

# Why the Need for Preventive Maintenance and Recalibration of Spectroscopic Analytical Instruments?

by

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Spectroscopic analytical instruments are complex optoelectronic devices that require careful mechanical, electronic and optical design to assure their long-term service reliability and performance.

All of these instruments are constantly experiencing changes in temperature and pressure; undergoing mechanical stress and optical decay, resulting in the gradual degradation of the designed critical performance parameters.

Miniature spectrometers are sturdier than their bench-top or larger counterparts thanks to their overall dimensions and lack of moving or adjustable parts. These smaller spectrometers also experience the aforementioned thermal cycles and mechanical stress. What's more, they have a higher probability of internal damage or at least performance changes caused by extreme mechanical shock due to their portability and flexibility of use.

Preventive maintenance resolves all possible major performance changes. In addition, it also offers cleaning, as well as electronic and firmware updates required for the optimum performance of the instrument.

Calibration is required to detect and control the gradual degradation mentioned above. This relentless change in performance is defined as "drift". If drift is not managed through periodic and systematic calibration, the measurements and test results obtained by the device become unreliable and degrade the quality of the research or products.

Calibration is nothing more than the comparison of the instrument or tool performance to a known standard of accuracy. The known value should be of a similar nature and of better quality than the instrument to be calibrated.

It is a well-known fact that measuring and recording devices must be maintained and calibrated on a regular basis to ensure reliable and accurate results. This requirement is not only emphasized by regulations and norms such as ISO, ASTM, ANSI, but is also necessary for Good Manufacturing Practices and basic ethical research results needed for peer-reviewed scientific publications.

In summary, proper preventive maintenance and calibration practices ensure that the measurements and results obtained by one instrument will be comparable (if not the same) as those obtained by any other person or entity using similar equipment that has been maintained and calibrated with the same parameters and reference.

The following famous quote by Albert Einstein better summarizes the importance of preventive maintenance and calibration:

**“No amount of experimentation can ever prove me right; a single experiment can prove me wrong”**  
Albert Einstein

Preventive maintenance and recalibration will minimize the probability of performing an experiment improperly thereby proving someone wrong and will help to minimize the costs involved in proving someone right. It is very important to realize that the aforementioned costs can not only be measured financially, but also in time and effort, and most importantly, in credibility and reputation.

Just Einstein's quote and the previous paragraph should be enough for you to consider maintenance and calibration of your instrument to be an investment that will add value to your research, products and services. An investment in maintenance and calibration is better than the expense necessary to regain customers and reputation. The return on this investment comes from better production yields, resource optimization, consistency, reputation and assured compliance with sector-specific standards and regulations.

We are all well aware of the importance of measurement in the worlds of science, industry and commerce. We are constantly measuring and depend on the accuracy of such measurements, from filling our car's fuel tank to buying produce at the supermarket. All of these ordinary activities depend on the proper maintenance and calibration of the devices used to make the measurements, and all of them are traceable and regulated by different international standards and regulatory entities.

For proper calibration, the calibration standard or reference must be more accurate than the instrument. As previously mentioned, calibration is the comparison of an instrument's measurement to a known standard. In a pure sense, any calibration should be traceable, which means that it has a well-documented paperwork link that shows the chain of measurements back to a master standard maintained by an official and reliable entity such as the National Institute of Science and Technology (NIST) in the United States.

In miniature spectrometers, the need for preventive maintenance and calibration arises from the same factors that affect any other analytical or measuring device. Preventive maintenance ensures that any major changes that have occurred in the instrument are reversed so that the instrument is brought back to the original design for proper performance. These changes can come from consecutive and additive events like small power surges or extreme thermal cycling. They can also result from major events such as dropping the instrument, excessive vibration, or fumes or water condensation in the optics that have entered through the spectrometer slit, for example (if it's left open to the atmosphere).

