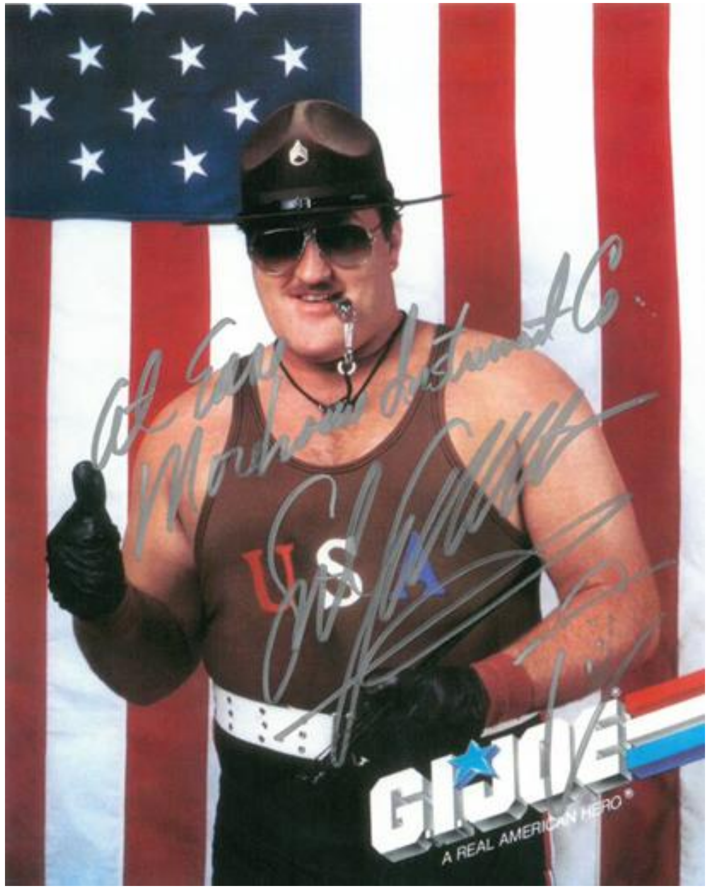
FUNDAMENTALS OF FORCE CALIBRATION ½ DAY COURSE

MHFORCE Morehouse
THE FORCE IN CALIBRATION SINCE 1925

Force Calibration



Some Basics

- The workshop is for your benefit, and its success is dependent on **YOU**.
- Enter the discussion **ENTHUSIASTICALLY** ☺
- **FREELY** give your experience relating to the topic
- Say what you think to the **GROUP**. (Private conversations while someone else is speaking are distracting.)

FUNDAMENTALS OF FORCE CALIBRATION

- Henry Zumbrun II, Morehouse Instrument Company
- 1742 Sixth Ave
- York, PA 17403
- PH: 717-843-0081   web: www.mhforce.com
- sales: hzumbrun@mhforce.com

Course Abstract

- This course will cover applied force calibration techniques. It will cover the importance of calibrating force measurement devices in the way they are being used to reduce measurement errors and lower uncertainty.
- There will be mini-review sessions throughout today's session.
- We will also take a coffee break at the allotted time.

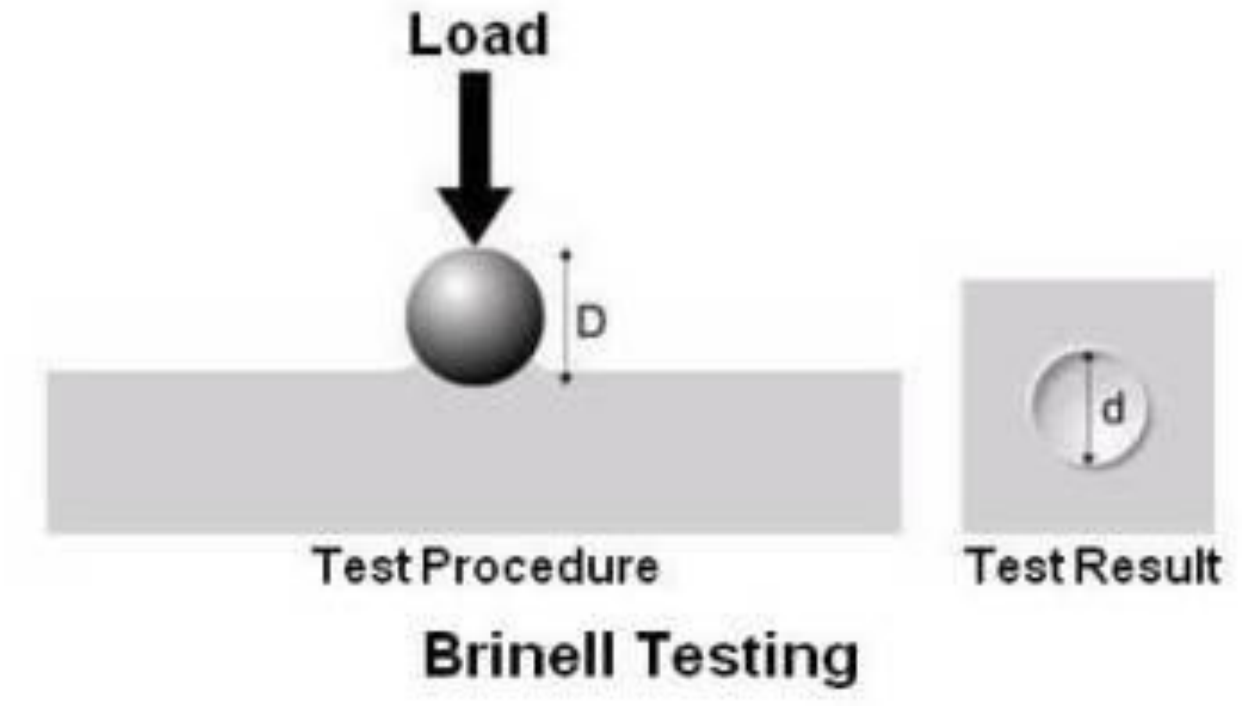
Course Agenda – Imagine Leaving This Session With Knowledge About All of the Information Below

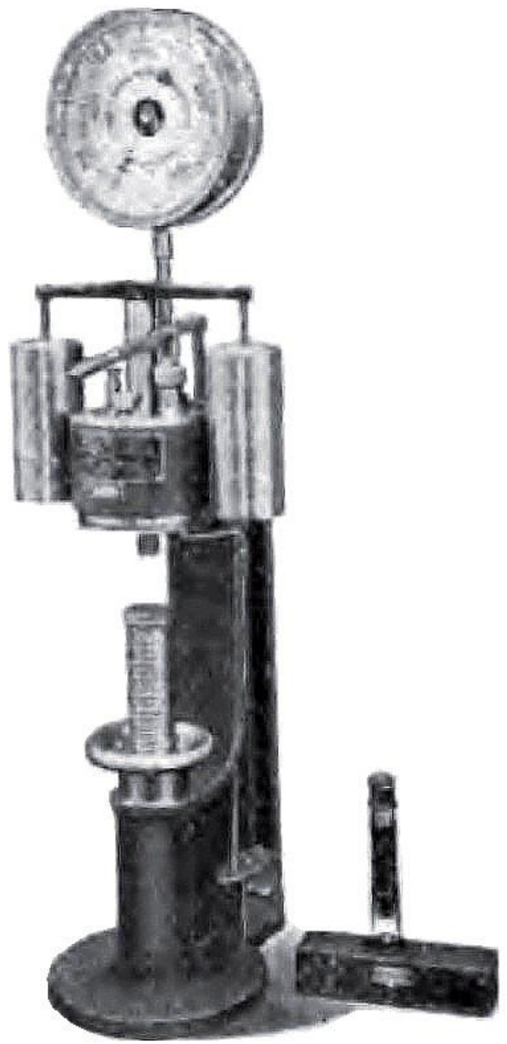
- Company History
- Force Calibration
- Force Calibration Equipment
- Choosing the Right Load Cell System
- Low-Capacity Force Measurements
- ASTM E74 (Brief Discussion)
- Potential Force Measurement Errors

Morehouse

Why We Exist?

Why We Exist?





1921 Brinell Hardness Machine

Company History

- 1920s – Morehouse and the U.S. Bureau of Standards started to design and refine force calibration products (Proving Rings) to generate an accurate force for Brinell Hardness Testing.

Pictured above: Morehouse Brinell Proving Ring S/N 14 Calibrated by U.S. Bureau of Standards test # 47197 May 24, 1926

Form 1a
11—5809

SNP:WMH
VI-5/Trm 47197
Lab.No.0522a26 DEPARTMENT OF COMMERCE

Informal Request
May 21, 1926

Bureau of Standards

Certificate

COPY

FOR

Proving Ring
No. 14

Maker:
Morehouse Machine Co.,
233 West Market St.,
York, Pa.

SUBMITTED BY W. E. Morehouse

B. S. No. 47197

Brinell Proving Ring No. 14 was submitted by the Morehouse Machine Co., 233 West Market St., York, Pa., for calibration and certification.

The ring was calibrated in the Brinell dead-weight machine. The results of calibration are found in the table below:

TABLE -- Deformation of Ring

Ring No.	Standard loads in Divisions of Dial: 500 Kg.	1000 Kg.	1500 Kg.	2000 Kg.	2500 Kg.	3000 Kg.	Value of 1 division of dial Kg.
14	25.8	51.1*	76.1	100.8	125.25*	149.55	19.7

* The values of deformations for 1000 and 2500 Kg. loads were obtained by interpolation.

The error of ring for any load does not exceed ±0.1 division of dial. The above values were obtained at a temperature of 60°F. In order to compare the deformation of a ring in a testing machine with those given in the table, the former must be reduced to the temperature of 60°F by means of the formula:

$d_{60} = d_t \times 1 - 0.00015 (t - 60)$ where

d_{60} = deformation of ring at 60°F
d_t = " " " " t°F
t = temperature, °F, during the test.

Test Number 47197.
Washington, D. C.
May 24, 1926.

