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1 Calibration Summary

The Fourteenth Intercomparison Campaign of the Regional Brewer Calibration Center Europe (RBCC-E) was held from June 17th to the 28th, 2019, at the El Arenosillo Atmospheric Sounding Station of the Instituto Nacional de Técnica Aeroespacial (INTA), Spain.

Brewer UK#172 participated in the campaign in the period from June 17th to 28th, although few measurements were taken the last day before the instrument was packed. The campaign days of Brewer UK#172 correspond to Julian days 168 – 178.

For the evaluation of the initial status, we used 136 simultaneous direct sun (DS) ozone measurements from days 170 to 172. For final calibration purposes, we used 362 simultaneous DS ozone measurements taken from day 173 to 178.

![Graph showing ozone relative difference (%)](image)

**Figure 1** – Mean DS ozone column percentage difference between Brewer UK#172 and Brewer IZO#185, plotted as a function of the ozone slant path. Results for the current (issued in the previous calibration campaign) configuration are show in blue; the red dotted line corresponds to the same configuration, but with the standard lamp correction applied; the black line corresponds to results obtained with the updated configuration proposed in the current campaign. The shadow areas represent the standard deviation of the mean. The plot corresponds to the final days of the campaign.

As shown in Fig. 1, the current ICF (ICF15117.172, blue dashed line) produces ozone values with an average difference of around 0.5% with respect to the reference instrument. This is a rather small difference, and highlights the stability of Brewer UK#172. This is confirmed by the stability of the R6 standard lamp measurements, see Fig. 2. The SL correction (Fig. 2, red dotted line) is thus not necessary and does not improve the comparison with Brewer IZO#185.

All the other parameters analyzed (run/stop tests, Hg lamp intensity, CZ & CI files, dead time,...)
show results inside the tolerance limits only Dead time (DT) shows a small difference between the current and campaign values of around 1 ns, with its value changing from $3 \times 10^{-8}$ to $2.9 \times 10^{-8}$.

We have not applied any correction to filters, but filter #4 shows no-linearity issues.

The sun-scan tests (SC) at the instrument’s station before the campaign and those performed during the first days of the intercomparison, confirm the current cal step value (286, within a step error of ±1).

We do not suggest changing the Ozone Absorption Coefficient, retaining its current value of 0.341.

1.1 Recommendations and Remarks

1. The R6 standard lamp test results from Brewer UK#172 have been very stable during the last 2 years. The old R6 reference value was 444 and, although the difference is almost within the acceptable error of ±5, it could be updated to 437.

2. We suggest a new R5 reference value of 697.

3. We suggest updating the DT to $2.9 \times 10^{-8}$ seconds, which is one units less than the value proposed in the last intercomparison.

4. The neutral density filters show significative correction for filter #4.

5. Due the small change, we don’t suggest to change configuration, but if the DT value is update we suggest updating also the ETC value from 1700 to 1703.

6. Despite the stability of the instrument and the good agreement with the reference, the instrument shows an slope on the comparison to the reference, underestimating at low air masses and overestimate at high airmass, this suggest a change on the ozone absorption coefficient of two steps not confirmed during wavelength calibration.

1.2 External links

Configuration File
http://rbcce.aemet.es/svn/campaigns/are2019/bfiles/172/ICF17818.172

Calibration Report
https://docs.google.com/spreadsheets/d/1WBzxK6bPrkD6mKIzkG8Bbh1Qgx0zLpsvvSmh1iwDciw/edit#gid=401824256

Calibration Reports Detailed
Historic and instrumental

Temperature & Filter

Wavelength

ETC transfer
2 Instrument History: Analysis of Average files

2.1 Standard Lamp Test

As shown in Figure 2 and 3, the standard lamp test performance is quite stable since August 2017, with mean values around 437 and 700 for R6 and R5, respectively. The current R6 value is only 7 units less that the reference value given in the previous intercomparison campaign. A small change in R5 can be associated with a variation of the lamp’s intensity as shown in Fig. 4. Finally, small seasonal variations can be identified.

![Figure 2](image-url)

*Figure 2 – Standard Lamp test R6 (Ozone) ratios. Horizontal lines are labeled with the original and final reference values (red and blue lines, respectively)*
2.1 Standard Lamp Test

Figure 3 – Standard Lamp test R5 ($SO_2$) ratios

Figure 4 – SL intensity for slit five.
2.2 Run Stop and Dead Time

Run stops test values are within the test tolerance limits, see Fig. 5.

