Portable Force Calibrating Machines Solve Several ~~Measurement~~ Management Headaches

Figure 1. Morehouse Portable Calibrating Machine

Abstract

Hiring the right people is challenging and retaining them is becoming harder. Employee retention is a major challenge in the modern business environment, and it is tempting to replace technically competent personnel with less professional personnel to keep costs down. When it comes to calibration, we see a distinctive trend of replacing retirees or technically competent personnel with ‘cheaper’ hires who, supposedly, “will learn this stuff in no time.” Unfortunately, we rarely see this happening. These ill-conceived practices result in incorrect metrological measurements and bad practices, which harm corporate reputations and output and place individuals in danger.

Furthermore, purchasing the right equipment can correct these “bad” measurement practices, making a technician’s job easier and much safer. Such equipment, in particular, includes force measurement equipment, which in some cases can reduce the number of technicians needed for calibration from two or three to one. Good force measurement equipment and consistent, repeatable measurement practices drastically improve employee safety while limiting workers’ compensation and, more importantly, reducing overall liability.

This paper examines several “bad” measurement practices, such as using multiple technicians to calibrate instruments (including hand-held dynamometers). Such practices include using a free-floating cable and stacking weights to calibrate a cable tensiometer. This paper discusses how purchasing better equipment can lead to a safer and more engaged workforce.

Introduction

We have all been through a kind of perfect storm in recent times, dealing with a global pandemic that has forced most of us to reevaluate our goals and aspirations; a lot of the workforce has relocated to less densely populated areas, where working remotely is encouraged; another large section of the workforce has resorted to early retirement. However, when the overall labor shortage is considered, is now a good time to reflect and consider whether the dust has settled, or will we continue to struggle to find talent? These questions have been answered by economists and talking heads who have predicted anything from a mild recession to a full-scale depression by the end of this decade.

The field of metrology is no exception. Many metrology professionals have retired, and since the world paused to take a breath, replacements were not hired, or if they were, they might not have been trained by seasoned professionals. However, regardless of what happens, two things are certain: training new employees in the field of metrology is a challenge, and retaining good employees is more complicated than ever before.

Fortunately, some exceptional individuals are leading the charge to step up and develop training programs if employers are prepared to invest in their employees. One such company is Sine Calibration, which offers online training at various levels, including training on temperature, force, pressure, measurement uncertainty, and statistics for metrology. Sine has stepped up and filled a gap left by the United States Air Force's (USAF) **Precision Measurement Equipment Laboratory** (PMEL) training programs, as only a fraction of people are being trained today compared to two decades ago. In addition, some companies are graciously offering free webinars, papers, and tools to help both existing and new technicians. Here at Morehouse, we are passionate about providing proper metrology guidance so anyone performing force or torque measurements can reduce their measurement errors. For example, under the *Documentation Tools* section on our website, www.mhforce.com, we offer a variety of free guidance documents, papers, Excel workbooks, and software. These tools unquestionably help, but only if technicians are empowered and motivated to improve their work environment.

Each work environment is unique, as are the levels of employee engagement, 'headaches,' 'firefighting,' disengagement, rework, and turnover. However, if these levels become too high, the quality of work suffers and mistakes are more frequent, potentially resulting in more incorrect calibration certificates being issued, potentially containing bad data that can ultimately lead to safety implications for consumers and liability issues for employers.

Consider what would happen if manufacturers and calibration laboratories failed to correctly calculate the uncertainty and risk of equipment used to test medical equipment, airplanes, cars, and bridges. Consequently, your confidence and comfort level will be much lower than normal when you schedule surgery, sit in a traffic jam on a bridge, or experience mechanical problems on your next flight.

New technology can help us all, though the measurement chain needs to better account for measurement errors. In addition, employees need to be empowered by their managers to find better solutions to measurement challenges. Besides, the days of repeatedly instructing employees to perform tasks that could result in injury are gone, as another company will be happy to hire that unhappy employee.

Consequently, Morehouse has developed smaller force calibration machines that address specific challenges with smaller measurements. Our portable force calibrating machine, model PCM, eliminates the need to handle and stack large weights; our Mechanical Cable Tensiometer Calibrator provides a safer means to calibrate cable tensiometers; and our Benchtop Force Calibrating Machine, model BCM, offers an affordable alternative for calibrating crane scales, load cells, and dynamometers. These machines, combined with adapter sets to connect a reference loadcell to the unit under test, simplify the calibration process for the technicians, significantly improve safety, and reduce risk and liability.

