REPORT OF THE TENTH WMO
INTERNATIONAL COMPARISON OF DOBSON
SPECTROPHOTOMETERS

(Arosa, Switzerland, 24 July - 4 August 1995)
NOTE

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1. **INTRODUCTION**

The WMO representative, Dr Antti Kulmala welcomed the participants and expressed the appreciation of Prof. G.O.P. Obasi, Secretary-General of WMO, for the valuable work the ozone community has done for the benefit of humankind in maintaining the high quality of Dobson observations. He also thanked the Swiss Meteorological Institute for their decisive financial and material support in organizing the Intercomparison. He commended NOAA for maintaining the reference instruments and helping WMO in operating the global ozone network. He also gave special tribute to Bruno Hoegger from SMI and Robert Evans from NOAA in the organization of the Arosa event.

2. **PURPOSE OF THE INTERCOMPARISON**

The Intercomparison was organized by the WMO Secretariat in close cooperation with and financial assistance from the Swiss Meteorological Institute (SMI). It was a regular event in a campaign to maintain the network of the Dobson ozone spectrophotometers operated in RA VI (Europe). It is the tenth comparison thus organized. The Intercomparison served as an assurance of the quality of the total ozone data sets created at the GAW ozone stations operated by WMO Member countries in Europe. This action is an application of WMO/GAW/QA requirements for monitoring of the atmospheric total ozone.

The main tasks were:

- The technical inspection and adjustment of the instruments,
- Comparison of the Dobson spectrophotometers with the World Secondary Dobson Standard Instrument (WSSI) No. 65, to determine the existing calibration level,
- Determination of new calibration constants for each Dobson spectrophotometer, as necessary,
- To provide a forum for instruction for operation of the Dobson spectrophotometers at home stations, and in sharing of knowledge concerning the management of an ozone observing programme.

3. **ORGANIZATION**

The Intercomparison was held at the Lichtklimatisches Observatorium (LKO) of the Swiss Meteorological Institute in Arosa during the period 24 July to 4 August 1995. Its programme was arranged by the Scientific Director, Robert Evans (NOAA) and by Technical Director, Bruno Hoegger (SMI) in cooperation with an Executive Team of the following specialists:

<table>
<thead>
<tr>
<th>Archie Asbridge</th>
<th>AES</th>
<th>Retired</th>
</tr>
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<tbody>
<tr>
<td></td>
<td></td>
<td>Scientific and technical assistance</td>
</tr>
<tr>
<td>Karel Vanicek</td>
<td>CHMI</td>
<td>Scientific and technical assistance</td>
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<tr>
<td>Lars Opedal</td>
<td>Univ. Oslo</td>
<td>Technical assistance</td>
</tr>
<tr>
<td>Martin Stanek</td>
<td>CHMI</td>
<td>Technical assistance</td>
</tr>
</tbody>
</table>

The infrastructure of the Intercomparison was supported by the following Swiss experts:

| Johannes Stähelin | ETH Zurich |
| Pierre Viatte     | SMI, Aerological Station, Payerne |
| Herbert Schill    | SMI-LKO |
| Kurt Aeschbacher  | SMI-LKO |
Reto Wetter  SMI-LKO
Franz Herzog  SMI-LKO

More than 28 specialists from 18 countries (see Annex A), participated at the Intercomparison. The following national Dobson spectrophotometers were inspected and compared:

<table>
<thead>
<tr>
<th>No. of Dobson</th>
<th>Country</th>
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</thead>
<tbody>
<tr>
<td>D015</td>
<td>WMO/RA VI Spare instrument</td>
</tr>
<tr>
<td>D030</td>
<td>Sweden (Vindeln)</td>
</tr>
<tr>
<td>D032</td>
<td>UK</td>
</tr>
<tr>
<td>D040</td>
<td>Belgium (Uccle)</td>
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<tr>
<td>D041</td>
<td>UK</td>
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<tr>
<td>D048</td>
<td>Italy (Sestola)</td>
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<tr>
<td>D049</td>
<td>France (Bordeaux)</td>
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<tr>
<td>D050</td>
<td>Iceland (Reykjavik)</td>
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<tr>
<td>D062</td>
<td>Switzerland (LKO Arosa)</td>
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<tr>
<td>D065</td>
<td>USA (Boulder) Reference instrument (WSSI)</td>
</tr>
<tr>
<td>D084</td>
<td>Poland (Belsk)</td>
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<tr>
<td>D085</td>
<td>France (OHP)</td>
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<tr>
<td>D092</td>
<td>Denmark (Greenland)</td>
</tr>
<tr>
<td>D101</td>
<td>Switzerland (LKO)</td>
</tr>
<tr>
<td>D104</td>
<td>Germany (Hohenpeissenberg)</td>
</tr>
<tr>
<td>D107</td>
<td>Russia (CAO Moscow)</td>
</tr>
<tr>
<td>D110</td>
<td>Hungary (Budapest-Lőrinc)</td>
</tr>
<tr>
<td>D121</td>
<td>Romania (Bucharest)</td>
</tr>
</tbody>
</table>

