## Key comparison CCM.D-K2

**MEASURAND : Density of liquids**

**LIQUIDS and TEMPERATURES:**

Water at 20 °C
Pentadecane at 20 °C
Pentadecane at 15 °C
Pentadecane at 40 °C
Pentadecane at 60 °C
Tetrachloroethylene at 20 °C
Tetrachloroethylene at 5 °C
Viscosity oil VO-2 at 20 °C

Measurements were carried from 27 April 2004 to 28 June 2004
The results of the participants are given in Section 5 of the CCM.D-K2 Final Report (see Tables 9 to 17) for each liquid and temperature.

**The key comparison reference value, $x_R$ , and associated expanded uncertainty at a 95% level of confidence, $U_R$, for each liquid and temperature, are calculated according to Procedure A or Procedure B explained in *Metrologia* , 2012, 39, 589-595 (see page 17 of the Final Report).**
**In Procedure A, the key comparison reference value is basically a weighted mean of the results.**
**In Procedure B, in which discrepant data are detected, the key comparison reference value is calculated by a Monte Carlo method using the median. In this case, the distribution is usually non-symmetric and the confidence interval may not be equally spaced around the reference value.**

| Liquid and temperature | $x_R$ / (kg/m$^3$) | $U_R$ / (kg/m$^3$) | Procedure |
|---|---|---|---|
| Water at 20 °C | 998.3220 | +0.0038<br>-0.0038 | B |
| Pentadecane at 20 °C | 768.5652 | 0.0027 | A |
| Pentadecane at 15 °C | 772.0696 | +0.0053<br>-0.0047 | B |
| Pentadecane at 40 °C | 754.5871 | 0.0040 | A |
| Pentadecane at 60 °C | 740.6078 | 0.0048 | A |
| Tetrachloroethylene at 20 °C | 1622.7252 | 0.0106 | A |
| Tetrachloroethylene at 5 °C | 1647.5491 | 0.0119 | A |
| Viscosity oil VO-2 at 20 °C | 845.6817 | 0.0052 | A |

**For a given liquid and temperature, in Procedure A, the degree of equivalence, $D_i$ , of laboratory *i* with respect to the key comparison reference value is calculated as the offset to $x_R$ together with its expanded uncertainty $U_i = 2(u_i^2 - u_R^2)^{1/2}$, where $u_i$ and $u_R$ are the standard uncertainties of the laboratory result and the key comparison reference value, respectively. In Procedure B it is calculated by the Monte Carlo method described in *Metrologia* , 2012, 39, 589-595.**

**LINKING EURAMET.M.D-K2 to CCM.D-K2**

The linking is made via PTB and MKEH. The linking procedure is described in Section 4.2 of the EURAMET.M.D-K2 Final Report.

**Water at 20 °C**

| Lab*i* | $D_i$ / ($10^{-3}$ kg/m$^3$) | $U_i$ lower / ($10^{-3}$ kg/m$^3$) | $U_i$ upper / ($10^{-3}$ kg/m$^3$) | $U_i$ / ($10^{-3}$ kg/m$^3$) |
|---|---|---|---|---|
| NRC | **-10.5** | 14.9 | 12.6 | - |
| PTB | **4.5** | 4.5 | 4.0 | - |
| MKEH | **-1.2** | 5.8 | 4.5 | - |
| NMIJ | **2.0** | 13.7 | 14.0 | - |
| KRISS | **-5.0** | 5.0 | 5.0 | - |
| CENAM | **0.0** | 5.1 | 5.0 | - |
| VNIIM | **12.5** | 6.9 | 7.2 | - |
| BEV | **2.5** | - | - | 5.3 |
| CEM | **-104** | - | - | 54 |
| GUM | **1.6** | - | - | 4.6 |
| INM | **34.9** | - | - | 11.9 |
| INRiM | **13.2** | - | - | 5.8 |
| IPQ 1 | **-877** | - | - | 69 |
| IPQ 2 | **-29.8** | - | - | 34.5 |
| LNE | **-9.6** | - | - | 9.3 |
| MIKES | **3.0** | - | - | 7.6 |
| NPL | **3.4** | - | - | 6.9 |
| SMU | **11.0** | - | - | 12.7 |
| UME | **16.8** | - | - | 11.1 |

