Design and Evaluation of an experimental Apparatus for Quantitative Measurement of Wave-driven upwelling pump

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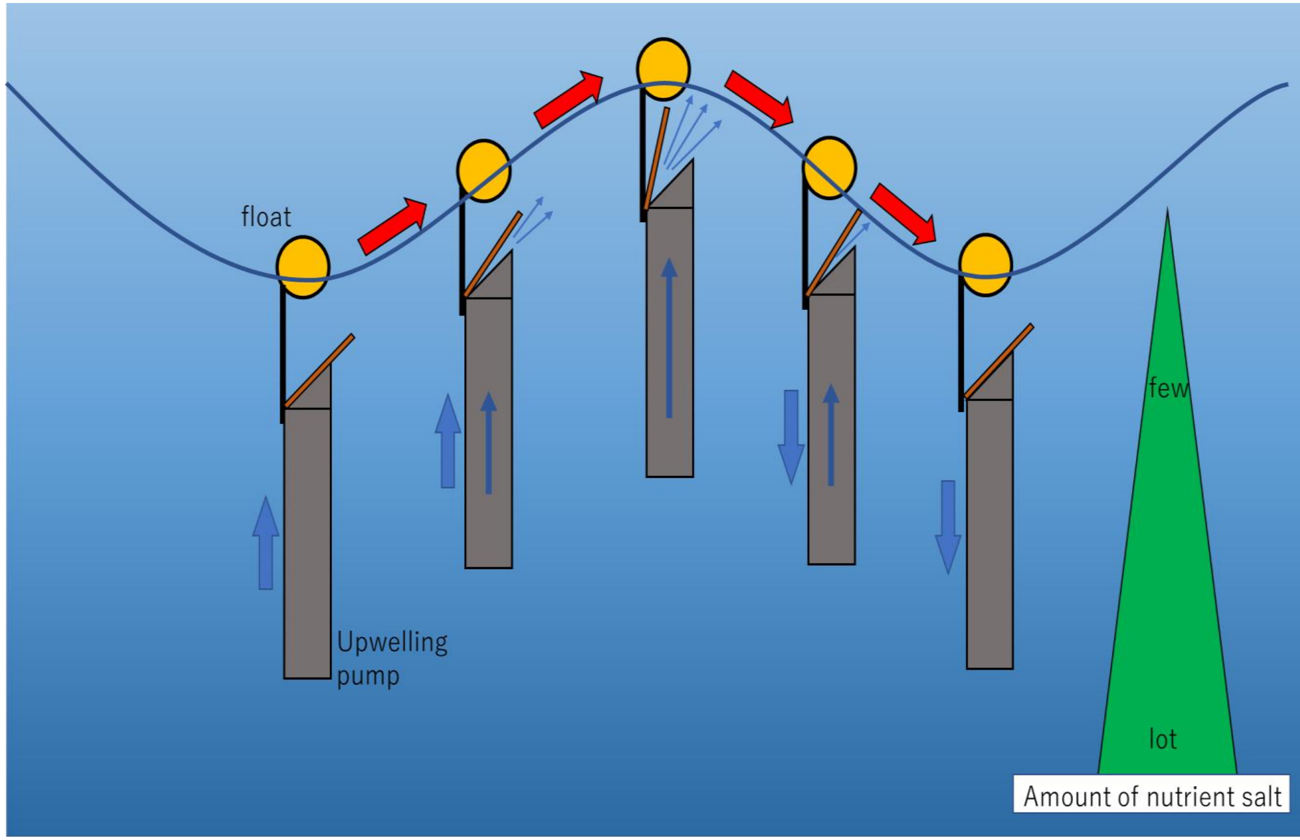
Contents

About the wave-driven upwelling pump

- The upwelling pump is connected to the float to transmit the movement of the waves to the pump.

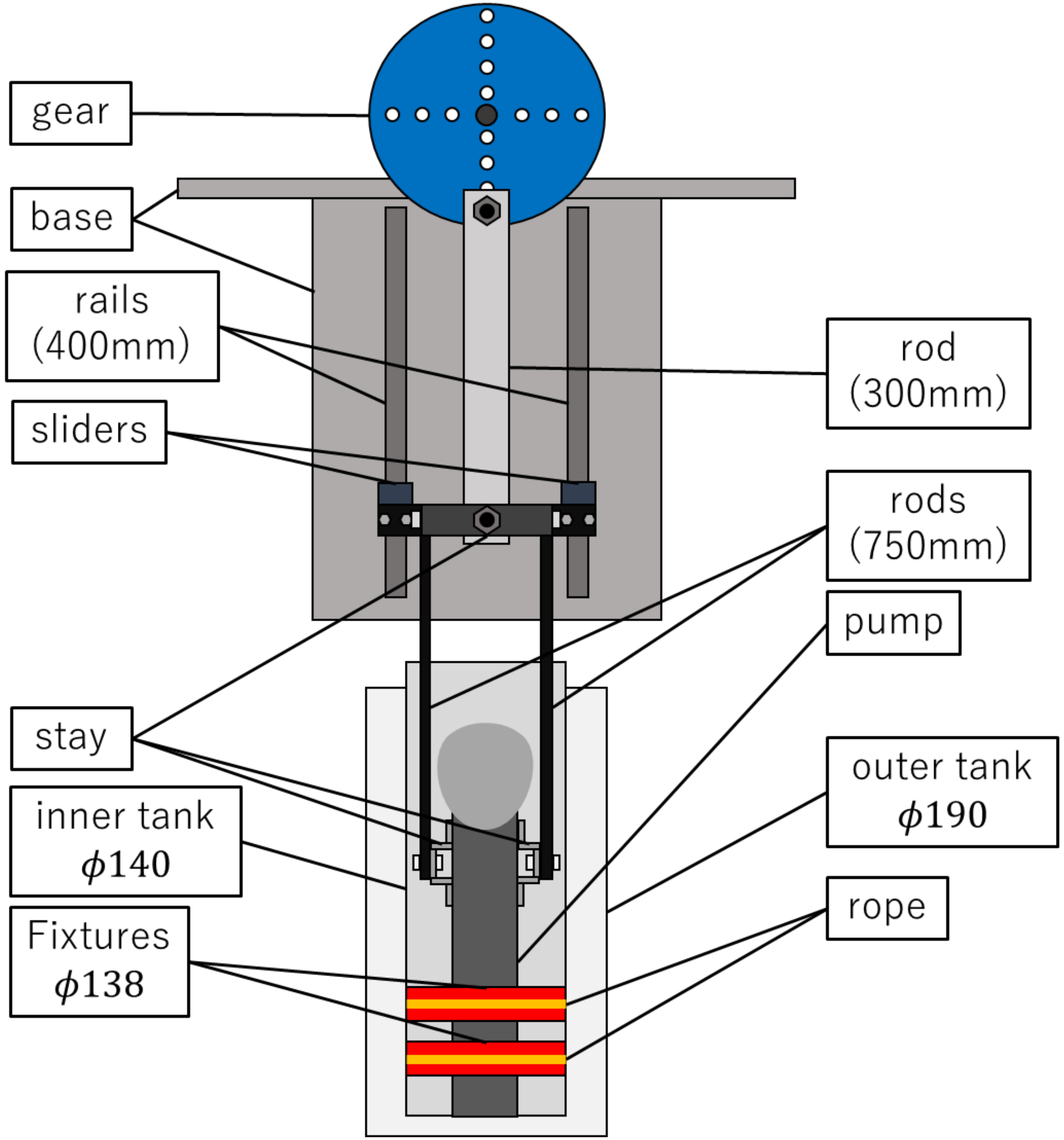
- As the pump rises and accelerates, the water in the pipe pushes open the valve and pumps the water.

