

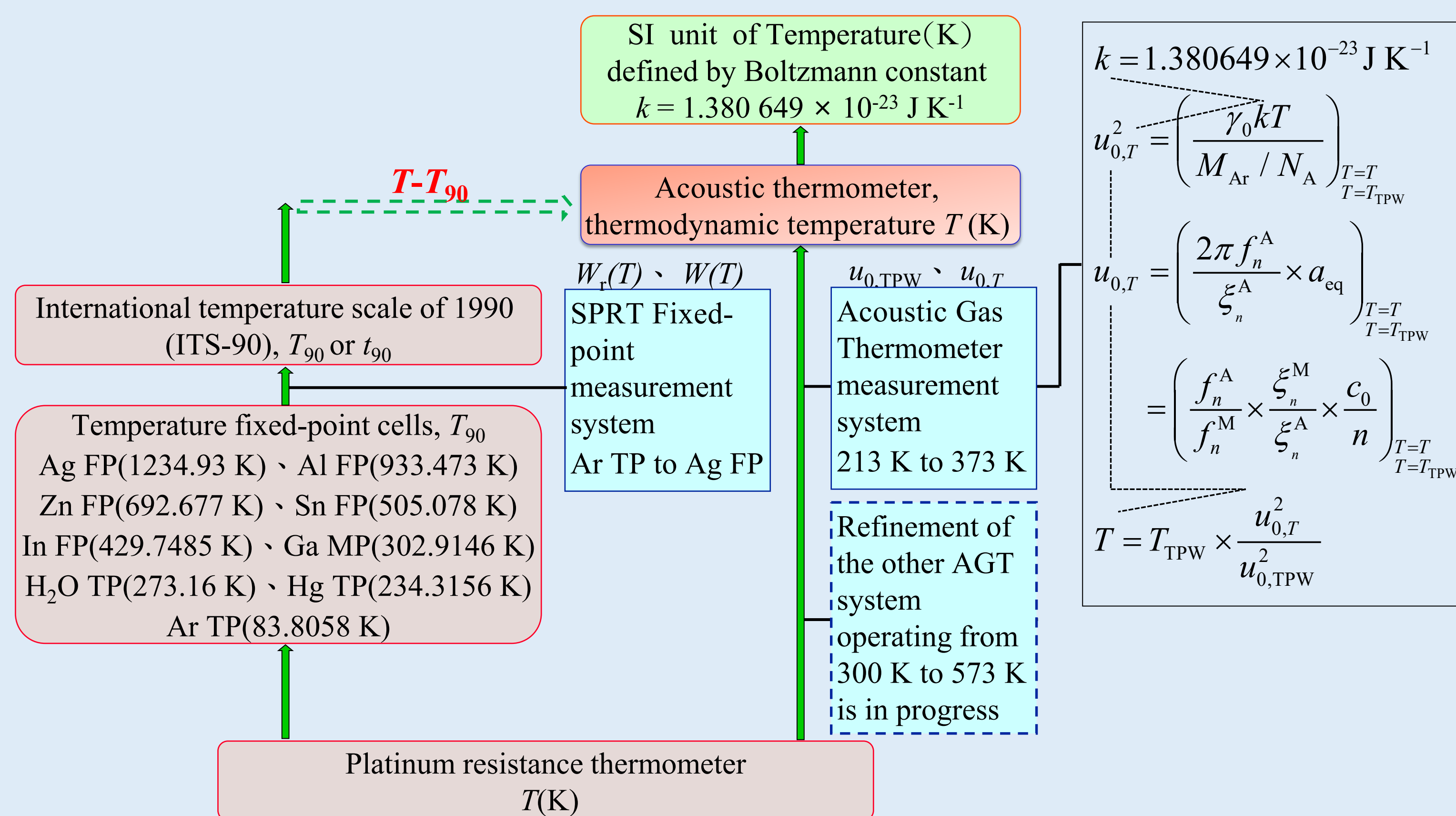


Assessment of $T-T_{90}$ Differences in the Temperature Range from 213 K to 303 K Using Quasi-Spherical Resonator Acoustic Gas Thermometry

