Liquid Hydrogen Experiment Facility with System Enabling Observation under Horizontal Vibration*

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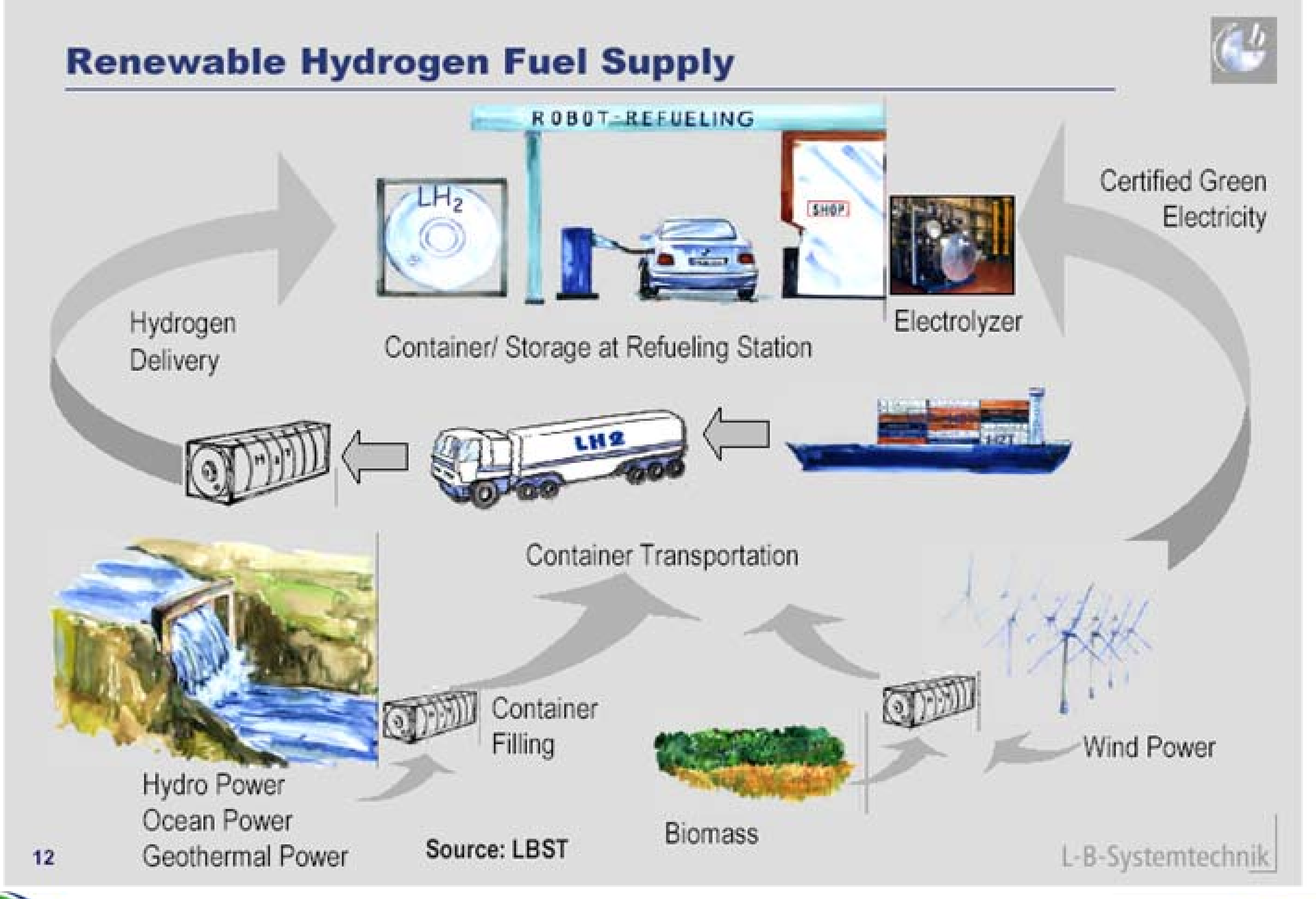
1. INTRODUCTION
Background (1)



Background (2)

Recently, superconducting magnesium diboride (MgB_2) level sensors have been reported as new sensors for detecting the level of liquid hydrogen (LH_2):

Self-heating-type sensors (Haberstroh *et al*., Kajikawa *et al*.)

External-heating-type sensors (Takeda *et al*.)

Research on their level-detecting characteristics and durability under vibration conditions of the LH_2 surface has been insufficient.

The behavior of the LH_2 surface in the tank under vibration conditions has not yet been sufficiently clarified experimentally.

Objectives

To establish a storage and transport system for large quantities of LH_2, it is important to develop an LH_2 level gauge and to clarify the vibrational behavior of the LH_2 surface.

⬇

Objectives of this work is to construct a liquid hydrogen experiment facility (LHEF) enabling observation under horizontal vibration.

The details of the constructed LHEF and experimental results on the damped oscillation of the LH_2 surface as well as other cryogens surface are presented.