The Intercomparison (IC) was conducted and all activity arranged in daily schedules according to the weather conditions and with respect to the technical state of the individual instruments. The technical infrastructure of SMI and special facilities from NOAA, Boulder were utilized for the IC.

The main steps specified below were generally applicable to each Dobson spectrophotometer:

- unpacking of the instrument, its check after the transport and installation on the roof of LKO;
- inspection of the technical condition of the spectrophotometer and its monitoring by means of the daily SL and HG tests;
- initial comparison against the WSSI to determine the existing calibration level;
- definition of the technical adjustments and special tests required (wedge calibrations, discharge lamp tests, cleaning and adjustment of the optics, refurbishing of the electronics etc.);
- final comparison against the WSSI;
- assessment of the results, determination of the new calibration constants (Reference R-N tables, Q-table and Reference Standard Lamp Readings);
- interview by the scientific director with the operator in charge concerning the results of his instrument intercomparison and other calibrations (meta data). At this point, copies of documentation related to the spectrophotometer calibration were given to the operator;
- packing of the instrument and other technical apparatus for transport to home station.

All work done and the results obtained for each individual instrument are described in Annex B, and briefly indicated in Table 1. This information is retained in detail in the files kept by operators and by the scientific director of the IC.

The success of the IC was accomplished mainly through the instructions provided by the scientific and technical directors at the regular daily meetings of all participants. These instructions were determined at the daily meetings of the scientific and executive group.

With regard to the goal of sharing knowledge of the operation of the instruments and the management of an observing programme, the individual participants were required to perform necessary calibration procedures under the supervision of the scientific staff. For example, all wedge calibrations were performed by each instrument’s own operator.

During the IC, two young scientists (Lars Opdal and Martin Stanek) received, under the supervision of Mr. A. Asbridge, senior scientist, special training in the service and repair on the Dobson spectrophotometers. The theory behind the operation and measurement of the Dobson spectrophotometer was discussed in detail with them. These two young scientists performed well beyond expectations and the call of duty. The experience they gained will serve well the future of RA VI Dobson ozone spectrophotometer operations.

4. OTHER ACTIVITIES

After the daily joint meetings, several participants presented, in seminar form, scientific papers concerning their organization’s total ozone and UVB observation programme.

The updated version of the generalized software for processing of Dobson total ozone observations, DOBSON 2.2, created by the CHMI-SOO at Hradec Kralove was also presented and the participants, on request, were provided with an entire software package on floppy discs.

Dr John Miller and Dr Antti Kulmala, representatives of the WMO Secretariat, Geneva and Prof. Volker Mohnen, Director of the WMO GAW Quality Assurance Science Activity Centre, visited the Intercomparison. Prof. Mohnen discussed important issues related to the application of GAW total ozone monitoring programme objectives and QC/QA activities with individual participants.

Based on these discussions and taking into account the urgent needs of QC/QA, the participants recommended implementation of a system of regular intercomparisons of the Brewer spectrophotometers from the network under the supervision of WMO. Mr. Karel Vanicek was directed to request his Permanent Representative with WMO, the Director of the Czech Hydrometeorological Institute, to submit to the Executive Council of WMO of a proposal to this effect.

Morning observations on the zenith sky were made, both to evaluate the reduction of the measurements to ozone values, and to evaluate Umkehr measurement reliability. These measurements were conducted under poor observing conditions. (Reduced data will be available later).

Measurements with a SAOZ instrument (diode array spectrometer) were made parallel to the Dobson measurements (data will be available later).