As shown in Fig. 6 the current DT reference value of $3 \times 10^{-8}$ seconds is slightly larger than the value recorded during the calibration period, $2.9 \times 10^{-8}$ s. Therefore, this new value has been used in the new ICF.

![Figure 5 - Run/stop test](image)

2.3 Analog Test

Fig. 7 shows that the high voltage has remained almost constant around at 1171 over the last two years. Furthermore, analog test values are within the test tolerance range.
2.3 Analog Test

**INSTRUMENT HISTORY: ANALYSIS OF AVERAGE FILES**

<table>
<thead>
<tr>
<th>Date</th>
<th>Description</th>
<th>Time (x10^-9 seconds)</th>
</tr>
</thead>
<tbody>
<tr>
<td>17/07/26</td>
<td>Dead Time Test, DTOAVG.172</td>
<td>3e-08</td>
</tr>
<tr>
<td>17/10/12</td>
<td>Dead Time Test, DTOAVG.172</td>
<td>2.9e-08</td>
</tr>
</tbody>
</table>

**Figure 6** – Dead Time test. Horizontal lines are labelled with the current (red) and final (blue) values.

<table>
<thead>
<tr>
<th>Date</th>
<th>Description</th>
<th>SL Current (A)</th>
<th>H.T. Voltage (V)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jul17</td>
<td>Analog Printout Log, APOAVG.172</td>
<td>4.65</td>
<td>1167</td>
</tr>
<tr>
<td>Jun18</td>
<td>Analog Printout Log, APOAVG.172</td>
<td>4.7</td>
<td>1168</td>
</tr>
<tr>
<td>Jun19</td>
<td>Analog Printout Log, APOAVG.172</td>
<td>4.75</td>
<td>1169</td>
</tr>
</tbody>
</table>

**Figure 7** – Analog voltages and intensity.

Izaña Atmospheric Research Center, La Marina 20, 38071 S/C de Tenerife, Spain
Tel: +34922151718/Fax: +3492274475

UK#172, 6
2.4 Mercury Lamp Test

No noticeable internal mercury lamp intensity events have been observed during the campaign.

![Graph of Mercury Lamp Test](image)

**Figure 8** – Mercury lamp intensity (green squares) and Brewer temperature registered (black dots). Both parameters refer to maximum values for each day.

2.5 CZ scan on mercury lamp

In order to check both the wavelength settings and the slit function width, we analyzed the scans performed on the 296.728 nm and 334.148 nm mercury lines, see Fig. 9. As a reference, the calculated scan peak, in wavelength units, should be within 0.013 nm from the nominal value, whereas the calculated slit function width should be no more than 0.65 nm. Analysis of the CZ scans performed on Brewer UK#172 during the campaign show reasonable results, with the peak of the calculated scans close, although slightly below, the accepted tolerance range. Regarding the slit function width, results are good, with a FWHM lower than 6.5 Å.
Figure 9 – CZ scan on Hg lines. The upper panels show differences with respect to the reference line (solid lines represent the limit ±0.013 nm) as computed by the slopes (red circles) and center of mass (green squares) methods. Lower panels show the Full Width at Half Maximum value for each scan performed (solid lines represent the 0.65 nm limit).
2.6 CI scan on internal SL

CI scans of the standard lamp recorded at different times can be compared to investigate whether the instrument has changed its spectral sensitivity. We shown in Fig. 10 percentage ratios of the Brewer UK#172 CI scans performed during the campaign relative to the scan CI17217.172. As it can be observed, the lamp intensity has varied respect to the reference spectrum around 5%. Similar variation have been observed in the daily R6 and R5 values. This behavior is normal for a SL lamp.

![Figure 10](image)

Figure 10 – CI scan of Standard Lamp performed during the campaign days. Scans processed (upper panel) and relative differences with respect to a selected reference scan (lower panel). Red line represents the mean of all relative differences.
3 Absolute Temperature Coefficients

Temperature coefficients are determined using the standard lamp test. For every slit, the raw counts corrected for zero temperature coefficients are used in a linear regression against temperature with the slopes representing the instrument’s temperature coefficients. From this we obtain the corrected $R6$ and $R5$ ratios to analyze the new temperature coefficients’ performance.

