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Density measurement with the vibrating tube densimeter

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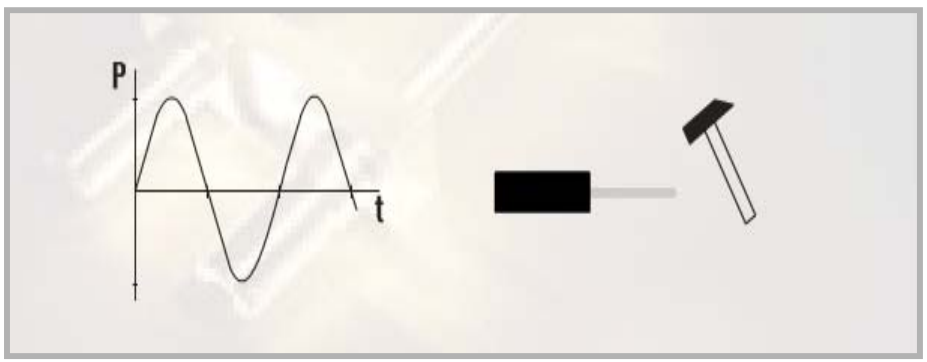
Objectives

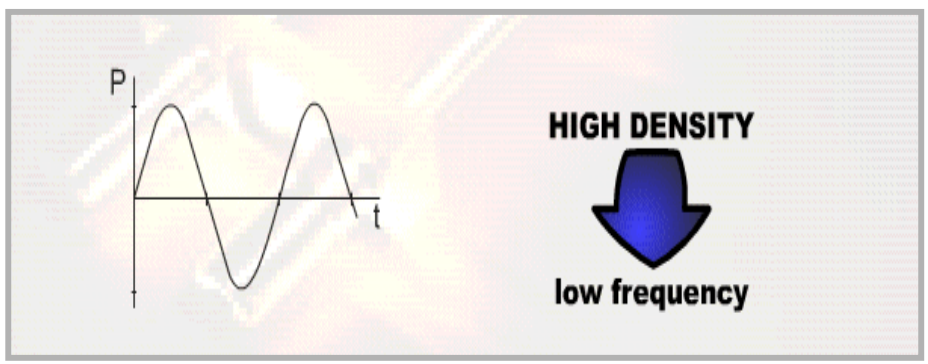
- 초임계를 포함한 고온, 고압영역까지 Density를 측정할 수 있는 실험 장치를 설계 및 고안.
- 기준물질로 water와 vacuum을 이용하여 Densimeter 보정.
- CO_2 period를 측정하여 Densimeter 보정식으로 결정된 Density를 보고된 실험결과와 비교, 검토하여 실험장치의 건전성 확인.

