Extension of thermodynamic temperature data up to 36 K with dielectric-constant gas thermometry using ^3He, ^4He and Ne as measuring gases

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Since 25 years dielectric-constant gas thermometry (DCGT) has been a well established method for primary thermometry at PTB. The first generation of DCGT (DCGT1) led to results for the thermodynamic temperature between 4.2 K and 27 K [1]. Using a second generation of DCGT (DCGT2), thermodynamic temperature measurements with reduced uncertainty were performed in the extended temperature range from 2.5 K to 36 K. The results obtained with ^4He in the range between 3.7 K and 26 K and the related uncertainty budgets are discussed in [2, 3], and in greater detail in [4]. Besides the thermodynamic temperature data, these publications are focused on comparisons between the results for the virial coefficients determined via DCGT and ab initio calculations, respectively. Additional measurements using ^3He as measuring gas at 2.5 K and 3.2 K are described in paper [5], which deals as main topics with the creation of bosonic clusters in ^4He and the determination of the molar polarizability of ^3He. The latest results obtained with ^4He and Ne between 23 K and 36 K will be published together with uncertainty budgets in [6]. In this submitted work, furthermore, a combination of all data sets (DCGT1 and DCGT2) using ^3He, ^4He and Ne leads to the deviation of the weighted mean from the ITS-90 [7] shown in Figure 1. Even at the highest temperatures, the thermodynamic values measured with DCGT are in perfect agreement with the ITS-90. In contrast, the estimates [8] on the basis of acoustic gas-thermometry measurements performed at 24.5 K and 77 K suggested significant negative differences T-T_{90} already at 35 K. Therefore, these results underpin the necessity of thermodynamic measurements between the triple points of Ne and Ar.

Table 1 Deviation of the weighted mean of the DCGT2 data, $T_{\mathrm{DCGT}}^{\mathrm{mean}}$, measured with ^4He and Ne, from ITS-90 [7] values, T_{90}, together with the related standard uncertainty estimates u. For details see [6].

T_{90} (K)	$T_{\mathrm{DCGT}}^{\mathrm{mean}}$ - T_{90} (mK)	u($T_{\mathrm{DCGT}}^{\mathrm{mean}}$ - T_{90}) (mK)
27.0	0.14	0.34
28.5	0.09	0.34
30.0	0.09	0.34
31.5	0.12	0.34
33.0	0.16	0.36
34.5	0.21	0.38
36.0	0.23	0.41

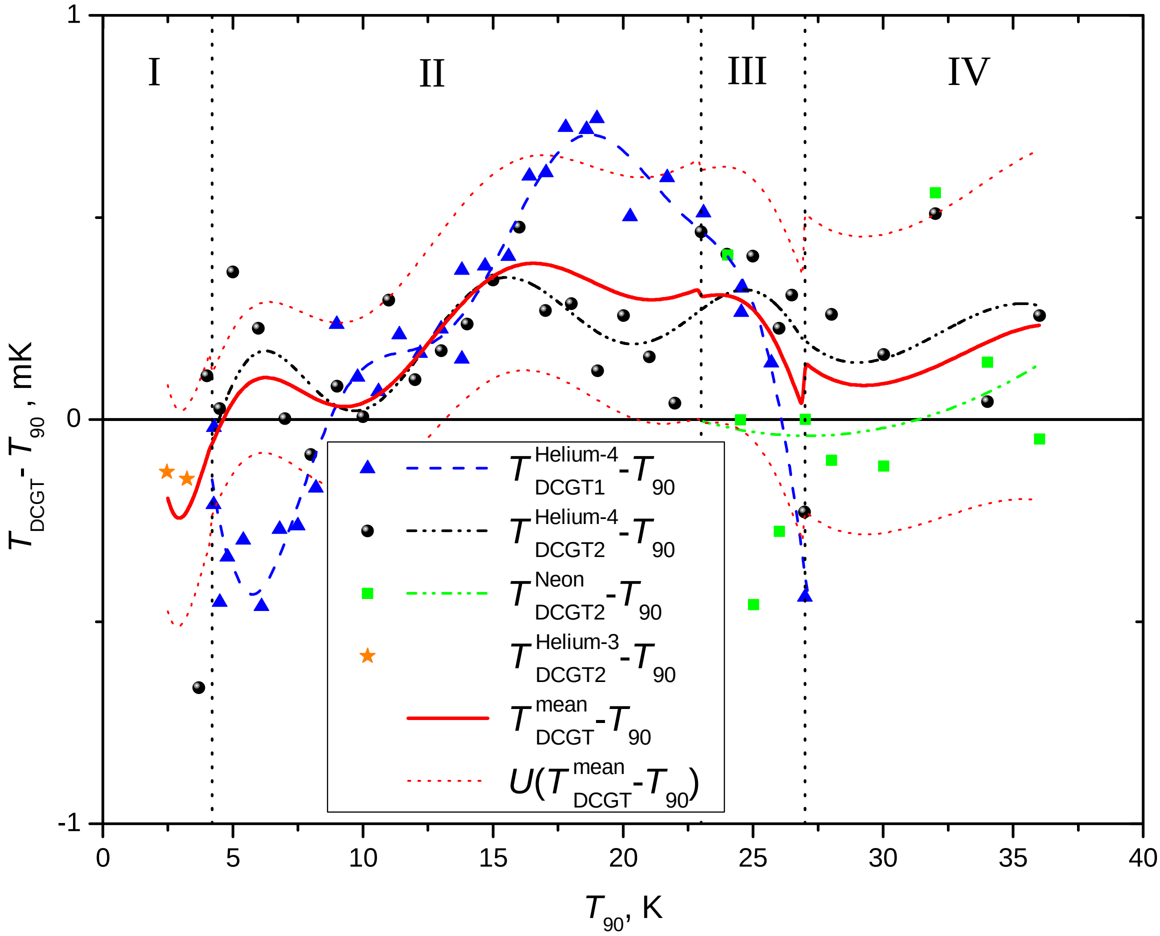

Figure 1 Deviations of the DCGT temperature values, T_{DCGT}, measured with two different setups (DCGT1 [1] and DCGT2 [2]) from the ITS-90 [7] temperature values, T_{90}. The ^{4}He datasets of DCGT1 [1] (blue triangles) and DCGT2 [6] (black dots) have been evaluated via multi-isotherm fits (for details see [3]). The results of two measurements made with ^{3}He [5] are plotted in orange asterisks. The results obtained with DCGT2 using Ne as measuring gas are also shown, in green squares. The smooth curves $T_{\mathrm{DCGT}} - T_{90}$ versus T_{90} for the DCGT1 dataset (dashed blue line) and the DCGT2 dataset (dashed dotted black line) have been approximated using polynomial fits of ninth order to the experimental differences. For Ne a fit of second order (dashed dotted green line) was sufficient. In addition, the curve $T^{\mathrm{mean}}_{\mathrm{DCGT}} - T_{90}$ versus T_{90} (red line), resulting from a weighted mean of all plotted DCGT data, and the related standard confidence interval $U(T^{\mathrm{mean}}_{\mathrm{DCGT}} - T_{90})$ (dotted red lines) are shown. The plot is divided in four regions, in which different data is used: I) (2.5 K to 4.2 K) only DCGT2 data obtained with ^{3}He and ^{4}He, II) (4.2 K to 23 K) DCGT1 and DCGT2 with ^{4}He, III) (23 K to 27 K) DCGT1 and DCGT2 with ^{4}He, DCGT2 with Ne, IV) (27 K to 36 K) DCGT2 with ^{4}He and Ne. This is the reason why at the crossover from one region to the other the mean curve is not smooth.

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