

8. Air Pocket

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The Problem

A **vertical air jet** from a **straw** produces a cavity on a **water surface**. What parameters determine the **volume** and **depth** of the cavity?

Cavity of Consideration

Stable Parabola
Splashing
Turbulent

volume, depth

Flow Chart

Theory	Experiment	Conclusion
<ul style="list-style-type: none"> Depth Volume Velocity Decay Eq. Parabola 	<ul style="list-style-type: none"> Parameters: Jet Pressure, Height, Nozzle Diameter Preliminary Experiments 	<ul style="list-style-type: none"> Relationship?

Theory

- Depth

H : Nozzle height
 h_c : Cavity depth
 v_N : Velocity at nozzle
 v_C : Velocity at cavity
 d_N : Nozzle diameter

$$\frac{1}{2} \rho_G v_C^2 = \rho_L g h_C \quad \leftarrow \quad \frac{v_C}{v_N} = K \frac{d_N}{H}$$

Dynamic Pressure of Jet = Hydrostatic Pressure

- Banks & Chandrasekhara, J. Fluid Mechanics (1962)

Theory

- Decay of center-line velocity

v_C (m/s)
 v_N
 $\frac{v_C}{v_N} = K \frac{d_N}{H}$
 $K = 6.4$
 $\frac{H}{d_N} > 8$

- Banks & Chandrasekhara, J. Fluid Mechanics (1962)

Theory

- Depth

P_N : Dynamic pressure of jet at Nozzle

$$h_c = \frac{1}{\rho \Delta g} \left(\frac{\rho K d_N^2}{2 C_H} \right)^2 \left(\frac{1}{2} \rho g h_c v_N^2 \right)$$

Decay

Theory

- Volume

$\frac{\Delta p}{\Delta t}$: change of vertical momentum per unit time

$$V = \frac{\Delta p}{2 \rho \Delta g} = \frac{K d_N^3}{2 H} \rho v_N^2 (1 + \sin \theta)$$

- Frank R. Cheslak, J. Fluid Mechanics (1968)

Theory

- Volume

Parabola

$$y = \frac{4h_c}{d_c^2} x^2$$

$$V = \frac{\pi d_c^2 h_c}{8} \quad \theta = \tan^{-1} \left(\frac{4h_c}{d_c^2} \right)$$

Preliminary Experiment

Measurement of air jet velocity

$$\frac{v_C}{v_N} = K \frac{d_N}{H}$$

$\frac{H}{d_N} > 8$

- Banks & Chandrasekhara, J. Fluid Mechanics (1962)

Pressure Gauge

Stagnation Pressure P_1

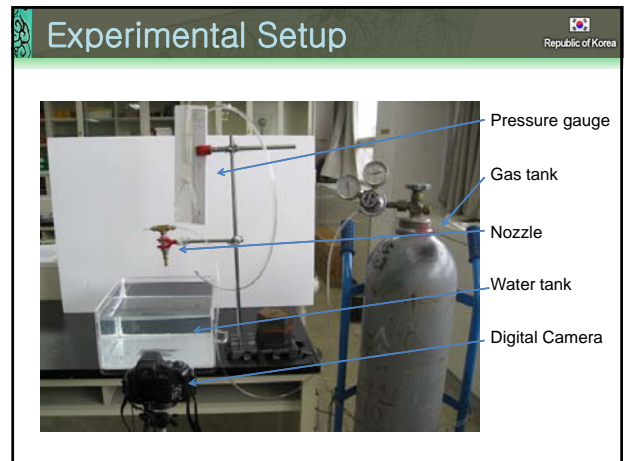
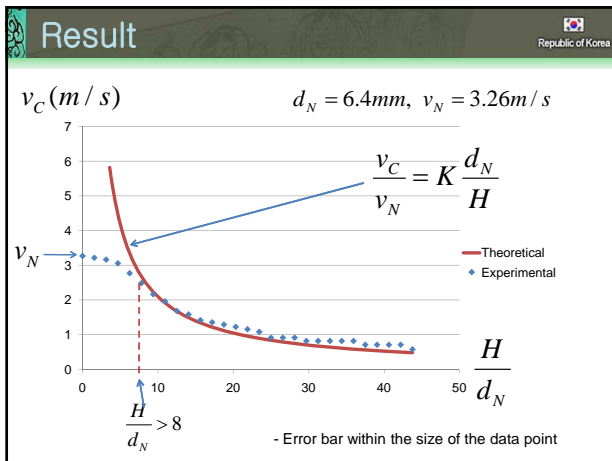
Static Pressure P_2

