Site Audit at the JRC, 15 – 16 April 2002

Formal Statement

This audit was the fourth of some one dozen site visits that will be conducted within the European project EDUCE by project's Scientific Secretary. The Scientific Secretary is responsible for drafting a confidential summary (which is sent to the site operator and the EDUCE project coordinator) and this formal report (which is published at the project web pages). The wording of both the summary and the full report is agreed with the site operator. The full terms and scope of the audit are described within the audit definition, which may be retrieved from the project website at http://www.muk.uni-hannover.de/EDUCE.

Overview

The Joint Research Centre (JRC) is the European Union's scientific and technical research laboratory and an integral part of the European Commission. The JRC provides scientific advice and technical know-how to support EU policies and functions as a reference centre of science and technology for the Union.

The UV group at the JRC functions within the Institute for Environment and Sustainability (IES). The mission of the IES is to provide scientific and technical support to EU strategies for the protection of the environment and sustainable development.

Measurements of UV irradiance have been made at the Joint Research Centre (JRC) in Ispra (45.81º N, 8.63º S, 214 m a.m.s.l.), Italy, since 1991, forming one of the longest continuous datasets in Europe.

In addition to obtaining a reliable, long-term data set of spectral UV measurements, the UV group at the JRC aims to present itself as a reference centre for UVR measurements. In the spring of 2001, with a letter of support from the WMO, the European Reference Centre for Ultraviolet Radiation measurements (ECUV) was created in response to a number of requests by the international UVR community.

The goals of the ECUV are presently

- To maintain a suite of well-characterised solar UV spectroradiometers that provide accurate spectral measurements of global solar irradiance with known uncertainties
- To develop and maintain a calibration facility for the characterisation of solar UV instruments
- To administer auxiliary instruments necessary for quantification of parameters influencing solar UV radiation (cloud, ozone, aerosol optical depth, etc.).
- To help verify the quality of solar UV measurements for interested institutions by means of a travelling spectroradiometer. (The validation of this instrument will be obtained through the joint European project QASUME).

In marketing themselves as a European reference centre, the UV group at the JRC aim to provide some of the highest quality data in Europe.

The JRC dataset begins in 1991 with commissioning of a single Brewer (instrument #066). Initially, the emphasis was on measurements of ozone column depth, and only a few spectral measurements were made each day about noon, with calibrations performed using a set of 50 W lamps. In 1994 three broadband instruments were added to the site and the number of spectral measurements was increased to 30 or 40 a day, with a more regular calibration regime. In 1997, regular measurements of the aerosol optical depth became possible with the purchase of a Cimel sunphotometer (operated within the activities of AERONET). Regular calibrations using a 1 kW lamp began in 2000. A double Brewer was added (and included in the regular calibration schedule) in 2001. Two Bentham DM150 spectroradiometers also appeared at this time, to be used primarily for laboratory work and as a travelling instrument.

The present spectral measurement regime is as follows:

Instrument	Wavelength range	Wavelength step	Bandwidth	Measurement frequency
Br. #066 [single]	290 – 325 nm	0.5 nm	0.5 nm	~ 5/hour
Br. #163 [double]	287 – 363 nm	0.5 nm	0.5 nm	~ 4/hour
Bentham DM150	285 – 500 nm	0.2 nm	0.8 nm	occasional

Measurements are made from sunrise to sunset. The single Brewer data represents the average of two scans, performed in opposite directions within about 5 minutes.

Data are used for investigating the correlation between ozone, aerosol optical depths and UV irradiance, as well as for trend analysis and the calculation of photolysis rates. Spectral data are submitted to both the European UV Database and the World Ozone and UV Data Centre.

In addition to the spectroradiometers, two pyranometers, two UV-B meters and one UV-A meter take measurements every minute (before 2002, measurements were made each second, returning the average value once a minute).

The horizon at the Ispra site lies mostly below 5 degrees altitude, except for some treetops to the North-East. The local surroundings are flat, with a mix of lake, urban, woodland and agricultural cover. Planes lie to the South, while the Alps sit at 20 to 40 km distance in the North and North-West.