George K. Burgess, Director.

Certificate of Calibration

and Traceability to the

United States National Bureau of Standards

MOREHOUSE PROVING RING, S/N 14: 3,000 kgf capacity COMPRESSION TYPE
(APPARATUS CALIBRATED AND SERIAL NO.)

MOREHOUSE PROVING RING, S/N 14, was calibrated according to ASTM specification E74-81, "Standard Methods of Calibration of Force-Measuring Instruments for Verifying the Load Indication of Testing Machines." The uncertainty of this Proving Ring as determined by statistical analysis is 7.14 kgf, at the calibrated loads only.

APPLIED LOAD kgf	Run 1 div	Run 2 div	Run 3 div	Average div
500	26.6	26.5	26.7	26.60
1000	52.1	52.0	52.1	52.07
1500	76.8	76.7	76.9	76.80
2000	101.3	101.5	101.7	101.50
2500	126.5	126.8	126.8	126.70
3000	151.3	151.4	151.4	151.37

Temperature during calibration = 23° C.

Calibration Apparatus Used:
DEAD WEIGHT FORCE MACHINE, S/N M-4644, accurate within .003% of load, calibration traceable to the U.S. National Bureau of Standards, Laboratory No. 737/229759

Date
July 25, 1984

Calibrated By
MOREHOUSE INSTRUMENT COMPANY

MOREHOUSE INSTRUMENT CO. MI-CO

MOREHOUSE INSTRUMENT COMPANY
FORCE CALIBRATION LABORATORY
1742 SIXTH AVENUE
YORK, PENNSYLVANIA 17403-2675
PHONE 717/843-0081

FORM 229-3

- Morehouse Proving Ring S/N 14 Calibrated in 1926, and the last calibration we have on record is July 25, 1984. The ring was in service for over 58 years.

What Morehouse Does

- We manufacture force calibration products
- We calibrate force-measuring equipment using standards with very low uncertainties.
- These standards allow us to lower the uncertainties of equipment sent to us for calibration
- We help labs make better measurements, which makes the world a safer place!

What Morehouse Does

We create a safer world by helping companies improve their force and torque measurements

Force Capability

Morehouse offers dead weight primary standards calibrations accurate to 0.002 % (20 parts per million) of applied force up to 120,000 lbf. Other force calibrations offered up to 2,250,000 lbf know to be within 0.01 % (100 ppm).

Torque Capability

Morehouse torque calibration laboratory features a primary torque calibration standard accurate to 0.0025 % (25 ppm) of applied torque. This standard is the second most accurate torque standard in the world.

Please Feel Free to Ask Anything
Common Questions

- What are the common error sources?
- How do I calculate Measurement Uncertainty?
- How do I know if my devices are “In tolerance”?
- What are traceable measurements?
- Proving Ring versus Load Cell, what is better?
- What adapters do I need to calibrate load cells?
- How do I keep my technicians from squashing load cells?
- No specific question. Just here to learn as much as possible!

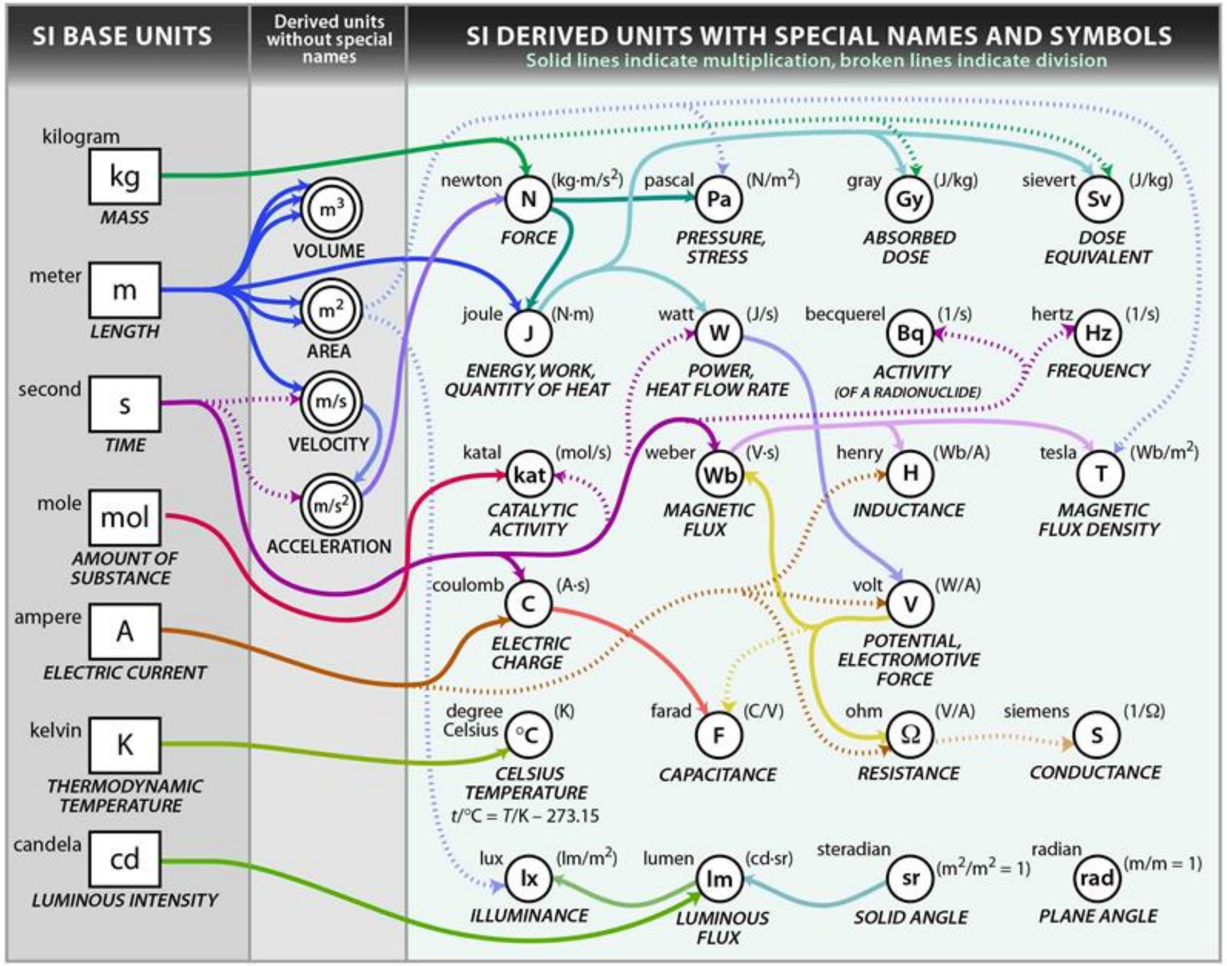
Learning Objectives

By the end of this course, you should be able to

- Identify various types of force calibration equipment and perform some basic load cell troubleshooting techniques.
- Identify potential force measurement errors.
- Implement and apply proper force calibration techniques as discussed and demonstrated in the class.
- Use the appropriate force equipment and method to make statements of conformance.

Force = Mass x Acceleration

- Force is a derived unit. The SI Base units for force are Mass, Time, and Length, as shown in the illustration.



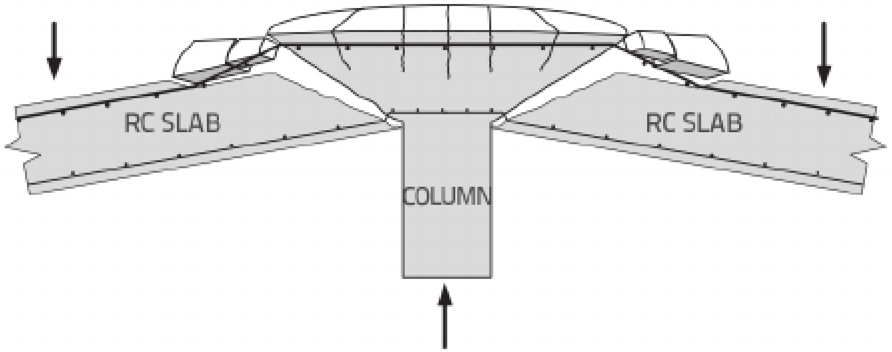
Force = Mass X Acceleration

- CIPM/BIPM defines 1N as the force required to accelerate one kg to one meter **per second** per second in a vacuum.

The Importance of Force Measurement

What **happens if we do not perform force measurements properly?**

This session is to help you make the world a bit safer by helping others to make better force measurements.