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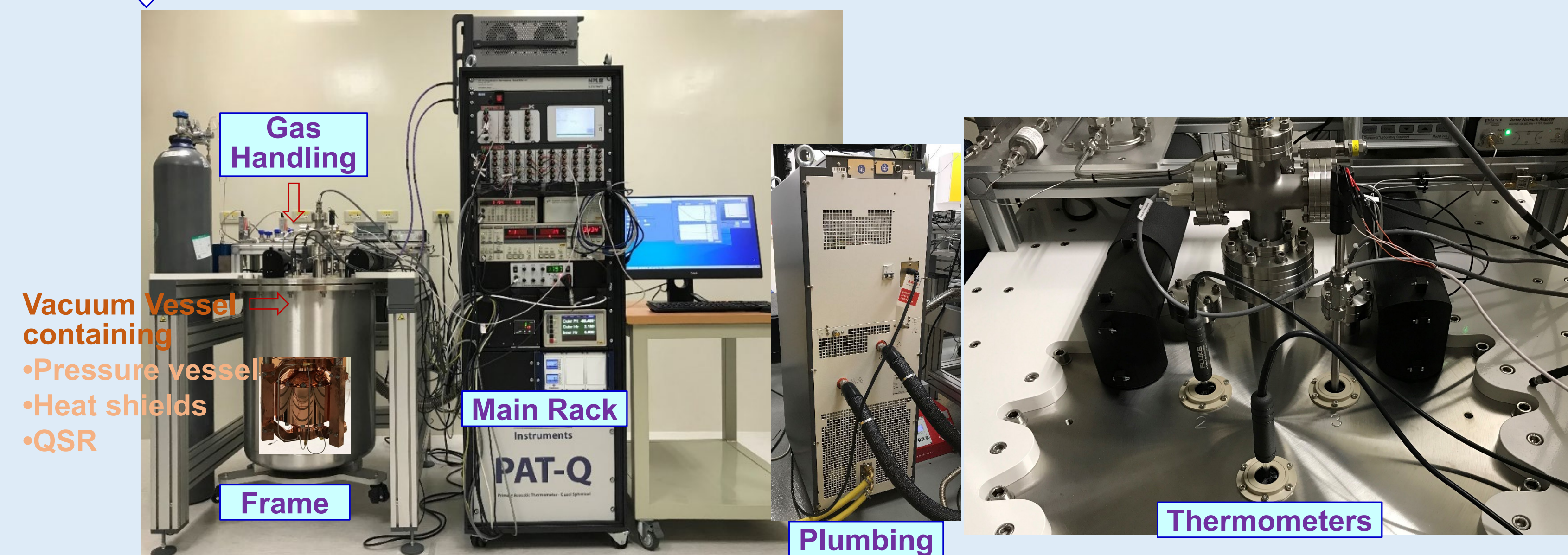
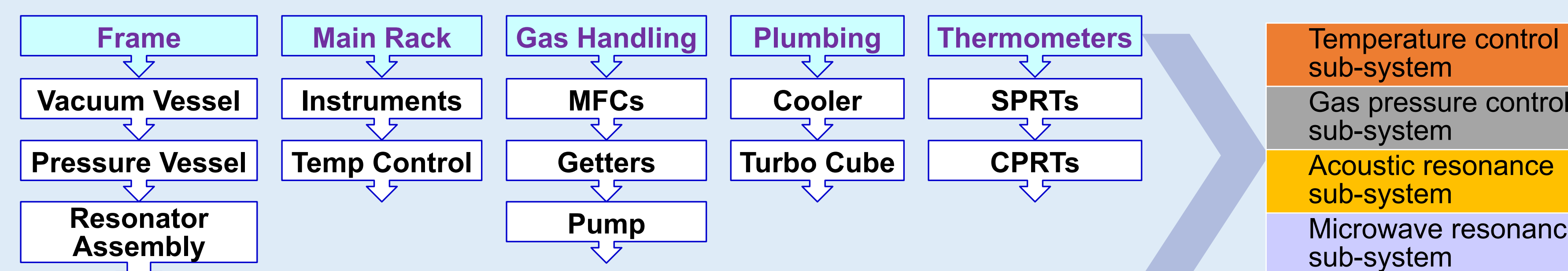
Introduction

- Primary thermodynamic thermometry underpins all temperature measurements in science and industry.
- Following the redefinition of the kelvin, this marks the first step toward thermometry calibrations beyond the International Temperature Scale of 1990.



