# Quality Assurance Project Plan
# for
# Quality Assurance and Maintenance of the Ultraviolet Monitoring Program

## Contract Number: 68-D-04-001

submitted by
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# 1 PROJECT PLANNING AND ORGANIZATION

## *1.1 Introduction*

Under the direction of the U.S. Environmental Protection Agency (EPA), Office of Research and Development (ORD), the Ultraviolet Research Monitoring Program is operating a nationwide Ultraviolet (UV) monitoring system in contract with the University of Georgia (UGA) at Athens, GA, and with the National Park Service (NPS) via an Interagency agreement. The network employs the Brewer spectrophotometer, manufactured by Kipp and Zonen Instruments in Saskatoon, Canada. These instruments measure full sky UV radiation, total column ozone, total column sulfur dioxide, total column nitric oxide, and are performing Umkehr measurements from which the stratospheric ozone profile can be derived. The final clients for the data will be the ORD, NPS, the National Weather Service (NWS), EPA's Office of Air and Radiation (OAR), and scientists around the world doing ecological and health effects assessment work and atmospheric radiation research.

## *1.2 Background*

At present the National UV Monitoring Center (NUVMC) at UGA is gathering the data from these sites on a daily basis and providing quality assurance and quality control to ensure accurate and timely data, which are made available to the public. UGA has provided the means by which each of the Brewer spectrophotometers have been fully characterized for slit width, wavelength dependence for stray light, and cosine response function of the input optics. The NUVMC has standard FEL lamps, calibrated in the vertical burning orientation by the National Institutes of Standards and Technology (NIST). These secondary standards have been transferred to uncalibrated FEL lamps burning in the horizontal orientation to make them accessible to the Brewer's input optics. Currently all Brewers in the network are calibrated against lamps traceable to NIST standards.

The Brewer network is comprised of 21 sites located in National Parks and urban areas around the U.S. The Brewer set-up includes a computer to log the collected data and a telephone hook-up by which data can be retrieved.

## *1.3 Project Scope and Work Objective*

The NUVMC has been, and will continue to deal with all aspects of the daily data gathering from the network in order to obtain, in a timely manner, a high capture rate of quality assured data. The NUVMC is providing regular communication, guidance and support to the site operators concerning daily operations, calibrations, and maintenance. On a daily basis, data is retrieved by telephone from each site and stored in a central database. Potential problems with Brewer operations are identified and remedial actions taken. The NUVMC has developed efficient and effective methods for dealing with operator training, equipment problems, and will continue to provide consumables and spare parts in order to keep the network in operation and producing high quality data.

The work objectives of this project consist of the following activities:

1. Ninety percent of all potential UV and ozone data shall be recovered from each site per year.
2. All of the UV and erythemally weighted UV data shall be traceable to NIST standard

lamps and be within 3 percent of the standards for wavelengths over 300 nanometers.

3. One hundred percent of the recovered UV data shall be processed utilizing the latest version of the response file within 60 days after the backup tapes have been received from the sites.
4. One hundred percent of the UV data will be QA/QC'd within 60 days after the backup tapes have been received from the sites. Site operators will perform the data backups in quarterly intervals, usually between the 1st and 10th of January, April, July, and October. Instructions on how to perform a tape backup are summarized in Appendix D.

The NUVMC provides the necessary personnel, facilities, supplies and spare parts, except the site operators. The NUVMC performs all activities necessary for, or incidental to, providing quality control, field support, data reduction, and data archiving in order to operate and maintain a UV monitoring network consisting of 21 Brewer spectrophotometers. The final output from the NUVMC shall be a complete data set from the network that has passed the quality assurance/quality control of the Quality Assurance Project Plan.

### *1.4 Project Description*

(1) Data Recovery

Provided that the Brewer instruments do not develop operational problems, which necessitate major repairs and/or would require off site transportation, data recovery from a Brewer instrument should run continuously during the course of the year. The NUVMC communicates with the Brewers remotely through the use of the communication program *CLOSE-UP* that operates every day around midnight (local time at Athens, Ga). The program connects to each Brewer site and downloads all Brewer raw data files generated on the previous day. If any part of the the automatic communication fails, the NUVMC staff downloads the missing files the following morning. Each of the Brewer site operators are instructed to perform a data backup of the Brewer computer every three months and return the data to the NUVMC. Once NUMVC staff has received the backup tapes, the previously downloaded data will be compared to the data from the backup tape in order to ensure the accuracy of the downloaded data set.

(2) Traceability

To ensure that UV data are traceable to NIST standard lamps, the NUVMC performs annual calibrations (see Appendix A for the calibration SOP). The NIST-calibrated standard FEL lamp radiance is transferred to field FEL lamps burning in the horizontal orientation (Appendix B). These field FEL lamps are recalibrated against the standard FEL lamp periodically to ensure continued accuracy of the Brewer calibrations. In addition, the operators are instructed to perform bi-weekly calibrations using the 50W lamps (Appendix D).

(3) UV processing

After each annual calibration a new response file is generated and labeled RESdddyy.###, where ddd is day of year, yy is the year and ### is the Brewer number. The latest response file is implemented into the operational schedule for the operational derivation of the erythemal UV radiation by updating the operational status file OP_ST.### in the C:\bdata\### directory on the Brewer site computer. Refer to the *Brewer Spectrophotometer Operator's*

*Manual* for more details.

It should be pointed out that the latest version of the UV response file will not ensure that the absolute irradiance is traceable to NIST standard lamps at all times. The sensitivity of the instrument is dependent on time and temperature. Absolute irradiance measurements taken in between calibrations need to be corrected.

(4) Quality Control

The QA/QC cannot take into account changes in the instrument response until the instrument has been re-calibrated. Thus the data available within 60 days after the tape backups will not necessarily have traceability within 3% of NIST standard lamps. Correction for instrument drifts should therefore be applied after re-calibration of the instrument performed approximately once annually. These corrections have been tested and implemented. They are discussed in more detail later in this document.

To ensure the quality of the UV data, the results of the 50-Watt lamp scans (XL scans) are monitored. Although the lamp output of the 50W lamps is not stable enough to perform absolute calibrations, a relative change in sensitivity can be surveyed. A sudden drop in normalized sensitivity would suggest a problem with the Brewer (e.g. zenith prism alignment, or other) and would lead to further troubleshooting procedures followed by remedial actions. The monitoring of the 50-Watt lamp scans is part of the ongoing quality control. Summary graphs are included in the quarterly reports (QRdddyy.txt).

The trace gas measurements are dependent on the intensity ratios of four discrete wavelengths. Regular daily scans of the internal lamp allow the monitoring of the ratios of intensity for the determination of ozone, $SO_2$ and $NO_2$. These ratios (R5 and R6 when the Brewer is in ozone mode) and R6 (for $NO_2$ mode) can indicate alignment problems at the Brewer that would result in wavelength dependent sensitivity changes. It is also possible that the ratios drift slowly over time. A drift in R5 and/or R6 values requires an adjustment of the constants that are used in the trace gas algorithm (refer to the *Brewer Spectrophotometer Acceptance Manual, Appendix B: Preliminary Data Reduction* for further details). The monitoring of the R5 and R6 values is part of the ongoing quality control of the Brewer data. We perform diagnostic analysis of such data on a weekly basis. Summary graphs are included in the quarterly report (QRdddyy.txt).

Various diagnostic checks are performed daily by the Brewers and the data is logged to a file corresponding to the specific diagnostic. These files are termed "average" or "avg" files and are appended to on a daily basis as the instrument collects data in the field. The diagnostics which will be used are the standard lamp intensity values (SL), the shutter motor timing values (SH), the spectrometer shutter run/stop ratios (RS), the photomultiplier tube dead-times (DT), the ozone calculating ratios (R6) and the micrometer position (MI). Due to an interdependency of some of the diagnostics, the order in which they are analyzed is critical. Specifically the SH should be optimized before the RS or DT can be properly diagnosed. Adjustments made to the instrument to correct the SH, RS or DT diagnostics will likely cause changes to the SL and R6 values. If the micrometer system is not working properly as evidenced by the MI results, there will be adverse affects to all of the diagnostics.

The raw data files from each Brewer instrument are downloaded each day. At the end of each quarter, we ensure that the data files have been transferred completely. Since there may be communication problems with the Brewer sites, the data will undergo validation after the backup tapes have been received from the site operators. The data will go through several validation steps. First, the transferred data files are compared against files on the backup tapes. The number of days with missing data files will be determined; a file size check will be performed to investigate the completeness of the daily data files. Additional details are listed in Table 1.

*Table 1. Brewer data file validation*

| Daily transferred files ddd-day of year, yy-year, ###-Brewer number | Contents (see *Brewer Spectrophotometer Operators Manual* for a detailed description of all files listed here) | Validation |
|---|---|---|
| UVdddyy.### (UV-files; before 1996 UX-files) | UV-files contain UV count rates as a function of wavelength. A complete UV scan consists of 154 data points. As the Brewer schedule is adjusted daily (section 1.5), the number of UV scans per day varies. The schedule predicts the number of UV scans in a given day and a given site. A table will be prepared for each site that will list the number of predicted UV scans for a given day. | (1) Check file length. Nominal ca. 75,000 (winter) -165,000 (summer) bytes.<br>(2) Determine whether each UV scan is complete, i.e. consists of 154 data points.<br>(3) Check whether the time recordings are correct.<br>(4) A precalculated table that predicts the number of scans at a given day will be used to determine if the number of actually measured UV scans in a given day is complete. |
| Bdddyy.### (B-file) | The B-files contain a recording of all measurements except the UV scans, i.e. a data header, instrument constants, comment blocks, results of the Hg lamp scans, the internal lamp, and the results of the direct sun, zenith sky, and Umkehr measurements. | Check file size. The size of the B-files is usually about 60,000 bytes. Any files with a size less than 50,000 bytes would indicate potential incompleteness of the daily schedule. All summary and daily average files are based on the recording in the B-files. As the average files are easier to interpret, they will be used to monitor trace gas and lamp measurements. |
| Ddddyy.### | Daily log file of Brewer operations. | Check file size. Nominal 15,000-18,000 bytes. |
| DUVdddyy.### | Erythemally (Diffey) weighted UV irradiance calculated operationally with the latest spectral response function. | Check file size. Nominal ca. 500-700 bytes. |

| | | |
|---|---|---|
| Sdddyy.### (S-file or summary file) | Contains the summary data from the B-file. | Check file size. Nominal 9,500-16,000 bytes. Used for validation if the validation of average files indicate problems. |
| Udddyy.### | Umkehr summary file. | Check file length. Nominal ca. 5000-7800 bytes. |
| Ydddyy.### | UV measurements to determine aerosol optical depth. | Check file length. Nominal ca. 800-3,000 bytes. |
| Lamp files | | |
| XLdddyy,### | Data from the external extended lamp scan test, i.e. 50W-lamp calibration. | Process XL-files, i.e. calculate the irradiance and monitor changes in the instrument sensitivity. |
| Average Files | Created by the ??sum.rtn program, where '??' identifies the type of average file, i.e. ??OAVG.### (for $O_3$ mode) and ??NAVG.### (for $NO_2$ mode). | Verify that the files were updated daily. |
| UVOAVG.###<br>OZOAVGyy.###<br>NONAVG.###<br>ZSNAVG.### | Daily integrated erythemally weighted UV.<br>Daily average of $O_3/SO_2$.<br>Daily average of $NO_2$.<br>$NO_2$ zenith sky data. | Plot time series for quarterly report. |
| SLNAVG.###<br>SLOAVG.### | Standard lamp R6 ratio in $NO_2$ mode.<br>Standard lamp R5 and R6 ratios in $O_3$/ $SO_2$ mode. | Plot R5 and R6 ratios for quarterly report. |
| APOAVG.###<br>DTOAVG.###<br>HGOAVG.###<br>MIOAVG.### | Voltages<br>Dead time for high and low intensities<br>Hg scans<br>Micrometer steps | No validation. For reference only. |
| OPAVG.###<br>RSOAVG.### | Contents of OP_ST.fil<br>Run/stop ratio for slit mask positions 0 through 7 | |

### *1.5 Experimental Design*

Twenty-one Brewer instruments are employed at the field sites. NUVMC has developed an automatic measurement schedule that takes into account the differences in length of day. In the morning and afternoon, this schedule, *EPA96d*, takes UV scans for every five degrees in solar zenith angle. An UV scan takes approximately 8 minutes. In between UV scans, the Brewer instrument performs a series of ozone/$SO_2$, $NO_2$, Hg lamp wavelength calibration, and internal lamp measurements. During midday the solar zenith angle does not change as rapidly. If the last UV scan is within 5 degrees of the minimum solar zenith angle for the day, the schedule switches from taking measurements in equidistant angular steps to taking measurements every 20 minutes. This schedule runs automatically. At the end of each day several summary files are produced in which the daily status of the instrument is recorded. Every day NUVMC personnel connect to each of the Brewers for data transfers and to determine whether the Brewer has run on schedule.

- **Hypothesis to be tested**

  It is possible to obtain UV irradiance measurements, which are within 3 percent of the irradiance obtained by a NIST traceable standard lamp?
- **Dependent and independent variables; and any key co-variables**

(1) UV spectral count rates

(a) Wavelength accuracy

The Brewer spectrophotometer uses one spectral line from its internal mercury (Hg) lamp at 302 nm to reset the scanning micrometer to the correct position. At present Hg scans are built into the Brewer automated schedule. The Hg lamp spectrum is regularly measured to help determine if the scanning micrometer is still functioning correctly.

(b) Sky conditions

The number of photons measured by the instrument is dependent on the amount of trace gases and sky conditions. Under clear-sky conditions the UV count rates are a function of the solar elevation and the column ozone amount. It is possible to assess the performance of a Brewer instrument on a clear-sky day, assuming the amount of aerosols is constant. Under cloudy conditions the number of photons are reduced significantly. Photon count rates under cloudy skies are indistinguishable from potentially reduced count rates due to a decrease in instrument sensitivity.

(2) Spectral response function (time- and temperature-dependent)

The objectives of this project include the specification of UV irradiance to within 3% of the absolute calibration against a FEL 1000 W NIST traceable standard lamp. Dividing the raw UV data by the spectral response function of the instrument will result in absolute UV irradiances; the response function is obtained annually during the calibration measurements on site. However, the response of the Brewer changes with time and is a function of ambient temperature. As a result, while the goal of 3% is possible immediately after a calibration and when the instrument is at the same temperature as that available during the calibration, this objective cannot in general be met. Therefore a correction should ideally be applied to the data. UGA will provide EPA with a linear correction factor to account for the decrease in sensitivity over time after a re-calibration has been performed.

(3) Cosine error of diffuser

The Brewer spectrophotometer uses a nearly flat horizontally oriented diffuser to collect the UV full sky irradiance. Its sensitivity to a ray of light arriving at a certain zenith angle should ideally depend on the cosine of that angle. Deviations from the ideal cosine response are present in all diffusers and vary from one instrument to the other. UGA has determined the instrument cosine responses of all Brewers prior to their field deployment (Appendix C). The deviation leads, in all cases, to an underestimation of the UV irradiance; its magnitude is dependent on the solar zenith angle and the sky conditions. A procedure for correcting this error is presently under development. As the sky conditions are generally not known, UGA has devised a cosine correction procedure as a function of solar zenith angle for each site. The correction will be based on model calculations.

- **Discriminating ability of tests**

The primary tests are the periodic calibrations of the spectrophotometers using the 1000W FEL lamps, the 50 W lamp scans and the internal lamp scans to determine the accuracy of the UV irradiance, ozone, $SO_2$, and $NO_2$.

- **Acceptable limits on the number of false positive and false negative results**

Each trace gas measurement is repeated 6 times before the intensity ratio between wavelengths is calculated. Average and standard deviation are recorded. A measured value is not taken into account if the standard deviation of the instantaneous measurements is greater than 2.5%.

The number of false positive and false negative of the UV spectral scans cannot be determined. Although it would be possible to control the UV scans on a clear sky day, the effects of clouds can lead to significant reductions of UV even at local solar noon. As there is no independent information about the amount of cloud cover, it cannot be determined operationally. It is suggested that the site-operators record the cloud conditions at least once per day and provide this information as metadata to NUVMC. .

### *1.6 Personnel Qualifications*

The three faculty members who oversee the program management are trained in optical spectroscopy. The computer systems analyst will have a science degree and several years of experience in computer programming, computer networking, and data analysis. The technician positions require a bachelor's degree in science. The position of assistant computer analyst requires several years of experience in computer programming and operations.

### *1.7 Training Required*

Site operators received training in the operation of a Brewer from KIPP AND ZONEN and NUVMC at the time of the Brewer installation. In the event of a change of operators, training by the NUVMC is restricted to guidance by telephone or e-mail and to instruction during regularly scheduled site visits. Instructions on how to operate a Brewer instrument have been summarized in the *National Park Service Air Quality Monitoring Standard Procedures* (Appendix D). The NUVMC currently has two trained staff members on a senior and junior level who are able to carry out the 1000W FEL calibrations. Hands-on training of NUVMC staff will be carried out with the Brewer at UGA. The computer system analyst will oversee the data handling and quality control, see that the local computer network and site computers are operational and will oversee day-to-day operations including Brewer maintenance and repair. Experienced staff will train new staff in the day-to-day operations.

### *1.8 Communication Plan*

The documentation of the QA/QC activities, site operations and maintenance problems are sent to the EPA Project Officer, the NPS Program Manager, and the Park Research and Intensive Monitoring of Ecosystems Network (PRIMENet) Program Manager, and to all operators and interested staff on a weekly basis. Quarterly reports, which summarize the performance of the Brewer including external lamp calibrations as well as the R5 and R6 ratios, will be sent to the EPA Project Officer and will be made available on the web to all users. The data will be available on the EPA website as well as on the website of the NUVMC. The UGA program manager and EPA project officer will be the spokespersons who authorize release of information.

## 2 MANAGEMENT ASSESSMENT

The management assessment of the project will be through independent audits, instrument intercomparisons and publications.

### *2.1 Assessment Responsibility*

UGA will be responsible for making the arrangements to participate in the annual intergovernmental instrument intercomparison.

### 2.2 *Assessment Type*

The EPA will arrange for independent audits of the UV intensity measurements of each Brewer against a NIST standard lamp. Independent audits will be scheduled no more frequently than once per year per site. Peer reviews will be held annually at Research Triangle Park. The first review will be about one year after the contract issue date. The Project Officer will designate a panel of experts. Reviews will not exceed two days.

### 2.3 *Assessment Usage*

The NUVMC will fully incorporate all information given by the Project Officer from these independent audits into the QA/QC for the data and the calculations of final response functions. Peer reviews will be used to evaluate project plans and to verify technical adequacy of the QA/QC of the data. The NUVMC will incorporate the results of the intercomparisons to assess and if necessary revise their calibration procedure.

### 2.4 *Assessment Criteria*

The audits will be undertaken by an agency independent of EPA and UGA. In the past, NOAA has performed audits.

### 2.5 *Assessment Documentation*

Weekly, quarterly, and annual reports are prepared which will include the assessment documentation. Weekly reports will summarize the activities in any given week. Quarterly reports will contain a summary of the 50W lamp calibrations for each site as well as the R5 and R6 values. An Annual Quality Assessment Report (AQAR) will be prepared to summarize the quality management and assessment activities during the previous calendar year. Reports of audits and peer reviews written by auditors/reviewers should be provided by the Project Officer in a timely fashion to UGA to provide feedback of the QA/QC of the data.

## 3 PROJECT IMPLEMENTATION

### 3.1 *Project Responsibilities*

Dr. Rives coordinates all activities of the National Ultraviolet Monitoring Center (NUVMC) in its operation of the UGA/USEPA UV Network;

Dr. Meltzer serves as the co-coordinator of all activities in the NUVMC;

Dr. Kimlin oversees the day-to-day operations, supervises the calibration and characterization facilities, carries out data quality assurance (QA) on the UV data, and supervises management of the UV database and webpage;

Mr. Bettenhausen is in charge of the computer operations associated with the daily transfer of data from the sites to NUVMC, design, operation and maintenance of the UV database, webserver and FTP system. He is also in charge of the design, maintenance and security of the NUVMC's server operation, which coordinates all computer operations in the NUVMC including daily computer backups of all systems;

Mr. Wilson's primary duties involve the maintenance, repair and calibrations of the Brewer UV Spectrophotometers. He maintains direct contact with the Brewer operators, is responsible for writing and modifying the SOP's for all network activities, schedules the calibration and repair visits to the Brewer sites, writes the Weekly Report of the status of the network Brewers, oversees the writing of the Brewer Calibration Reports, and is in charge of the operation of the calibration and characterization laboratory at the NUVMC;

Mr. Taylor's primary duties involve carrying out the calibrations of the Brewers, assisting in all NUVMC laboratory activities, including the calibration of secondary standard lamps for use in the site calibrations, and writing the calibration reports for each Brewer.

Student assistants perform specific duties associated with the analysis of, and the presentation of, the data under the direction of Dr. Kimlin and assisting Dr. Rives in accounting matters associated with the USEPA contract.

### *3.2 Project Design Criteria*

- **Site Selection**

  The site selection is completed. Twenty-one sites have been selected and are located throughout the US. Seven stations are in large metropolitan areas, and 14 are in National Parks as part of PRIMENet.

- **Sample Collection Media**

  The measurements are carried out with a Brewer spectrophotometer developed by KIPP AND ZONEN.

- **Sampling Time and Frequency**

  As measurements are obtained during daylight only, the number of measurements per day varies with latitude and season. To account for the changes in length of day a dynamic schedule, developed by the NUVMC is being used. In the morning and afternoon, UV scans are taken every 5 degrees in solar zenith angle. Between UV scans a series of ozone/$SO_2$, $NO_2$, Hg lamp calibrations and internal lamp measurements are performed. At the beginning and the end of the day several Umkehr measurements are carried out. Near local noon when the solar zenith angle changes very slowly, measurements are performed every 20 minutes. The total number of measurements at each site varies from day to day. A new schedule is calculated day-by-day and is dependent on the minimum of the solar zenith angle for the day.

- **Sample Collection**

  Data are stored locally on the hard disk of the site computer immediately after a measurement has been taken. At the end of the day, several summary files are written which record the daily status of the instrument.

- **Sample Handling**

  After midnight, the daily data files are transferred automatically to NUVMC with the communication program *CLOSE-UP*. In the event of communication problems this process has to be repeated manually at a later time under control of the assistant computer systems analyst. All data will be stored on a hard disk at the NUVMC server. These files are backed up weekly and are written to CD-ROM's quarterly.

- **Sample Custody**

  The raw and processed data is stored at the UGA UV data center on a hard disk. Tape backups will be stored off-site to prevent loss of data in case of an emergency situation. The amount of data per year per site is between 80-100 Mbytes. With 21 sites in operation this amounts to 1.6-2 Gbytes of raw data per year. Quarterly CD-ROM's containing the Brewer data will be produced. The NUVMC data server utilized is an Apple G4 rack mounted server, with a 40Gb HP data tape back-up system and a rack mounted uninterrupted power supply. The server is partitioned into 3 main sections: 1) "Mabel" which is the data storage server, for uncorrected and Level 1 Corrected data; 2) "Dante" contains back-up of individual's workstations and 3) "Dante-Shared" contains hard drive space where common use documents and information can be shared amongst NUVMC computer users.

- **Sample Preparation**

Does not apply.

- **Sample Analysis**

Absolute irradiance values are calculated from the raw data files using the most recent instrument response function. Procedures for correcting the UV irradiance have been developed (see Sec. 1.5). Column ozone values are derived from double ratios of intensity values at four wavelengths. The Brewer is monitored for these functions from a measurement of these ratios during the internal lamp scan (XL scans). Changes in these ratios require adjustments of the constants used to derive the column ozone, $SO_2$ and $NO_2$ values. (See *Brewer Spectrophotometer Acceptance Manual, chapter "Preliminary Data Reduction"*.)

### *3.3 Data Quality Indicators*

- **Accuracy requirements**

UV results should be within 3% of the absolute calibration against a FEL 1000 W NIST traceable standard lamp. A comparison between a simultaneous calibration performed by the NUVMC and the auditor (NOAA) with a portable unit has shown that the 3% accuracy objective is achieved. The ability to provide column ozone accuracy will depend on the implementation of a calibration plan that includes a Brewer instrument, or other portable device, as traveling ozone standard.

- **Detection limit requirements**

Irradiances less than $10^{-6}$ W/m$^2$/nm cannot be detected. The observed signal generally drops below the noise level for wavelength less than 290 nm. This is limited by scattered light from longer wavelengths in the Brewer. As $SO_2$ and $NO_2$ column abundances are generally very small, their detection is limited by the uncertainty of measurement.

- **Comparability requirements**

The UV irradiance data from the Brewer spectrophotometer should be comparable to other spectroradiometers when data are taken at the same time and place. UV irradiance data under clear sky and pristine conditions should be comparable to modeled UV irradiances using the Brewer ozone data as input. Instrument intercomparisons are necessary to determine the performance of different Brewer spectrophotometers compared to other spectrophotometers used in other UV networks. UGA will participate in the annual Boulder spectroradiometer intercomparison to assure the comparability of the Brewer calibration and data correction procedures. Attendance at the intercomparison has occurred for the 1994, 1995, 1996, 1997 and 2003 campaigns. Note, there were no UV intercomparisons between 1997 and 2002.

- **Completeness requirements**

In order to ensure the quality of the measurements being taken, all measurements must be recorded. Spectral response functions from field calibrations, 50W lamp calibrations and the results from audits and instrument intercomparisons are required to ensure the quality of the data set.

- **Representativeness requirements**

UV scans are taken for every five degrees in solar zenith angle in the morning and afternoon. An UV scan takes approximately 8 minutes. In between UV scans a series of ozone/$SO_2$, $NO_2$ and internal lamp measurements are performed. During midday the solar zenith angle does not change as rapidly, so the schedule switches from taking measurements in equidistant angular steps to taking a measurement every 20 minutes. To provide quality assurance, field calibrations with traceable FEL lamps will be scheduled once per year for each site. The 50 W lamp calibrations are taken every other week to allow for monitoring the temperature dependence and instrument stability.

# 4 DATA ACQUISITION

The previous section discussed the sampling and handling of measurements. As the Brewer spectrophotometer takes UV measurements and produces data files, the previous sections on sample handling and the following sections on data handling will have some overlap.

## *4.1 Data Recording*

All Brewer instruments perform measurements automatically and are controlled by software installed on IBM compatible PC's. The software records all measurements in data files (see Table 1 for a list of data files). The uncalibrated UV irradiances are calculated from raw counts (stored in UV-files), with the appropriate spectral response function (RES-files). All raw measurements files (UV-, B-,U-, and Y-files) and instrument constant files (as discussed in the Brewer Spectrophotometer Operator's manual) are essential for the completeness of the data set. Discrete UV measurements in the six wavelengths used for the ozone, $SO_2$ and $NO_2$ determination are stored in B-files. Summary data from Umkehr measurements are stored in U-files, information to calculate aerosol optical depths are stored in Y-files. Operational processing of the data produces Diffey weighted integrated UV and daily doses in DUV-files. A summary of all measurements of the day is stored in D- and S-files. Various daily average files are computed operationally to monitor the status of the Brewer instrument.

## *4.2 Identification of Data*

Data are stored in files that contain in the name of the file: year, day of year, and Brewer number. The times at which measurements are taken are recorded in the files. All files are text files and are described in detail in the *Brewer Spectrophotometer Operator's Manual.*

## *4.3 Control of Erroneous Data*

To ensure that the data files are complete and do not contain incomplete UV scans or unexpected control characters, programs will be developed that read each data file and check the quality of the data in files. The validation procedures are discussed in Section 1.4 and are summarized in Table 1. UGA will prepare a quality control validation report that is placed in a file on the CD-ROM's with validated Brewer data. This report will list all missing data files as well as the files that are incomplete with an explanation. The validation of the UV files will include an examination of the completeness and the validity of the time recordings of the UV scans. The validation report will discuss erroneous data, but the raw data files will remain unchanged.

### *4.4 Data Evaluation*

Annual FEL lamp calibrations will be used to ascertain if changes have occurred in the instrument response. If changes have occurred, corrections need to be applied to bring the UV irradiance results within the accuracy objectives. Procedures are in operation as described in Sec. 1.5.

### *4.5 Data Validation*

The UV irradiance data is processed to produce level 1 corrected UV data. Level 1 Brewer data is corrected for dark count, dead time and stray light using the algorithms of Sci-Tec (now Kipp and Zonen). Additionally, the fully corrected level 1 data uses an estimated daily temporal response based on an annual UV irradiance calibration, using a secondary standard lamp traceable to the NIST 1000 W lamp. The response function is calculated for each day based on a linear interpolation between the two temporally closest response functions. Finally, the level 1 data is corrected for the instrument's cosine response and temperature dependence.

## 5. DATA MANAGEMENT

- **Types of data to be collected, processed, and utilized**

  The operational Brewer instruments collect raw photon counts on-site. These photon count rates are processed automatically on-site to derive erythemal UV radiation, as well as ozone, $SO_2$ and $NO_2$ column amounts. All data produced by the Brewer Spectrophotometer measurement system are collected daily. The 50W lamp scans and response files from the 1000W calibrations are needed to obtain absolute calibrated UV irradiances (see Section 1.5).

- **Data sources**

  Data sources are the Brewer measurements from twenty-one field stations, and the data from field and laboratory calibrations. Annual audits and instrument intercomparisons may provide additional sources of data for evaluation purposes.

- **Data management resources needed**

  All field sites have one personal computer exclusively for the operation of the Brewer instruments. These field computers store the operational data on their hard disks. All site computers are equipped with backup tape drives and modems. At NUVMC, a network of personal computers is used for data management, i.e. data transfers, storage and backups. All computers are equipped with backup tape drives. A CD-ROM writer for the production of the quarterly validated data sets is located on a central computer.

- **Data collection activities**

  The data will be collected from each site via modem using the communication program *CLOSE-UP*. New spectral response functions are collected once a year when an instrument is re-calibrated.

- **Data processing activities**

  Photon count rates obtained by a Brewer instrument are processed automatically on-site to derive erythemal UV radiation, as well as ozone, $SO_2$ and $NO_2$ column amounts. After the data is transferred to NUVMC, the data is processed into spectral UV irradiances (PUV-files) and into plots of daily integrated erythemal UV radiation and total column abundances, which are displayed on a website. Furthermore, the results of the 50 W lamp scans as well as the R5 and R6 ratios are analyzed with spreadsheet software. These graphs are monitored regularly to identify problems with the network.

- **Data verification and validation activities**

  Software has been developed to scan the transferred data files for erroneous data. Table 1 lists the validation activities for the Brewer data files. An electronic validation report will be prepared and will accompany the CD-ROM's with validated data. The quarterly reports will contain graphs of the 50W lamp scans and R5 and R6 ratios and summarize the instrument performance during the validation period.

- **Data management and geographic information systems (GIS) to be used**

  Programs in Visual Basic, Fortran, PERL, C and C++ have been developed depending on the required application. In addition the spreadsheet software, Excel, and other software are used as needed.

- **Data, data base, and systems controls and administration**

  The database consists of data in text file format. These data are organized in directories, which are identified by site name. Each site directory has several subdirectories. Data from measurements (see Section 4.1) are stored in annual directories. Daily average files are stored in the directory *Avg*. Brewer instrument constants are found in directories identified by Brewer number. Figure 1 gives an example for the directory structure.

- **Data reporting needs**

  The data is available for public and EPA use on an ftp server at NUVMC (oz.physast.uga.edu; logon ftp; cd Brewer-data). The level 1 Corrected UV data is available for pubic use in several formats: 1) DUV files (daily integrated erythemal data), 2) SV files (spectral erythemal data in 5nm increments) and 3) RV files (spectral data, unweighted).

- **Data archival**

  Data will be archived on DAT tapes, CD-ROM's and DVD's.

- **Data Software**

*Close Up 6.5*

Client/Server software providing remote control of the Brewer in addition to data transfers from each of the Brewer sites.

*download_and_transfer.pl*

Perl script controlling automated nightly download of Brewer data via Close Up, placement of that data into the data tree, and emailing of summary of those actions to NUMVC staff (ndreport_jjjyy.log).

*DataSync*

Visual Basic program providing byte-by-byte comparison of downloaded data and data provided each quarter by operators.

*Quarterly backup batch file (q302zip.bat)*

MSDOS batch file executed by the local operator that automates the quarterly backup process (data zipped, and placed on floppies provided by operator).

*Quarterly deletion batch file (q204del.bat)*

MSDOS batch file usually executed remotely by NUVMC staff that deletes data older than the previous two quarters. Only run when necessary, not really on a quarterly basis.

*Brewer_screenshots.pl*

Perl script that controls Close Up, which, in turn, takes screenshots of Brewer computer, and emails screenshots to NUVMC staff.

*create_tmp.pl*

Perl script that summarizes the XL scans taken and the Pcclock dial out status for the last week. Emails summary to Mr Corey Bettenhausen (tmpjjjyy.log).

*Pcclock*

Synchronizes Brewer computer to the NIST timeserver in Fort Collins, Colorado on a daily basis.

## 6. RECORDS MANAGEMENT

### *6.1 Records Management System*

The raw data files are stored on an UGA server. The weekly reports (WRdddyy.txt) serve as a data record about the activities within the network. Quarterly reports (QRdddyy.txt) summarize the instrument performance; quality control validation reports sum up the results of the data validation. All reports will be stored in a directory on the UGA server and backed up weekly.

### *6.2 Records Identification, Authentication, and Indexing*

Data for the different Brewer sites are stored in directories named after the site. This directory is further subdivided by year and contains separate directories for instrument constants and average files. In 1996 aerosol optical depth measurements were added to the schedule. Data directory structure for data on the ftp site *oz.physast.uga.edu:*

*Brewer-data\Sitename\yyyy\Bdddyy.### ... Ydddyy.###*
*Brewer-data\Sitename\Avg\APOAVG.### ... ZSNAVG.###*

See Figure 1 for an example of the Gaithersburg directory.

