



Force Calibration Adapters Guidance



Examples of Morehouse Calibration Adapters





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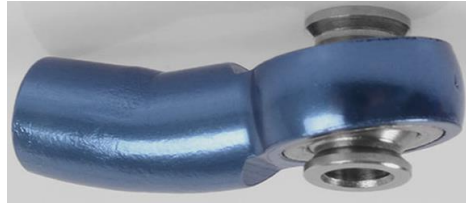


Figure 1: Bent Rod End

The Importance of Adapters in Force Measurement

Several force measurement errors can result from using adapters different from what the force measuring instrument was calibrated with. The basic premise is that mechanical measurements are being made. Most adapters used at a laboratory level will be manufactured to keep the line of force free from eccentric error and apply the same stresses from the adapter interface to the force measuring instrument that was done at the time of calibration.

Not using the proper adapters to calibrate load cells, truck scales, aircraft scales, tension links, dynamometers, and other force measuring devices can produce significant measurement errors and pose serious safety concerns. Different adapters can change the stress distribution on the force measuring instrument. They can produce errors that range from minimal to an output difference that produces errors more significant than the allowable tolerance.

Other important things to consider are safety and adapters that are not machined properly. Improperly machined adapters may not allow for a distortion-free load path. However, they may fixture the force measuring device in the frame without the end-user knowing about the safety factor or other potential errors.

One purpose of this guidance document is to explain the safety concerns of using older adapters and discuss some of the error sources associated with using the wrong adapters. After safety, selecting the proper fixturing is critical because not using the proper adapters can result in significant measurement errors. These errors can have magnitudes of ten to twenty times that of what the end-user may be expecting. Calibration of a force-measuring instrument without the proper adapters can result in miscalibration, massive recalls, and consumer risks. Improperly calibrated equipment used for critical testing could result in product failures and loss of life.



Figure 2: Grade 8 Bolt that Failed at 120,000 lbf and close to 350,000 load cycles

Safety Concerns with Old Adapters

Let's start with those old adapters that have been in use for decades. The service life for force calibration adapters depends on several factors including material, design, manufacturing, number of load cycles, and magnitude of each load. There may come a time when the material begins to lose strength due to fatigue and eventually breaks. Today, there are better material and manufacturing control processes that provide more reliable design engineers' strength values than decades ago. There are also computer programs that greatly help in modeling and conducting all kinds of stress analysis.

I often am asked, "What we should do with older adapters?" My guidance is to visually inspect all adapters for any signs of wear or fatigue and replace them if they show any signs of potential failure. Morehouse recommends replacing adapters that have been in use for more than 20 years or 100,000 load cycles (10,000 calibrations). Adapters today are designed for a life cycle of at least 500,000 load cycles (50,000 calibrations) and failure at close to 1,000,000 load cycles.

Common Adapters to Reduce Force Measurement Error



Figure 3: Load Cell showing eccentric forces

Keeping the line of force pure, which is also known as free from eccentric forces, is key to the calibration of load cells. ASTM E74-18 states "Force-measuring instruments have sensitivity in varying degrees depending on design to mounting conditions and parasitic forces and moments due to misalignment. A measure of this sensitivity may be made by imposing conditions to simulate these factors such as using fixtures with contact surfaces that are slightly convex or concave, or of varying stiffness or hardness, or with angular or eccentric misalignment, and so forth. Such factors can sometimes be significant contributors to measurement uncertainty and should be reflected in comprehensive measurement uncertainty analyses."¹ ISO 376 has an entire Annex devoted to force adapters. A good start to what makes a good tension adapter is the ISO 376 standard.