As shown in Fig. 11 (temperature range from 19°C to 32°C), the current coefficients do an excellent job at reducing the temperature dependence, performing even better that the coefficients calculated using the data from the present campaign. The values of the coefficients are summarized in Table 1.

We have also extended our analysis using the data recorded since the previous campaign. As shown in Figs. 12 and 13, the current and new coefficients have a similar performance, the current coefficients being slightly better. For this reason, in the final ICF we have used the current coefficients.

**Figure 11** – Temperature coefficients performance. Red circles represent standard lamp R6 ratio calculated from raw counts without temperature correction (temperature coefficients null). Black crosses and green circles represent standard lamp R6 ratio corrected with original temperature coefficients and corrected with calculated temperature coefficients respectively. The values plotted correspond with the measurements obtained during the campaign.

**Table 1** – Temperature Coefficients. Calculated coefficients are normalized to slit#2

<table>
<thead>
<tr>
<th>slit #2</th>
<th>slit #3</th>
<th>slit #4</th>
<th>slit #5</th>
<th>slit #6</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Current</strong></td>
<td>6.2369</td>
<td>5.8351</td>
<td>5.7129</td>
<td>5.4500</td>
</tr>
<tr>
<td><strong>Calculated</strong></td>
<td>0.0000</td>
<td>0.4000</td>
<td>0.3000</td>
<td>0.3000</td>
</tr>
<tr>
<td><strong>Final</strong></td>
<td>6.2369</td>
<td>5.8351</td>
<td>5.7129</td>
<td>5.4500</td>
</tr>
</tbody>
</table>
3 ABSOLUTE TEMPERATURE COEFFICIENTS

**Figure 12** – Same as Fig. 11 but for the whole period between calibration campaigns.

**Figure 13** – Standard lamp R6 (MS9) ratio as a function of temperature. We plotted R6 ratio recalculated with the original (black) and the new (green) temperature coefficients.
4 Attenuation Filter Characterization

4.1 Attenuation Filter Correction

The filter’s spectral dependence affects the ozone calculation because the Brewer software assumes that their attenuation is wavelength-neutral. We can estimate the correction factor needed for this non-linearity by multiplying the attenuation of every filter and every wavelength by the ozone weighting coefficients.

During the calibration period, a total of 123 FI tests were analyzed to calculate the attenuation for every filter and slit. Fig. 14 shows the results of these tests, and Table 2 shows the calculated ETC corrections for each filter.

Compared to the current ETC filter corrections, suggested at the previous calibration campaign, the corrections calculated at the present campaign are lower. This is specially the case for Filter #3, which has a correction of -15 in the current configuration. For this filter, the correction obtained from the data of the present campaign (see Table 2) is within the ±5 error, so the correction could be even set to 0. Despite this, the current ETC corrections perform well, and we don’t suggest changing them.

Table 2 – ETC correction due to Filter non-linearity. Median value, mean values and, 95% confidence intervals are calculated using bootstrap technique

<table>
<thead>
<tr>
<th>Filter#1</th>
<th>Filter#2</th>
<th>Filter#3</th>
<th>Filter#4</th>
<th>Filter#5</th>
</tr>
</thead>
<tbody>
<tr>
<td>ETC Filt. Corr. (median)</td>
<td>-3</td>
<td>-6</td>
<td>-5</td>
<td>-17</td>
</tr>
<tr>
<td>ETC Filt. Corr. (mean)</td>
<td>-2.5</td>
<td>-7.5</td>
<td>-4.5</td>
<td>-12.3</td>
</tr>
<tr>
<td>ETC Filt. Corr. (mean 95% CI)</td>
<td>[-5.7, 0.8]</td>
<td>[-11.4, -3.7]</td>
<td>[-7.9, -1.1]</td>
<td>[-18.7, -5.9]</td>
</tr>
</tbody>
</table>
4.1 Attenuation Filter Correction

Attenuation Filter Test, FIOAVG.172

Diff. (%) with respect to operational values [1, 4400, 10330, 14020, 21560, 25950]