5. CONCLUSIONS

All instruments that were compared left the intercomparison in proper calibration. Two spectrophotometers, D104 and D121, were recommended to be further checked for their optical alignment (See Annex B, Individual Instrument Results.)
The results of the IC confirmed improvement in technical stability of the calibration level of the Dobson spectrophotometers operated in the RA-VI Region (Europe) as a result of previous regular intercomparisons organized by WMO. Nevertheless, systematic attention must be paid to the maintenance of the instruments at the stations in the future.

6. RECOMMENDATIONS

Long-term maintenance of the World Primary Standard Dobson Spectrophotometer (WPSS) D083 and the Secondary Standard D065 by NOAA, Boulder has established well defined calibration background for the Dobson spectrophotometers worldwide. To transfer the calibration scale in a more efficient way into the network and to assist the stations with operational problems, the Scientific Committee recommends the establishment of a Centre for the Region where a regional standard instrument, well qualified specialists and laboratory facilities would be available to assist national stations. Taking into account long-term experience in Dobson ozone spectrophotometer issues, the qualifications of the staffs and the existing infrastructures, either the Solar and Ozone Observatory, Hradec Kralove, Czech Republic or the Meteorological Observatory, Hohenpeissenberg, Germany should be designated the RA-VI (Europe) Dobson Ozone Centre. The terms of reference of this centre should be defined by an ad hoc scientific committee from RA VI.

The Dobson spectrophotometer D015 should be identified as a RA VI spare instrument which would be located at place to be specified later.

The instruments compared displayed a remarkable variety of electronic circuitry. Most of the circuits are composed of obsolete components. Many are needlessly complicated, and are missing spare parts and documentation. Some of the instruments on arrival at the IC site, were not operational, and great effort was required to repair those instruments. Some of the instruments were wired incorrectly, with respect to the main AC power, thus were not safe to operate before repair. Considering this, a recommendation is made for WMO to standardize the electronic circuits with a simple, effective design using readily available components. To ensure the use of this design, WMO should provide the means of converting the various instruments to this standard.

The Scientific Steering Committee of the Tenth WMO International Comparison of Dobson Spectrophotometers, Arosa, Switzerland, 24 July - 4 August urges that the four to five year schedule of comparison of RA VI Dobson Ozone Spectrophotometers be continued because of the obvious benefits they provide.

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ANNEX A
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ANNEX B

INDIVIDUAL INSTRUMENT REPORTS

Instrument D015 - WMO Spare Dobson

Original calibration data:
No existing calibration, as the instrument was rebuilt in 1993 and 1994 by SMI.

Initial calibration results:
Not applicable.

Work performed:
Instrument was in full working order.

Final intercomparison:
30 July 1995.
New N-tables and Reference Standard Lamp values defined.
Highest Difference against the standard for ADDSGQP observations in mu range 1.15 to 3.2 was 0.7% in total ozone.

No recommendations.

Instrument D030 - Vindeln, Sweden

Original calibration data:
N-tables from 10 May 1990, Boulder Colorado intercomparison.
Reference Standard Lamp Values for lamps 30Q1, 30Q2, 30Q4, and 30Q5.
Lamp tests results used in data processing at home station.

Initial calibration results: (Adjustments based on the results of Standard Lamp tests included)
25 July 1995

d_Na: -0.14  d_Nc: +0.66  d_Nd: +0.35  d_Nad: -0.5

The d_Nad value implies an average +0.7% error in calculated ozone value, Mu = 1 to 3,
Total Ozone = 300 Dobson Units.

Work performed:
- Interior Cleaned, and gaskets replaced.
- Optics cleaned of dust.
- New temperature coefficient determined from mercury tests at LKO, and inspection of
  the mercury test record at the station.
- A discharge lamp test series was performed, and a new Q-setting table determined
- Optical Symmetry checked and found to be in limits.
Final intercomparison:

30 July 1995.
New N-tables and Reference Standard Lamp values defined for instrument lamps plus UQ2 and UQ8.
Highest Difference against the standard for ADDSGQP observations in mu range 1.15 to 3.2 was 0.3% in total ozone.

No recommendations.

Instrument D032 - United Kingdom

Original calibration data:

N-tables from May 1995, defined from lamps, after Ealing Electro-Optics rebuild.
Reference Standard Lamp Values for lamps 32Q3.
No data record exists for this instrument after the rebuild.