There is one full-time staff member, who works with the UV instruments and data. Approximately 5 days a week are dedicated to routine maintenance, calibration, data collection and data analysis.

The general operation appears organised and proficient. The routine calibration, measurement and data analysis procedures are clearly carried out according to well-practiced routines. The UV group has access to excellent resources and benefits significantly from the infrastructure and facilities available at the JRC. The group also profits from the superior knowledge and skills of the personnel. One member of the group has nearly a decade of experience in UV radiation measurements.

Those involved in the measurement of UV irradiance clearly possess a perceptive understanding of the operation, calibration and characterisation of the instruments. Detailed and careful attention is paid to all aspects of the measurement and analysis.

The single Brewer has proven to be exceptionally stable in operation, in both the irradiance and wavelength scale. Over the past two years, the sensitivity of the instrument has apparently changed by less than ±1.5%, while the wavelength acquisition is stable to within ±20 pm over the same period. The routine instrument operation and data analysis is the responsibility of a single person with considerable experience. Together, these points imply a significant level of repeatability and reproducibility.

The newer double Brewer is expected to prove equally reliable, although the shorter lifetime of this instrument means that this is not yet demonstrated. Operating two spectroradiometers side-by-side permits regular inter-comparisons, which are a powerful tool for quality control and the analysis of anomalous data. Continuation of UV measurements at the JRC site is secure for the foreseeable future.

The uncertainties in measured values of spectral UV irradiance have been estimated (and presented at the 2001 EGS meeting in Nice). Taking into account the uncertainties in lamp irradiance, calibration reproducibility, the correction of cosine errors, temperature dependence, etc., and assuming a systematic distribution, the JRC data are believed to have an absolute 2-sigma accuracy in the region of ± 8%. An estimate of the uncertainty budget for the single Brewer has been made, based loosely on the structure described in Bernhard and Seckmeyer (1999). This would benefit greatly from being documented and published.

The darkroom is well equipped. Despite a lack of regular 1 kW calibrations over the complete dataset of spectral UV irradiance measurements, an on-going analysis and re-assessment of existing data suggest that the historical changes in the instrument's sensitivity can be estimated within quantified uncertainties, and that the extended data record is credible.

Bearing in mind the high standards that the UV group at the JRC sets itself, the routine operation at JRC would benefit from additional documentation. Furthermore, while there is no reason to believe that the JRC irradiance data are subject to significant error, confidence in the quality of the data set could be increased appreciably by the application of slightly more rigorous practices in the use of calibration lamps. The calibration procedures are not currently based around the use of three 1 kW lamps supplied by a national standards laboratory, with systematic procedures for checks and corrections for lamp drift.

Some of the facilities utilised and practices followed at JRC are exemplary. In particular, the combination of an experienced operator, a very stable instrument, and a potent variety of quality-control tools gives rise to a high level of confidence in the reliability of the dataset.

Plans for future development include the creation of a facility for the characterisation and calibration of filter radiometers. A monochromatic source will allow the determination of the spectral sensitivity of the instrument in the laboratory, while the absolute calibration will be obtained through simultaneous measurements with the reference spectroradiometers. The ECUV intend to purchase a set of three PTB-traceable FEL lamps.

Figures

Figure 1. Single (back) and Double (front) Brewer spectroradiometer, both pointing East