ISO 376 Adapters



Tensile force transducers should be fitted with two ball nuts, two ball cups

Figure 4: Tension Members with two ball nuts and two ball cups

ISO 376 says "Loading fittings should be designed in such a way that the line of force application is not distorted. As a rule, tensile force transducers should be fitted with two ball nuts, two ball cups and, if necessary, with two intermediate rings, while compressive force transducers should be fitted with one or two compression pads."²

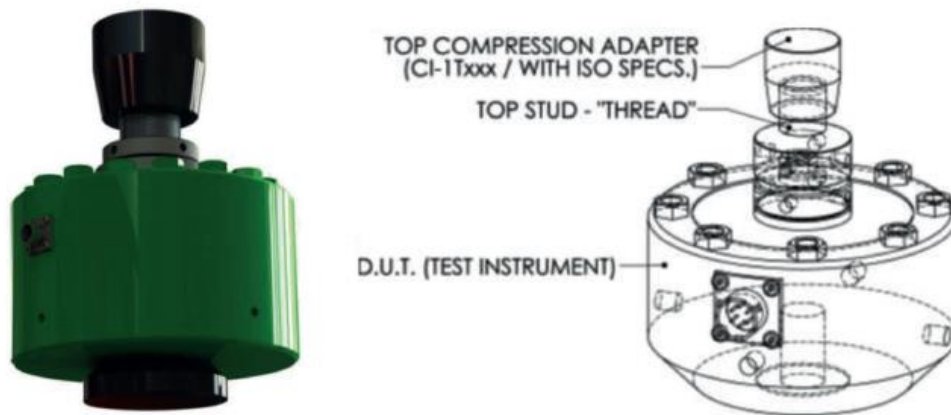


Figure 5: Morehouse ISO Compliant Compression Adapters



Alignment Plugs for Better Centering

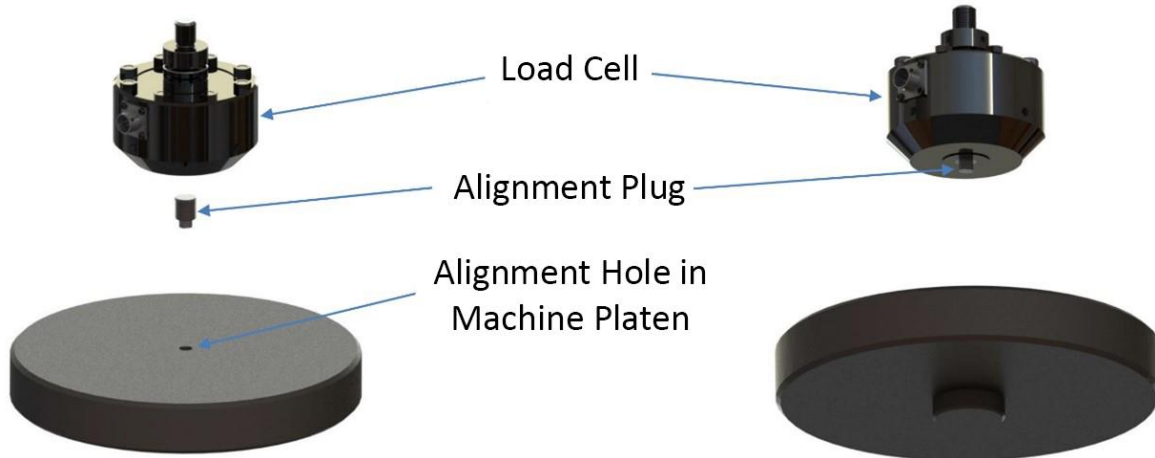
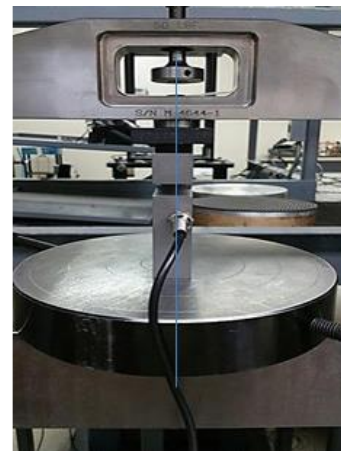


Figure 6: Morehouse Alignment Plugs

Centering a load cell is critical to obtaining the correct line of force. To make sure the load cell is centered, a proper bottom alignment adapter and other calibration fixtures should be manufactured to match the load line of the calibrating machine. No matter how good an operator may be, they are no match for something machined with precision. By using bottom adapters with concentric rings for alignment or alignment plugs to perfectly center the force-measuring instrument, the end user will be able to reduce misalignment error.