$$P_1 - P_2 = \text{Dynamic Pressure}$$

$$\text{Dynamic Pressure} = \frac{1}{2} \rho v^2$$

Preliminary Experiment – Setup

- Nozzle
- Pressure gauge
- 30cm Ruler



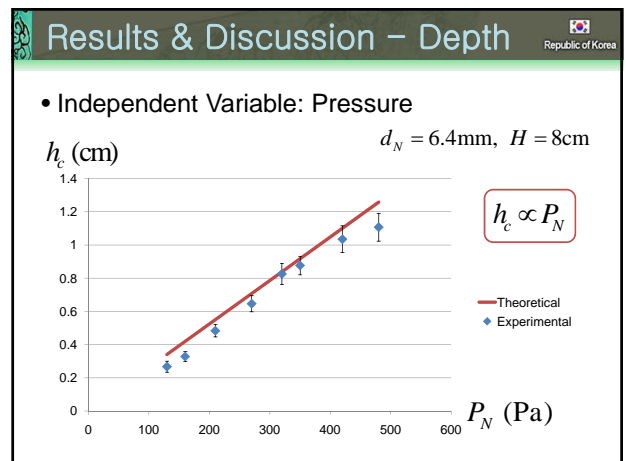
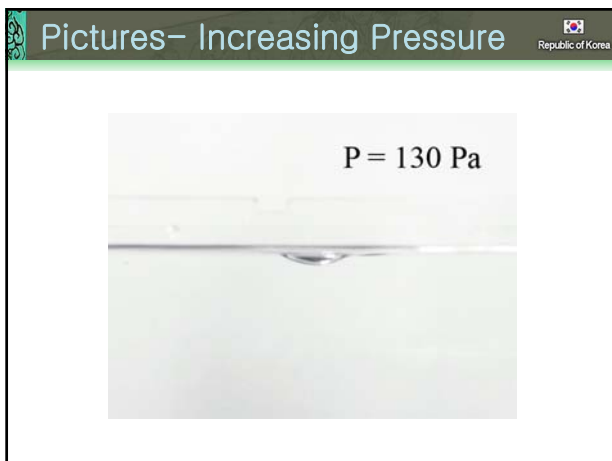
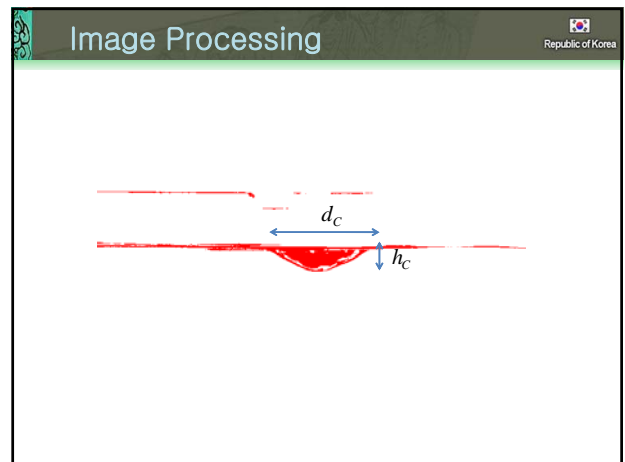
Experimental Parameters