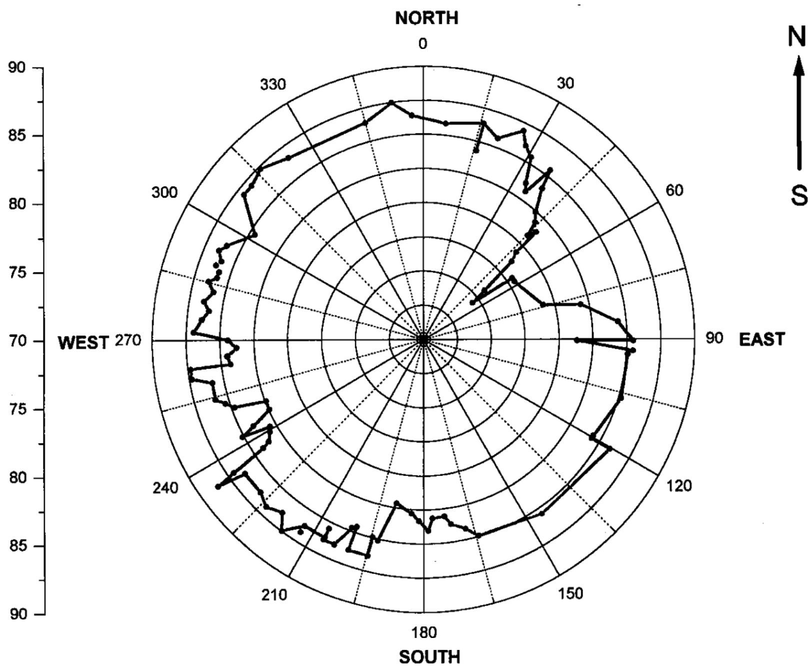

Figure 2. Horizon at JRC site (the radial grid gives steps of 2.5º in altitude, with an altitude of 0º at the perimeter and 20º in the centre)

Summary

- The measuring site is representative of the local environment.

- The measurements made at the site are representative of the local conditions.

- There are adequate records relating to calibration history, instrument characterisation and data processing. These records are maintained in laboratory notebooks, or in the form of electronic files and graphs (particularly Matlab documents). While a required file can generally be located without too much difficulty, the exact location, content and significance of the files is known only to the principal scientist. The provision of thorough written protocols for instrument operation, calibration and data processing, and the keeping of detailed written records for the instruments' characterisation, sensitivity and uncertainty analysis, would offer significant advantages for the purposes of quality assurance and clarity.

- All procedures relating to data measurement and analysis are repeatable and reproducible and performed to a high standard. Calibration and data collection procedures would benefit from more rigorous documentation.

- The facilities and resources available are sufficient for the site objectives to be fulfilled. The instrumentation and experience available to the European Reference Centre for UV Radiation measurements at the JRC permits measurements to be made to a consistently high standard. For the planned future activities of the group more manpower will probably be needed, however.

- The analysis of relative uncertainty in the measurements of spectral irradiance by the single Brewer is defendable. This analysis should be published or made publicly available, if possible. Having access to two spectroradiometers for routine intercomparisons of spectral measurements is a powerful tool for quality control and assessment. Uncertainties have also been estimated for weighted irradiance and daily doses.

- The measurement and collection of data are carried out diligently and to a high standard. The claims made to the quality of the data appear to be justified. Despite the lack of detailed written protocols and detailed documentation on the instrument characterisation, the on-going analysis and re-assessment of existing data suggest that the extended data record is credible. While the calibration procedures appear to be scrupulous and performed with care, it is clear that some improvements could be made in the area of lamp husbandry. A more rigorous determination of lamp drift should be made. This point is already being considered.

Graded results

	.1	.2	.3	.4	.5	.6	.7	.8	.9	.10	.11	.12	.13	.14
1		A	C											
2	B	B	B											
3	C	B	A	B	B	B	B							
4	C	A	B	B	A	B	B							
5	C	B	C	C	B	B	B	C	B	A	B	A	A	B
6	C	B	B	B	B	A								
7	C	B	B	B	B	B	B	B	B					
8	C	A	A	B	B	C								

A	Exemplary
B	Satisfactory
C	Could be improved
D	Should be improved
	Not gradeable
	Not assessed

1. Resources and mission statement

1.1. In creating a European reference centre for measurements of UVR, the UV group at the JRC aim to provide some of the highest quality data and to maintain extremely dependable and well-characterised instrumentation. The main goals of the ECUV are:

- To maintain a suite of well-characterised solar UV spectroradiometers that provide accurate spectral measurements of global solar irradiance with known uncertainties
- To develop and maintain a calibration facility for the characterisation of solar UV instruments
- To administer auxiliary instruments necessary for quantification of parameters influencing solar UV radiation (cloud, ozone, aerosol optical depth, etc.).
- To help verify the quality of solar UV measurements for interested institutions by means of a travelling spectroradiometer. (The validation of this instrument will be obtained through the joint European project QASUME).