Figure 14 – Notched box-plot for the calculated attenuation relative differences of neutral density filters with respect to operational values. We show for each subplot relative differences corresponding to correlative filters (color box-plots). Solid lines and boxes mark the median, upper and lower quartiles. The point whose distance from the upper or lower quartile is 1 times larger than the interquartile range is defined as outlier.
5 WAVELENGTH CALIBRATION

5.1 Cal-Step determination

The sun scan routine takes DS ozone measurements by moving the micrometer about 15 steps below and above the ozone reference position (wavelength Calibration step-number). A Hg test is required before and after the measurement to assure the correct wavelength setting during the sun scan test. Ozone versus step number ideally shows a parabolic shape with a maximum at the ozone reference position. With this choice, small wavelength shifts (≈ ±2 steps) do not affect the ozone value. This optimal micrometer position is a near-linear function of the ozone slant path at the time of the scan, see Fig. 15.

During the campaign, sun-scan (SC) tests covering a ozone slant path range from 400 to 1200 DU were collected, see Fig. 16). The calculated Cal-Step Number (CSN) was 1 step lower than the value in the current configuration: 285 vs. 286. SC tests performed at the station before the campaign provide a CSN of 287. Taking all this into account, we suggest keeping the current CSN, 286.

**Figure 15** – Ozone measurements moving the micrometer 15 step around the operational CSN defined in the initial configuration.
5.1 Cal-Step determination

OSC clim. = 680   Calc Step = 285.2 [283.9, 286.5]
Calibration Step from config file ICF17319.172 = 286

Figure 16 – Ozone Slant Path vs Calc – Step number. Vertical solid line marks the calculated Cal Step Number for a climatological OSC equal to 680 (horizontal solid line). Blue area represents a 95% confidence interval.
5.2 Dispersion Test

We analyzed the dispersion tests carried out in the previous and present calibration campaigns. For all of them, we processed data from Mercury and Cadmium spectral lamps, using quadratic functions to adjust the micrometer step number to wavelength positions. The results of this historical analysis are summarized in Table 3.

In particular, for the current campaign, Fig. 17 shows that the quadratic fitting was good for all the dispersion tests, with residuals being lower than 0.1 Å in all slits. For the dispersion tests performed using the UV dome and the internal Hg lamp, Table 4 provides individual wavelength resolution, ozone absorption coefficient, sulfur dioxide absorption coefficient, and Rayleigh absorption for the operational CSN and those at ±1 step.

An absorption coefficient equal to 0.3412 is suggested in the final configuration.

<table>
<thead>
<tr>
<th>Date</th>
<th>Calc-step</th>
<th>O3abs coeff.</th>
<th>SO2abs coeff.</th>
<th>O3/SO2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current</td>
<td>286</td>
<td>0.3410</td>
<td>2.3500</td>
<td>1.1585</td>
</tr>
<tr>
<td>16-Jun-2013</td>
<td>286</td>
<td>0.3453</td>
<td>3.2066</td>
<td>1.1539</td>
</tr>
<tr>
<td>02-Jun-2015</td>
<td>286</td>
<td>0.3425</td>
<td>3.2190</td>
<td>1.1466</td>
</tr>
<tr>
<td>02-Jun-2017</td>
<td>286</td>
<td>0.3420</td>
<td>3.2256</td>
<td>1.1452</td>
</tr>
<tr>
<td>23-Jun-2019</td>
<td>286</td>
<td>0.3412</td>
<td>3.2053</td>
<td>1.1435</td>
</tr>
<tr>
<td>Final</td>
<td>286</td>
<td>0.3410</td>
<td>2.3500</td>
<td>1.1585</td>
</tr>
</tbody>
</table>
Figure 17 – 2019 Residuals of quadratic fit
Table 4 - 2019 Dispersion derived constants