Introduction

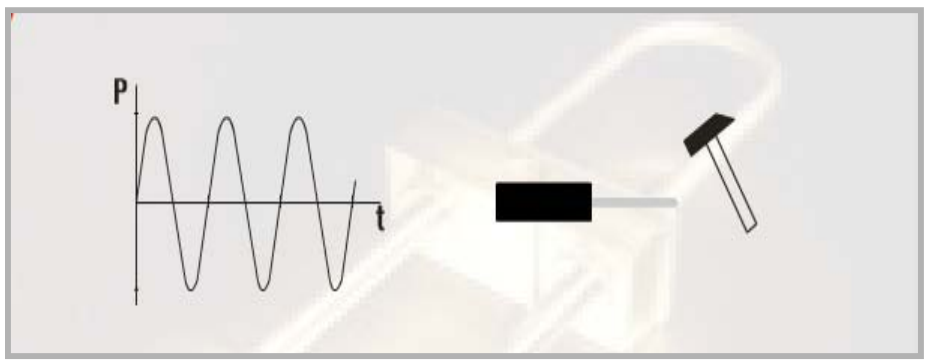
- **U-tube method principle**

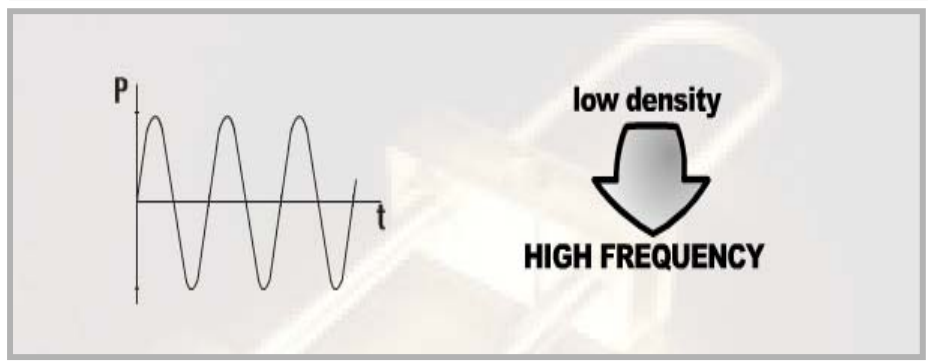
◈ U- tube filled with water





◈ U- tube filled with vacuum





Introduction

- **Anton Paar DMA 512P**

Cell material:	Hastelloy C-276
Temperature range:	-10 to +150 °C (14 to 302 °F)
Pressure range:	0 to 700 bar (0 to 10,000 psi)
Density range:	0 to 3 g/cm3
Density resolution:	1 x 10E-5g/cm3
Density repeatability:	±1 x 10E-5 g/cm3
Accuracy:	1 x 10E-3 g/cm3 up to 3 x 10E-5 g/cm3
Volume of the measuring cell:	Approx. 2,5 cm3
Temperature coefficient of the measuring cell:	Typically -3 x 10E-3 g/cm3/K
Pressure coefficient of the measuring cell:	Typically 2 x 10E-5 g/cm3/bar
Dimensions / Weight:	320 x 120 x 430 / 25 kg
Power supply:	110/220 V a.c., 60/50 Hz
Connections:	Pressure fittings for metal tubes with 1/8" outer diameter

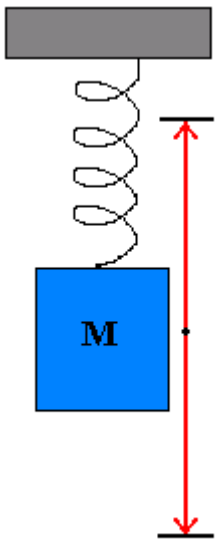
Introduction

• **Comparison**

	Hydrometer	Pycnometer	U-Tube
Volume of sample	> 100 ml	10 to 100 ml	1 ml
Time per measurement	A few minutes	A few hours	A few minutes
Uncertainty of measurement	10^{-3} to 10^{-4} g/cm^3	10^{-4} to 10^{-5} g/cm^3	10^{-3} to 10^{-5} g/cm^3
Repeatability	10^{-3} to 10^{-4} g/cm^3	10^{-3} to 10^{-4} g/cm^3	10^{-4} to 10^{-6} g/cm^3
Limiting factors	Temperature Surface tension Human influence	Temperature Volume determination Human influence	Dynamic effects

Results

- **Calibration method**



$$f = \frac{1}{2\pi}\sqrt{\frac{C}{M}} = \frac{1}{2\pi}\sqrt{\frac{C}{M_u + \rho V_u}} \qquad \tau = 2\pi\sqrt{\frac{M_u + \rho V_u}{C}}$$

M_u ; The mass of tube

V_u ; The internal volume of tube

C ; Elasticity constant

$$\rho(T,P) = A(T,P)\times\tau^2(T,P) - B(T,P)$$

Introduction

- **Case Ⅰ) At constant T and P**

$$\rho = A \times \tau^2 - B$$

$$A = \frac{\rho_1 - \rho_2}{P_1^2 - P_2^2}$$

$$B = \frac{\tau_2^2 \times \rho_1 - \tau_1^2 \times \rho_2}{\tau_1^2 - \tau_2^2}$$

ρ ; unknown density of sample

ρ_1 ; density of reference 1

ρ ; density of reference 2

τ ; Period of reference 1

τ ; Period of reference 2

τ ; Period of sample

Introduction

- **Case Ⅱ) Over wide T and P ranges**

$$\rho(T,P) = \rho_w(T,P) + \frac{\rho_w(T,1)}{\tau_w^2(T,1) - \tau_v^2(T)}\left[\tau^2(T,P) - \tau_w^2(T,P)\right]$$