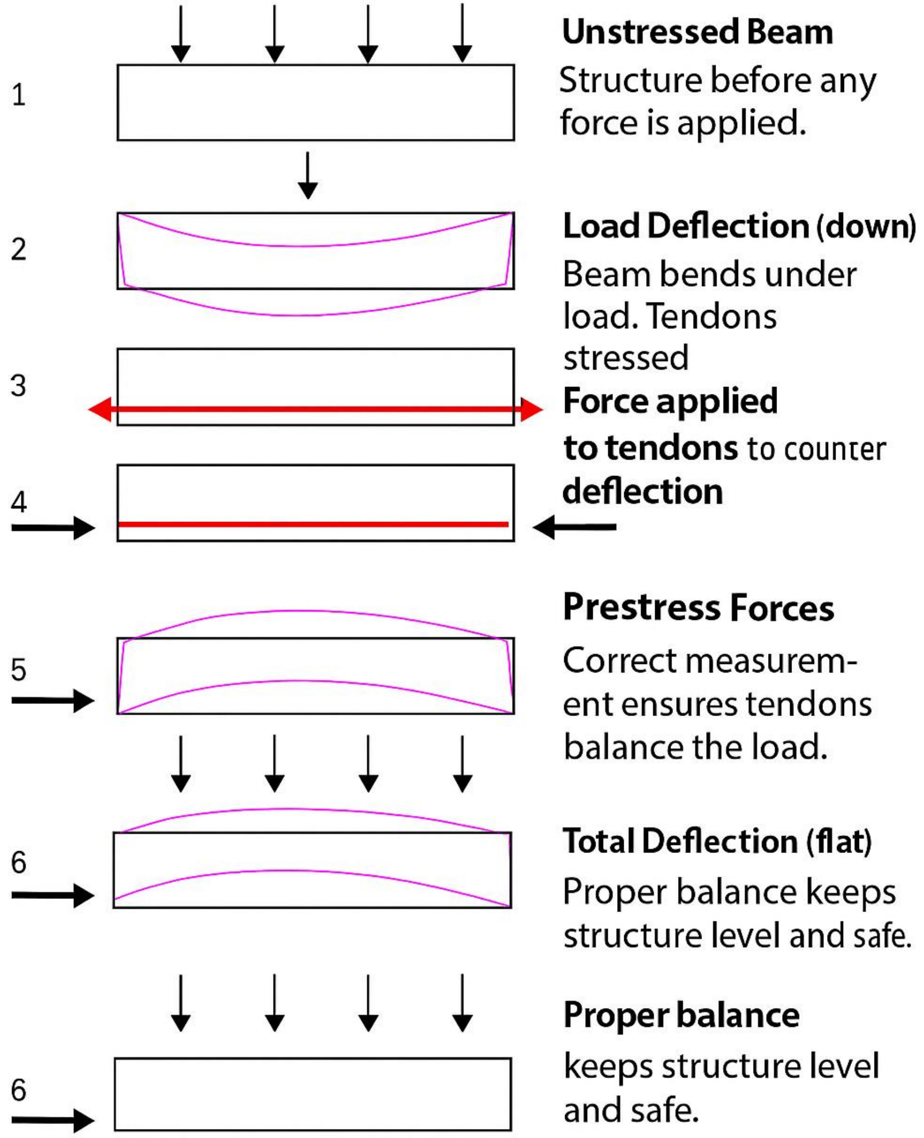


What Could Happen if you Fail to Get the Force Measurement Correct?

- Incorrect Concrete Strength Measurement
- Incorrect Steel Strength Measurement
- Cables not checked properly for prestress or post tension

Why Accurate Force Measurement Matters

Incorrect force measurement leads to unbalanced stress, excessive deflection, and real-world structural failures like the one pictured.



Force General Information
Why is Force Measurement Important?

- *The measurement of force is performed so frequently and routinely that we tend to take these measurements for granted.*

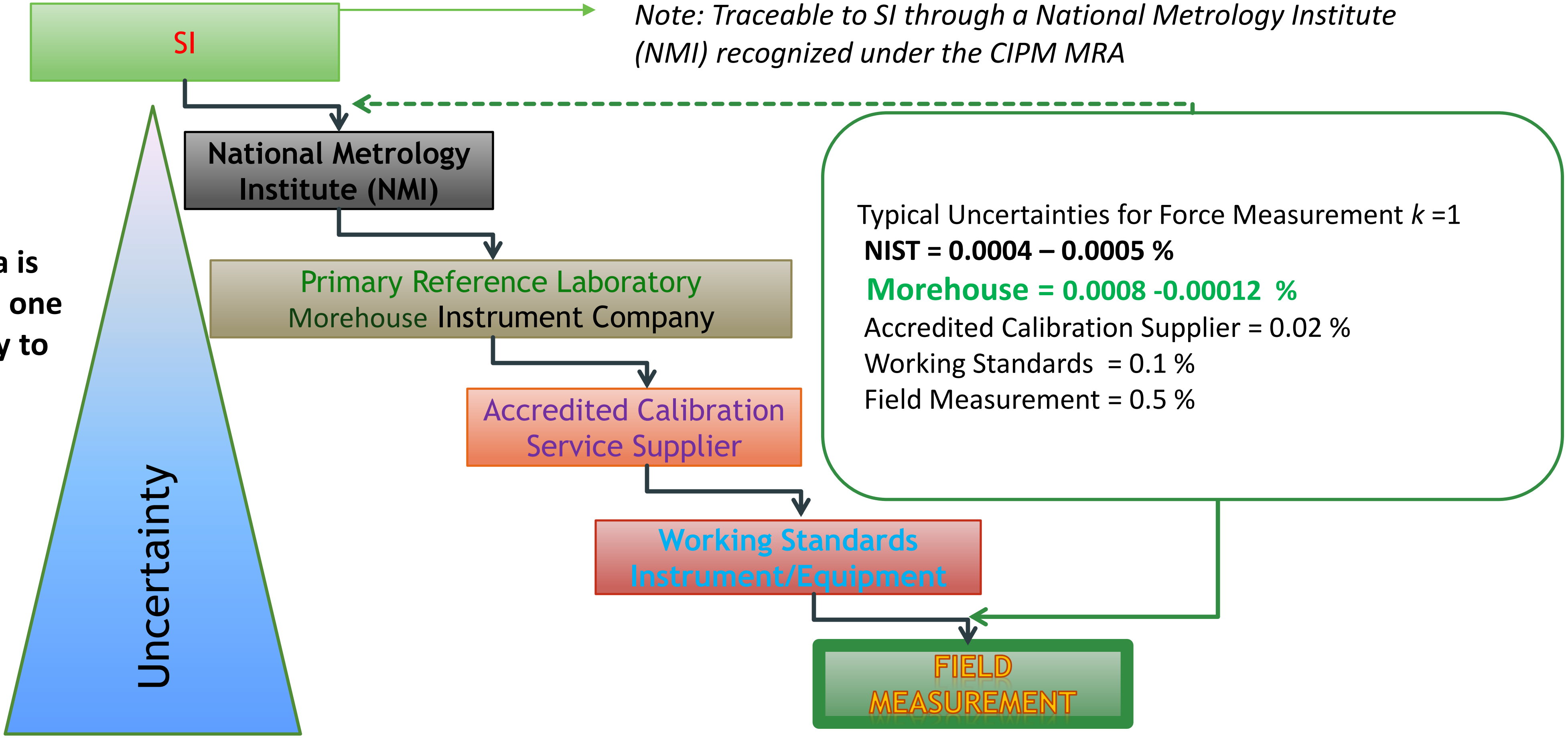
- Almost every material item is tested using some form of traceable force measurement.

- Manufacturers are often required to do sample testing on the products they manufacture.

- These products may vary from the wood that was used to build your house to the cardboard that holds your toilet paper on the roll.

Measurement Traceability and Uncertainties

Typical Metrological Traceability Uncertainties for Force Measurements

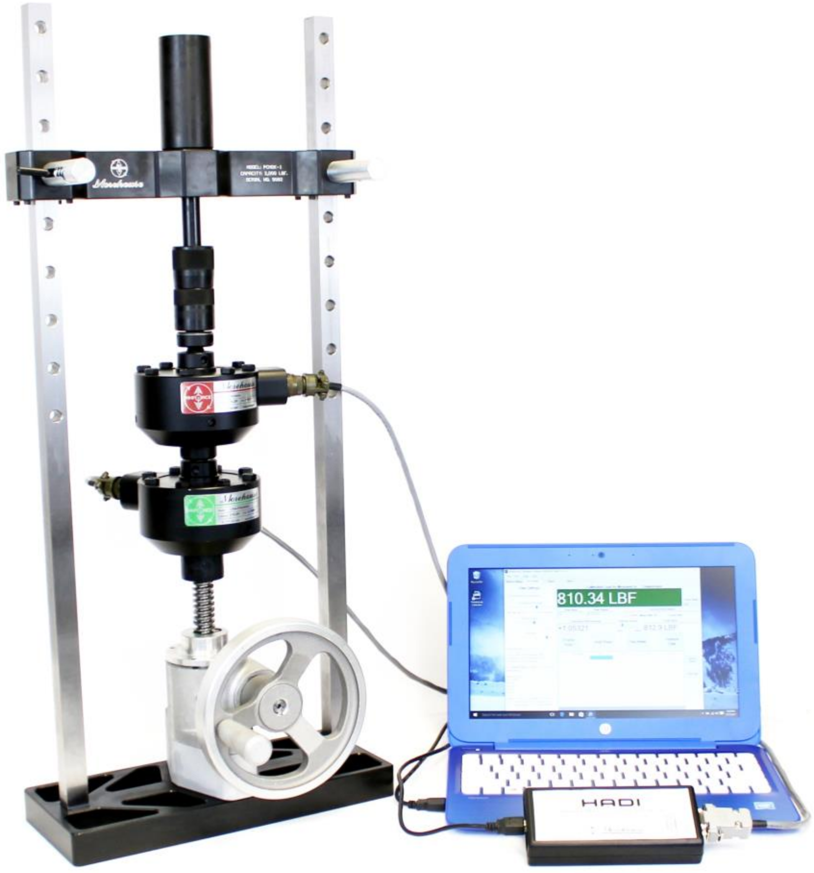


Measurement Uncertainty Data is cumulative from one level of hierarchy to another!

Force General Information
Why is Force Measurement Important?