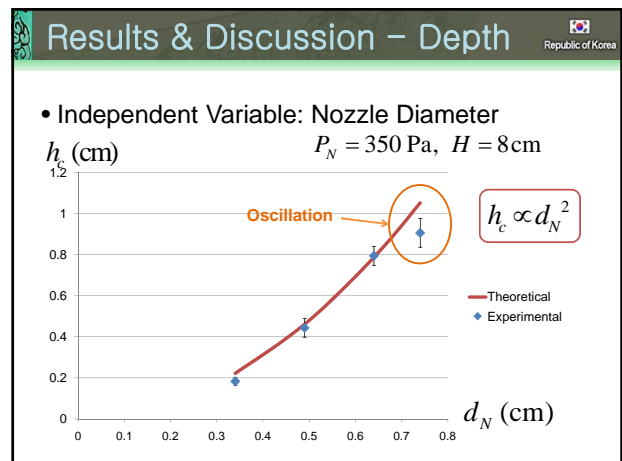
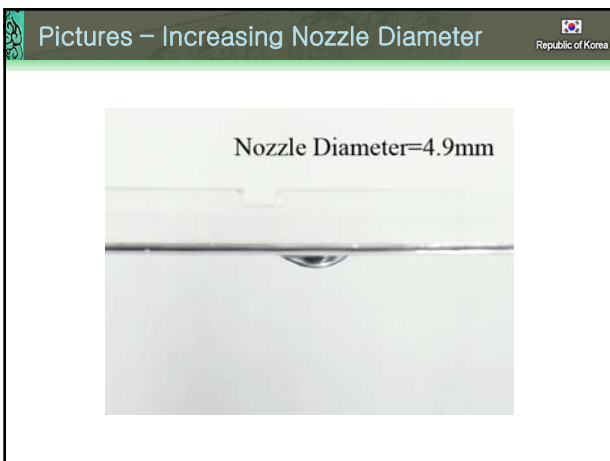
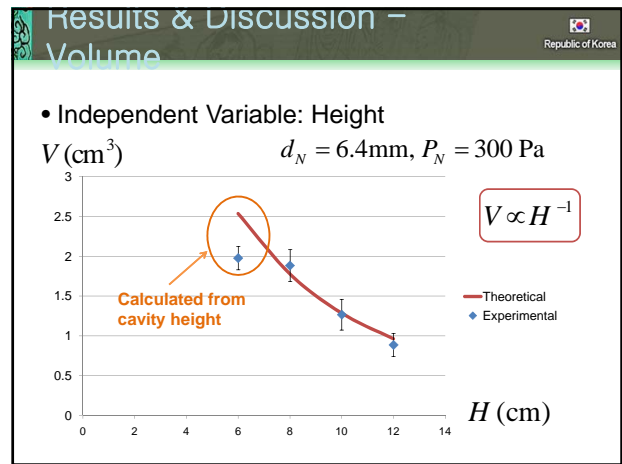
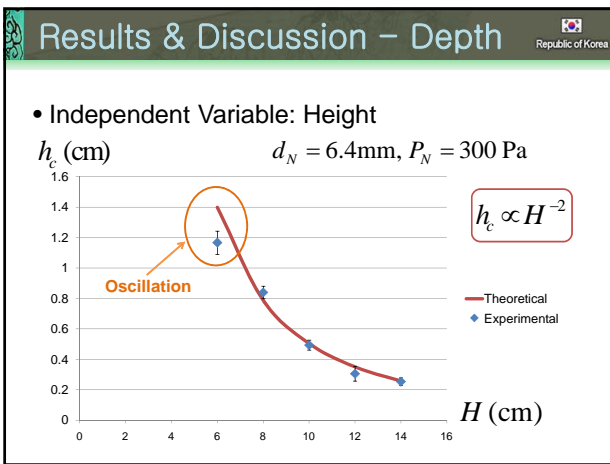
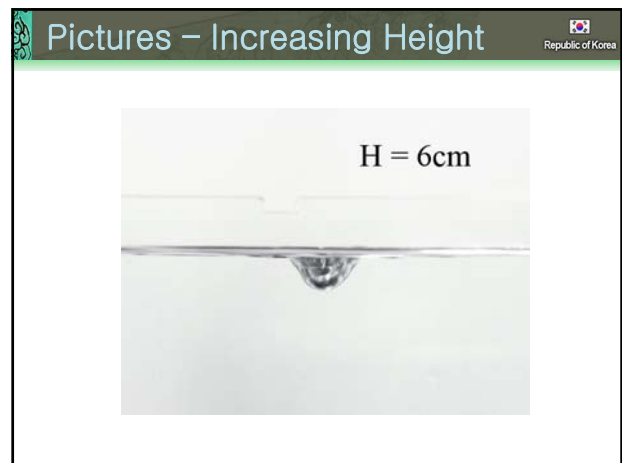
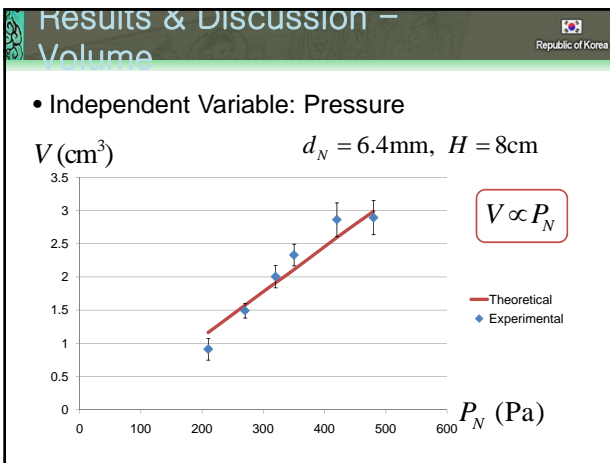
Temperature = 27°C