The simplification, improved safety, and reduction of bad measurement practices ultimately help a company's engagement score by reducing turnover and freeing up calibration technicians' time to perform more calibrations or improve their skills, which leads to better measurements and, ultimately, increased customer retention, a better company reputation, and growth.

Let's examine several bad measurement practices associated with force calibration under 50 kN (11,000 lbf) and figure out how to correct them.

Current "bad" Measurement Practices – Stacking Weights

Figure 2. Stacking Weights on a Hook

It is common to walk into any laboratory performing force measurements and find technicians using free weights and stacking them onto a force-measuring instrument. They might use a homemade system in which weights are placed on a hanger to calibrate the force-measuring instrument.

However, there are several problems associated with stacking weights, all of which significantly impact the, perhaps most widespread, issue of using mass weight to calibrate a force-measuring instrument.

Stacking Weights-Bias Error from Not Converting Mass to Force Properly

Under almost every terrestrial circumstance, mass is the measure of matter in an object with units of kg, lb., g, oz., etc. Additional factors, such as buoyant forces and gravity, are considered when measuring force, which has units of lbf, N, and kN. Besides, the effect of gravity can produce significant errors when comparing mass and force measurements.

Gravity is not constant on Earth's surface. The most extreme difference is 0.53% between the poles and the equator (983.2 $cm.s^{-2}$ at the former compared to 978.0 $cm.s^{-2}$ at the latter). As a result, a force measuring device calibrated in one location using mass weights and then deployed somewhere else will produce different strains on the physical element, resulting in significant measurement errors.

Correcting the difference in force and mass measurements is possible. When a device is calibrated using weights corrected for force, the device will measure force without additional error due to corrections for local gravity, air density, and so on. If this same device was calibrated using force units such as lbf, kgf, kN, N, and gf, then it could be used anywhere in the world to measure forces. However, force weights are different; if they are relocated, they need to be corrected for the new local gravity and air density of their new location of use.

When mass weights are used to calibrate force devices, the bias is transferred directly to the customer. This bias can vary anywhere from 0.05 % to 0.5 % or more; however, we typically observe errors of around 0.1 % and 0.2 % of the applied force. It could be argued that this bias is accounted for in an uncertainty budget, although few individuals consider the correction needed for the location where the device will be used.

Stacking Weights – Off Center Loading Error

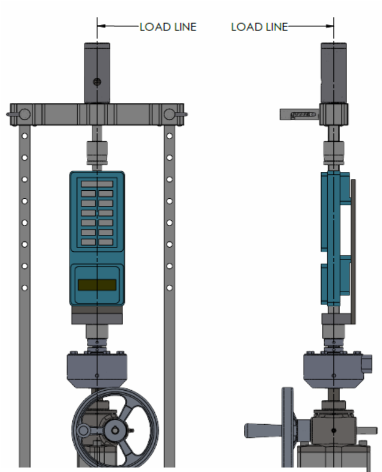


Figure 3. Drawing of Hand-Held Force Gauge Setup

Manufacturers of hand-held force gauges and other force gauges have designed hand-held force gauges and other force gauges with different backplate mount designs and centering fixtures.

If these gauges are not mounted, weights are applied by one technician holding or lifting the force gauge while another stacks weights.

Misalignment can cause errors that exceed 1 % of the applied reading on specific load cells and other devices. This error rate is probably significantly higher with a technician holding the force gauge, not to mention that this practice is time-consuming and has some serious safety implications.

Figure 4. Morehouse Force Gauge Calibration Kit

Stacking Weights – Slow, Dangerous, and Potentially very Expensive.

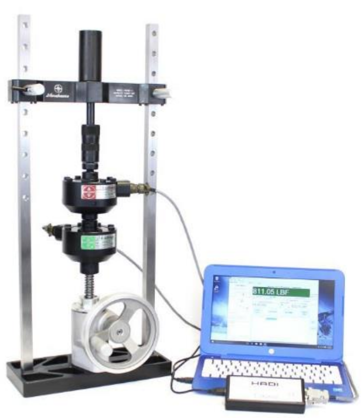
It is reasonable to assume that homemade jigs cannot produce results as accurately as well-designed, engineered, machined parts. Additionally, requiring technicians to calibrate these devices by stacking weights has the potential for a liability nightmare. For example, if weights fall off and land on a technician's foot, workman's compensation claims could last a year and possibly exceed $100,000. Of course, that is assuming other organizations do not get involved.

Another consideration is that if weights do fall and the technician is lucky enough not to suffer injury, the weights will likely suffer damage and need to be calibrated immediately; they might even need to be replaced.