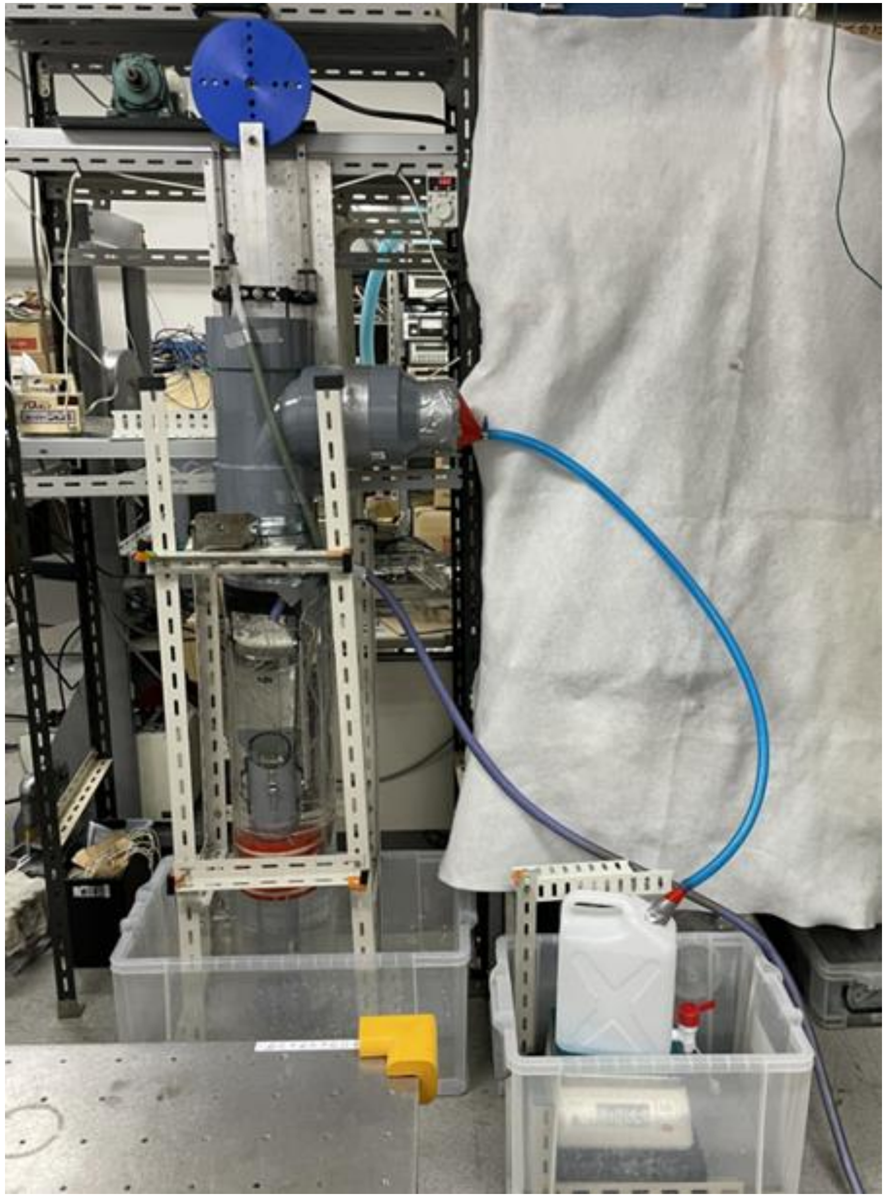
- It has the effect of lifting the water to the surface by containing more nutrients that exist in the deeper layers.



Experimental apparatus

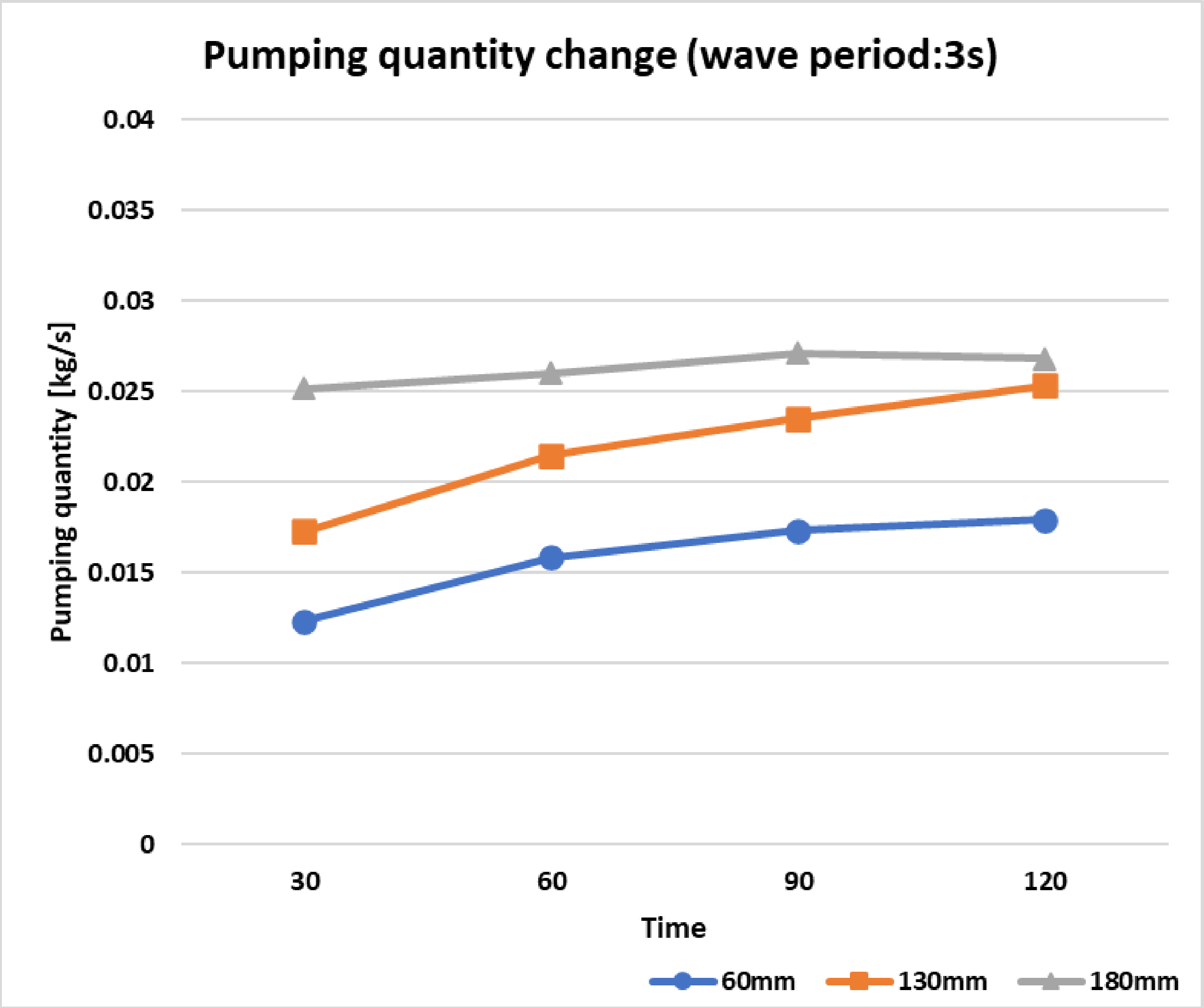
- Uses motor and gearhead with an output of 90W and a reduction ratio of 30
- The amplitude can be changed by drilling hole in the gears.
- The fixture is made with a 3Dprinter and wrapped with a string to prevent leakage.