1.2. ECUV maintains four spectroradiometers: a single Brewer, a double Brewer and two Bentham DM150s. In addition to the spectral instruments, there are a number of broadband filter radiometers (2 x UV-B, 1 x UV-A, 2 x pyranometer) and a Cimel sunphotometer. The broadband instruments are calibrated. The capacity for simultaneous broadband and spectral measurements by more than one instrument provides a powerful tool for quality management and diagnostics.

1.3. One member of staff is involved with the regular measurement and analysis of UV irradiance. The group would benefit from more manpower, particularly for the tasks of documentation and setting up new calibration facilities.

2. Location

2.1. Coordinates for longitude and latitude are available from GPS readings; the altitude is taken from a map reading.

2.2. The horizon has been measured using a theodolite. Most of the horizon lies at large distance and below 5º, except for some nearby trees in the North-East. The effect of the horizon on measurements of global irradiance is estimated to be about 1%.

2.3. The measuring site is representative of the local environment. Local surroundings are flat to the South, with a mix of urban, woodland, lake and agricultural cover at scales of 1 to 10 km and beyond. The Alps lie to the North, at a distance of 20 km and more. A large industrial area (the Po Valley with the city of Milan) lies at about 50 km to the South.

3. Operational matters

3.1. There are no written protocols or standard documentation for normal site operation. At present, standard procedures are carried out by one individual and are carefully followed, but for quality assurance and as a guarantee for future consistency, written protocols are recommended.

3.2. Sufficient manpower is available for the routine maintenance, calibration, data collection and data analysis tasks; The equivalent of one permanent post is dedicated to these tasks. More staff will be needed for the planned expansion. Maintenance, calibration and data analysis typically require about 5%, 10% and 70% of available time, respectively.

3.3. All staff concerned with operation of instruments and data analysis are highly qualified, with many years experience.

3.4. Staff changes are infrequent. The last change occurred in 2000.

3.5. New staff work alongside existing personnel.

3.6. New calibration procedures were introduced in 2000. The double Brewer was included in the normal calibration schedule in 2001.

3.7. The adoption of the WMO/GAW guidelines on site quality control is planned.

4. Instrumentation

4.1. Details of the instrument characteristics are documented in the form of graphical plots stored as electronic files. The provision of thorough written records of the instruments' characterisation, together with protocols for standard operation, calibration and data processing procedures, would offer significant advantages for quality assurance and future operations.

4.2. The spectroradiometers, sun photometer and broadband meters used for continuous monitoring are adequate for the fulfilment of the JRC objectives. Access to a second spectroradiometer provides the opportunity for regular simultaneous measurements of spectral irradiance. This is a powerful QC tool, helping to confirm the reliability of a dataset, including the application of error corrections, and simplifying the investigation of unexplained behaviour. Access to calibrated broadband measurements from multiple instruments also improves quality control.

4.3. The spectral instruments are characterised as required.

4.4. The cosine response of the single Brewer's diffuser is measured in 4 planes. The error introduced by a non-perfect response is estimated to be in the region of 6% (and corrected for). The Brewer follows the Sun, so the azimuthal dependence of the angular response is less important. The double Brewer uses a cosine-corrected diffuser. Cosine errors for this instrument are estimated to be below 0.5%.

4.5. The slit function is regularly measured using a set of mercury, cadmium and zinc spectral discharge lamps, giving good knowledge of the wavelength dependence of the slit function. The basic properties of the slit function are also verified indirectly through the routine application of the SHICrivm algorithm. The slit function has also been measured with a HeCd laser at 325 nm for the purpose of investigating near- and far-field stray light.