<table>
<thead>
<tr>
<th>step= 285</th>
<th>slit#0</th>
<th>slit#1</th>
<th>slit#2</th>
<th>slit#3</th>
<th>slit#4</th>
<th>slit#5</th>
</tr>
</thead>
<tbody>
<tr>
<td>WL(A)</td>
<td>3031.91</td>
<td>3063.06</td>
<td>3100.43</td>
<td>3134.88</td>
<td>3167.89</td>
<td>3199.88</td>
</tr>
<tr>
<td>Res(A)</td>
<td>5.5014</td>
<td>5.4777</td>
<td>5.425</td>
<td>5.488</td>
<td>5.4343</td>
<td>5.3254</td>
</tr>
<tr>
<td>O3abs(1/cm)</td>
<td>2.5983</td>
<td>1.7794</td>
<td>1.0051</td>
<td>0.67736</td>
<td>0.37483</td>
<td>0.29482</td>
</tr>
<tr>
<td>Ray abs(1/cm)</td>
<td>0.50506</td>
<td>0.48319</td>
<td>0.45852</td>
<td>0.43718</td>
<td>0.41792</td>
<td>0.40027</td>
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<tr>
<td>SO2abs(1/cm)</td>
<td>3.4245</td>
<td>5.6707</td>
<td>2.3995</td>
<td>1.9213</td>
<td>1.0531</td>
<td>0.61551</td>
</tr>
<tr>
<td>step= 286</td>
<td>slit#0</td>
<td>slit#1</td>
<td>slit#2</td>
<td>slit#3</td>
<td>slit#4</td>
<td>slit#5</td>
</tr>
<tr>
<td>WL(A)</td>
<td>3031.98</td>
<td>3063.13</td>
<td>3100.5</td>
<td>3134.95</td>
<td>3167.96</td>
<td>3199.95</td>
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<tr>
<td>Res(A)</td>
<td>5.5013</td>
<td>5.4777</td>
<td>5.4249</td>
<td>5.4879</td>
<td>5.4342</td>
<td>5.3253</td>
</tr>
<tr>
<td>O3abs(1/cm)</td>
<td>2.5957</td>
<td>1.7778</td>
<td>1.0049</td>
<td>0.67708</td>
<td>0.37488</td>
<td>0.29434</td>
</tr>
<tr>
<td>Ray abs(1/cm)</td>
<td>0.50501</td>
<td>0.48314</td>
<td>0.45847</td>
<td>0.43714</td>
<td>0.41788</td>
<td>0.40023</td>
</tr>
<tr>
<td>SO2abs(1/cm)</td>
<td>3.4093</td>
<td>5.6912</td>
<td>2.4073</td>
<td>1.9096</td>
<td>1.0543</td>
<td>0.61325</td>
</tr>
<tr>
<td>step= 287</td>
<td>slit#0</td>
<td>slit#1</td>
<td>slit#2</td>
<td>slit#3</td>
<td>slit#4</td>
<td>slit#5</td>
</tr>
<tr>
<td>WL(A)</td>
<td>3032.06</td>
<td>3063.2</td>
<td>3100.57</td>
<td>3135.02</td>
<td>3168.03</td>
<td>3200.02</td>
</tr>
<tr>
<td>Res(A)</td>
<td>5.5013</td>
<td>5.4776</td>
<td>5.4248</td>
<td>5.4878</td>
<td>5.4341</td>
<td>5.3253</td>
</tr>
<tr>
<td>O3abs(1/cm)</td>
<td>2.5932</td>
<td>1.7761</td>
<td>1.0047</td>
<td>0.67675</td>
<td>0.37495</td>
<td>0.29387</td>
</tr>
<tr>
<td>Ray abs(1/cm)</td>
<td>0.50496</td>
<td>0.48309</td>
<td>0.45843</td>
<td>0.4371</td>
<td>0.41784</td>
<td>0.40019</td>
</tr>
<tr>
<td>SO2abs(1/cm)</td>
<td>3.3946</td>
<td>5.711</td>
<td>2.4155</td>
<td>1.8977</td>
<td>1.0556</td>
<td>0.611</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>step</th>
<th>O3abs</th>
<th>Rayabs</th>
<th>SO2abs</th>
<th>O3SO2Abs</th>
<th>Daumont</th>
<th>Bremen</th>
</tr>
</thead>
<tbody>
<tr>
<td>285</td>
<td>0.34304</td>
<td>9.636</td>
<td>3.2174</td>
<td>1.1485</td>
<td>0.35377</td>
<td>0.34512</td>
</tr>
<tr>
<td>286</td>
<td>0.34201</td>
<td>9.6342</td>
<td>3.2256</td>
<td>1.1452</td>
<td>0.35283</td>
<td>0.34415</td>
</tr>
<tr>
<td>287</td>
<td>0.34096</td>
<td>9.6323</td>
<td>3.2329</td>
<td>1.1417</td>
<td>0.35185</td>
<td>0.34313</td>
</tr>
</tbody>
</table>
5.3 Umkehr

For the Umkehr calibration, only the lines shorter than 3400 Å were used. The Umkehr offset is calculated by forcing the wavelength of slit #4 at the ozone position to be the same as on slit #1 at the Umkehr setting. The Umkehr offset calculated is 1694 Å. Table 5 summarizes the dispersion test for umkehr: wavelength, resolution and ozone absorption coefficient.