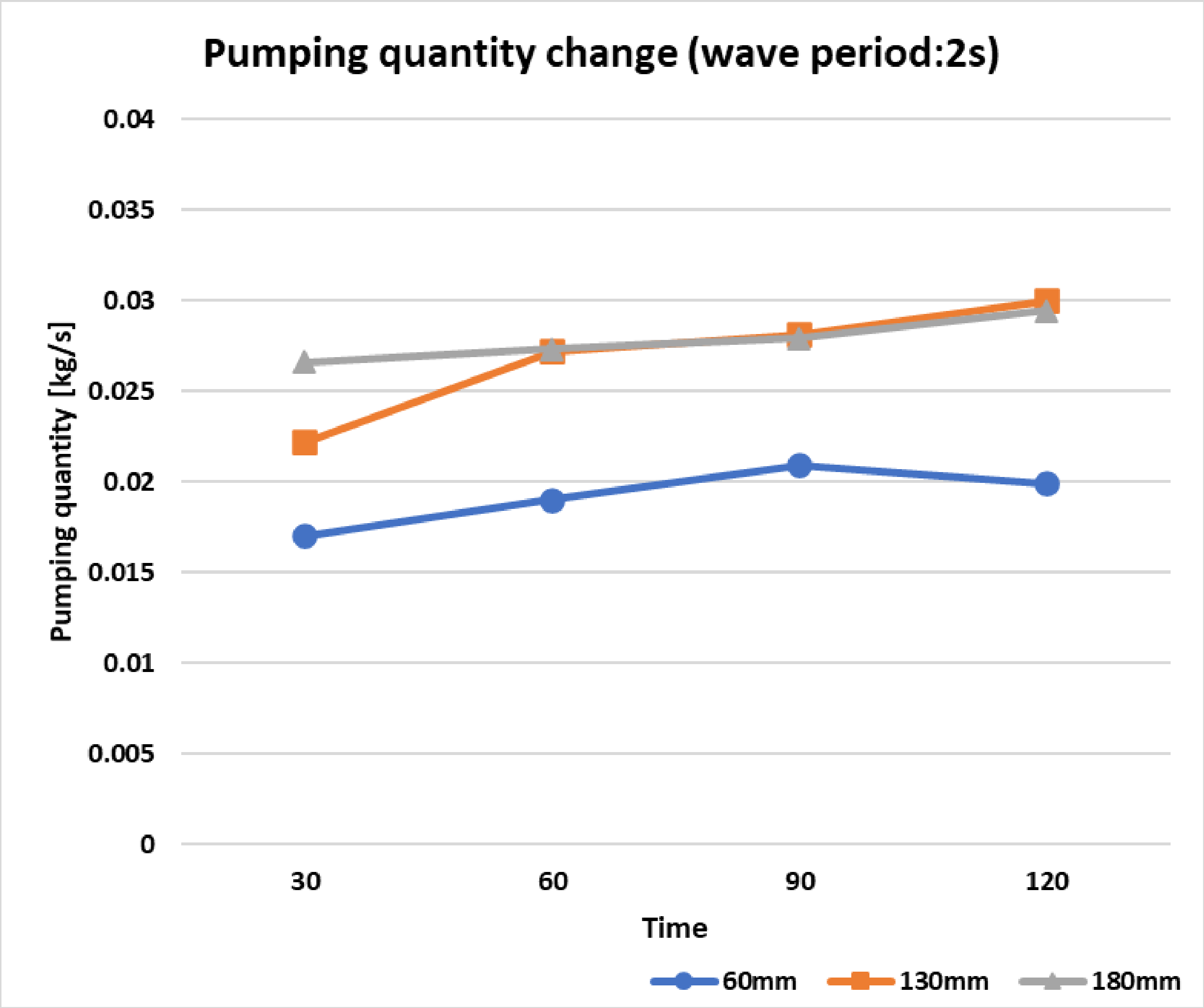


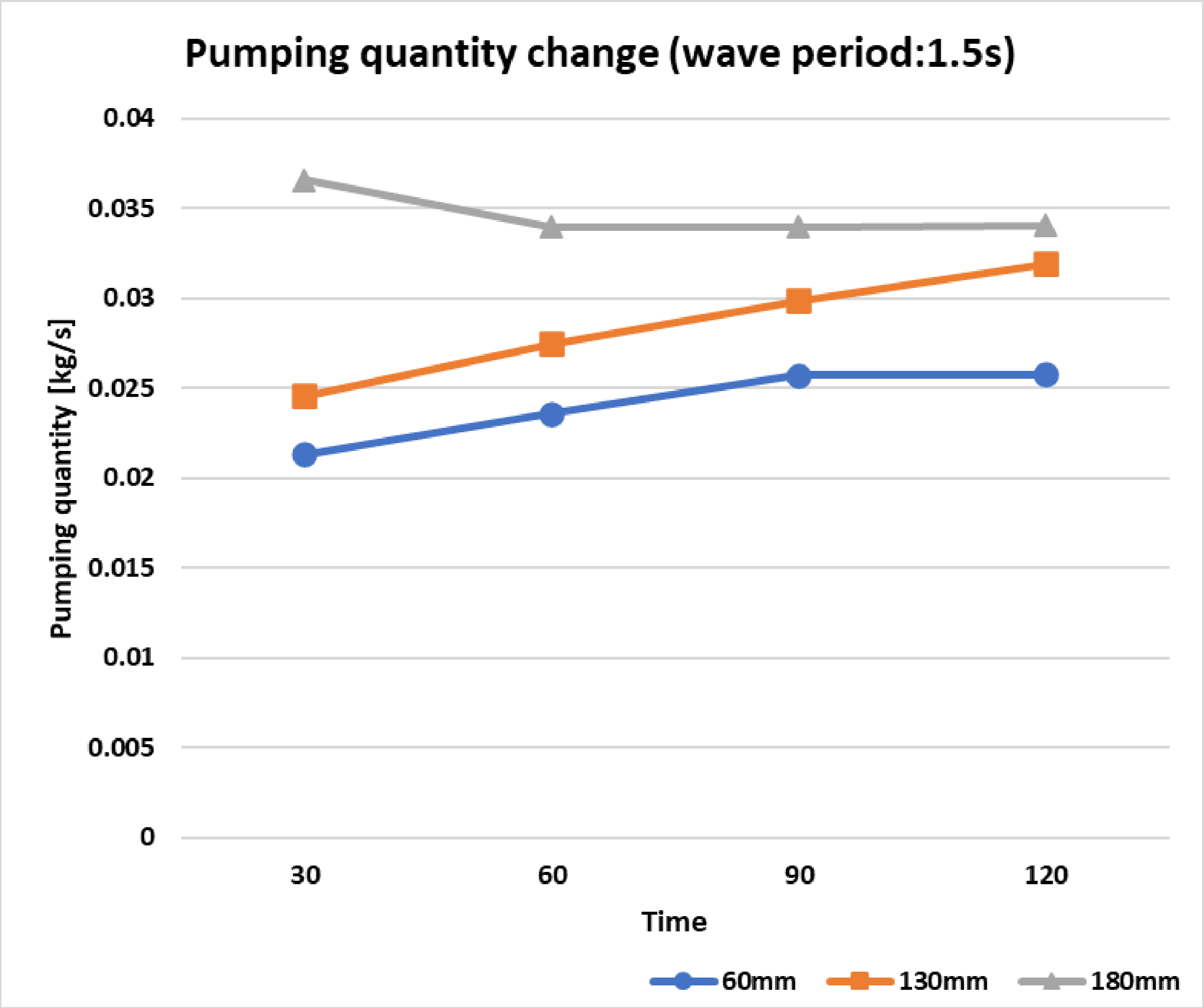


Measurements

- Measurement results for a wave period of 3 seconds
- The larger the amplitude, the greater the amount of upwelling.
- It’s asymptotic to a constant amount over time.