- Acoustic gas thermometry facility, renowned for its low measurement uncertainty, was established at CMS/ITRI with technical support from the NPL, covering the temperature range of 213 K to 373 K.
- The chart above shows the temperature standard traceability chain at CMS/ITRI. It illustrates how $T-T_{90}$ measurements can contribute to the development of a new temperature scale which is closer to thermodynamic temperature.

Outline Structure of Acoustic Gas Thermometry (AGT) System at CMS/ITRI



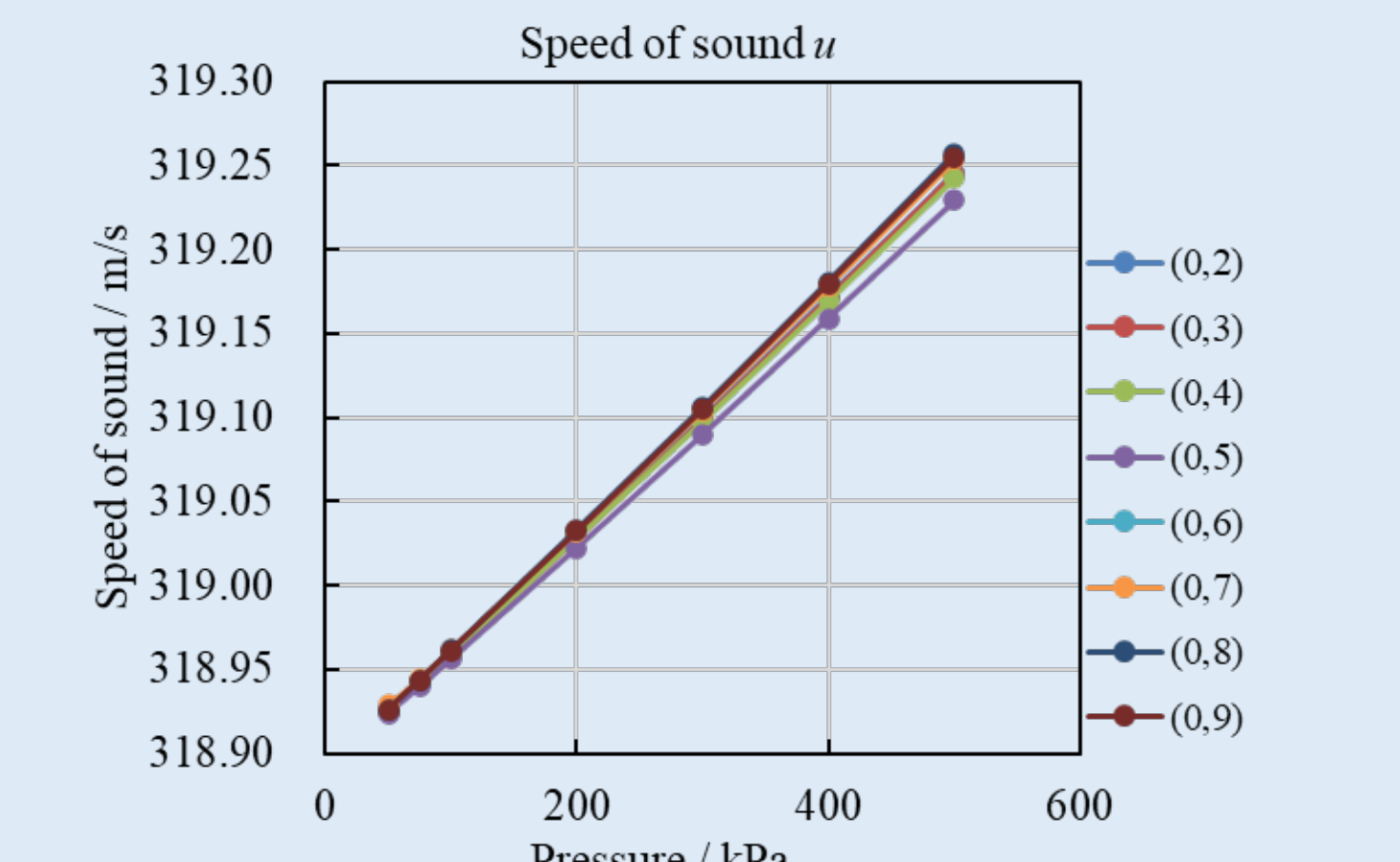
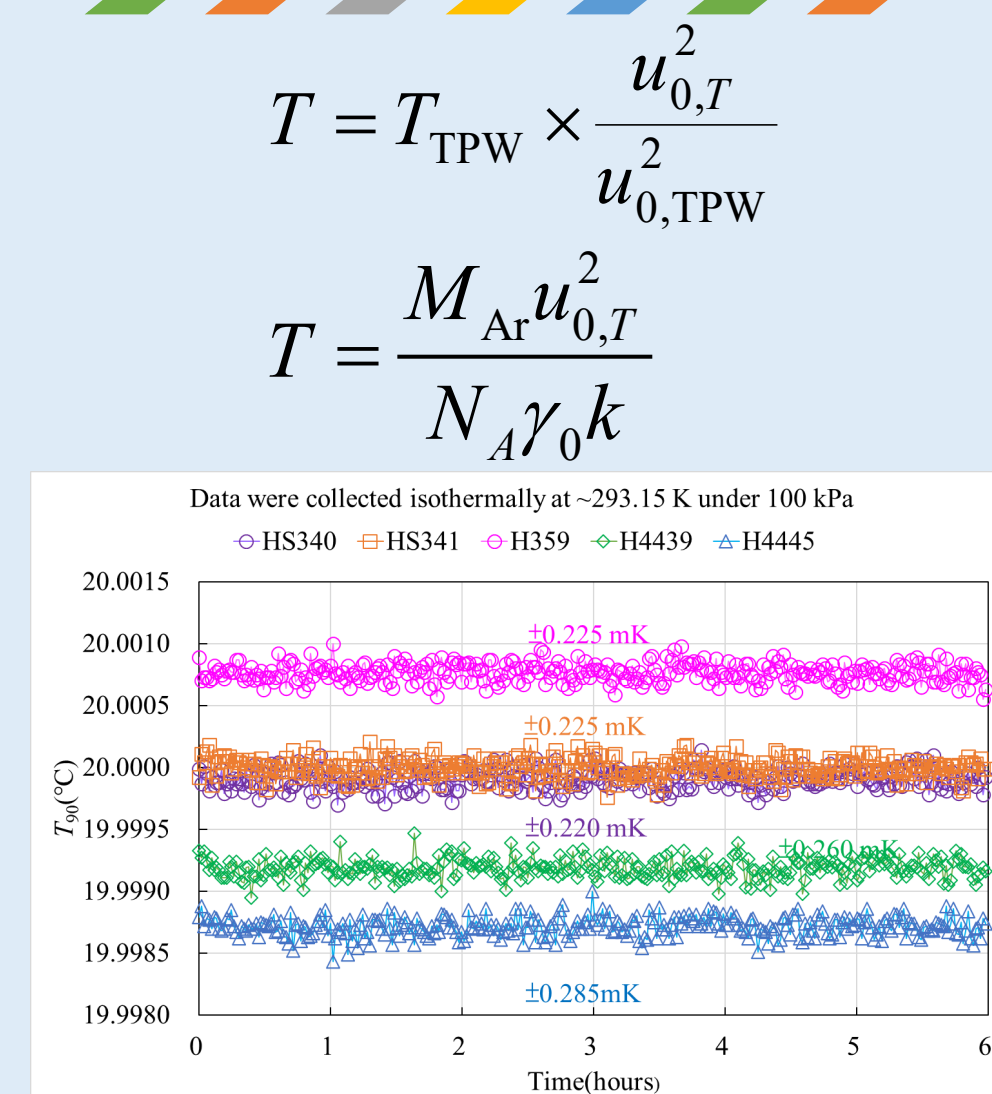
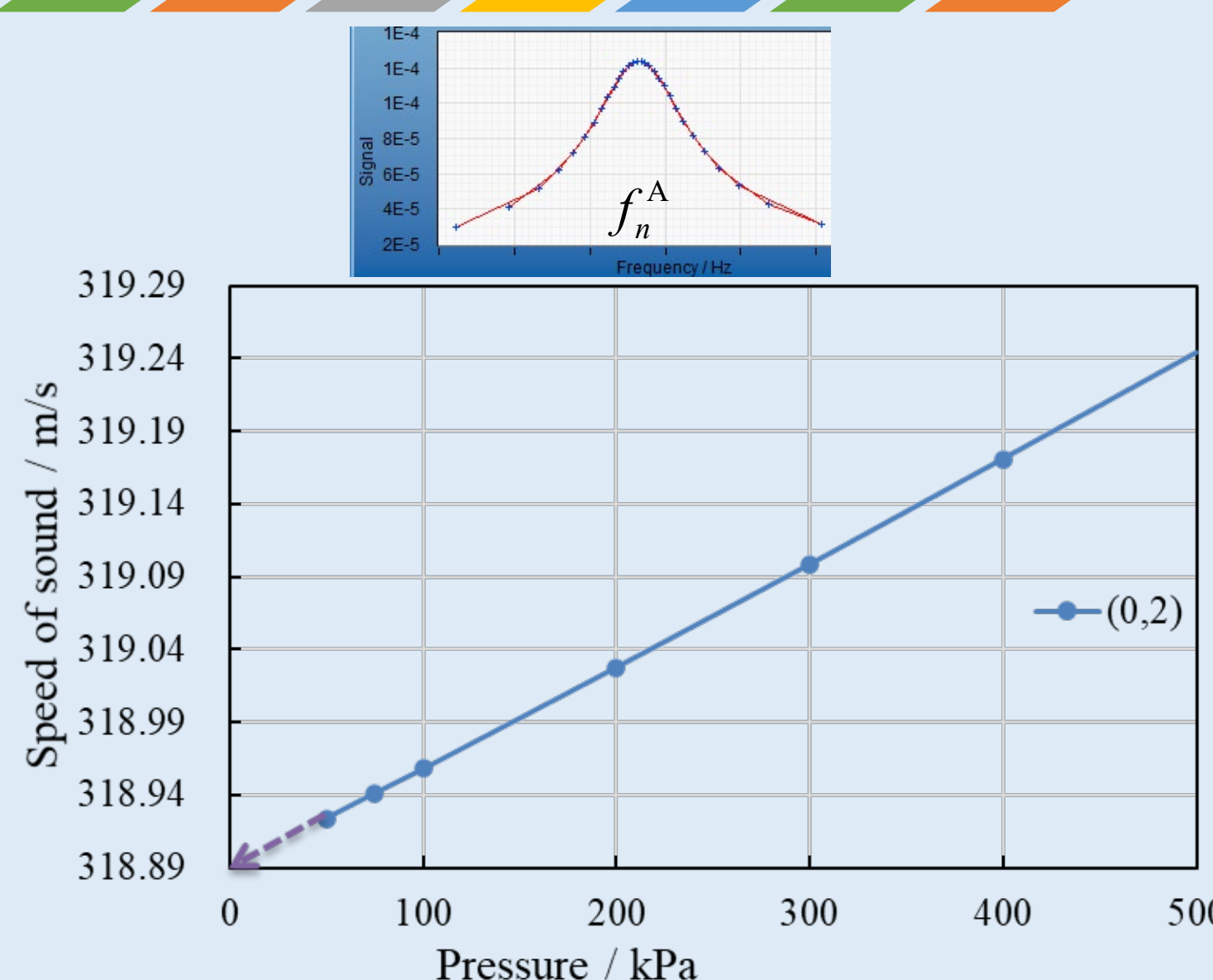