ρ ; unknown density of sample

ρ_w

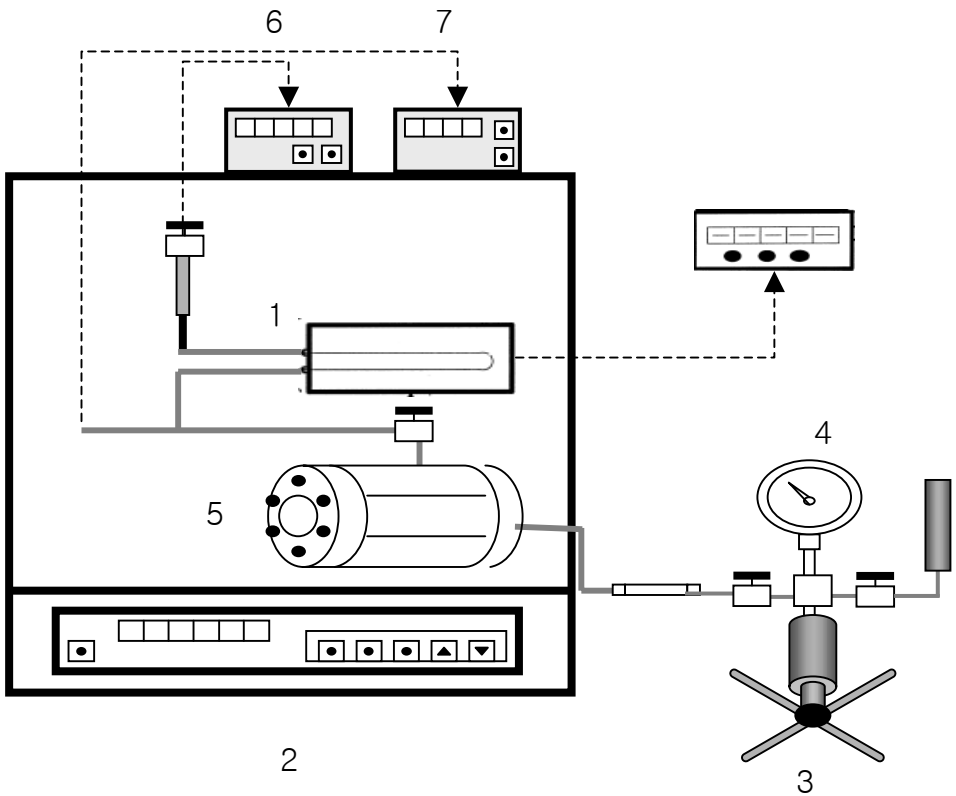
τ_υ ; the period of vacuum

τ ; the period of sample

τ_w ; the period of water

Experimental Apparatus

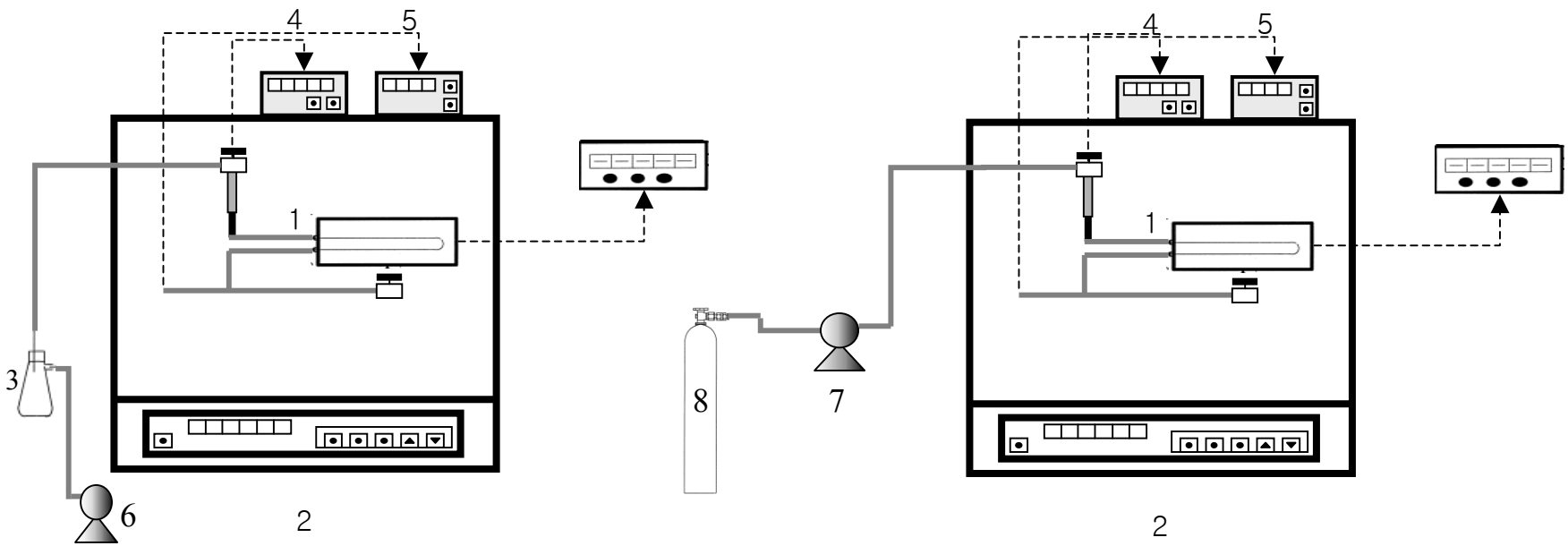
- **water**



1. U-tube
2. Air bath
3. Hand pump
4. Pressure gauge
5. View cell