In addition to the data directory all instrument specific data, i.e. dispersion constants file, instrument constants file, the zenith sky coefficients file, and response files are kept in a separate directories. The rationale is to collect the instrument history information in one directory, which is particularly useful in case the instrument is moved from one site to another. This record structure was developed to keep track of the instrument specific constants and calibration information (Figure 2).

*Figure 1: Example of data directory structure for the NUVMC file server (eg. Gaithersburg)*

```
Mabel
  Data_Central
      Brewer_Data
      Gaithersburg
          Br105
            Raw_Data
            2003
            2002
            Pcclock
            Comment
          Br106
            Raw_Data
              1998
              1999
            Pcclock
            Comment
    Brewer_Constants
        Br105
            response_files
            icf_files
            dcf_files
            zsf_files
            op_st_files
            xl_files
            lamp_files
            cosine
            dispersion
            high_voltage
            shutter_timing
            slit_width
            temperature_dependence
            st_files
            j_files
        Br106
            response_files
            icf_files
            dcf_files
            zsf_files
            op_st_files
            xl_files
            lamp_files
            cosine
            dispersion
            high_voltage
            shutter_timing
            slit_width
            temperature_dependence
            st_files
            j_files
```

### *6.3 Records Distribution and Storage*

All data records are accessible for public use on the NUVMC ftp server (*oz.physast.uga.edu)*. The EPA may download daily data from the NUVMC server. Weekly reports are sent by e-mail to NUVMC, EPA, and network staff. The reports are stored on the NUVMC server hard disk in */Nuvmc-reports*, on backed up on DAT tapes and CD-ROM's.

### *6.4 Records Retrieval*

As data records are identified uniquely, they can be retrieved easily if the name of the site, Brewer number, year, day of year and type of data are known.

### *6.5 Records Retention*

All raw data sets will be retained indefinitely on tapes at NUVMC, as they provide an important part of information that will be essential for trend analysis projects.

### *6.6 Data Validation*

We correct the Brewer data for: (i) non-ideal cosine response, (ii) stray light, (iii) temperature dependency and (iv) temporal change in response. Using this program we process and correct the raw UV data to produce the level 1 corrected UV data, which we store in our database. We have fully documented these computer programs and have provided copies of the documentation and the software to our current EPA project officer. Specific details on how the raw Brewer UV data is corrected are shown in Appendix B; however, a brief overview of the program we developed is indicated below:

Brewer UV data is corrected for dark count, dead time and stray light using the algorithms of Kipp and Zonen. The fully corrected UV data uses an estimated daily temporal response based on the annual UV irradiance calibrations, using a secondary standard lamp traceable to the NIST 1000W lamp (described elsewhere). The response function is calculated for each day based on a linear interpolation between the two temporally closest response functions. The temporal corrections tend to increase the UV irradiance relative to that of the uncorrected data, which assumes the last response, since typically the instrument response decreases with time such that the actual response is less than that assumed based simply on the last calibration.

The data is then corrected for the instrument's cosine response and temperature dependence. The cosine correction leads to an increase in the UV irradiance relative to that of the uncorrected data since the full sky collector operates at a reduced throughput for rays at large angles from zenith, the angle for which the instrument is calibrated. The temperature response function of each instrument in the EPA/UGA network has its own wavelength dependent characteristic temperature dependence that can be as large as almost 1% per degree centigrade, but which typically falls in the range of –0.1 to –0.4%/ degree Celsius. Temperature corrections can be positive or negative depending on the relative temperature of a UV scan to that of the temperature when the calibrations were performed. A brief overview of the correction program procedures follow:

The raw counts (RC) for each 154 wavelengths (286.5 to 363 nm in steps of 0.5 nm), are converted to light intensity. The dark-count (DCT), which is an average of a number of shutter cycles, is stored in the header information for each scan of the UV file. Additionally, the number of slit-mask cycles (CY), 2 x integration time (IT) and dead-time (DT) are also stored in the header.

1) **Dark-count correction and conversion to count rate (CR), units of counts / sec:**

For each of the raw UV counts corresponding to the 154 wavelengths per scan of the UV file -

$$CR = \frac{2 * (RC - DCT)}{CY * IT} \quad (1)$$

where the abbreviations and header positions are defined in the last paragraph, with IT equal to 0.1147.

**2) Dead-time correction (DC):**

For each of the dark-count corrected count rates corresponding to the 154 wavelengths per scan –

$$D1 = CR * e^{(CR*DT)} \quad (2a)$$

where DT is the current week and future week 'running' average of the corresponding average of the HI and LO values (units of nano seconds), from the DTOavg file. Continue to iterate Equation 2b eight times, by replacing CR with DC per iteration.

$$DC = D1 * e^{(CR*DT)} \quad (2b)$$

**3) Stray-light correction (SC):**

For each of the dead-time corrected count rates corresponding to the 154 wavelengths per scan –

$$SC = DC - \frac{\sum_{286.5}^{292.0} DC}{12} \quad (3)$$

(Note: divide by 12, not 11, as in Brewer manual)

**4) Out-lier correction (OC):**

Compares the ratio corresponding to each of the corrected, 154 wavelengths to the clear-sky reference ratios (RR) stored at position 1 of ST3JJJYY.###. Interpolate the value/s of SC for any wavelength/s ($x$), where x ≥ 305 nm, that meet the following criteria –

$$\left(\frac{SC_{x+1}}{SC_x} \geq 2 * RR_{x+1}\right) AND \left(\frac{SC_{x+2}}{SC_{x+1}} \leq 2 * RR_{x+2}\right) \quad (4)$$

Using the corresponding RR value to adjust the SC value proportionally performs this linear interpolation. This set of SC values, including any interpolated values, now becomes known as the out-lier corrected data (OC).

**5) Cosine correction (CC):**

The OC values corresponding to the 154 wavelengths are corrected by dividing the OC values by the following cosine correction factors ($f_g$), which are dependent on $SZA^{(X)}$ (converted to radians) and $AOD^{(Y)}$ (Note: (a) this equation assumes clear-skies and is a first order approximation under cloudy skies, (b) if a calculation involves the value of –99, then $f_g = 1$) –

$$f_g = (1 - f_{bg}) * f_d + f_{bg} * f_b \quad (5)$$

where $f_b$ (the direct correction), uses the 5 coefficients ($e$ to $a$) from the closest file CSOJJJYY.### (unless a specific filename was input by the user), in the following equation:

$$f_b = e + d*x + c*x^2 + b*x^3 + a*x^4 + \quad (6)$$

where the x values are the SZA converted to radians by the factor of π/180.
$f_d$ (the diffuse correction) is given by –

$$f_d = 2 \int_0^{\pi/2} (f_b * \cos(x) * \sin(x)) d(x) \quad (7)$$

where $f_{bg}$ is the ratio of direct / global UV irradiance from the CJJJYYnn.### file. (Note: The above integration can be performed using a trapezoidal routine available upon request). This file name is chosen based on the nn value (AOD*10), where $AOD^{(Y)}$ is obtained from the ST1JJJYY.### file based on the season that is determined from the JJJ of the UV filename. Refer to the file format of CJJJYYnn.### to decide on how to choose the correct value of $f_{bg}$ based on SZA. If the value of the SZA does not correspond to one of the rows (SZA of 90° to 0° in steps of - 5°), then a linear interpolation will be required between the values in the rows. Example, for a SZA of 69° the values will be proportional to the ratios between the 154 values in the corresponding 70° and 65° rows.

6) **Conversion of count rate to irradiance [not optional] using either Temporal response (TR), or Temporal response with temperature correction (TC):**

The CC values, corresponding to the 154 wavelengths, are converted to irradiances (W/m²), by dividing the CC values by the linearly interpolated responsivity values contained in two response files. One approach is to 'call-out' to a subroutine or another program that can generate 365/366 responsivity values by assigning all days to their astronomical Julian day number and preparing a look-up table or temporary file of interpolated responsivity values. This option may be set when first running the program. The interpolation is based on a proportional adjustment of the CC values based on the number of days between the UV file and the two corresponding adjacent response files (e.g. using files UV01500.123, RES00100.123 & RES03000.123, the irradiance at say wavelength 320 nm would equal the CC value at wavelength 320 nm divided by the adjusted response value (AR) at 320 nm, where AR would equal the responsivity value of [RES00100.123 @ 320 nm - (RES00100.123 @ 320 nm - RES03100.123 @ 320 nm) times 15 divided by 30)]. These response files are chosen starting with the name of the UV file and selecting the closest two response files (i.e. one before and after the UV file, in terms of date). The names of the response files are found in the CTJJJYY.### file. If only one response file is available, then the same response file will be used for both, in which case the code (TO), should not be stored in the header of the output file, to indicate that no temporal correction was used (see section B). Alternatively, the user may override this automatic selection of appropriate response files and allow entry of the response files that the user wishes to use.

When the temperature correction is included then the responsivity values in the response files ($RV_{1or2}$), and the cosine-corrected counts (CC), are normalized to equivalent values representative of measurements made at 20°C. This will be accomplished by applying the following formula to this data BEFORE dividing CC by the linear interpolated RV values –

$$RV_{1or2} * e^{(C_t - W50)*(20 - T_{RV})} \quad (8a)$$

$$CC * e^{(C_t - W50)*(20 - T_{CC})} \quad (8b)$$

where $C_t$ is the corresponding temperature coefficient found in the closest TCJJJYY.### (unless the filename was input by the user), $W50$ is the 50 W lamp correction value (currently equal to 0.0007), $T_{RV}$ and $T_{CC}$ are the INSTRUMENT temperatures corresponding to the response files and UV file respectively. The INSTRUMENT temperatures for the response files are found in the corresponding CTJJJYY.### file. The INSTRUMENT voltage for the associated UV file is found at position 11 in the UV file corresponding to each scan. To convert this INSTRUMENT voltage (PV) to temperature in units of °C, one of the following equations is used –

$$T_{cc} = -33.27 + PV * 18.64 \quad (9a)$$

$$T_{cc} = -30 + PV * 16 + 0.5 \quad (9b)$$

(Note: Equation 9b is for Brewer #087 only). If no temperature correction is to be included then set all values of $C_t = W50$ in Equation 8. *This will then use the uncorrected values of RV and CC because the exponential terms will have a zero power that equal 1.*

**The RV file:**

1) Local Standard Time – calculated from the UTC time (minutes) from the UV file header, position 15, and repeated for each scan; and using the Time difference to UTC, row 5, of the ST1JJJYY.### file;
2) SZA$^{(X)}$ – calculated using the latest Kipp and Zonen subroutine zenang. This subroutine requires the inputs of JJJ and YY (from the filename); latitude and longitude (from positions 2 and 3 of ST1JJJYY.###; and UTC time (minutes) from the UV file header, position 15, and repeated for each scan;
3) The names of the response files used;
4) INSTRUMENT Temperature (°C) – use Equation (9) above; and
5) UV/QA program version and correction abbreviations – recorded as necessary.

**Producing the SV file:**

i) Grouping scans into 4 and 5 nm bands – sum the TR <u>or</u> TC (temperature corrected) values together for each set of 5 nm wavelengths, producing a total of 14 values, e.g. value 1 is: $\sum_{286.5}^{295} TC$ and the last value is $\sum_{355}^{363} TC$. The values in between are in 5 nm bands.

ii) Applying the action spectrum – the following criteria is used to weight (W) i.e. multiply, the 0.5 nm spectral data (TR or TC) for each wavelength (L) e.g. W * TR, (<u>not</u> the 5 nm band data) –

W = 1 if (286.5 <= L < 298 nm);
W = 10^(9.399999E-02*(298 - L)) if (298 <= L < 329.5 nm);
W = 10^(1.5E-02*(139 - L)) if (329.5 <= L < 363 nm).

*This action spectrum is based on:*
*McKinlay, A.F. and Diffey, B.L. 1987 'A reference action spectrum for ultraviolet induced erythema in human skin, in Human Exposure to Ultraviolet Radiation: Risks and*

*Regulations, edited by W.R. Passchier and B.F.M. Bosnjakovic, pp.83-87, Elsevier, New York.*

iii) UVA correction (UC) – *because the Brewer MK IV only scans to 363 nm, a correction is applied to enable the action spectrum to be weighted as if to the complete UVA range to 400 nm.* Same weightings as in ii) above, except for the single wavelength (L = 356.5 nm), which uses W = 0.027 *i.e. weight this wavelength greater than before.*

iv) Biologically effective irradiance (BEI), units of W/m$^2$ –

$$\text{BEI} = \sum_{286.5}^{363} UC * 0.5 \qquad (10)$$

*the 0.5 is necessary because the weightings given in ii) and iii) above is designed for 1 nm steps, where as these are 0.5 nm steps.* The file format has been discussed earlier in section B. The additional information to be added to this file, as compared to a DUV file, is repeated below for clarity:

1) Local Standard Time – calculated from the UTC time (minutes) from the UV file header, position 15, and repeated for each scan; and using the Time difference to UTC, row 5, of the ST1JJJYY.### file;
2) SZA$^{(X)}$ – calculated using the Kipp and Zonen subroutine zenang. This subroutine requires the inputs of JJJ and YY (from the filename); latitude and longitude (from positions 2 and 3 of ST1JJJYY.###; and UTC time (minutes) from the UV file header, position 15, and repeated for each scan;
3) The names of the response files used;
4) INSTRUMENT Temperature (°C) – use Equation (9) above;
5) The 14 unweighted and weighted values from i) above; and
6) UV/QA program version and correction abbreviations – recorded as necessary.

**Producing the DV file:**

The BEI irradiance values, from the last section, can be converted to exposure (energy) values and integrated for all scans to represent the daily integrated damaging UV (DUV) in units of J/m$^2$. Because the scans do not necessarily represent a uniform time increment, the following algorithm will be used:

$$\sum_{1}^{n-1} \left(\frac{BEI_n + BEI_{n+1}}{2}\right) * (t_2 - t_1) \qquad (11)$$

where $n$ is the scan number corresponding to the BEI value, and $t_2$ and $t_1$ is the difference between the local standard time of the two scans, $n$ and $n + 1$ (in units of sec), calculated from the UTC time (minutes) from the UV file position 15 and repeated for each scan; and using the Time difference to UTC, row 5, of the ST1JJJYY.### file. *The difference in local standard time avoids the change of UTC at midnight.*

The file format has been discussed earlier in section B. The additional information to be added to this file, as compared to a UVO file, is repeated below for clarity:

1) The second response file name that was used for the temporal interpolation;
2) Ideal number of scans – from position 1 or 2 of ST2JJJYY.###; and
3) UV/QA program version and correction abbreviations – recorded as necessary.

# 7 ROUTINE CONTROLS AND PROCEDURES

## *7.1 Control and Calibration of Measurement and Test Equipment*

The equipment consists of 21 Brewers and their accessories on-site, and NUVMC test equipment used both in the laboratory to calibrate FEL lamps and to calibrate and characterize instruments before they go out into the field or if they are returned for repair.

NUVMC staff calibrates the Brewer instruments annually during a visit to the site (Appendix A). This consists of calibration with two FEL lamps traceable to NIST standards, and calibration of the 50 W lamps. In addition a variety of checks are performed on operating parameters of each Brewer. These are documented in "Visit to Site Reports" (CALdddyy.txt).

The NIST traceable calibration lamps are calibrated in the NUVMC using a vertical to horizontal transfer procedure described in a SOP (Appendix B). The lamps are always operated at the same constant current. This current is accurately maintained by monitoring the voltage across a standard resistor whose accuracy is known to 0.01%.

## *7.2 Procedures*

Procedures are described in SOP's that are included as appendices at the end of this report. The procedures covered include: Appendix A: *Procedure for Performing the Annual Calibration Visit on MK IV Brewer Spectrophotometers in the National Ultraviolet Monitoring Network;* Appendix B: *How to Transfer the Irradiance Calibration of the 1000W FEL Lamps;* Appendix C: *How to Measure the Cosine Dependence of a Brewer Spectrophotometer;* Appendix D: *Standard Operating Procedure For The Brewer Spectrophotometer.*

## *7.3 Establishing the Adequacy of Technical Practices*

Audits are scheduled to be performed annually at most sites by NOAA. Reports of these audits will be used to continually monitor the adequacy of the technical practices.

## *7.4 Maintenance of Equipment*

Local site personnel will perform regular periodic duties such as cleaning the input quartz ports and changing the desiccants according to needs. Local personnel, under supervision from the NUVMC will perform minor repairs of the instrument with spare parts on site or parts shipped from UGA. All repairs will be performed quickly in order to return the instrument to the network as soon as possible. The local logbook will include a record of all maintenance and repairs with date and signature of the person in charge of the work.

## *7.5 Quality of Consumables*

Consumables are printer paper, desiccant, backup tapes etc. Standard off the shelf products are supplied from UGA to the field sites.

## *7.6 Labeling*

Does not apply.

## *7.7 Acceptance of Equipment and Materials*

The UV spectroradiometers have been purchased from Kipp and Zonen by the USEPA. The

NUVMC will purchase spare parts as needed.

### *7.8 Storage of Equipment and Materials*

The UV spectroradiometers are designed and intended to operate 'in the field' under all weather conditions. At each site the computer controls are located in office space nearby, or in EPA designed trailers with environmental controls (heat, AC, humidity etc.). The calibration equipment, consumables, and spare parts are stored at the NUVMC. Some key spare parts are stored on site for those sites which are not easily accessible for overnight deliveries in the case of emergencies.

## 8 TECHNICAL ASSESSMENT AND RESPONSE

### *8.4 Assessment Procedures*

Any major malfunction of the UV spectroradiometer will cause errors and interruption in the computer software schedule that controls all operational aspects of the instrument. If the computer interrupts the instrument operation the error will be detected either by local staff, or when that day's files are transferred to the UGA Data Center. In this event local staff will be alerted by the NUVMC staff to help them in rectifying the problem. The operation of the spectroradiometer is checked at least twice daily with an internal lamp source. Any gross malfunction, or drift in spectral sensitivity will be evident in the lamp data when it is transferred to NUVMC. External 50W lamp calibrations will be performed bi-weekly to monitor the absolute accuracy of the data. Once every year a field calibration with 1000W FEL lamps will be performed. In addition annual instrument intercomparisons and audits will provide further assessment of the calibration procedure.

### *8.5 Assessment Evaluation*

Problems can often be identified by the absence of files in the daily download of data. Based on which files are missing it is often possible to identify the source of the problem. In this case, NUVMC staff, either working alone with *CLOSE-UP* or with the local site operators can correct the problem. Other problems do not lead to missing data but rather to data that is not accurate. The most common problem involves a change in the response of the instrument. This can be caused by dirt on the optics or optical misalignment of the instrument due to poor sun sighting or misadjustment of the input prism. Most of these problems cannot be prevented since they occur in the normal operation of the instruments. They should be identified as soon as possible from surveys of the 50W lamp or internal lamp scans. To be successful, site operators must closely follow the tasks described in the SOP especially the standard procedure of performing bi-weekly 50W lamp calibrations (Appendix D). This will help avoid unnecessary instrument downtime and provide the means to correct the response functions for temporal and temperature dependencies.

### *8.6 Assessment Response and Follow-up*

Meetings of the NUVMC monitoring staff will be held as required to assess the status of the network and plans for future operations. Problems with the instrument will be reviewed and corrective measures evaluated. Written reports of the problem, response to the problem, and suggested changes for future operations, if applicable, will be used to document action. Local site actions will be entered into the electronic instrument logbook (CMdddyy.###), with appropriate sections copied and transmitted to the NUVMC. Such records will be permanently stored at the

UGA data center.

# 9 Brewer Operation and Subsequent Impact on Data Collection

## *9.1 Assessment Procedures*

As the Brewer instruments age, a subsequent deterioration in instrument performance is expected. However, through novel preventative work, we are able to reduce this deterioration, hence increasing the life of the instruments. During an annual site visit, the standard NUVMC annual maintenance procedure is performed to maintain various moving parts such as the micrometer and zenith drive gear. However, if required, more advanced upkeep would take place at the NUVMC including measurement of the dispersion of the spectrometer grating, a rebuild of the mechanical zenith bearing assembly and replacement of the instrument's environmental seals. After completion of the overhaul a full set of optical characterizations would be necessary, including spectral response, temperature dependence, stray light, slit function and cosine dependence, all of which can be conducted at NUVMC. Field testing of the instrument at the NUVMC facility for a short period of time would also be required before redeploying the instrument to the field site.

Not all instruments require such a major overhaul. About three (3) instruments will need replacement of the PMT tubes and will require new $NiSO_4$ filter assemblies in the three (3) year contract period. Through weekly diagnostic checks and annual calibrations, the NUVMC can determine which Brewer instruments require this work. Only instruments requiring the $NiSO_4$ filter or PMT replacements would require a full characterization.

***References***

SCI-TEC 1995: *Brewer MKIV Spectrophotometer Operator's Manual,* SCI-TEC Instrument Inc., 1526 Fletcher Road, Saskatoon, Sask., Canada

SCI-TEC 1994: *Brewer Ozone Spectrophotometer Acceptance Manual,* SCI-TEC Instrument Inc., 1526 Fletcher Road, Saskatoon, Sask., Canada

Appendix A

# Procedure for Performing the Annual Calibration Visit on MK IV Brewer Spectrophotometers in the National Ultraviolet Monitoring Network

**National Ultraviolet Monitoring Center**
**Department of Physics and Astronomy**
**University of Georgia**
**Athens, GA 30602**

**Document 16**
**Revision A**

**Prepared by Dr M.G. Kimlin A.W. Wilson and T.E. Taylor**
**Last updated July 2, 2003**

National
Ultraviolet
Monitoring
Center

**Introduction**
Spectral response calibrations measure the response of a Brewer Spectrophotometer to a known light source. This calculated response is used to produce absolute irradiance for all UV data taken during the adjacent time period. To ensure that the UV data taken by a Brewer is valid, a spectral response calibration is done at least once a year.

During a site visit by NUVMC personnel, a spectral response calibration is done along with maintenance and repairs. The maintenance is a large reason for our large data capture rate over the last few years and over all good health of the instruments.

**Equipment**
UGA built field calibrator housing
Power supply with 8.2 Amp output
Highly stable, high resolution multimeter
10 mili-Ohm shunt resistor
Lamp alignment jig
Alignment rods and dome cover
Cables
Log pages
Blank calibration report
Replacement parts
Kimwipes
Methanol
Krytox grease
Laptop computer with Excel
RES file for processing xl data
Rx.exe file
Tools (hex wrenches, adjustable wrenches, screwdrivers.....)

**Purpose**
To maintain and calibrate a Brewer Spectrophotometer in the field.

## Procedure

### ❑ Abort Schedule.

Press the "home" key to interrupt the schedule.

### ❑ Check date and time of Brewer computer.

To check the time and date, at the brewer home screen type "WDWX". This will initiate the dialout sequence that will automatically update the date and time from the standard clock at NIST. Record the changes printed to the PCCLOCK screen after the update in the log pages and in the blank calibration report on hand.

### ❑ Update Brewer computer to current software version (UGA2b). Update op_st.fil, and computer.txt file. Make sure the autoexec.bat configuration is routed properly.

Look at the top right corner of the screen, the software name is listed. If this does not indicate UGA2b as the software name, install UGA2b software.

To install the UGA2b software, the software for V374a, UGA1, UGA2, UGA2a and UGa2b must be on hand.
Follow the procedure for installing Brewer software found on the Server.

### ❑ Turn printer on and set on-line. Give "PN" command at Brewer Home screen.

### ❑ Look through the written log to pin-point any major problems. The electronic log should have been looked through at UGA.

Notice any reoccurring problems and resolve them.

### ❑ Check the Zenith Prism Alignment (ZE, B2, B0).

Type "ZE" and wait until completion and then "B2". Then look into the iris viewport. The light image should be centered over the middle of the iris. If this is not the case DO NOT REALIGN at this point. If the prism is not aligned, a second calibration has to be done after the realignment. Then type "B0" at the home screen to turn off all lamps.

### ❑ Perform sun sighting (SI). Record changes.

Type "SI" at the home screen. The SI command points the azimuth tracker and the zenith prism to the sun based on the current settings for day, time (CUT) and Brewer location (latitude and longitude). Peering through the Iris View Port use the four buttons located on the front face of the Brewer to adjust both the zenith angle and the azimuthal angle until the image of the sun fills the iris. The adjustment motions are very small; a button may have to be pressed for up to 20 seconds to observe the direction of the correction. There is a 1 to 2 second delay of movement after a button has been depressed and there will be 1 or 2 seconds of movement after the button is released.

Once the rough alignment is made using the Iris View Port, look through the Entrance-Slit View Port and adjust the zenith and azimuthal angles using the buttons until the sun's image is split by the image of the entrance slit. The sky must be reasonably clear for this test. Since the sun's image enters the Brewer through the quartz window take precautions not to block the quartz window with your shoulder as you peer into the view port.

Record the new data. Once the image is properly aligned, enter <CTRL> + <END> on the computer and press "Y" to save to the new setting. Under normal conditions, the azimuth setting doesn't change by more than 10 steps and the zenith setting by more than 4 steps.

If there have been reoccurring problems with the image of the sun on the slit at the same time as the image is centered on the iris it may indicate that the iris or slit view tube(s) may be loose and out of alignment. The tubes can be checked once the instrument has been moved inside. If the SI setting has been constantly altered by the operator between checks performed in the morning and checks performed in the afternoon then it indicates a mis-leveling of the tracker. This can be checked and adjusted once the Brewer has been removed.

- ❑ **Perform Steps per Revolution Test (SR).**

The tracker moves to the zero azimuth position and then measures the total number of steps in one revolution of the tracker. Upon completion of the test compare the steps/revolution value to the original steps/revolution value in the Final Test Record for the particular Brewer. The number should be approximately 14660. Record the steps/revolution value in the Brewer Operations Log and the electronic log. If the indicated number and the original value differ by more than ±20 steps, it may indicate the friction wheel is slipping and needs to be cleaned or that the springs need to be tightened.

- ❑ **Cover the UV dome and quartz window.**

- ❑ **Power off Brewer and tracker. Remove 3 circular connectors and 4 hex bolts from the Brewer. Cap outside cables. Replace any missing caps.**

- ❑ **Remove Brewer from tracker.**

Setup the brewer and computer to communicate inside a building. This will protect the internal components while doing maintenance.

- ❑ **Reroute internal amplifier to short cable configuration if necessary. Establish communication between Brewer and computer.**

- ❑ **Check the EPA identification numbers, the serial numbers and any other identification numbers of the equipment. Fill out calibration report.**

In the blank calibration report, a list of information blanks are provided to record needed information on the computer and other equipment on site. The Brewer Computer will have the manufacturer issued serial number but can also have a UGA and/or EPA issued serial number. Please record both in the report.

- ❑ **Re-Check the Zenith Prism Alignment (ZE, B2, B0).**

Type "ZE" and wait until completion and then "B2". Then look into the iris viewport. The light image should be centered over the middle of the iris. If the image was aligned before moving the instrument but it is misaligned now an adjustment to the alignment should be made before performing the spectral response calibration.

- ❑ **Oil Gear.**

The middle gear between the motor and the zenith gear has an oil hole. Rotate the zenith upwards until this oil hole is pointing to the ceiling. Place a drop if 3-in-1 oil in the hole. Take care not to rotate the zenith drive into the hardstop, which can cause the zenith prism to become misaligned.

- ❑ **Inspect the zenith gear tab for signs of looseness.**

Check all zenith gears and tabs for looseness.

- ❑ **Clean zenith prism and UVB prism with alcohol and kimwipe.**

- ❑ **Check the Zenith Prism Alignment (ZE, B2, B0)**

Recheck Zenith prism alignment to verify that it is in the same position.

- ❑ **Check the mercury count values found in Hgoavg. This should be done before you go on the trip. Change Mercury bulb is necessary.**

If the mercury counts are falling and are below 100,000 counts replace the HG bulb. Follow the SOP on diagnosing and replacing mercury bulbs.

- ❑ **Give "FR" command at Brewer Home screen.**

Open spectrometer box and record micrometer position in mm's. Record the position in the log pages

- ❑ **Perform "HG" calibration.**

Look for peak photon counts at step 15. Several iterations may take place. After completion of the scan open the spectrometer box and record the position of the micrometer in mm's in the log book.

- ❑ **Clean and grease micrometer, pushrod, and end bearing.**

- ❑ **Follow SOP for replacing micrometer and drive shaft.**

- ❑ **Follow SOP for correct positioning of micrometer.**

- ❑ **Check the electrical readings using the voltmeter from the 50W lamp kit.**

Record each reading in the blank calibration report.

- ❑ **Run Diagnostic Scans (HG, SL, RS and DT)**

At home screen, type "PNHGSLRSDT". "PN" causes the output of each scan to be written in the D?????.### file. (????? = day, ###= brewer number).

- ❑ **Run the shutter motor (SH) diagnostic scan.**

Do not type any other command with "SH". 40 = minimum time delay 140= maximum time delay 2= increment.

- ❑ **Check diagnostic readings.**

At home screen , type "end_day". Open D?????.### and check the results of each diagnostic scan.

- ❑ **Perform spectral response calibration.**
  - ❑ Place metal dome covering over the UVB dome.
  - ❑ Place field calibrator housing on top of the brewer.
  - ❑ Place lamp alignment jig in lamp holder
  - ❑ Screw thick alignment rod into metal dome covering. Make sure crosshairs on the alignment jig are directly over the center of the rod. Remove rod and covering.
  - ❑ Take thin metal 50 cm rod and measure from the highest metal ridge on the dome to the closest post of the alignment jig. The top of the rod should just barely touch the jig. If the jig is not the same on either side, try to average the distance.
  - ❑ Place the black shroud around the housing.
  - ❑ Screw large circular connector into housing.
  - ❑ Replace lamp jig with lamp making sure the metal plate on the lamp is facing away from brewer.
  - ❑ Clean lamp with kimwipes and methanol.
  - ❑ Clean UVB dome with kimwipes and methanol.
  - ❑ Put top of housing in place. Be sure it fits snugly all the way around.
  - ❑ Plug fan cord into fan.
  - ❑ Make sure power supply is in the off position.
  - ❑ Plug PS and DMM into 3 wire extension cord. Then plug the extension cord into the wall, making sure fan on the housing is on. If possible plug the Brewer and the lamp circuitry into a different circuit than the lamp power supply as both devices may cause the circuit breaker to flip.
  - ❑ Switch power supply and multimeter on.
  - ❑ Slowly ramp power up until the desired voltage appears on the multimeter. Record lamp-on time in the log pages and lamp burn log sheet. Or use automated program.

- ❑ Record information on log sheets and on the lamp burn log sheet.
- ❑ Align the background rod inside the housing over the UVB dome.
- ❑ At home screen, type "PNHGXL".
- ❑ Frequently check the voltage.
- ❑ When home screen appears again, remove background rod.
- ❑ Type "HGB1XLHGXL".
- ❑ When home screen appears again, ramp power down and open the black shroud at the bottom to draw air through the housing to cool the lamp. Record lamp-off time.
- ❑ Repeat process for second lamp. There is no need to realign the lamp on the second lamp unless there is some reason to suspect that the lamp mount has moved.

## ❑ Check inventory of parts and electronic boards

Record all parts and supplies in the blank calibration report.

## ❑ Perform any major adjustments to the instrument as determined necessary. Follow the appropriate SOP's.

- ❑ High voltage check and optimization.
- ❑ Adjustment to spectrometer shutter and mirror.

## ❑ Install a humidity sensor.

Follow the instructions provided from Scitec.

## ❑ Perform a final spectral response calibration if major adjustments to the instrument were required.

## ❑ Check the leveling on the tracker.

The tracker level test is performed whenever there is reason to believe that the Brewer platform level has changed or has been compromised. The indicator of mis-leveling is if the solar alignment tests are consistently off. Perform the level test with the tracker power off. In this condition the tracker may be manually turned through one revolution.

Place the carpenter's level on top of the tracker case. Note the position of the level bubble. The bubble does not necessarily indicate that the tracker case is level; this test challenges only the tracking mechanism. Observe the level bubble as you rotate the tracker to see if it changes position. If the level bubble changes position during the rotation this indicates that the Brewer is not leveled properly. The leveling is adjusted by loosening the bolts on the tripod feet and turning the screws with a flathead screwdriver. Return the tracker to the original position so that the ground strap does not wrap around the tracker post. Record any changes to the log book and electronic log.

## ❑ Clean tracker friction wheel and check the tensions on the friction arm (9kg on the lower spring and 4 kg on the upper).

Open up the back of the tracker. Clean the tracker wheel and drive rod. Test the strength of the springs holding the friction arm.

## ❑ Check the tracker kill switch.

The toggle switch inside the tracker should have a fishing line tied to it which is secured to the tracker post via a clamp. The line should have enough slack to allow the tracker to turn just more than 360 degrees in the CW direction (when looking down on the unit). If an adjustment needs to be made to the length of the fishing line a screw driver can be used to loosen the clamp holding the line to the post. The line can then be swiveled until it pulls the toggle switch at about 400 degrees.

## ❑ Update the response file. There is a detailed SOP for creating a RES file. Below are basic instructions;

- ❑ When lamps are done, at home screen, type "shell".
- ❑ Then copy the xl file (xl?????.###) to a floppy drive then to the laptop.