Figure 5. Morehouse PCM Hand-Held Force Gauge Calibration

In addition to being dangerous, stacking weights to calibrate a force-measuring device requires more technicians and takes much longer than using a Morehouse Portable Calibration Machine (PCM), which can calibrate a hand-held force gauge in tension and compression by using a precision load cell as the reference standard. Then, the technician simply turns the wheel clockwise for compression and counter-clockwise for tension.

The Morehouse PCM is designed with field calibration requirements in mind, providing all the necessary force calibration tools in a portable package. This calibrator gives accurate and stable force measurements (capable of controlling force applications as low as 0.005 lbf) in a robust, low-maintenance design.



The system is equipped with several time-saving features that enable quality force calibration where portability and time are critical. In addition, the Morehouse PCM drastically reduces ergonomic, safety, and side-loading issues and allows calibration laboratories to simulate and replicate how the device is used, further reducing additional measurement errors.

The Morehouse PCM has measurement uncertainties of between 0.03 – 0.05 % of applied force. However, with additional adapters, the capabilities of this system can be expanded to accommodate a broader range of force sensors. For example, the PCM can calibrate force sensors, including shear web load cells, S-type load cells, force gauges, button load cells, beam load cells, etc.

Figure 6. Morehouse PCM-2MD-1
Shown Calibrating a Load Cell

Current "bad" Measurement Practices – Cable Tensiometer Calibration

Frequently, we are asked, "What is a Cable Tensiometer?" A cable tensiometer is a device with an accuracy specification, typically 1-5 % of capacity force, used to measure the tension of wire cables. This device is typically used in aircraft rigging and textile manufacture. Thus, it is essential to calibrate these devices properly.

Figure 7. Cable Tensionmeter Calibration

The design of a tensiometer employs a force gauge that reacts against the cable via a riser and displays the result on a dial scale via a gearbox. The dial is often just a linear scale numbered 0 through 100; a conversion table is then created to convert the number to a meaningful result, typically in lbf.

Calibration is often performed by repeatedly loading a known cable to the same force point and taking an average of the readings. Tensiometers should be calibrated based on their use and other factors. However, some common problems to watch for are physical damage, overstretching of the spring (which can happen when the correct riser is not installed for calibration), corrosion, and damaged risers.

One standard method for calibrating cable tensiometers is fixing one point of the cable and stacking weights, or even filling a bucket with the appropriate weight to generate the force on the known cable.

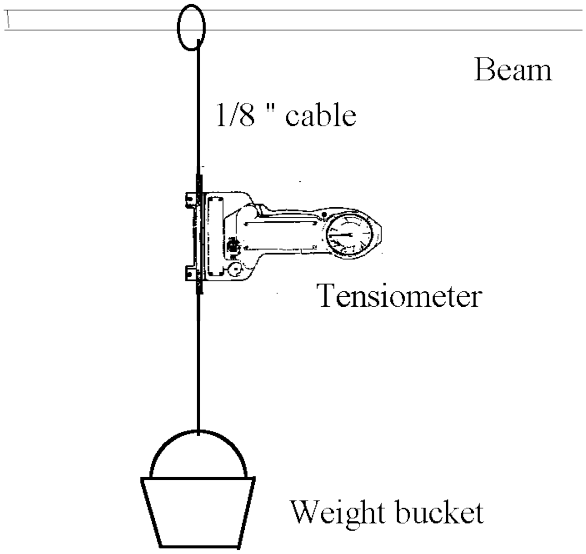
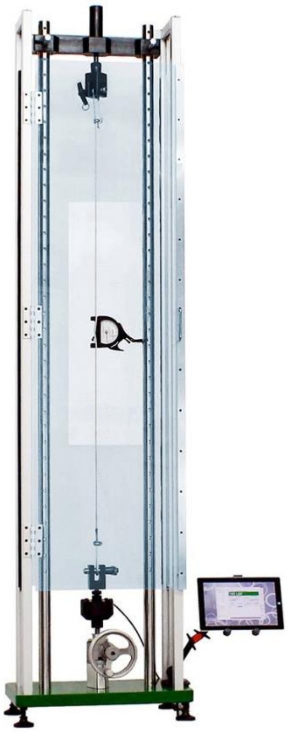


Figure 8. Unsafe Bucket Method

Numerous issues exist with stacking weights or filling a bucket, and the bucket method is considered a bit of a joke in many circles, citing significant metrological traceability concerns. Other common methods include hanging a cable from a beam or fixed position using a pan and lifting about 2,000 lbs. onto that pan or using a torque machine to back-calculate force using a short rigid cable.