**Pentadecane at 20 °C**

| Lab*i* | $D_i$ / ($10^{-3}$ kg/m$^3$) | $U_i$ / ($10^{-3}$ kg/m$^3$) |
|---|---|---|
| NRC | **7.8** | 44 |
| PTB | **-0.8** | 4.3 |
| MKEH | **-3.1** | 3.7 |
| NMIJ | **-13.5** | 15.7 |
| KRISS | **6.1** | 4.7 |
| CENAM | **-0.5** | 12.7 |
| VNIIM | **2.0** | 9.2 |
| BEV | **-1.8** | 4.2 |
| CEM | **7.9** | 47 |
| GUM | **-4.5** | 8.5 |
| INM | **19.0** | 10.4 |
| INRiM | **0.3** | 9.0 |
| IPQ 1 | **-1324** | 69 |
| IPQ 2 | **65.5** | 84 |
| LNE | **14.2** | 12.6 |
| MIKES | **29.8** | 6.9 |
| NPL | **-5.5** | 8.5 |
| SMU | **-5.0** | 15.4 |
| UME | **-4.0** | 12.9 |

*For upper and lower uncertainty limits, cf. CCM.D-K2 Final Report*

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## Pentadecane at 15 °C

| Lab *i* | $D_i$ | $U_i$ lower | $U_i$ upper | $U_i$ |
|---|---|---|---|---|
| | / ($10^{-3}$ kg/m$^3$) | | | |
| NRC | **30.4** | 52.8 | 56.2 | - |
| PTB | **-0.7** | 6.3 | 5.3 | - |
| MKEH | **-1.3** | 6.5 | 5.0 | - |
| NMIJ | **-13.2** | 15.0 | 15.1 | - |
| KRISS | **9.2** | 8.0 | 7.7 | - |
| CENAM | **-2.6** | 13.5 | 11.5 | - |
| BEV | **0.2** | - | - | 5.3 |
| CEM | **29.6** | - | - | 81 |
| GUM | **0.6** | - | - | 8.7 |
| INM | **-1.3** | - | - | 10.9 |
| INRiM | **11.3** | - | - | 10.7 |
| IPQ 1 | **-1107** | - | - | 496 |
| IPQ 2 | **81** | - | - | 248 |
| LNE | **15.3** | - | - | 16.6 |
| MIKES | **38.8** | - | - | 7.5 |
| NPL | **0.1** | - | - | 19.8 |
| SMU | **9.7** | - | - | 32.3 |
| UME | **-3.4** | - | - | 13.7 |

*For upper and lower uncertainty limits, cf. CCM.D-K2 Final Report*

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## Pentadecane at 40 °C

| Lab *i* | $D_i$ | $U_i$ |
|---|---|---|
| | / ($10^{-3}$ kg/m$^3$) | |
| PTB | **4.2** | 4.3 |
| MKEH | **-3.2** | 4.3 |
| NMIJ | **-8.0** | 15.9 |
| CENAM | **3.1** | 34.4 |
| BEV | **0.7** | 4.2 |
| CEM | **67** | 152 |
| GUM | **-6.4** | 8.6 |
| INRiM | **5.6** | 17.6 |
| LNE | **1.7** | 19.5 |
| MIKES | **108** | 13 |
| SMU | **-29.2** | 28.2 |
| UME | **7.9** | 16.6 |

## Pentadecane at 60 °C

| Lab *i* | $D_i$ | $U_i$ |
|---|---|---|
| | / ($10^{-3}$ kg/m$^3$) | |
| PTB | **3.7** | 3.5 |
| MKEH | **-6.3** | 7.8 |
| NMIJ | **-9.1** | 16.4 |
| CENAM | **-16.8** | 145.9 |
| BEV | **3.5** | 4.8 |
| GUM | **-7.9** | 14.9 |
| INRiM | **40.5** | 31.5 |
| LNE | **-17.3** | 20.5 |
| MIKES | **132.4** | 37.6 |
| UME | **44.4** | 16.5 |