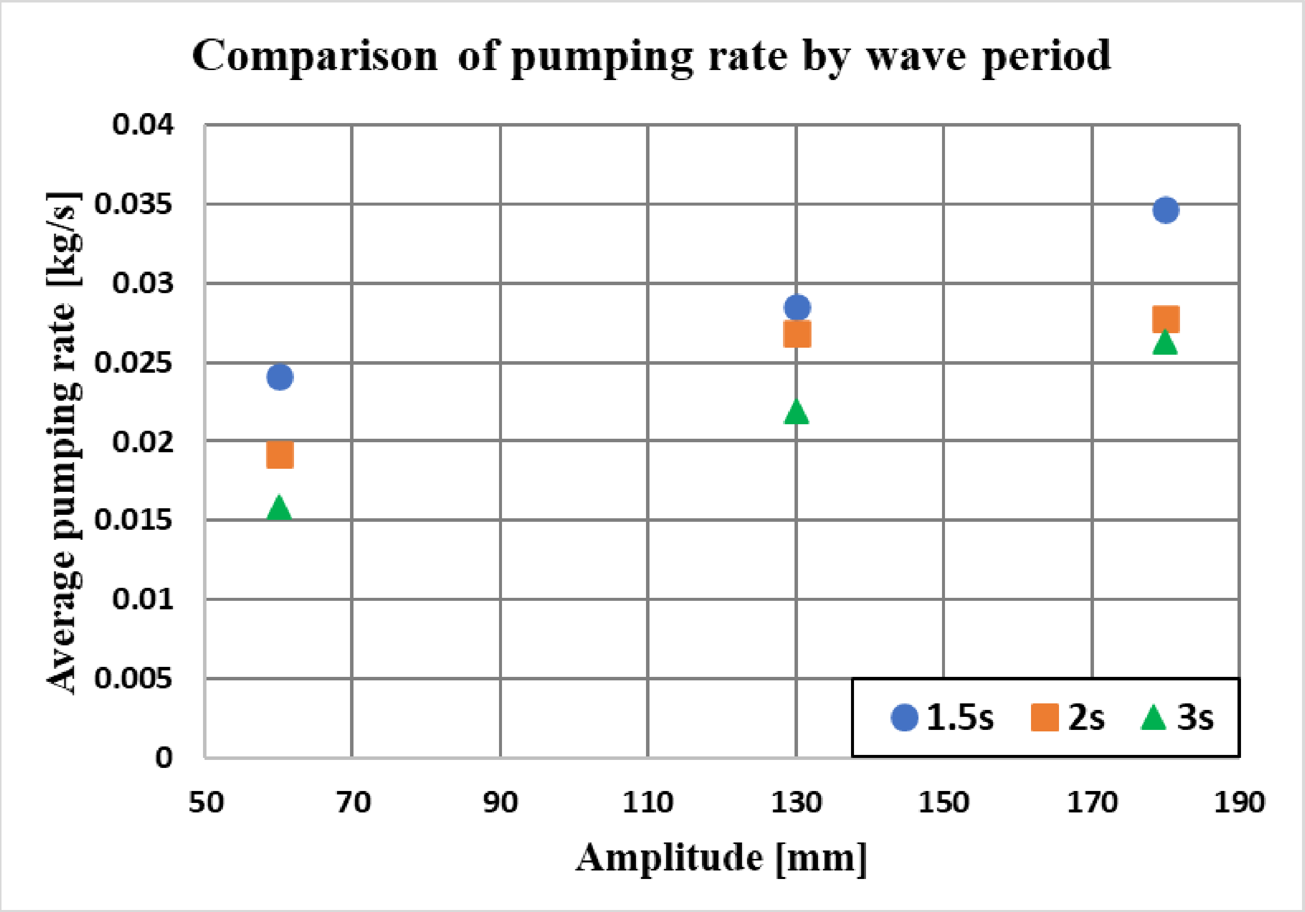



Pumping quantity change (wave period:2s)
Pumping quantity [kg/s]
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
30
60
90
120
Time
60mm
130mm
180mm

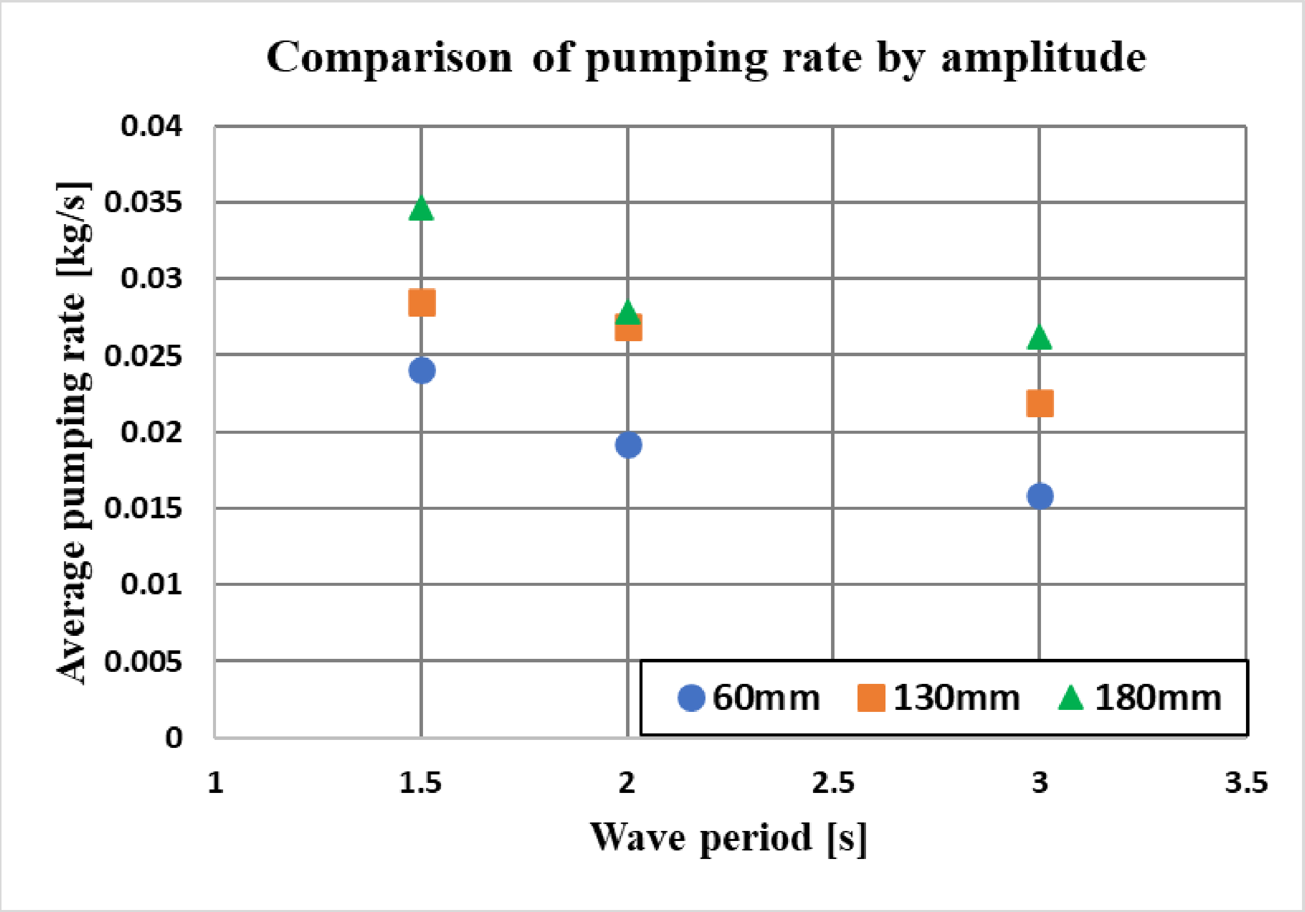

Pumping quantity change (wave period:1.5s)
Pumping quantity [kg/s]
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
30
60
90
120
Time
60mm
130mm
180mm

Considerations

- Comparison of the amount of upwelling for each amplitude.
- There is a proportional relationship between the amplitude and the amount of upwelling.
- The upwelling rate increased by a factor of 1.44~1.66 when the amplitude increased by a factor of 3



- Comparison of the amount of upwelling for each wave period.
- There is an inverse relationship between wave period and the amount of upwelling.
- The upwelling rate increased by a factor of 1.32~1.52 when the wave period increased by a factor of 1/2



- Theoretical equation of upwelling rate

$$Q_{th} = \frac{\pi AH}{T}\left(-\frac{\Delta\rho}{\rho} gAT\right)$$

(A : Pipe cross section, H : Amplitude, T : wave period)

(ρ : Density of water, $\Delta\rho$: Density difference,

g : Acceleration of gravity)