Aircraft Weighing Applications

Force CMCs at Different Tiers



Tier 1: Primary Standard 0.0016 % used to calibrate Secondary Standards to Class AA

Tier 2: Secondary Standard 0.02 % used to calibrate load cells to Class A

Uncertainty Propagation For Force Calibration Systems

Table 1. Uncertainty Propagation Analysis for Load Cell Calibrations

TIER >>>			TIER 0 Primary Standards	TIER 1 Primary Lab	TIER 2 Secondary Lab
UUT Info >>>			No UUT (Deadweight CMC Calculation)	Load Cell Calibrated by Primary Standard (Class AA Assigned)	Load Cell Calibrated by Secondary Standard (Class A Assigned)
Uncertainty Source		Divisor	Primary Cal (Deadweight)	Primary Cal (Deadweight)	Working Cal (UCM)
Reference	U_{REF}	2	0.396893 N †	1.42 N	17.57 N
Resolution (Reference)	$U_{RES,REF}$	3.464	N/A (deadweight)	1.07 N	1.07 N
Resolution (UUT)	$U_{RES,UUT}$	3.464	0.2780 N ††	1.07 N	1.07 N
UUT Repeatability	U_{REP}	1	0.2567 N	1.7646 N	1.7646 N
B/W Techs Reproducibility and Repeatability	$U_{R\&R}$	1	0.49 N	3.910 N	3.910 N
Stability	U_{STA}	1.732	0.0178 N	4.45 N	4.45 N
Environmental	U_{ENV}	1.732	Included in U_{REF}	0.667 N †††	0.667 N
Side Load Sensitivity	U_{MISC}	1.732	N/A (deadweight frame)	2.67 N	2.67 N
ASTM Lower Limit Factor (LLF)	U_{ASTM}	2.4		18.296 N (Class AA Assigned)	23.718 N (Class A Assigned)
Expanded Uncertainty	U	-	0.0016 % (1.42 N) ‡	0.01974 % (17.57 N) ‡‡	0.031 % (27.45 N) ‡‡‡

Tier 0 is the CMC of Morehouse Machine. Tier 1 is Calibration by Primary Standards Class AA loading Range Assigned. Tier 2 is the actual CMC of the Secondary Standard. The % error is based on a 20 % test point.

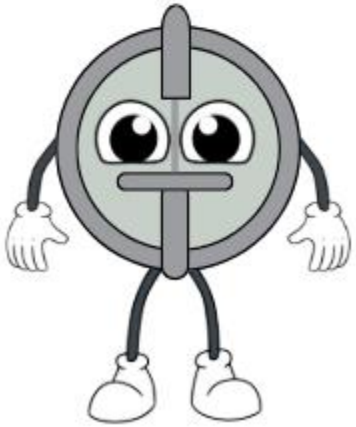
Common types of Force Equipment

- Bolt Testers
- Proving Rings
- Force Gauges
- Brinell Calibrators
- Traction Dynamometers
- Tension Links
- Crane Scales
- Load Cells –multiple types

Bolt Testers

- Used to test high-strength bolts
- Calibration requires special fixtures based on factory recommendations. Accuracy is typically 1 % of applied reading between 20-80 percent of the range. These are typically used to test structural fasteners and test torque/tension relationships.

Proving Rings



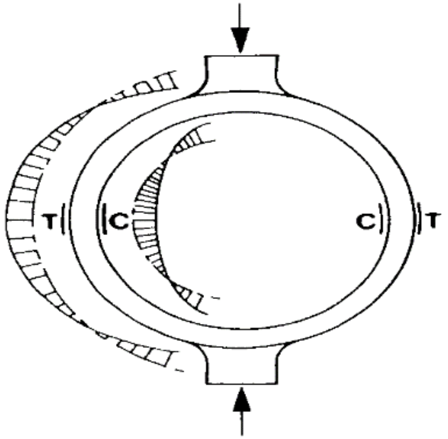
Reliability

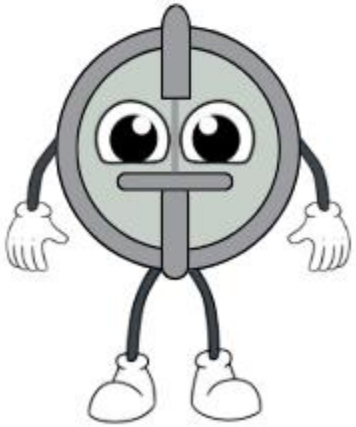
It has been proven that a steel ring made of the correct steel alloy and properly manufactured will perform as a near-perfect elastic member. The Proving Ring, if used and maintained properly, can last indefinitely.

Repeatability

Proving Rings, unlike other force-measuring instruments, are not sensitive to rotation/positioning problems.

Proving Ring





- The bending moment of a Proving Ring does not vary significantly in the region of the horizontal diameter, which leads to a nearly uniform strain distribution.

Digital Proving Rings

- Digital Proving Rings have been designed to lower uncertainties by reducing operator error associated with reading mechanical contacts. The calibration cycle time is also improved with digital rings.

Force Gauges

- Typically used for calibration of certain testing machines, weighing devices, assembly presses, control instruments, cable tension, soil testing, or other equipment measuring force, as a prime weighing device or permanent load-sensing component in testing or production equipment.
- Force Gauges can either be analog or digital and usually have an accuracy anywhere from 0.1 % of full scale to 2 % of full scale.

Adapters for hand-held force gauges

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

Brinell Calibrators

- Typically used for calibration of Brinell hardness testers and calibrated in accordance with ASTM E74 as a limited load device.
- The Brinell hardness test for steel involves impressing a ball, 10 mm diameter, of hard steel or tungsten carbide, with a loading of 3000 kilograms into the steel surface. The hardness of the steel is then determined by measurement of the indentation.

Traction Dynamometers

- Typically used for adjusting the tension on guy wires, field testing chain, rope, wire, or anything requiring precision force or tension measurement.
- Calibration should be performed with shackles if possible. Typical accuracy is 0.5 % of full scale, which may be difficult to achieve on some models.

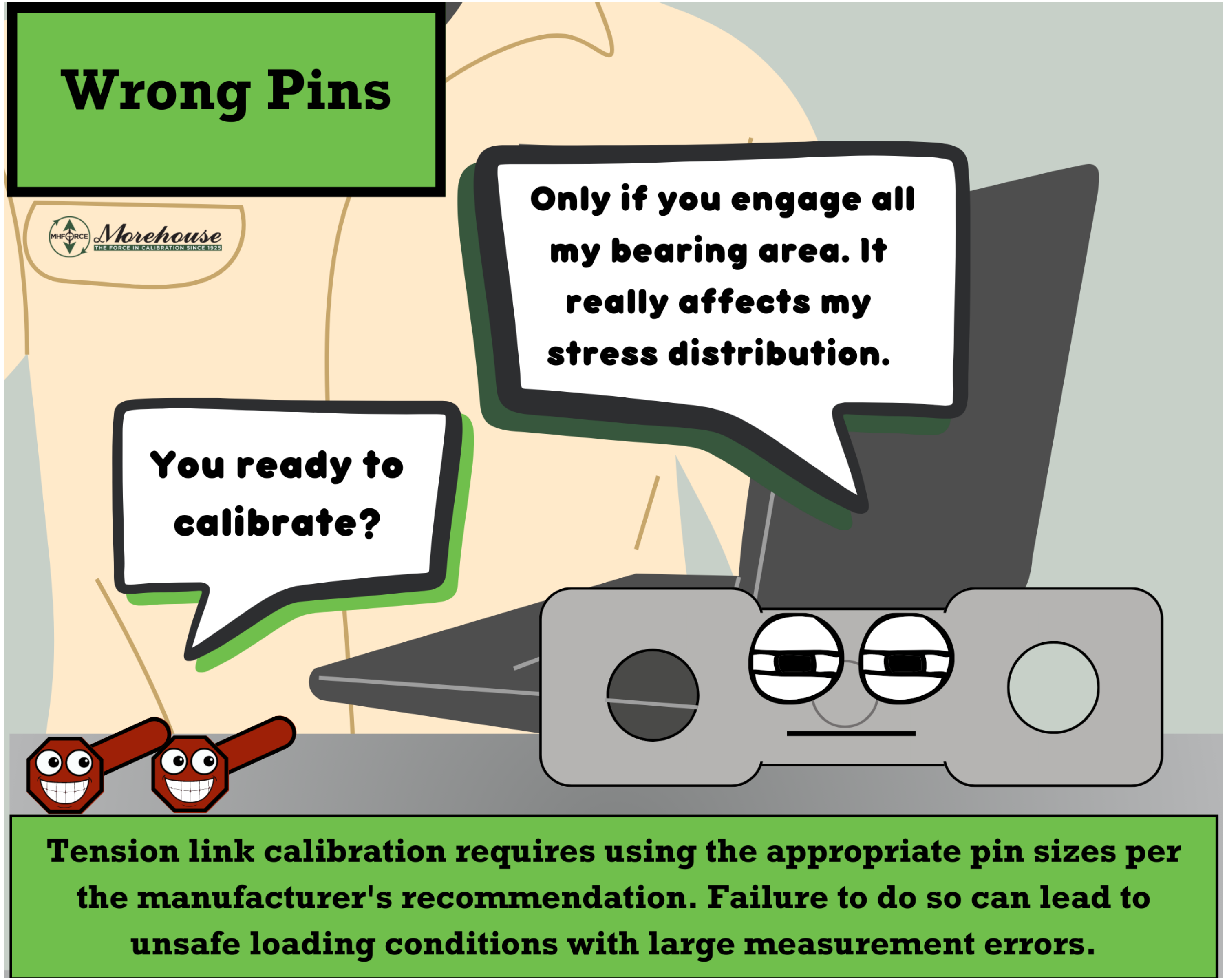
Tension Links PROPER PIN DIAMETER

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

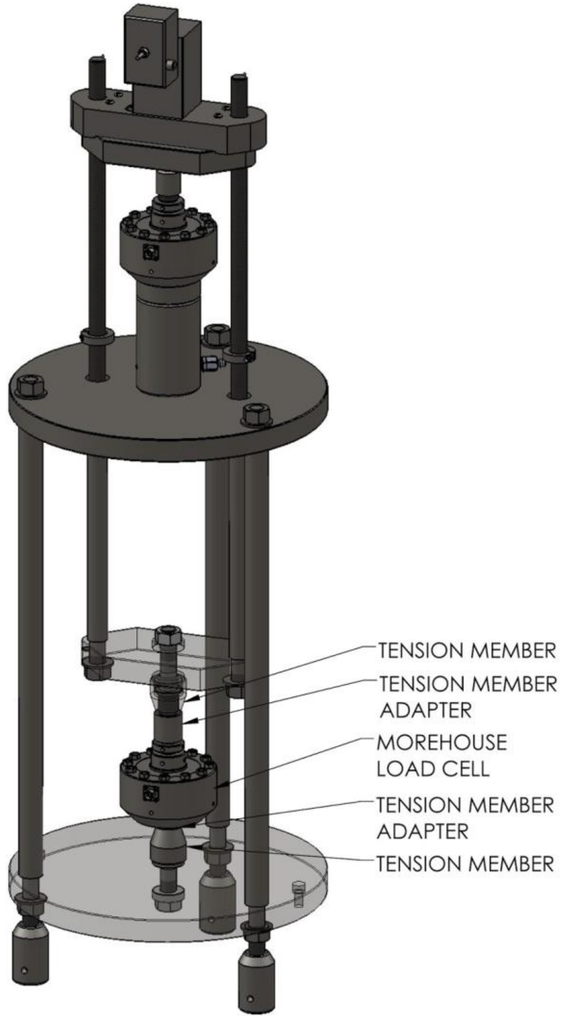
- Out of Tolerance Versus In Tolerance
- Note: Most Tension links of this design seem to exhibit similar problems.