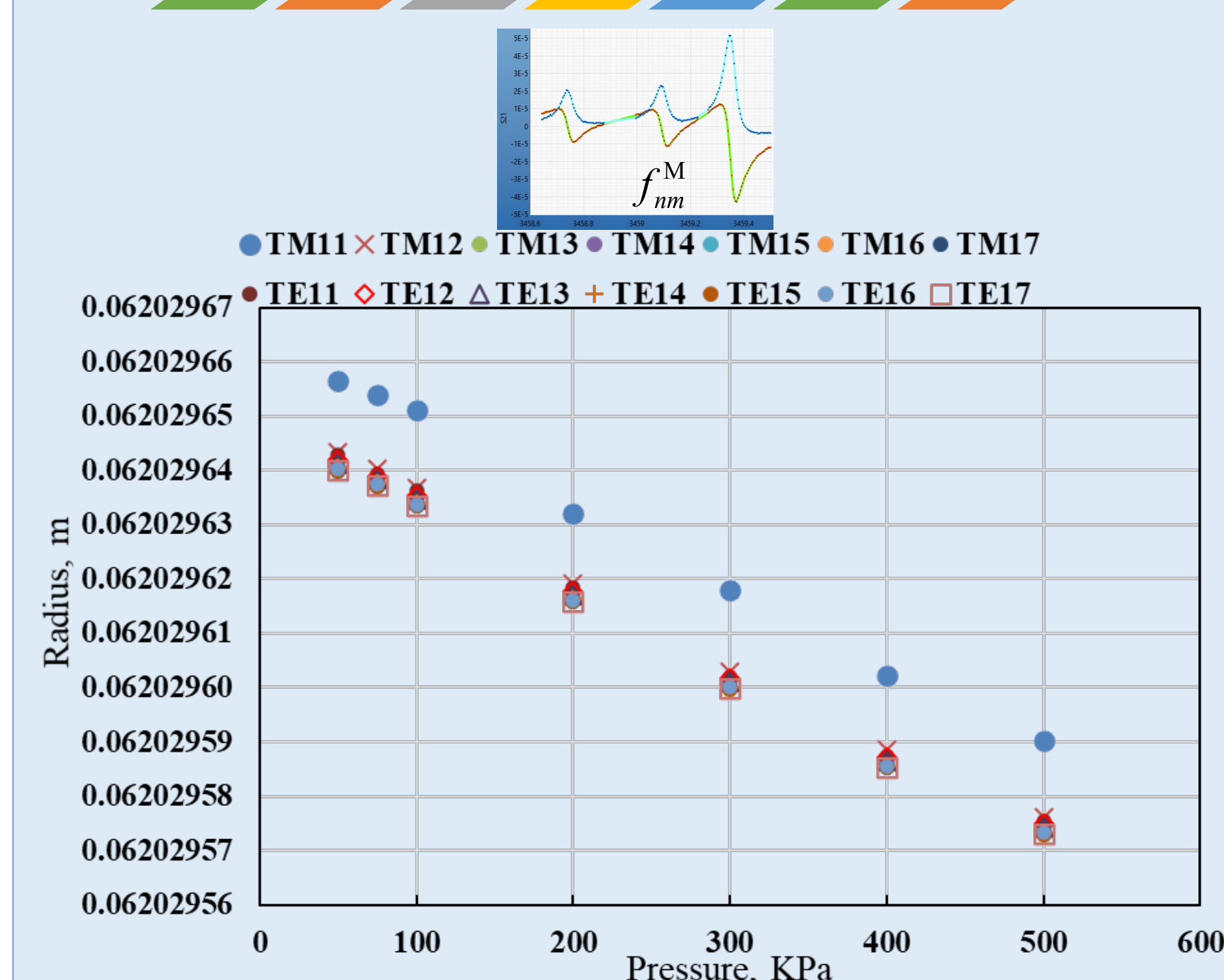
- The main structure in this system is a quasi-spherical resonant cavity that combines acoustic and microwave resonance. It is enclosed within a pressure chamber filled with high-purity argon gas at a pressure of 50–500 KPa, maintaining a constant flow rate of 2 sccm.
- A distinctive feature of this facility is the inclusion of three external thermowells, which connect the top of the cryostat to the quasi-spherical resonator (QSR) at the bottom, while three capsule thermometers were attached to the resonator: at the top, bottom, and around the equator of the resonator.