Table 5 – 2019 Umkehr dispersion constants

<table>
<thead>
<tr>
<th>step= 286</th>
<th>slit#0</th>
<th>slit#1</th>
<th>slit#2</th>
<th>slit#3</th>
<th>slit#4</th>
<th>slit#5</th>
</tr>
</thead>
<tbody>
<tr>
<td>WL(A)</td>
<td>3032</td>
<td>3063</td>
<td>3101</td>
<td>3135</td>
<td>3168</td>
<td>3200</td>
</tr>
<tr>
<td>Res(A)</td>
<td>5.5631</td>
<td>5.4696</td>
<td>5.4163</td>
<td>5.5463</td>
<td>5.4702</td>
<td>5.3528</td>
</tr>
<tr>
<td>O3abs(1/cm)</td>
<td>2.6025</td>
<td>1.7791</td>
<td>1.0045</td>
<td>0.67539</td>
<td>0.3749</td>
<td>0.2944</td>
</tr>
<tr>
<td>Ray abs(1/cm)</td>
<td>0.50514</td>
<td>0.48318</td>
<td>0.4584</td>
<td>0.43699</td>
<td>0.41792</td>
<td>0.40024</td>
</tr>
<tr>
<td>step= 1691</td>
<td>slit#0</td>
<td>slit#1</td>
<td>slit#2</td>
<td>slit#3</td>
<td>slit#4</td>
<td>slit#5</td>
</tr>
<tr>
<td>WL(A)</td>
<td>3133</td>
<td>3164</td>
<td>3200</td>
<td>3233</td>
<td>3265</td>
<td>3296</td>
</tr>
<tr>
<td>Res(A)</td>
<td>5.4319</td>
<td>5.3516</td>
<td>5.2838</td>
<td>5.4119</td>
<td>5.339</td>
<td>5.2277</td>
</tr>
<tr>
<td>O3abs(1/cm)</td>
<td>0.67844</td>
<td>0.39767</td>
<td>0.29471</td>
<td>0.1229</td>
<td>0.062304</td>
<td>0.033359</td>
</tr>
</tbody>
</table>
6 ETC Transfer

Based on the Lambert-Beer law, the total ozone column in the Brewer algorithm can be expressed as:

\[ X = \frac{F - ETC}{\alpha \mu} \]  

(1)

where \( F \) are the measured double ratios corrected for Rayleigh effects, \( \alpha \) is the ozone absorption coefficient, \( \mu \) is the ozone air mass factor, and \( ETC \) is the extra-terrestrial constant. The \( F \), \( \alpha \) and \( ETC \) parameters are weighted functions at the operational wavelengths with weighting coefficients \( w \):

The transfer of the calibration scale (namely ETC) is done side by side with the reference instrument. Once we have collected enough near-simultaneous direct sun ozone measurements, we calculate the new extraterrestrial constant after imposing the condition that the measured ozone will be the same for simultaneous measurements. In terms of Equation 1, this leads to the following condition:

\[ ETC_i = F_i - X_{i,\text{reference}} \alpha \mu \]  

(2)

For a good characterized instrument, the ETC determined values show a Gaussian distribution and the mean value is used as the instrument constant. One exception to this rule is the single monochromator Brewer models (MK-II and MK-IV) which are affected by stray light. In this case, the ETC distribution shows (see Fig. 1) a tail at the lower ETC values for high Ozone Slant Column (OSC, the product of the total ozone content by the airmass). For this type of Brewer, only the stray-light free region is used to determine the ETC, generally from 300 to 900 DU OSC, depending on the instrument.

The stray light effect can be corrected if the calibration is performed against a double monochromator instrument, assuming that it can be characterized following a power law of the ozone slant column

\[ F = F_o + k(X \mu)^s \]  

(3)

where \( F \) are the true counts and \( F_o \) the measured ones.

\[ ETC_i = ETC_o + k(X \mu)^s \]  

(4)

where \( ETC_o \) is the ETC for the stray light free OSC region and \( k \) and \( s \) are retrieved from the reference comparison. These parameters, determined in several campaigns, have been found to be stable and independent of the ozone calibration.