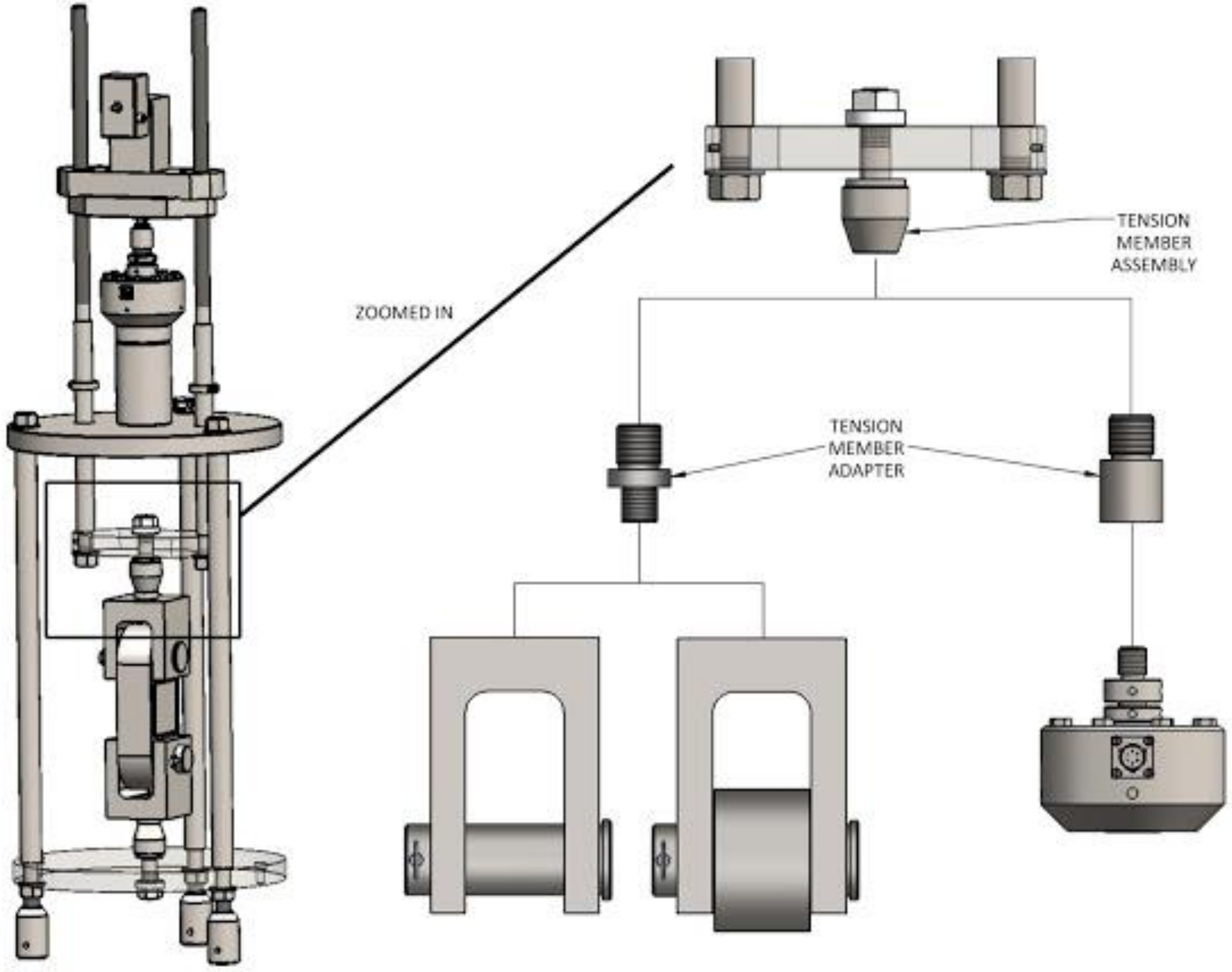
Tension Links PROPER PIN DIAMETER

Pin B (2.0030 to 2.0060)	Pin A (2.0005 to 2.0045)
50,070	50,010
50,050	50,020
50,040	50,010
50,070	50,020
50,090	50,020
50,060	50,030
50,080	50,010
50,070	50,030
50,090	50,020
50,090	50,070
50,080	50,060
50,100	50,070
17.81640375	22.74696117
Out of 24 tests 13 did not meet spec ± 50	


Wrong Pins
Morehouse
THE FORCE IN CALIBRATION SINCE 1925
Only if you engage all my bearing area. It really affects my stress distribution.
You ready to calibrate?
Tension link calibration requires using the appropriate pin sizes per the manufacturer's recommendation. Failure to do so can lead to unsafe loading conditions with large measurement errors.

Morehouse Quick-Change Adapter System





Proper Adapters for Tension Links

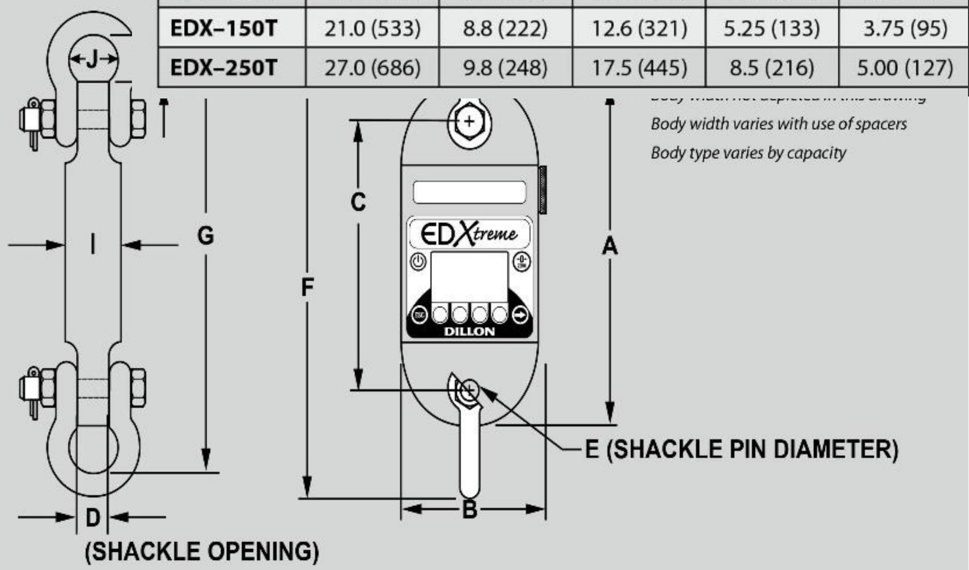
Dimensions inches

Model	A
EDX–1T	10.6 (
EDX–2T	10.6 (
EDX–5T	11.4 (
EDX–10T	11.5 (
EDX–25T	13.7 (
EDX–50T	15.8 (
EDX–75T	16.5 (
EDX–100T	18.0 (
EDX–150T	21.0 (
EDX–250T	27.0 (

*Dimensions shown using

Dimensions inches (mm)

Model	A	B	C	D	E
EDX–1T	10.6 (269)	5.0 (127)	7.8 (198)	1.06 (26)	0.75 (19)
EDX–2T	10.6 (269)	5.0 (127)	7.8 (198)	1.06 (26)	0.75 (19)
EDX–5T	11.4 (289)	5.3 (135)	8.1 (206)	1.38 (35)	1.00 (25)
EDX–10T	11.5 (291)	5.3 (133)	7.9 (201)	1.97 (50)	1.38 (35)
EDX–25T	13.7 (348)	6.0 (152)	9.0 (229)	2.75 (70)	1.97 (50)
EDX–50T	15.8 (400)	6.8 (172)	10.3 (262)	3.88 (99)	2.75 (70)
EDX–75T	16.5 (419)	7.8 (197)	10.3 (262)	3.88 (99)	2.75 (70)
EDX–100T	18.0 (457)	7.8 (197)	11.0 (280)	5.00 (127)	3.25 (83)
EDX–150T	21.0 (533)	8.8 (222)	12.6 (321)	5.25 (133)	3.75 (95)
EDX–250T	27.0 (686)	9.8 (248)	17.5 (445)	8.5 (216)	5.00 (127)



Body width varies with use of spacers

Body type varies by capacity

Dimensions inches (mm)