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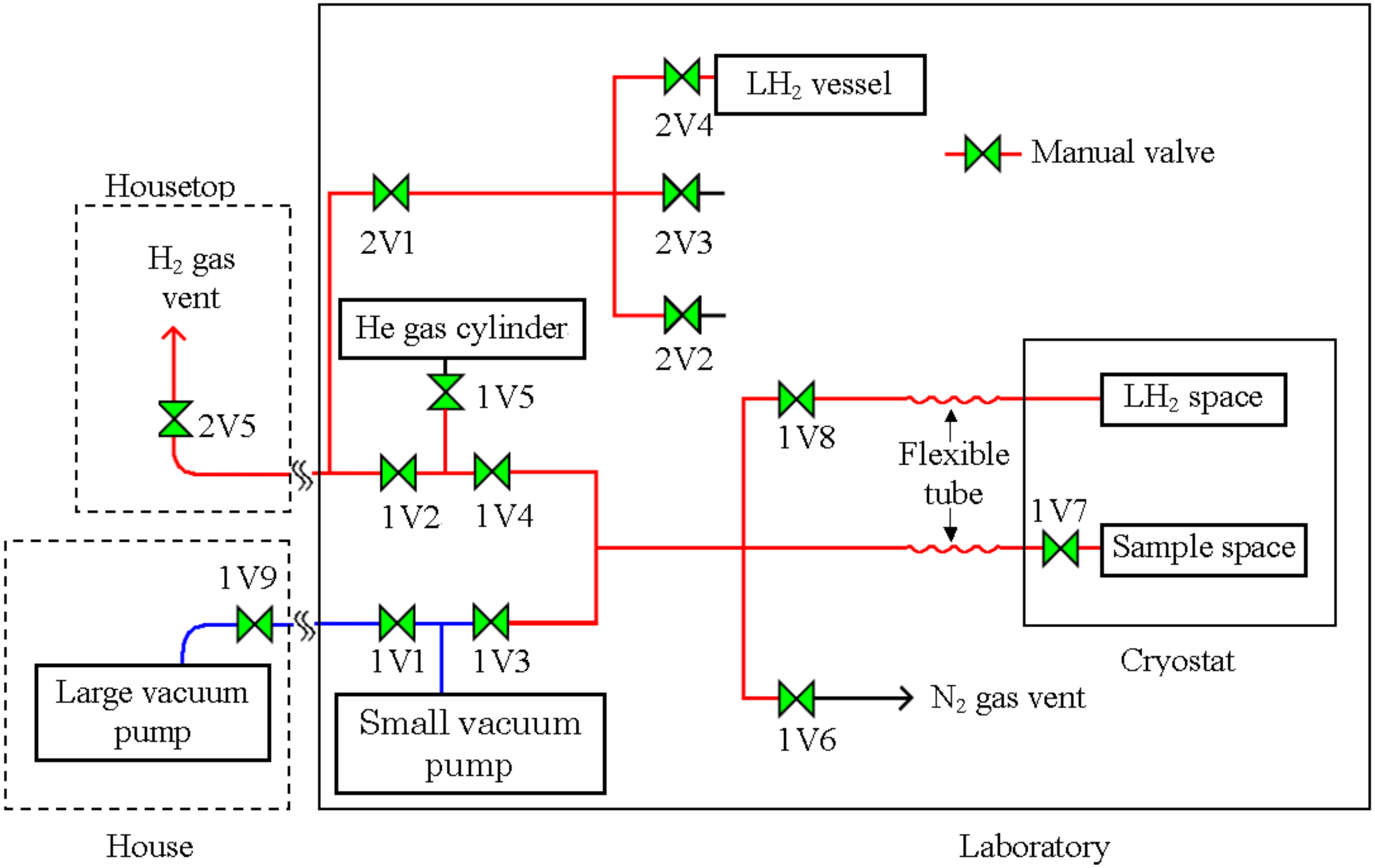
2. EXPERIMENTAL
Basic Layout of LHEF