An instrument that has experienced major changes resulting from the aforementioned causes or other similar conditions needs to be reconditioned at a specialized laboratory with the necessary optical alignment and electronic tools. Reconditioning is a difficult job performed by skilled, certified technicians. Preventive maintenance servicing is also a good time to adjust and certify the instrument's baseline and gain, as well as to update the firmware with the latest versions for enhanced performance of the unit.

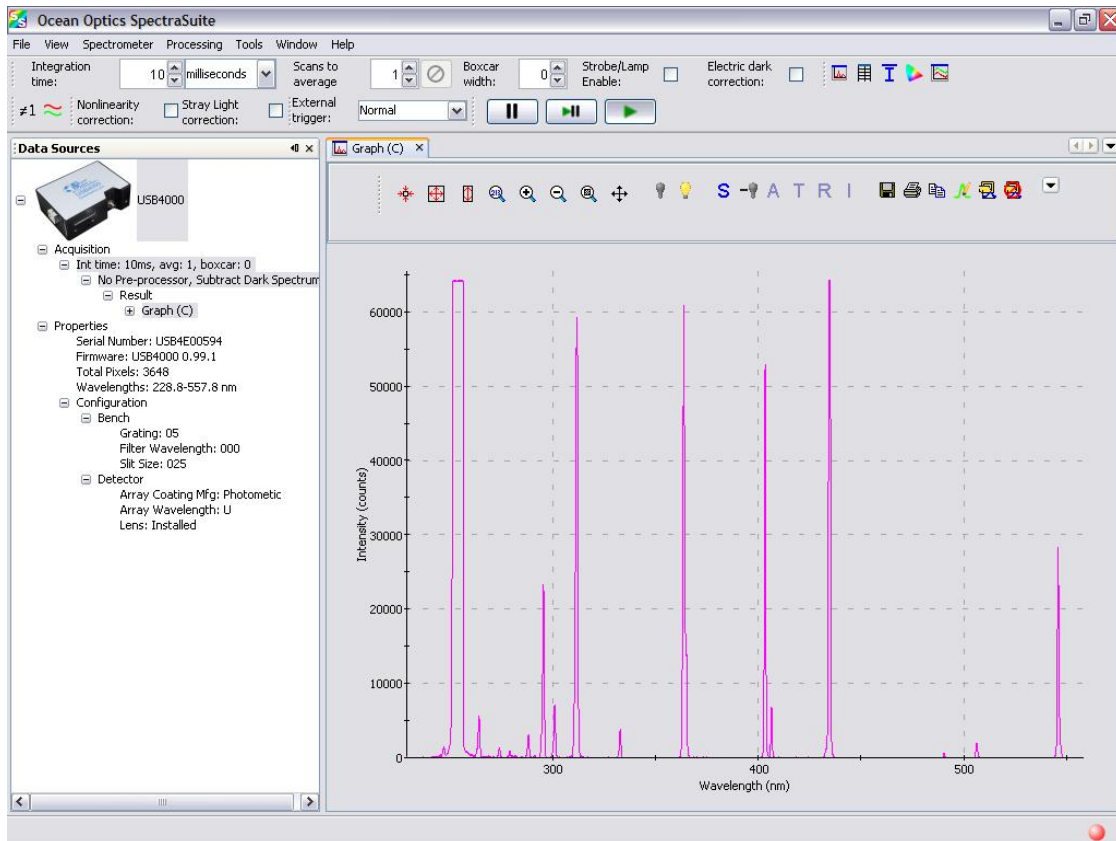
The instrument's manufacturer generally recommends the preventive maintenance schedule based on the spectrometer's design. Users can follow this recommendation or change it to occur at shorter intervals based on their application, environment or SOPs for their instrumentation calibration, such as those specified in ISO manuals or similar documents.