Model	A	B	C	D	E
EDx–1T	10.6 (269)	5.0 (127)	7.8 (198)	1.06 (26)	0.75 (19)
EDx–2T	10.6 (269)	5.0 (127)	7.8 (198)	1.06 (26)	0.75 (19)
EDx–5T	11.4 (289)	5.3 (135)	8.1 (206)	1.38 (35)	1.00 (25)
EDx–10T	11.5 (291)	5.3 (133)	7.9 (201)	1.97 (50)	1.38 (35)
EDx–20T	13.7 (348)	6.0 (152)	9.0 (229)	2.75 (70)	2.0 (51)
EDx–50T	15.8 (400)	6.8 (172)	10.3 (262)	3.88 (99)	2.75 (70)
EDx–75T	16.5 (419)	7.8 (197)	10.3 (262)	3.88 (99)	2.75 (70)
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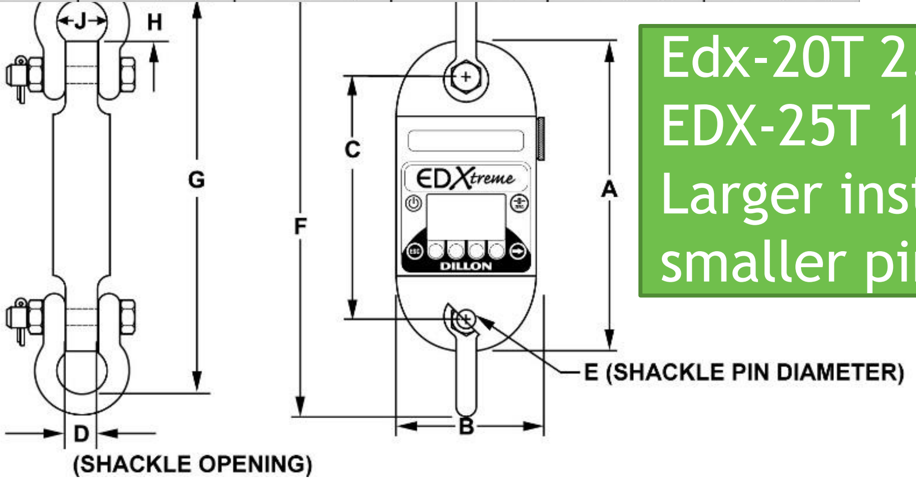
EDx–250T	27.0 (686)	9.8 (248)	17.5 (445)	8.5 (216)	5.00 (127)

G	H	J
3.4 (340)	1.36 (34)	1.69 (43)
3.4 (340)	1.36 (34)	1.69 (43)
5.8 (402)	2.17 (56)	2.28 (58)
8.8 (478)	3.67 (93)	3.25 (83)
5.2 (640)	5.7 (146)	5.0 (127)
4.3 (870)	9.3 (235)	7.3 (184)
4.3 (870)	8.9 (225)	7.3 (184)
.5 (1027)	11.2 (284)	7.8 (200)
5.6 (1159)	12.3 (313)	9.0 (229)
2.8 (1595)	17.9 (454)	13.0 (330)



Edx-20T 2.0 inch pin
EDX-25T 1.97 inch pin
Larger instrument takes smaller pin!

Link to Morehouse Clevis kits

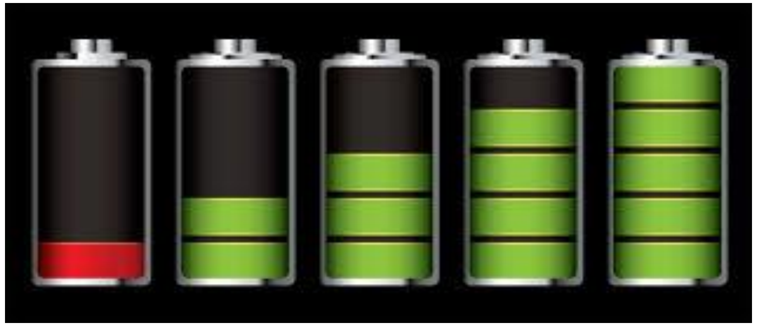
Crane Scale

- Typically used for lift tests, towing tension, cable tension, crane scale, hoist scale, and tensile testing systems.

- These devices tend to be very forgiving in fixture selection for calibration. Accuracies are typically 0.1 % applied force ± 1 count (MSI specifically) or, for some manufacturers, 1 % of full scale.

Batteries

Confidence in your test and measurement results starts with your calibration provider.



To produce more confidence in our measurements, Morehouse has adopted a new policy to calibrate instruments with a new set of fully charged batteries. These batteries are shipped back with your instruments. Most instruments will operate fine with a lesser charge; the word “most” is what concerns us. The Morehouse mission is to be regarded as the best independent force calibration resource in the world. In keeping with our mission, Morehouse provides a new set of batteries to ensure we can provide meaningful measurement results with the lowest uncertainties possible.

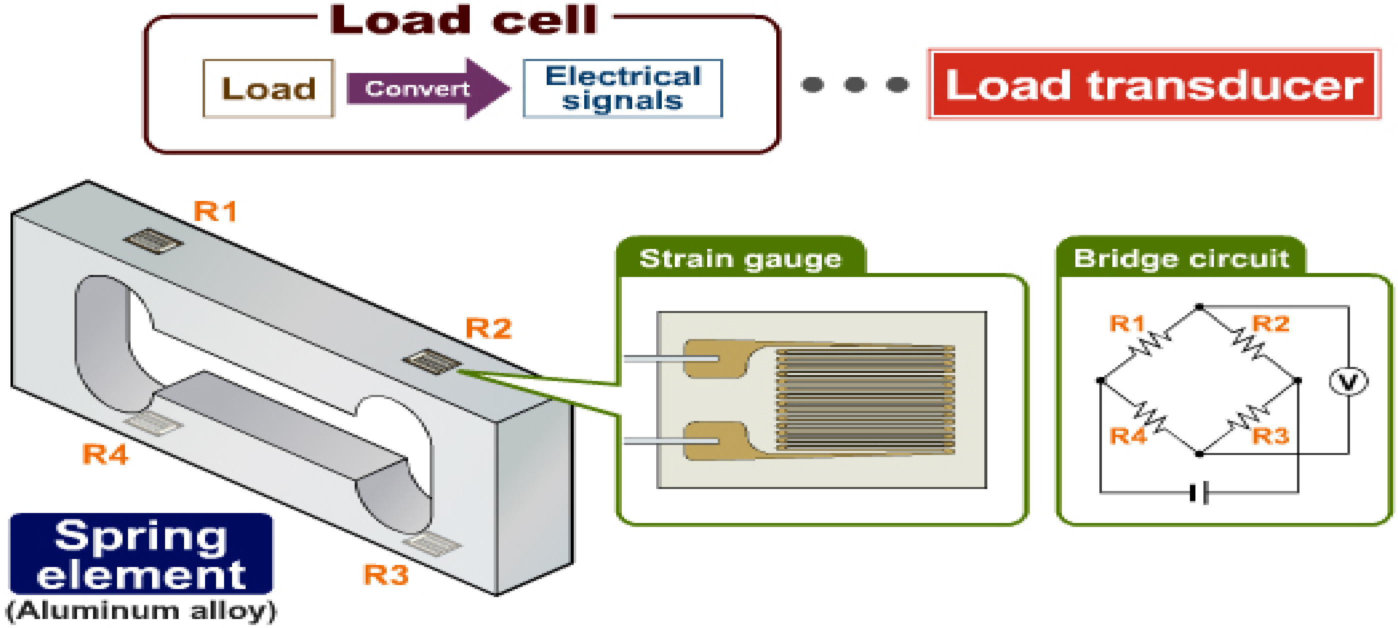
Thank you for thinking of us for your calibration work.

Batteries

Force Applied	"As Received" With Customer Supplied Batteries	Error lbf	"As Returned" With New Batteries	Error lbf	Difference Between Used Versus New
-	0	0	0	0	
25,000	24900	-100	25000	0	100
50,000	49900	-100	50100	100	200
75,000	74800	-200	75100	100	300
100,000	99700	-300	100200	200	500
125,000	124700	-300	125200	200	500
150,000	149600	-400	150200	200	600
175,000	174600	-400	175200	200	600
200,000	199600	-400	200200	200	600
225,000	224500	-500	225200	200	700
250,000	249500	-500	250200	200	700
-	0	0	0	0	

Difference of 700 lbf @ Capacity 0.28 % on a Device with an Accuracy Specification of 0.1 % of Full Scale ± 250 lbf.

Load Cells



A load cell is a force sensor that receives a voltage (excitation) from a regulated power source (usually a digital indicator or signal conditioner) and sends back a low-voltage signal (signal) when force is applied.

How Load Cells Work

The load cell signal is converted to a visual or numeric value by a "digital indicator." When there is no load on the cell, the two signal lines are at equal voltage. As a load is applied to the cell, the voltage on one signal line increases very slightly, and the voltage on the other signal line decreases very slightly. The difference in voltage between the two signals is read by the indicator.

Understanding a Load Cell Specification Sheet

- What does all this stuff mean to you?