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Photograph of LHEF

Gas-handling system

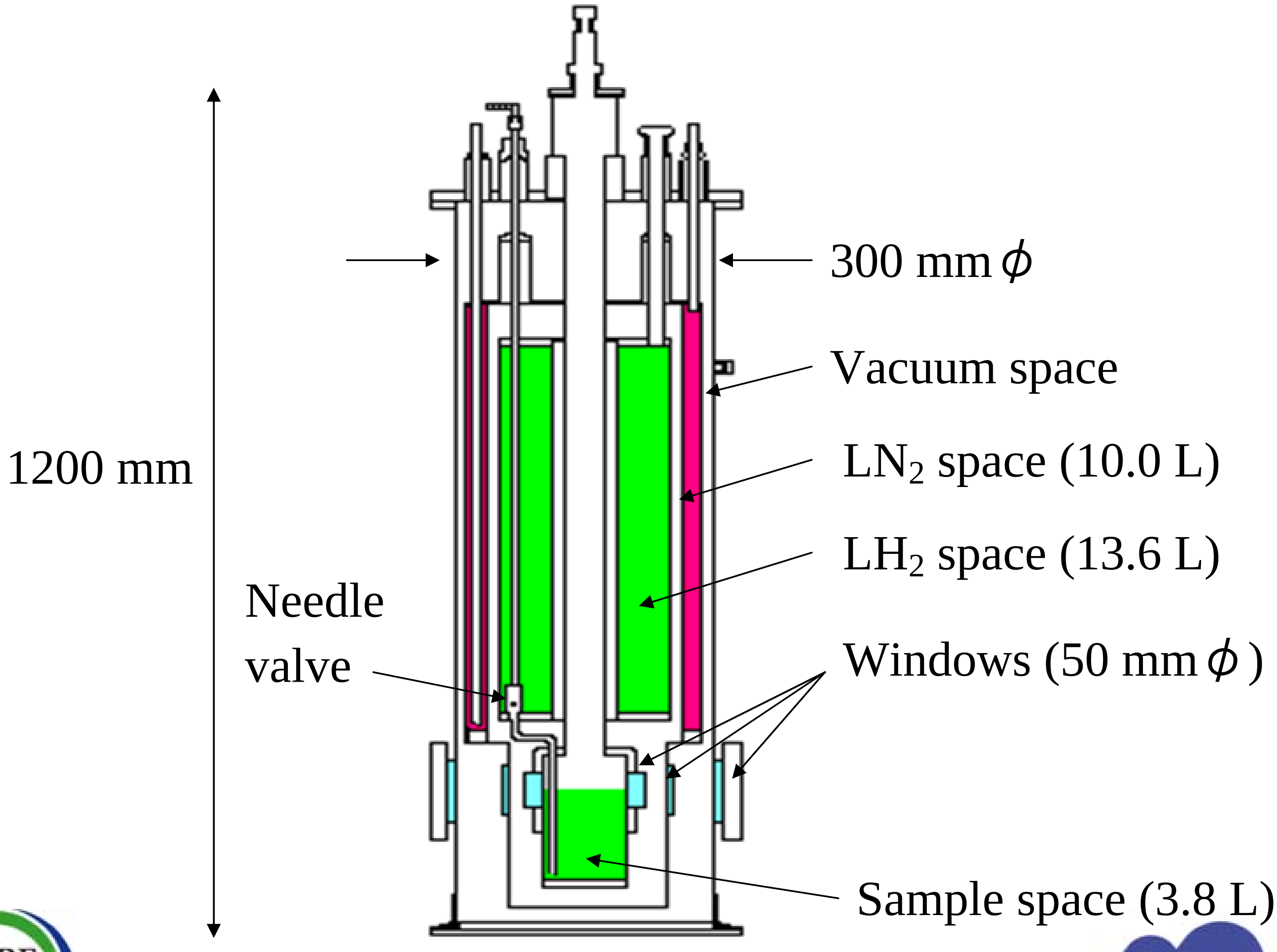
Small vacuum pump

Apparatus for generating horizontal vibration

Cryostat

Windows

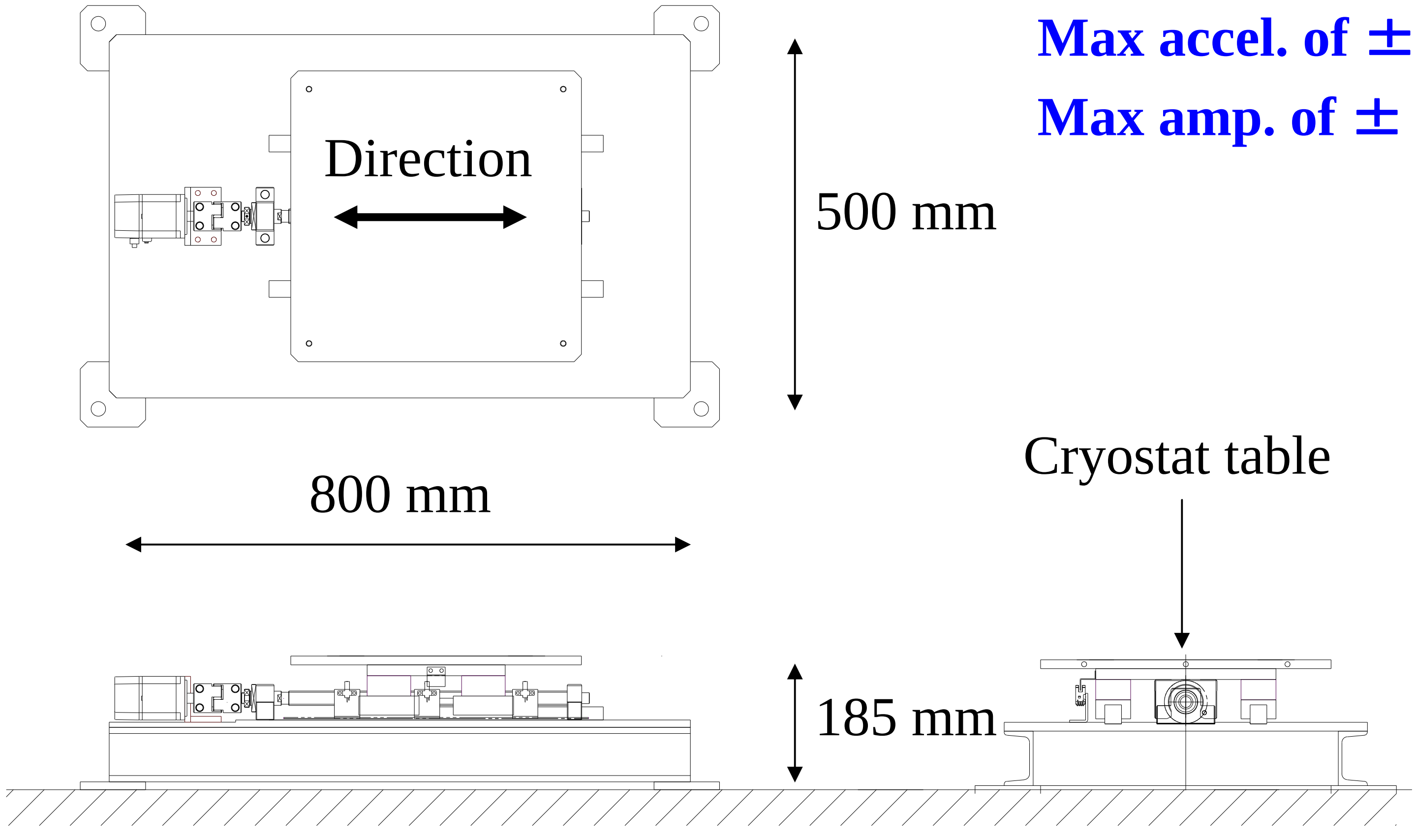
Schematic Diagram of LH_2 Optical Cryostat



Schematic Diagram of Apparatus for Generating Horizontal Vibrations

Max accel. of ± 0.1 G

Max amp. of ± 100 mm



3. EXPERIMENTAL RESULTS
Evaporation Rates of LN_2 and LH_2

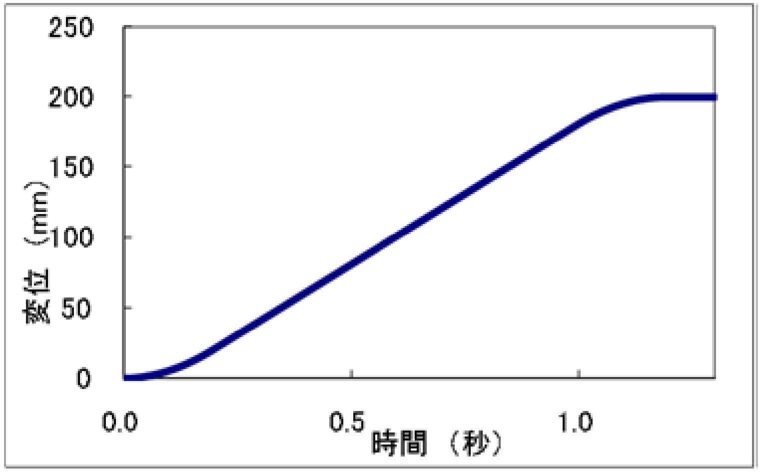
Subject	Evaporation rate [L/h]	Heat Leak [W]	Heat Leak (Cal.) [W]
LN_2 Space	0.30	13.6	13.9
LH_2 Space	0.05	0.40	0.33