- Upwelling flow efficiency

$$\eta_u = \frac{Q_m}{Q_{th}}$$

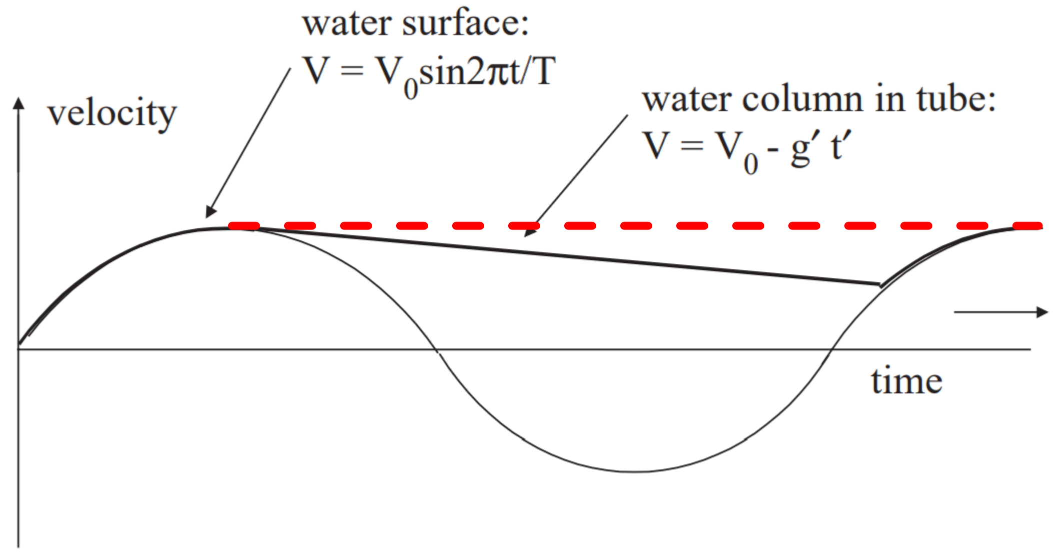
(Q_m : Measured flow, Q_{th}: Theoretical flow)

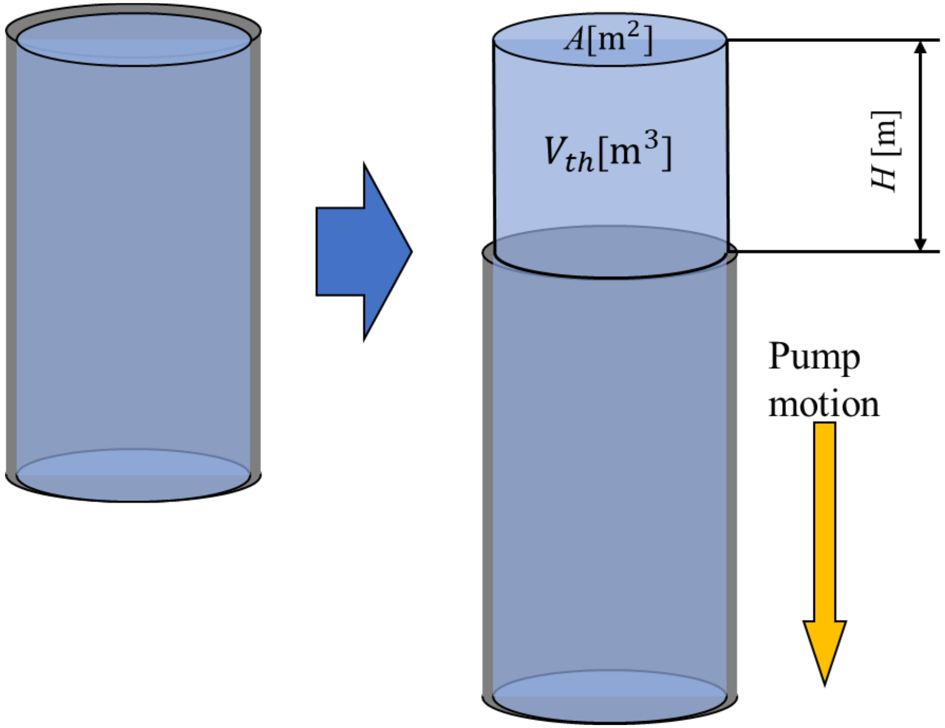
- Upwelling volume efficiency

$$\eta_V = \frac{V_m}{V_{th}}$$

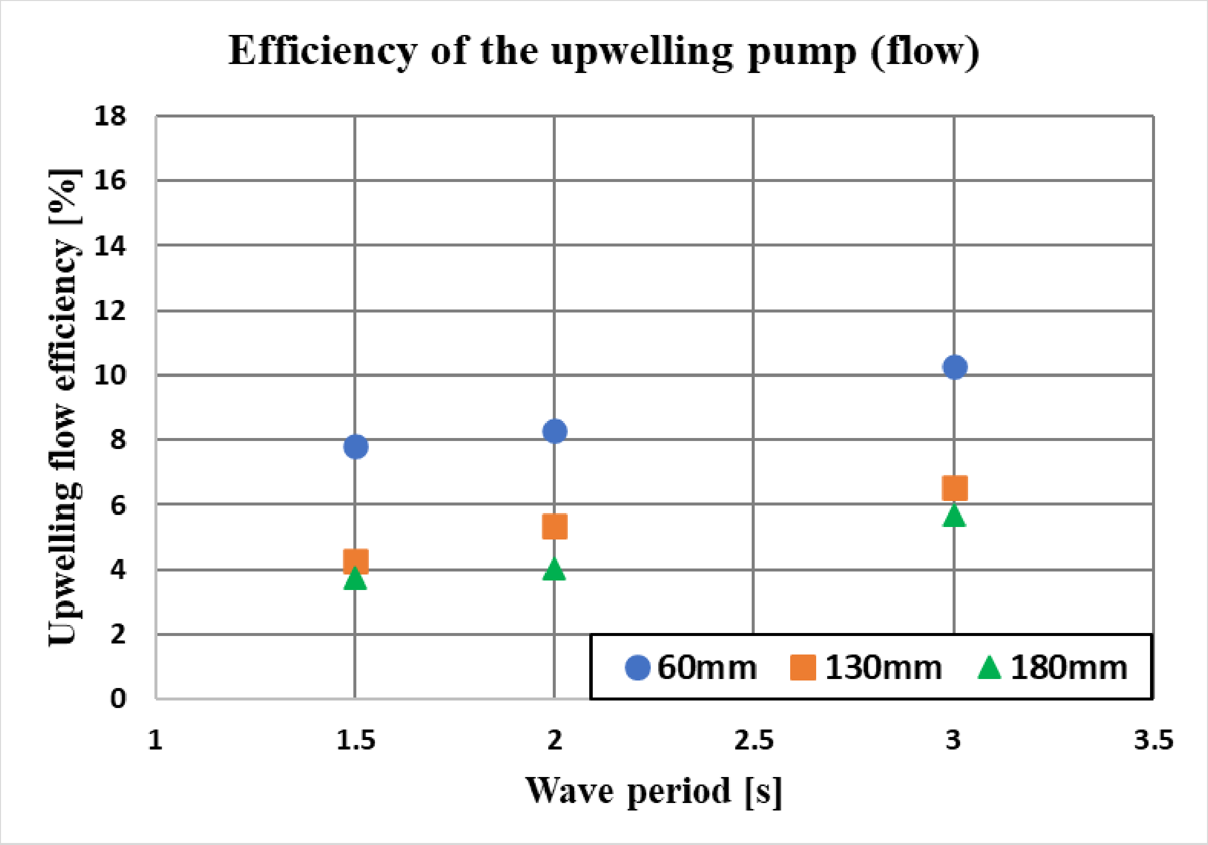
(V_m: Measured volume, V_{th}:Theoretical volume)