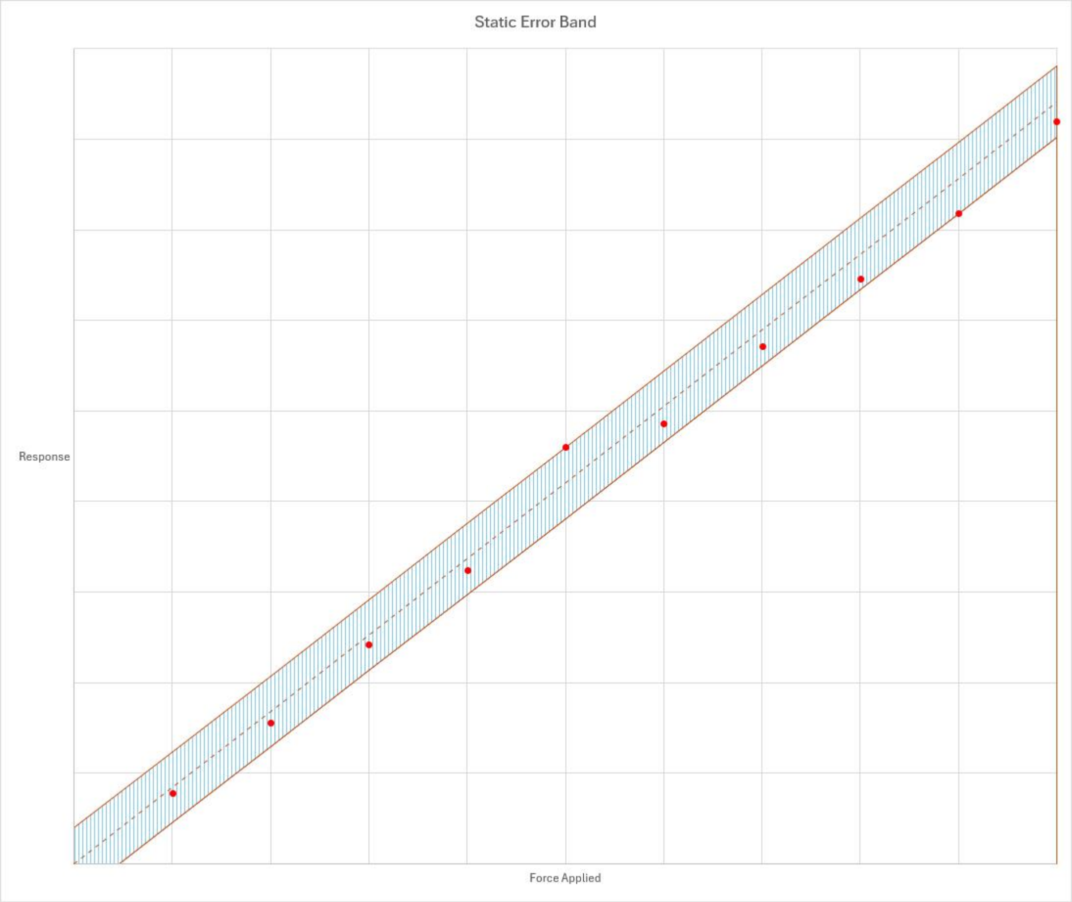
Specifications	Model - Capacity (lbf / kN)					
	300-2K / 1-10	5K-10K / 25-50	25K-50K / 100-250	60K / 300	100K / 500	200K / 900
Accuracy						
Static Error Band, % R.O.	±0.02	± 0.025	± 0.025	± 0.025	± 0.05	± 0.05
Non-Linearity, % R.O.	±0.03	± 0.035	± 0.035	± 0.035	± 0.05	± 0.05
Hysteresis, % R.O.	± 0.02	± 0.035	± 0.045	± 0.045	± 0.05	± 0.05
Non-Repeatability, % R.O.	± 0.005	± 0.005	± 0.005	± 0.005	± 0.005	± 0.005
Creep, % Rdg / 20 Min.	± 0.01	± 0.01	± 0.01	± 0.01	± 0.01	± 0.01
Off-Center Load Sensitivity, %/in	±0.1	± 0.1	± 0.1	± 0.1	± 0.1	± 0.1
Side Load Sensitivity, %	± 0.1	± 0.1	± 0.1	± 0.1	± 0.1	± 0.1
Zero Balance, % R.O.	± 1.0	± 1.0	± 1.0	± 1.0	± 1.0	± 1.0
Temperature						
Range, Compensated, °F	+15 to +115	+15 to +115	+15 to +115	+15 to +115	+15 to +115	+15 to +115
Range, Operating, °F	-65 to +200	-65 to +200	-65 to +200	-65 to +200	-65 to +200	-65 to +200
Sensitivity Effect, % Rdg / 100°F	0.08	0.08	0.08	0.08	0.08	0.08
Zero Effect, % R.O. / 100°F	0.08	0.08	0.08	0.08	0.08	0.08
Electrical						
Recommended Excitation, VDC	10	10	10	10	10	10
Input Resistance, Ω	350 +40/-3.5	350 +40/-3.5	350 +40/-3.5	350 +40/-3.5	350 +40/-3.5	350 +40/-3.5
Output Resistance, Ω	350 ± 3.5	350 ± 3.5	350 ± 3.5	350 ± 3.5	350 ± 3.5	350 ± 3.5
Sensitivity (R.O.), mV/V, Nominal	2	4	4	4	4	4
Insulation Bridge/Case, MegΩ	5000 @50 VDC	5000 @50 VDC	5000 @50 VDC	5000 @50 VDC	5000 @50 VDC	5000 @50 VDC
Mechanical						
Safe Overload, % R.O.	150	150	150	150	150	150
Weight, lbs	3.8	8.0	23.5	26.0	58.0	171.0
Flexure Material	Aluminum	Steel	Steel	Steel	Steel	Steel

Capacity (lbf)	300	500	1,000	2,000	5,000	10,000	25,000	50,000	60,000	100,000	200,000
Capacity (kN)	1	2.5	5	10	25	50	100	250	300	500	900
Part No.	UPC-300	UPC-500	UPC-1k	UPC-2k	UPC-5k	UPC-10k	UPC-25k	UPC-50k	UPC-60k	UPC-100k	UPC-200k

Load cells for other capacities are available. Contact Morehouse for more information.

Static Error Band (SEB), % R.O.:

Static Error Band (SEB), % R.O.: This represents a subset of errors in the load cell's output, including sources such as non-linearity, hysteresis, and return to zero after loading. A lower SEB means higher accuracy. For example, the static error band for smaller capacities is ±0.02 % R.O., meaning the error is within 0.02 % of the rated output (R.O.).



Our goal is to find a line that results in the smallest, maximum error. This line also needs to fit through the origin (0, 0), so only the slope needs to be calculated via $(y_1+y_2) / (x_1+x_2)$. The best approach to this is to iterate across every pair of percent force applied of full scale (**% FS**) and the zero adjusted responses.

For each pair, calculate the slope, use the slope to calculate the percent error for all % FS, and take the largest error as that slope's "absolute error" value. Repeat this for all possibilities, taking the slope that has the smallest absolute error value.

Non-Linearity, % R.O.(Rated Output):

Non-Linearity, % R.O.(Rated Output): This specifies the deviation from a straight line when force is applied. A lower value indicates that the load cell response is more linear, which is ideal for precise measurements. Reported Non-linearity can vary for the same cell depending on how this straight line is defined. Typical definitions are endpoint, best fit straight line and best fit straight line thru zero.

An ideal measurement device has a perfectly linear response to force applied ratio. However, this is rarely true; most devices have a non-linear ratio. The purpose of the non-linearity calculation is to show how the recorded responses deviate from the ideal ratio. Non-linearity is typically expressed in the percent of full-scale (% FS).

Calculate Slope

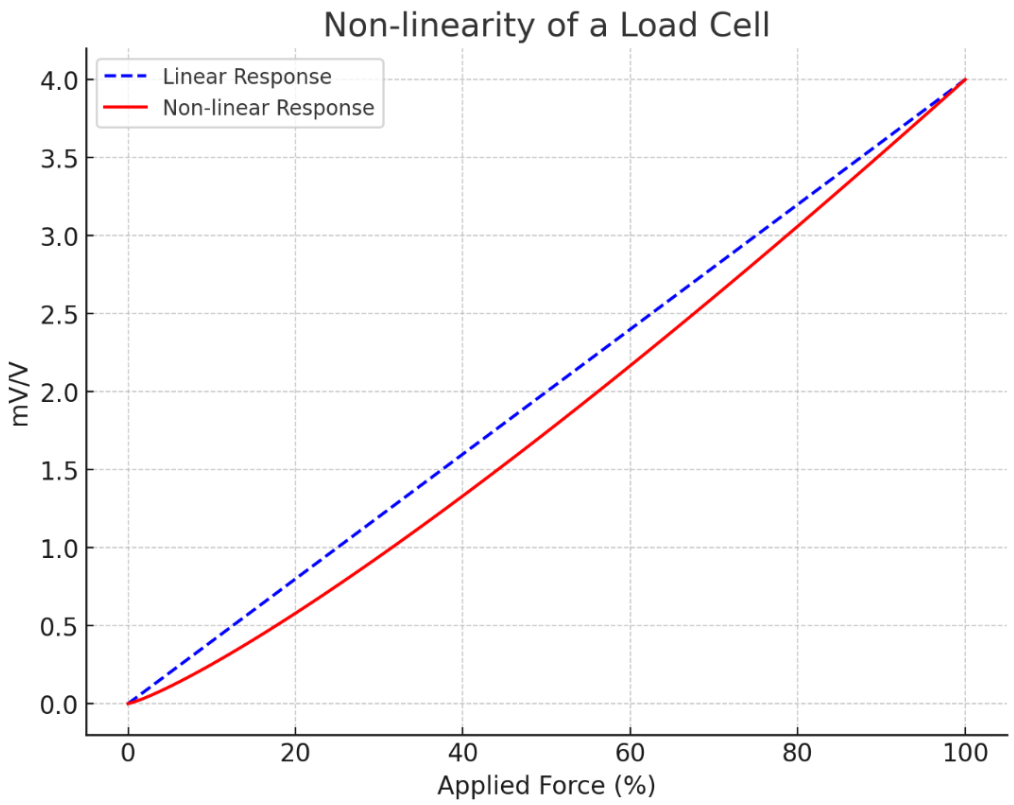
$Slope = (0_{start(force)} - FullScale_{(force)}) / (0_{start(response)} - FullScale_{(response)})$

Calculate Intercept

$Intercept = FullScale_{(force)} - Slope \times FullScale_{(response)}$

Calculate Non-Linearity per Response

$Non\text{-}Linearity = (Point_{(force)} - (Slope \times Point_{(response)} + Intercept)) / FullScale_{(force)}$



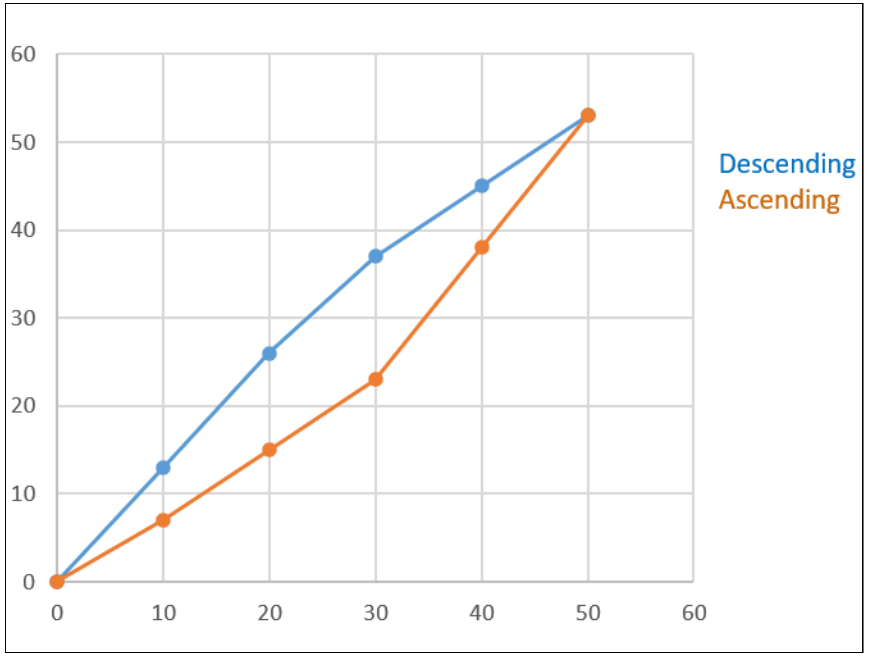
Hysteresis, % R.O.:

Hysteresis, % R.O.: Hysteresis measures the difference in output between ascending and descending values. It reflects the load cell’s ability to return to its initial state. Lower hysteresis values (as low as ±0.02 %) indicate less error and better accuracy.

