A Study on Evaporation Phenomenon of Trap Seal Water

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1. *Background and purpose of the research*

Contents

1 . *Background and Purpose of the Research*

■ Background of research

Water seal trap is used for the drainage system

Problem

■Trap seal water gradually losses by evaporation,
If drainage is not done for a long time, it will cause seal break.

⇩

・No design measures have been taken to deal with evaporation of trap seal water.

・ Nothing can be done except to rely on water replenishment with the water supply system to prevent seal break.

⇩

<u>The cycle of replenishment must be established for effective water replenishment.</u>

1 . *Background and Purpose of the Research*

■Previous studies

・The theoretical values obtained from the conventional formulas greatly differ from actual measurements. It practically means that no reliable calculation method exists, that can be applied to water seal trap.

■Purpose of research

We compared theoretical values of water evaporation rate with measured values

⇩

Create a new theoretical formula, one modified based on the existing one.

2．*Measurement of evaporation rate using cylinders*

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２．１ Purpose　２．２ Outline of experiment

■Purpose

・ The effects of various experimental conditions on evaporation rate were analysed to collect data on evaporation volume inside cylinders.

■ Common condition

・ Cylinders filled with water under various conditions were weighed with an electronic scale, and evaporation volumes were calculated as the differences of weights at each measurement cycle.

◆ Sampling cycle：
Multi-functional anemometer 720sec
Radiation thermometer 8hour
Electronic scale 8hour

◆ Measurement location：
indoors (with no air conditioning, doors and windows closed)

◆ Measurement period：
September to November 2016

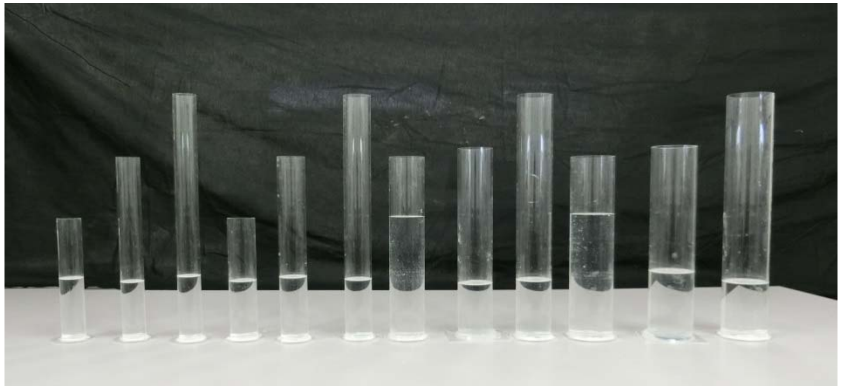
(a)9/30～10/6
(b)10/15～10/24
(c)10/21～10/30
(d)10/30～10/6
(e)11/7～11/14
(f)11/14～11/21

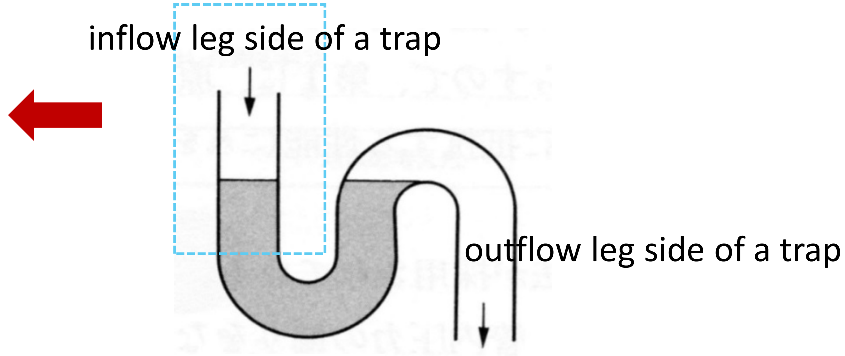
List of measurement parameters and apparatuses

Measurement parameters	Unit	Measurement apparatuses
Temperature	℃	Multi-functional anemometer
Humidity	%	
Wind velocity	m/s	
Water temperature	℃	Radiation thermometer
Evaporation volumes	g	Electronic scale