**Tetrachloroethylene at 20 °C**

| Lab $i$ | $D_i$ / ($10^{-3}$ kg/m$^3$) | $U_i$ / ($10^{-3}$ kg/m$^3$) |
|---|---|---|
| NRC | **25.8** | 93.5 |
| PTB | **-5.4** | 20.4 |
| MKEH | **0.8** | 19.7 |
| NMIJ | **-21.1** | 26.9 |
| KRISS | **9.1** | 21.2 |
| CENAM | **16.2** | 37.1 |
| VNIIM | **2.8** | 25.5 |
| BEV | **-2.1** | 15.1 |
| GUM | **-18.5** | 17.5 |
| INM | **27.8** | 23.6 |
| INRiM | **-3.8** | 24.0 |
| IPQ 1 | **-2314** | 131 |
| IPQ 2 | **47.2** | 66.4 |
| LNE | **-48.2** | 30.2 |
| NPL | **-166** | 29 |
| SMU | **-4.2** | 24.5 |
| UME | **7.7** | 30.1 |

**Tetrachloroethylene at 5 °C**

| Lab $i$ | $D_i$ / ($10^{-3}$ kg/m$^3$) | $U_i$ / ($10^{-3}$ kg/m$^3$) |
|---|---|---|
| NRC | **24.9** | 120.0 |
| PTB | **5.2** | 19.7 |
| MKEH | **-6.8** | 19.5 |
| NMIJ | **-14.3** | 27.9 |
| KRISS | **7.0** | 20.5 |
| CENAM | **14.9** | 54.3 |
| BEV | **-0.5** | 20.0 |
| GUM | **-15.1** | 28.7 |
| LNE | **-10.7** | 39.1 |
| SMU | **11.3** | 27.6 |
| UME | **41.0** | 35.3 |

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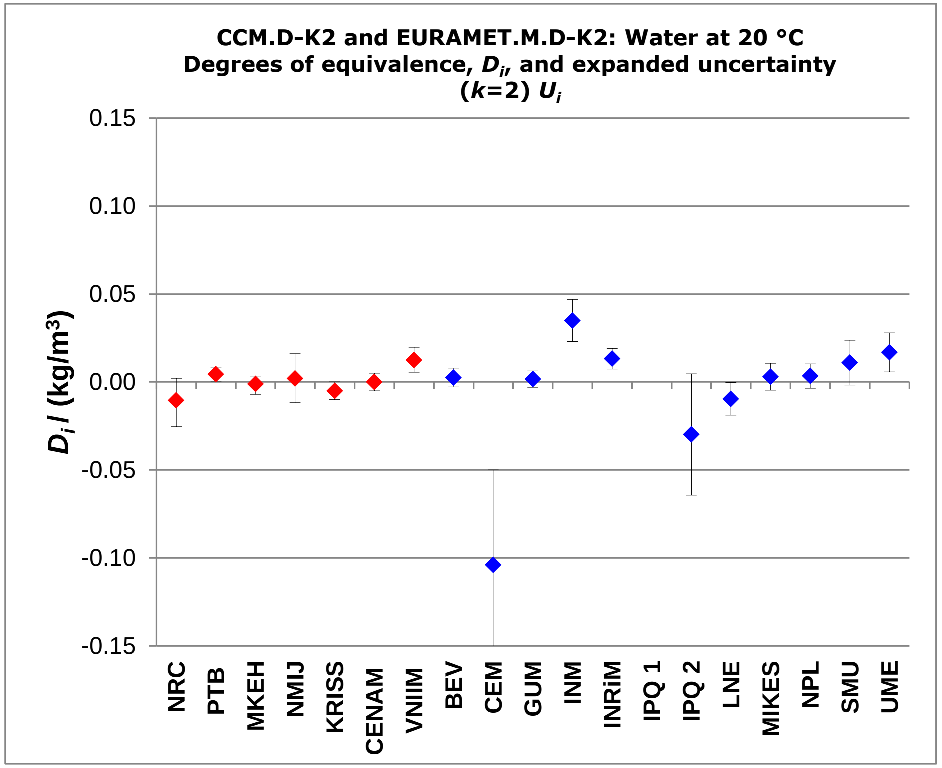
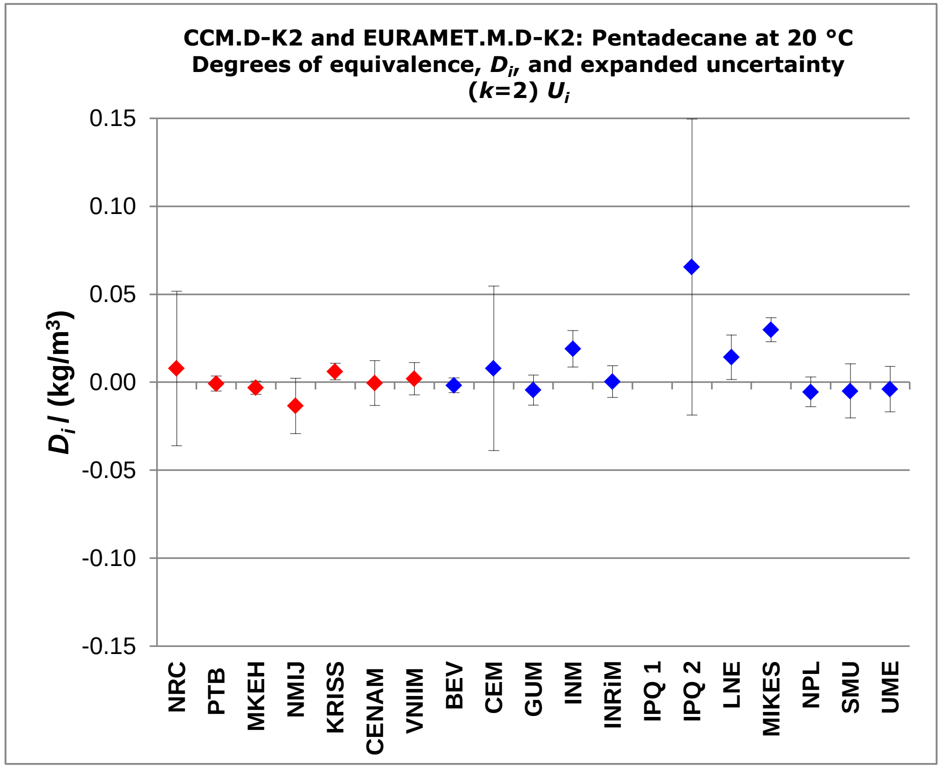
**Viscosity oil VO-2 at 20 °C**