- ❑ Process the data through "Rx.exe".
- ❑ Copy the PXL?????.### that the Rx.exe file outputted into the RES?????.###.xl file. Process the data using lamp irradiances and compare the lamp data together and with the previous response data.
- ❑ If all is well, average the two lamps scans together and save in a space delimited file named ("RES?????.###").
- ❑ To do this, copy the averaged data to another page with the corresponding wavelengths in angstroms. Insert a blank column between the wavelength column and the data column. Save the worksheet. Then SAVE AS... then select (formatted text (Space delimited)) and put quotation marks around the file name, then okay to all questions.
- ❑ Copy the resultant RES file to C:\bdata\### on the brewer computer.
- ❑ Update the "op_st.###" file to reference the new RES file.
- ❑ Reboot computer.

**❑ Run 50 watt lamp calibrations**

Setup 50 watt lamps as always and type "PNHGQSTUXL" at the home screen.
Frequently check the voltage.

**❑ Move the newest 50 Watt lamp data to the top of the document.**

After each lamp scan, type "shell" at home screen and edit C:\bdata\lamp_***.###. (***=lamp number) Copy the last line, which should start out with the current day's date, to the top of the file.

**❑ Change desiccant packs. Add fresh silica gel to breather tube and spectrometer tube.**

**❑ Check micrometer position.**

**❑ Move Brewer back on tracker.**

Restore the brewer and computer to the usual operating configuration.

**❑ Run another SR.**

**❑ Give commands "WSWQ" followed by "WDWX".**

Type these two separately.

**❑ Perform another sun sighting (SI).**

**❑ Check the Zenith Prism Alignment (ZE, B2, B0).**

**❑ Log actions in the comments file (CO).**

**❑ SKC; EPA96D.**

**❑ Upon return to UGA,**

- **❑ Fill out lamp burn time log sheet**
- **❑ Fill out CT worksheet**
- **❑ Spectral response Calibration data worksheet.**
- **❑ Plot data from time of first calibration to time of second plus 20 days beyond to look for any odd post-calibration results.**
- **❑ Inform diagnostic technician of new calibration date for instrument to be used in 50W lamp analysis.**
- **❑ Deliver all response, op_st and ICF files to the data manager.**

Appendix B

# Procedure for performing a vertical to horizontal irradiance transfer of FEL type 1000 Watt lamps in the NUVMC Laboratory

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**Document 12**
**Revision B**

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National
Ultraviolet
Monitoring
Center

## Introduction

1000 Watt lamps calibrated by the National Institute for Standards and Technology (NIST) are used as primary standards for the calibration of 1000 Watt lamps of unknown spectral irradiance. These secondary lamps are used regularly as traveling standards by NUVMC for Brewer spectrophotometer calibrations. The NIST lamps were calibrated in the vertical orientation but to calibrate a Brewer spectrophotometer it is most convenient to burn the lamps in the horizontal orientation. Since the output of a 1000W lamp changes slightly with orientation due to cooling and gravity effects, it is necessary to "transfer" the irradiance of a vertical NIST lamp into the horizontal direction to obtain the irradiance of the unknown 1000W lamp.

### Equipment

1. Swivilling alignment arm for positioning 1000W lamps into the vertical and horizontal orientations. Custom designed and machined by UGA machine shop.
2. X-Y-Z translation stage for mounting 1000W lamp mount to adjustable arm.
3. *SPEX* 1680B monochromator.
4. Specially designed mounting stand for *SPEX* monochrometer.
5. NM-23-6 integrating sphere.
6. Fitting port for the *SPEX* to mount the integrating sphere. Custom designed and machined by UGA machine shop.
7. Custom designed target plate with crosshairs for integrating sphere entrance port.
8. *Philips* XP2254B photomultiplier tube.
9. *Product for Research* cooled PMT housing and power supply.
10. *Newport* 271 lab jack to support PMT and housing.
11. *Stanford Research System* PS350 high voltage power supply for PMT.
12. *Stanford Research System* SR445 quad-preamplifier.
13. *Stanford Research System* SR400 photon counter.
14. 10MHz cutoff high-pass filter.
15. *UPS* power line conditioner/surge suppressor for AC power.
16. *Xantrex* XHR 150-7 power supply, modified for 8.3 Amp max output with RS232 comm port.
17. *Hewlitt Packard* digital multimeter with RS232 comm port.
18. *Tinsley* 10 mili-Ohm shunt (RUG-Z-R010-0.1).
19. Hand held DMM for reading lamp voltage.
20. Standard 50 cm alignment rod.
21. *Gamma Scientific* 5000-17 alignment jig.
22. Custom black box for shielding *SPEX* monochrometer from 1000W lamp.
23. Black cloth for shielding PMT from 1000W lamp and for covering optical table.
24. NIST calibrated 1000 Watt lamps.
25. Uncalibrated 1000 Watt lamps.
26. Low pressure mercury lamp.
27. A PC running Windows 3.1 with QBASIC compiler and data acquisition program, with 2 comm ports.
28. A PC running the "lamp stabilizer" program, with 2 comm ports.
29. Optical table.
30. Water supply and drain for cooling the PMT housing.
31. Sufficient 120 Volt AC power sources for running electronic equipment.

32.Two office fans for cooling electronic equipment.

Manuals for all equipment used in this calibration procedure should be consulted whenever there is a specific question pertaining to that instrument.

**Purpose**

The purpose of this procedure is to obtain irradiance values for FEL type 1000 Watt lamps to be used in the horizontal orientation for spectral response calibrations of spectrophotometers.

**Procedure-General Precautions:** There are several precautions that should be observed to maximize the success of the irradiance transfer procedure.

1. All of the electronic equipment should be given a substantial warm up period. Twelve hours should be sufficient time for the equipment to equilibrate.

2. Be aware of the instruments tendency to "drift". To avoid having unwanted instrument drift hidden in the data the transfers should be performed without long delays between lamp burns. The NUVMC technique to reduce this problem is to run the NIST standard lamps at the beginning and the end of the day and use an average of these values when calculating the irradiance of the traveling horizontal standards.

3. The 1000W lamp power supply and the digital multimeter should draw current from a source other than that used for the rest of the equipment. If too much current is drawn a circuit breaker may flip during the measurement, which can potentially cause damage to the lamp.

4. The alignment of the 1000W lamps with respect to the integrating sphere entrance port should be very precise, especially with respect to the z-axis, in order to provide the best possible lamp irradiance results.

5. Take care that the lamp is installed with the correct polarity each time. The positive current from the 1000W lamp power supply should always be connected to the positive lead on the 1000W lamp. The output of the 1000W lamp changes if the current flows in reverse through the lamp.

6. Take precautions to reduce reflected light from the 1000W lamp in the laboratory. Any shiny metal surfaces or white objects should be covered so as to reduce the amount of reflected light. The stray light should not exceed 1.0% of the total light during the experiment. The NUVMC uses a room with walls painted flat black and also covers the optical table with black cloth. Initial testing of the background signal should be performed in both the vertical and horizontal burn orientations. The background rod size and placement should be designed into the setup to be repeatable.

7. The mercury discharge lamp used for the wavelength calibration of the *SPEX* monochrometer creates ozone molecules in the laboratory. If precautions are not taken it is possible for the ozone to accumulate inside the integrating sphere.

Since ozone absorbs UV radiation the UV light from the lamp will be absorbed and will therefore produce errors in the irradiance transfer calibration. The NUVMC places the HG lamp approximately six inches from the entrance port of the integrating sphere and places an office fan on the optics table to blow air away from the integrating sphere while the lamp is on. Lamp on time is kept to a minimum.

**Procedure-Instrument Setup**: A diagram of the equipment layout can be seen in Figure 1. The equipment is normally left set up in the laboratory between calibrations so the following steps may not need to be performed each time.

1. Place the custom stand for the *SPEX* monochrometer on the optics table.

2. Set the *SPEX* monochrometer onto the specially designed stand so that the three spectrometer legs mate into the holes on the stand's posts.

3. Secure the stand to the optical table via the angle brackets so that the spectrometer is aligned approximately square with respect to the optical table.

4. Mount the integrating sphere to the entrance port on the side of the *SPEX* monochromator. A special fitting was machined so that the sphere can be rotated 90 degrees to view the 1000W lamp in both the vertical and horizontal positions. The sphere locks in position via two $^{7}/_{64}$" hex head set screws.

5. Mount the PMT housing to the exit port of the *SPEX* monochromator via the mounting plate with four bolts.

6. Place the lab jack underneath the PMT housing to provide support. Be sure the jack is not lifting the spectrometer off of the mounting plate.

7. Carefully insert the PMT into the housing and lock it down with three screws. Avoid exposing the PMT window to bright light.

8. Wrap black cloth around the PMT housing to reduce the amount of stray light entering the tube.

9. Place the black thermally insulated box over the *SPEX* monochrometer to shield it from the direct beam of the 1000W lamp.

10. Place the PMT high voltage power supply, the PMT cooled housing power supply, the photon counter and the pre-amplifier underneath the optical table to avoid exposure of the equipment to the 1000W lamp light during the calibration.

11. Mount the swiveling lamp alignment arm to the optics table oriented such that the lamp can be positioned 50 cm from the entrance port of the integrating sphere in both the vertical and horizontal orientations.

12. Connect the lamp mount to the alignment arm via the mounting plate and two bolts.

**Procedure-Instrument Wiring**: Figure 2 shows a wiring schematic of the instrument layout.

1. Connect the PMT housing cooler power supply to the cooled housing via the circular connector.

2. Connect the two thermistor wires to the underside of the PMT housing near the front of the unit. These wires monitor the temperature of the cooled housing.

3. Use a coaxial high voltage cable to connect the PMT high voltage power supply to the input (cathode) of the PMT.

4. Connect the output (anode) of the PMT to the first channel input of the preamplifier using coaxial high voltage cable.

5. Connect channel one output of the preamplifier to the second channel input of the preamplifier with a high voltage coaxial cable.

6. Connect the second channel preamplifier output to the 10M Hertz high pass filter with a high voltage coaxial cable.

7. Connect the output of the 10M Hertz high pass filter to the "Signal, Input 1" connector on the front of the photon counter via a high voltage coaxial cable.

8. Connect the water input of the PMT cooler housing (the top tube) to the water source via a rubber hose.

9. Connect the water output of the PMT cooler housing (the bottom tube) to an appropriate water drain via a rubber hose.

10. To provide proper cooling the water should be set to flow through the system at about two liters per minute. This rate is highly dependent on the temperature of the water. The temperature of the PMT housing should be observed for an hour or so prior to taking data and if the temperature does not meet the –38.5° C requirement the water flow should be increased.

11. Plug the PMT high voltage power supply, the preamplifier and the photon counter into the UPS power line conditioner/surge suppressor.

12. Plug all of the equipment into a 120 Volt source. Choose a circuit that does not have an existing load, and in particular a circuit other than the one which will be used for the 1000 Watt lamp power supply. This will ensure that the circuit breaker does not flip during the irradiance transfer calibration.

13. Connect the positive lead of the *XANTREX* power supply to the positive lead of the 1000W lamp mount using a 12 gauge wire. The NUVMC has a wiring harness designed specifically for the irradiance transfer setup.

14. Connect the negative lead of the 1000W lamp mount to a post on the shunt

using 12 gauge wire.

15. Connect the negative lead of the power supply to the second post on the shunt using a 12 gauge wire.

16. Connect the voltage leads on the shunt to the voltage inputs of the DMM. This connection will read the voltage across the shunt, which is used to calculate the current of the circuit.

17. Connect the positive and negative posts of the lamp mount to the inputs on the hand held DMM. This connection will read the voltage across the lamp and is used to determine the stability of the lamp.

18. Plug the *XANTREX* power supply and DMM into a 120 volt source. Do not use the same electrical circuit as is being used to power the photon counter, preamp, PMT high voltage supply and PMT cooler housing.

19. Connect a null modem 25 pin serial cable from the *SPEX* monochrometer to the com 2 port on the controlling computer.

20. Connect a 25 pin serial cable from the photon counter output to the com 1 port on the controlling computer.

**Procedure-Configuration of *SPEX* Controlling Computer**

1. Initiate the *SPEX* monochrometer with the controlling computer. The "dumb terminal" mode should be used to establish communication between the computer and *SPEX*.

2. In the "terminal mode, under the "Settings/Communications" menu set "com=2", "baud=19200", "data=8 bits", "stop bit=1", "no parity" and "no flow control". Click "OK" to activate the settings.

3. When the computer returns to the "Terminal" window press <space bar> several times to get the *SPEX* monochromator greeting screen. For detailed information on communicating with the *SPEX* monochromator via the operating software, see **Appendix A**.

4. Create a new directory on the controlling computer and copy the most recent version of the data acquisition program and QBasic compiler into this directory. The NUVMC normally uses the naming convention "MMMYY", where "MMM" represents the month and "YY" represents the year.

5. Run the QBasic compiler from this directory.

6. Open the data acquisition program by selecting "Open" under the "File" menu and selecting the name of the program from the list.

7. Run the data acquisition program by selecting "Start" under the "Run" pull down menu.

**Procedure-Equipment Operating Parameters**

1. NIST Calibrated 1000 Watt lamps; Operating current 8.2 A in the vertical orientation.
2. Uncalibrated 1000 Watt lamps; Operating current 8.2 A in the horizontal orientation.
3. *SPEX* monochrometer slit size; 0.5 mm for entrance and exit slits.
4. PS350 high voltage PMT power supply; Operating at -2250V.
5. Refrigerated PMT housing; Cooled to -38.5°C.
6. SR445 Preamplifier; Channels one and two used.
7. SR400 Photon counter; "Channel *A disc level=* -20.0 mV", "*A disc slope=* falling edge", "T preset=1 second". Connected to PC com port 1; settings: 19,200 bit/s, no parity, 8 bit data, and 2 bit stop.

**Procedure-Vertical Lamp Alignment:**

1. Rotate the alignment arm to the lower position i.e., such that the 1000W lamp can be mounted in the vertical orientation.

2. Rotate the integrating sphere such that the integrating sphere entrance port is facing the vertically aligned 1000W lamp.

3. Align the integrating sphere port exactly perpindicular to the optics table using a 90° carpenters square. Lock the sphere via the two $^{7}/_{64}$" hex head set screws.

4. Mount the arm which holds the diode laser onto the lamp alignment arm such that the laser is pointing toward the entrance port of the integrating sphere.

5. Tape a microscope slide to the entrance port of the integrating sphere, perpendicular to the optics table. This will aid in aligning the sphere port perpendicular to the 1000W lamp.

6. Place a piece of cardboard with a pin hole in front of the laser beam. Adjust the laser so that the reflected beam from the microscope slide comes back to the hole in the cardboard or very near to it.

7. If the alignment cannot be made it may be necessary to swivel the base plate on which the *SPEX* monochrometer is mounted. Alternatively the alignment arm can be readjusted on the table to change the angle of the lamp with respect to the integrating sphere. When the alignment is properly made, remove the microscope slide from the sphere.

8. Place the cross haired target plate inside the integrating sphere entrance port. Slide the laser up or down in the laser mount to align the laser incident on the target plate cross hairs. Take care not to change the angle of incidence of the laser on the target plate. The angle can be rechecked by following the previous step if need be.

9. Place the alignment jig in the lamp mount and align the jig using the x-y positioning of the translation stage so that the laser beam is centered on the jig crosshairs.

10. Place the standard 50 cm rod inside the entrance port of the integrating sphere such that one end rests on the inside flange. Use the Z positioning of the translation stage to align the bottom of the alignment jig 50 cm from the sphere.

11. If the alignment arm is positioned properly with respect to the *SPEX* monochrometer the alignment jig will now be positioned such that all surfaces are the same distance from the entrance port of the integrating sphere. If all sides of the alignment jig are not of equal distance from the entrance port of the spectrometer the lamp alignment arm of *SPEX* base plate may need to be repositioned on the table. This will affect the previous alignments and they will therefore need to be rechecked. It may take several iterations of the alignment procedure to get all the parameters within tolerance but once the alignments are set correctly they should remain undisturbed for future calibrations.

12. After all alignments are made satisfactorily the alignment jig can be removed from the lamp mount.

**Procedure-Vertical Lamp Scan**

1. Place the first 1000W lamp to be burned in the vertical position into the lamp mount. Be sure that the positive lead of the lamp is set in the positive lead of the lamp mount. Normally the face plate on the lamp base is oriented away from the integrating sphere. Note that mounting the lamp backwards will run electric current through the lamp in the reverse direction which affects the irradiance of the lamp.

2. Use a lens tissue and spectroscopic grade methanol to clean the quartz envelope of the lamp.

3. Verify that the laser beam is incident approximately on the center of the lamp filament.

4. If the alignment appears to be correct the laser arm can be removed from the alignment arm by removing the four screws.

5. Place a mercury discharge lamp at least six inches away from the front of the integrating sphere entrance port. Setting the lamp too close to the sphere may cause ozone to accumulate inside the sphere which will have adverse effects on the collected irradiance data since ozone absorbs UV radiation.

6. Set a small office fan on the optics table blowing air away from the entrance port of the integrating sphere to keep ozone from entering the sphere.

7. Turn off the lights in the laboratory. The NUVMC setup is in a subroom of the main room so a small office lamp is used inside the main room during the calibration.

8. Turn on power to the *XANTREX* power supply and DMM. Initiate the current control program "lamp stabilizer". The input settings are; baud =9600, lamp=?, shunt # =?, log file format = "logdddyy.###", where ddd =Julian day, yy =year and ### =lamp number.

9. Print out a copy of the lamp burn log in the Figures section of this document and record the information such as serial numbers of equipment and lamp on

and off times. This information should be updated to the electronic log stored on the NUVMC Mabel/Shared directory after the measurements are finished. It is important to keep track of the total lamp burn times for archival purposes.

10. Press "Enter" to ramp up the current to the lamp. The automated program uses the RS232 comm port on the multi-meter to sample the shunt voltage about once per second and make adjustments to the power supply to maintain the circuit current at 8.2 Amps. An electronic log file with current and shunt voltage is written.

11. Insert the background rod between the 1000W lamp and the integrating sphere such that a shadow is cast over the entire entrance port. Testing to ensure that the background signal is less than 1% of the full signal should have been carried out as independent testing prior to the irradiance transfer calibration.

12. Once the data acquisition program has been initiated as in the "Configuration of *SPEX* Controlling Computer" section of this procedure, the user will be prompted to input the dial setting displayed on the side of the *SPEX*. Add one to the dial readout and enter this number into the computer. Note; a wavelength accuracy alignment was performed on the *SPEX* monochrometer during the summer of 2002 following the procedure in the instrument manual. However there is still a small discrepancy between the dial readout and the actual wavelength.

13. The user will then be prompted for a new data filename. The filename convention "n-dddyy.###" is typically used, where "n" = the number of times the lamp has been scanned that day, i.e. 1, 2, 3..., "ddd" is the three digit Julian day, "yy" is the two digit year and "###" is the FEL lamp number.

14. The user will then be prompted to choose to perform a mercury line calibration. Typically a new mercury calibration is always performed prior to each FEL lamp scan to ensure proper wavelength accuracy.

15. After successful completion of the mercury scan immediately turn off power to the HG lamp to avoid producing ozone in the laboratory. Move the lamp away from the optical path of the monochrometer and set it aside for use in the next scan.

16. Move the desk fan that was blowing ozone away from the integrating sphere entrance port off of the optics table. This fan may be used to blow on the electronic counting equipment to ensure that it is properly cooled.

17. Allow the 1000W lamp to warm up for 30 minutes prior to beginning the background scan. Monitor the lamp and the shunt voltage and make adjustments to the lamp output as needed.

18. Enter the 1000W lamp number into the SPEX controlling computer and press Enter to begin the background scan.

19. When the background scan is completed the computer will prompt the user with a beep to remove the background rod and begin the signal scan.

20. Begin the signal scan by pressing the Enter key. Continue to monitor the lamp and shunt voltages, making small adjustments to the current control knob on the lamp power supply as necessary to keep the lamp operating at 8.2 Amps.

21. The current version of the irradiance transfer program takes ten count cycles at each wavelength from 270 to 370 nm in 10 nm increments. Five sub-scans are performed. This yields 50 data points at each wavelength to be averaged in the final calculations.

22. When the signal scan is completed the computer will prompt the user if another scan is desired. If so press "y" to continue with the program. If no more scans are needed, press "n" to abort the data acquisition program.

23. Power down the current to the lamp by pressing the "Q" key on the lamp controlling computer.

24. Allow the 1000W lamp to cool for several minutes before attempting to remove it. A small office fan blowing on the lamp will greatly reduce the amount of cooling time required.

25. While the lamp is cooling the mercury lamp should be turned on for a three to four minute warmup.

26. For each lamp to be burned in the vertical position repeat steps 1 through 25 in this section of the procedure.

**Procedure-Horizontal Lamp Alignment**

1. After all lamps have been burned in the vertical position the alignment arm can be rotated to the horizontal burn position. There is a screw knob to lock the arm in the horizontal position.

2. Rotate the integrating sphere 90° to view the lamp in the horizontal position by loosening the two hex bolts and swiveling the sphere in the mount.

3. Level the sphere with respect to the Earth by placing a small bubble level on top of the entrance port. Lock both set screws to securely fasten the sphere in the mount.

4. Follow steps 4 through 12 in the Vertical Lamp Alignment section to align the 1000W lamp with respect to the integrating sphere. The idea is to have all alignment parameters in the vertical and horizontal positions identical.

**Procedure-Horizontal Lamp Scan**

1. Follow steps 1 through 25 in the Vertical Lamp Scan section for each lamp to be burned in the horizontal position.

**Procedure-Data Analysis**

1. After all scans are completed for the day the data files should be copied off of the *SPEX* controlling computer to a machine with MS Excel or some similar data analysis spreadsheet program.

2. Copy each of the text files into one spreadsheet for ease of documentation of

the data. Each scan can be saved as a separate worksheet within the MS Excel file.

3. For the first 1000W lamp calibrated, plot the mercury scan data and verify that the peak count occurs at the 296.76 nm position, plus or minus one step.

4. Plot the counts as a function of cycle number at 270 nm and 370 nm for the five subscans. Check for linearity of the counts with time. If excessive ozone was produced and collected inside the integrating sphere during HG calibrations, the counts will increase with each successive subscan at 270 nm but the counts will remain linear with time at 370 nm.

5. Average the counts from the ten cycles at each wavelength for the background scan and each of the five sub scans.

6. Average the counts at each wavelength for the five subscans to produce one set of averaged photon counts as a function of wavelength.

7. Calculate the percent background of the signal scan at each wavelength. The background should remain less than 1% of the signal scan at all wavelengths. Generally the percent background is higher in the vertical lamp orientation than in the horizontal orientation for the NUVMC irradiance transfer setup.

8. Subtract the background counts from the signal scan counts at each wavelength to produce the final photon count values as a function of wavelength to be used in the irradiance calculations.

9. Repeat steps 3 through 8 for each lamp scanned for the day.

10. Compare the photon counts of the NIST lamps from the beginning to the end of the day. The percent difference in the counts will reflect the accuracy of the alignment of the 1000W lamp, the stability of the lamp power supply and counting circuitry and the repeatability of the spectrometer.

11. Determine if any of the NIST lamps gave bad results by plotting the ratio of the counts of two lamp and the ratio of the given irradiance values for the same two lamps. Theoretically the ratio of the counts should match the ratio of the irradiance values for any two lamps.

12. Decide if any of the data from the NIST lamps should be discarded due to anomalous values.

13. For each one of the NIST lamps selected as good data, average the photon counts as a function of wavelength from the beginning of the day and end of the day scans.

14. Calculate the irradiance as a function of wavelength of each traveling standard lamp by using the ratio technique;

    $$Irradiance_{unknown} = (Irradiance_{NIST}/counts_{NIST})*counts_{unknown.}$$

    The NIST irradiance values are provided with purchase of the calibrated lamp in Watts per $cm^2$.

15. The preceding step will yield "n*m" sets of irradiance values where n=total

number of unknown lamps and m=total number of NIST lamps.

16. For each unknown lamp average the sets of irradiance values calculated using the various NIST lamps. This will produce "n" sets of irradiance values.

17. Calculate the percent change since the last calibration in the calculated irradiance values of the traveling standard lamps. Plot the percent change values as a function of wavelength for each lamp. Generally the NUVMC finds a 1 to 2% change in the lamp irradiance over a six month period. This is within the error of the measurement.

18. Fit a $6^{th}$ order polynomial to the calculated irradiance values. Note that a $6^{th}$ order polynomial fit is appropriate for interpolating the irradiance values of the 1000W lamp due to the structure of the blackbody curve determined by the Plank radiation law, $I(T)=2\pi hc^2/[^5(e^{ax}-1)]$, where a=hc/kT and x=1. When the denominator of the Plank expression is expanded is present in the first 6 terms.

19. Choose to display the equation on the chart. Highlight it to change the number setting to "scientific" with 15 decimal places.

20. Use the fitting equation to interpolate the irradiance values from 286.5nm to 363nm in 0.5nm increments.

21. Convert the wavelength unit from nm to Angstroms to produce irradiance values as a function of wavelength from 2865 Å to 3630 Å in 5 Å increments. This matches the range and step size of a Brewer full sky UV scan (UX scan).

22. Calculate the percent change since the last calibration in the extrapolated irradiance values of the traveling standard lamps. Plot the percent change values as a function of wavelength for each lamp. This step is similar to step 17 above but will highlight any possible errors in fitting the polynomial to the data.

23. Disseminate the final irradiance values of the traveling standard lamps to the calibration technician for use in calculating the spectral response of Brewers during the site visits.

24. Document the MS Excel file appropriately and create a summary report of the irradiance transfer calibration.

**For further information or advice concerning this SOP please contact the NUVMC at the University of Georgia at http://oz.physast.uga.edu**

**Figure 1. Schematic of 1000W Lamp Irradiance Transfer**

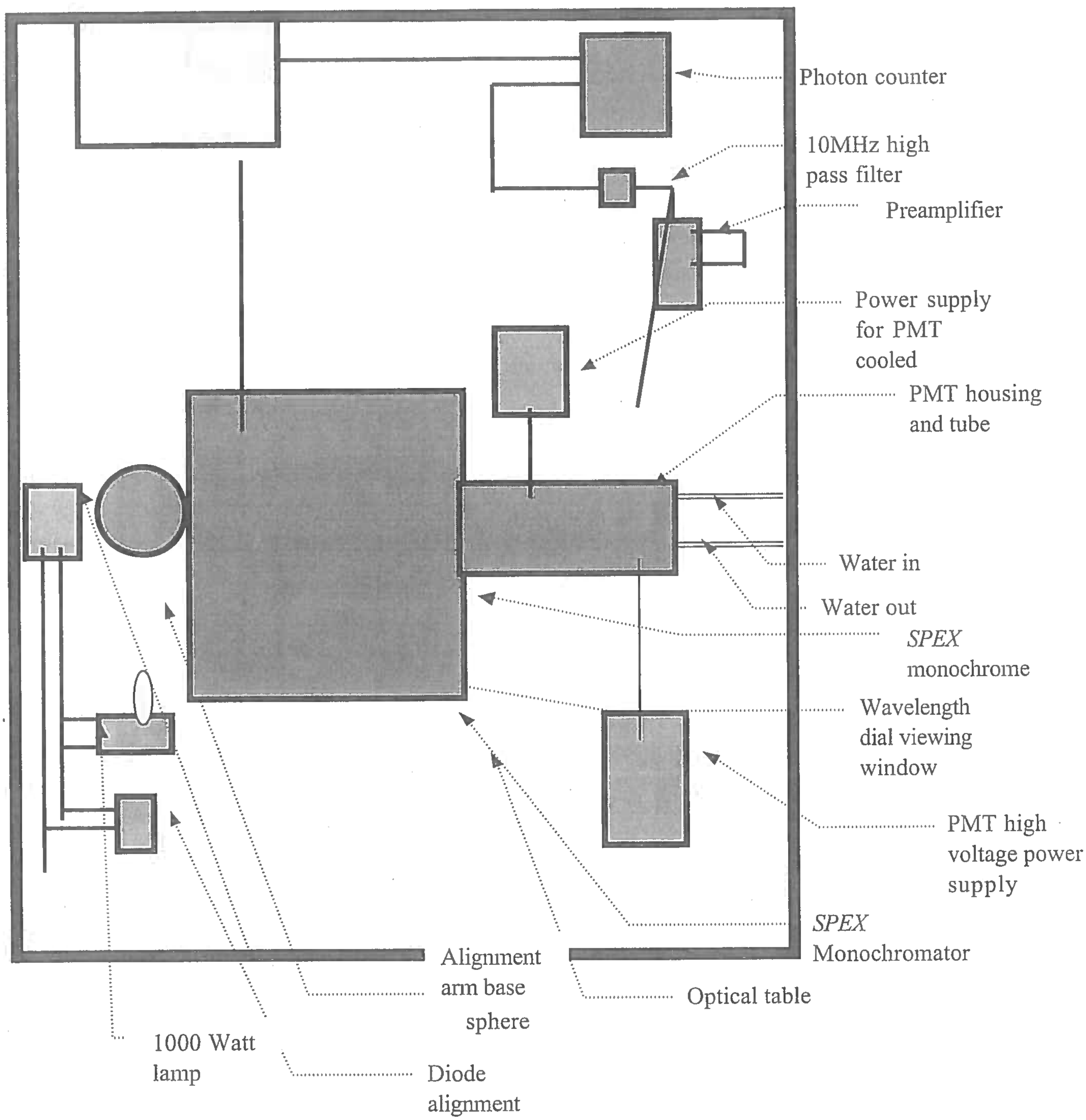
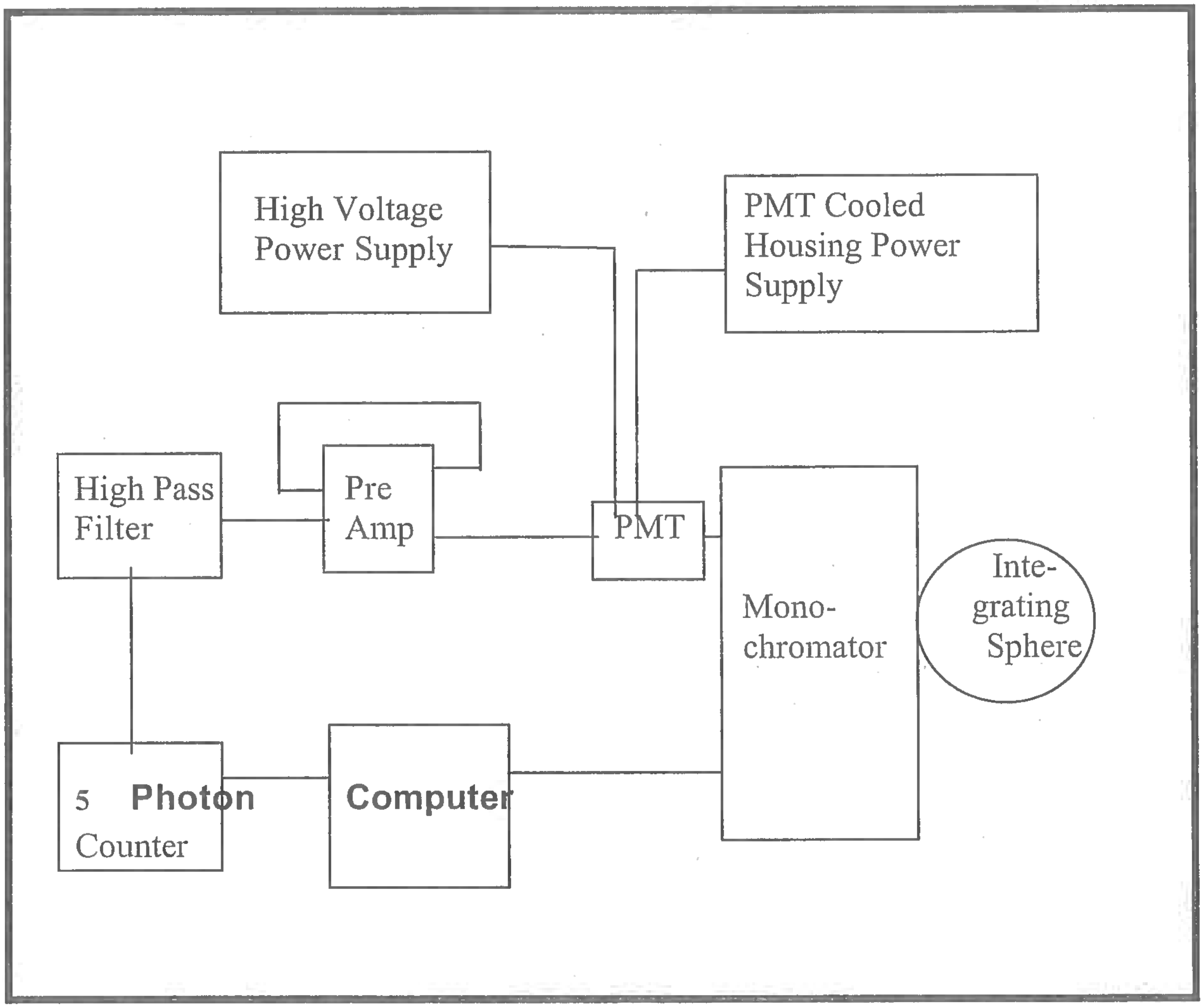

Photon counter
10MHz high pass filter
Preamplifier
Power supply for PMT cooled
PMT housing and tube
Water in
Water out
SPEX monochrome
Wavelength dial viewing window
PMT high voltage power supply
SPEX Monochromator
Optical table
Alignment arm base sphere
1000 Watt lamp
Diode alignment

**Figure 2. Wiring Diagram for Vertical to Horizontal Irradiance Transfer**



# National Ultraviolet Monitoring Center

## Lamp Burn Log

| Lamp # | Date | Done by | Location | Multimeter | Power supply | Shunt | Housing | Instrument # |
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# Appendix A1: Communicating with the *SPEX* 1640B monochromator

## a. Description of the *SPEX* monochrometer:

*SPEX* representitives: Clément Remy (908) 494-8660 x114 or Kimberly Lopez x376.