2．1 Purpose 2．2 Outline of experiment

■ An example of cylinder placement in evaporation experiment





Water seal trap

■ Internal diameters and hollow heights of cylinders

Internal diameters (d) [cm]	hollow heights (h) [cm]
2.5	10 ・ 20 ・ 30
3.0	
4.0	
5.0	

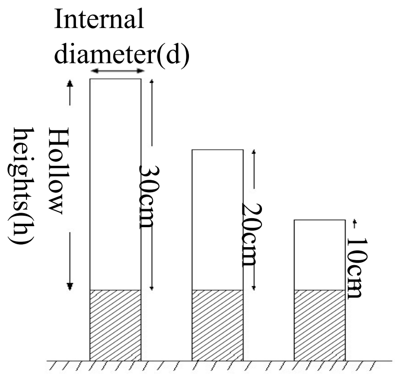
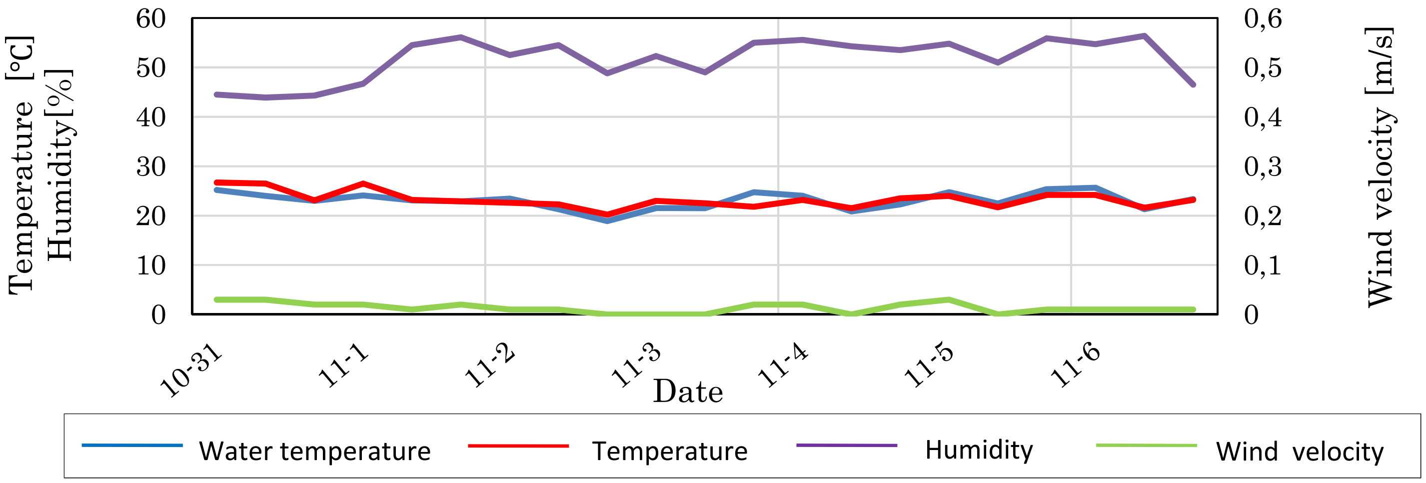


Diagram of Cylinders

■ Results and discussion

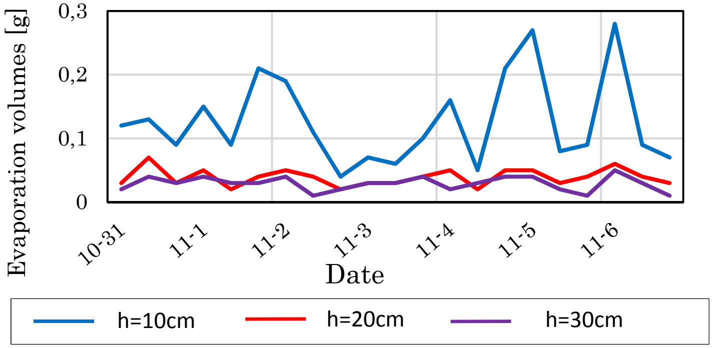


Indoor environmental data (10/31～11/6)