Output in mV/V
Aligned in machine
-1.96732 mV/V



Output in mV/V
Slightly misaligned in machine
-1.98211 mV/V

Figure 7: S-beam load cell with slight misalignment producing a 0.752 % error



Why is it critical to reduce misalignment error? Figure 7 shows a test of the spherical adapter without an alignment plug. The error observed above is 0.752 % on S-beam load cells with less than 1/8" misalignment. When the load cell was aligned and calibrated properly, the expanded uncertainty was calculated at about 10 lbf. When the load cell was misaligned, the expanded uncertainty became approximately 90 lbf.

This is a large difference on a 10,000 lbf S-beam load cell. If the technician misaligned the load cell in a testing machine, they may end up adjusting a machine that is actually "in tolerance" and a recall may result from this simple error. Alignment plugs and base plates with alignment holes (Figure 6) drastically reduce misalignment error.

Another error source is the adapter used for compression tests. The recommendation is to use a spherical alignment adapter and alignment plugs for any load cell with a female thread that needs to be calibrated in compression. For a shear web load cell, Morehouse recommends installing the integral threaded adapter. The shear web load cell is very susceptible to varying thread engagement and the integral adapter eliminates this error.

For users who still need to use a shear web type cell and have height restrictions, a spherical adapter is recommended, but will not produce results as good as an integral threaded adapter. The errors from varying the thread length of adapters in load cells can be as high as 0.5 %.

Common Compression Adapters for Load Cells



Figure 8: Morehouse Top Alignment Adapters - Spherical Alignment Adapter (L), Ball Adapter (R)

For the top of the load cells, Morehouse recommends loading with either a spherical or ball adapter (Figure 8). In compression, using a ball adapter, if the machine has a ball seat adapter, often yields the best results. If a ball seat adapter does not exist, then a spherical alignment adapter will help align the force.

For calibration in compression, Morehouse recommends using a spherical alignment adapter for any load cell that is not a shear web load cell with a female thread. For a shear web load cell, Morehouse

recommends installing the integral threaded adapter. The shear web load cell is very susceptible to varying thread engagement and the integral adapter eliminates this error. For users who still need a shear web load cell and have height restrictions, a spherical adapter is recommended. However, results will not be as good as they would be with an integral threaded adapter.

Compression Adapters for Button and Washer Type Cells



Figure 9: Morehouse Button (L) and Washer (R) Load Cell Adapters

The number one complaint with button and washer load cells is that they do not repeat well between rotations. These load cells are notoriously sensitive in rotation and any misalignment will produce large errors. The sensitivity to off-axis or side loading conditions is quite high. High enough that 0.1 % of misalignment is going to produce a rather large cosine error. The error can sometimes be as large as 10 % of rated output.

At Morehouse we typically find this error to be between one and two percent in well aligned deadweight machines. The Morehouse button and washer load cell adapters improve alignment and yield better calibration results. Usually the results are better by a factor of 5 when using the adapters as compared with a technician trying to center (Figure 10).