Initial calibration results:

20 July 1995

\[ d_{Na} = +0.94 \quad d_{Nc} = -0.20 \quad d_{Nd} = +0.90 \quad d_{Nad} = +0.04 \]

The results were variable, Mu range to Mu range, so these numbers are not representative of the true performance.

Work performed:

- Optical Symmetry checked and found to be in limits.
- Cleaning as needed.
- Electrical repair and inspection performed.

Final intercomparison:

New N-tables and Reference Standard Lamp values defined for 32Q3, 32Q5, 32Q6, 32Q8, UQ2 and UQ8.
Highest Difference against the standard for ADDSGQP observations in mu range 1.15 to 3.2 was 0.2% in total ozone.

No recommendations.

Instrument D040 - Uccle, Belgium

Original calibration data:

N-tables from 01 August 1990, LKO Arosa intercomparison.
Lamp tests results used in data processing at home station.

Initial calibration results: (Adjustments based on the results of Standard Lamp tests included)

25 July 1995

\[ d_{Na} = -2.22 \quad d_{Nc} = -1.59 \quad d_{Nd} = -0.82 \quad d_{Nad} = -1.4 \]
The d_Nad value implies an average +2.0% error in calculated ozone value, \( \mu = 1 \) to 3, Total Ozone = 300 Dobson Units.

**Work performed:**

- New Q-setting table created from discharge lamp test series dated 26 July 1995.
- Wiring repair and inspection performed.
- Optical cleaning, and small adjustment of mirror M1 performed.
- Optical Symmetry was checked and found to be in limits.

**Final intercomparison:**

New N-tables and Reference Standard Lamp values defined for G9, G7, UQ2 and UQ8. Highest Difference against the standard for ADDSGQP observations in \( \mu \) range 1.15 to 3.2 was 0.4% in total ozone.

No recommendations.

**Instrument D041 - United Kingdom, Standard**

**Original calibration data:**

N-tables from 02 August 1990, LKO Arosa intercomparison, but with the Nc-table adjusted after the intercomparison by +0.4 N-unit.
Reference Standard Lamp Values for lamps 41Q3, 41Q4 and 41Q5.
Lamp tests results used in data processing at home station.

**Initial calibration results:** (Adjustments based on the results of Standard Lamp tests included)

19 July 1995

\[ d_{Na} = -0.82 \quad d_{Nc} = -0.41 \quad d_{Nd} = +0.02 \quad d_{Nad} = -0.8 \]

The d_Nad value implies an average +1.2% error in calculated ozone value, \( \mu = 1 \) to 3, Total Ozone = 300 Dobson Units.

**Work performed:**

- Wedge drive mechanism repaired.
- Optics cleaned, and gaskets replaced.
- Wiring and electronics repair and inspection performed.
- Optical Symmetry was checked and found to be in limits.

**Final intercomparison:**

30 July 1995.

New N-tables and Reference Standard Lamp values defined for 41Q5, 41Q4, 41Q5, UQ2 and UQ8.
Highest Difference against the standard for ADDSGQP observations in \( \mu \) range 1.15 to 3.2 was 0.3% in total ozone.

No recommendations.
Instrument D048 - Sestola, Italy

Original calibration data:

N-tables from 12 November 1980.
Lamp tests results used in data processing at home station.

Initial calibration results: (Adjustments based on the results of Standard Lamp tests included)

19 July 1995

d_Na: 1.1   d_Nc: +0.61   d_Nd: +2.27   d_Nad: -1.7

The d_Nad value implies an average +2.4% error in calculated ozone value, \( \mu = 1 \) to 3, Total Ozone = 300 Dobson Units.

Work performed:

- Optics cleaned, and gaskets replaced.
- Wiring and electronics repair and inspection performed.
- New instrument temperature coefficient defined from Mercury tests during several days.
- Discharge lamp test series performed, and a new Q-setting table created, dated 23 July 1995.

Final intercomparison:

New N-tables and Reference Standard Lamp values defined for 48/1, 48/3, 48/5, 48/6, UQ2 and UQ8.
Highest Difference against the standard for ADDSGQP observations in \( \mu \) range 1.15 to 3.2 was 0.6% in total ozone.

No recommendations.