4.6. Instruments are maintained as and when required.

4.7. The broadband instruments were last calibrated in 2001. The planned schedule is for a yearly calibration.

5. Calibrations

5.1. Histories of instrument calibrations are recorded in lab book summaries. There is also automatic software logging of lamp number and burn time, etc. Some written protocol for conducting calibrations including, for example, a list of pre-requisites, an introductory description of the calibration, details of the apparatus and software used, and parameters to be recorded, would be beneficial for quality assurance.

5.2. Considerable attention has been paid to possible errors introduced by the effects of reflected light and temperature changes within the shunt. The power supply gives constant current with real-time adjustment. The voltage drop across the lamp is also monitored. For the Bentham calibration, there is presently some uncertainty over the definition of the diffuser's reference surface (placing the fiducial plane at half the height of the diffuser's dome introduces an uncertainty of ± 1.25 mm). The distance from lamp to diffuser is measured using a collapsible metal tape. The distance from the lamp to diffuser is measured with a metal rod in the case of the Brewers. The single Brewer has a flat diffuser, so the reference plane is unambiguous.

5.3. The certificate of one voltmeter is one year out of date, but systematic comparisons with newer instruments show good agreement.

5.4. A variety of lamps are used, with irradiance scales traceable to PTB and NIST.

5.5. The calibration lamps used at the site fall slightly short of the ideal. There should also be some periodic and systematic measurement of lamp drift. Detailed analysis of existing lamp measurements and lamp intercomparisons suggest that there is no problem. Plans are already afoot to install a system of 3 reference lamps (one of which is traceable to a National Standards Laboratory) and 3 working lamps. New calibrated lamps are collected from the supplier by hand, and not received through the post.

5.6. Available lamps include 7 x FEL (6 from Gigahertz Optic; 1 from Eppley); 9 x DXW from Optronic, 5 x DXW from Osram, and 1 x DXW from Gigahertz Optic (1 calibrated; 8 seasoned) and 1 Gigahertz optic with vertical alignment. The secondaries were calibrated at the end of 1999, and all have less than 8 hours burn time.

5.7. All used lamps agree to within ± 1.2%.

5.8. There are no procedures in place for the routine and systematic determination of lamp drift, but on existing measurements there is no evidence to suggest that the drift is greater than 1%.

5.9. 1 kW calibrations are typically performed 6 times a year per instrument, or more frequently when there is significant drift in the instrument's sensitivity.

5.10. Over a two-year period in 2000/2001, the single Brewer was stable to within ± 1.5%.

5.11. The calibration procedures appear to be scrupulous and performed with care.

5.12. The observed stability of the single Brewer over a period of years attests to the level of repeatability and consistency in the calibration regime.

5.13. Every scan begins with the measurement of a Hg lamp. A mercury lamp is also used in the dark room. Errors in the wavelength scale rarely exceed ±20 pm.

6. Measurement regime

6.1. The operation would benefit from a slightly more rigorous documentation of all aspects of the routine and exceptional measurement regime.
6.2. The standard operating procedures ensure sufficient data are collected in a reliable and repeatable manner.
6.3. Global spectral irradiance data are recorded continuously every day from before sunrise until after sunset. These data are supplemented with pyranometer and broadband UV measurements. Information on ozone column depth and aerosol optical depth is also available from direct-beam measurements and a sun photometer.
6.4. Global spectral irradiance is recorded from 290 to 325 nm in steps of 0.5 nm (FWHM 0.5 nm). The double Brewer scans from 287 to 363 nm, also in steps of 0.5 nm (FWHM 0.5 nm).
6.5. Routine data backups and cleaning do not interrupt measurements. For calibrations, a break of 2 or 3 days is needed. Scans of internal lamps occasionally introduce a slight extra delay between spectra.
6.6. All aspects of the routine measurement regime are demonstrably repeatable.

