MEASUREMENT TOLERANCES

Accuracy and Precision in the Gem Industry

By GIA Research

For many applications measurement is fairly straightforward: we use the appropriate tool to measure the object or substance of interest. Whether it is the length of a board, the amount of salt to add to a recipe or the dimensions of a gemstone, we often measure things without giving much thought to the inherent uncertainty of the process. Often this uncertainty is inconsequential, but in some cases a high degree of precision and accuracy is required. We need to know that the measurement reflects the true dimensions of the object measured and that if we were to measure the same item again we would obtain the "same" measurements for that item. Gemstones are just such a case. Since measurements are often used to identify a particular gemstone and in some cases — like diamonds — to predict or assess features such as the overall cut quality, the reliability of these measurements is critical. Otherwise, the conclusions we draw from them may be incorrect. In this article we will share some of the measurement issues we deal with on a daily basis in the Gemological Institute of America (GIA) Gem Laboratory.

Above: These three measuring instruments offer different levels of precision as shown on the scale of each one. The pearl gauge can be read to ±0.05 mm, the slide micrometer to ±0.01 mm (or 0.0003 inches) and the digital screw micrometer is precise to ±0.001 mm.

All measurements have some uncertainty associated with them. Uncertainty means something not exactly known; in the case of measurements, it is often described as the error associated with the measurement. Measurement uncertainties can affect the accuracy of a measurement and they are fundamental in determining its precision. Accuracy describes how closely a given measurement matches the "true" measurement. Precision describes how finely the measurement has been made, but not whether the value is accurate. Precision tells us something about

the scale of a measurement and whether a second measurement matches the first one, while accuracy relates to the correctness of it. Precision is important because two measurements can only be determined to be the same or different with respect to some reported precision. A generally accepted precision for a specific measuring tool or process is often referred to as its tolerance [e.g., a ruler marked every 1 millimeter (mm) has a tolerance of ±0.5 mm].

Even in the absence of operator error, measurement uncertainty originates from the precision of the tools used to measure and the fact that measuring is not a perfect process.

GEMSTONES

Accuracy, precision and the inherent uncertainty of measurements affect the world of gemstones in many ways. Consider these points:

•Measurement tools for gemstones such as scales, micrometers and optical measuring devices need to be calibrated regularly to provide the most accurate measurements possible within their stated tolerances.

•Reports of measurements should include their precision. False levels of precision should be avoided.

•The known tolerance for each measuring tool should be factored into consideration of any measurement taken.

In the GIA Gem Laboratory, the accuracy and precision of measurements affect the daily process of assessing gemstones. These effects can be broken into roughly three separate, but related, areas: calibration, identification and quality assessment.

CALIBRATION

An integral part of the GIA Gem Laboratory's processing of goods is the accurate measuring and recording of various properties of the gemstones it receives. High-precision gem scales, optical noncontact measuring devices, micrometers and table gauges are used. Each of these measurement tools has its own tested accuracy and precision, but the levels of accuracy and precision can degrade over time. The regular process of calibration allows the GIA Gem Laboratory to ensure that the measuring tools used are always operating at their highest levels.

An example of this process is the calibration and regular verification of optical noncontact measuring devices — Sarin or OGI devices. To carry out this process, one must obtain a set of calibration objects — gemstones — and measure them as accurately as possible on higher-precision measuring instruments. Once these gems have accurate and precise measurements, we can use them to verify the accuracy of the optical measuring devices by assessing how close repeated measurements of the calibration gemstones are to the known measurements. Discrepancies can be used to calculate adjustments to the measuring devices; after making such adjustments (as indicated by the manufacturer), the devices are tested again. When the repeated measurements fall within the accepted tolerance of the device, the device is considered calibrated. These same calibration stones are measured regularly to verify that the devices remain in good working order.

IDENTIFICATION

When a measuring tool is properly calibrated, the measurements it produces can be used reliably to accurately identify a particular gemstone. However, it is important to be aware of the precision and tolerance of the tool.

Consider a report that shows measurements for a gemstone of 6.02 – 6.06 x 3.66 mm. A jeweler wants to verify that the gemstone she has is the same as that listed in the report so she measures it using a calibrated

Above and opposite page: The precision and repeatability of optical measuring systems, like these models from Sarin and OGI, are found by analyzing repeated measurements for several gemstones of different sizes.

measuring tool and gets 6.04 – 6.07 x 3.64 mm. For this example, the uncertainty of these diameter and depth measurements — that is, the tolerance of the measuring device for these dimensions — is ±0.01 mm. Recall that two values that are different, yet are still within the stated tolerance of the measuring device, cannot reliably be distinguished from each other. The two measurements are within tolerance (they match) if the difference between them is up to twice the uncertainty (here, 0.02 mm). Therefore, in the example above, even though the measurements look different, they can represent the same gemstone since each pair of values is no more than 0.02 mm apart. However, if the jeweler measured the gemstone as 5.98 – 6.05 x 3.68 mm, then she could reliably suspect that it was not the one reported because the difference between one pair of values (5.98 versus 6.02) was greater than 0.02 mm, the stated tolerance of the device.

QUALITY ASSESSMENT

The measurements of a gemstone's dimensions and proportions can also be used to assess other attributes of that gemstone. GIA's research into diamond cut has shown that the proportion values of a round brilliant diamond can be used to predict and assess the overall cut quality of that diamond. Again, knowledge of the accuracy and precision of the measuring tool is essential if we are to rely on these measurements to predict cut quality.

GIA research has found that all the facets in a round brilliant diamond affect its cut quality; the complete set of proportions used to predict cut quality must provide a realistic three-dimensional model of a round brilliant diamond. This is one reason why, when requesting a measurement recheck of a single diamond proportion from the GIA Gem Laboratory, it is no longer appropriate to change a single proportion value without remeasuring all proportion values. If a diamond is remeasured and the new measurements are found to be within the tolerance of the device used, those measurements are considered "the same" as the first set and, therefore, there is no need to change any of the values. If one or more values are found to be outside the measuring tool's tolerance, then the new measurements can be considered different and one or the other complete set of values needs to be chosen. The diamond should be measured additional times to help determine which complete set of values was the most accurate.

CONCLUSION

Accuracy and precision are both important parts of the measuring process. The accuracy of a measurement tells us how close the measured value is to the true value. However, measuring is never exact. Each measuring tool has its own level of achievable precision that tells how finely it is capable of measuring the particular quantity.

A measured value is not just a number, but has some error or uncertainty associated with it. When two measured values differ by less than their combined uncertainty, they are said to be within tolerance of each other with respect to that measuring tool. Two measured values are only reliably different from each other when their difference is greater than the tolerance of the measuring device.

Measurements are used to identify gemstones and to assess other properties, including those leading to a cut quality assessment. Properly calibrated, well-maintained measuring tools are necessary to achieve accurate measurements within the precision those tools provide. A complete, consistent set of measurements that reliably represents a given gemstone is vital for evaluating cut. ✦