Instrument D049 - Bordeaux, France

Original calibration data:

N-tables from 10 July 1995, intercomparison at l’Observatoire de Haute Provence.
Reference Standard Lamp Values for lamps 49/2H1, 49/3H1, and 49/4H1.
Lamp tests results not used in data processing at home station.

Initial calibration results: (Adjustments based on the results of Standard Lamp tests included)

25 July 1995

d_Na: -1.39   d_Nc: -1.04   d_Nd: -1.15   d_Nad: -0.2

The d_Nad value implies an average +0.3% error in calculated ozone value, \( \mu = 1 \) to 3, Total Ozone = 300 Dobson Units.
Work performed:

- Some optics cleaned (see recommendations), and gaskets replaced.
- Wiring and electronics repair and inspection performed.
- Discharge lamp test series performed, and a new Q-setting table created, dated 29 July 1995.
- Symmetry test performed and found to be in limits.

Final intercomparison:

30 July 1995.
New N-tables and Reference Standard Lamp values defined for 49/2H1, 49/3H1, 49/4H1, UQ2 and UQ8.

Highest Difference against the standard for ADDSGQP observations in mu range 1.15 to 3.2 was 0.2% in total ozone.

Recommendations:

This instrument is equipped with an absolute encoder for recording the R-dial position. The electronics for this device are completely out of date. The encoder mount keeps the wedge bridge from being removed. The optics, including the optical wedge in this instrument need though cleaning, as the interior is coated with a thin film. The recommendation is that the instrument be electronically modernized, and the optics cleaned. At this point, a wedge calibration should be performed and the instrument compared again to a standard.

Instrument D050 - Reykjavik, Iceland

Original calibration data:

N-tables from 02 August 1990, LKO Arosa Intercomparison.
Reference Standard Lamp Values for lamp 50Q1.
Lamp tests results not used in data processing at home station.

Initial calibration results:

25 July 1995

\[d_{Na} = -1.1 \quad d_{Nc} = 0.30 \quad d_{Nd} = 0.28 \quad d_{Nad} = -0.8\]

The \(d_{Nad}\) value implies an average +1.1% error in calculated ozone value, \(Mu = 1\) to \(3\), Total Ozone = 300 Dobson Units.

Work performed:

- Optics cleaned, and gaskets replaced.
- Wiring and electronics repair and inspection performed.
- Discharge lamp test series performed, and a new Q-setting table created, dated 28 July 1995.

Final intercomparison:

30 July 1995.
New N-tables and Reference Standard Lamp values defined for 50Q1, UQ2 and UQ8. Highest Difference against the standard for ADDSGQP observations in mu range 1.15 to 3.2 was 0.3% in total ozone.

No recommendations.
Instrument D062 - LKO Arosa, Switzerland

Original calibration data:


Initial calibration results: (Adjustments based on the results of Standard Lamp tests included)

27 July 1995

d_Na: -1.14 \ d_Nc: +0.08 \ d_Nd: +0.06 \ d_Nad: -1.2

The d_Nad value implies an average +1.7% error in calculated ozone value, Mu = 1 to 3, Total Ozone = 300 Dobson Units.

Work performed:

- Discharge lamp test series performed, and a new Q-setting table created, dated 26 July 1995.

Final intercomparison:

New N-tables and Reference Standard Lamp values defined for 62V, 62W, 62X, 62Y, 62Z UQ2 and UQ8. Highest Difference against the standard for ADDSGQP observations in mu range 1.15 to 3.2 was 0.2% in total ozone.

No recommendations.

Instrument D084 - Belsk, Poland

Original calibration data:

N-tables from 02 August 1990, LKO Arosa intercomparison. Reference Standard Lamp Values for lamps 84Q1 and 84Q2. Lamp tests results used in data processing at home station. Note: Photomultiplier tube replaced before shipping to LKO Arosa. Some mechanical damage had occurred to the S4 shutter. Instrument arrived without an operating amplifier.

Initial calibration results: (Adjustments based on the results of Standard Lamp tests included)

27 July 1995

d_Na: +0.64 \ d_Nc: -0.19 \ d_Nd: +0.86 \ d_Nad: -0.2

The d_Nad value implies an average +0.2% error in calculated ozone value, Mu = 1 to 3, Total Ozone = 300 Dobson Units.