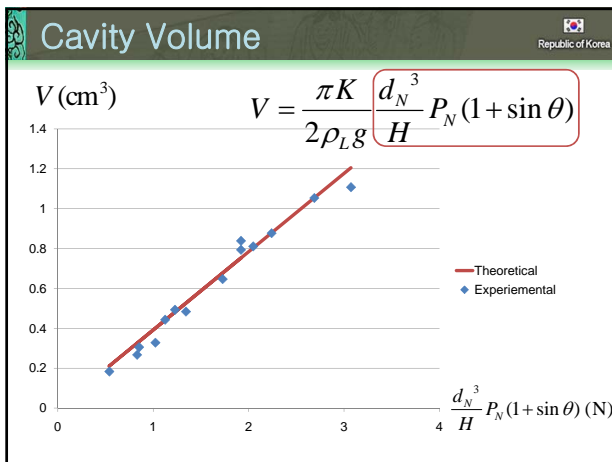
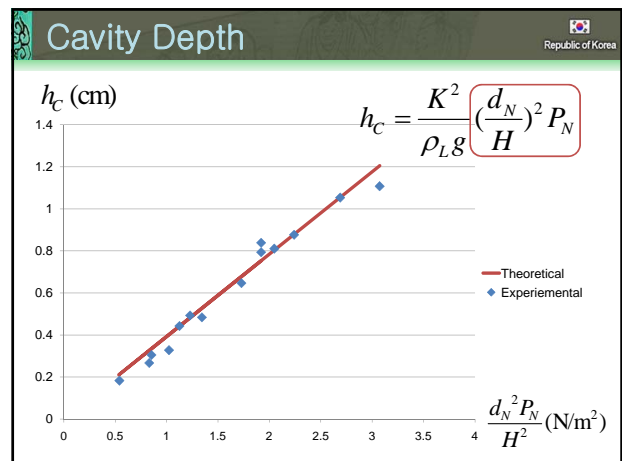
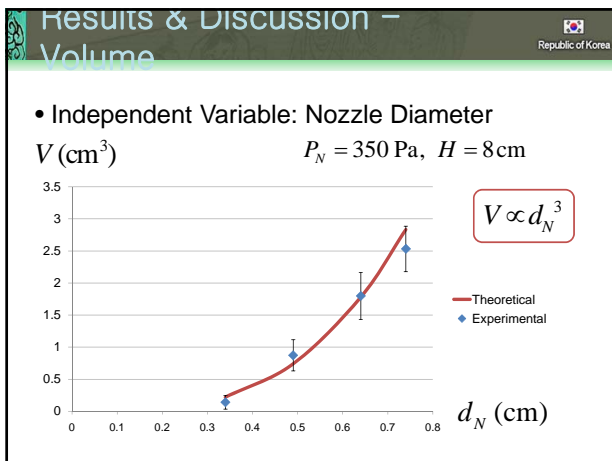
Pressure (P_N): 130 Pa ~ 480 Pa

Height (H): 6cm, 8cm, 10cm, 12cm, 14cm

Nozzle Diameter (d_N): 3.4mm, 4.9mm, 6.4mm, 7.4mm







Conclusion

Parameters that determine,

Depth, Volume ← P_N, H, d_N

Depth $h_c \propto P_N, H^{-2}, d_N^2$

Volume $V \propto P_N, H^{-1}, d_N^3$

Additional points,
Velocity decay eq. Parabola

Thank You