What are uncertainties and why do they matter?

Have you ever seen uncertainties on your calibration cert or heard someone talk about uncertainties, and wondered what they mean? Do you know how to use this information, and/or do you know how it can impact your measurement data?

At the most basic level, uncertainties are a statement of the quality of the data that is reported. Even after all measurement error has been taken into account, there still remains unavoidable doubt regarding how well the measurement accurately represents the quantity measured.

To better explain that, let's walk through a simple example. If you measure the length of a part using calipers and the reading is 8.52 inches, this doesn't represent the *true* length, it is the *measured* length. Unfortunately, in real life applications you have no way of knowing the true length, but if you estimate the uncertainty of the measurement by traditional means, you will know that the measurement you make will have a very high probability to lay within the uncertainty determined.

The expanded measurement uncertainty is typically reported at a confidence level of 95% where the coverage factor or k =2. This simply means that you take the combined measurement uncertainty and multiply it by 2. So, for our example, if the expanded measurement uncertainty is determined to be ± 0.2 inches, then you can be confident that the true value lays somewhere within a range of 0.4 inches, or in this case between 8.32 - 8.72 inches.

To determine the combined uncertainty of your results you must account for all uncertainty sources which could impact your measurement. Uncertainty sources include specification or tolerance of the standard used, calibration uncertainty of the vendor who certified the standard, repeatability and reproducibility of the measurement process, environmental factors, resolution of the device under test, and more, depending on the type of equipment being used. All uncertainty sources can be divided into two categories: Type A and Type B.

- **Type A** refers to random effects that can be calculated through standard deviations of repeated measurements. These sources of uncertainty have to do with repeatability and reproducibility. Type A sources can be improved by analyzing and improving your measurement processes.
- **Type B** sources refer to uncertainties which do not come from analyzing repeated measurements. These are typically provided on the certificates of calibration for the reference materials you use to calibrate the equipment, or are given by the equipment manufacturer in the manual or on product spec sheets.

The sources, once identified, are combined based on their estimated impact on the total uncertainty through uncertainty budget analysis. This is a rather complex process of assessing and combining all of the uncertainty factors in a table to find the combined uncertainty value. If you want to dive deeper into this process feel free to reach out to one of our measurement experts, who can provide more information on uncertainty analysis.

So, why do uncertainties matter?

The short answer is that measurements cannot be compared without uncertainties. A commonly used example is that of measuring a string. If you give a piece of string to three different people and ask them to measure it with no further instruction, they would all do it slightly differently. One might lay the string next to a ruler and read the result. The next might hold the string vertically and use a tape measure to determine the length. And the third might lay the string next to a calibrated ruler, stretch the string out to its full length and measure it 5 times, then take an average of their 5 results. As you may imagine, all three would get slightly different measurements. The last would probably have the lowest uncertainties, because their protocol minimized the effects from random error and bias in the measurement process. Essentially, without uncertainties you are not able to compare measurement results "apples to apples".

Uncertainties are important when determining whether or not a part or a substance that you are measuring is within tolerance. For instance, think of the caliper example from earlier. Let's assume that the part you were measuring had a tolerance of 8.4 inches to 8.6 inches, and it was critical to your process that the part was within tolerance. Based on the expanded measurement uncertainty provided in the earlier example, the part may not be acceptable. While there is chance that the part is within range, there is also a high probability that the part is as small as 8.32 inches or as large as 8.72 inches. You would need to either reevaluate your process, adjust your tolerance, or use a different tool that has a lower uncertainty. As a general rule, you want to make sure that your expanded measurement uncertainties are less than the tolerance of the process or device, and that they are sufficiently small enough to ensure they do not affect the validity of the calibration results (i.e. pass, fail, adjusted, etc.).

At J.A. King when making statements of compliance we utilize the "Shared Risk Principle", which means that we do not take the measurement uncertainty into consideration when making statements of compliance. We do, however, take steps to minimize uncertainty and avoid tolerance related issues when calibrating equipment. We require a Test Accuracy Ratio (TAR) of 4:1 in our calibration procedures. This means that the standard being used is at least 4 times more accurate that the accuracy tolerance of the unit under test. On occasion, a minimum 4:1 TAR can be impossible to achieve. In these cases, we evaluate the expanded uncertainty to ensure that measurement results remain valid, or we look at outsourcing to another lab with better uncertainty. Additionally, when we calibrate equipment we will adjust it to within 70% of tolerance. This means that if we find your equipment to be within tolerance, but on the upper or lower limits without valid cause, we will adjust the equipment so it reads closer to the middle of the acceptable range. Practices like these help to mitigate the risk associated with measurement uncertainties, and to ensure that the Probability of False Acceptance (PFA) represents an "acceptable risk" to the customer and the supplier of products and services.*

Now that you know more about uncertainties, you may notice that they are not on all of your calibration certs. Typically, only accredited calibration certificates will include uncertainty data. Contact us today to learn more about our levels of calibration and what uncertainty data could mean for your process. Our measurement experts can help you to determine what level of service is needed for your quality system.

**The concept of PFA when making statements of conformity and determining acceptable risk is a complex one that is emphasized in the new ISO 17025: 2017 standards. Look out for us to explore this topic in greater detail in a future article.*