*SPEX* 1680 B spectrometer
Serial Number: 1953
UGA Control Number: 477295.

| | |
|---|---|
| Dispersion | 1.8 nm/mm |
| Resolution | 0.2 nm at 500 nm |
| Repeatability | ± 0.2 nm |
| Aperture | f/4 |
| Spectral range | 185-900nm |
| Accuracy | 0.4 nm |

Gratings catalog # 3006-300A, 300groves/mm, 300 nm blazed, serial # 1129.

Entrance and exit slits measurements; Ports, 2.75" OD, 1.875"ID. Four 6-32 screws distances at 2.375".

Panel Limits: high limit =1056.6 nm, low limit =9964.6 nm. The low limit means that the number will go below 0 and go to 9964.6 nm on the counter on the front panel. An internal Large Stepper Drive (LSD) provides an electronic link to the outside world. Gratings can be rotated as small as 0.02 nm (1200 grooves/mm grating).

The included angle is 30 degrees. The monochromator type to the software is 6. For the entrance and exit ports, the side with the height limiter is the exit side, while the side without the limiter is the entrance side. The intermediate slit is not used anymore in the 1680B, although there are some more slits sent in from the manufacturer, but they have no mounting place. Perhaps they are provided for curing serious stray light problems. Since the grating has 300 grooves/mm the dispersion will be 7.2nm/mm. To obtain the actual wavelengths the readings on the front panel should be multiplied by four for the first order and multiplied by two for the second order.

## b. Communicating through a Dumb Terminal:

Hook the monochromator to either com1 or com2, then set your terminal (in WINDOWS or other environments) to that port with baud=19.2K, data 8 bit, stop 1 bit and no parity.

After booting up the spectrometer press SPACEBAR and you should see:

* BOOT VER: V2.6! Press [ENTER]

After you press enter, you should see:

**!**!+ DIS Initialize! MONO1 MONO DRIVE! 0.000!+EDIT

Since the 1680B is not a self-calibrating spectrometer, you have to tell it where it is at by looking at the counter in the front of the monochromator. The last part is telling you that it thinks it's at 0.00 nm at this moment and is waiting for input. You can tell the monochromator where it is by issuing the *K* command. If the counter reads 200nm, type

K200 ENTER

to tell it where it's at. You will receive the following output:

**!** + !+ SCAN MENU **!**!+OPT ! MONO A SCN!+OPT 0

You are in the scan menu. Press ENTER and you will see the default settings of the scan. First ENTER gives you:

START nm +SCN A! 300.000 !+EDIT

Whenever you see +EDIT in the screen, you can input numbers. For example, it tells you that the starting wavelength of the default scan is 300.000 nm but you can change it to any number within the monochromators range.

Press ENTER again you see:

END nm +SCN A! 650.000!+EDIT

You can input the ending wavelength that you want to use. Press ENTER again and you see:

nm / SEC +SCN A! 5.000 !+EDIT

This is for setting the speed of the scan in nm/sec. Press ENTER one more time and you see:

TRIGGER +SCN A!+OPT 0! OFF !+OPT 0

You can turn the trigger on by input 1, but it is not needed for this calibration so just leave it turned off. Once this is all set, the following commands will let you operate the spectrometer.

Glossary of commands for the 1680B terminal communication

**A** This will trigger the above set scan. If the spectrograph is not in the starting wavelength, it will first go to the starting wavelength, taking care of the backlash, and scan. Like all *SPEX* spectrometers, it is accurate only when scanning from shorter to longer wavelengths.

**B** This command lets you choose where you want to set the spectrometer wavelength. For example, you can type B200 to set the spectrometer at 200 nm, but no decimal numbers will be accepted.

**C** This command and the D, E, and F commands lets you manipulate the fine calibration of the wavelength. You have to type one of them first (it doesn't matter which one), and then use any one, or any combination of them. By default, C will move the wavelength relative to the current wavelength by 1 nm.

**D** See C. Move 0.1 nm shorter side.

**E** See C. Move 0.1 nm longer side.

**F** See C. Move 1.0 nm longer side.

**I** This command gives you the current version of the hardware.

**K** Tells the monochromator what wavelength it is at. For example, K200 tells it it's at 200 nm, though in reality it can be anywhere. Always use numbers based on the 1200g/mm grating, or consistent with the front counter readings.

**S** Anywhere in the control, press S gives you the scan menu.

**T** Shows the turret status. It must be used after the C, D, E, or F commands. Then the options 0 and 1 change the grating. You have to press ENTER after the selection for the Turret change to take place.

**V** This gives you the function menu. There are 4 options:

- Option 0, the increments. press ENTER gives you the A increment. default is 5, which means that the C and F commands will move the spectrometer by 50 base steps, and the D and E commands are moving the spectrometer by 5 base steps. One base step in the 1680 is 0.02 nm for the 1200g/mm grating and 0.08 nm for the 300 groves/mm grating. You may want to use smaller increments for fine adjustment.

- Option 1, monochromator initialization. Press 0 for `no'. Press 1 for `yes'. This does not do anything to the 1680 since it is not self-calibrating, but it does change the current value to 0 nm no matter where it is really at.

- Option 2, config dev. This is for the configuration of devices. You will need this menu if you have changed something. A grating, for example.

- Option 3, device list. Will show you what's installed. All higher numbers are treated as 3.

All other letters not listed are treated as ENTER.

**c: Programs required to run *SPEX***

1. Qbasic compiler, "qb.exe";
2. "terminal.exe", which is already included in the Windows 3.1 software in location: C:\WINDOWS\ and is used to set up the baud rate of the *SPEX* monochrometer;
3. The *SPEX* data acquisition software program, "IRRJAN03.bas", which is attached below: This program has been modified but is based on the original "irrtran.bas" program.

```
DECLARE SUB scan (a())
DECLARE SUB cstep ()
DECLARE SUB calibration ()
DECLARE SUB delay (a!)
DECLARE SUB init ()
DECLARE FUNCTION count! ()

DIM a(16)
CLS
PRINT "this program is explicitly written for data taking"
PRINT "in the FEL lamp calibration procedure using"
PRINT "the SPEX 1680B monochromator and the SR 400"
PRINT "photon counter"
PRINT "it does not do autobauding so manual bauding through"
PRINT "the Windows terminal on com2 for the monochromator "
PRINT "to be done inititially"
PRINT "all parameters on the SR400 should be manually set"
PRINT "they are:"
PRINT "A channel disc level -20.0 mV"
PRINT "A disc on falling edge"
PRINT "T preset at 1 second"
PRINT "High voltage for XP2254B at -2250V"
INPUT " Press ENTER to continue", y$
CLS

 OPEN "COM1:19200,N,8,2,CS,DS,CD" FOR RANDOM AS #1
```

```
    OPEN "COM2:19200,N,8,1" FOR RANDOM AS #2
    CALL init
    PRINT #1, "      "
    PRINT #2, "    ";
    FOR i = 1 TO 11
    READ a(i)
    NEXT i

    WHILE (LOC(2) > 0)
    PRINT INPUT$(1, #2)
    WEND
    PRINT #2, CHR$(13);
    PRINT " Please be careful on the next input!!!"
PRINT "Read the wavelength (rounded to closest integer) from the
spectrometer side panel."
    PRINT "Input the number here: "
    INPUT LAMBDA$
    PRINT LAMBDA$
    ggg$ = "k" + LAMBDA$ + CHR$(13)
    PRINT #2, ggg$;
    CALL delay(.5)
    CALL cstep

200    CLS
    k = 0          ' # for blocked scan display
    INPUT "Enter New Data Filename: ( create one for each new lamp) "; n$
    OPEN n$ FOR OUTPUT AS #3

    PRINT " "
    PRINT "want new calibration? (y/n)"
    INPUT "needed as the program starts and first lamp is measured"; y$
    IF (y$ = "y") THEN CALL calibration

INPUT "Input lamp number"; y$
    PRINT #3, y$
    PRINT #3, DATE$; TIME$
    INPUT "starting background scan as FEL beam is blocked. Press ENTER
when ready"; y$
    PRINT #3, "dark scan"
    CALL scan(a())
    SOUND 1000, 50
    INPUT "Take out the shutter and press ENTER"; y$
 FOR k = 1 TO 5
 PRINT #3, "scan #"; k
 CALL scan(a())
 NEXT k
```

```
 CLOSE #3
b$ = "b280" + CHR$(13)  'put wavelength in final postion
 PRINT #2, b$
 CALL delay(15)
SOUND 2000, 100
PRINT " "
PRINT " Check the spectrometer position now"
PRINT " Is it very close to 68 ?"
PRINT " If not, There might be a problem in the last scan'"
PRINT " "
 INPUT "this scan finished. one more: y/n?"; y$
 IF (y$ = "y" OR y$ = "Y") THEN GOTO 200
 END
DATA  270,280,290,300,310,320,330,340,350,360
DATA 370

'Newtran.bas -by mou  Page 4

SUB calibration STATIC
DIM numbers(94)
    numb = 1
300      PRINT #2, "b293"; CHR$(13);
    CALL delay(15)
    Peak = 0: M% = 0:                ' y,x parameters for the peak
    FOR i = 1 TO 94    'scan 94 x 0.08 nm across 296.728 line'
        numbers(i) = count
        PRINT #2, "e"
        PRINT #3, 293 + .08 * i, " ", numbers(i)
        CALL delay(.5)
        IF numbers(i) > Peak THEN
            Peak = numbers(i): M% = i:
        END IF
        NEXT i
IF M% < 3 OR M% > 92 THEN
    PRINT " The Peak is too close to the spectral end"
    PRINT " The program is terminated."
    END
END IF

S% = (304 - 296.73) * 12.5 + M% - 94 'cal. steps to 304 nm at 0.08nm/step

    FOR i = 1 TO S%          ' advances to 304 nm
    PRINT #2, "e"
    CALL delay(.2)
    NEXT i
```

```
    PRINT #2, "k76"; CHR$(13);       ' Tells spectrometer it is at 304 nm now.
    numb = numb + 1:
    IF numb > 5 THEN
            PRINT " Calibration failure after 5 attemps "
            PRINT " Please make sure the wavelength input is correct"
            PRINT " If the second try fails, a complete calibration is required"
            CLOSE
            END
    END IF
IF (ABS(M% - 47) > 1) THEN GOTO 300      '#47 is the steps from 293 to
296.73nm
    END SUB

FUNCTION count
    PRINT #1, "CR;CS"
10      PRINT #1, "QA1"
    INPUT #1, nt
    IF nt = -1 THEN GOTO 10
    count = nt
PRINT nt
END FUNCTION

SUB cstep
PRINT #2, "    "; CHR$(13)
PRINT #2, "v"
CALL delay(.1)
PRINT #2, CHR$(13)
PRINT #2, "1"
CALL delay(.1)
PRINT #2, CHR$(13)
PRINT #2, "s"
CALL delay(.1)
END SUB

SUB delay (a)
t0 = TIMER
WHILE ((TIMER - t0) < a)
WEND
END SUB

SUB init
PRINT #1, "    "
FOR i = 1 TO 500: NEXT i
PRINT #1, "CI0,1"
END SUB
```

```
SUB scan (a())
DIM c(10)
b$ = "b" + RIGHT$(STR$(a(1)), 3) + CHR$(13)      'preset spectrometer to
s.w
 PRINT #2, b$
 CALL delay(30)
FOR i = 1 TO 11
 PRINT a(i); "nm"
 b$ = "b" + RIGHT$(STR$(a(i)), 3) + CHR$(13)
 PRINT #2, b$
 CALL delay(10)
   FOR j = 1 TO 10
   c(j) = count
   NEXT j
   PRINT #3, t; a(i); c(1); c(2); c(3); c(4); c(5); c(6); c(7); c(8); c(9); c(10)
 NEXT i
END SUB
```

Appendix C:

# Procedure for measuring the angular dependence of the full sky UV collector on a Mk IV Brewer spectrophotometer

**National Ultra Violet Monitoring Center**
**Department of Physics and Astronomy**
**University of Georgia**
**Athens, GA 30602**

National
Ultraviolet
Monitoring
Center

**Document 13**
**Revision A**

**Prepared by Dr M.G. Kimlin and T.E. Taylor**
**Last updated March 3, 2003**

**Introduction**

**The Brewer Mk IV spectrometer uses a flat spectral diffuser as the input for the full sky UV scans. Theoretically the throughput of the diffuser should fall off as the cosine of the input angle of the light source. Due to imperfections in the surface of the material and other considerations, the throughput of the diffuser actually deviates from a natural cosine decay. Each Brewer instrument requires an angular dependence characterization in order to fully correct the UV data for this phenomenon.**

**Equipment**

Mk IV Brewer spectrophotometer
Optical table
Mounting tree
Cosine arm assembly with translation stages
1000W Lamp mount
Alignment laser with translation stages
1000W FEL lamp
*Xantrex* power supply
Digital multimeter with two input panels
Standard shunt
Wiring harness for 1000W lamp
Hex wrench set (English sizes)
3/8" box wrench
Bubble level
Lamp alignment jig

**Purpose**

This Standard Operating Procedure (SOP) outlines the NUVMC technique for measuring the angular dependence of the full sky UV diffuser on a Mk IV Brewer spectrophotometer.

Procedure-Apparatus Setup and Alignment

1. Set up and secure the mounting tree on to the optical table. The cosine arm and the alignment laser will be mounted to this tree. The tree should be positioned so that the cosine arm will mount square with respect to the optics table.

2. Mount the cosine arm assembly with translational stages to the mounting tree.

3. Attach the 1000W lamp mount to the cosine arm.

4. Mount the HeNe aligning laser with translational stages to the mounting tree above the cosine arm assembly.

5. Position the Brewer on a tracker and tripod next to the optical table. It is ideal to use the tracker since the Brewer optics are leveled via the three mounting nubs on top of the tracker unit. This will best simulate the outdoor conditions in which the Brewer takes data.

6. Connect the AC power cable from the AC source to the connector on the bottom of the tracker.

7. Connect the AC cable from the tracker to the connector labeled "AC power" on the Brewer.

8. Connect the data cable from the controlling computer to the connector labeled "computer" directly on the Brewer, i.e. bypass the tracker so that the unit does not move during the cosine measurement.

9. Adjust the Brewer position by sliding the tripod and rotating the tracker so that one of the optical axis of the instrument is parallel to the optics table. That is either the "short" side or the "long" side of the Brewer case should be made parallel to the optics table. The cosine measurement will be taken along the orthogonal axis of the Brewer instrument.

10. Power on the Brewer and the tracker. This will lock the tracker and therefore keep the alignment of the Brewer steady during the cosine measurement.

11. Establish communication with the Brewer via the controlling PC. The NUVMC normally sets up the controlling computer in a room separate from the room containing the cosine apparatus in order to avoid prolonged exposure to the high intensity UV irradiance from the 1000W lamp.

12. Move the cosine arm to the zero degree position and lock it by tightening the 5/8" bolt and wing nut.

13. Adjust the cosine arm assembly so that the axis of rotation of the cosine arm is aligned with and level to the Brewer's full sky UV diffuser. The idea is that as the arm is rotated it will sweep out a cosine with the origin defined at the center of the Brewer's diffuser.

14. Align the laser so that it is incident on the center of the Brewer full sky UV diffuser.

15. Set an adjustable optics bench mirror on top of the Brewer case near the UV dome so that the mirror is facing approximately toward the laser source.

16. Level the mirror with respect to the Brewer case by placing a bubble level on the mirror and adjusting the mirror mount appropriately.

17. Adjust the aligning laser using the translational stages so that the laser beam reflects off the mirror and back to the source.

18. Insert the lamp alignment jig into the lamp mount on the cosine arm.

19. The laser should now be incident on both the crosshairs of the lamp alignment jig and the center of the diffuser. If this is not the case then further adjustments to the system are required.

20. Once the alignment is properly made, remove the alignment mirror from the Brewer case.

Procedure-1000W Lamp Wiring and Operation

1. Connect the current leads of the lamp wiring harness to the posts on the lamp mount. The current leads should be of appropriate rating in order to safely handle the 8.2 Amp current from the power supply to the lamp.

2. Connect the other end of the current leads to the *Xantrex* power supply. The positive lead from the *Xantrex* should pass through the shunt so that the current to the lamp can be monitored.

3. Connect the voltage leads of the lamp wiring harness to the posts on the lamp mount.

4. Plug the voltage leads from the 1000W lamp mount into the back panel of the DMM to monitor the voltage across the lamp.

5. Plug the voltage leads from the shunt into the front panel on the DMM to monitor the voltage across the shunt.

6. Remove the lamp alignment jig and insert a 1000 Watt FEL lamp.

7. Clean the lamp with methanol and lens tissue.

8. Set the *Xantrex* power supply to constant current mode by turning the voltage knob to the maximum position and the current knob to the minimum position before engaging the power to the unit.

9. Provide 8.2 Amps current to the 1000W lamp by turning the current

adjustment knob in the clock wise direction until the voltage drop across the shunt reads 82.000 mV (assuming a 10 mili Ohm resistor is being used). The output of the lamp should be closely maintained during the cosine test although the absolute intensity of the lamp is not critical. Allow the lamp to warm up for at least 30 minutes prior to taking any measurements.

Procedure-Cosine Measurement

1. Move the cosine arm into the -80 degree position by loosening the 5/8" bolt with wing nut on the cosine arm assembly and rotating the arm to the desired position. The negative sign of the angular position is standardized by the NUVMC to indicate the position counter clock wise from the zero degree position when facing the cosine arm.

2. Begin the cosine test by giving the command "LZ" at the Brewer Home screen. Note that the "LZ.rtn" is a routine created by staff at the NUVMC and is therefore not standard Brewer software.

3. When prompted, enter the input angle of the lamp. The scan takes about one minute and will beep when finished.

4. Put on safety goggles and protective clothing and enter the room with the cosine apparatus. Move the cosine arm into the next ten degree increment position by loosening the 5/8" bolt and wing nut and swiveling the cosine arm. Tighten the bolt and nut firmly when the desired position is reached.

5. Continue to take measurements for the input angles -80 to +80 degrees in ten degree increments for a total of 17 scans.

6. When the last scan is completed power down the lamp by rotating the current adjust knob on the *Xantrex* power supply in the counter clock wise direction.

7. Turn off power to the *Xantrex* and DMM.

8. Allow the lamp to cool before removing it for storage in a clean, protected environment.

9. Rotate the Brewer, tracker and tripod so that the instrument is oriented 90 degrees from the previous direction. If the first measurement was made along the "short" optical axis of the instrument the second should be made along the "long" optical axis.

10. Repeat the measurement procedure for the second optical axis of the instrument.

**Procedure-Data Analysis**

1. Copy the data files from the Brewer computer to a machine with MS Excel or similar data analysis program. The naming convention of the files is "LZdddyy.###", where "ddd" is the Julian day, "yy" is the two digit year and "###" is the Brewer number.

2. The first column in the file are the angle headers that were input by the user. The second through sixth columns are photon counts at the ozone calculating wavelengths, i.e. 306.3, 310.1, 313.5, 316.8 and 320.1 nm. The seventh column is the dark count.

3. Use the spreadsheet to sum the counts at the five operational wavelengths and subtract the dark count from this number.

4. Calculate the experimental cosine of each angle by dividing the photon counts at each measured angle by the photon counts at the zero input angle. Use the header "experimental cosine" to label this new column.

5. Create a new column with the calculated cosine of the input angles. For MS Excel the formula is "cos(A*pi/180)" where "A" is the input angle. Use the header "theoretical cosine" to label this new column.

6. Calculate the deviation in the experimental value from the theoretical value for each input angle by calculating the ratio of the two values in a new column.

7. Create a chart with plots of the experimental, theoretical and ratio values as a function of input angle. Typically the agreement between experimental and theoretical is within 10% for the angles less than 50 degrees and within 20% for angles larger than 50 degrees.

8. The algorithm used to calculate the cosine correction for the Brewer UV data will not be discussed in this procedure. The user is referred to the paper "Cosine corrections for ultraviolet radiation data from the USEPA/UGA Brewer Network" by J. Sabburg and R.S. Meltzer.

**For further information or advice concerning this SOP please contact the NUVMC at the University of Georgia at http://oz.physast.uga.edu**

# Appendix D: Standard Operating Procedures

# Procedure for checking and replacing the internal mercury bulb in a Mk IV Brewer spectrophotometer

National Ultraviolet Monitoring Center
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National
Ultraviolet
Monitoring
Center

**Prepared by Dr M.G. Kimlin and T.E. Taylor**
**Last updated September 25, 2002**

## Introduction

The Mk IV Brewer spectrophotometer is equipped with an internal mercury (HG) bulb powered by circuitry within the instrument. The HG bulb is used on a daily basis to verify the wavelength calibration of the spectrometer. Over time the bulb filament ages and mercury is deposited on the quartz envelope, leading to a decrease in the output of the bulb. As long as the output of the bulb remains stable over the time period of an HG scan (approximately three minutes), the bulb can continued to be used even when the peak counts fall to around 10,000. However the NUVMC normally replaces bulbs during annual site visits if the peak counts have fallen under 100,000 and are still dropping. On occasion the bulb filament may break, at which time it should be replaced by the operator before further atmospheric data is collected with the Brewer.

## Equipment

Brewer Mk IV spectrophotometer (multiple electronic boards)
Replacement HG bulb
Cleaning alcohol
Kimwipes or tissue

## Purpose

This Standard Operating Procedure (SOP) outlines the NUVMC technique for checking the condition of the internal HG bulb and replacing the bulb if necessary in a Mk IV Brewer spectrophotometer with multiple electronic boards.

## Procedure

1. If the Brewer is still running in schedule exit the schedule by pressing the Home key when the message "Press Home to abort schedule" message appears on the computer screen. The Brewer may already be at the Home screen if the HG bulb has failed because it will not be able to remain in automated schedule containing an HG routine.

2. For the next few steps leave the power to the Brewer in the on position.

3. Place a protective cover on the quartz dome on the top of the Brewer outer cover.

4. Remove the Brewer outer cover by loosening the four latches and lifting the cover up. Never remove the cover during inclement weather and try to pick the driest, wind free day possible.

5. Locate the zenith prism assembly, which is mounted in the area of the instrument under the quartz window when the outer case is on. Refer to Figure 1 below (Figure 2-3 "Spectrometer Targets for Various Zenith Angles" from page 6 of the Brewer Operators Manual OM-BA-C231 REV B, August 15, 1999)

6. Locate the HG lamp base, inside which the Hg bulb is mounted, directly under the zenith prism, referring to Figure 1. The HG lamp lies in the horizontal plane and is hidden from view inside the zenith prism assembly. Only the base that the bulb is screwed into is visible.

7. Locate the two thumb screws that secure the Hg lamp base to the zenith prism assembly. Loosen the thumbscrews. You do not have to completely remove the screws.

8. The lamp base can now backed out of the zenith prism assembly. There is not much maneuvering room, but the lamp will come out with a little finesse. Use only a clean Kim-Wipe or other similar textile to touch the bulb. DO NOT TOUCH THE BULB WITH BARE FINGERS. If the bulb is touched by accident with skin, use some alcohol to clean it as quickly as possible.

9. At the Brewer Home screen command line give the command "B1" to turn on the HG lamp (B0 turns the lamp off). If the lamp is firing the filament will turn red, and a blue tint within the bulb's envelope can be observed if the ambient atmosphere is not too bright. Note any build up of mercury (silvery layer) on the envelope of the bulb. Excessive build up may lead to compromised HG results.

10. If the lamp is firing and there is minimal build-up, then proceed to step 19, otherwise continue on to step 11.

11. If it is visually determined that the HG bulb is not firing and/or there is excessive mercury deposit on the envelope, then turn off the Brewer power by pressing the push button on the side of the instrument before continuing. Also unscrew the AC power cable from the tracker to avoid electrocution.

12. Unscrew the mercury bulb from the threaded socket and put a new bulb in its place. Be sure to handle the new bulb only with a tissue or Kimwipe.

13. Note the small key located on the outer shell of the base that the bulb is screwed into. In order to ensure proper mercury line calibration, the filament of the bulb should be aligned in the same plane with the key in the base, i.e, in the vertical plane. The orientation of the old HG bulb may not be correct so be careful of using that as a reference point. The base that the bulb screws into is actually made up of two parts, a threaded socket and the outer shell containing the key. There is a set of tabs that hold the two pieces together. After screwing the bulb into the socket it may be necessary to rotate the threaded socket inside the outer

shell so that the filament is properly aligned with the key. In some cases the threaded socket will not rotate within the outer shell unless the multiple tabs that secure the shell to the socket are loosened first. Be sure not to touch the bulb envelope with your skin. If you touch it be sure to clean it with alcohol. Make sure the Brewer does not have power. Currently there are two styles of lamps within the network, either of which may be found at any Brewer site. One lamp style has a spherical shaped bulb while the other has a cylindrical shaped bulb. The cylindrical bulbs are more difficult to insert into the zenith prism assembly, but it can be done with a little patience.

14. Replace the AC power cable to the tracker and turn on the Brewer power by pushing the push button on the side of the instrument.

15. Check the computer to see if communication with the instrument is being established. The message "Brewer failed to respond 5 times. Check power and cables and press Enter when ready" may appear on the screen. Press Enter and the Brewer initialization process should be enacted. Once the Brewer has reinitialized the Home screen will appear on the computer monitor.

16. Give the command "B1" at the Home screen command line.

17. Observe if the HG bulb is firing as described in step 9.

18. If the bulb appears to be operating normally, continue to step 19. If the bulb is still not firing after replacement there is likely a problem with the lamp circuitry. These problems will not be addressed in this procedure.

19. If it is visually determined that the HG lamp is firing and there is minimal mercury deposit on the envelope, then carefully place the base back into the zenith prism assembly. Note the small key in the rim of the lamp base outer shell. The key mates into the key-way on the zenith prism assembly to ensure that the Hg lamp is always positioned with the same orientation.

20. Tighten the thumbscrews which fasten the HG base to the zenith prism assembly.

21. Check the desiccant and breather tube for signs of saturation and replace if necessary. This can be determined before beginning the procedure.

22. Replace the Brewer outer cover and secure the four latches, ensuring that the outer cover is mounted evenly all the way around the Brewer case. Remove the quartz dome protector.

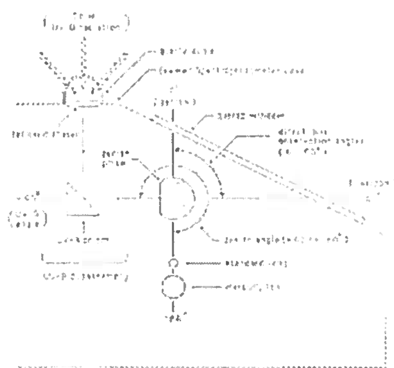
23. Give the "HG" command at the Brewer Home screen command line and observe if the scan is successful. A successful scan is when the peak HG counts are found at step number 15 as appearing on the computer monitor.

24. Perform the SR/SI tests if possible before returning the Brewer to schedule.

25. Enter an electronic comment (CM or CO command) describing briefly if the bulb was replaced or and any other observations made. Also enter a brief entry in the paper station log form.

26. Place the Brewer back into schedule by giving the command "skc" at the command line. When prompted for schedule, enter the name of the current network schedule (epa96d for the US EPA/UGA network as of September 2002).

27.



6 *Figure 1: Spectrometer Targets for Various Zenith Angles*

**For further information or advice concerning this SOP please contact the NUVMC at the University of Georgia at http://oz.physast.uga.edu**

# Procedure for using the external 50 Watt lamp kit to monitor the spectral responsivity of a Mk IV Brewer spectrophotometer

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Last updated September 25, 2002

National Ultraviolet Monitoring Center

## 7 Introduction

The external 50 watt lamp power supply kit is used to determine the stability of the Brewer spectral responsivity. NUVMC staff routinely analysis the full spectra data obtained from the lamp scans which are performed during the annual spectral response calibration visit and by the local Brewer operators on a bi-weekly schedule. A rotating lamp schedule is used so that a change in the measured lamp intensity due to an actual change in the Brewer responsivity can be distinguished from a change in the output of the lamp or power supply. It is strongly recommended that the 50 Watt lamps be calibrated immediately after the Brewer spectral responsivity is calibrated via standard 1000 Watt FEL lamps.

**Equipment**

Brewer Mk IV spectrophotometer (multiple electronic boards)
50 Watt lamp calibration kit
50W lamps
Personal UV protection, such as hats, sunscreen and sunglasses

**Purpose**

To measure the response of a Mk IV Brewer spectrometer to an external 50 W QTH lamp for spectral response performance evaluation.

**Lamp Setup**

1. If the Brewer is still running in schedule exit the schedule by pressing the Home key when the message "Press Home to abort schedule" appears on the computer screen.

2. Carefully mount the 50W lamp base over the UV dome on the top of the Brewer case. The lamp base can only be oriented one way. The two nylon pegs should be snug against the side of the Brewer. Care should be taken not to bump the quartz dome which may cause scratches.

3. Select the 50W lamp to be tested, noting the three digit number inscribed on the lamp shell.

4. Check the alignment of the 50W bulb by looking through the two holes in the side of the lamp shell. The center of the filament should be horizontally aligned with the holes. The lamp alignment can be adjusted if necessary by gently pushing the bulb slightly up or down. DO NOT TOUCH THE BULB WITH BARE FINGERS, USE A KIMWIPE OR TISSUE.

5. Clean the lamp with a Kimwipe® and methanol. Do not touch the bulb with fingers or allow other objects to come into contact with the bulb. This will reduce the life of the lamp.

6. Remove the rectangular lamp cover by unscrewing the thumb screw which secures it to the lamp base. Insert the lamp, ensuring that it is seated completely into the socket. There is a tab on the lamp base and a groove

on the lamp shell. Be sure that the lamp is oriented properly so that the tab goes in the groove. Replace the rectangular lamp cover and fasten the thumb screw to the base.

7. Place the 50W lamp kit on the ground beside the Brewer so that the wind does not blow it off. Connect the leads from the voltage readout of the digital multi meter (DMM) to the connections inside the 50W kit. Then connect and latch the signal cable 9 pin connector from the from the lamp kit to the 9 pin connector on the cable coming from the lamp base. Plug the AC power cord from the lamp kit into a 120V power outlet. Turn the lamp power supply on by flipping the toggle switch inside the kit.

8. **CAUTION!** The 50W lamps emit harmful UV radiation. This can cause damage to your skin and eyes. Always ensure that the lamp cover is in place before turning the power supply on.

9. Press the yellow button on the DMM while turning the dial on the meter to the DC Volts position. Release the yellow button after two or three seconds. The meter should display an output with three decimal places. (If the yellow button is not depressed while turning on the Voltmeter, it displays two decimal places.)

10. To maintain the 50W lamp and a stable power output the voltage readout on the DMM should be kept at 12.000 +/- 0.003 volts. Carefully monitor the voltage during the calibration and make adjustments as needed by turning the potentiometer dial inside the 50W kit to maintain a stable level of 12.000 +/- 0.003 volts.

11. 50W lamps should be warmed up for a minimum of 10 minutes prior to a scan to ensure the stability of the lamp output.

**Computer commands**

12. After the 50 Watt lamp is turned on, type "PNHGQSTUXL" at the Brewer Home screen command line and press the **Enter** key to initiate the sequence. The commands in the sequence are described below;

- PN- turns the printer on,
- HG- performs the mercury lamp wavelength calibration. It takes about 7-9 minutes,
- QS- performs the "Quick Scan" of the UV lamp. It uses or creates a reference file named lamp_???.###, where ??? represents the lamp number and ### represents the Brewer serial number,
- TU- measures the zenith motor step position at which the UV lamp intensity is the highest through slit number one of the spectrometer slit mask,
- XL- measures a spectral scan of the 50W lamp from 286.5 to 363nm at 0.5 nm steps.

13. Enter the following information into the computer when prompted;

- The 3 digit lamp number inscribed on the 50W lamp shell;

- The lamp to diffuser distance: 5cm. If the default value equals to 5cm, you can press the **Enter** key to accept it,
- If a data file does not exist for a particular 50W lamp number, the computer will prompt the user to press the **Esc** key to create a new reference file,
- If the lamp has already warmed up for ten minutes, press the **Delete** key to skip the lamp warm-up delay.

14. The computer software will initiate the five commands in sequence and print the results if a printer is available. The data are stored to various data files and will be analyzed later by NUVMC staff.

15. After the last scan has finished, the UV lamp power supply can be turned off via the toggle switch. The lamp and mount will be **VERY HOT.** Wait about 5 minutes before removing the rectangular lamp cover from the lamp base. Remove the lamp from the socket by pulling firmly on the shell. The lamp should be allowed to cool adequately (a total of 15 minutes or so) prior to being stored in the 50W lamp kit.

16. Repeat steps 4 through 15 for each 50W lamp.

17. Perform the SR/SI tests if possible before returning the Brewer to schedule.

18. Enter an electronic comment (CM or CO command) describing the work done at the site and any other observations made. Also enter a brief entry in the paper station log form and the lamp log form.

19. Place the Brewer back into schedule by giving the command "skc" at the command line. When prompted for schedule, enter the name of the current network schedule (epa96d for the US EPA/UGA network as of September 2002).

**For further information or advice concerning this SOP please contact the NUVMC at the University of Georgia at http://oz.physast.uga.edu**

# Procedure for correctly positioning the micrometer inside a Mk IV Brewer spectrophotometer

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**Prepared by Dr M.G. Kimlin and T.E. Taylor**
**Last updated September 27, 2002**

1785

## Introduction

It is possible for the micrometer in a Mk IV Brewer spectrophotometer to be incorrectly positioned such that the diffraction grating is not moved for the first few or last few wavelength positions during a full spectrum scan. If the micrometer is set too far back (toward higher dial numbers) in the clamp the spectrometer is not able to read the first several wavelength measurements properly because the diffraction grating sine arm stays in one place. Likewise if the micrometer is positioned too far to the front (toward lower dial numbers) in the clamp the spectrometer is not able to read the last few wavelength measurements properly. Another problem occurs when the optical switch blocker ring, (the black barrel component attached to the back end of the micrometer), is set too close to the optical switch. In this case the blocker ring may cause the micrometer to become jammed and will not be able to move out of this position until someone manually adjusts the system.