Work performed:

- Optics cleaned, and gaskets replaced. Mirror M2 adjusted.
- Wiring and electronics repair and inspection performed. Amplifier was rebuilt.
- Discharge lamp test series performed, and a new Q-setting table created, dated 28 July 1995.
Final intercomparison:

30 July 1995. 
New N-tables and Reference Standard Lamp values defined for 84Q1, 85Q2, UQ2 and UQ8.
Highest Difference against the standard for ADDSGQP observations in mu range 1.15 to 3.2 was 0.6% in total ozone.

Recommendation:

There was a change in the CDDSGQP calibration. The data from this instrument on that observation should be examined in the time periods before and after this intercomparison for a shift.

Instrument D085 - l’Observatoire de Haute Provence, France

Original calibration data:

N-tables from 10 July 1995, intercomparison at l’Observatoire de Haute Provence.
Reference Standard Lamp Values for lamps 85Q1 and Q.
Lamp tests results used in data processing at home station.
Instrument is used in an automated Umkehr observing programme.

Initial calibration results: (Adjustments based on the results of Standard Lamp tests included)

27 July 1995

d_Na:-0.77  d_Nc:-0.23  d_Nd:-0.27  d_Nad:-0.5

The d_Nad value implies an average +0.7% error in calculated ozone value, Mu = 1 to 3,
Total Ozone = 300 Dobson Units.

Work performed:

- Optics cleaned, and gaskets replaced.
- Wedge Calibration performed, for historical record.
- Wiring and electronics repair and inspection performed.
- Discharge lamp test series performed, which verified existing Q-setting table.

Final intercomparison:

31 July 1995.
Existing calibration scale maintained.
Highest Difference against the standard for ADDSGQP observations in mu range 1.15 to 3.2 was 1.0% in total ozone.

No recommendations.

Instrument D092 - Denmark

Original calibration data:

N-tables from 02 August 1990, LKO Arosa Intercomparison.
Reference Standard Lamp Values for lamps Q, Q, Q, Q and Q.
Lamp tests results used in data processing at home station.
Initial calibration results: (Adjustments based on the results of Standard Lamp tests included)

25 July 1995

$d_{Na}: -0.65 \quad d_{Nc}: +0.21 \quad d_{Nd}: +0.07 \quad d_{Nad}: -0.7$

The $d_{Nad}$ value implies an average $+1.0\%$ error in calculated ozone value, $Mu = 1$ to $3$,
Total Ozone $= 300$ Dobson Units.

Work performed:

- Optics checked, and gaskets replaced.
- Wiring and electronics repair and inspection performed.
- Discharge lamp test series performed, which verified existing Q-setting table.
- Symmetry test was performed, with the results out of limits. This not evident in the
intercomparison results.

Final intercomparison:

30 July 1995.
Existing calibration maintained. The $d_{Nad}$ value was $-0.4$ unit.
Highest Difference against the standard for ADDSGQP observations in mu range $1.15$ to
$3.2$ was $0.6\%$ in total ozone.

No recommendations.

Instrument D101 - LKO Arosa Switzerland

Original calibration data:

N-tables from 02 August 1990, LKO Arosa Intercomparison.
Reference Standard Lamp Values for lamps A and B.
Lamp tests results used in data processing at home station.

Initial calibration results: (Adjustments based on the results of Standard Lamp tests included)

20 July 1995

$d_{Na}: -0.01 \quad d_{Nc}: +0.96 \quad d_{Nd}: +1.23 \quad d_{Nad}: -1.5$

The $d_{Nad}$ value implies an average $+2.1\%$ error in calculated ozone value, $Mu = 1$ to $3$,
Total Ozone $= 300$ Dobson Units.

Work performed:

- Wedge Calibration performed, for historical record.

Final intercomparison:

New N-tables and Reference Standard Lamp values defined for 101A, 101B, 101C, UQ2
and UQ8.
Highest Difference against the standard for ADDSGQP observations in mu range $1.15$ to
$3.2$ was $0.6\%$ in total ozone.

No recommendations.
Instrument D104 - Hohenpeissenberg, Germany

Original calibration data:

- Reference Standard Lamp Values for lamps A and B.
- Lamp tests results used in data processing at home station.