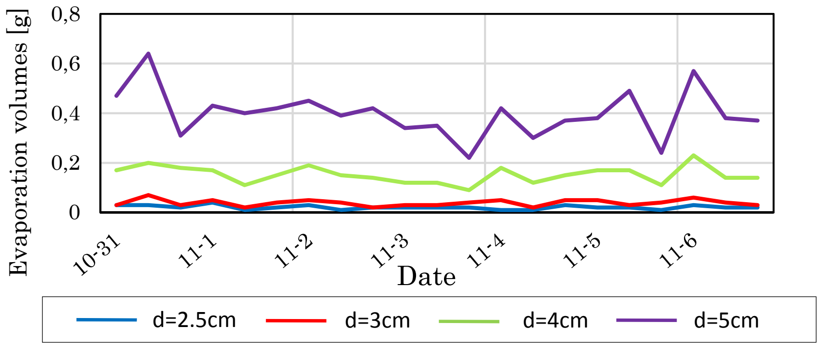
◆As measurements were made indoors, wind velocity stayed around 0.0 m/s, and no significant changes in temperature and humidity were recorded.

2．3　Results and discussion

■ Results and discussion



Changes in evaporation volume in cylinders with internal diameter of 3 cm (10/31 ~ 11/6)



Changes in evaporation volume in cylinders with hollow height of 20 cm (10/31 ~ 11/6)

◆The comparison of various size cylinders indicated that the larger the internal diameter and the smaller the hollow height, the larger the evaporation rate.

◆Evaporation volumes were extremely small with hollow heights of 20 and 30 cm, and no significant difference was seen.

◆Evaporation varied depending on the time of measurement. This seems to suggest that evaporation areas increase in proportion to the internal diameter and the effect of turbulence becomes more prominent with smaller hollow heights.

3 . Derivation of modified theoretical formula

Contents

3. 1 Theoretical formula

■The amount of evaporation of water increases in proportion to the following two points

- Difference in water vapor pressure (e_s-e)
- Water surface area

in addition, hollow height affected the evaporation volume of water inside vertically held cylinders.

Evaporation rate theoretical formula

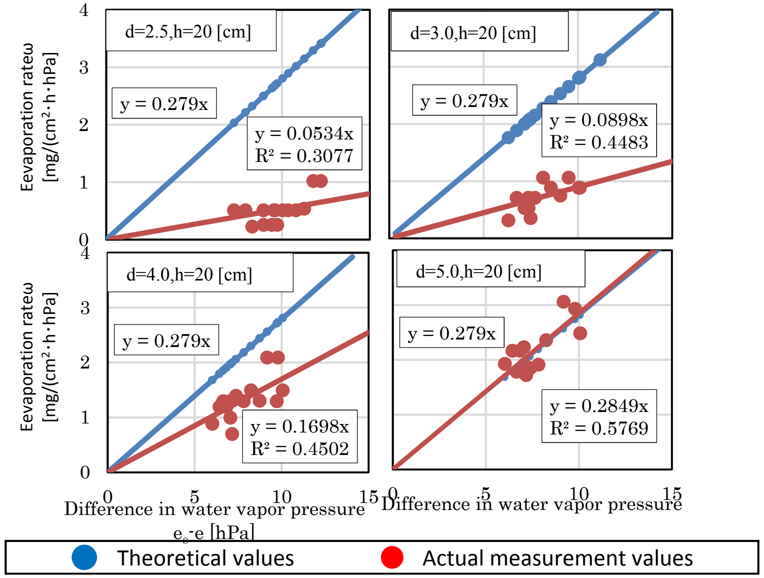
$$\omega = 0.59 \frac{1}{h^{1/4}} (e_s - e)$$

ω : Evaporation rate [mg/(cm^2・h・hPa)]
e_s : Water vapor pressure on the water surface [hPa]
e : Water vapor pressure of air [hPa]
h : Hollow height [cm]