As the counts \( F \) from the single brewer are affected by stray light, the ozone is calculated using an iterative process:

\[ X_{i+1} = X_i + \frac{k(X \mu)^s}{\alpha \mu} \]  

(5)

Only one iteration is needed for the conditions of the intercomparison, up to 1500 DU. For ozone slant path measurements in the 1500–2000 DU range, two iterations are enough to correct the ozone.

The ETC is obtained by comparison with the reference Brewer IZO#185 using near-simultaneous measurements during 6 days (two measurements are considered near-simultaneous if they are taken less than 3.5 minutes apart). Measurements with airmass difference greater than 3% were removed from the analysis.
6.1 Initial Calibration

For the evaluation of initial status of Brewer UK#172 we used the period from days 170 to 172 which correspond with 136 near-simultaneous direct sun ozone measurements. As shown in Fig. 18 the current calibration constants produce an ozone values slightly higher than the reference instrument (0.5%). When the ETC is corrected taking into account the difference between the SL and R6 reference (SL correction), the results do not improve.

Figure 18 – Mean direct-sun ozone column percentage difference between Brewer UK#172 and Brewer IZO#185 as a function of ozone slant path.
6.2 Final Calibration

After the maintenance on day 172, a new ETC value was calculated (see Fig. 19). For the final calibration, we use 362 simultaneous direct sun measurements from days 173 to 178. The new value (1703) is only three units higher than the current ETC value (1700) due the change in DeadTime. The change is very small, therefore, we recommend to use the current configuration, together with the new proposed standard lamp reference ratios, 437 for R6. For reference we provide a new configuration with this new ETC taking into account the new suggested dead time, $2.9 \cdot 10^{-8}$.

![UK172 ETC Transfer from RBCC-E reference IZO#185](image)

**Figure 19** – Mean direct-sun ozone column percentage difference between Brewer UK#172 and Brewer IZO#185 as a function of ozone slant path.
6.3 Standard Lamp Reference Values

The reference values of standard lamp ratios during the calibration period were 437 for R6 (Figure 21) and 697 for R5 (Figure 22).

Figure 20 – Mean direct-sun ozone column percentage difference between Brewer UK#172 and Brewer IZO#185 as a function of ozone slant path.
Figure 21 – Standard Lamp $O_3$ R6 ratios: daily mean and standard deviation (squares), seven day running mean (circle) and individual tests (black dots). Reprocessed using old and new instrumental constants.

Figure 22 – Standard Lamp $SO_2$ R5 ratios: daily mean and standard deviation (squares), seven day running mean (circle) and individual tests (black dots). Reprocessed using old and new instrumental constants.
Figure 23 – Standard Lamp intensity: daily mean and standard deviation (squares), seven day running mean (circle) and individual tests (black dots)
### 7.1 Instrument constant file

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8  Daily Summary report

Table 7 – Ozone Summary Report. Mean daily ozone, grouped by ozone slant path ranges, with original and final configuration (with an asterisk)

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<td>NaN</td>
<td>NaN</td>
<td>NaN</td>
<td>310</td>
<td>5.2</td>
<td>0.3</td>
</tr>
<tr>
<td>206</td>
<td>700&lt;osc&gt;400</td>
<td>314</td>
<td>3.4</td>
<td>20</td>
<td>NaN</td>
<td>NaN</td>
<td>NaN</td>
<td>313</td>
<td>1.8</td>
<td>-0.5</td>
</tr>
</tbody>
</table>

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UK#172, 27
9 Appendix: Summary Plots

**Figure 24** – Overview of the intercomparison. Brewer UK#172 data are evaluated using final constants (blue circles)

**Suggested configuration**

Blind day 17019
Suggested configuration
Blind day 17119

Suggested configuration
Blind day 17219
9 APPENDIX: SUMMARY PLOTS

Final configuration
Final day 17619

Final configuration
Final day 17719

Final configuration
Final day 17819
Final configuration
Final day 17919

Total Ozone (DU)

IZO#185 UK # 172 UK # 172 old config.