| Lab $i$ | $D_i$ / ($10^{-3}$ kg/m$^3$) | $U_i$ / ($10^{-3}$ kg/m$^3$) |
|---|---|---|
| NRC | **-18.7** | 58.5 |
| PTB | **7.9** | 8.7 |
| MKEH | **-3.0** | 10.6 |
| KRISS | **-7.8** | 8.9 |
| CENAM | **8.5** | 14.3 |
| VNIIM | **-2.5** | 11.9 |
| BEV | **4.9** | 7.9 |
| CEM | **-204.7** | 40.1 |
| GUM | **9.1** | 8.3 |
| INM | **16.3** | 12.6 |
| INRiM | **9.9** | 11.6 |
| IPQ 1 | **-1069.8** | 74.1 |
| IPQ 2 | **-215.9** | 37.6 |
| LNE | **20.6** | 13.6 |
| NPL | **3.1** | 9.5 |
| SMU | **38.3** | 15.7 |
| UME | **24.3** | 13.7 |

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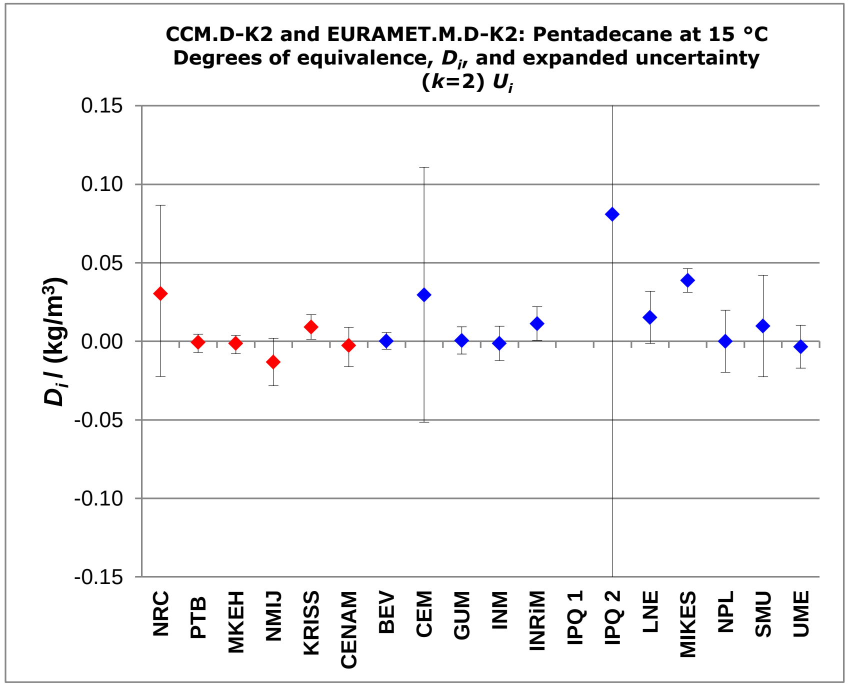