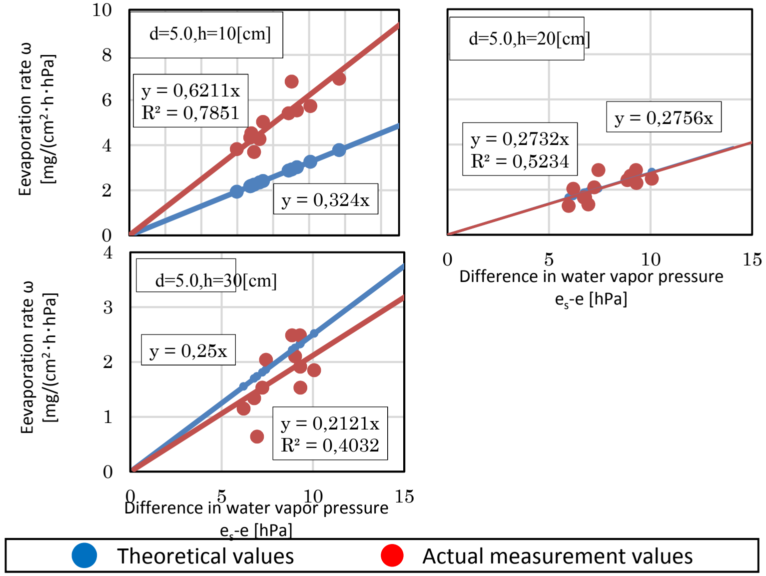
3. 2 Comparison of theoretical values with actual measurements

The theoretical values of evaporation rate per unit time and unit surface area are calculated from the theoretical formula and compared with actual measurements.

■ Results and discussion



Examples of comparison with h = 20 cm (11/14 ~ 11/21)



Examples of comparison with d = 5 cm (11/7 ~ 11/14)

Actual measurements were relatively small compared with theoretical values as internal diameter became smaller while the hollow heights of the cylinders stayed the same.

Actual measurements increased in comparison with the theoretical values as hollow height became smaller while the internal diameters of the cylinders stayed the same.

3．3 Modification of theoretical formula

■ Modification of theoretical formula

Ratio of theoretical value to actual measurement

List of ratios (theoretical values / actual measurements) (11/14~11/21)

Conditions		Internal diameter (d) [cm]			
		2.5	3.0	4.0	5.0
Hollow height(h)[cm]	10	2.34	0.87	0.65	0.54
	20	5.23	3.11	1.64	0.98
	30	5.93	3.78	2.01	1.08

The ratios under all conditions decreased as the internal diameters increased and increased as the hollow height increased.

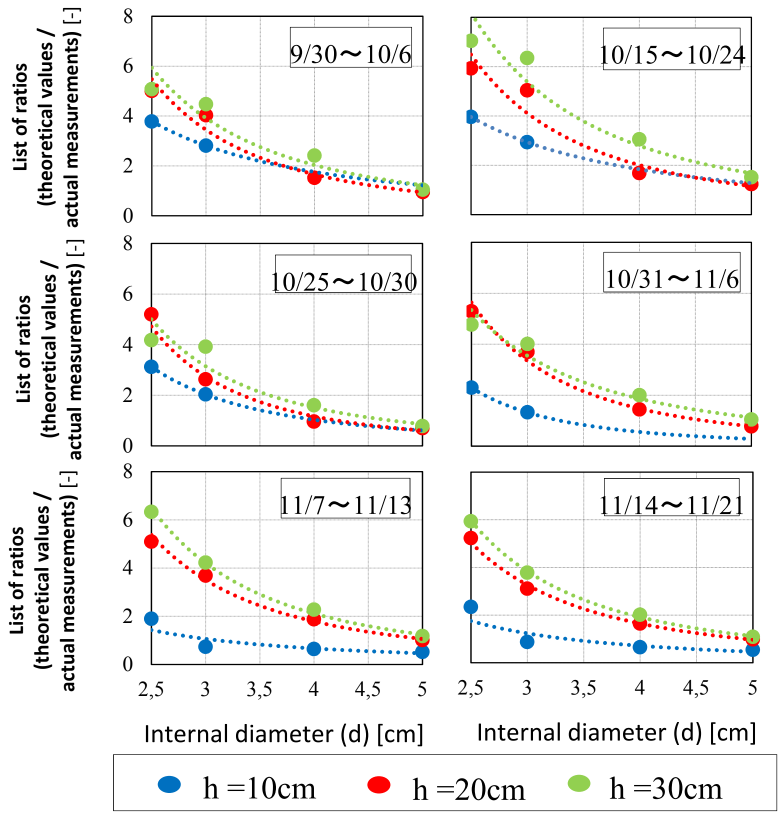
In the theoretical formula and measured values, a large difference of about 0.5 to 6 times was confirmed.