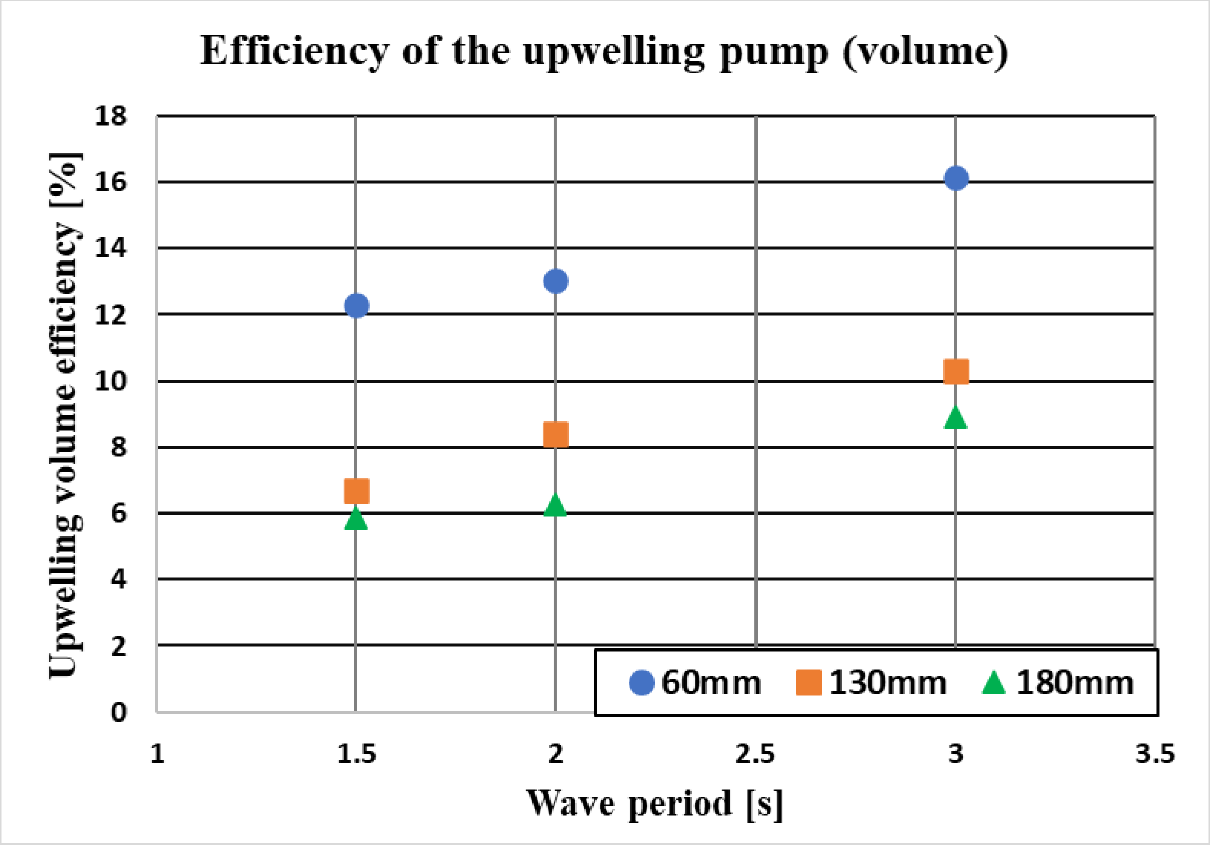
$$V_{th} = AH$$



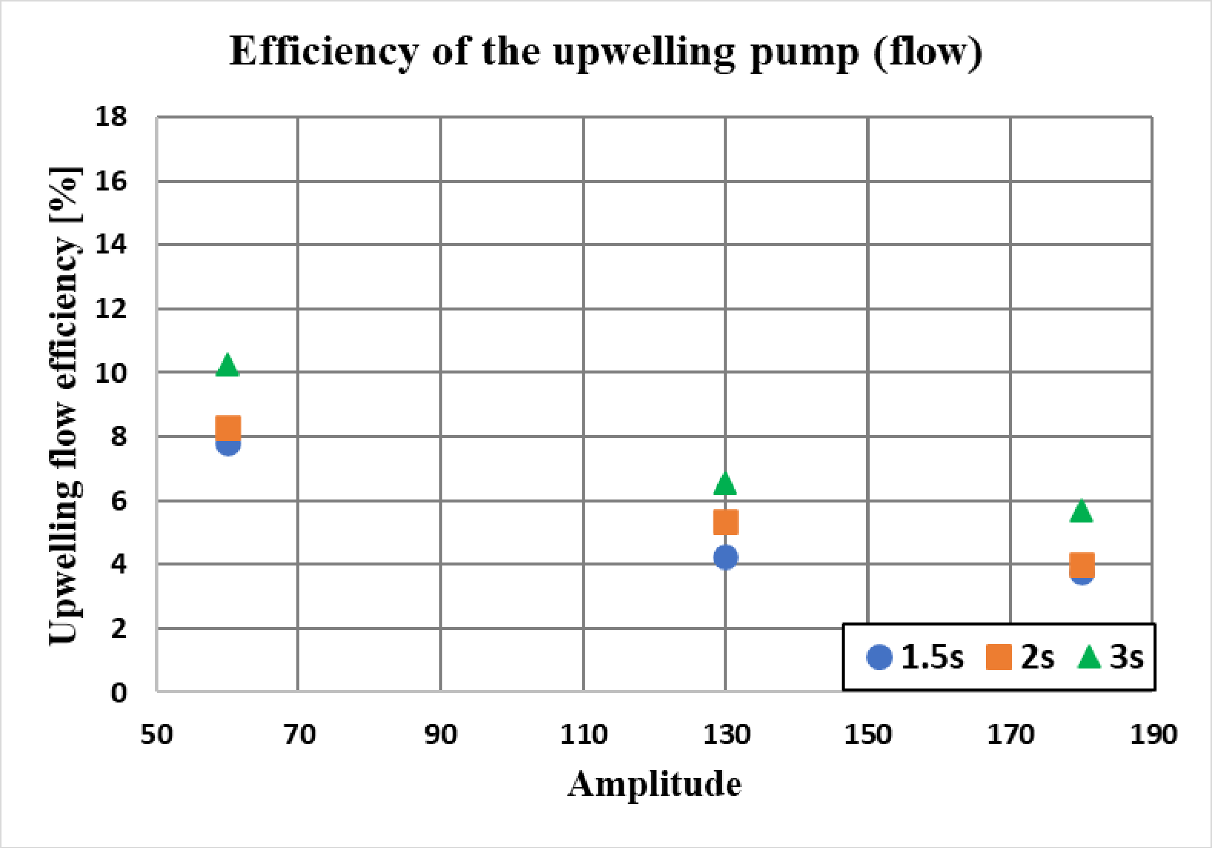


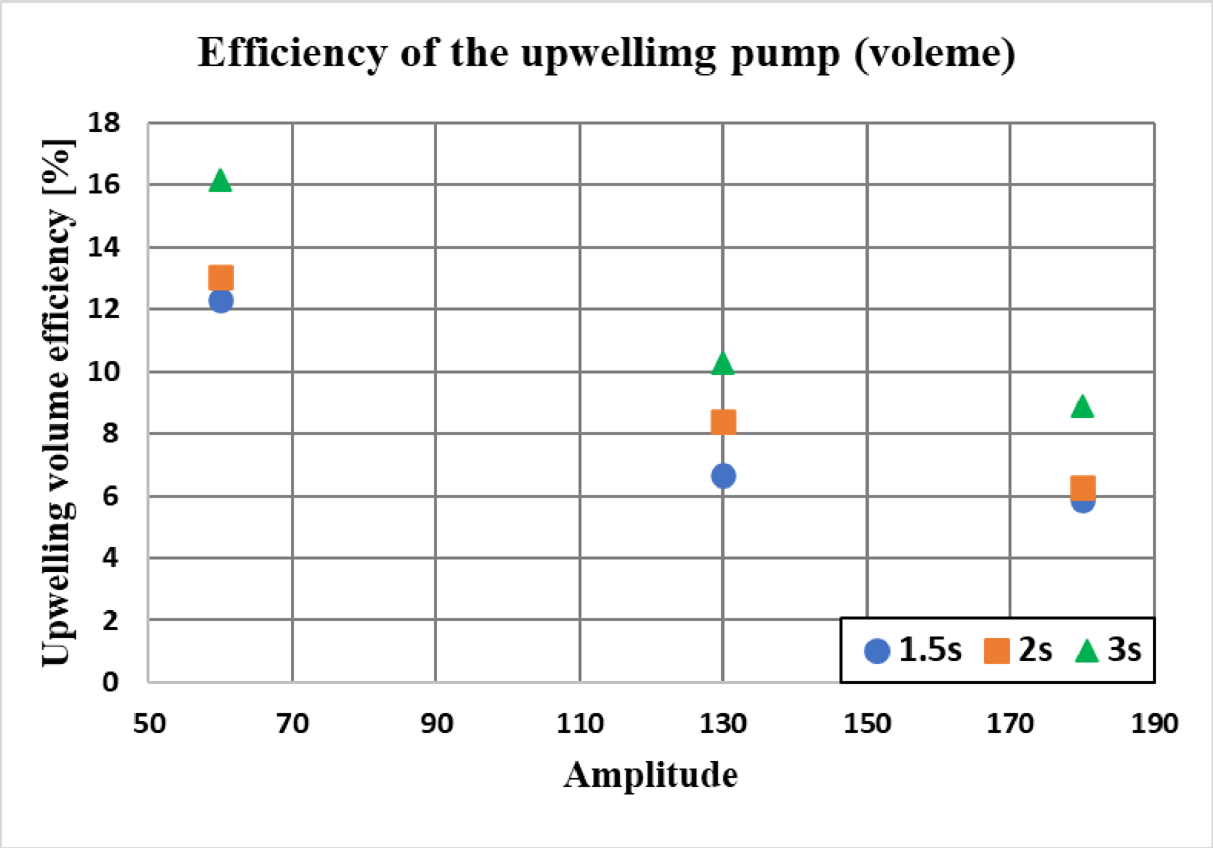
Upwelling efficiency of each

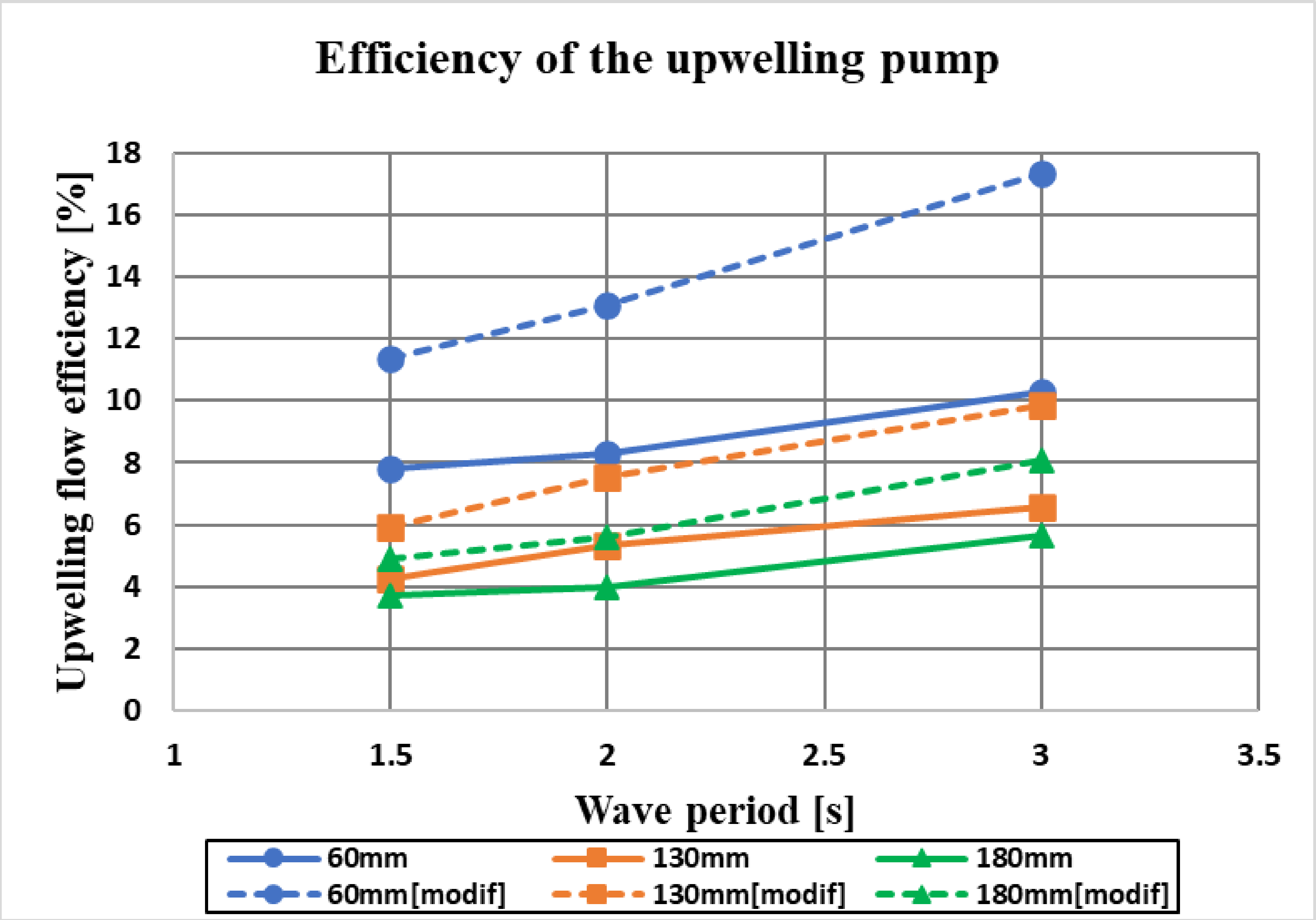


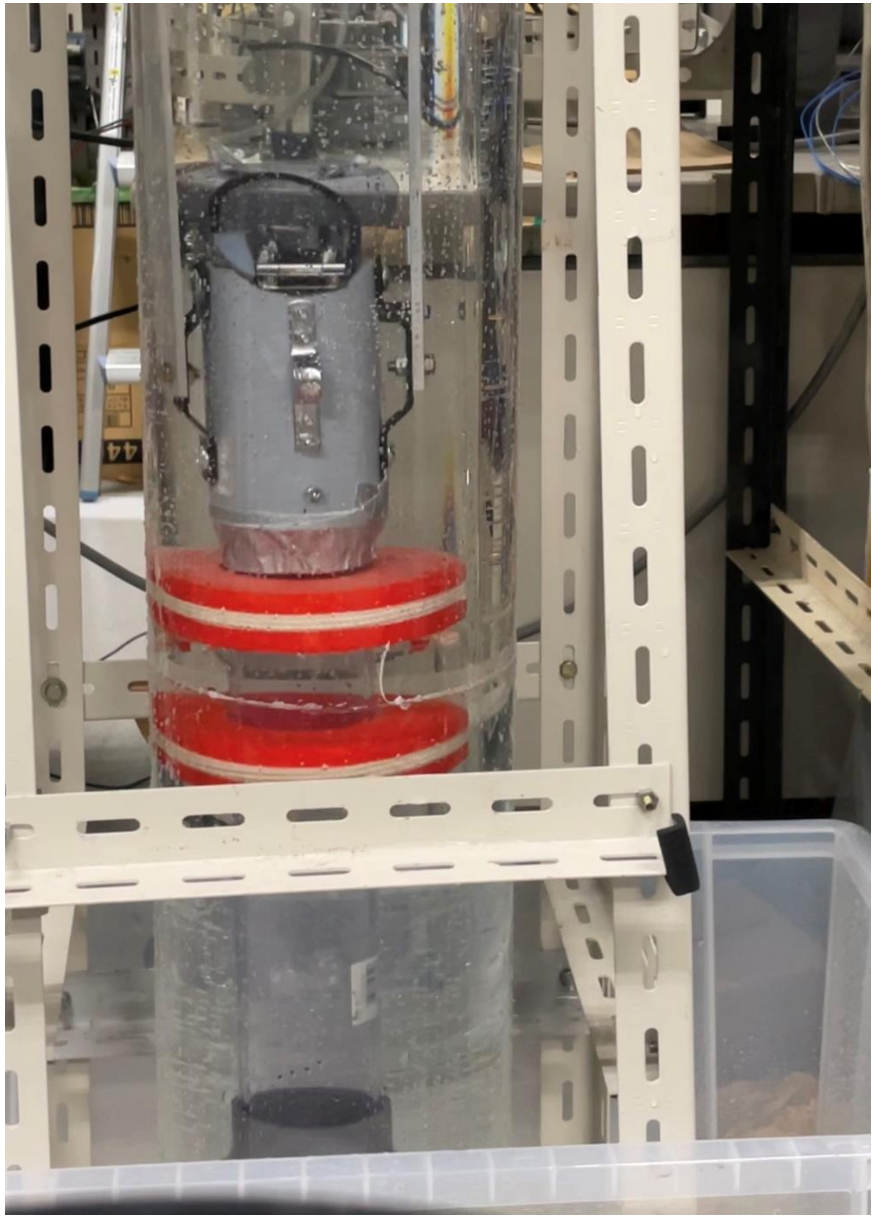


Upwelling efficiency of each






Efficiency of the upwelling pump
Upwelling flow efficiency [%]
0
2
4
6
8
10
12
14
16
18
1
1.5
2
2.5
3
3.5
Wave period [s]
60mm
130mm
180mm
60mm[modif]
130mm[modif]
180mm[modif]



Proposal of experimental apparatus

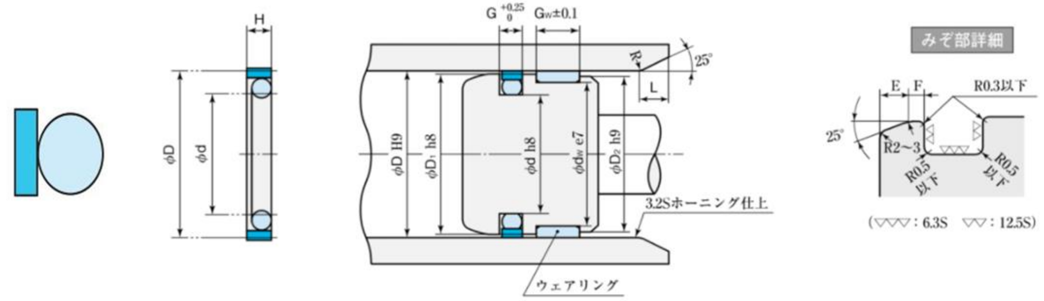
- Reduce the water head difference
- Packing optimization
- Pump movement force measurement

油圧用パッキン

STシール（STタイプ）（ピストン専用）