## Equipment

7.3.1 Mk IV Brewer spectrophotometer

Hex wrench set (English sizes)

Towel or cloth to cover spectrometer

7.3.2

## Purpose

7.3.3 This Standard Operating Procedure (SOP) outlines the NUVMC technique for positioning a micrometer in a Mk IV Brewer spectrophotometer so that the diffraction grating will move the full operating range, thus allowing the instrument to scan its full spectral range. Also instructions are given to position the optical switch blocker ring so that it does not cause the micrometer to become jammed.

## Procedure

1. If the Brewer is still running in schedule exit the schedule by pressing the Home key when the message "Press Home to abort schedule" appears on the computer screen.

2. Give the "HG" command at the Brewer Home screen command line and observe if the scan is successful. A successful scan is one at which the peak HG counts are found at step number 15 as appearing on the computer monitor.

3. Place a protective cover on the quartz dome on the top of the Brewer outer cover.

4. Remove the Brewer outer cover by loosening the four latches and lifting the cover up. Never remove the cover during inclement weather and try to pick the driest, wind free day possible. The NUVMC moves Brewers indoors for this work whenever possible.

5. Remove the black spectrometer cover by loosening the two latches and pulling the cover back. Observe and record the default position on the micrometer dial in millimeters. Never remove the cover during inclement

weather and try to pick the driest, wind free day possible. DO NOT TOUCH THE MIRROR OR DIFFRACTION GRATING WITH FINGERS OR ANY OTHER OBJECT. DO NOT ATTEMPT TO CLEAN THE MIRROR OR DIFFRACTION GRATING IF ACCIDENTALLY TOUCHED AS THIS WILL CAUSE ADDITIONAL HARM TO THE OPTICAL SURFACES. Use a towel or cloth to cover the spectrometer during the procedure.

6. Observe the engineering of the micrometer system. The micrometer body is inserted into a clamp mounted to the spectrometer bulk head. The clamp is locked down via a 7/64" hex bolt. A long, brass gear is connected to a stepper motor at one end of the spectrometer bulkhead. There is a nylon gear around the micrometer body which is in contact with the brass gear. At the front end of the micrometer is the micrometer tip, which is flush against a pushrod with a ball bearing race. The other end of the pushrod is mounted against the end of the diffraction grating sine arm. When the stepper motor is activated the brass gear rotates, in turn rotating the nylon gear and micrometer. As the micrometer rotates in the forward direction toward smaller dial numbers the micrometer tip extends, pushing against the pushrod. This causes the sine arm to move which rotates the diffraction grating, allowing the instrument to cover the spectral range 286.5 to 363 nm.

7. Give the command "W0UX" at the Brewer Home screen and move immediately to the spectrometer to watch the micrometer movement. The W0 command gives a delay of 1 minute before the UX scan begins. If the Brewer and the computer are separated by a great distance multiple W0 commands can be used or the W1 or W2 command can be inserted to give delays of 5 or 10 minutes, respectively.

8. When the UX scan begins, the micrometer will be rotated back toward larger dial numbers (16mm or so). If the micrometer is not properly positioned in the clamp the tip of the micrometer will retract inside the micrometer casing at large micrometer numbers. If the micrometer tip is observed to retract inside the casing such that the pushrod is not being moved at the first few wavelength positions of the scan then the micrometer needs to be repositioned back in the clamp slightly.

9. Continue to observe the micrometer as the UX scan reaches the middle of the spectrum (325 nm). The micrometer should read about 4 mm on the dial at this point. Then the micrometer will rotate back toward larger numbers to about 12 mm before beginning the second half of the scan (The shutter will also rotate from position 2 to position 6). When the scan reaches 363 nm, the micrometer should be near its minimum position (numbers on the dial may no longer be visible). Observe if the micrometer is still rotating and moving the pushrod for the last few wavelength positions of the scan. If the micrometer has reached its physical end point before the last wavelength position has been reached then the micrometer needs to be adjusted forward in the

clamp slightly. The micrometer could become jammed at the minimum position if it is not set properly.

10. If it has been determined that the positioning of the micrometer is correct and needs no adjustment, proceed to step 20. If the micrometer needs adjustment or if it has been adjusted but is still not set correctly proceed to step 11. If the micrometer was adjusted in the clamp and is now in the proper position proceed to step 15 to check the default settings.

11. To reposition the micrometer in the clamp loosen the 7/64" hex bolt and gently slide the micrometer either forward or back slightly as determined in steps 8 and 9. Sometimes it is helpful to gently pry the clamp loose from the micrometer barrel using a small screwdriver, but take care not to apply too much torque to the clamp.

12. Once the micrometer is repositioned in the clamp replace the black spectrometer lid and give the command FR at the Home screen command line. This will reposition the micrometer to the set default position using the optical switch as a zero reference.

13. Give the command HG at the Home screen command line and observe if the scan is successful. A successful scan is one at which the peak HG counts are found at step number 15 as appearing on the computer monitor.

14. If the micrometer was repositioned repeat steps 7 through 9 to check the new position of the micrometer. If the micrometer has now been verified to be in the correct position proceed to step 15 to check the default settings.

15. Once the positioning of the micrometer has been verified using the UX scan, replace the spectrometer lid and perform an HG scan.

16. Remove the spectrometer cover and observe and record the dial position on the micrometer in millimeters.

17. Give the FR command at the Home screen command line. Observe on the computer screen or printout the measured step position of the micrometer as well as the set step position. These numbers should match within 10 steps.

18. If the measured step position is different by more than 10 steps from the set step position the micrometer zero position constant in the Instrument Constants File (ICF) should be updated (line 43) in the current file and the ICF renamed with the current Julian date. The op_st.### file should be updated to reflect the new ICF.

19. If the micrometer zero position constant is updated the wavelength calibration step number may also need updating in order to ensure the quality

of the ozone scans. This number is determined via the SC scan but will not be discussed in this SOP. More information concerning the SC scan can be found in the Kipp and Zonen Brewer Operator's Manual.

20. *Print out a copy of the instrument constants file by typing PO.

21. Note the "WL cal step number" and the "Micrometer Zero" numbers from the printout.

22. Go to the Main Menu screen on the computer.

23. Perform an HG calibration.

24. After the HG scan is finished, remove the Brewer lid and the spectrometer cover. Note the micrometer default position.

25. Issue the teletype command on the computer by typing TT.

26. Issue the command M,10,-nnn, where nnn is the wavelength calibration number found on the printout. (Note the negative sign).

27. Issue the command M,10,-nnnn, where nnnn is the micrometer zero position found on the printout. (Note the negative sign).

28. Press home to exit teletype.

29. Check the micrometer position. There should now be ~ a 1 mm gap between the extreme right edge of the blocker and the block on which the sensor is mounted.

30. If the gap between the end of the blocker and the sensor mount appears to be less than 1mm, then loosen the set screw that holds the blocker ring to the micrometer and adjust the blocker ring to the left (it is ok to rotate the blocker ring slightly to access the set screw). Ensure that the set screw is well tightened once the adjustment has been made.

31. Reposition the micrometer to the reading noted in step 5, replace the black spectrometer cover, and do an HG calibration.

32. Test the blocker ring setting by issuing the commands W0UX. (W0 is W-ZERO)

33. (W0 will create a delay that allows you 1 minute to get to the Brewer and remove the black spectrometer cover.(use W0W0UX if you need 2 minutes, and so on)

34. Following the delay, the filters will set up, the Zenith prism will rotate to

the UV port, the micrometer will move to the low wavelength end (right), and will then move in small increments toward the higher wavelength end (left).

35. Note carefully how close the blocker ring gets to the sensor mount as it moves to its rightmost position - the gap should be about 1mm. If the gap appears to be less than 1mm, then the blocker ring should be adjusted again once the UX scan has been completed.

36. Replace the spectrometer cover and secure both latches.

37. Replace the Brewer outer cover and secure the four latches, ensuring that the outer cover is mounted evenly all the way around the Brewer case. Remove the quartz dome protector.

38. Perform the SR/SI tests if possible before returning the Brewer to schedule.

39. Enter an electronic comment (CM or CO command) describing briefly if the micrometer was reset or and any other observations made. Also enter a brief entry in the paper station log form.

40. Place the Brewer back into schedule by giving the command "skc" at the command line. When prompted for schedule, enter the name of the current network schedule (epa96d for the US EPA/UGA network as of September 2002).

*** Steps 20 through 35 paraphrases a letter from Albert Maione on November 21, 1997 labeled BREWER SPECTROMETER SERVICE NOTE.**

**For further information or advice concerning this SOP please contact the NUVMC at the University of Georgia at http://oz.physast.uga.edu**

# Procedure for resetting a jammed micrometer inside a Mk IV Brewer spectrophotometer

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**Last updated October 2, 2002**

1785

## Introduction

It is possible, under certain operating conditions, for the micrometer within a Mk IV Brewer spectrophotometer to become inoperational due to a physical jamming against its minimum end stop position. This situation sometimes occurs when there has been a power outage on the Brewer unit but no power loss to the computer. Once a micrometer becomes stuck, the stepper motor which controls its movement will no longer be able to rotate it and the micrometer has to be reset by hand in order for the Brewer instrument to become operational again.

## Equipment

Mk IV Brewer spectrophotometer

## Purpose

This Standard Operating Procedure (SOP) outlines the NUVMC technique for resetting a micrometer in a Mk IV Brewer spectrophotometer when it has become jammed.

## Procedure

1. Place a protective cover on the quartz dome on the top of the Brewer outer cover.

2. Remove the Brewer outer cover by loosening the four latches and lifting the cover up. Never remove the cover during inclement weather and try to pick the driest, wind free day possible.

3. ***Remove the black spectrometer cover by loosening the two latches and pulling the cover back. Observe and record the default position on the micrometer dial in millimeters. Never remove the cover during inclement weather and try to pick the driest, wind free day possible. DO NOT TOUCH THE MIRROR OR DIFFRACTION GRATING WITH FINGERS OR ANY OTHER OBJECT. DO NOT ATTEMPT TO CLEAN THE MIRROR OR DIFFRACTION GRATING IF ACCIDENTALLY TOUCHED AS THIS WILL CAUSE ADDITIONAL HARM TO THE OPTICAL SURFACES.***

4. Locate the micrometer assembly inside the spectrometer. The micrometer barrel has a scale measured in millimeters engraved on its side.

5. Using fingers to rotate the micrometer barrel set it to the default position that is listed on the piece of paper taped to the spectrometer cover. This should be a number between about 11 and 13 mm. If there is no paper with default position listed then set the micrometer to 12 mm.

6. Replace the black spectrometer cover and latch it.

7. At the Brewer Home screen command line give the FR command. The micrometer will run in increments until it reaches the optical switch at the shortest micrometer position. Once the switch is reached the micrometer will back up several steps and then move forward again in smaller increments until

the exact step position is determined. The micrometer will then move back to the default position (11-13mm) as set in the Instrument Constants File (ICF). The FR routine also zeroes filter wheel #3.

8. At the Brewer Home screen command line give the HG command and observe if the scan is successful. A successful scan is one at which the peak HG counts are found at step number 15 as appearing on the computer monitor.

9. Remove the black spectrometer cover and note the position of the micrometer in mm's. Replace the cover.

10. At the Brewer Home screen command line give the FR command again.

11. When the routine is complete, remove the black cover again and note the position of the micrometer in mm's. It should match that of the HG scan. Replace the black spectrometer cover.

12. If the micrometer position after the second FR routine does not match the position found after the HG scan, repeat steps 8 through 11. If the micrometer positions from the two scans do match, proceed to step 13.

13. Replace the spectrometer cover and secure both latches.

14. Replace the Brewer outer cover and secure the four latches, ensuring that the outer cover is mounted evenly all the way around the Brewer case. Remove the quartz dome protector.

15. Perform the SR/SI tests if possible before returning the Brewer to schedule.

16. Enter an electronic comment (CM or CO command) describing briefly if the micrometer was reset or and any other observations made. Also enter a brief entry in the paper station log form.

17. Place the Brewer back into schedule by giving the command "skc" at the command line. When prompted for schedule, enter the name of the current network schedule (epa96d for the US EPA/UGA network as of September 2002).

**For further information or advice concerning this SOP please contact the NUVMC at the University of Georgia at http://oz.physast.uga.edu**

# Procedure for replacing the micrometer and drive shaft inside a Mk IV Brewer spectrophotometer

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1785

## Introduction

As the micrometer within a Mk IV Brewer spectrophotometer ages the grease coating on the internal threads begins to break down, causing friction to the micrometer rotation. This condition can eventually cause the micrometer to function erratically due to excessive wear. Erratic micrometer behavior is evidenced in failed HG calibrations and is usually accompanied by a coating of fine, black dust on the micrometer barrel. If the instrument operates too long without a rebuild or replacement of the micrometer, the micrometer can become stuck at its minimum end position. Once the micrometer has become stuck, the stepper motor will continue to turn and damage to the brass micrometer drive gear can result. The drive gear may become warped and then will cause unsmooth micrometer rotation, which compromises the certainty of the mercury line calibration.

## Equipment

Mk IV Brewer spectrophotometer
Hex wrench set (English sizes)
Replacement micrometer (or Krytox lubricant to rebuild old micrometer)
Replacement micrometer drive gear
C-clip pliers (if brass drive gear is to be replaced)

## Purpose

This Standard Operating Procedure (SOP) outlines the NUVMC technique for removing and replacing a micrometer and micrometer drive gear in a Mk IV Brewer spectrophotometer.

## Procedure

1. If the Brewer is still running in schedule exit the schedule by pressing the Home key when the message "Press Home to abort schedule" appears on the computer screen.

2. Place a protective cover on the quartz dome on the top of the Brewer outer cover.

3. Remove the Brewer outer cover by loosening the four latches and lifting the cover up. Never remove the cover during inclement weather and try to pick the driest, wind free day possible.

4. ***Remove the black spectrometer cover by loosening the two latches and pulling the cover back. Never remove the cover during inclement weather and try to pick the driest, wind free day possible. DO NOT TOUCH THE MIRROR OR DIFFRACTION GRATING WITH FINGERS OR ANY OTHER OBJECT. DO NOT ATTEMPT TO CLEAN THE MIRROR OR DIFFRACTION GRATING IF ACCIDENTALLY TOUCHED AS THIS WILL CAUSE ADDITIONAL HARM TO THE OPTICAL SURFACES.***

5. Locate the micrometer assembly inside the spectrometer. The micrometer barrel has a scale measured in millimeters engraved on its side. Observe and record the default position on the micrometer dial in millimeters.

6. Locate the vertical spring that provides pressure between the brass micrometer drive gear and the white, nylon gear attached to the micrometer barrel. The upper end of the vertical spring is attached to the drive gear bearing housing via a hex head bolt. Remove

the 5/64" hex head bolt from the drive gear bearing housing and let the spring and the bolt fall out of the way. They will still be attached to the chassis of the spectrometer box.

7. Manually rotate the micrometer to the zero position. Locate the 7/64" hex head micrometer clamp screw. It is oriented in a vertical position. Note the approximate position of the micrometer in the clamp before removing it. Loosen the screw completely and slide the micrometer assembly toward the mirror to remove it from the clamp. Sometimes the micrometer is held tightly in the clamp. A small screwdriver can be used to pry the clamp open while the micrometer is slipped out. Do not pry the aluminum too hard as it might snap.

8. Determine if the micrometer needs to be replaced with a new unit or if a re-greasing to the internal threads is appropriate. If the micrometer tip has excessive wear, or if the micrometer has been operated too long without proper lubrication, it is better to replace it. Also check for binding between the inner and outer shell of the micrometer which may result if the unit became jammed too many times. If it is decided that the unit should be replaced proceed to step 10. To rebuild the old micrometer proceed to step 9.

9. Rotate the micrometer toward larger numbers until the internal threads begin to expose. Continue rotating the outer barrel until the micrometer separates into two pieces. Use a clean cloth to wipe away old grease on the threads of the micrometer barrel. Apply a thin layer of Krytox lubricant to the internal threads and join the two halves of the micrometer together. Rotate the micrometer to the minimum end position for reinstallation into the Brewer. Now skip to step 14.

10. With the micrometer removed, locate the diode blocking barrel mounted on the back of the micrometer and note the approximate position of the barrel with respect to the white, nylon micrometer gear. Loosen the 0.05" hex head set screw and remove the barrel diode blocking barrel from the micrometer.

11. Locate the collar attached to the white, nylon gear. Loosen the 1/16" hex head set screw and remove the nylon gear assembly from the old micrometer.

12. Place the nylon gear assembly onto the new micrometer, oriented so that the black collar is toward the back of the micrometer and the white gear is toward the micrometer tip. Tighten down the 1/16" hex head set screw to lock the assembly in place.

13. Position the black diode blocking barrel into place on the back of the replacement micrometer in the approximate position as it was on the old micrometer. Tighten the 0.05" set screw to lock the barrel in place.

14. With the etched numbers on the micrometer barrel oriented so that they can be easily viewed, slip the micrometer assembly back into the clamp in approximately the same position as it was before. The SOP "Procedure for correctly positioning the micrometer inside a Mk IV Brewer spectrophotometer" should be followed upon completion of this SOP.

15. If it has been determined that the brass drive gear needs replacement due to warping, proceed to step 16. If the drive gear is not to be replaced proceed to step 24 to

finish up the procedure.

16. The brass drive gear has a bearing on the mirror end of the spectrometer and is connected to a stepper motor at the diffraction grating end of the spectrometer. Locate the bearing housing pin and retaining C-clip at the mirror end of the drive gear. Remove the retaining C-clip carefully using a pair of small C-clip pliers and place it somewhere safe. It is easy to lose the C-clip while trying to remove it because it is so small.

17. Slide the bearing housing off of the pin. The mirror end of the micrometer drive gear will now be unsupported.

18. Remove the micrometer drive gear by pulling it out of the stepper motor cog at the diffraction grating end of the gear. Be careful not to drop the collar off of the mirror end of the drive shaft. Notice that on the mirror end of the drive shaft there are two collars. The little collar is free to come loose once the bearing housing is removed from the system. During operation the little collar sits flush with the bearing. The larger collar is held in place with a flat head set screw. On the grating end of the drive shaft is a cog held in place with a 0.05" hex bolt. There is a rubber band type connector to mesh the cog on the drive shaft to the cog on the micrometer stepper motor.

19. Remove the hardware from the old drive shaft and mount it on the new shaft in approximately the same location. The old shaft can be rolled along a smooth surface such as a table top to determine if it is warped.

20. Insert the new drive shaft into the stepper motor cog hole and mate the rubber band to the two cogs.

21. While supporting the mirror end of the drive shaft with one hand, slide the bearing housing onto the pin with the other hand. The housing should be oriented so that the flush side of the bearing goes toward the drive shaft and the hole for the vertical spring should be closer to the bottom side of the instrument.

22. Replace the retaining C-clip on the pin. Be sure it sets properly in the groove.

23. Slide the large and small collars on the mirror end of the drive shaft until they are flush with the bearing. Tighten the flat head set screw to lock the collars in place.

24. Replace the vertical spring that provides pressure between the drive gear and micrometer gear into the bearing housing via the 5/64" hex head bolt.

25. Manually rotate the micrometer to be sure the new drive shaft is meshed with the drive gear.

26. Replace the spectrometer cover and secure both latches.

27. Replace the Brewer outer cover and secure the four latches, ensuring that the outer cover is mounted evenly all the way around the Brewer case. Remove the quartz dome protector.

28. To be sure that the new micrometer system is installed in the proper position, follow the most current SOP provided by NUVMC titled "Procedure for correctly positioning the micrometer inside a Mk IV Brewer spectrophotometer".

29. Enter an electronic comment (CM or CO command) describing briefly if the micrometer or drive gear were replaced or and any other observations made. Also enter an entry in the paper station log form.

**For further information or advice concerning this SOP please contact the NUVMC at the University of Georgia at http://oz.physast.uga.edu**

# Procedure for optimizing the photomultiplier tube high voltage in a Mk IV Brewer spectrophotometer

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National
Ultraviolet
Monitoring
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**Prepared by Dr M.G. Kimlin and T.E. Taylor**
**Last updated October 7, 2002**

1785

## Introduction

A Mk IV Brewer spectrophotometer utilizes a photomultiplier tube (PMT) with the cathode set to a potential in the range 1100 to 1800 volts. In order to provide the highest quality data possible the PMT high voltage (HV) must be set to an optimum value which maximizes photon count rates while minimizing dark count rates. The optimum PMT HV is found by performing the HV test. For specific information on the HV test the reader is referred to the Brewer Operator's Manual and the Acceptance Manual or Final Test Record for the particular instrument.

It has been found that the optimum PMT HV may change over time as the tubes age or when modifications or adjustments are made to a Brewer. The National Ultra Violet Monitoring Center (NUVMC) normally performs an HV test during an annual Brewer site visit based on various diagnostic considerations. Initial and final spectral response calibrations are required if the HV test is performed.

**Equipment**

Mk IV Brewer spectrophotometer
Hex wrench set (English sizes)
Digital Multi-Meter (DMM) with positive and negative leads
Small flat-head screwdriver

**Purpose**

This Standard Operating Procedure (SOP) outlines the NUVMC technique for optimizing the PMT high voltage in a Mk IV Brewer spectrophotometer.

## 8 Procedure

1. Perform an initial spectral response calibration on the instrument before altering the PMT HV. The NUVMC has an SOP for performing this procedure.

2. If the Brewer is still running in schedule exit the schedule by pressing the Home key when the message "Press Home to abort schedule" appears on the computer screen.

3. Give the "HG" command at the Brewer Home screen command line and observe if the scan is successful. A successful scan is one at which the peak HG counts are found at step number 15 as appearing on the computer monitor.

4. Place a protective cover on the quartz dome on the top of the Brewer outer cover.

5. Remove the Brewer outer cover by loosening the four latches and lifting the cover up. Never remove the cover during inclement weather and try to pick the driest, wind free day possible. The NUVMC moves Brewers indoors for this work whenever possible.

6. Locate the secondary power supply (SPS) in the upper right hand corner of the instrument as viewed from the quartz window side. The SPS consists of an electronic card mounted in a slot with several voltage test point leads that are labeled.

7. Remove the vented cover to the SPS by loosening the two 9/64" hex head bolts at one end and removing the 7/64" hex head bolt located in the middle of the cover.

8. Place the DMM leads into the plugs labeled "HV" and "ground" on the secondary power

supply. Set the DMM to the DC voltage setting. The number read on the DMM is 1/200 of the high voltage value at the PMT.

9. **IMPORTANT;** Record the current SPS HV value in the log book before proceeding.

10. Give the "HV" command at the Brewer Home screen command line. The program will prompt the user to enter some initial information before beginning the HV test.

11. Enter the PMT number, which is usually labeled on the side of the PMT cylinder. Press the "Enter" key.

12. Enter the pre-amplifier discriminator voltage. Check the Brewer Acceptance Manual or Final Test Record to find the value set at the factory. If the value has been changed it should be well documented in the Brewer log book. Typically the value is 30mV. The number is used solely as a file header so it is not critical for the performance of the HV test. Press the "Enter" key.

13. Enter the minimum test voltage desired. Normally 900 volts is used. Press the "Enter" key.

14. Enter the maximum test voltage desired. Normally 1800 volts is used. Press the "Enter" key.

15. Enter the voltage increment desired. Normally 50 volts is used. Press the "Enter" key.

16. Locate the potentiometer screw on the secondary power supply board labeled R202. This screw controls the output voltage to the PMT. Turn the screw CCW using the flathead screwdriver until the voltmeter reads -4.5 volts; this corresponds to -900 volts at the PMT.

17. Press the "Enter" key at the computer to initiate the HV test. Photon counts are measured at the dark count channel, the mercury wavelength channel and the slit 1 channel and are recorded to the HV data file.

18. After counts are recorded at a particular increment the computer will prompt the user to increase the voltage by the appropriate amount. Use the screwdriver to adjust the potentiometer in the CW direction before pressing the "Enter" key.

19. Repeat step 18 as prompted by the computer, increasing the display on the voltmeter by the appropriate amount via the R202 screw (0.25 volts on SPS =50 volts to PMT). The computer will return to the Home menu after readings have been made at all the voltages.

20. Retrieve the HVDDDYY.### file from the \bdata directory.

21. Plot the slit 1 intensity values on a logarithmic ordinate scale versus the high voltage values. On the same chart and scale plot the dark count values versus the high voltage values. Also on the same chart plot the ratio of the wavelength one values to dark count on a normal ordinate scale as a secondary axis. The optimum set point for the high

voltage is a point at which the photon counts are maximized while the dark count is minimized. Normally the ratio plot will have a plateau just above the point where the signal to noise ratio is minimized and the set point is normally chosen at the lower end of the plateau. Consult the Brewer Acceptance manual or Final Test Record for the particular instrument to compare the new results to the factory results to help determine the new set point.

22. Once the optimum HV set value is determined, turn the R202 potentiometer to the appropriate position so that the DMM reads 1/200 of the value, e.g. -6.5 volts on the DMM to obtain -1300V on the PMT.

23. Give the "AP" command at the Brewer Home screen command line. Determine if the HV readout on the screen matches the desired HV set on the SPS.

24. Replace the SPS cover and tighten down the three hex head bolts.

25. Give the "HG" command at the Brewer Home screen command line and observe if the scan is successful. A successful scan is one at which the peak HG counts are found at step number 15 as appearing on the computer monitor.

26. Replace the Brewer outer cover and secure the four latches, ensuring that the outer cover is mounted evenly all the way around the Brewer case. Remove the quartz dome protector.

27. Perform a final spectral response calibration on the instrument before collecting UV data.

**For further information or advice concerning this SOP please contact the NUVMC at the University of Georgia at http://oz.physast.uga.edu**

# Procedure for aligning the spectrometer mirror and shutter mask inside a Mk IV Brewer spectrophotometer

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**Last updated October 8, 2002**

## Introduction

The Mk IV Brewer spectrophotometer is equipped with a movable shutter which allows wavelength selection at the spectrometer exit slits determined by the shutter position and the angle of the diffraction grating which is moved via an automated micrometer. There are eight shutter positions, five of which correspond to the ozone calculating wavelengths 306.2, 310.0, 313.5, 316.8 and 320.0 nm. There are also shutter positions for mercury (Hg) counts, dark counts and dead-time tests.

During a UV scan the instrument rotates the diffraction grating via the micrometer assembly while the shutter is set to position 2, slit 1 (306.2 nm) for the spectral region 286.5nm to 325nm. Position 6, slit 5 (320.0 nm) is used for the spectral region 325.5nm to 363nm and the micrometer is reset to near the original start position to begin the second half of the scan. During ozone scans the instrument rapidly cycles the shutter across positions 2 through 6 which correspond to the ozone calculating wavelengths.

The Run Stop (RS) test monitors the operation of the shutter position and the alignment of the mirror by taking measurements while the shutter is still and again while it is in motion using the instrument's internal lamp as a source. The "run" results are compared to the "stop" results for each slit. The ratios for positions 0 and 2 through 6 should fall in the range 1.0003 to 0.997 as stated in the Brewer's Acceptance manual.

Drifts in the RS values may indicate an alignment of the spectrometer mirror and shutter mask are needed. The NUVMC monitors the performance of the various Brewer diagnostics and performs a shutter and mirror alignment if RS values have fallen outside of tolerance range. The spectral sensitivity of the Brewer may be affected due to changes in the optical properties of the instrument. Therefore, initial and final response calibrations are always performed when making adjustments to an instrument's optics.

## Equipment

Mk IV Brewer spectrophotometer
Hex wrench set (English sizes)
Small flashlight or head lamp

## Purpose

This Standard Operating Procedure (SOP) outlines the NUVMC technique for checking and aligning the mirror and shutter mask in a Mk IV Brewer spectrophotometer.

### Procedure

1. Perform an initial spectral response calibration on the instrument before adjusting the spectrometer shutter or mirror. The NUVMC has an SOP for performing a calibration.

2. If the Brewer is still running in schedule exit the schedule by pressing the Home key when the message "Press Home to abort schedule" appears on the computer screen.

3. Make sure the Brewer is in the ozone (O3) mode by giving the command "O3" at the Home screen command line.

4. Give the "PNHG" command at the Brewer Home screen command line and observe if the scan is successful. A successful scan is one at which the peak HG counts are found at step number 15 as appearing on the computer monitor. If the scan fails an error message will be printed to paper.

5. Run a series of diagnostic tests by giving the command sequence "PNFRSLRSDT" at the Home screen command line. The results from these tests will be used to monitor the effects of any adjustments that may be made to the instrument by performing an alignment. The tests in this sequence are Filter wheel Reset (FR-measures micrometer zero position), Standard Lamp (SL), Run/Stop (RS), and Dead-Time (DT) test. Information on each of these is available in the Brewer Operator's Manual for each instrument. The above diagnostic results can be conveniently viewed if they are printed to paper via the PN command, otherwise the results can be found in the data files.

6. Give the command "TT" at the Home screen command line to access the instrument's low level command environment (teletype mode). Press the "Enter" key several times until a prompt symbol appears on the computer screen. The TT commands are used to control the filter wheels (FW), zenith prism, iris, internal lamp and shutter mask. A comprehensive list of the commands can be found in Table 1.

7. Give the command "M,1,0" at the TT prompt to configure the Brewer so that the zenith prism is facing the internal lamps (zero position).

8. Give the command "M,4,128" at the TT prompt to configure the Brewer so that FW1 is at position 3.

9. Give the command "M,5,0" at the TT prompt to configure the Brewer so that FW 2 is at position 0.

10. Give the command "M,3,75" at the TT prompt to configure the Brewer so that and the iris is open.

11. Place a protective cover on the quartz dome on the top of the Brewer outer cover.

12. Remove the Brewer outer cover by loosening the four latches and lifting the cover up. Never remove the cover during inclement weather and try to pick the driest, wind free day possible. The NUVMC moves Brewers indoors for this work whenever possible.

13. Remove the black spectrometer cover by loosening the two latches. **DO NOT TOUCH THE MIRROR OR DIFFRACTION GRATING WITH FINGERS OR ANY OTHER OBJECT. DO NOT ATTEMPT TO CLEAN THE MIRROR OR DIFFRACTION GRATING IF ACCIDENTALLY TOUCHED AS THIS WILL CAUSE ADDITIONAL HARM TO THE OPTICAL SURFACES.**

14. Locate the shutter, shutter motor and mount and the exit slits of the spectrometer. Gently wiggle the motor to check that it is tightly connected to its mount. If it feels loose then the screws that fasten it should be tightened down. Also check that the shutter is firmly connected to the motor and that there is some resistance to turning the shutter from position to position when the Brewer AC power is on.

15. Working in a darkened room, use a flashlight to illuminate the exit slits and shutter mask inside the spectrometer. When viewing the position of the shutter mask it is important to level your eyes as close to possible with the horizontal plane to avoid parallax error.

16. Cycle the shutter from position 0 to position 7 using the TT commands "M,11,0" and "M,11,14" to observe if the shutter mask holes are aligned with the spectrometer exit slits. Shutter position 0 has one slot while shutter position 7 has two slots. The slots in the shutter are a bit larger than the exit slits. Ideally the slot in the shutter should symmetrically frame the exit slit. The key to this step is to avoid the parallax error associated with the lining up of the shutter mask and exit slit due to the small lateral distance that separates the two.

17. If it is observed that the shutter slits do not symmetrically frame the exit slits then an adjustment of the shutter assembly is necessary. To move the shutter up or down in the same orientation as the slits, loosen the 7/64" hex head bolt that secures the aluminum brace that the shutter stepper motor is mounted to. The brace can then be slightly adjusted to the correct position so that the shutter slits frame the exit slits. Firmly retighten the hex bolt once the correct adjustment has been made.

18. If the shutter needs an adjustment to one side or another relative to the exit slits loosen the two 0.050" hex head set-screws that secure the shutter to the stepper motor drive axel. Make the necessary adjustment to the shutter and firmly retighten the two set-screws.

19. Recheck the alignment of the shutter mask to the slits. Verify that all set-screws have been firmly retightened once the shutter is moved into the proper position.

20. Cycle the shutter from position 0 to position 7 again using the TT

commands "M,11,0" and "M,11,14" to observe if the shutter mask holes are now properly aligned with the spectrometer exit slits.

21. Once the adjustment is properly made, press the "Home" key to exit teletype mode.

22. Next, check the alignment of the spectrometer mirror. The instrument's foreoptics should still be set as in steps 7 through 10.

23. Turn on the internal lamp by giving the command "B2" at the Home screen command line.

24. A rectangular spectrum of blue light from the internal lamp will appear inside the spectrometer, incident on the shutter. When the mirror is adjusted properly the spectrum should be incident horizontally across the shutter so that the exit slits are symmetrically illuminated.

25. Cycle the shutter through its various positions using the commands in Table 1 and observe the illumination on the slits. Ideally the spectrum should fall in the middle of both the shutter and exit slits. Also observe any slanting of the spectrum across the shutter, as this is an indication that the shutter is crooked.

26. If the exit slits are not properly illuminated by the spectrum, then an adjustment to the mirror should be made. Loosen the 7/64" hex head set-screw located on top of the mirror mount which locks the mirror thumb screw. Now the thumb screw which controls the angle of the mirror is free to rotate. If the lamp spectra needs to be shifted up on the shutter mask, rotate the thumb screw in the CCW direction if looking from the back of the mirror.