Initial calibration results: (Adjustments based on the results of Standard Lamp tests included)

19 July 1995

d_Na: -0.45 \quad d_Nc: +0.04 \quad d_Nd: +0.75 \quad d_Nad: -1.2

The d_Nad value implies an average +1.6% error in calculated ozone value, \( \mu = 1 \) to 3,
Total Ozone = 300 Dobson Units.

Work performed:

- Optics cleaned, and gaskets replaced. Discovered that top cover is warped. If the
  securing nuts are not tightened completely, there are light leaks.
- Wiring and electronics repair and inspection performed.
- Discharge lamp test series performed, which verify existing table.
- Symmetry test performed, the results are out of limits. This is not evident in the
  intercomparison results.

Final intercomparison:

30 July 1995.
New N-tables and Reference Standard Lamp values defined for 101A, 101B, 101C, UQ2
and UQ8.
Highest Difference against the standard for ADDSGQP observations in \( \mu \) range 1.15 to
3.2 was 0.7% in total ozone.

Recommendations:

The warped cover should repaired if possible. At that point, the optical alignment should
be fully verified, and comparison made to a standard.

Instrument D107 - Moscow, Russia

Original calibration data:

- N-tables from 05 August 1990, LKO Arosa intercomparison.
- Reference Standard Lamp Values for lamps Q, Q and Q.
- Lamp tests results not used in data processing at home station.

Initial calibration results:

27 July 1995

\[ d_{Na} = -0.86 \quad d_{Nc} = +0.32 \quad d_{Nd} = +0.18 \quad d_{Nad} = -1.0 \]

The \( d_{Nad} \) value implies an average +1.4% error in calculated ozone value, \( \mu = 1 \) to 3,
Total Ozone = 300 Dobson Units.
Work performed:

- Optics cleaned, and gaskets replaced.
- Wiring repair and inspection performed.
- Discharge lamp test series performed, which verified the existing Q-setting table.
- Symmetry test performed, the results are out of limits. This is not evident in the intercomparison results.

Final intercomparison:

30 July 1995.
New N-tables and Reference Standard Lamp values defined for 107Q1, 107Q2, 107Q4, UQ2 and UQ8.
Highest Difference against the standard for ADDSGQP observations in μ range 1.15 to 3.2 was 0.2% in total ozone.

No recommendations.

Instrument D110 - Budapest, Hungary

Original calibration data:

N-tables from 02 August 1990, LKO Arosa intercomparison.
Reference Standard Lamp Values for lamps.
Lamp tests results not used in data processing at home station.

Initial calibration results:

25 July 1995

d_Na: -1.45 \hspace{1cm} d_Nc: -0.62 \hspace{1cm} d_Nd: -1.16 \hspace{1cm} d_Nad: -0.3

The d_Nad value implies an average +0.5% error in calculated ozone value, Mu = 1 to 3,
Total Ozone = 300 Dobson Units.

Work performed:

- Optics cleaned, and gaskets replaced.
- Wiring repair and inspection performed.
- Discharge lamp test series performed, which verified the existing Q-setting table.

Final intercomparison:

30 July 1995.
New N-tables and Reference Standard Lamp values defined for 110/G18, 110/G20, 110/G25, UQ2 and UQ8.
Highest Difference against the standard for ADDSGQP observations in μ range 1.15 to 3.2 was 0.3% in total ozone.

No recommendations.

Instrument D116 - Tsukuba, Japan, Standard

Original calibration data:

N-tables from 29 June 1992
Reference Standard Lamp Values.
Lamp tests results used in data processing at home station.  
Note: Instrument is fully automated.

Initial calibration results: (Adjustments based on the results of Standard Lamp tests included)

25 July 1995

d_Na:-1.39  d_Nc:-1.3  d_Nd:-1.0  d_Nad:-0.4

The d_Nad value implies an average +0.6% error in calculated ozone value, Mu = 1 to 3,  
Total Ozone = 300 Dobson Units.

Work performed:

- Gaskets replaced.
- Discharge lamp test series performed, which verified the existing Q-setting table.
- Symmetry test performed, the results are out of limits. This is not evident in the intercomparison results.

Final intercomparison:

30 July 1995.
Existing calibration level maintained.
Highest Difference against the standard for ADDSGQP observations in mu range 1.15 to 3.2 was 0.9% in total ozone.

No recommendations.

