannabis, as presented in Figure 9. The control elements of Arduino board, solenoid valve, selector switch, LCD monitor, and drip emitter are selected to develop plant watering system.

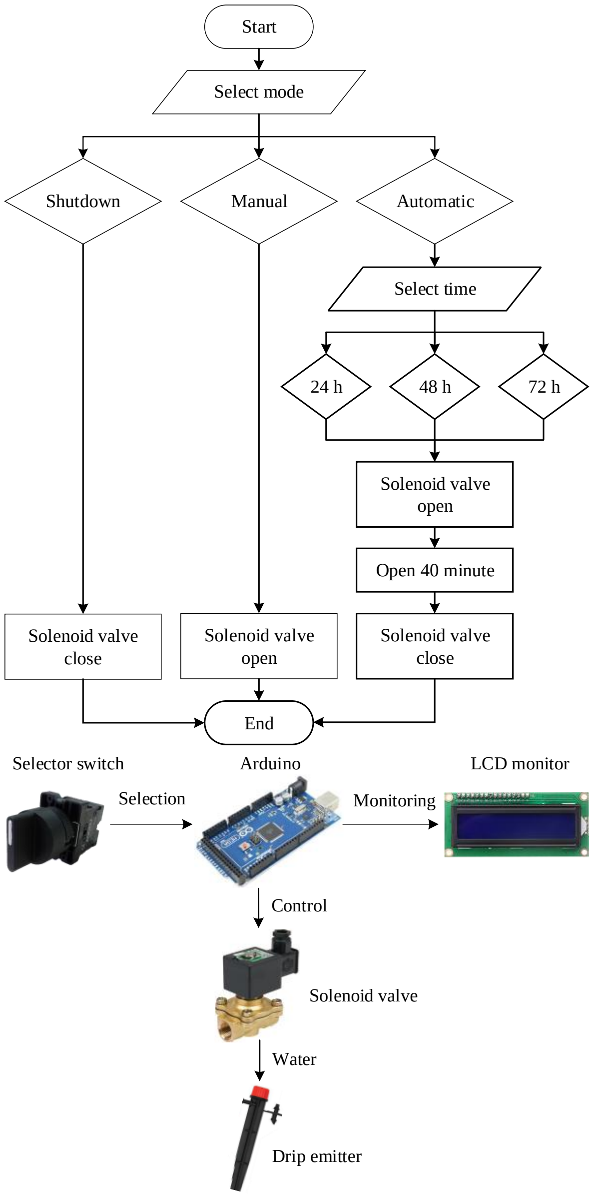

Figure 9 The conceptual design and control devices of plant watering system.

4.4 Prototype of wastewater recovery of air conditioning

A prototype of wastewater recovery from air conditioning is illustrated in Figure 10. All conceptual designs of indoor cannabis room, air conditioning, lighting set, and plant watering system are considerably performed. The cannabis production from the controlled cultivation can produce output production at a harvest time of 4 months, which is lower than the cannabis greenhouse at approximately 2 months (6 months for general process of greenhouse system).

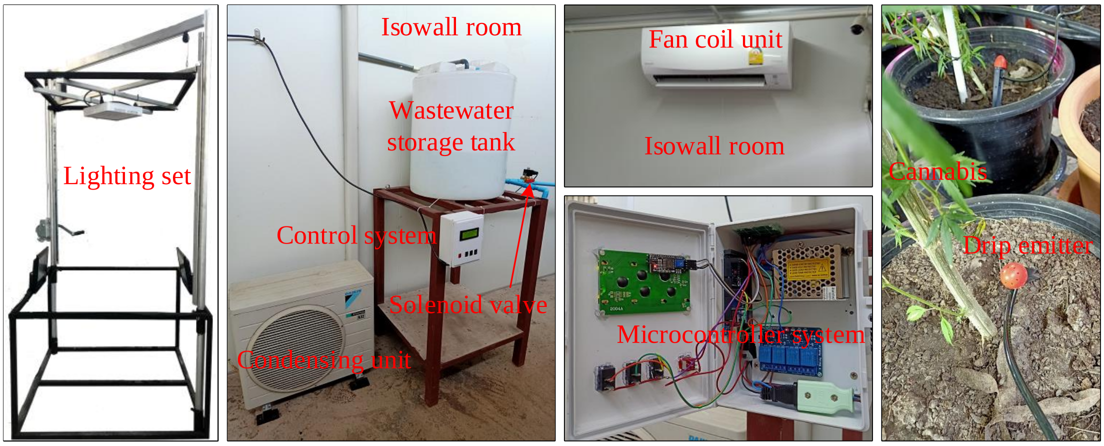

Figure 10 A prototype set of wastewater recovery of air conditioning.

5. Conclusions and recommendations

From the above study results, it can be concluded as follows:

- The cannabis room of 2.4 m x 3.4 m x 2.5 m is design, which uses for the lighting set of 1.0 m x 1.0 m x 1.8 m, cannabis pot of 12 L, violet LED of 300 W_e, and 2-daylight LEDs at each of 100 W_e.
- The optimal size of air conditioning is 12,300 BTU/h (3.6 kW) model for supplying the air flow rate of 0.212 m^3/s, average pressure of 101.322 kPa, average air temperature of 25.41 °C.
- The 12,300 BTU/h air conditioning generates the wastewater of 18.302 l/day, which is suitable for supply for the 12 L-cannabis pot of 22 plants. The prototype of plant watering system is developed from Arduino board, solenoid valve, selector switch, LCD monitor, and drip emitter.
- The controlled system can produce the harvest time of approximately 4 months, which is lower than the greenhouse system of approximately 6 months.

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Abbreviations and symbols

Nomenclature

EER	energy efficiency ratio, (kW_{th}/kW_e)
h	enthalpy, (kJ/kg)
M	mass, (kg)
$\dot{m}$	mass flow rate, (kg/s)
P	pressure, (bar)
Q	heat capacity, (kW)
T	temperature, (°C)
W	Power, (kW_e)

Abbreviations	
AC	air conditioning
Greek	
ω	humidity ratio, (kg_W/kg_{da})
Subscript	
a	moist air
C	condenser
Comp	compressor
da	dry air
e	electricity
E	evaporator
f	liquid fluid
g	vapor fluid
i	inlet
o	outlet
th	thermal
W	water

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