On the other hand, calibration takes care of small changes. Proper analytical procedures and GMPs require the use of standards or reference materials for performance monitoring of any instrument. If such monitoring shows that the instrument is not performing according to its designed parameters, the instrument needs to be recalibrated to bring it back to peak performance so that it can make good measurements and obtain reliable and repetitive results.

In electronic-based instruments, special software program take care of the recalibration. These programs use sometimes-complex mathematical algorithms to transform the actual measurements into standardized results by making minor adjustments to the electronics gain and baselines, data collection rates, power conditioning and other specific factors inherent to the instrument.

In very simplistic terms, the recalibration is telling the instrument to go back to its original factory settings or at least to certain values considered to be part of the specifications or tolerances of the device. However, recalibration can only do so much. If this procedure fails, the instrument will need “major” adjustments that generally require the use of specialized tools and trained personnel.

Specifically with spectrometers, wavelength monitoring and recalibration requires the use of a reference light source that emits well-defined wavelengths. High purity gas or vapor lamps (light sources) are the primary standards recommended for testing wavelength accuracy 1-7. Light sources such as a mercury vapor lamp are recommended by testing organizations such as ASTM (E275-01 and E925-02), United States Pharmacopoeia (USP) and British Pharmacopoeia (V.6.19). Low-pressure Mercury vapor lamps have a number of intense, narrow and well-identified emission bands that cover the UV-VIS spectral range. Other lamps such as Argon-filled are used for monitoring and calibrating in the NIR spectral range. It is also common to use a combination of gases in order to manufacture reference light sources to cover extended spectral ranges. For example, Argon-Mercury lamps cover a spectral range from 253 nm to 1700 nm.



*Actual spectrometer monitoring using a low-pressure Mercury vapor light source.*

A highly recommended practice before taking a measurement using a spectrometer is to first measure the reference light source (low-pressure Mercury vapor for example). If the lines are detected at their specified wavelength, the actual experiment can follow. If there is drift between the expected values and the results, the instrument must be recalibrated and the calibration confirmed by measuring the reference source (monitoring again) with the spectrometer in Acquisition mode. If the monitored results are satisfactory, it is recommended that the experimental measurements be taken relatively soon after the recalibration.

Depending on the required accuracy of the results, the calibration step might be postponed or programmed to occur on a regular basis (shift, daily, weekly, etc.) after developing a calibration procedure based on statistical data and method development for the application.

**“Refining is inevitable in science when you have made measurements of a phenomenon for a long period of time”**  
**Charles Francis Richter**

As mentioned before, if recalibration fails using the recommended procedure, either the reference light source, the instrument’s software, and/or the spectrometer itself are not working properly and must be checked out by the manufacturer’s technical service personnel.

The following table summarizes the suggested actions to assure proper spectrometer performance and accurate results:

Application Procedure	Scientific	Field/Production
<b>Monitoring</b>	Before experiment	Before Experiment
<b>Calibration</b>	Before Experiment	Based on method development, statistical data and required results
<b>Preventive Maintenance</b>	As recommended by manufacturer or before if there are problems with calibration.	As recommended by manufacturer or before depending on the environmental conditions of the application. As required by internal QA, SOP or general maintenance schedules.

Proper analytical techniques in all fields require adequate maintenance and calibration services to ascertain the required levels of accuracy and repeatability. It is easy to see that measurements directly quantify a product: when you buy a gallon of fuel you expect to get a gallon of fuel. However, behind this final or user-related measurement other measurements and calibrations have to take place in order to assure the accuracy of measuring that gallon of fuel. The fuel-dispensing machine is periodically calibrated using calibrated and traceable containers to accurately measure the specific volume.

Calibration makes sure that all levels of measurement are accurate. Properly performing such calibrations assures that errors are not propagated throughout the system, directly affecting the end user and resulting in important issues for the supplier.

**“In a few years, all great physical constants will have been approximately estimated, and that the only occupation which will be left to men of science will be to carry these measurements to another place of decimals”**  
**James C. Maxwell**

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