In addition, concerns regarding mass to force, ergonomics, time, and safety are identical to those mentioned previously, with the added risk of a much more severe injury. If the cable snaps and 2000 lbs. of mass starts to fall 2 to 3 feet or more, there is a clear risk of severe injury or even death. This method is unsafe and should never be used.

Also, using a torque machine or a rigid cable has all sorts of errors. Although the torque machine is designed for torque, mounting a bracket to back-calculate force creates issues in calculating measurement uncertainty. So, it creates a logistical mess to prove the force values.



However, the more tests we conduct, the more we find the rigid cable more problematic. Typically, cables are connected to two fixed points and have a length of more than 3 feet (1 meter). When a cable has greater rigidity, it is harder to clamp the cable tensiometer, and the readings vary greatly. If you have a cable tensiometer and a long cable, you can apply the force and take readings along the cable. Do the numbers all agree? No, because the closer you are to the end of the cable, the further the readings deviate. The same is true when the cables are not long enough.

Cable tensiometers are mechanical devices that can exhibit high errors, and their calibration should be repeated after each use. If they are being used to test short runs of 12-18” fixed cables, they should be calibrated using shorter cables. If they are being used to measure longer fixed cables, calibrating them using 3–5-foot cables will yield results much closer to the actual value.

Figure 9. Morehouse Mechanical Cable Tensiometer Calibrator (PCM-2MD-T1) Shown with a Five-Foot Cable

The Morehouse tensiometer solves the cable length problem while also reducing safety concerns. It is a high-value machine compared to paying someone to lift weights onto a pan and take a reading manually. It features a plexiglass safety cage to minimize injury if the cable breaks. The machine is versatile as it can be used to calibrate dynamometers, load cells, S-type load cells, force gauges, hand-held force gauges, button load cells, washer load cells, and beam load cells. In addition, the machine can apply force with a typical measurement uncertainty of between 0.03 % - 0.05 %.

Figure 10. PCM-2MD-T1 Shown Calibrating a Crane Scale and Calibrating a Shear Web Load Cell

Additional Portable Machines

The two machines shown so far generate forces ranging from 1 lbf to 2,000 lbf; Morehouse has a third machine that can be used to generate forces up to 10,000 lbf.

Figure 11. Morehouse BCM Example of Load Cell Calibration

The Morehouse Benchtop Calibration Machine (BCM) is a laboratory-grade force calibration system that can sit on any table or desk and support 150 lbs. (75 kg).

This calibrator gives accurate and stable force measurements (control is capable of 0.05 lbf) in a robust, low-maintenance design. In addition, it is equipped with several time-saving features that enable a quality force calibration where limited space is a concern and saving time is critical.

The machine is recommended if force measurements above 2,000 lbf are needed and a Morehouse Universal Calibration Machine (UCM) is too large. The general measurement uncertainty of this machine is around 0.05 % of the applied force, whereas the Morehouse UCM will typically provide measurement uncertainties of better than 0.02 % of the applied force.

Conclusion

Morehouse manufactures calibrating machines up to 3 million lbf. In addition, we manufacture deadweight machines with measurement uncertainties of below 0.002 % of the applied force, and we design and make adapters to reduce measurement errors, simplifying a technician's job.

This paper has presented information demonstrating why purchasing the right calibration equipment can benefit a company in many ways, including improved safety, reduced liability claims, and an easier and happier life for the calibration technician. The right equipment also drastically reduces calibration time and, with the appropriate adapters, allows the utmost confidence in the measurement results. Thus, the right equipment improves the overall engagement score, which reduces turnover, leading to a better company reputation and hopefully more growth. Morehouse has the capability to provide equipment that will make a technicians work safer and easier. To start improving your force measurements, call us at (717) 843–0081 or email info@mhforce.com.

At the beginning of this paper, we discussed the shift in the employment landscape. Companies that take the appropriate actions to make their employees' jobs more fulfilling will likely win in the new economy. At the same time, those that continue to use unsafe, outdated practices will likely struggle.

Are you interested in learning more? Morehouse offers monthly newsletters to keep you up to date on all of our published content. To subscribe to our newsletter, click here.

We want to help you make better measurements. As such, we have created a section on our website full of resources from guidance documents to excel spreadsheets that help with Measurement Uncertainty, Converting Mass to Force, TUR and Risk calculations, calculating coefficients, and more. Please visit https://mhforce.com/documentation-tools/ for more information.