Observation under Horizontal Vibration

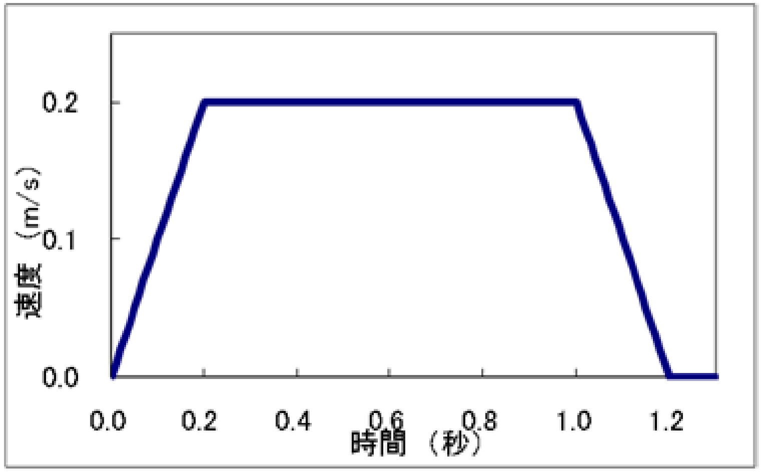
液水振動実験08.mpg

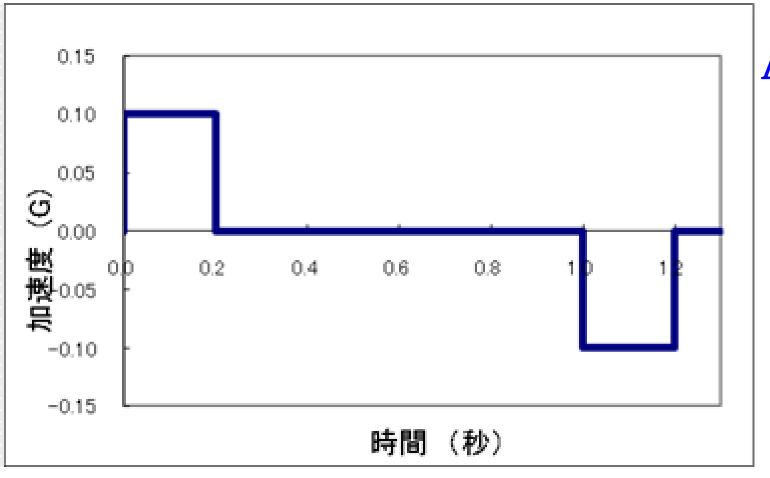
Horizontal Vibration: example of 0.1 G

Displace. vs. Time



Speed vs. Time





Accel. vs. Time

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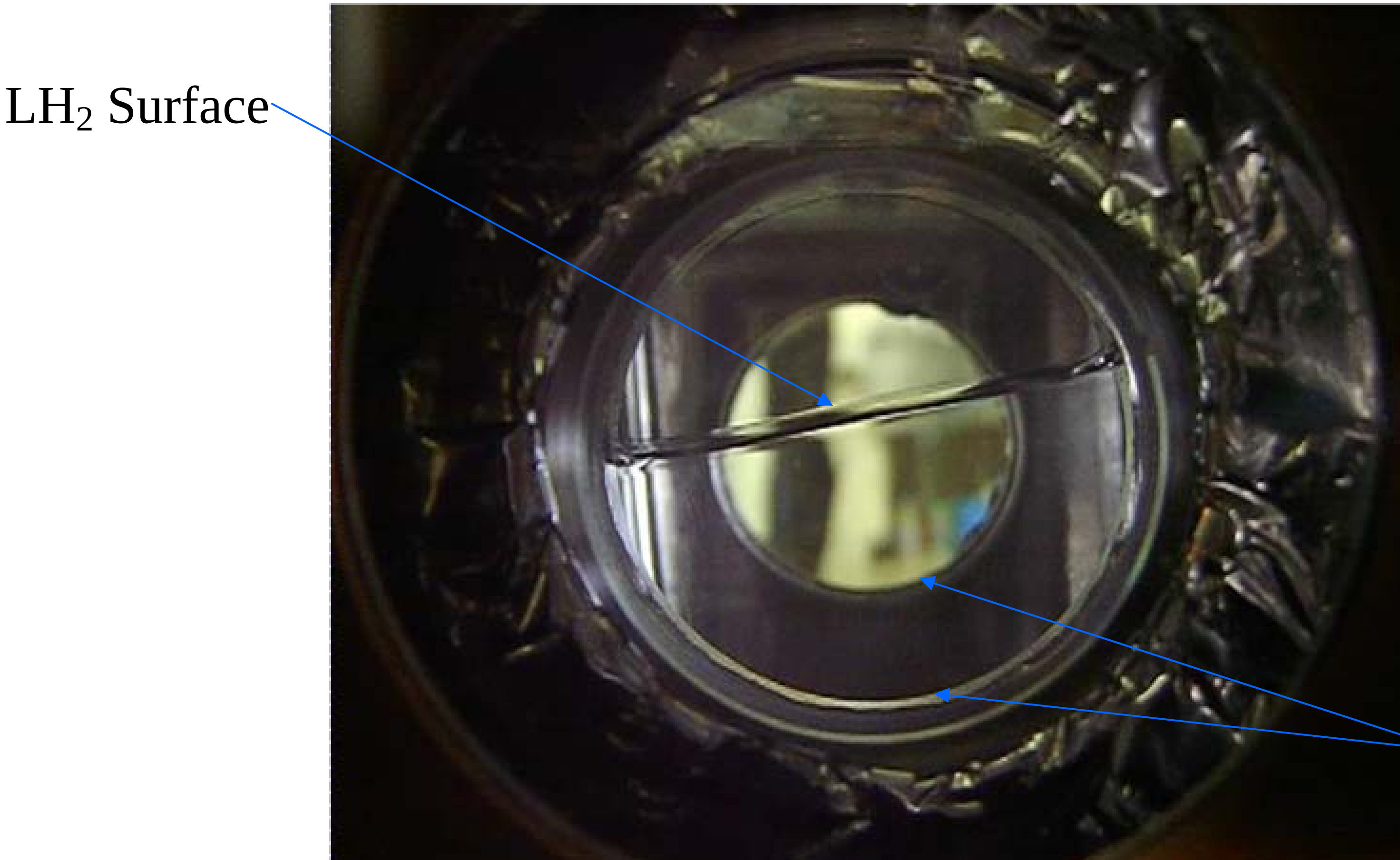
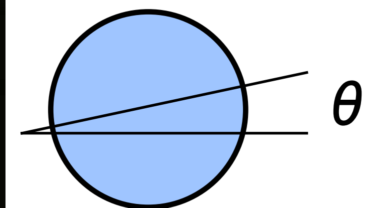
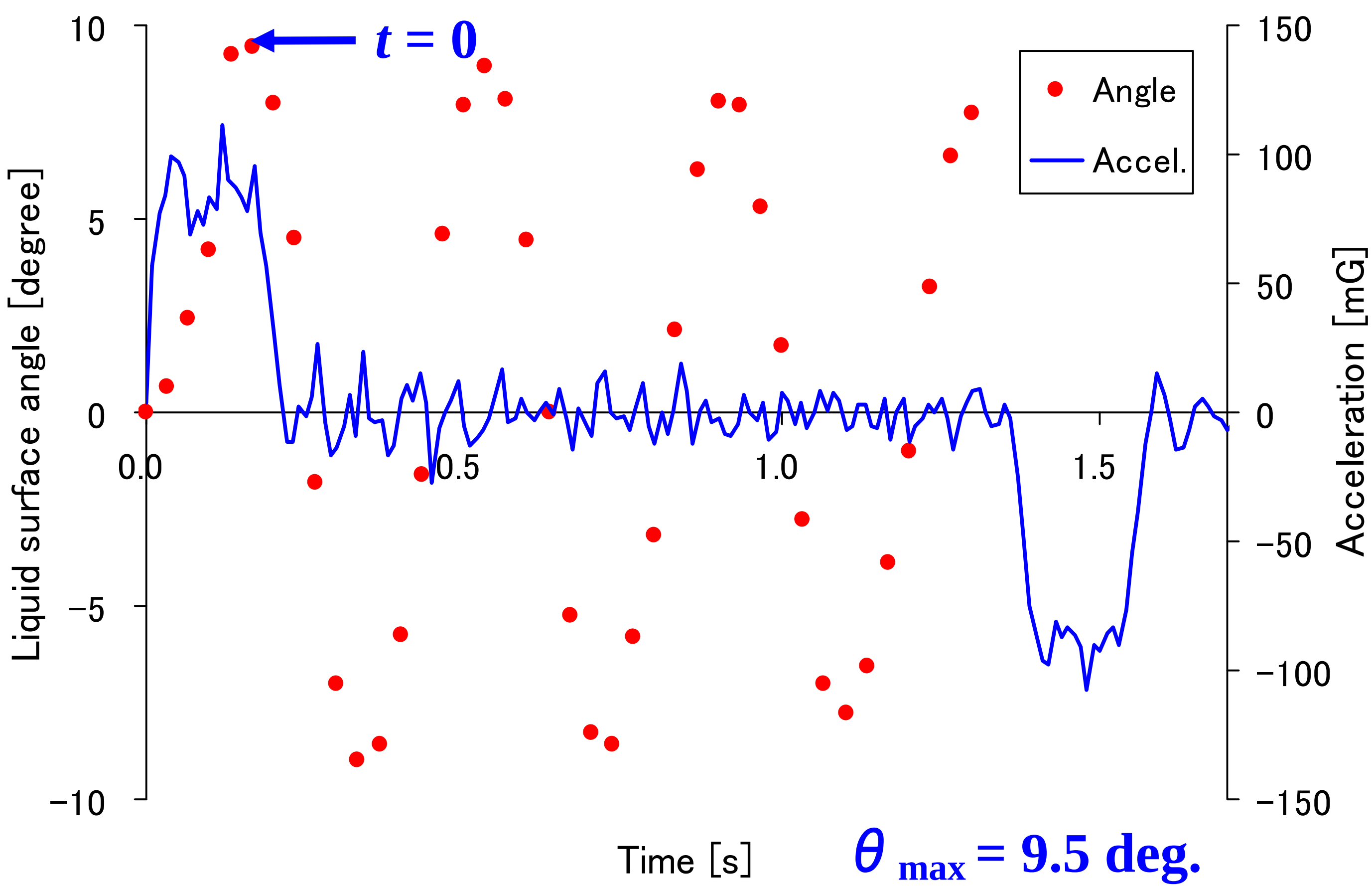
Photograph of LH_2 Surface (20.3 K) under Horizontal Vibration