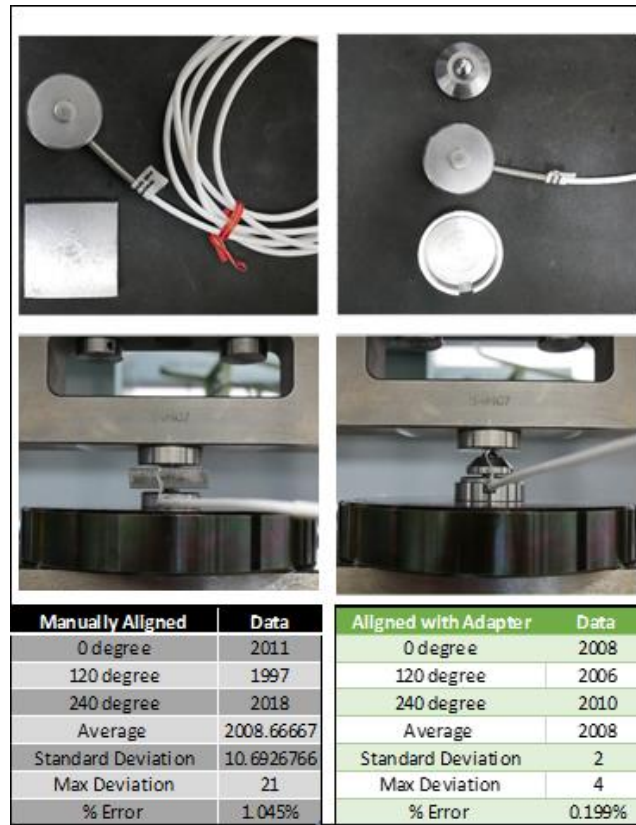


Figure 10: Typical button load cell calibration (L) versus one with Morehouse adapters (R)

The picture on the left shows a typical setup, where it is nearly impossible to get the readings to agree within 0.5 % when repositioning the button load cell. The picture on the right shows a setup with Morehouse adapters, which improves alignment and yields much better results.

The data in Figure 10 shows a 525 % improvement in rotation when using the proper alignment adapters. The reproducibility error went from 1.045 % to 0.199 %. Most button load cell systems cannot achieve better than 0.25 % of full scale, even with the proper adapters. I have seen some specifications where the end user is expecting 0.1 % of full scale or better. Without the proper adapters, 1 % of full scale is nearly impossible to achieve.

Proper testing would involve putting the unit back into the machine and demonstrating agreement between the tests. With the Morehouse adapters, reproducibility of better than 0.25 % is possible. To achieve these results, the button load cell must not be damaged or have wear patterns. Load cells with wear patterns are going to have much larger errors. The adapters in Figure 9 will improve those results as well, but these adapters will not turn a worn button load cell with a 5-10 % error into a cell with an error of better than 0.5 % of full scale.

At Morehouse we generally see improvements with a magnitude of 2 - 10 times better when using the proper adapters. These adapter sets can also accommodate alignment plugs to align the whole calibration setup with the calibration machine; a deadweight system, hydraulic Universal Calibrating Machines (UCM), or Portable Calibrating Machines (PCM).

Tension Clevis Adapters for Tension Links, Crane Scales, and Dynamometers

Difference of 860 LBF or 1.72 % error at 50,000 LBF from not using the proper size load pins.



Figure 11: Tension Link Difference in output with pin size

If the calibration lab decides to use a pin that is different from manufacturer's recommendations, there will be larger than expected bias. Most manufacturers will agree on the following:

- Using correctly sized pins is critical
- Do not use pins that are worn or bent
- If the links are damaged, highly used, or worn, decrease the time between calibrations
- The same size and style of shackle and pin used during operation should be used for calibration

To demonstrate the error in pin size, Morehouse loaded a tension link in our deadweight machine with accuracy of better than 0.002 % of applied force. We loaded to 50,000 lbf with two different size load pins and the results were:

- Loaded with a 1.85 inch pin, the device read 49,140 lbf
- Loaded with a 2 inch pin, the device read 50,000 lbf

The calibration should be performed with the same load pins the end user is using with the device. However, when the end user does not send in an adapter, the calibration laboratory has to load the device with some pin. Therefore, the calibration lab must try and match the manufacturer's recommendations.



Finding the right pin size can be tricky because the manufacturer's recommendations may be counterintuitive. For example, a 20 ton tension link may require a 2.0 inch pin and a 25 ton tension link may require a 1.97 (50mm) pin. It may seem like 0.03 inches will not make a difference, so the lab can go ahead and test it. However, on a device with an accuracy specification of 0.1 % of full scale, Morehouse has observed a change of 0.03 inches will use up 70 % of that specification.