Instrument D121 - Bucharest, Romania

Original calibration data:

N-tables from 05 August 1990, LKO Arosa intercomparison.  
Reference Standard Lamp Values for lamps 121Q1, 121Q2 and 121Q3.  
Lamp tests results not used in data processing at home station.  
Notes: Instrument was dropped in 1992, and the optics were out of alignment.

Initial calibration results:

19 July 1995
The instrument alignment was so far out that conventional intercomparison results are not useable. The data taken since the damage should be considered approximately:
1.5% too low in mu range 1.15 to 1.5
correct in mu range 1.5 to 2.0
3.75% too high for mu greater than 2.0.

Work performed:

- Optics cleaned, and gaskets replaced.
- Realignment of Mirrors and Prisms.
- Complete optical inspection for damage.
- New instrument temperature coefficient defined from Mercury tests during several days.
- Discharge lamp test series performed, and a Q-setting table was created on 29 July 1995.
- Slit alignment, separation, and parallelism checked, and found to be out of specification. See recommendation.

**Final intercomparison:**

31 July 1995.
New N-tables and Reference Standard Lamp values defined for 121Q1, 121Q2, 121Q3, UQ2 and UQ8.
Highest Difference against the standard for ADDSGQP observations in mu range 1.15 to 3.2 was 1.2% in total ozone.

**Recommendation:**

The instrument is to be operated for AD type observations only, in the Mu Range 2.5 and lower.

The measurements in this range, with these wavelengths, was shown to be within 1% of the Standard at a measured ozone value of 300 Dobson units. Measured values of substantially ozone larger than this should be made at lower mu values.

The measurement of the instruments slits showed that the slits are NOT parallel, and are wider than specified for the Dobson instrument. This means that at mu values larger than 2.5, the instrument is effectively operating on incorrect wavelengths. Large Stratospheric ozone amount will amplify this problem at large mu.

A further recommendation that the instrument have the slits reset to the correct values, in an optical laboratory, by experts familiar with the technique. At this point, the wedge calibration would have to be verified, and the calibration level defined by comparison with a Standard Dobson Instrument.

The instrument can not be used for Umkehr observations before re-adjustment of the slits and entire optical alignment and final comparison with a Standard instrument.

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ANNEX C
DEFINITIONS

A, C and D Wavelength Pairs: The Dobson instrument measures the difference between the intensity of selected wavelengths in the range of 3000 to 3400 Ångstroms. Certain pairs were chosen to measure ozone. These are called the A, C and D pairs. There was a B, but it is rarely used due to interference by other atmospheric absorbers.

Intercomparison: Series of simultaneous measurements made by several Dobson instruments, one of which is a standard. Usually, the time period is chosen so the measurements are made over a wide range of Mu.

Standard Lamp Test: A measurement of the N-value of a specific Quartz-Halogen (normally) bulb for the standard wavelength pairs. These bulbs are usually specific to an instrument. The result is used as a measure of the drift of the instrument’s specific ETC.

Q-setting Table: The table used to set the instrument’s wavelength controls to a wavelength pair. The setting is dependent on instrument temperature. The controls are rotatable quartz plates, hence the name Q-setting.

Discharge lamp test series: A series of measurements on various spectral lines from discharge lamps to calibrate the instrument’s wavelength controls.

Mercury Test: A test to determine the correctness of the Q-setting table with respect to a single spectral line of mercury. Normally performed routinely to verify the optical alignment of the primary (right hand side) optics to the slit S2.

Symmetry Test: A series of tests on two spectral lines of mercury to verify the spectral dispersion, and the right to left side alignment of the optics.

Wedge Calibration: The procedure used to determine the density of the optical wedge used in the instrument.

Mu(µ): Normalized optical path length through the atmosphere of radiation at the wavelengths used by the Dobson instrument. Calculated from the solar zenith angle, Mu ranges from 1.0 (sun overhead) to greater than 12.0 (sun on the horizon).

G-table: Table relating the position of the optical wedge, defined by degrees of arc on the R-dial, to relative attenuation. G-tables are defined for each A, C, and D wavelength pair by the Wedge Calibration.

N-table: A G-table converted by the addition of the instrument’s extra-terrestrial constant (ETC) to all the entries. The ETC can be determined by lamps with a known N-value, direct intercomparison with a standard Dobson instrument, or by a Langley plot method.

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