7. Data Processing

7.1. The routine data processing is applied automatically according to computer algorithms. The provision of thorough written protocols for data processing, and the keeping of written records for the characterisation and estimation of measurement errors and uncertainties, would offer significant advantages for quality assurance and future operations.
7.2. The present processing algorithm has been fixed since 2001, when the complete data set was re-analysed. Any adaptations are applied retrospectively to the entire data set. Daily plots compare broadband measurements with integrated spectral data.
7.3. For all instruments, wavelength errors are routinely analysed using the SHICrivm algorithm. Temperature-induced errors are determined. The influence of the local horizon on measurements is estimated to be approximately 1%. For the single Brewer, stray light (dependent on ozone column and SZA) is estimated to be ±5% at 300 nm, and unimportant at 305 nm. Non-linearity in the photomultiplier is significant for the Brewers and corrected within the standard data processing. The wavelength error is found to be less than ± 40 pm for 99% of all spectra, and less than ± 20 pm for more than 90% of all spectra.
7.4. Cosine errors are routinely corrected for, making use of the calibrated direct-beam measurements. A correction is made for all other known errors. There is no systematic correction for lamp-drift errors.
7.5. Broadband measurements are used in routine quality control.
7.6. An estimate of the uncertainty budget for the single Brewer has been made, based loosely on the structure described in Bernhard and Seckmeyer (1999). The analysis was presented at the 2001 EGS in Nice. The 2-sigma measurement uncertainty for the single Brewer (neglecting stray light) is estimated to be ± 3% between 305 nm and 325 nm, relative to the absolute irradiance scale. Between 300 nm and 305 nm, there may be an additional 10% uncertainty arising from the effects of stray light. A comparison with data from the double Brewer shows agreement to within ± 10% at 300 nm. The uncertainties associated with measurements from the double Brewer have not yet been calculated completely, but the double Brewer has a cosine-corrected

diffuser, negligible stray light and probably an insignificant temperature dependence.

7.7. Uncertainties in the erythemal daily dose are estimated to be ± 5%, including the effects of stray light.

7.8. Any changes to the irradiance scale or standard error-correction procedures are applied retrospectively to the entire data set.

7.9. Data are stored on a central server. Manual backups are made to CDROM and several local pcs. Raw and processed data are also archived at the WOUDC.

8. Quality management

8.1. The provision of more thorough records and documentation of quality management procedures would offer significant advantages for quality assurance and future operations. For example, summaries of various variables, such as the magnitude of any error in the wavelength scale, could be prepared and details of any problems or exceptional circumstances could be recorded.

8.2. Access to a second spectroradiometer provides the opportunity for regular simultaneous measurements of spectral irradiance. This is a powerful QC tool, helping to confirm the reliability of a dataset, including the application of error corrections, and simplifying the investigation of unexplained behaviour. Additionally, integrated spectral data are compared with output from the calibrated broadband instruments.

8.3. The SHICrivm algorithm is used. A real-time comparison of various data is presented graphically on externally viewable web pages (http://www.ecuv.jrc.it), alongside other data such as daily ozone and erythemal dose values. This is a superb feature for quality assurance.

8.4. The WMO/GAW guidelines for site quality control have been read and applied where reasonable.

8.5. A large intercomparison took place at Ispra in 1995 (at the time, the largest intercomparison of spectroradiometers to date). A new intercomparison of the double Brewer with other instruments is planned at Ispra for May 2002, as part of the QASUME project. The Bentham DM150 is a travelling spectroradiometer, and will visit several sites.

8.6. Any changes to the irradiance scale are applied retrospectively to the entire data set. Data versions are labelled by way of a Windows time stamp on the data file. Older data versions can be re-created with some trouble, by reference to the programs used in the routine data processing. Since older data versions are maintained at the EUVDB and WOUDC and could conceivably be used in publications, it would be advisable to document and record any changes to the data processing routines.