27. After adjusting the mirror to the proper position firmly retighten the 7/64" hex head set-screw.

28. Replace the spectrometer cover and secure both latches.

29. Replace the Brewer outer cover and secure the four latches, ensuring that the outer cover is mounted evenly all the way around the Brewer case. Remove the quartz dome protector.

30. Run another series of diagnostic tests by giving the command sequence "PNHGFRSLRSDT" at the Home screen command line. Compare the new RS values to the values recorded before the adjustment was made.

31. The RS ratios should be in the range 1.003 to 0.997 for positions 0 and 2 through 7. If the RS values are within tolerance levels, the adjustments have been successful; proceed to step 32. Otherwise go back to step 6 to recheck

the shutter alignment and mirror alignment.

32. Compare the pre and post adjustment FR results and note any change to the measured micrometer zero position. Any discrepancy in this number may indicate that an adjustment to the constant value in the ICF may be required. Also a sun scan (SC) test may need to be performed in order to determine if the wavelength calibration step number is optimized for the ozone scans. More information concerning the SC test can be found in the Operator's Manual for each instrument.

33. Compare the pre and post adjustment SL results and note any change in the R5 and R6 values. Any change in these numbers will require changes to be made to the ETC constants to produce accurate ozone calculations. A new ozone calibration is preferred.

34. Compare the pre and post adjustment dead-time results and note any changes. In general, changes made to the dead-time constant in the ICF file should be carefully considered and the method for determining an adjustment is subtle. If a change is made to the dead-time constant, careful inspection of data should ensue to determine if the change adversely affected the instrument's counting rate. If the high and low dead-time standard deviations do not fall within the tolerance values given in the acceptance manual, then it may indicate that the shutter is not aligned properly.

35. Once both shutter and mirror are determined to be in proper alignment a new spectral response calibration should be performed on the instrument. The NUVMC has a written procedure for performing calibrations.

36. An ozone adjustment or calibration is required as well but the NUVMC does not perform these as the contract with the EPA Brewer network is for UV measurements only.

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9 **Table 1: Brewer Motor Positions and Control Commands**

| **Motor # and Name** | **Step #** | **Position** | **Command String** |
|---|---|---|---|
| 1:Zenith Prism | 0 | Pointing at standard lamp | M,1,0 |
| | 1408 | Pointing at zenith sky | M,1,1408 |
| | 2112 | Pointing at UVB port | M,1,2112 |
| | | | |
| 3:Iris | 0 | Iris fully closed | M,3,0 |
| | 75 or 250 | Iris fully open | M,3,75 or M,3,250 |
| | | | |
| 4:Filterwheel #1 | 320 | 0:film polarizer (horizontal) | M,4,320 |
| | 256 | 1:quartz diffuser (translucent) | M,4,256 |

| | | | |
|---|---|---|---|
| | 192 | 2:blocked aperture (opaque) | M,4,192 |
| | 128 | 3:clear aperture | M,4,128 |
| | 64 | 4:quartz diffuser; ND of f=2.0 (translucent) | M,4,64 |
| | 0 | 5:film polarizer (vertical) | M,4,0 |
| | | | |
| 5:Filterwheel #2 | 0 | 0:f=0 | M,5,0 |
| | 64 | 1:f=0.5 | M,5,64 |
| | 128 | 2:f=1.0 | M,5,128 |
| | 192 | 3:f=1.5 | M,5,192 |
| | 256 | 4:f=2.0 | M,5,256 |
| | 320 | 5:f=2.5 | M,5,320 |
| | | | |
| 11:Slit Mask | 0 | 0:slit 0 (Hg; 303.2-426.4 nm) | M,11,0 |
| | 2 | 1:dark count | M,11,2 |
| | 4 | 2:slit 1 (306.3-431.4 nm) | M,11,4 |
| | 6 | 3:slit 2 (310.1-437.3 nm) | M,11,6 |
| | 8 | 4:slit 3 (313.5-442.8 nm) | M,11,8 |
| | 10 | 5:slit 4 (316.8- 448.1 nm) | M,11,10 |
| | 12 | 6:slit 5 (320.1-453.2) | M,11,12 |
| | 14 | 7:dead time | M,11,14 |

**For further information or advice concerning this SOP please contact the NUVMC at the University of Georgia at http://oz.physast.uga.edu**

# Procedure for checking and replacing the internal standard lamp inside a Mk IV Brewer spectrophotometer

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**Last updated October 14, 2002**

## Introduction

The Mk IV Brewer spectrophotometer is equipped with an internal standard lamp (SL) powered by circuitry within the instrument. The SL bulb is used on a daily basis as a light source for several of the instrument diagnostic tests. As the instruments age the measured counts of the lamp generally decrease and on occasion the bulb filament may break. If the output of the lamp becomes too low or the filament breaks the bulb should be replaced before further atmospheric data is collected with the Brewer.

## Equipment

Mk IV Brewer spectrophotometer
Hex wrench set (English sizes)
Replacement standard lamp bulb
Kimwipes or tissues
Cleaning alcohol

## Purpose

This Standard Operating Procedure (SOP) outlines the NUVMC technique for checking and replacing the internal standard lamp inside a Mk IV Brewer spectrophotometer.

Procedure

1. If the Brewer is still running in schedule exit the schedule by pressing the Home key when the message "Press Home to abort schedule" appears on the computer screen.

2. At the Brewer command line give the command "PNSL" to perform a standard lamp measurement. The PN will ensure that the results are printed to paper. Otherwise the data can be viewed in the daily B-file.

3. For the next few steps leave the power to the Brewer in the on position.

4. Place a protective cover on the quartz dome on the top of the Brewer outer cover.

5. Remove the Brewer outer cover by loosening the four latches and lifting the cover up. Never remove the cover during inclement weather and try to pick the driest, wind free day possible.

6. Locate the zenith prism assembly, which is mounted in the area of the instrument under the quartz window when the outer case is on. Refer to Figure 1 below (Figure 2-3 "Spectrometer Targets for Various Zenith Angles" from page 6 of the Brewer Operators Manual OM-BA-C231 REV B, August 15, 1999).

7. Locate the SL lamp base, inside which the SL bulb is mounted, directly under the zenith prism. Refer to Figure 1. The SL lamp lies in the horizontal plane and is hidden from view inside the zenith prism assembly. Only the base that the bulb is mounted in is visible. When looking from the direction of the slanted quartz window, the base plate is located in the plane of the long edge of the Brewer and it has two wires for power leading into it.

8. Locate the hex head screw, or screws, that secures the SL lamp base to the zenith prism assembly. The screws may vary in size and number for each particular instrument but generally there are one or two with 1/16" hex heads. Loosen and remove the screw(s).

9. The lamp base can now be removed from the zenith prism assembly. Use only a clean Kim-Wipe or other similar textile to touch the bulb. DO NOT TOUCH THE BULB WITH BARE FINGERS. If the bulb is touched by accident with skin, use some alcohol to clean it as quickly as possible.

10. At the Brewer Home screen command line give the command "B2" to turn on the SL lamp ("B0" turns the lamp off). If the lamp is firing the filament will emit intense visible light. **CAUTION; THE SL LAMP EMITS UV RADIATION WHICH IS HARMFULL TO EYES AND SKIN. AVOID OVEREXPOSURE OR DIRECTLY LOOKING AT THE LAMP WHILE ON.**

11. If the lamp is firing proceed to step 19, otherwise continue on to step 12.

12. If it is visually determined that the SL bulb is not firing turn off the Brewer power by pressing the push button on the side of the instrument before continuing. Also unscrew the AC power cable from the tracker to avoid electrocution.

13. Remove the old SL bulb from the pin socket by firmly pulling on the envelope of the bulb. Insert the replacement bulb and clean the envelope with Kimwipe and alcohol. Be sure to handle the new bulb only with a tissue or Kimwipe.

14. Replace the AC power cable to the tracker and turn on the Brewer power by pushing the push button on the side of the instrument.

15. Check the computer to see if communication with the instrument is being established. The message "Brewer failed to respond 5 times. Check power and cables and press Enter when ready" may appear on the screen. Press Enter and the Brewer initialization process should be enacted. Once the Brewer has reinitialized the Home screen will appear on the computer monitor.

16. Give the command "B2" at the Home screen command line.

17. Observe if the SL bulb is firing as described in step 10.

18. If the bulb appears to be operating normally, continue to step 19. If the bulb is still not firing after replacement there is likely a problem with the lamp circuitry. These problems will not be addressed in this procedure.

19. If it is visually determined that the SL lamp is firing, turn it off by giving the command "B0" at the command line.

20. Carefully place the lamp base back into the zenith prism assembly. Note the small pin located on the side of the bulb base. Insert the pin into the hole in the zenith prism assembly to be sure the base is seated properly so that the orientation of the SL lamp will be optimized. Be sure not to touch the bulb envelope with your skin. If you touch the lamp it is necessary to clean it with alcohol. Make sure the Brewer does not have power during this step.

21. Tighten the hex bolt(s) which fasten(s) the SL base to the zenith prism assembly.

22. Check the desiccant and breather tube for signs of saturation and replace if necessary. This can be determined before beginning the procedure.

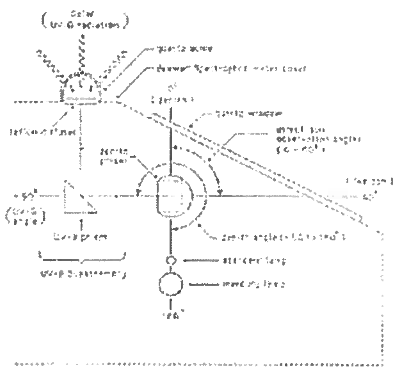
23. Replace the Brewer outer cover and secure the four latches, ensuring that the outer cover is mounted evenly all the way around the Brewer case. Remove the quartz dome protector.

24. Give the "PNSL" command at the Brewer Home screen command line. Compare the new results to the previous results and note changes in the measured lamp intensity and the R5 and R6 ratios in the log book.

25. Perform the SR/SI tests if possible before returning the Brewer to schedule.

26. Enter an electronic comment (CM or CO command) describing briefly if the bulb was replaced or and any other observations made. Also enter a brief entry in the paper station log form.

27. Place the Brewer back into schedule by giving the command "skc" at the command line. When prompted for schedule, enter the name of the current network schedule (epa96d for the US EPA/UGA network as of September 2002).



10 *Figure 1: Spectrometer Targets for Various Zenith Angles*

**For further information or advice concerning this SOP please contact the NUVMC at the University of Georgia at http://oz.physast.uga.edu**

# Procedure for checking and adjusting the zenith prism alignment of a Mk IV Brewer spectrophotometer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National Ultraviolet Monitoring Center


**Prepared by Dr M.G. Kimlin and T.E. Taylor**

**Last updated October 15, 2002**

**Introduction**

The zenith prism in a MkIV Brewer spectrophotometer is fixed to a shaft which rotates via a gear assembly driven by a stepper motor. Mounted to the main drive gear is a thin metal tab, which passes through an optical sensor, designating the zero position of the assembly. A proper alignment is when the zenith prism is focused on the internal lamp at the same time as the tab is centered in the diode sensor.

It is possible for the zenith prism to become misaligned on its shaft due to communication failures that may occur between the Brewer and the computer, especially during power outages. A zenith prism misalignment is observable as a step decrease on the order of 10 to 50% in the measured standard lamp intensity as well as in the measured 50W lamp output.

Due to the way in which the zenith prism mechanism was engineered it is difficult to move the zenith prism back to the precise position at which it was set before the misalignment occurred. Since the Brewer's spectral responsivity is extremely sensitive to the zenith prism position, any change to the prism position will compromise the spectral response calibration of the instrument. In an ideal situation, an initial and final calibration should be performed using the NUVMC standard 1000W lamp calibration technique. Oftentimes a calibration using the 50W field lamps will have to suffice.

**Equipment**

Mk IV Brewer spectrophotometer
Hex wrench set (English sizes)
Coat or towel to cover head on sunny day

**Purpose**

This Standard Operating Procedure (SOP) outlines the NUVMC technique for checking the alignment of a MkIV Brewer zenith prism and correcting the alignment if necessary.

Procedure

1. If the Brewer is still running in schedule exit the schedule by pressing the Home key when the message "Press Home to abort schedule" appears on the computer screen.

2. At the Brewer command line give the command "ZE" to rotate the zenith prism to the zero position.

3. At the Brewer command line give the command "B2" to turn on the standard lamp.

4. Look into the iris view port on top of the Brewer case. Refer to Figure 1: Brewer View port Locations (from page 3 of the Brewer Operators Manual

OM-BA-C231 REV B, August 15, 1999). An image of the standard lamp should be present on the image of the iris. The lamp image is oblong and about one centimeter in width. The long axis of the lamp image is oriented along the long axis of the Brewer case. If the lamp image is centered on the iris within half the width of the lamp image then the alignment is considered to be good and no further action needs to be taken. Proceed to step 25. If the image is off centered by more than half the width of the lamp image then the prism alignment is off centered and requires an adjustment.

5. If you are not confident in the accuracy of the present alignment and you would like to see how the alignment of the image on the iris changes with a change to the position of the zenith drive gear, the zenith prism can be rotated manually. Place fingers on the 2 inch diameter brass drive gear which is mounted to the zenith prism assembly and rotate the gear in the clock wise direction. Rotation of the brass drive gear in the clock wise direction will correspond to a counter clock wise rotation of the 2 $^{3}/_{4}$ inch main zenith prism drive gear. The main drive gear is the one mounted directly to the zenith prism shaft. It has a tab which moves into the optical switch when the zenith drive is in the zero position. Be careful not to rotate the brass drive gear too far in the counter clock wise direction as eventually the zenith prism will reach its hard stop and then the drive gear may slip with respect to the zenith prism shaft on which it is mounted. Slippage of the main drive gear on the zenith prism shaft is what causes zenith prism misalignment.

6. As the zenith drive is rotated manually by hand the image of the lamp should be observed to move back and forth across the iris along the short axis of the Brewer when viewed through the iris view port. Once the zenith drive has been moved by hand give the ZE command in order to rezero the drive with the optical switch. You should be able to confidently determine if the image of the lamp is in fact oriented on the center of the iris when the tab is in the sensor after performing the ZE. If there has recently been a noticeable step decrease in the SL and 50W lamp results and the lamp image is off center by more than about half the width of the lamp image it may be necessary to perform a zenith prism realignment.

7. If the zenith prism alignment is off by a large degree the lamp image may not appear at all. Visual inspection of the zenith prism should indicate that it is pointing down toward the internal lamp. Use steps 5 and 6 to manually search for the image moving across the iris. If the test is being performed outdoors on a bright, sunny day, the image may be hard to see. A coat or similar item over the head to block the direct beams of the sun will help.

8. Once a decision has been made concerning the accuracy of the alignment, give the command "B0" to turn off the standard lamp.

9. Before making adjustments to the zenith prism, perform either a 1000W lamp spectral response calibration or a bi-weekly 50W lamp calibration on two or three lamps per the procedure given in the most current edition of the NUVMC SOP for operating the Brewer. If the zenith prism alignment is uncertain it may be better to not make any adjustments unless an initial and final spectral response calibration can be performed.

10. After performing the spectral response calibration or the 50W scans, give the command "PNSL" at the Brewer Home screen command line to turn on the printer and perform a standard lamp check. This diagnostic check monitors the intensity of the internal lamp and will help to document any change in the Brewer sensitivity due to a zenith prism realignment.

11. Give the command "ZE" at the Home screen command line to zero the prism.

12. Give the command "B2" at the Home screen command line to turn on the internal lamp.

13. Place a protective cover on the quartz dome on the top of the Brewer outer cover.

14. Remove the Brewer outer cover by loosening the four latches and lifting the cover up. Never remove the cover during inclement weather and try to pick the driest, wind free day possible.

15. Locate the zenith prism assembly directly under the quartz window. Refer to Figure 2 below for a schematic (Figure 2-3 "Spectrometer Targets for Various Zenith Angles" from page 6 of the Brewer Operators Manual OM-BA-C231 REV B, August 15, 1999).

16. Locate the zenith prism clamp on the very end of the zenith prism shaft. This clamp secures the gear to the shaft so that they rotate in unison.

17. Loosen the 7/64" hex bolt that secures the clamp to the shaft. The zenith shaft will now be free to rotate.

18. Manually rotate the shaft to the position such that the lamp image is centered on the iris image.

19. Tighten the 7/64" clamp bolt to resecure the shaft to the gear, being sure that the image of the lamp remains centered on the iris as viewed through the iris view port. Be sure to torque the clamp down very firmly. If the clamp is pulled out slightly from the end of the shaft before

tightening, there will be greater pressure between the clamp and shaft, which will reduce the chance that the gear is able to rotate on the shaft. This precaution will help prevent zenith prism misalignments from occurring.

20. Repeat steps 2 through 4 of the procedure to recheck the alignment of the zenith prism.

21. If the lamp image is still not properly aligned, repeat steps 17 through 19 to adjust it again. If the alignment has been successfully corrected proceed to step 22.

22. Replace the Brewer outer cover and secure the four latches, ensuring that the outer cover is mounted evenly all the way around the Brewer case. Remove the quartz dome protector.

23. At the Brewer Home screen command line give the command "PNSL" to turn on the printer and perform a standard lamp check. Compare the results with those from the initial SL test to document any change in the Brewer sensitivity due to a zenith prism realignment.

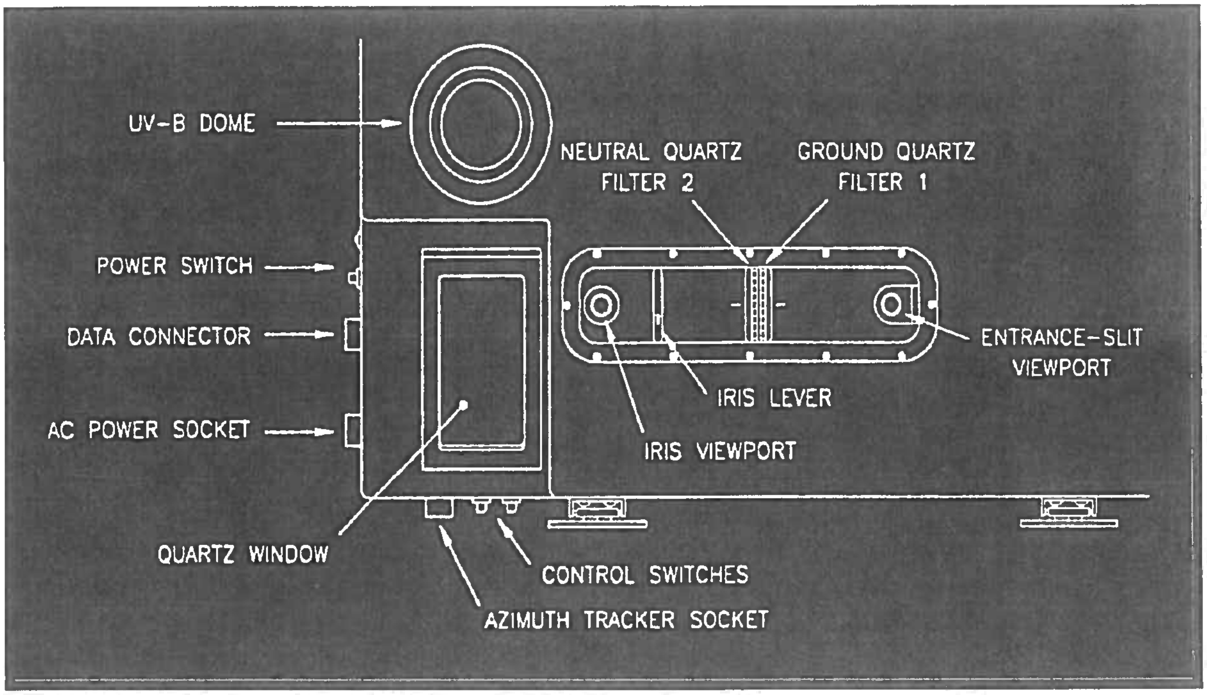
24. Run a final set of 50W lamp calibrations using the same lamps as before the zenith prism adjustment was made. Alternatively, perform a final spectral response calibration using the 1000W lamps.

25. Perform a tracker steps per revolution (SR) test followed by a sun sighting (SI) per the procedure in the Operators SOP. This will ensure that the Brewer optical path is reoriented properly if the zenith prism was realigned. The date and time on the computer should be verified to be correct for this step.

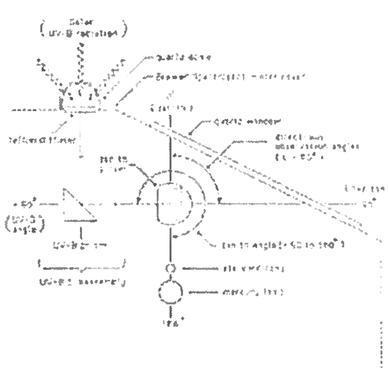
26. Enter an electronic comment (CM or CO command) describing briefly if the zenith prism was adjusted or and any other observations made. Also enter a brief entry in the paper station log form.

27. Place the Brewer back into schedule by giving the command "skc" at the command line. When prompted for schedule, enter the name of the current network schedule (epa96d for the US EPA/UGA network as of September 2002).

**Figure 1: Brewer Viewport Locations**




11 **Figure 2: Spectrometer Targets for Various Zenith Angles**



## For further information or advice concerning this SOP please contact the NUVMC at the University of Georgia at http://oz.physast.uga.edu

# Procedure for maintenance to filter wheel #3 in a Mk IV Brewer spectrophotometer

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**Last updated October 30, 2002**

1785

**Introduction**
Brewer Mk IV spectrophotometers are equipped with several rotating filter wheels which allow selection of different filters for various instrument scans. On occasion the mechanical components of the filter wheels encounter difficulties and maintenance work must be performed to correct these problems. In particular, filter wheel #3 can present trouble since it contains a hygroscopic $NiSO_4$ filter and is enclosed in a sealed housing. When the NiSO4 filter absorbs moisture its optical properties are compromised, usually resulting in a decrease in transmittance. This leads to a decrease in the overall sensitivity of the Brewer in the region where the NiSO4 filter is used (2865-3250 A for a full spectrum UV scan). Changes to the filter trasmittance also compromise the ozone measurements taken by the instrument.

Erratic R5 and R6 ratios recorded in the instrument's Sloavg file are symptomatic of a problem with the operation of FW#3. The results of filter wheel reset tests will help in determining if FW#3 is being found in the correct position. Decaying $NiSO_4$ transmission can be observed in the bi-weekly 50W lamp scans and in the standard lamp intensities as well as spectral response calibrations.

**Equipment**
Mk IV Brewer spectrophotometer
Hex wrench set (English sizes)
Flat head screw driver (small)
Wire snips
Replacement $NiSO_4$ filter (if necessary)

**Purpose**
This Standard Operating Procedure (SOP) outlines the NUVMC technique for checking the operation of filter wheel #3 in a Mk IV Brewer and removing and replacing the $NiSO_4$ filter if necessary.

Procedure

1. If the Brewer is still running in schedule exit the schedule by pressing the Home key when the message "Press Home to abort schedule" appears on the computer screen.

2. Turn on the computer printer and give the command "PN" at the Brewer Home screen command line to allow the computer to write information to the printer.

3. Give the command "O3" at the Home screen command line to set the Brewer in the Ozone mode.

4. To determine if the FW#3 is operating properly perform a filter wheel reset by giving the command FR at the Brewer Home screen command line. This routine zeroes the micrometer and then zeroes FW#3. Note the FW#3 position on the computer screen or the printout. The proper FW#3 position is step -242. If FW#3 was not in the correct position the result will deviate from this number. Perform two more FR tests and note the results.

5. If it is determined that the FW#3 is not operating properly or if the $NiSO_4$ filter is to be replaced, perform an initial spectral response calibration on the instrument before performing any work to FW#3. The NUVMC has an SOP for performing a calibration. If the $NiSO_4$ filter is to be replaced a spectral response temperature dependence calibration should be performed also. An SOP for this procedure, both in the laboratory and in the field, has been written by the NUVMC.

6. If it is not possible to perform a spectral response calibration, perform 50W lamp scans per the normal bi-weekly procedure. Run three lamps instead of the usual two to provide more data.

7. Move the Brewer to a clean, indoor environment with ample space to work.

8. Connect the AC power and data cable and initialize communication between the Brewer and computer.

9. Once it has been determined that the system is able to communicate, kill the power to the Brewer and disconnect the AC power cable.

10. Place a protective cover on the quartz dome on the top of the Brewer outer cover.

11. Remove the Brewer outer cover by loosening the four latches and lifting the cover up.

12. Locate the FW#3 housing. It is sandwiched between the spectrometers exit slits/shutter and the photomultiplier tube (PMT). Refer to Figure 1. Note the figure shows a schematic of a single electronic board instrument. The layout of a multi board instrument is similar. Locate the stepper motor for FW#3 which is attached to the FW#3 housing to the left of the PMT tube. On top of the FW#3 housing there is a small hatch secured by two 3/32" hex head screws which allows for visual inspection of the FW#3. Just above the FW#3 view hatch there is a ribbon cable which connects to the shutter stepper motor which is hidden from view inside the black spectrometer box. There is another ribbon cable connected to a bulkhead connector located to the right side of the PMT. This is the cable that controls FW#3. There is a multi-colored bunch of wires from the

bulkhead connector to the FW#3 stepper motor.

13. Remove the connectors for the shutter motor by loosening the two 3/32" hex bolts.

14. Loosen the two 3/32" hex head bolts that secure the FW#3 hatch. It is unnecessary to remove the screws completely. Swivel the hatch to expose the internals of the FW#3 housing. Using a flashlight to illuminate FW#3, notice the black hash marks between the teeth of the cogs, similar to those on FW#1 and #2.

15. At the Brewer Home screen command line give the "TT" command to move to teletype mode. This mode of operation allows direct control of the Brewer's various motors. Using Table 1 as a reference, move FW#3 to various positions, noting via the hash marks if the wheel actually goes to the correct place. For example, typing "M,6,50" in TT mode should move FW#3 to position 1.

16. Give the command "M,6,0:M,6,256:a". This will rotate FW#3 continually from position 1 to 4 to 1. Observe if the FW#3 moves smoothly and does not bind. There should be a rhythm to the rotation that will be interrupted intermittently if there is a binding problem. Abort the command by pressing the "Home" key.

17. If FW#3 appears to be rotating erratically use a small screwdriver or similar tool inserted into the FW housing to gently rotate FW#3. Pay attention for any rough or uneven movement that may indicate problems with bearings or with the wheel getting hung up on something inside the housing.

18. If it is determined that the FW#3 is moving to the correct position each time then there is most likely no mechanical difficulty with the stepper motor or filter wheel. Close the FW#3 housing hatch and tighten down the two screws.

19. Any problem that may have been noted before in the Brewer diagnostic files could be intermittent. This could be due to a bad connection between the controlling I/O board and the stepper motor or between the bulkhead wires and the stepper motor. All connections should be inspected carefully for signs of damage or looseness, especially pin crimps on the wires from the bulkhead connector to the stepper motor. The FW#3 ribbon cable should be replaced.

20. If it is obvious that FW#3 is not moving as commanded the problem could be caused by any combination of faulty/intermittent cable/wire

connections, a faulty I/O board, faulty stepper motor or difficulties with the mechanical integrity of the FW#3 assembly.

21. The condition of FW#3's electronic board and ribbon cable can be checked by using them to run FW#2. Disconnect the ribbon cable connector from FW#3 and FW#2. Connect the FW#3 ribbon cable to the 25-pin connector for the FW#2 stepper motor. Refer to Table 2 for FW board positions and pin-jumper numbers.

22. Move FW#2 using the teletype mode of the Brewer and referring to Table 1 for the appropriate command string to operate FW#3. Remember that FW#2 is now being controlled by the I/O board for FW#3. Therefore commands appropriate to move FW#3 must be given.

23. Monitor the position of FW#2 as each string of commands is given and verify that the FW moves to the correct position as indicated by the hash marks. If the problem is in the I/O board and/or the ribbon cable then the same results should be obtained by this test as were observed with FW#3. If the same behavior is observed the I/O board and the ribbon cable should be swapped out with spare components. If FW#2 behaves in a normal manner then the problem probably lies in the FW#3 stepper motor or the mechanical assembly of FW#3.

24. If it is determined that there is a problem with the rotation of the filter wheel within the housing or if the $NiSO_4$ filter is to be replaced, The FW#3 housing will have to be removed from the Brewer.

25. Disconnect all the electronic ribbon cables from the card rack. The connectors should be labeled in black ink corresponding to the board and jumper to which they are connected.

26. Remove the two 3/32 inch hex bolts that secure the back card rack feet to the bottom of the Brewer case. These screws are accessed from underneath the instrument.

27. Remove the two 9/64 inch hex bolts securing the front card rack feet to the Brewer base.

28. Remove the card rack from inside the Brewer.

29. If there are wires fastened to the side of the rack by cable ties, the ties may be snipped so that the card rack can be moved.

30. Disconnect the FW#3 ribbon cable connector from the FW#3 housing via the two hex head bolts.

31. Disconnect the high voltage (HV) cable from the base of the photomultiplier tube (PMT) by twisting the BNC connector off the mate.

32. Remove the 9 pin signal line from the PMT base by loosening the two flat head screws on the 9-pin connector.

33. Remove the white face plate covering the foreoptics tube by removing the two 3/32 inch hex screws fastening the plate to the Brewer chassis at the spectrometer. Loosen the single 3/32 hex screw on the side of the face plate near the zenith prism. Lift the plate off and set it aside.

34. Remove the thermister that is inserted into the top of the FW#3 housing. Usually an epoxy is used to seal it.

35. Remove the four 5/32 inch hex head bolts holding FW#3 housing to the Brewer chassis. Remove the FW#3 housing from the Brewer with the PMT attached.

36. Cover the spectrometer exit slit with paper to protect it. Wipe any dirt or dust out of the chassis.

37. Loosen the six 9/64 inch hex head bolts that secure PMT to the FW#3 housing. Remove the PMT from the housing in a reduced light area and cover the open end of the PMT with cloth. Place the PMT in a padded box or other storage vessel and avoid exposing it to light.

38. Remove the white plastic insulating spacer from the FW#3 housing.

39. Remove four 3/32 inch hex head bolts that hold the two halves of FW#3 together.

40. Note the construction of the FW#3 system; the steel FW shaft inserts into the side of the housing containing the focusing lens, a white nylon spacer rides on the shaft, the FW rides on top of the spacer, one crushed washer with the flat side facing the FW rests on top of the FW (nylon spacers may be used instead of a crushed washer in order to adjust the position of the FW within the housing).

41. Each filter is held in a filter holder with three dabs of epoxy. The filter holders are secured to the wheel via two hex head bolts. To change a filter the holder should be removed from the wheel. The epoxy can be scraped away and the filter can then be removed from the holder. Be sure the replacement filter is sitting flush against the holder when applying the epoxy. Use low out gassing epoxy. The epoxy should be allowed to fully cure before the filter wheel assembly is reassembled.

42. Reassemble the housing and replace the two rubber o-rings which seal the housing; one large o-ring between FW housing halves and one small o-ring below the FW view hatch.

43. Once the FW halves are mated back together, rotate the FW with a small screw driver through the viewing hatch to test for smoothness. Be sure the optical flag mounted on the wheel does not bind on the optical diode. The thin nylon spacers on the FW shaft can be added or removed as needed to get the spacing correct.

44. Replace the white plastic insulating spacer with the flat side facing the FW housing.

45. Replace the o-ring between PMT and the FW housing and place the PMT against the housing.

46. Replace and tighten the six 9/64 inch hex head bolts and washers that mate the PMT to the FW housing.

47. Replace and tighten the four 5/32 inch hex bolts with bite washers which fasten the FW housing and PMT to the Brewer chassis.

48. Replace the white face plate covering the foreoptics tube by replacing the two 3/32 inch hex bolts into the Brewer chassis at the spectrometer. Tighten the single 3/32 hex screw on the side of the face plate.

49. Replace the 9 pin connector of the signal line to the PMT by tightening the two flat head screws on the connector.

50. Replace the high voltage cable to the PMT by twisting the BNC connector onto the mate.

51. Replace the FW#3 connector to the FW#3 housing via the two hex head bolts on the ribbon connector.

52. Place the card rack into position inside the instrument, being careful to get all the wires and cables into safe positions.

53. Replace the two 3/32 inch hex head bolts that secure the back card rack feet to the Brewer base. These screws are accessed from underneath the instrument.

54. Replace the two 9/64 inch hex bolts securing the front card rack feet to the Brewer base.

55. Connect all the electronic ribbon cables to the card rack. The connectors should be labeled in black ink corresponding to the board and jumper to which they should connect.

56. Replace the Brewer outer cover and secure the four latches, ensuring that the outer cover is mounted evenly all the way around the Brewer case. Remove the quartz dome protector.

57. Replace the AC power cable and restore power to the Brewer.

58. Initialize communication between the Brewer and the computer.

59. After the motors have initialized and the Home screen is visible, move to the Teletype mode by giving the TT command.

60. Give the command "M,6,0:M,6,256:a". This will rotate FW#3 continually from position 1 to 4 and back. Observe if the FW#3 moves smoothly and does not bind. There should be a rhythm to the rotation that will be interrupted intermittently if there is a binding problem. Abort the command by pressing the "Home" key.

61. If the FW does not seem to be rotating properly it may be necessary to add or subtract some of the nylon washers on the wheel shaft. The housing will have to be disassembled again.

62. Once it is determined that the FW#3 is operating properly a final spectral response calibration should be performed, especially if the $NiSO_4$ filter was replaced. If the filter was replaced it will be necessary to perform a spectral response temperature dependence calibration of the Brewer as well since the filter has a large temperature dependence of its spectral response.