標準材質：PTFE(PT111)

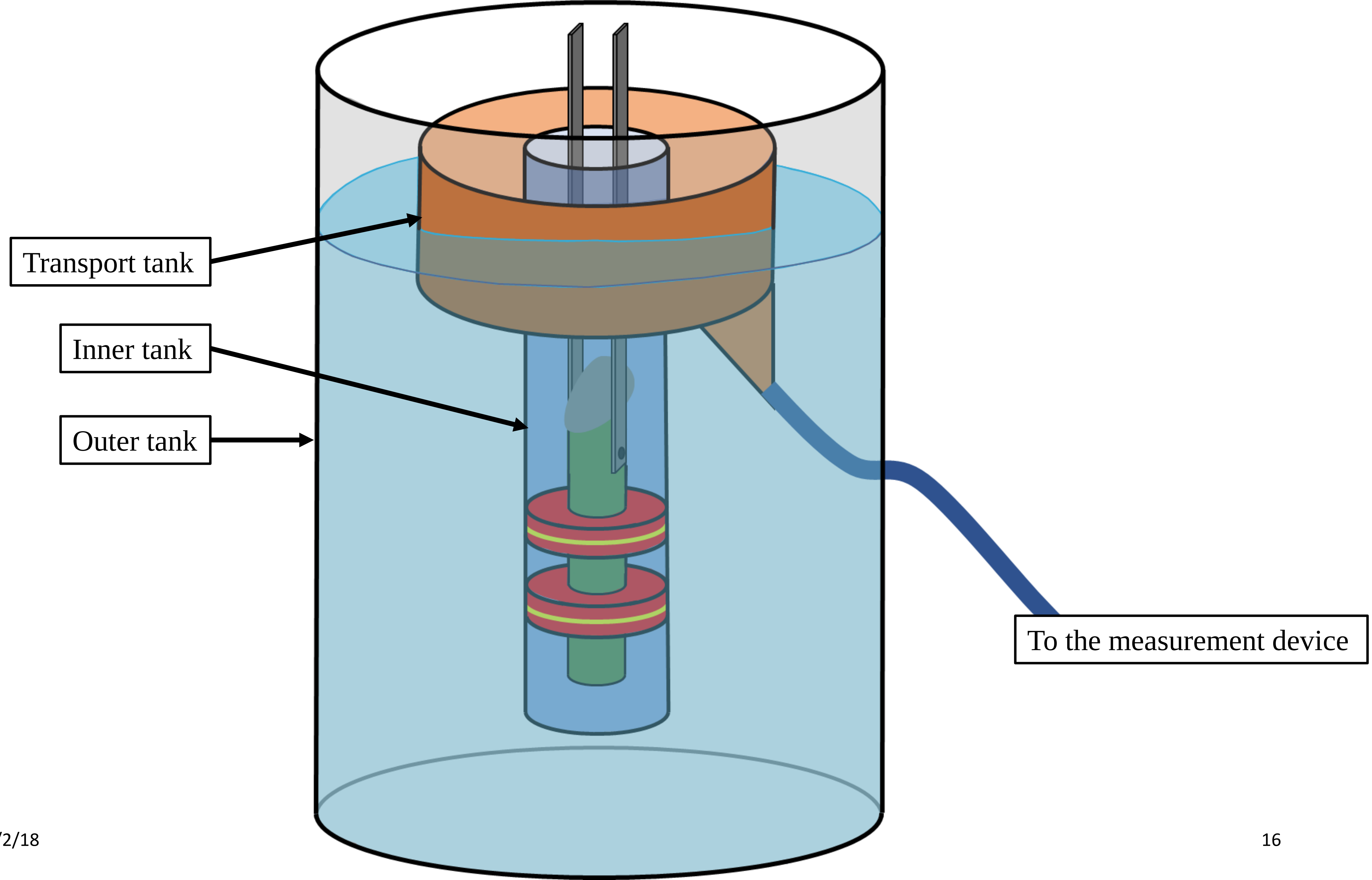
断面形状



使用範囲

標準材質				
材質番号	常用最高圧力 MPa {kgf/cm²}		最高速度 (m/s)	温度 (°C)
PTFE(PT111)	STタイプ	25 {250}	3	−30～100

パッキンおよびみぞ寸法 (単位：mm)											指示コード
D	d	H	G	D1	dw	D2	Gw	E	F	L	標準（PT 111）
120	106	6.2	6.5	119.4	114	118	30	7	3	4	ST-120
125	111	6.2	6.5	124.3	119	123	30	7	3	4	ST-125
130	116	6.2	6.5	129.3	124	128	30	7	3	4	ST-130
135	121	6.2	6.5	134.3	129	133	30	7	3	4	ST-135
140	126	6.2	6.5	139.3	134	138	40	7	3	4	ST-140
150	136	6.2	6.5	149.3	144	148	40	7	3	4	ST-150
160	146	6.2	6.5	159.3	154	158	40	7	3	4	ST-160
170	150	9	10	169.3	164	168	50	11	4	6	ST-170
180	160	9	10	179.3	174	178	50	11	4	6	ST-180


Transport tank
Inner tank
Outer tank
To the measurement device

Conclusion

1. Design and manufacture of experimental equipment for wave-driven upwelling pumps and flow measurement.
2. The relationship between the amount of upwelling and the period and amplitude of the waves was obtained from the measurements. The maximum upwelling rate was about 0.035 kg/s.
3. The upwelling effect was defined in flow rate and volume, respectively. The amplitude and period had an effect, with up to 10% and 16% results, respectively.
4. We studied the measurement error caused by water leakage and found that it affects the efficiency by about 6%, so we proposed an improvement plan.

Thank you for your attention