Time Chart of Acceleration and Liquid Surface Angle (LH_2: 20.3 K)



θ_{max} = 9.5 deg.

T = 0.372 s

A Damped Oscillation Model

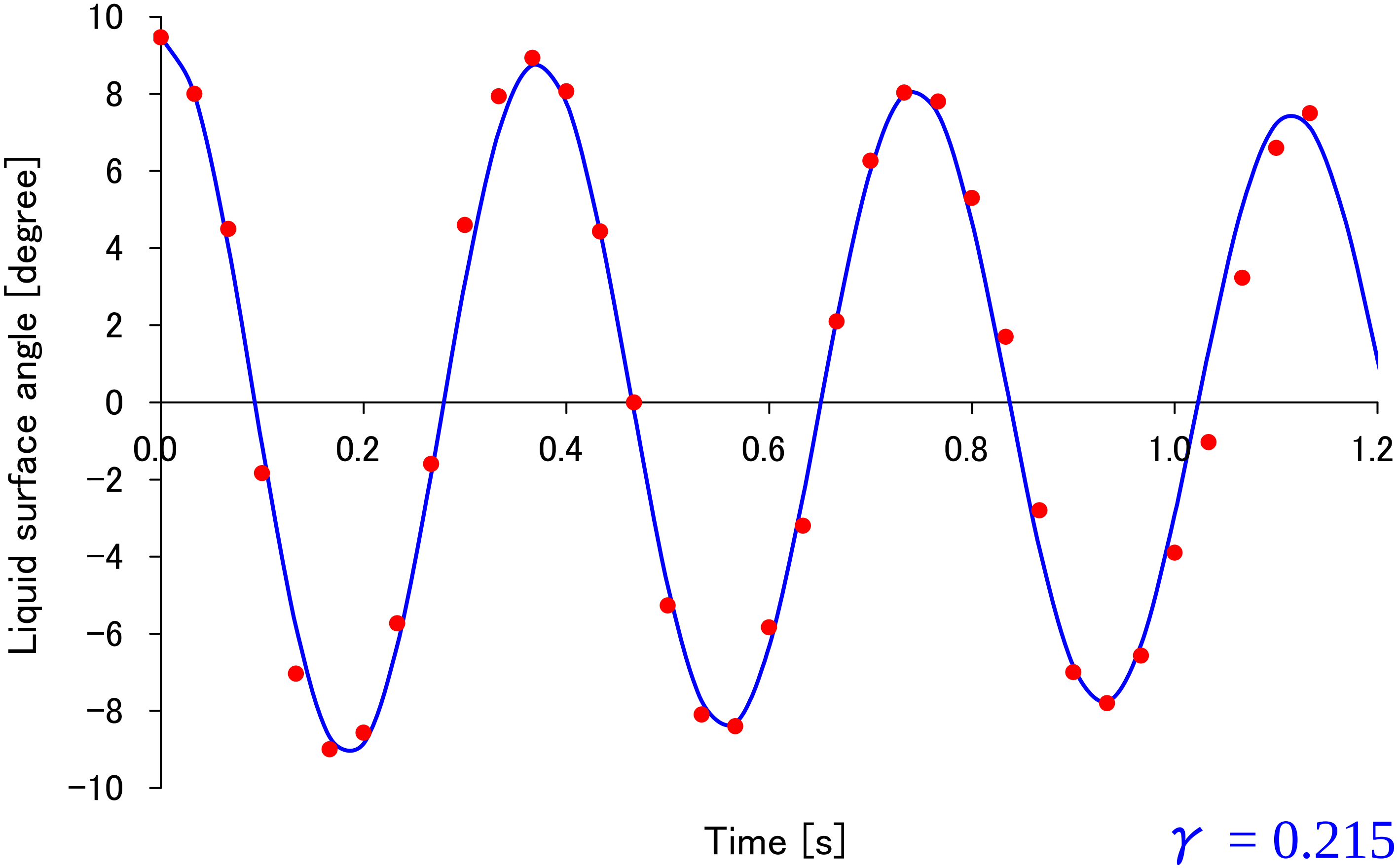
Assuming that the liquid surface angle θ is minute and that the effects of the breaking force is less than that of the restoring force, the slowly damped liquid surface oscillation can be expressed as