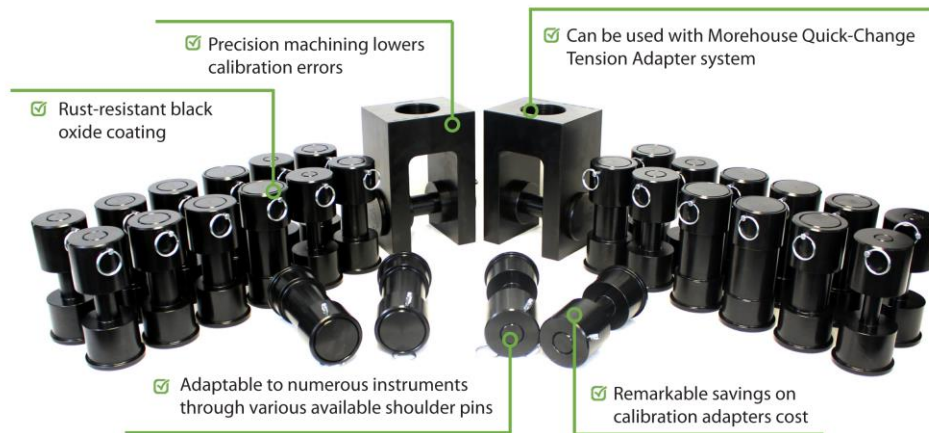


Figure 12: Morehouse Clevis Kits

Knowing these issues, Morehouse has designed clevis assemblies for use with our Quick-Change Tension Adapters. These assemblies cross reference the manufacturer's recommended pin size and allow the calibration laboratory to calibrate hundreds of tension links, crane scales, dynamometers, and rod-end load cells all with using the same clevis. Not only does this simplify the logistics of having the proper adapter, but it also improves cycle time and standardizes the calibration process.



Instruments which can be calibrated with the Adaptable Clevis Kits and corresponding part numbers

Common Clevis Part Number: TU-120-001						
Manufacturer	Model	Capacity (lbf)	Pin Needed for Calibration through Instrument Holes	Pin Needed for Calibration through Shackles	Basic Kit (v.1)	Premium Kit (v.1)
Dillon	EDx-20T	50000	TUZ-120-001-11	TP-120-001-01X	✓	✓
Dillon	EDx-25T	55000	TUZ-120-001-24	TP-120-001-01X		✓
Dillon	EDx-50T	100000	TUZ-120-001-10	TP-120-001-01X	✓	✓
Dillon	ED2000 (50000 lbf)	50000	TUZ-120-001-11	TP-120-001-01X	✓	✓
Dillon	ED2000 (100000 lbf)	100000	TUZ-120-001-14	TP-120-001-01X	✓	✓
Rice Lake	Port-A-Weigh; MSI-4260	20000	-	TUZ-120-001-11X	✓	✓
Rice Lake	Port-A-Weigh; MSI-4260	30000	-	TUZ-120-001-11X	✓	✓
Rice Lake	Port-A-Weigh; MSI-4260	50000	-	TP-120-001-01X	✓	✓
Rice Lake	Port-A-Weigh; MSI-4260	70000	-	TP-120-001-01X	✓	✓
Rice Lake	Port-A-Weigh; MSI-4260	100000	-	TP-120-001-01X	✓	✓
Rice Lake	Port-A-Weigh Plus; MSI-4300	20000	-	TUZ-120-001-11X	✓	✓
Rice Lake	Port-A-Weigh Plus; MSI-4300	30000	-	TUZ-120-001-11X	✓	✓
Rice Lake	Port-A-Weigh Plus; MSI-4300	50000	-	TP-120-001-01X	✓	✓
Rice Lake	Port-A-Weigh Plus; MSI-4300	70000	-	TP-120-001-01X	✓	✓
Rice Lake	Port-A-Weigh Plus; MSI-4300	100000	-	TP-120-001-01X	✓	✓
Rice Lake	Trans-Weigh; MSI-6260CS	20000	-	TUZ-120-001-11X	✓	✓
Rice Lake	Trans-Weigh; MSI-6260CS	30000	-	TUZ-120-001-11X	✓	✓
Rice Lake	Trans-Weigh; MSI-6260CS	50000	-	TP-120-001-01X	✓	✓
Rice Lake	Trans-Weigh; MSI-6260CS	70000	-	TP-120-001-01X	✓	✓
Rice Lake	Trans-Weigh; MSI-6260CS	100000	-	TP-120-001-01X	✓	✓
Rice Lake	Port-A-Weigh Plus; MSI-9300	20000	-	TUZ-120-001-11X	✓	✓
Rice Lake	Port-A-Weigh Plus; MSI-9300	30000	-	TUZ-120-001-11X	✓	✓
Rice Lake	Port-A-Weigh Plus; MSI-9300	50000	-	TP-120-001-01X	✓	✓
Rice Lake	Port-A-Weigh Plus; MSI-9300	70000	-	TP-120-001-01X	✓	✓
Rice Lake	Port-A-Weigh Plus; MSI-9300	100000	-	TP-120-001-01X	✓	✓
Rice Lake	Port-A-Weigh Plus; MSI-9300HT †	70000	TUZ-120-001-11 †	TP-120-001-01X †	✓	✓
Rice Lake	Port-A-Weigh Plus; MSI-9300HT †	120000	TUZ-120-001-13 †	TP-120-001-01X †		✓
Rice Lake	Dyna-Link 2; MSI-7300	25000	TUZ-120-001-25	TP-120-001-01X		✓
Rice Lake	Dyna-Link 2; MSI-7300	50000	TUZ-120-001-11	TP-120-001-01X	✓	✓
Rice Lake	Dyna-Link 2; MSI-7300	120000	TUZ-120-001-13	TP-120-001-01X		✓