Determine the Thermodynamic Temperature T

Corrected microwave resonant frequency f_{nm}^{CorrM} to determine the equivalent radius a_{eq}

Corrected acoustic resonant frequency f_n^{CorrA} and a_{eq} to determine the sound speed $u_{0,T}$

Thermodynamic temperature T is determined by $u_{0,T}^2$ or its ratio to $u_{0,TPW}^2$



•The sound speed $u_{0,T}$ is taken as the weighted mean of the extrapolated values at the low-pressure limit for each mode, excluding any modes with large fit residuals.

Assessment Results of $T-T_{90}$ Differences

213.14669 K	Expanded Uncertainty (Coverage factor =2.00)	293.15227 K	Expanded Uncertainty (Coverage factor =2.00)	302.91694 K	Expanded Uncertainty (Coverage factor =2.00)
$D_{CMS}(2) = -3.31 \text{ mK}(2)$	$U(T)_{CMS} = 0.40 \text{ mK}$ $U(D)_{CMS} = 0.85 \text{ mK}$	$D_{CMS}(1) = 2.56 \text{ mK}$ $D_{CMS}(2) = 2.05 \text{ mK}$	$U(T)_{CMS} = 0.40 \text{ mK}$ $U(D)_{CMS} = 0.57 \text{ mK}$	$D_{CMS}(1) = 3.84 \text{ mK}$ $D_{CMS}(2) = 4.15 \text{ mK}$	$U(T)_{CMS} = 0.40 \text{ mK}$ $U(D)_{CMS} = 0.57 \text{ mK}$
$D_{2022} = -3.56 \text{ mK}$	$U(D)_{combined} = 0.19 \text{ mK}$ $U(D)_{expanded} = 0.38 \text{ mK}$	$D_{2022} = 2.71 \text{ mK}$	$U(D)_{combined} = 0.25 \text{ mK}$ $U(D)_{expanded} = 0.50 \text{ mK}$	$D_{2022} = 3.84 \text{ mK}$	$U(D)_{combined} = 0.33 \text{ mK}$ $U(D)_{expanded} = 0.66 \text{ mK}$
$D_{CMS} - D_{2022} = +0.25 \text{ mK}$	$U(D_{CMS} - D_{2022}) = 0.93 \text{ mK}$	$D_{CMS} - D_{2022} = -0.15 \text{ mK}$ -0.66 mK	$U(D_{CMS} - D_{2022}) = 0.76 \text{ mK}$	$D_{CMS} - D_{2022} = 0.00 \text{ mK}$ 0.31 mK	$U(D_{CMS} - D_{2022}) = 0.87 \text{ mK}$

$D = T - T_{90}$: difference between thermodynamic temperature and ITS-90

D_{2022} and $U(D)_{combined}$: updated consensus values and estimated uncertainties in 2022, as reported in “2022 Update for the Differences Between Thermodynamic Temperature and ITS-90 Below 335 K”, J. Phys. Chem. Ref. Data 51, 043105 (2022)

$D_{CMS}(1) = (T - T_{90})$ measured at CMS/ITRI, where T_{90} is the average value measured by three CPRTs and two SPRTs

$D_{CMS}(2) = (T - T_{90})$ measured at CMS/ITRI, where T_{90} is the average value measured by three CPRTs

- The expanded uncertainty for the AGT system in the temperature range of 213 K to 373 K at CMS is evaluated to be 0.40 mK, based on the uncertainty sources shown in the right figure (details not presented here).

- In the range of 213 K to 303 K, the difference between D_{CMS} and D_{2022} is covered by the expanded uncertainties, regardless of whether T_{90} is determined using only three CPRTs or all five thermometers (three CPRTs and two SPRTs).

- When T_{90} is taken as the average of all five thermometers, difference between D_{CMS} and D_{2022} is insignificant.

- Thorough analysis is ongoing for the 303 K to 373 K range of the QSR AGT system.