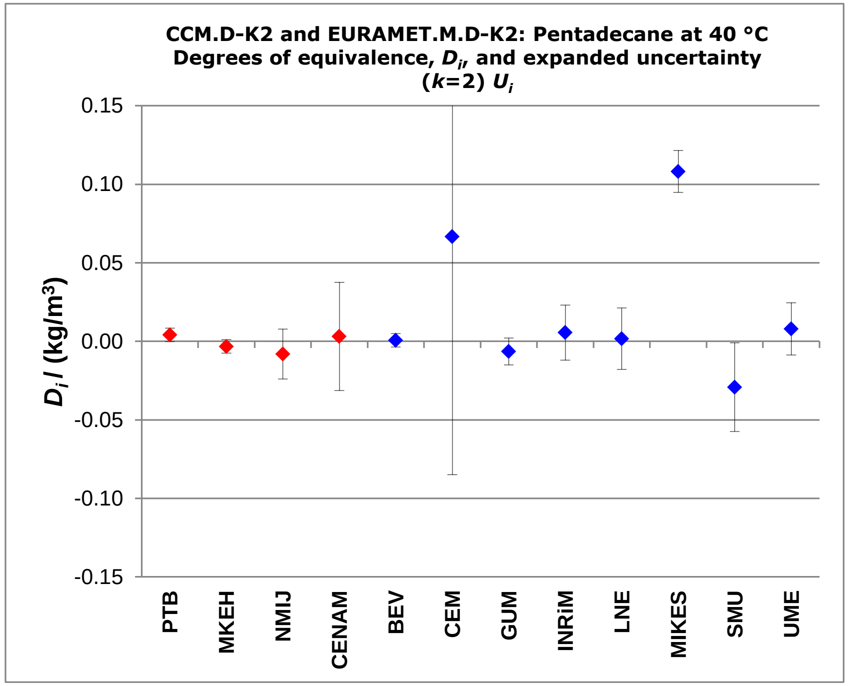


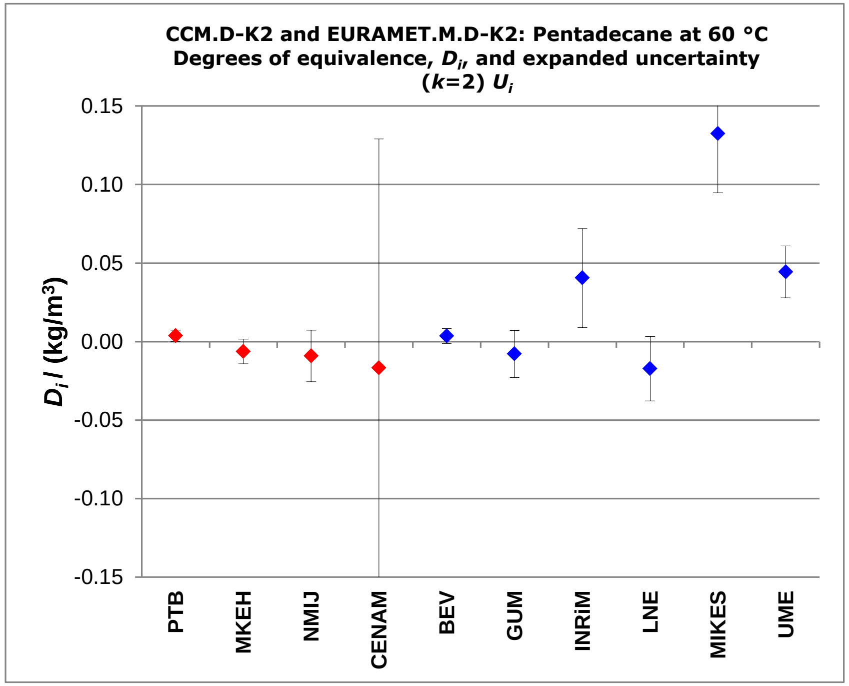


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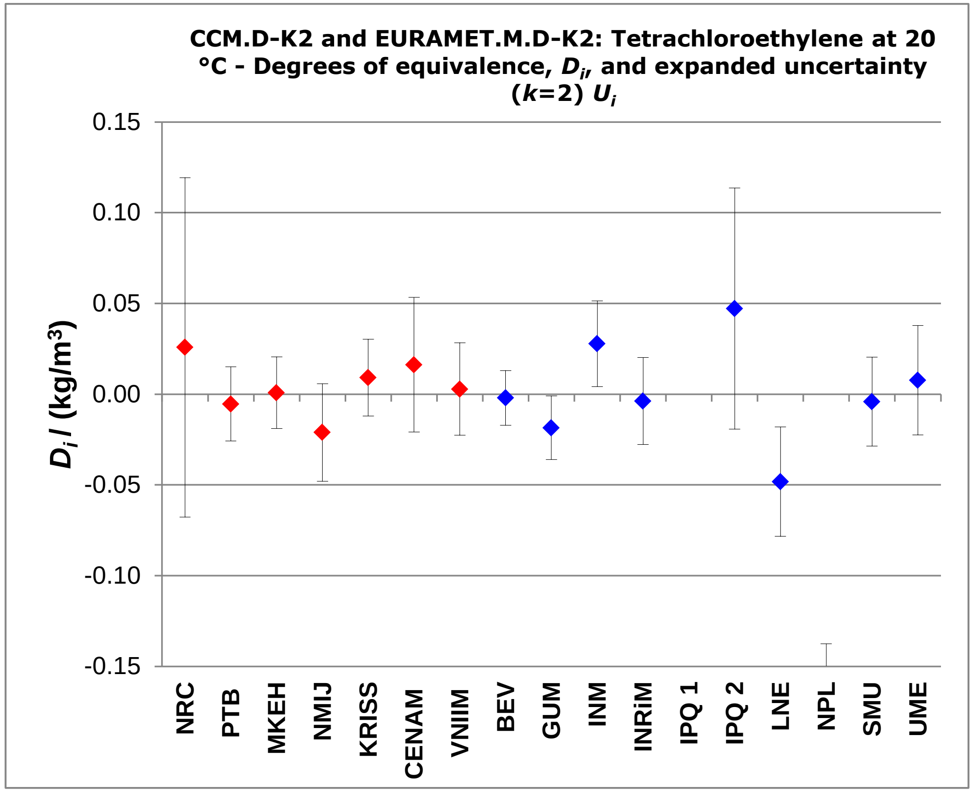