3．3 Modification of theoretical formula

■ Modification of theoretical formula

The scatter diagrams of the ratios during the entire measurement period are shown in Figure.

The approximate curves relative to the internal diameter indicated ascending powers, and tended to position themselves in the upper regions as hollow heights increased.
Therefore, it has been confirmed that the internal diameters and hollow heights have a correlation with approximate curves that shows the fluctuations of the ratios.



Variations of ratios

■Modification of theoretical formula

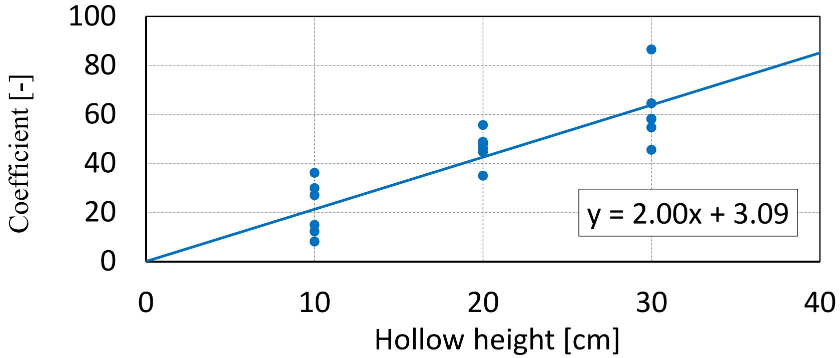
The list of regression equations for each approximate curve in Figure is shown in Table.

Period	**Hollow heights [cm]**		
	10	20	30
9/30〜10/6	$14.87x^{-1.54}$	$35.00x^{-2.22}$	$64.56x^{-2.50}$
10/15〜10/24	$29.90x^{-2.21}$	$47.76x^{-2.32}$	$58.27x^{-2.28}$
10/21〜10/30	$27.00x^{-2.36}$	$55.63x^{-2.81}$	$86.54x^{-2.90}$
10/30〜11/6	$36.16x^{-3.01}$	$48.78x^{-2.553}$	$45.56x^{-2.30}$
11/7〜11/14	$8.12x^{-1.78}$	$46.11x^{-2.35}$	$58.09x^{-2.39}$
11/14〜11/21	$12.18x^{-2.03}$	$44.70x^{-2.38}$	$54.66x^{-2.42}$

◆The indices were found to be more or less constant.
⇒The indices are calculated based on the average for each period.
◆The scatter diagram showing the rate of change of the coefficient with respect to the hollow height and its primary regression equation.
⇒The primary regression equation as a coefficient.

3．3 Modification of theoretical formula

■Modification of theoretical formula



Average rate of change in coefficient

Correction coefficient

$$\alpha = \frac{1}{(2h + 3.09)d^{-2.35}}$$

h : Hollow height [cm]

d : Internal diameter [cm]

Modified theoretical formula

$$\omega_t{}' = \alpha\omega_t$$

$\omega_t{}'$: Evaporation rate (modified theoretical formula) [mg/(cm²･h･hPa)]

α: Correction coefficient

ω_t: Evaporation rate (theoretical formula) [mg/(cm²･h･hPa)]

4 . Verification of the modified formula

Contents

■Purpose

・ Evaporation rates were calculated based on the formula created in 3.4, and compared with actual measurements.

■ Common condition

・ The experiment was set up in the same way as the evaporation rate experiment described above in Section 3, and the volume of evaporation was measured from March 5 to 15, 2017.