6. Digital pressure transducer
7. RTD Indicator

Experimental Apparatus

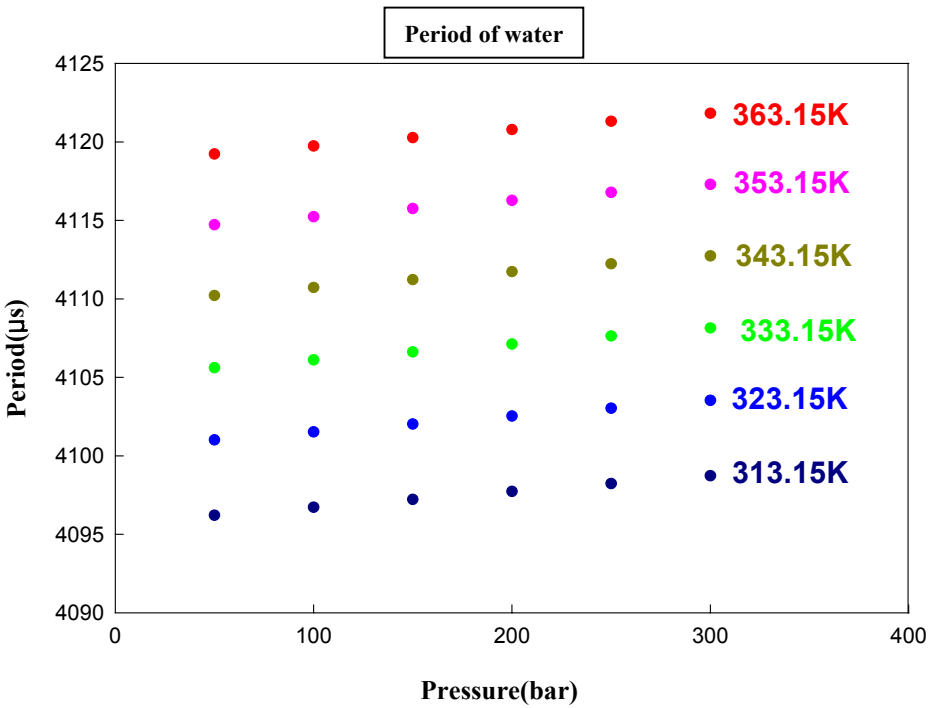
• vacuum , CO_2

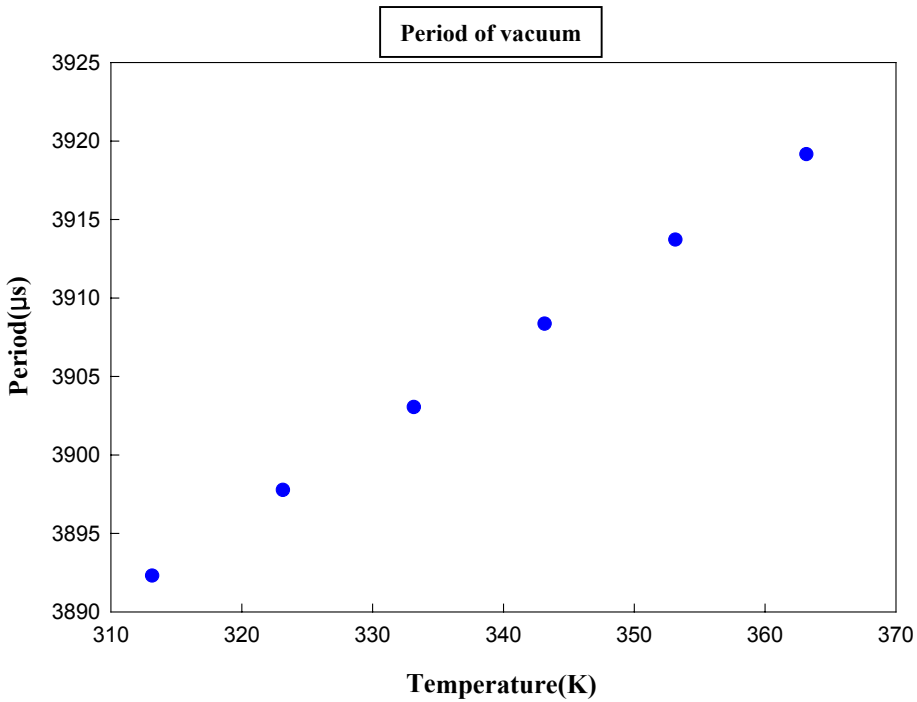


1.	U-tube	4.	Digital pressure transducer	7.	Gas booster
2.	Air bath	5.	RTD Indicator	8.	CO_2 bombe
3.	Trap	6.	Vacuum pump		