12 **Table 1: Brewer Motor Positions and Control Commands**

| Motor # and Name | Step # | Filter | FW Position | Command String |
|---|---|---|---|---|
| Filter wheel #1 | 320 | 0:film polarizer (horizontal) | O | M,4,320 |
| | 256 | 1:quartz diffuser (translucent) | I | M,4,256 |
| | 192 | 2:blocked aperture | II | M,4,192 |

| | | | | |
|---|---|---|---|---|
| | | (opaque) | | |
| | 128 | 3:clear aperture | III | M,4,128 |
| | 64 | 4:quartz diffuser; ND of f=2.0 (translucent) | IV | M,4,64 |
| | 0 | 5:film polarizer (vertical) | V | M,4,0 |
| Filter wheel #2 | 0 | 0:f=0 | O | M,5,0 |
| | 64 | 1:f=0.5 | I | M,5,64 |
| | 128 | 2:f=1.0 | II | M,5,128 |
| | 192 | 3:f=1.5 | III | M,5,192 |
| | 256 | 4:f=2.0 | IV | M,5,256 |
| | 320 | 5:f=2.5 | V | M,5,320 |
| Filter wheel #3 | 50 | Clear aperture (transparent) | I | M,6,50 |
| | 114 | Blocked aperture (opaque) | II | M,6,114 |
| | 178 | BG-12 filter | III | M,6,178 |
| | 242 | NiSO4 and UG-11 filter | IV | M,6,242 |

*12.3* **Table 2: Position of Filter Wheel Electronic Board and Jumper**

| **Filter Wheel** | **Electronic Board Number** | **Electronic Board Position (from top of card rack)** | **Jumper Number** |
|---|---|---|---|
| #1 | BA E50/B | 2 | 2 |
| #2 | BA E50/B | 2 | 3 |
| #3 | BA E50/D | 3 | 3 |

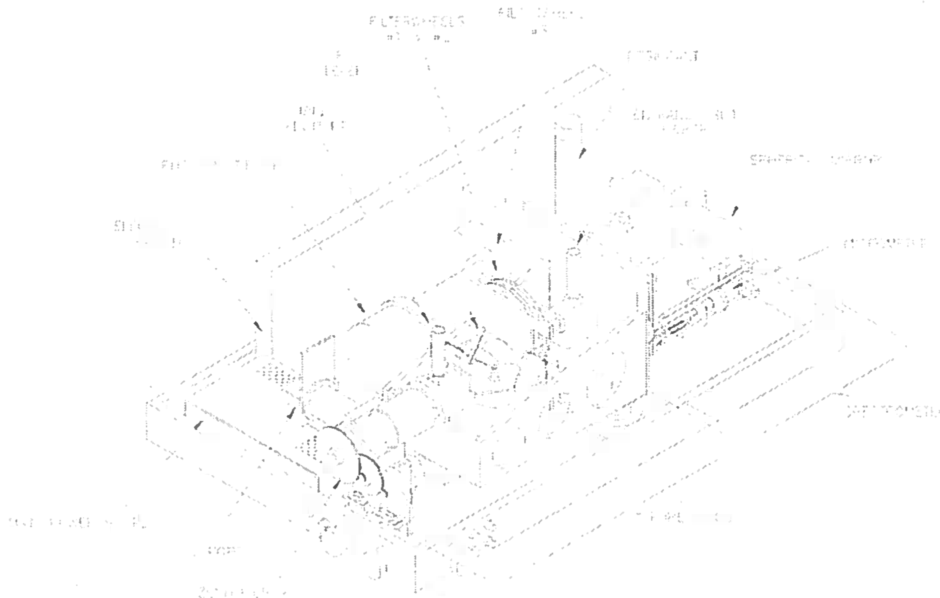

**Figure 1: Brewer components**

# Procedure for Measuring the Temperature Dependence of a Mk IV Brewer Spectrophotometer in the Laboratory

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Last updated March 24, 2003

1785

**Introduction**

It has been found by extensive testing in the laboratory that each Brewer Spectrophotometer has significant and unique wavelength dependent temperature dependence of the spectral response. This SOP gives a method for measuring the temperature dependence function using a 1000W lamp powered by a stable circuit with the Brewer operating in a temperature controlled environment. Currently a full sized deep freezer is used to provide the temperature controlled environment.

In order to accurately correct the spectrally resolved UV data collected from Brewer spectrophotometers operating in ambeint air environments, the temperature dependence of the unit must be taken into account. Each Brewer in the EPA network has a unique, wavelength dependent set of temperature coefficients. There are two main components that contribute to the temperature dependence of a Brewer, the photomultiplier tube (PMT) and the Nickel Sulphate ($NiSO_4$) filter. The PMT generally has a wavelength independent temperature dependence of approximately -0.2% per degree Celcius. The $NiSO_4$ filter, which is in the optical path from 2865 to 3250 Angstroms (A), generally has a wavelength dependent temperature dependence ranging from about -0.5% to +0.05% per degree C. The temperature dependence across the wavelength range of the $NiSO_4$ filter generally exhibits a predictable "S" shape.

**Equipment**

Mk IV Brewer spectrophotometer
Deep freezer with custom quartz window and heat dissipating top surface
Platform inside the freezer for positioning Brewer as close to the quartz window as possible
1000W lamp mount and angle bracket
1000W FEL lamp
*Xantrex* power supply
Digital multimeter with two input panels
Standard shunt
Wiring harness for 1000W lamp
Hex wrench set (English sizes)
Methanol and tissues

**Purpose**

This Standard Operating Procedure (SOP) outlines the NUVMC technique for measuring the temperature dependence of the spectral response of a Mk IV Brewer spectrophotometer.

Procedure-Apparatus Setup and Alignment

1. With the Brewer set up outside of the freezer, establish communication between the instrument and the computer.

2. In order to obtain maximum photon counts from the lamp scans, Filter

Wheel #2 (FW#2) should be moved to position zero and then disabled. Locate FW#2 under the plexiglass window on top of the Brewer. Notice the black hash marks that are between the teeth of the cogs on the FW's. The goal is to set FW#2 to the position in which no black hash marks are visible between the cogs.

3. Use teletype to move FW#2 to position 0 by first typing "tt" on the main menu screen. You do not need to make a hard copy, so when asked, type "n". Press ENTER until a command line with an arrow appears.

4. Type "M,5,0" and press ENTER to execute the command. Refer to **Appendix H, Computer/Brewer Interface (Teletype)** section in the Brewer's Operator's Manual for complete details of operating the Brewer in teletype mode. Before exiting teletype mode proced to step 3.

5. Remove the Brewer case and locate the 25-pin connector that lies to the side of FW#2. The FW#2 connector can be identified as the middle connector in a series of three similar connectors that are attached to the Brewer chassis in front of the foreoptics tube.

6. Visually verify that FW#2 is in position zero. There should be no hash marks visible between the cogs when looking from the top of the Brewer.

7. Disconnect the 25-pin connector from the bulkhead connector. Now commands from the electronic board cannot reach the stepper motor that controls FW#2. The position of the filter wheel can be adjusted both by computer commands and by manual adjustment so be sure not to accidentally move it from the zero position.

8. Disable the Brewer's internal heater by disconnecting the molex connector that runs from the AC power input to the heating pads which are usually mounted underneath the Brewer chassis. The heater connector is usually found near the zenith prism assembly area of the instrument.

9. Add fresh desiccant and a breather tube and replace the Brewer cover.

10. Exit the teletype mode by pressing the home key.

11. Verify that FW#2 is still in the zero position.

12. Place the Brewer into the deep freezer so that the UV dome is directly under the quartz window. The NUVMC built a custom platform out of wood to raise the instrument to within about 6 inches of the quartz window.

13. Close the freezer door. The freezer door will close even with the data and AC cable coming out. Make sure that communication with the computer is

established and that the Brewer is in working order before turning on the freezer.

14. Position a dual input electronic thermometer outside the freezer. Slide one thermistor lead inside the freezer to measure the internal freezer temperature. Leave the second thermistor lead exposed to the ambient air.

15. Let the Brewer sit in the freezer overnight so that it can reach equilibrium. This generally takes about 15 hours.

16. Program the Brewer to run scans during this cool down time, otherwise it is likely that some components will freeze up. Give the CS command at the Brewer Home screen and when prompted for the number of scans, enter 6. The six commands to be used are HG, SL, RS, DT, FR, AP. Enter these commands one at a time.

17. The computer will then prompt the user for the number of times to run the command sequence. This particular sequence of commands will take about 30 minutes to complete, so usually about 40 sequences are programmed. The command sequence can be aborted whenever it is time to start the temperature dependence experiment. If the results have been printed to paper, the instrument's internal temperature as reported in the AP printout can easily be viewed. Typically the Brewer gets down to about −10C if the internal heater has been disconnected, otherwise the internal temperature should not go below 5C. Remember that the internal temperature of the Brewer will always be a bit higher than the internal temperature of the freezer because of the heat generated by the electronics.

Procedure-1000W Lamp Wiring and Operation

10. The 1000W lamp mount is positioned directly over the quartz window on an angle bracket which is bolted to the freezer door.

11. Connect the current leads of the lamp wiring harness to the posts on the lamp mount. The current leads should be of appropriate rating in order to safely handle the 8.2 Amp current from the power supply to the lamp.

12. Connect the other end of the current leads to the *Xantrex* power supply. The positive lead from the *Xantrex* should pass through the shunt so that the current to the lamp can be monitored.

13. Connect the voltage leads of the lamp wiring harness to the posts on the lamp mount.

14. Plug the voltage leads from the 1000W lamp mount into the back panel of the DMM to monitor the voltage across the lamp.

15. Plug the voltage leads from the shunt into the front panel on the DMM to monitor the voltage across the shunt.

16. Insert a 1000 Watt FEL lamp.

17. Clean the lamp with methanol and lens tissue.

Procedure-Temperature Dependence Measurement

1. After the Brewer has fully equilibrated in the freezer, usually the morning after setup, the CS command sequence can be aborted when the message "press Home to abort" appears on the computer screen.

2. Set the *Xantrex* power supply to constant current mode by turning the voltage knob to the maximum position and the current knob to the minimum position before engaging the power to the unit.

3. Provide 8.2 Amps current to the 1000W lamp by turning the current adjustment knob in the clock-wise direction until the voltage drop across the shunt reads 82.000 mV (assuming a 10 mili Ohm resistor is being used). The output of the lamp should be closely maintained during the test although the absolute intensity of the lamp is not critical. Allow the lamp to warm up for at least 30 minutes prior to taking any measurements.

4. Monitor the voltage readout on the DMM during this thirty minute warm up period and adjust the current output of the power supply to keep the voltage across the shunt as close to 82.000 mV as possible.

5. Make sure the Printer is on by pressing the "on-line" button and then typing "PDPN" at the Brewer main menu screen.

6. Enter the command string "APB1XLHG". This will run the Hg calibration followed by AP and XL scans before returning to the Brewer Home screen. At some point the user will be prompted to enter the 1000W lamp number and the distance of the filament from the diffuser.

7. Once the first scan data has been collected, unplug the power to the freezer. The Brewer and the freezer will now begin the process of heating up as the heat generated by the Brewer is trapped in the freezer and the 1000W lamp irradiates the unit.

8. Enter CS at the Brewer Home screen.

9. Enter the command sequence "APB1XLHG". The B1 command turns on the mercury lamp so that it is warming up while the XL scan is running. This means the 5 minute warm up delay will be skipped each time the HG calibration is performed.

10. The AP command produces a voltage and temperature check of the Brewer. The results will be sent to the printer. The first line is "Channel 0, Brewer temp 1 (deg C)". Note this value on the Temperature Dependence Measurement log sheet before each XL scan. This will allow for monitoring of the temperature increase throughout the day.

11. The dark count as reported at the beginning of each XL scan should also be monitored and recorded to help determine when the instrument's PMT has neared equilibrium temperature. The dark count typically rises exponentially with temperature and is generally below 5 counts until the instrument temperature reaches about 20C.

12. Fill out the information in the header of the "Temperature Dependence Measurement Record". Monitor the relevant information on the Record Sheet throughout the temperature dependence test.

13. Run the "APB1XLHG" sequence repeatedly until the temperature of the Brewer as reported in the AP printout begins to level off. Typically data is collected for eight to ten hours. This produces about 24 to 30 data scans.

14. Power down the current to the 1000W lamp by rotating the "current" control knob in the counter-clock-wise direction.

15. Allow the lamp to cool before storing it in a clean, protected environment.

16. Remove the Brewer from the freezer and open the case.

17. Reconnect the FW#2 25-pin connector to the bulkhead connector.

18. Reconnect the molex heater connector.

19. Change the desiccant packs and the desiccant breather tube.

**Procedure-Data Analysis**

1. Process the XL file using the data reduction program "rx.exe". This will produce a PXL file containing a header and two columns of data. The header will give the lamp number used to perform the measurement as well as the distance of the lamp filament from the Brewer diffuser. The first column of data is wavelength in Angstroms and the second column is photon counts per second.

2. Using a spreadsheet application such as MS Excel, arrange the photon counts from each scan into side by side columns. The first column should be designated for wavelength. Refer to Figure 1 for a visual interpretation of the way the data should be organized.

3. Insert four blank rows above the columns of wavelength and photon counts. These rows will be labeled as "scan #", "volts", "temperature" and "dark count". Refer to the Example Spreadsheet.

4. The "volt" and "dark count" information is located in the header of the XL file. For each data scan in the file, the volt is located in the 14th row and the dark count is located in the 17th row. Copy and paste the information from each XL scan into the spreadsheet above the corresponding photon counts column.

5. The volts are converted into temperature using the formula "Celcius =volts*18.64-33.27" (Note Brewer 087 uses the formula "Celcius =volts*16-29.5").

6. For each scan#, use the spreadsheet to sum the counts for all wavelengths >3250A.

7. Normalize the data with respect to the summed counts of the first scan.

8. Plot the normalized data versus the temperature. The plot should indicate a decreasing linear change of the summed counts as a function of wavelength. Any points that lie far off the least squares fit should be flagged and possibly dismissed from further analysis.

9. Plot the counts versus temperature for the specific wavelengths 3000A, 3200A, 3400A and 3600A. These plots will highlight the wavelength dependence of the temperature dependence.

10. Plot the dark counts of each scan versus temperature. The dark count should increase exponentially with increasing temperature. If the counts are plotted on a logarithmic scale the curve should be linear. Generally the dark count will remain statistically noisy until the temperature reaches about 20 to 25 Celcius. Any delays in increasing dark count indicate a delay between the thermistor temperature and the temperature of the PMT.

11. Plot the temperature versus scan#. On the same chart plot the dark count versus scan#, using the second y-axis. This chart is useful for selecting the best scan# range to use for calculating the temperature coefficients because it again highlights delays between the thermistor temperature and the PMT temperature both at the beginning and the end of the days scans.

12. Using the charts from the previous steps as a guide, select the scan# range to use to create the temperature coefficients. Generally the first few scans are ignored due to the temperature delay between the thermistors and the PMT and the last few scans may be ignored as well if the temperature at

the end of the day had leveled off. Occasionally scans taken in the middle of the measurement show anamolous results. There is no definitive method for choosing the proper scan#'s to use in the temperature coefficient calculation.

13. Using the spreadsheet, determine the percent change in photon counts per degree Celcius (%/C) at each individual wavelength. This can be done in MS Excel using the "slope" formula. For example, if row 3 contains the temperatures for each scan# and row 5 contains the photon counts for 2850A, in columns c thru n, the formula for %/C would be of the format "slope(c5:n5,c$3:n$3)/average(c5:n5)*100". This formula can then be applied to the full wavelength range without additional user input by scrolling the formula down. The "$" holds the formula constant on row 3 when the formula is scrolled down so that the temperature row always remains as the independent variable.

14. Plot the %/C values versus wavelength. The values below 3250A should fall roughly in the domain -1% to +0.05% and should generally increase with wavelength. The shape of the curve should have some scructure generally referred to as "S-shape", with an inversion around 3000A. The values above 3250A should fall roughly in the domain –0.1% to –0.3% and appear more linear than the values in the lower wavelength range.

15. If the graph shows any %/C values for a particular wavelength which are way off scale, check the photon count raw data at that wavelength for anomolous values. Since the Brewer counting circuitry is statistical, occasionally values that are not real are recorded in the file. Correct any anamolous values using an average photon counts of the scan just before and just after.

16. To smooth out the statistical variation of the instruments counting circuitry, fit polynomials to the %/C values. Do this separately above and below 3250A since the shapes of the temperature dependence %/C curves are quite distinct in these two regions due to the $NiSO_4$ filter.

17. Fit a $6^{th}$ order polynomial to the values in the wavelength range 2865A to 3250A. An easy way to select the wavelength range for the fitting polynomial is to create two copies of the %/C chart and then modify the wavelength range so only data from 2865A to 3250A is present on one chart and data from 3255A to 3630A is present on the other. Select "options" under the "trendlines" pull down menu and select to display the polynomial formula on the chart. Format the text to scientific notation with 15 decimal places by double clicking on the text and selecting "number". Copy the formula for this polynomial to a blank cell in the spreadsheet (column T in the example spreadsheet). Change the variable "x" to the cell number of the wavelength. For example if 2865 is in column a, row 5, paste the formula into column t, row 5 and change the "x" variable to "a". Scroll the formula down the column to the cell corresponding to 3250A to create a new %/C for each wavelength

based on the fitting polynomial.

18. Fit a different $6^{th}$ order polynomial to the values in the wavelength range 3255A to 3630A. Set the polynomial to display on the chart and format the text to scientific notation with 15 decimal places. Copy this formula to the blank cell corresponding to wavelength 3255A and replace the variable as in the previous step. Scroll down the column to create new %/C values based on the fitting polynomial for the wavelength range 3255A to 3630A.

19. Plot the fitted %/C values onto the same graph with the unfitted %/C values to be sure that they fall within the correct domain and range. The fitted values should be a smooth version of the unfitted values.

20. To produce coefficients from the %/C values, divide the %/C column by 100. Format the values in the column of coefficients to 9 decimal places using the "format/cell/number" menu.

21. If the temperature dependence measurement was performed using a 1000W lamp in the lab, the coefficients have to be modified by +0.0007 to make them ready for the NUVMC corrections program. The reason for this is that the 50W lamps have a positive temperature dependence of 0.07%/C and the corrections program subtracts this value off of the values in the TC file because most of the measurements were done originally at the field sites using 50W lamps

22. Document some information into the spreadsheet such as the type of lamp used, when and where the measurement took place, who performed the measurement and if the filter wheel #2 was disabled.

23. Update the MS Excel master file "TC File Data for All Brewers" with the new set of coefficients and fill in the header information for documentation purposes.

## *12.4 Figure 1: Example MS Excel Spreadsheet*

| *12.5* | B | C | D | N | T | U | V |
|---|---|---|---|---|---|---|---|
| 1 | Scan# | Scan#1 | Scan#2 | Scan#N | | | |
| 2 | Volts | | | | | | |
| 3 | Temperature | "=c2*18.64-33.27" | "=d2*18.64-33.27" | "=n2*18.64-33.27" | %/C | Coefficient | Corrected for 1000W |
| 4 | Dark Count | | | | Scans #x-#y | Scans #x-#y | Scans #x-#y. |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 5 | 2865 | | | | "=slope(x5:y5:x$3:y$3)/average(x5:y5)*100" | =t5/100 | =u5+0.007 |
| 6 | 2870 | | | | "=slope(x6:y6:x$3:y$3)/average(x6:y6)*100" | =t6/100 | =u6+0.007 |
| 7 | 2875 | | | | | | |
| .. | .... | | | | | | |
| 82 | 3250 | | | | | | |
| 83 | 3255 | | | | | | |
| .. | .... | | | | | | |
| 158 | 3630 | | | | | | |
| 159 | | | | | | | |
| 160 | Summed counts>3250A | "=Sum(c83:c158)" | "=Sum(d83:d158)" | "=Sum(n83:n158)" | | | |
| 161 | Normalized | "=c160/$c160" | "=d160/$c160" | "=n160/$c160" | | | |

**For further information or advice concerning this SOP please contact the NUVMC at the University of Georgia at http://oz.physast.uga.edu**

# Procedure for servicing the zenith prism mechanical drive system in a Mk IV Brewer spectrophotometer

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**University of Georgia**
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National
Ultraviolet
Monitoring
Center

Prepared by M.G. Kimlin and T.E. Taylor
Last updated March 27, 2003

1785

## Introduction

In order to select the geometric light path for the variety of scans that the instrument is capable of performing the Brewer uses a prism assembly which rotates via a set of ball bearing races on a drive shaft. The shaft is clamped via a collar to the main drive gear. The main drive gear is rotated by a secondary gear which is in contact with a stepper motor. The stepper motor is controlled by the Brewer computer via internal electronic boards and ribbon cables.

The zenith prism has a range of 270 degrees. It can be turned from the full sky UV prism for UV scans to the internal test lamps for diagnostic routines. The prism can be set anywhere between these two positions for taking direct sun ozone measurements.

As the Brewer ages the ball bearings may eventually freeze up, making it necessary to remove the assembly to apply lubrication to the inner and outer bearings. Grit and dust will accumulate on the focusing lens positioned just above the internal lamps as well as on the UV and zenith prisms. These prisms and lens may be cleaned using spectroscopic grade methanol and lens tissues.

## Equipment

Mk IV Brewer spectrophotometer
Hex wrench set (English sizes)
Retaining ring "C-clip" wrench (small size)
Krytox grease
Spectroscopic grade methanol
Lens tissues
Spare AC power cable (optional)
Spare data cable (optional)

## Purpose

This Standard Operating Procedure (SOP) outlines the NUVMC technique for servicing the zenith prism drive mechanical assembly in a Mk IV Brewer.

Procedure

1. If the Brewer is still running in schedule exit the schedule by pressing the Home key when the message "Press Home to abort schedule" appears on the computer screen.

2. If possible perform a spectral response calibration on the Brewer using the 1000W lamps. If this is not possible run at least three 50W lamps to use as a reference for any change that may take place to the instrument's sensitivity due to the removal of the zenith prism assembly. Follow the procedure in the document "Procedure for 50W lamp calibrations" available from the NUVMC.

3. Power off the Brewer by pressing the push button located on the edge of the instrument near the zenith prism window.

4. Place a protective cover on the quartz dome on the top of the Brewer

outer cover.

5. Remove the circular connectors for the zenith drive, power and data cables which are connected from the tracker into the side of the Brewer.

6. Remove the 4 hex bolts connecting the Brewer feet to the tracker unit.

7. Lift the Brewer off the tracker and move it indoors to a clean working environment.

8. Connect the AC power and data cables to the Brewer and initialize communication between the Brewer and computer. If the cables that are normally used to control the instrument cannot be easily rerouted to the inside work space, it may be necessary to use spare cables.

9. Remove the Brewer outer cover by loosening the four latches and lifting the cover up.

10. Refer to Figure 1 for the location of the zenith prism assembly inside the instrument.

11. Loosen the 7/64" hex head bolt which inserts into the face of the brass zenith prism drive gear through its center. It is not necessary to completely remove this screw.

12. Loosen the 7/64" hex bolt which secures the main drive gear collar to the zenith prism shaft.

13. Remove the main drive gear from the zenith prism shaft by pulling it along the shaft.

14. Remove the retaining c-clip from the zenith prism shaft via the c-clip wrench.

15. Remove the three 1/16" hex head bolts which secure the zenith gear plate to the end of the foreoptics tube.

16. Remove the zenith gear plate from the instrument and set it aside.

17. Remove the three 5/64" hex head bolts securing the drive bearing plate to the foreoptics tube.

18. Loosen the 3/32" collar bolt which secures the bearing assembly to the foreoptics tube.

19. Remove the bearing assembly from the foreoptics tube by gently pulling it

away from the end of the tube.

20. Remove the zenith prism assembly from its housing. Note the position of the floppy washer on the zenith prism shaft.

21. Clean the internal lamp lens and the zenith prism using methanol and lens tissues.

22. Lubricate the inner and outer ball bearings with Krytox grease.

23. Reinsert the zenith prism shaft into the bearing housing taking care to insert the hard stop pin into the groove. The zenith prism should be able to rotate from the full sky UV position to the internal lamp position and should hit hard stops at both of these positions.

24. Remount the drive bearing plate into the end of the foreoptics tube.

25. Reinsert the three 5/64" hex bolts holding the bearing plate to the foreoptics tube.

26. Remount the zenith gear plate to the drive bearing plate and reinsert the three 1/16" hex bolts.

27. Tighten the 3/32" collar bolt which clamps the zenith prism assembly to the foreoptics tube.

28. Reinsert the c-clip onto the zenith prism shaft making sure that the clip engages into the groove on the shaft. It may be necessary to bend the c-clip to tighten it before it will engage into the groove.

29. Replace the main drive gear onto the drive shaft being sure the gear meshes with the brass drive gear.

30. Secure the 7/64" collar bolt which clamps the main drive gear to the drive shaft.

31. Tighten the 7/64" bolt which secures the brass drive gear to the zenith gear plate.

32. Loosen the two 7/64" hex bolts holding the full sky UV prism onto the foreoptics side tube.

33. Remove the prism assembly from the foreoptics side tube.

34. Clean the UV prism using methanol and tissue.

35. Reinsert the UV prism assembly into the foreoptics side tube and tighten the two 7/64" hex bolts.

36. Reconnect the AC power and data cables and reinitialize communication between the Brewer and computer.

37. Follow the NUVMC procedure "Procedure for zenith prism alignment" for adjusting the alignment of the zenith prism as it will have been compromised due to the removal of the assembly.

38. After the zenith prism alignment is corrected, disconnect the AC power and data cables and move the Brewer back to its position outside on the tracker.

39. Reinsert the four hex bolts securing the Brewer feet to the tracker.

40. Remove the quartz dome protector.

41. Reconnect the power and data cables and reinitialize communication with the computer.

42. Perform lamp scans on the same 50W lamps that were run prior to moving the Brewer or perform another spectral response calibration using 1000W lamps.

43. Perform a tracker steps per revolution (SR) test followed by a sun sighting (SI) per the procedure in the Operators SOP. This will ensure that the Brewer optical path is reoriented properly if the zenith prism was realigned. The date and time on the computer should be verified to be correct for this step.

44. Enter an electronic comment (CM or CO command) describing briefly if the zenith prism was adjusted of if any other work was performed. Also enter a brief entry in the paper station log form.

45. Place the Brewer back into schedule by giving the command "skc" at the command line. When prompted for schedule, enter the name of the current network schedule (epa96d for the US EPA/UGA network as of December 2002).

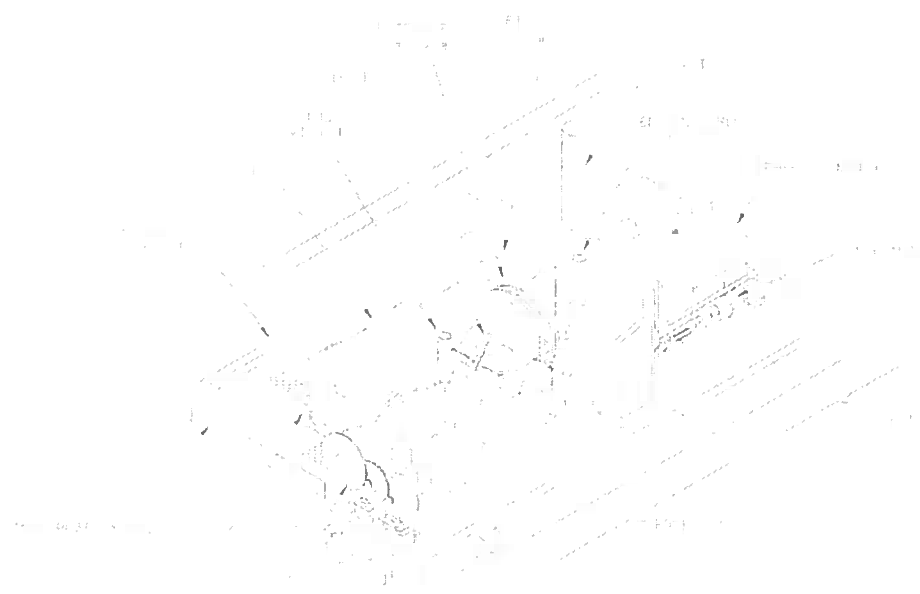

**Figure 1: Brewer components**

**For further information or advice concerning this SOP please contact the NUVMC at the University of Georgia at http://oz.physast.uga.edu**

## 13 Temperature Dependence Measurement Record (for use with 1000W lamp set up.

| Date | Julian Day | *13.3* User Name | *13.4* Site Location | *13.5* Brewer # | 1000W Lamp # |
|---|---|---|---|---|---|
| | | | | *13.6* | *13.7* |

| Power Supply (PS) Serial # | Digital Multimeter (DMM) Serial # | Shunt # | Desired reading on DMM (mV) |
|---|---|---|---|
| | | | |

Time Lamp turned on;

| XL Scan # | Time (CUT) | DMM Voltage 1 (shunt in mV) | DMM Voltage 2 (lamp in Volts) | Freezer Temp | Ambient Temp | Brewer Filter Temp (from AP test) | Dark Counts |
|---|---|---|---|---|---|---|---|
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| **Burn Time for Sheet** | | | | | | | |

# Procedure for Performing the Slit Width and Stray Light Measurement on a Mk IV Brewer Spectrophotometer

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**Prepared by Dr M.G. Kimlin and T.E. Taylor**
**Last updated July 29, 2003**

National
Ultraviolet
Monitoring
Center

## Introduction

The National Ultra-Violet Monitoring Center (NUVMC) performs stray light and slit width measurements on all Brewer Mk IV instruments in the EPA Brewer network. A frame Argon ion laser is used as the input source while the Brewer scans across the full spectrum at low (5A) increments and again across the peak of the laser in high (0.5A) increments. This data provides for both an analysis of the stray light structure of the instrument as well as the slit width function. The measurement is performed twice, once with laser line 3510 and again with the 3334 line.

The slit width of a typical Mk IV instrument is 5.5A. It has been found that the stray light structure of each instrument varies significantly. While a "good" instrument may have a ratio of the high to low intensity (Rejection or R-ratio) of about 4000, some instruments have been observed to have large structures providing an R-ratio of only 5000 or so.

An intense study was carried out at the NUVMC laboratory to study the cause of this poor R-ratio on Brewer 96-140 in 1997. It was found that multiple reflections of higher order light from the dispersion grating was the cause of the problem. It is was determined that a small mask placed in front of the concave mirror absorbs these unwanted orders and reduces the structure to tolerable levels.

## Equipment

1 Argon ion laser
4 adjustable UV reflecting mirrors
1 UV partially transmitting lens (~10% reflectance)
1 lens for expanding laser beam
1 adjustable iris
1 beam dump
1 beam blocking card
9 base and post sets for mounting mirrors and lenses
1 Brewer Mk IV spectrometer
1 Brewer controlling computer with "Lh.rtn", "Lo.rtn" and "Lhtest.rtn"
1 set of neutral density filters (0.1, 0.2, 0.3, 0.4, 0.5 and 1 attenuation)
2 interference filters with 10nm bandpass, center wavelengths 3510A and 3340A

## Purpose

The purpose of this procedure is to simultaneously measure the stray light rejection and slit width of a Brewer Mk IV using an Ar+ laser as the input source.

**Procedure-Setup**

1. Fill the dewer with liquid nitrogen and attach the hose to the laser so that the laser cavity will be cleansed of ozone which is created by the UV laser lines. Be sure the inlets are open on both valves.

2. Turn on the water to the laser cooling system via the lever on the wall near the water filter.

3. Turn the water pump on by pressing the "Power On" button on the pump housing.

4. Turn the laser power supply on by turning the key to the "ON" position on the main power supply.

5. Close the aperature near the exit port of the laser tube.

6. Power up the Ar+ laser by pressing the "Power System ON" key on the remote control module. It takes a few seconds for the system to warm up before it can be tuned to lase.

7. Place a blocking plate a few inches from the exit port of the laser. See Figure 1 for a picture of the Ar+ laser.

8. Open the aperature of the laser.

9. On the remote control module press the "tune" key so that the wavelength of the laser can be adjusted.

10. Press the Up Arrow key to increase the current to the laser tube so that it will have enough power to lase.

11. Using the adjustment knob on the end of the laser chassis, tune the laser until the power meter registers some output. The beam should change from fuzzy blue to intense blue.

12. Continue to fine tune the laser until the power is maximized at that particular wavelength. There is no way to determine which wavelength the laser is tuned to until a scan is made using the Brewer.

13. Once the laser wavelength is tuned to the position at which the scale reads the maximum output power, adjust the power supply current to the laser via the Up and Down Arrow keys so that the output power is a few Amps higher than the minimum output power required for the laser to lase at the particular line. This will be around 45 Amps for the 3510A line and around 55 Amps for the 3334 line.

14. Press the "track" key on the remote module to change to the track mode. This will automatically maintain the power output of the laser via an internal feedback loop.

15. Place mirror #1 at a 45 angle to the exit port of the laser tube to deflect the beam 90 to the right.

16. Place mirror #2 at a 45 degree angle to the beam to deflect the beam another 90 degrees to the right such that the beam is now traveling parallel to the tube.

17. Near the end of the laser optics table place mirror #3 at a 45 angle to the beam to reflect the laser 90 degrees such that it is traveling toward the black curtain that separates the laser room from the dark room. There is a hole in the curtain through which the beam should be made to pass. See Figure 2 for a picture of mirror #3. Sometimes a partially transmitting lens is used instead of a mirror to decrease the intensity of the laser beam. If this is used only a percentage of the beam will be reflected (10%) and a beam dump should be placed behind the lens to absorb the transmitted beam.

18. Adjust the mirrors so that the laser beam passes through the curtain into the dark room.

19. Place mirror #4 on the edge of the optics table in the dark room at a 45 angle to the beam such that the beam is reflected down to the floor. See Figure #3 for a picture of the placement of mirror #4.