◆ Sampling cycle :
Multi-functional anemometer 720sec
Radiation thermometer 8hour
Electronic scale 8hour
◆ Measurement location :
Indoors (with no air conditioning, doors and windows closed)
◆ Measurement period :
March 5 to 15, 2017

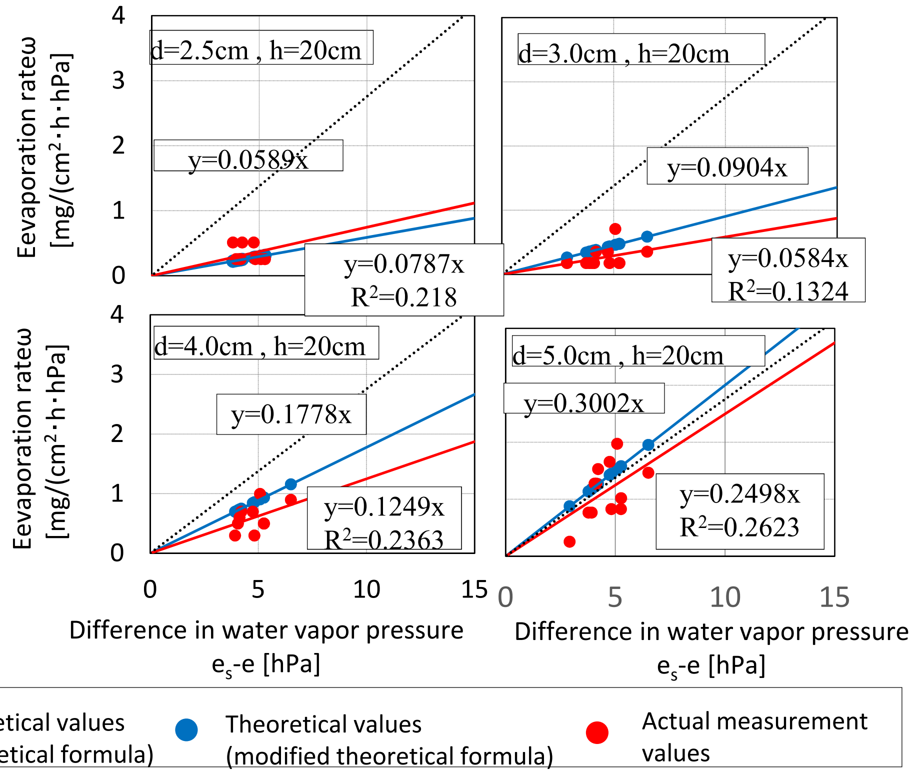
List of measurement parameters and apparatuses

Measurement parameters	Unit	Measurement apparatuses
Temperature	℃	Multi-functional anemometer
Humidity	%	
Wind velocity	m/s	
Water temperature	℃	Radiation thermometer
Evaporation volumes	g	Electronic scale

■ Results and discussion

In each diagram, the differences were found to be smaller than the theoretical values obtained by the conventional formula.

The trend of the changes in evaporation volume was similar.
Therefore, it can be concluded that the formula for evaporation rate created in 3.4 is, on the whole, applicable to the calculation of evaporation rate in cylinders.



Examples of comparison with h = 20 cm (3/5 ~ 3/15)

5 . Conclusion

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5. Conclusion

■ Conclusion

In this study we conducted an experiment using cylinders to measure evaporation rate, and compared the values with those obtained by the conventional theoretical formula.

1. Water in cylinders evaporated faster with larger internal diameters and smaller hollow heights.

2. The rate of evaporation can be expressed by the equation below:

$$\omega = \frac{1}{(2h + 0.309)d^{-2.35}} \cdot 0.59 \frac{1}{h^{1/4}} (e_s - e) \quad [\mathrm{mg/(cm^2 \cdot h \cdot hPa)}]$$

3. Although some differences were noted between the theoretical values obtained by the equation above and the actual measurements, evaporation volume changed in a similar way.

■ Future problem

The collection of a wide range of data, the improvement of the accuracy of the formula.
The use of test trap to simulate actual drainage conditions.

Fin.