Results

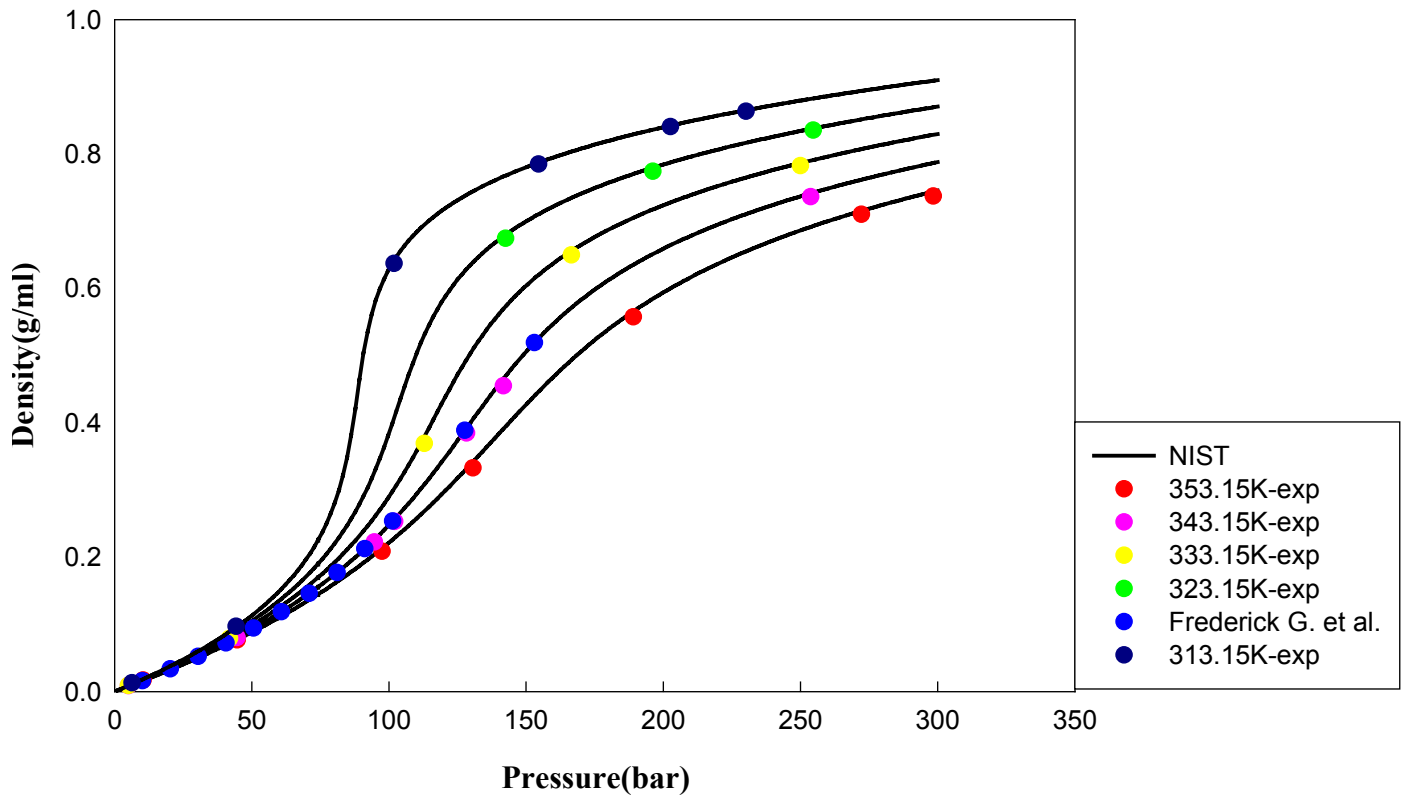
- **Period of water and vacuum**





Results

- Density of CO_2



Conclusions

- U-tube method를 이용하여 고온, 고압 및 초임계까지 density를 측정할 수 있는 실험장치를 설계 및 고안하였다.
- 기준물질로 water와 vacuum의 period를 측정하여 보정하였다.
- CO_2 period를 측정하여 densimeter 보정식으로 결정된 density를 보고된 실험결과와 비교, 검토하여 실험장치의 건전성을 확인하였다.
- 광범위한 온도, 압력조건에서 순수 물질과 혼합물질의 density를 측정하는데 활용할 수 있다.