JRC comments

<u>a defense of the calibration procedures applied at ECUV:</u>

1kW calibration started at ECUV in the beginning of 2000. Before that time, only one 1kW calibration was performed in 1999 by a travelling calibration setup (David Disterhoft). The calibrations were initiated using 1 calibrated lamp and two seasoned lamps of the DXW type. The lamp set was used only for calibrations of the single

brewer every second month until the summer of 2001. At this stage the lamps had accumulated burn-times of less than 4 hours each. At this time, several additional seasoned lamps together with a second calibrated lamp were bought.
As of the summer of 2001, each calibration was performed with at least 3 lamps, but occasionally with many more. Furthermore the lamps were interchanged from one calibration to the next, to:

1) reduce burntime of each individual lamp.
2) Slowly outsource the original set of three lamps so as to keep them for long term traceability.
3) Check for lamp drift by having lamps with different burn times.
4) Discover unstable lamps by regularly confronting them to a large set of lamps over a long time span.
5) Have a large set of regularly intercalibrated lamps (secondary standards).

Therefore the claims made in the audit about not sufficient lamps, unorthodox practices, not checking for lamp drift, etc… are only true for the initial period between 2000 and 2001, when the calibration activity was initiated. Since the burntimes of the lamps within this period were less than 4 Hours for each lamp, lamp drift was probably negligible based in part on lamp voltage monitoring data during this time period as well as on experience gained using similar DXW type lamps at other Laboratories (AES, Toronto, Canada).

After the summer of 2001, enough lamps were available to check for lamp drift, to outsource unstable lamps, provide a set of lamps which could form the basis for assuring a long term data set.

Future Plans are to trace all lamps, including the DXW type lamps used for the Brewer spectrophotometers to a set of FEL lamps maintained at ECUV. The reaon is that FEL lamps are the preferred lamp choice of the standards laboratories, and also represent the standard calibration lamp type. Recently (April 2002), all FEL and DXW lamps were measured within a two day period and related to each other with a transfer accuracy of ±1% in the range 250 to 500nm.

The total pool of 1kW lamps are :
-7 FEL, two with certificates, the other seasoned.
-15 DXW, three of which with certificates, the other seasoned.

The Irradiance scale of ECUV is traceable to NIST and PTB, and up to now (May 2002), the NIST irradiance scale based on the DXW type lamp with s.n. S-974 is used. In the foreseeable future, the irradiance scale will be referenced to the PTB, using for the moment the FEL type lamp with s.n. F330.

Scarce written Documentation:

Prior to 2000, the procedures followed for the calibration, maintenance and data analysis of the single Brewer #066 were fully within the standard procedures as described in the Brewer user manuals. The programs used for all these tasks were the standard procedures available within the Brewer community, and as such as transparent and easy to reproduce as is possible.

As of 2000, the post-processing of the acquired data was modifies, as more and more features were taken into account, such as temperature, cosine error, deadtime, lamp drifts, etc… However the raw data format was never changed. This is important because this guaranties that anyone can take any data obtained with the instrument, and perform the analysis using the standard set of routines.

Therefore:

1) There exists written documentation, identical for all the Brewer community, on the raw data format of the Brewer spectrophotometer.
2) Standard data processing can be done on all the data of ECUV using well known and well documented procedures which are identical within the whole Brewer community.
3) Special data treatment is performed at ECUV which reduces the uncertainties of the resulting data set. These procedures are documented in part in published and refereed publications, oral presentations. The actual processing is done by a set of software routines in a high level language, easily understandable by a scientist experienced in spectrometry. These software routines are grouped hierarchically, so that at the top level, all that is required for the processing of any data set is the start date, and date, and instrument type. (i.e the actual call to recalculate the whole data set of br#066 would be:

   isprauv('1-jan-1991','4-5-2002',66)

4) The raw data as well as the processed data is stored centrally in logically structured directories accessible over the local intranet by all authorized computers. Logical variables within the data processing system (Matlab) are setup to provide transparent access to the data files without an actual knowledge of the physical location of an individual file.

To teach someone to perform the actual data processing and the location of the data files would require a very short time.

Someone needing to understand the fine details of what actually happens could trace the software routines which are written in an intuitive high level language.

A tangible proof of the accessibility of the data to a person outside of the routine operator(s) was obtained in 2001 during a two month visit of a student who was able to work constructively with the data within very short time (i.e. including the learning of the data processing software).