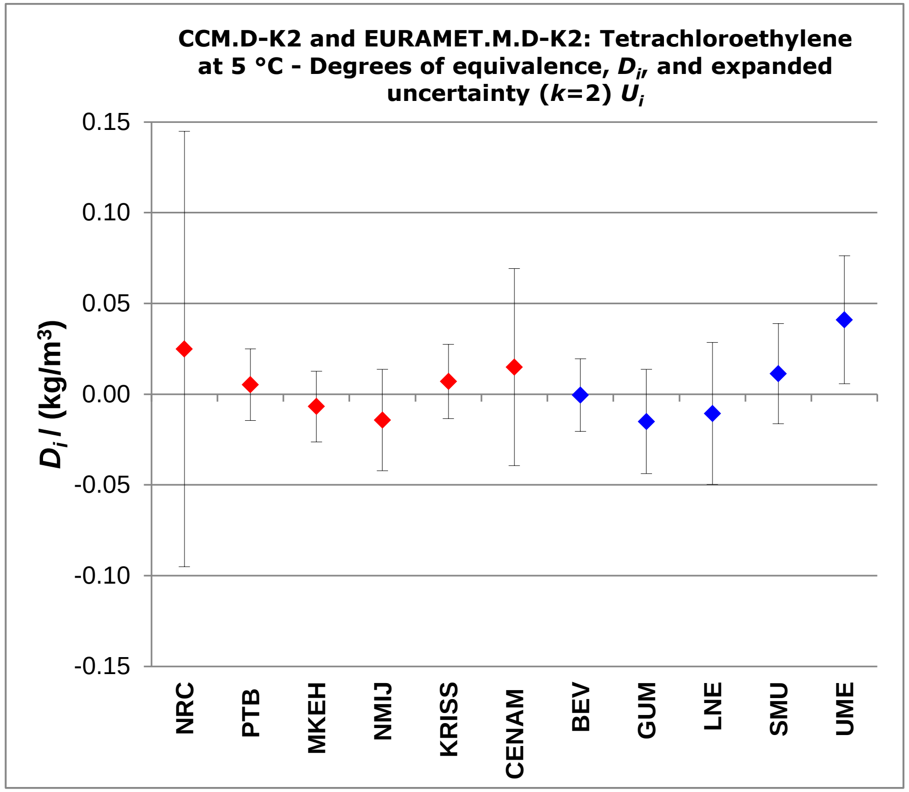


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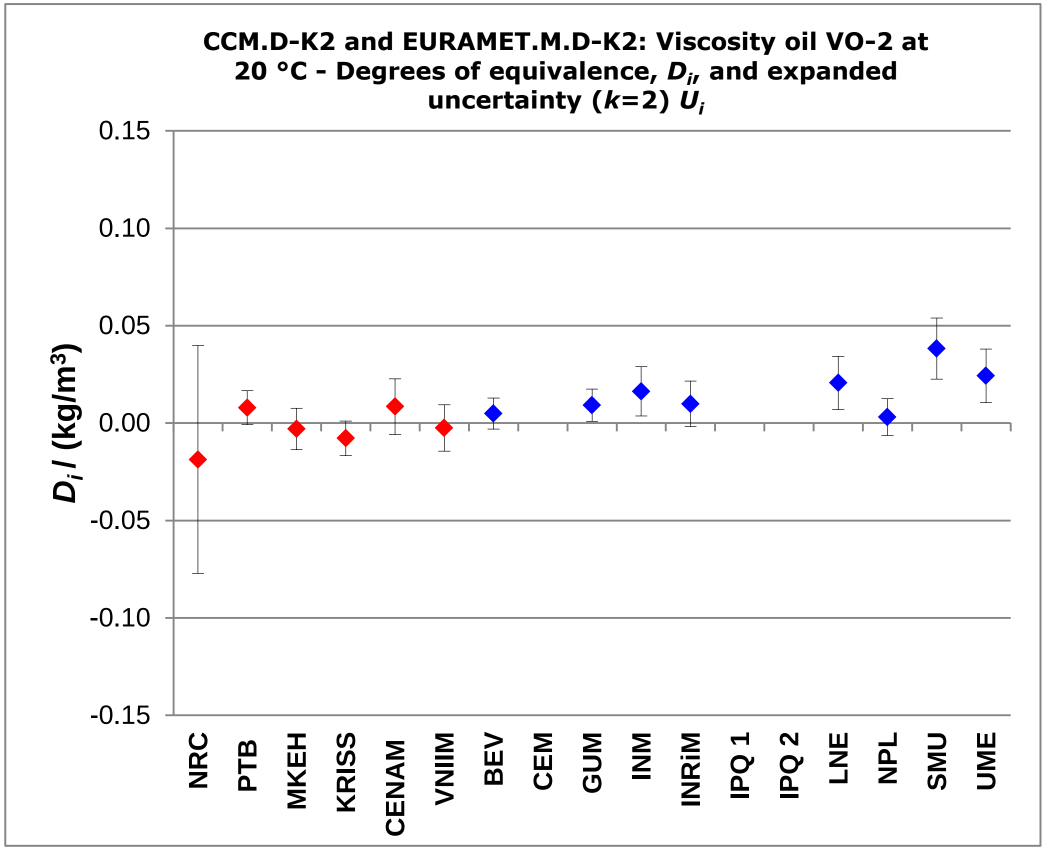


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