20. Place the Brewer on the floor, just next to the optics table in the dark room such that the laser beam is incident on the middle of the diffuser.

21. Set up some optical rods and bases on which the neutral density filters and interference filters can be mounted just in front of mirror #4. See Figure #3 for a picture of the optical train from the perspective of looking down on the Brewer.

22. In the laser room place the adjustable iris on the optics table in the path of the laser such that the beam in incident on the center of the iris. Adjust the iris to a diameter of about 5mm so that the extraneous plasma lines of the beam are attenuated. See Figure 2 for a picture of the placement of the iris.

23. In the laser room place the expanding lens on the optics table in the path of the laser between mirror #3 and the black curtain. The focal length of the lens should be such that the beam is expanded to about the size of the Brewer diffuser (3.5cm) at the path length distance from the lens to the diffuser. See Figure 2 for a picture of the placement of the expanding lens.

24. Adjust the mirrors as necessary to make the expanded beam incident evenly over the center of the Brewer diffuser.

25. Place a neutral density filter in the filter holder just in front of mirror #4 to attenuate the laser intensity before beginning any scans to protect the Brewer from over saturation.

**Procedure-Laser Line Scans**

1. Perform an HG line calibration on the Brewer. Verify peak counts at step 15.

2. Run the "lhtest.rtn" from 2870 to 2900 at 5A increments. Note the dark counts and the counts at 2900A.

3. Adjust the intensity of the beam by adding or subtracting ND filters until the counts at 2900 are about 100 times the dark count. If the counts are an order of ten too high then the partially transmitting lens mentioned in the Setup section should be used in place of mirror #3.

4. Determine which wavelength the laser is lasing by running "Lhtest" from 3300A to 3350A in 2A increments. The laser has a doublet between 3334 and 3345A. If no peak is observed, run "Lhtest" again from 3500 to 3520 in 2A increments to see if the laser is lasing at the 3510A line.

5. Insert either the 3340A or 3510A interference filter to match the laser line into the optical train in front of mirror #4. These filters have a bandpass of 10nm and will therefore attenuate unwanted plasma lines.

6. Run the "lhtest.rtn" again from 2870 to 2900 at 5A increments and adjust the beam intensity if necessary using ND filters until the counts are about 100 times the dark count.

7. Run the "Lo.rtn" to take the low resolution scan across the full Brewer spectrum.

8. Reduce the intensity of the laser beam by inserting a more powerful ND filter in the optical train in front of mirror #4. Do not adjust the output of the laser.

9. Run the "Lhtest.rtn" across 5A on both sides of the wavelength peak in 1A increments for a total of 10 data points.

10. Adjust the intensity of the beam as necessary using ND filters until the peak counts are between 100,000 and 150,000 counts.

11. Run the "Lh.rtn" across 30A on both sides of the wavelength peak

in 0.5A increments for a total of 120 data points.

12. Press the "tune" key on the remote module and adjust the current to the laser using the Up and Down Arrow keys to an appropriate level.

13. Tune the laser using the wavelength dial either up or down to the appropriate wavelength, i.e., 3351A or 3334/3345A.

14. Readjust the laser current using the Arrow keys to a little above the minimum threshold.

15. Repeat steps 1 through 11 for the measurement of the second laser line.

**Procedure-Data Processing**

1. Copy the files "Lodddyy.###" and "Lhdddyy.###" from the \bdata directory.

2. Open the Lo and Lh files in MS Excel spreadsheet using space delimited.

3. Copy and paste the data for the 3511A line into one worksheet so that there are columns for low resolution wavelengths, low resolution counts, high resolution wavelengths and high resolution counts.

4. Create a new column of wavelengths from 3485 to 3540A in 5A increments.

5. Copy and paste the data for these wavelengths from the low resolution and high resolution scans into the two adjacent columns.

6. Create a column of the low res counts divided by the high res counts in the adjacent column. These ratios should be similar at all wavelengths except for the few near the peak (because the Brewer counts were saturated during the low resolution scan).

7. In a line below the ratio column calculate a "fitting factor" by averaging the ratios at all but the anomalous wavelengths. Typically 10 of the 12 ratios will be "good" while the two near the peak will be smaller by a factor of 5 to 10.

8. Create a new column of the product of the fitting factor (FF) and the high resolution data points for each wavelength, i.e. (FF*high counts). This will allow the high and low resolution data to match (normalization) so that they can be plotted together on the same graph scale.

9. Plot a graph of the high and low resolution data. The low res data should be plotted as points while the high res should be plotted as a continuous line

for clarity. See Figure #4 for an example plot.

10. Calculate the Rejection ratio (R-ratio) by dividing the peak counts by the average counts over some selected wavelength interval. If there is very little stray light structure as in the example chart the R-ratio can be determined for just one wavelength interval such as 2865 to 3250A. In this case the R-ratio was nearly 40, 000 which is considered a good number. Figure #5 shows the plot for a Brewer with a poor stray light rejection.

11. Repeat steps 3 through 10 for the 3334A line.

12. Save the MS Excel file in the appropriate Brewer characterizations sub directory using the filename format "Slitwidth_Straylight_dddyy.###".

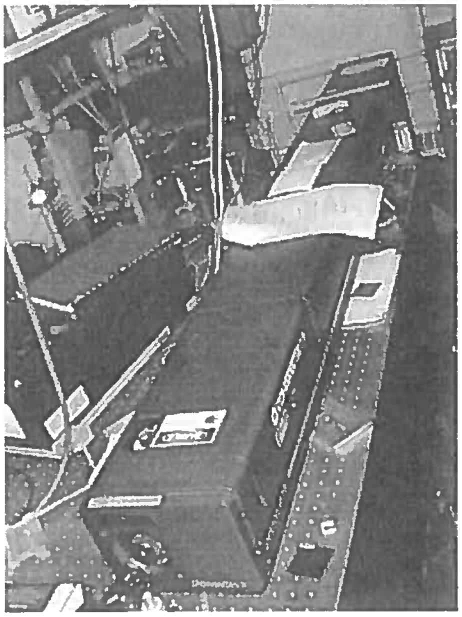

**Figure 1: Argon ion frame laser on optic table in laser room.**

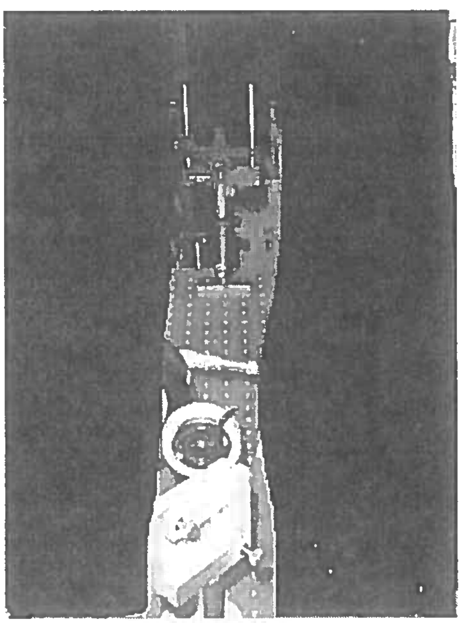

**Figure 2: Mirror #3, adjustable iris, expanding lens.**

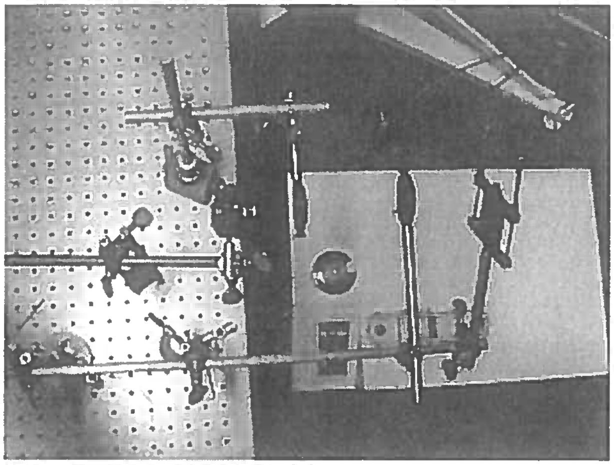

**Figure 3: Optical train of neutral density filters, interference filter, mirror #4 and Brewer.**

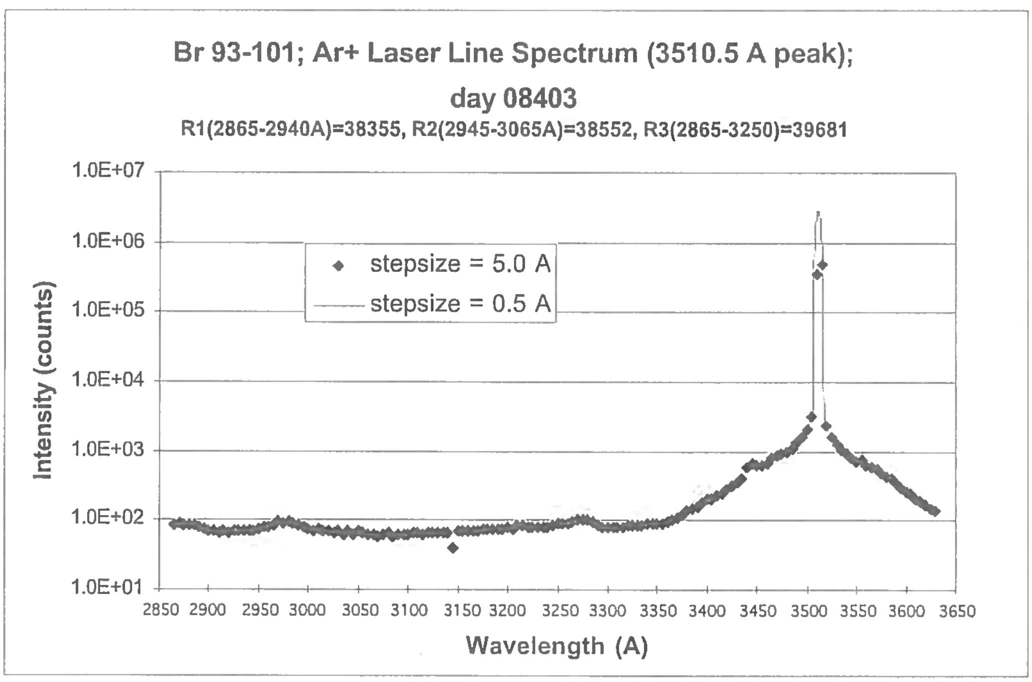


**Figure 4: Plot of typical high and low resolution data from the 3510A laser line. Example of <u>good</u> stray light rejection.**

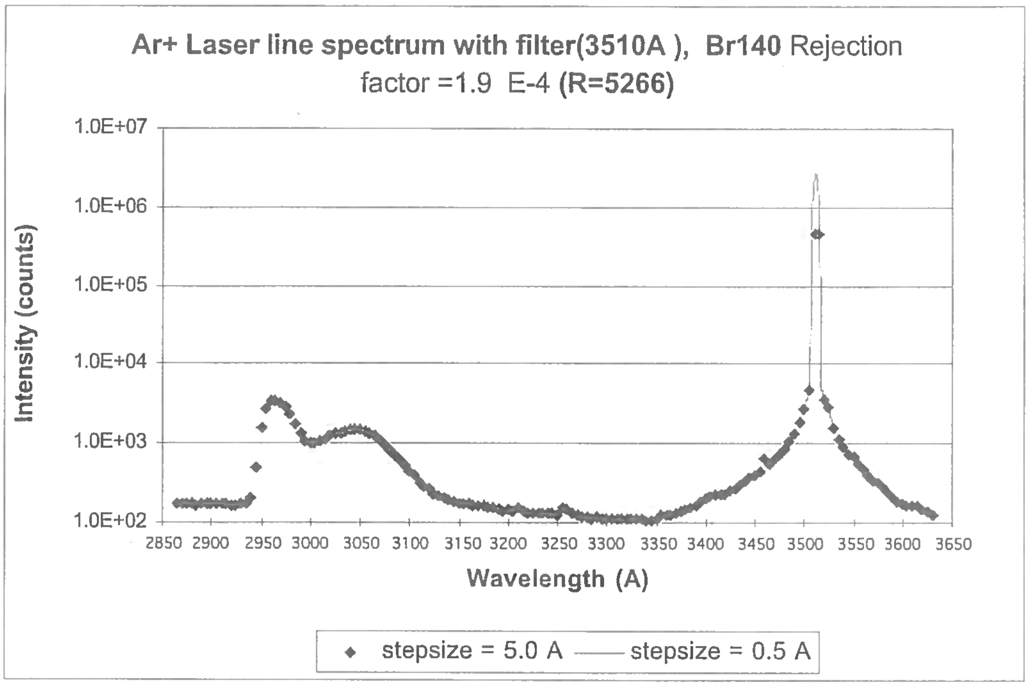


**Figure 5: Plot of typical high and low resolution data from the 3510A laser line. Example of poor stray light rejection.**

# Procedure for removing the photomultiplier tube in a Mk IV Brewer spectrophotometer

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National
Ultraviolet
Monitoring
Center

**Prepared by Dr M.G. Kimlin and T.E. Taylor**
**Last updated July 29, 2003**

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**Introduction**
During refurbishment of Brewers in the EPA network it is desirable to remove the PMT from the instrument to clean and tighten the electrical contacts. This will increase the operational lifetime of the tube. Normally the Filter Wheel #3 housing is removed in order to replace the $NiSO_4$ and UG11 filters during refurbishment. The added work of completely removing the tube from the housing is worth the time investment.

**Equipment**
Mk IV Brewer spectrophotometer
Hex wrench set (English sizes)
Flat head screw driver (small)
Bench vise
RTV silicon (Dow Corning #3145)

**Purpose**
This Standard Operating Procedure (SOP) outlines the NUVMC technique for removing the PMT assembly in a Mk IV Brewer.

Procedure
1. Place a protective cover on the quartz dome on the top of the Brewer outer cover.

2. Move the Brewer to a clean, indoor environment with ample space to work.

3. Connect the AC power and data cable and initialize communication between the Brewer and computer.

4. Perform a spectral response calibration per the SOP on the instrument before removing the PMT.

5. Remove the Brewer outer cover by loosening the four latches and lifting the cover up.

6. Locate the photomultiplier tube (PMT) assembly. Refer to Figure 1. Note the figure shows a schematic of a single electronic board instrument. The layout of a multi board instrument is similar.

7. Remove the connectors for the shutter motor by loosening the two 3/32" hex bolts.

8. Disconnect the FW#3 ribbon cable connector from the FW#3 housing via

the two hex head bolts.

9. Disconnect the high voltage (HV) cable from the base of the photomultiplier tube (PMT) by twisting the BNC connector off the mate.

10. Remove the 9 pin signal line from the PMT base by loosening the two flat head screws on the 9-pin connector.

11. Remove the white face plate covering the foreoptics tube by removing the two 3/32 inch hex screws fastening the plate to the Brewer chassis at the spectrometer. Loosen the single 3/32 hex screw on the side of the face plate near the zenith prism. Lift the plate off and set it aside.

12. Disconnect the D-sub pin connectors to both the internal lamp and the zenith prism motor.

13. Disconnect the iris and FW#1 and #2 motor connectors from the ribbon cables. The ribbon cables are mounted to the right foreoptics sidewall plate.

14. Remove the four 7/64" hex bolts which secure the foreoptics tube brace plate to the foreoptics tube left and right sidewall plates. The sidewall plates can be identified as the ones with a series of three holes bored out of them.

15. Grasp the foreoptics tube with one hand near the spectrometer box and the other hand near the zenith prism and gently slide the tube in the direction of the zenith prism-away from the spectrometer. The end of the tube near the spectrometer should come free of the spectrometer wall and the entire foreoptics tube should be able to be lifted out of the instrument.

16. Loosen the six 9/64 inch hex head bolts that secure PMT to the FW#3 housing.

17. Remove the PMT from the housing in a reduced light area. Quickly cover the open end of the PMT with lens tissue and the wrap in an outer layer of cloth.

18. Remove the white plastic insulating spacer from the FW#3 housing.

19. Remove the rubber O-ring from the end of the tube housing.

20. With the PMT housing now removed from the instrument, unscrew the amplifier cap which is threaded onto the end of the housing. Note the large O-ring between the inside of the cap and the housing.

21. Place the PMT housing assembly into a bench vise with the tube pointed skyward. Use a block of wood or thick rubber to hold the threads in the vise

so they are not damaged.

22. Rotate the PMT housing to loosen it from the base assembly. The PMT will now be exposed. Avoid overexposure to ambient light.

23. If the Brewer is equipped with an EMI #9789 type tube (38mm diameter) then the magnetic shield ground line needs to be unsoldered from the plastic base.

24. Remove the shield from the PMT.

25. Remove the PMT pins from the ring socket by gently pulling them apart.

**26.** Protect the tube by wrapping it with cloth. Work only with diffuse room light and avoid overhanging fluorescent lights. See **Precautions for handling a photomultiplier tube.**

27. Hold the tube with the pins pointing downward and gently clean the pins with emory paper.

28. Wipe the pins clean using methanol and tissue.

29. Probe each connection on the ring socket using a solid piece of wire approximately the same diameter as the pins. Feel for any connections that feel loose.

30. Tighten any loose connections using a small screw driver.

31. Align the blank pin spot with the blank connection on the ring socket and gently reinsert the tube pins into the ring socket into the tube is fully mated against the socket.

32. Loosen the two 8/32" hex bolts holding the amplifier board to the base assembly and carefully swing the amp aside with the wires still connected.

33. Loosen the three 8/32" hex bolts with spring loading which secure the electronic base to the base mount.

34. Loosen the three 8/32" nylon bolts which secure the amp mounting plate and carefully slip the mounting plate away from the tube.

35. There should now be good access to the shield grounding line resistor.

36. Slip the magnetic shield over the PMT and insert the shield grounding line into the socket on the base.

37. Slip the resistor wire loop over the grounding line. Remove any access solder from the line or loop.

38. Solder the grounding line to the resistor. Limit the amount of heat provided to the tube by using a heat sink.

39. Apply a dab of RTV silicon to the ground connection for protection. Allow the RTV to cure for 24 hours before reassembling the tube in the housing.

40. Replace the three 8/32" nylon bolts with springs and tighten until a clicking noise is heard.

41. Replace the three 8/32" bolts securing the electronic base to the base mount.

42. Replace the two 8/32" bolts holding the amp board to the base.

43. Place the PMT assembly into the bench vise with the tube facing skyware.

44. Carefully slip the PMT housing over the tube and tighten the threads to the base housing.

45. Replace the amplifier board end cap and tighten the threads. Be sure to place the large O-ring inside the cap.

46. Replace the white plastic insulating spacer with the flat side facing the FW housing.

47. Replace the o-ring between PMT and the FW housing and place the PMT against the housing.

48. Replace and tighten the six 9/64 inch hex head bolts and washers that mate the PMT to the FW housing.

49. Replace the foreoptics tube assembly into the instrument. Be sure the conical end mates firmly into the spectrometer entrance port. Watch for the possibility of pinching wires near the zenith prism end of the foreoptics tube.

50. Replace the ribbon cable connectors to FW#1, FW#2 and the iris.

51. Replace the D-sub connector to the internal lamps.

52. Replace the ribbon cable connector to the zenith drive motor.

53. Replace the white face plate covering the foreoptics tube by replacing the two 3/32 inch hex bolts into the Brewer chassis at the spectrometer. Tighten

the single 3/32 hex screw on the side of the face plate.

54. Replace the 9 pin connector of the signal line to the PMT by tightening the two flat head screws on the connector.

55. Replace the high voltage cable to the PMT by twisting the BNC connector onto the mate.

56. Replace the FW#3 connector to the FW#3 housing via the two hex head bolts on the ribbon connector.

57. Initialize communication between the Brewer and the computer.

58. Perform a High Voltage test to determine the optimal HV for the tube. The NUVMC has written an SOP for this procedure.

59. Replace the Brewer outer cover and secure the four latches, ensuring that the outer cover is mounted evenly all the way around the Brewer case.

60. Perform a spectral response calibration following the NUVMC SOP.

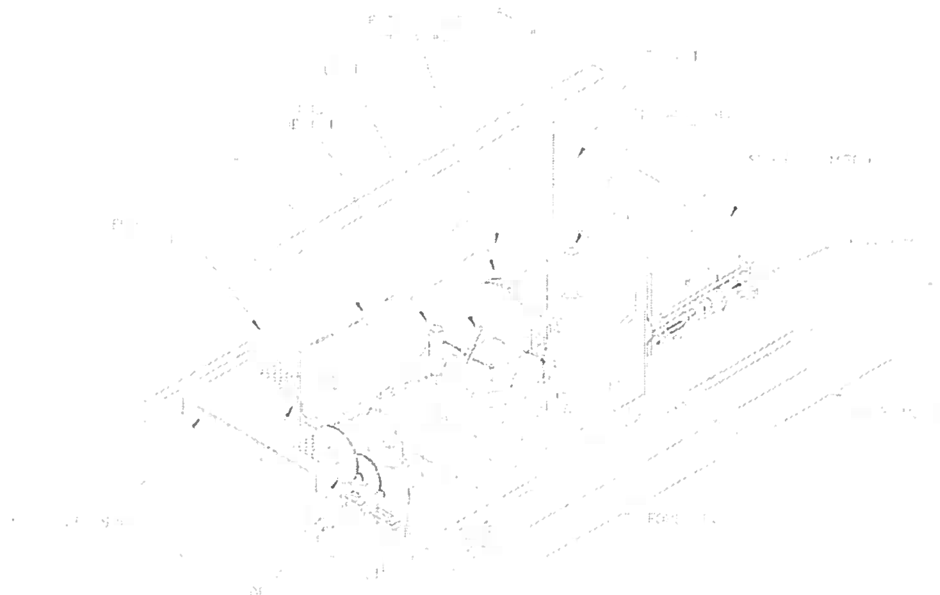

**Figure 1: Brewer components**

## Precautions for handling a photomultiplier tube.

Only sockets approved by Electron Tubes Limited must be used. Components fixed to the socket must not distort the natural pitch circle diameter of the contacts. From January 1990 PES (polyethersulphone) replaced DAP and PTFE previously used for sockets and over-caps and the following precautions apply:-

a. When soldering to the contacts the temperature must not exceed 220°C.

b. Sockets or over-caps must not be allowed to come into contact with the following substances: Cyanoacrylate adhesives ('Super glue'), Acetone, Chloroform, Dichloromethane (paint stripper).

Adhesives which are suitable for this material are Epoxy Resins ('Araldite'), Polyurethane glues and Silicones. Prior to bonding the surface should be cleaned with a suitable alcohol. Electrical connections must not be made to socket contacts marked ic.

The pins on the base of the photomultiplier should not be modified in any way whatsoever without prior reference to Electron Tubes Limited . Never solder directly to the pins of a hard-pin photomultiplier. When inserting or removing the photomultiplier from the socket, maintain the tube perpendicular to the plane of the socket and avoid undue force.
phototmultiplier envelop

Remove the window protector disk before use.

Unless otherwise stated, this will safely withstand an over pressure of one atmosphere. If additional support or attachments to the envelope are necessary please contact Electron Tubes Limited for advice.

If installed in a vacuum or reduced pressure environment, photomultipliers with a blue over-cap must have a 1mm diameter hole drilled in the over-cap to allow trapped air to escape.

*Safety precaution*

A comprehensive photomultiplier safety information sheet is available on request from Electron Tubes Ltd.

*High voltage*

High voltages used by these products may present a shock hazard. They should be installed and serviced only by suitably qualified personnel and operated in accordance with the operating instructions.

*General operating precautions*

Do not exceed the maximum ratings in the specifications or the overload voltage on the test ticket. Photomultipliers are adversely affected by magnetic fields and suitable mu-metal shields should be used wherever possible. Photomultipliers are generally robust, but will not tolerate extremes of heat, mechanical shock and, unless adequately screened, external high voltages. For use under adverse conditions, please contact Electron Tubes Limited for advice.

For high stability, care must be exercised in mounting tubes to prevent external charging and discharging caused by high voltages applied to the photomultiplier or from external apparatus. Photomultipliers should be kept in the dark prior to use otherwise dark current will be temporarily increased. The housing into which the tube is fitted must be light tight. To obtain the lowest dark current the tube should be clean and dry, especially the base, cleaning with methyl alcohol is recommended. Care must be taken to avoid damaging the cathode pin connection strip on uncapped tubes.

If the tube is operated with negative high voltage, increased dark noise may result. In this situation, only PTFE or a similar high quality insulator should be in direct contact with the glass envelope. Unless the operating conditions have already been determined, it is recommended that the high voltage supply be increased gradually until the required setting is obtained. Shielding material must be maintained at cathode potential. Failure to do this will impair performance and reduce pmt life. For HV applications, the window must be kept at least 4mm from any earth plane and any locating rings used near the window must be made from PTFE (Teflon). +HV is recommended for pulsed applications such as scintillation and photon counting

*Storage*

It is recommended that photomultipliers are stored in the dark. Incident light on photomultiplier tubes should be avoided or subdued. Exposure to bright light, especially fluorescent or sunlight will excite phosphorescence in the glass and photosensitive layers of the photomultiplier. Do not store or use photomultipliers in a helium rich atmosphere. This will diffuse through the envelope and destroy the internal vacuum. Photomultipliers should be protected from moisture, vibration, shock, extremes of temperature and dirt.

# Procedure for refurbishing a Mk IV Brewer spectrophotometer

**National Ultra Violet Monitoring Center**
**Department of Physics and Astronomy**
**University of Georgia**
**Athens, GA 30602**

National
Ultraviolet
Monitoring
Center

**Prepared by Dr M.G. Kimlin and T.E. Taylor**
**Last updated July 29, 2003**

## Introduction

The harsh environments to which Brewers in the EPA UV network are subjected causes them to begin having certain mechanical and optical problems at different times in their operational lifetime. Some instruments seem to be more robust than others, due in part to the quality of the local site operator care and to local climatic conditions. It has been established that the spectral responsivity of Mk IV Brewers decreases on the order of 2 to 20% per year. Much of this aging is due to the decrease in transmission of the $NiSO_4$ filter which is used to block out visible wavelengths of radiation. Some of the decrease in response is due to degradation in the efficiency of the photomultiplier tube (PMT) as well as other optical components.

Replacement and cleaning of these filters and PMT are suggested in order to increase the operational lifetime of the instrument. For instruments in the EPA UV network refurbishment is considered when the spectral responsivity falls below about 1/3 of its original value.

The Brewer uses many mechanical components to control the iris, zenith prism, micrometer and three filter wheels. Over time these components loose some integrity, leading to less reliable operation of the instrument. During annual site visits the National Ultra-Violet Monitoring Center (NUVMC) performs some minor maintenance to some of these components but some of them are too complex and time consuming to disassemble during a site visit. Maintenance or replacement to these parts takes place in the laboratory where full characterizations of the instrument can be performed.

## Equipment

Mk IV Brewer spectrophotometer
Hex wrench set (English sizes)
Standard tools (screw drivers, wrenches, etc)
RTV silicon (Dow Corning #3145)
Calibration and characterization equipment

## Purpose

This Standard Operating Procedure (SOP) outlines the NUVMC technique for refurbishing a Mk IV Brewer spectrometer in the laboratory.

Procedure

1. Perform a spectral response calibration on the Brewer following the NUVMC SOP.

2. Perform a temperature dependence calibration on the Brewer following the NUVMC SOP #14.

3. Perform an angular dependence calibration on the Brewer following the NUVMC SOP #13.

4. Perform a stray light/slit width calibration on the Brewer following the NUVMC SOP #17.

5. Remove and rebuild the foreoptics tube as outlined in SOP #11 for maintenance to filter wheels #1 and #2. Before replacing the foreoptics tube complete the next two steps.

6. Remove and clean or replace the PMT as outlined in the SOP #18 for removing the PMT.

7. Remove FW#3 housing and replace the $NiSO_4$ and UG11 filters as outlined in SOP #10. Before reassembling the FW#3 housing, PMT and foreoptics tube into the Brewer follow the next step.

8. Remove the three 3/16" hex bolts which secure the spring loaded feet to the base of the instrument. Replace the rubber gaskets on the feet and reassemble.

9. Replace the FW#3 housing, the PMT housing and the foreoptics tube into the instrument.

10. Optimize the PMT high voltage as outlined in the SOP #6.

11. Check and replace the HG bulb as outlined in SOP #1.

12. Check and replace the standard lamp bulb as outlined in SOP #8.

13. Rebuild the zenith drive system as outlined in SOP #15.

14. Align the zenith prism following the outline in SOP #9.

15. Remove and rebuild the micrometer assembly as outlined in SOP #5.

16. Determine the optimum position of the micrometer as outlined in SOP #3.

17. Check the alignment of the spectrometer shutter and mirror as outlined in SOP #7.

18. Perform a shutter timing test "SH.rtn" from 40 to 140 increments of 2. Modify the constant in the ICF as necessary.

19. Clean the Brewer case and plexiglass window. Replace the plexiglass window seal if necessary.

20. Replace the gaskets on the three circular connectors for the AC power, data line and azimuth tracker line.

21. Install an electronic humidity sensor.

22. Measure the dispersion of the grating using the external cadmium, HG and zinc lamps. Use the "DSP.rtn" to collect the data and use the "Dispro.exe" software supplied by Ken Lamb's group to analyze the data. Create a new DSP file as necessary.

23. Perform scans on the internal lamps using the "CI.rtn". Use 1A increments for the HG lamp and 5A increments for the standard lamp.

24. Perform a temperature dependence calibration on the Brewer following the NUVMC SOP #14.

25. Perform an angular dependence calibration on the Brewer following the NUVMC SOP #13.

26. Perform a stray light/slit width calibration on the Brewer following the NUVMC SOP #17.

27. Perform a spectral response calibration on the Brewer following the NUVMC SOP.

28. Set the Brewer outside and follow the steps in the SOP for the annual site visit to initialize it and perform the diagnostic checks.

29. On a sunny day perform several sun scans "SC.rtn" to check the optimal position of the micrometer for ozone scans.

30. Verify that the data from the UV scans is correct and closely monitor all diagnostics.

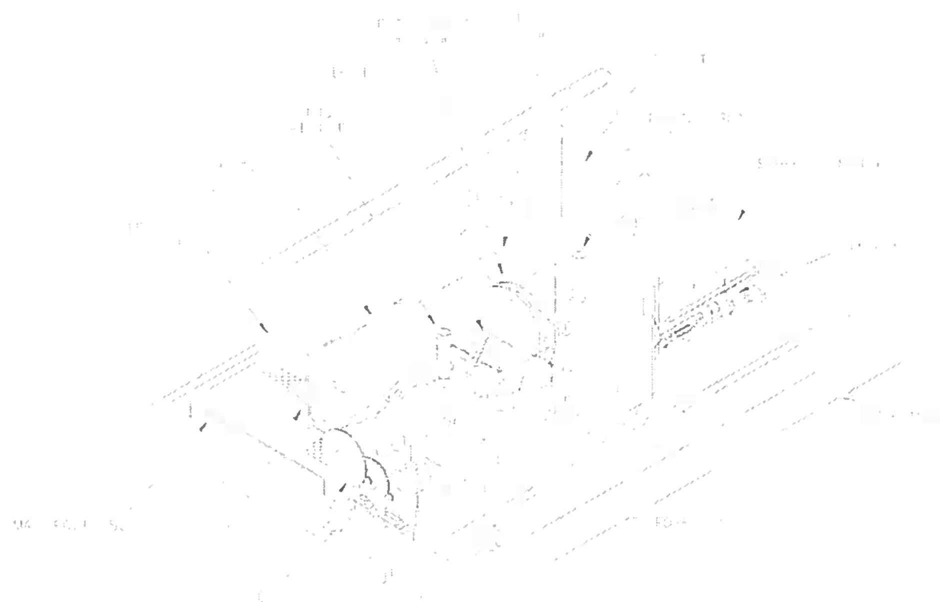

**Figure 1: Brewer components**

**Precautions for handling a photomultiplier tube.**

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a. When soldering to the contacts the temperature must not exceed 220°C.

b. Sockets or over-caps must not be allowed to come into contact with the following substances: Cyanoacrylate adhesives ('Super glue'), Acetone, Chloroform, Dichloromethane (paint stripper).

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phototmultiplier envelop

Remove the window protector disk before use.

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*High voltage*

High voltages used by these products may present a shock hazard. They should be installed and serviced only by suitably qualified personnel and operated in accordance with the operating instructions.

*General operating precautions*

Do not exceed the maximum ratings in the specifications or the overload voltage on the test ticket. Photomultipliers are adversely affected by magnetic fields and suitable mu-metal shields should be used wherever possible. Photomultipliers are generally robust, but will not tolerate extremes of heat, mechanical shock and, unless adequately screened, external high voltages. For use under adverse conditions, please contact Electron Tubes Limited for advice.

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If the tube is operated with negative high voltage, increased dark noise may result. In this situation, only PTFE or a similar high quality insulator should be in direct contact with the glass envelope. Unless the operating conditions have already been determined, it is recommended that the high voltage supply be increased gradually until the required setting is obtained. Shielding material must be maintained at cathode potential. Failure to do this will impair performance and reduce pmt life. For HV applications, the window must be kept at least 4mm from any earth plane and any locating rings used near the window must be made from PTFE (Teflon). +HV is recommended for pulsed applications such as scintillation and photon counting

*Storage*

It is recommended that photomultipliers are stored in the dark. Incident light on photomultiplier tubes should be avoided or subdued. Exposure to bright light, especially fluorescent or sunlight will excite phosphorescence in the glass and photosensitive layers of the photomultiplier. Do not store or use photomultipliers in a helium rich atmosphere. This will diffuse through the envelope and destroy the internal vacuum. Photomultipliers should be protected from moisture, vibration, shock, extremes of temperature and dirt.