$$\theta(t) = \theta_{\max} \exp(-\gamma t) \cos \sqrt{\omega_0{}^2 - \gamma^2}\, t \,, \qquad (1)$$

$$T = 2\pi \Big/ \sqrt{\omega_0{}^2 - \gamma^2} \,, \qquad (2)$$

where $\theta_{\max}$: the maximum liquid surface angle at $t = 0$, γ : the attenuation constant, ω_0: the intrinsic angular frequency, T: the period.

Damped Oscillation of LH_2 Surface (20.3 K)



$\gamma = 0.215$

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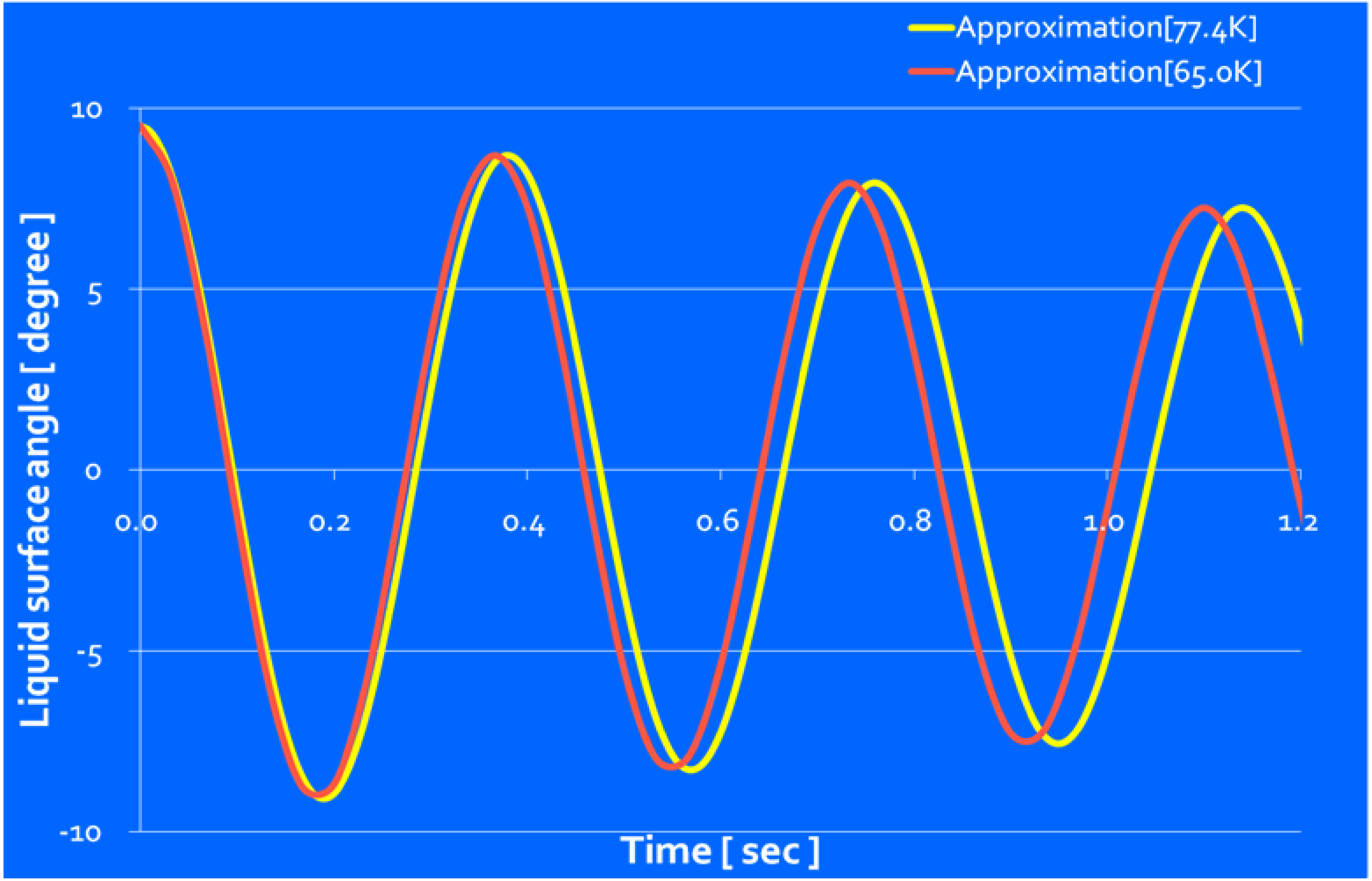
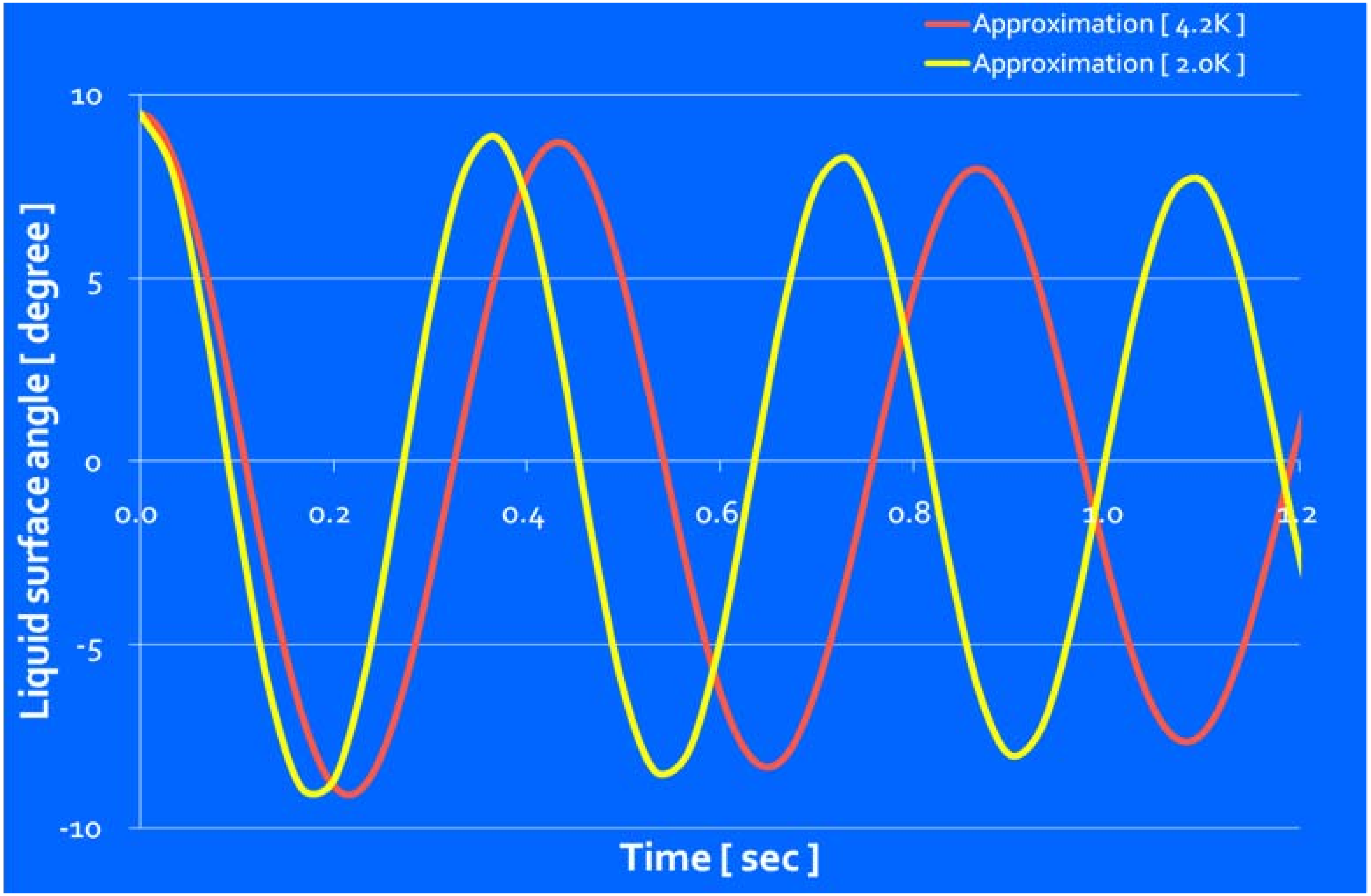
LN_2 (77.3 K and 65.0 K)