† Instrument has two different hole sizes. Thus, two pins with two different diameters are required; one for instrument hole and one for shackle.

Figure 13: 1 of 3 pages of model numbers the Morehouse Adaptable Clevis Kits can be used to calibrate tension links

Aircraft and Truck Scale Calibration Adapters

When someone calibrates a scale using weights or a hydraulic cylinder are they simulating how the scale is used? Most truck and aircraft scales have the truck or aircraft tire sitting directly on them. So how could it make sense to calibrate the scales without using an adapter that replicates actual use?

To ensure accurate results, any adapter used during calibration should be composed of the same type of rubber and have the same footprint as the tire. Morehouse has a line of aircraft and truck calibration presses. We can make adapters for any scale that simulate the tire. For more information please visit our [website](#).



Figure 14: Calibration Adapter for Truck and Aircraft Scales

Adapters for Hand-Held Force Gauges

Are you or your calibration technicians tired of lifting weights to calibrate hand-held force gauges? Calibrating some of the hand-held force gauges is like playing Jenga when a technician must stack weights in compression. What happens when those weights fall and shatter a toe?

To solve this problem, Morehouse has developed a portable calibrating machine with [kits for hand-held force gauges](#). These kits can be used to calibrate several handheld force gauge models available on the market. For each model, a certain combination of a back-plate, bottom-plate, and threaded adapter must be assembled together.



Morehouse L-Bracket kits are available for tension and compression calibration of hand held force gauges. These kits simplify setup and reduce errors with stacking weights

Figure 15: Morehouse Portable Calibrating Machine with Hand-Held Force Gauge Adapters

The 2,000 lbf capacity Morehouse Portable Calibrating Machine (PCM) can handle any force instrument. The machine can use the button and washer load cell adapters for compression calibrations on those types of load cells as well as common tension setups and hand-held force gauges. The hand-held force gauge kit simplifies setup and allows the technician to calibrate these types of gauges in the same setup. The line of force pure is kept pure by using different offset plates included in the kits. These kits simplify setup, improve alignment and drastically improve safety. The kits are also available for Morehouse deadweight and Universal Calibrating Machines.

Multi-Axis Load Cell Adapters

Morehouse can make adapters for almost any force application from small (1 lbf) to large (2.5 million lbf). Morehouse has also designed and manufactured adapters for calibrating various multi-axis load/torque cells which enables a laboratory to calibrate such cells in single axis calibrating machines. If you have an instrument that is not listed here, please contact sales@mhforce.com.

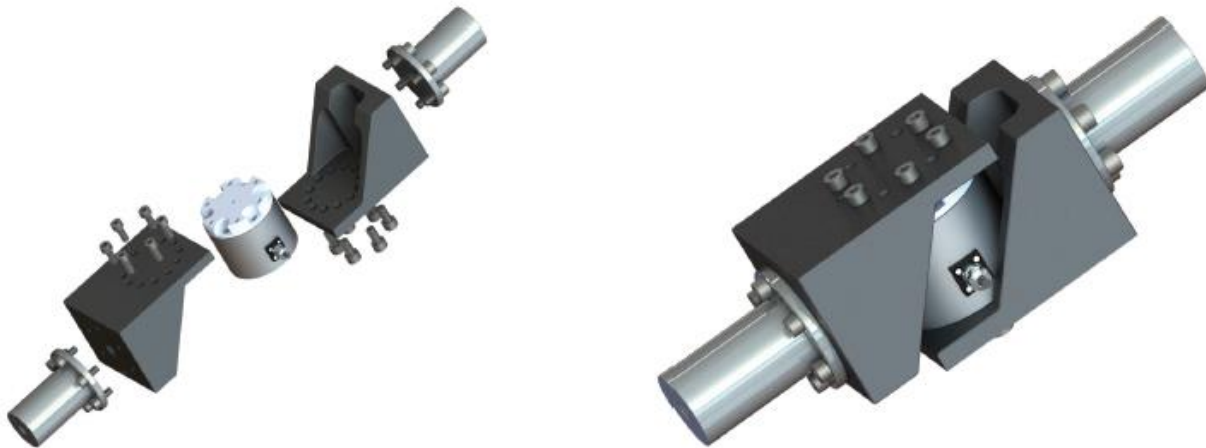


Figure 16: Morehouse Calibration Adapters for 6-Axis Force/Torque Cell

Conclusion

Most force measuring instruments are susceptible to misalignment error, errors from not exercising the force measuring instrument to full capacity, and errors from improper adapter use. In almost all cases, there will be additional errors if the end user fails to have the force measuring instrument calibrated with the same adapters used in their application.

When evaluating other error sources, it is important that the end user of the force measuring instrument is replicating how the force measuring instrument was calibrated or that the laboratory performing the calibration is replicating how the instrument is going to be used.

Fixturing and adapters used with the force measuring instrument may have a significant contribution to the overall uncertainty of the force measuring instrument. From the examples provided in this paper, these errors can be quite large and produce measurement errors that are over twenty times greater than the instrument's accuracy specification.

Morehouse Calibrating Machines simplifies force calibration by reducing rework, errors from misalignment, and problematic setups. The operator can replicate how the force instruments are used for ASTM E4 and ISO 7500 calibrations by using different setups for tension and compression, and proper adapters recommended by several standards, including ISO 376.

Morehouse has conducted extensive testing throughout our 100 plus years of making force equipment. We have reference force standards with calibration and measurement capabilities of better than 0.002 % to conduct many tests on adapters and provide solutions that improve measurements for our customers. The frightening part of this is that not everyone in the industry is part of our customer base and several do not realize they have these errors.

Can you imagine the company making critical measurements using a misaligned S-Beam load cell? How about weighing something like a ton of uranium with the wrong pin size and a tension link? These measurements matter and can impact our safety! Please join us in educating people who underestimate the importance of adapters and help us create a safer world by helping companies improve their force measurements.

References

1. ASTM E74-18, note 5 <https://www.astm.org/Standards/E74.htm>
2. ISO 376, Annex A.4.1 <https://www.iso.org/obp/ui/#iso:std:iso:376:ed-4:v1:en>

Visit www.mhforce.com for additional guidance on adapters, uncertainty, calibration techniques, and more.

Your time is valuable. Morehouse thanks you for taking the time to read this document. We wish you the very best and are always here to help!

About Morehouse Instrument Company

Our purpose is to create a safer world by helping companies improve their force and torque measurements. We have several other technical papers, guidance documents, and blogs that can add to your knowledge base. To learn more and stay up to date on future documents and training, subscribe to our newsletter and follow us on social media.

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