LHe (4.2 K) and He Ⅱ (2.0 K)



Damped Oscillation of Some Cryogens

Subject	Max angle $\Theta_{\mathbf{max}}$ [deg.]	Atten. const. γ [1/s]	Period $\boldsymbol{T}$ [s]	Log. atten. const. $\gamma \boldsymbol{T}$ [-]
LN_2 (65.0 K)	9.5	0.249	0.367	0.091
LN_2 (77.3 K)	9.5	0.239	0.380	0.091
LH_2 (20.3 K)	**9.5**	**0.215**	**0.372**	**0.080**
LHe (4.2 K)	9.5	0.200	0.433	0.087
He Ⅱ (2.0 K)	9.5	0.180	0.363	0.065

Discussion about γ and T

$$\gamma \propto \eta / \rho \quad (= \nu : \text{dynamic viscosity})$$

where η : viscosity and ρ : density.

$$T \propto 1 / \sqrt{\omega_0{}^2 - \gamma^2}$$

Physical Properties of Some Cryogens

Subject (Sat. vap)	Eq. temp. T_{eq} [K]	Viscosity η [μ Pa s]	Density ρ [kg/m^3]	Dy. viscosity ν [mm^2/s]
LN_2	65.0	284	882	0.322
LN_2	77.3	158	809	0.195
LH_2	**20.3**	**12.5**	**70.8**	**0.176**
LHe	4.2	3.17	125	0.025
He Ⅱ	2.0	1.5	145	0.010

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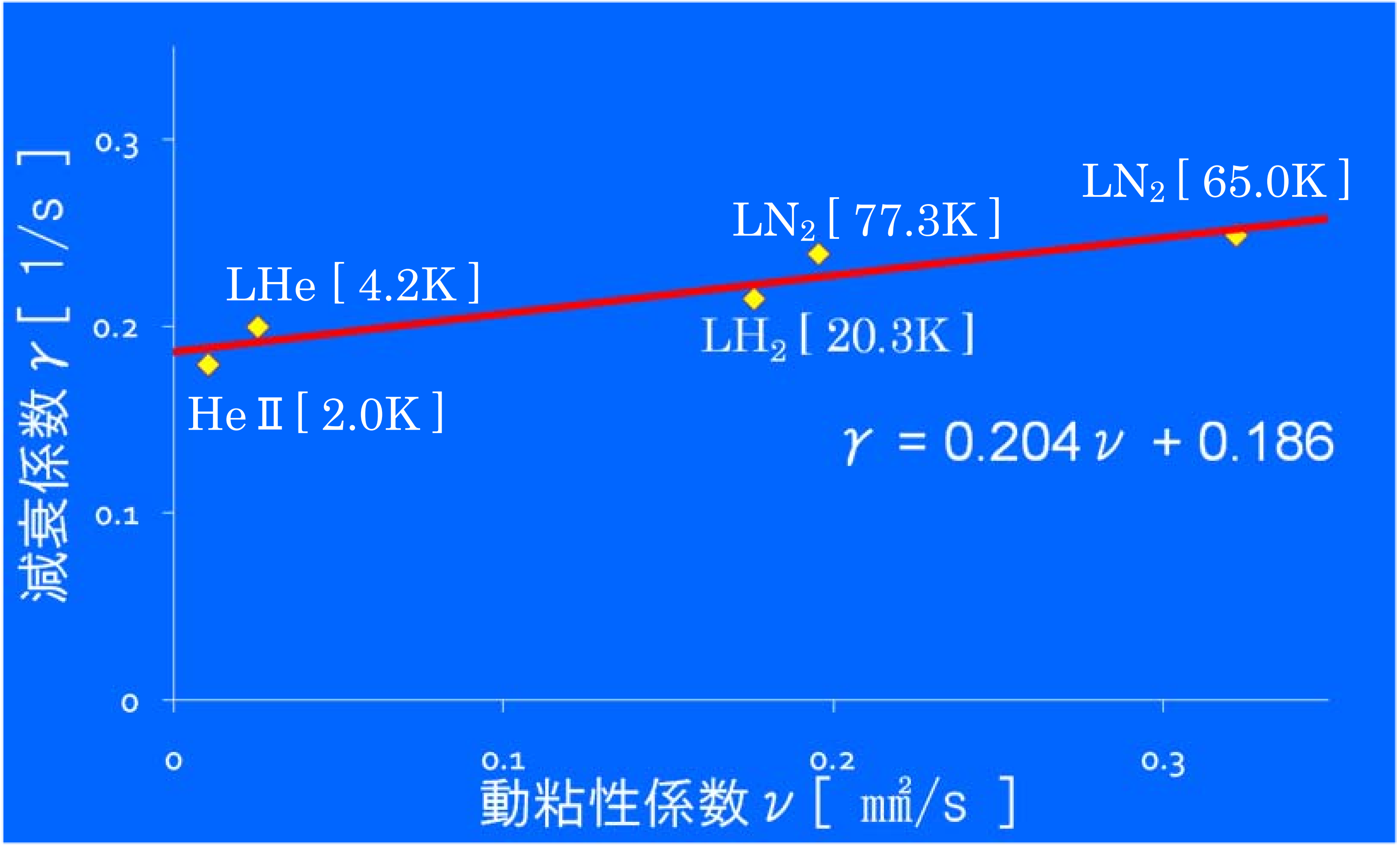
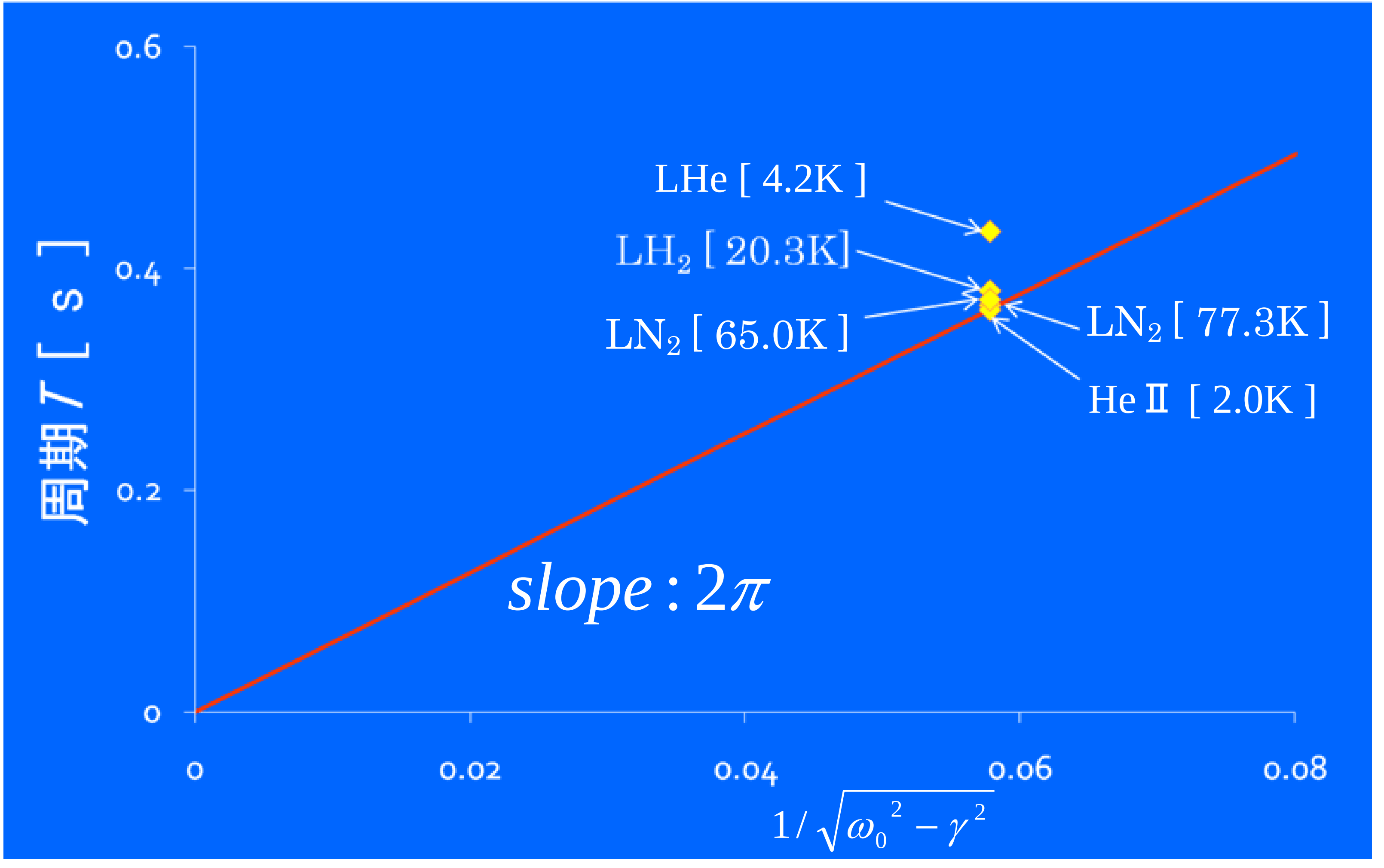
Relationship between γ and ν



Relationship between *T* and $1/\sqrt{\omega_0{}^2-\gamma^2}$



4. SUMMARY

(1) A liquid hydrogen experiment facility (LHEF) with system enabling observation under horizontal vibration was designed and constructed.

(2) The LHEF performance test results show that the heat leak in the LH_2 space was sufficiently small.

(3) Using LHEF under horizontal vibration, observations of the LH_2 surface as well as other cryogens under damped oscillation were carried out successfully.

(4) The calculated values of liquid surface angle based on a damped oscillation model were in good agreement with the experimental values.

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