For force measurements, **Hysteresis** is defined as the difference between two responses of a single given load, one ascending from the lowest non-zero load applied, the other descending from the full-scale load. Hysteresis is typically calculated near 50 % load.

Calculate Hysteresis

Hysteresis = | (Ascending(response) - Descending(response)) / FullScale (response) |



Non-Repeatability, % R.O.:

Non-Repeatability, % R.O.: This is the maximum difference between repeated measurements under the same conditions. Non-repeatability values as low as ±0.005 % show that the load cells produce very consistent results.

Non-Repeatability, % R.O.: This is the maximum difference between repeated measurements under the same conditions. Non-repeatability values as low as ±0.005 % show that the load cells produce very consistent results.

Non-repeatability = ABS(Run1-Run2)/AVERAGE (Run1, Run2, Run3) *100

Non-repeatability tells the user a lot about the performance of the load cell. It is important to note that non-repeatability does not tell the user about the load cell's reproducibility or how it will perform under different loading conditions (randomizing the loading conditions). At Morehouse, we have observed numerous load cells with good non-repeatability specifications that do not perform well when the loading conditions are randomized, or the load cell is rotated 120 degrees as required by ISO 376 and ASTM E74.

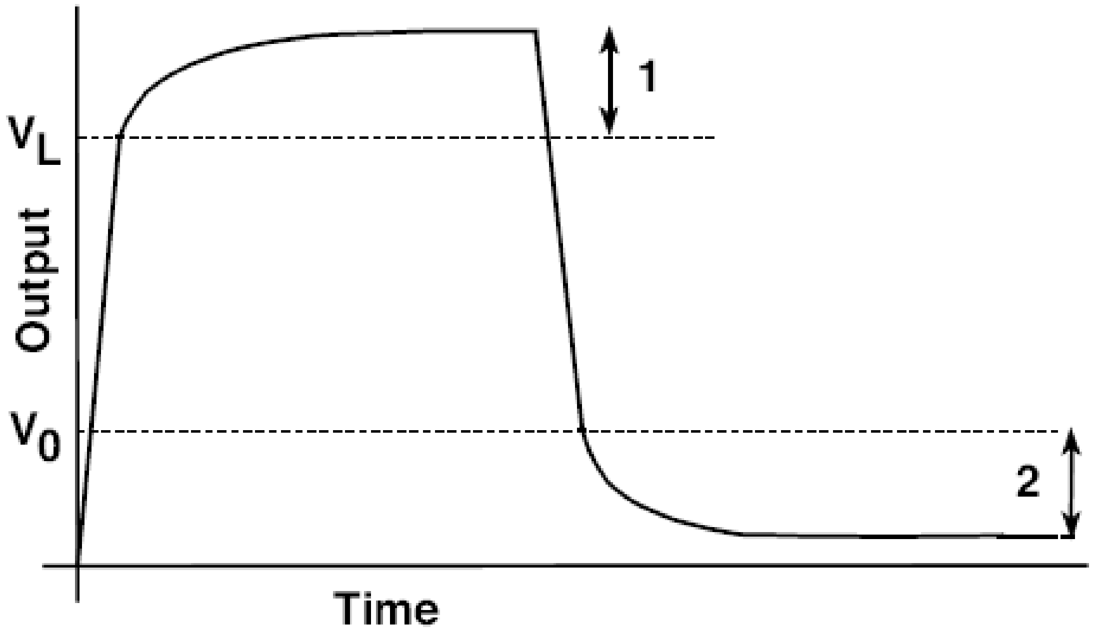
non-repeatability calclulations		
Run 1	Run 2	Run 3
4.0261	4.02576	4.02559
Difference b/w 1 & 2 (%FS)	Difference b/w 1 & 3 (%FS)	Difference b/w 2 & 3 (%FS)
0.0084	0.0127	0.0042
Non-Repeatability (%FS)=		0.013

Creep:

Creep.: The change in Load Cell Signal occurring with time while under load and with all environmental conditions remaining constant.

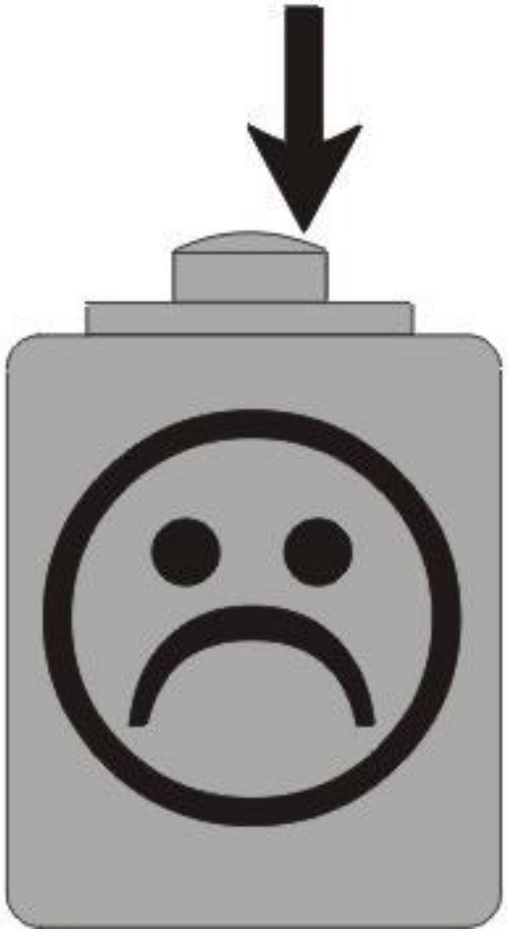
Creep Recovery.: The change in LOAD CELL SIGNAL occurring with time immediately after removal of a load which had been applied for a specified time interval, environmental conditions and other variables remaining constant during the loaded and unloaded intervals.

Creep, % Rdg(Reading)/20 Min: Creep measures how much the load cell's output drifts when a constant load is applied over time. Low creep values (±0.01 %) indicate that the output remains stable, even during long measurements.



Off-Center Load Sensitivity (%/in):

Off-Center Load Sensitivity (%/in): This specification refers to how much the load cell's output changes when a load is applied off-center, i.e., not directly along the central axis of the load cell.



If a load is not perfectly centered on the load cell, it can create bending or uneven force distribution. The off-center load sensitivity quantifies how sensitive the load cell is to this type of misalignment.

Example from the Load Cell Specification: In the datasheet, off-center load sensitivity is specified as ±0.1 %/in. This means that if the load is applied 1 inch away from the center of the load cell, the output could deviate by up to 0.1 % of the rated output.

Side Load Sensitivity (%):

Side Load Sensitivity (%): Side load sensitivity measures how much the load cell's output changes when a force is applied perpendicularly or laterally, rather than along the intended load axis.

Side loads can introduce measurement errors by causing strain on parts of the load cell that are not designed to measure force in those directions. High side load sensitivity would make the load cell less accurate under such conditions.

Example from the Load Cell Specification: The side load sensitivity in the datasheet is listed as ±0.1%. This means that if a side load is applied, the output could deviate by up to 0.1% of the rated output at the maximum rated side load. This specification reflects the load cell's ability to minimize errors when forces are applied in directions other than the primary loading axis.

Most specification sheets do not list the exact amount of side load a load cell can withstand. While a load cell may survive its maximum rated side load, it is not recommended to operate at this limit in high-accuracy applications. If a large side load is applied to a load cell used as a reference standard, recalibration may be required.

Zero Balance

Zero Balance (% R.O.): Zero balance refers to the output signal of the load cell when no load is applied. Ideally, the output should be zero when no force is acting on the load cell. However, due to manufacturing tolerances, material properties, and slight imbalances in the strain gauges, there is usually a small non-zero output even when the load is at zero. This small output is referred to as the zero balance.

Zero balance is typically expressed as a percentage of the Rated Output (R.O.). In the specification sheet for the **Ultra Precision Shear Web Load Cells, the zero balance is listed as ±1.0% R.O.** This means that when there is no load on the load cell, the output could be up to 1% of the rated output in either direction (positive or negative).

Thus, a 4.0 mV/V load cell would be in spec at ± 0.04 mV/V

Temperature Specifications

Temperature Range, Compensated (°F): The compensated temperature range (+15°F to +115°F) is the range within which the load cell compensates for temperature effects to maintain accuracy. Outside of this range, temperature fluctuations might affect the accuracy of measurements.

Temperature Range, Operating (°F): The operating range (-65°F to +200°F) is broader than the compensated range. The load cell can function within this range but may experience more temperature-related errors outside the compensated range.

Sensitivity Effect, % Rdg / 100°F: This represents how much the load cell's sensitivity changes with temperature. The specification indicates that the sensitivity may change by 0.08 % of the reading for every 100° F temperature change.

Zero Effect, % R.O. / 100°F: This parameter measures the change in zero balance (the output when no load is applied) due to temperature variations. Like the sensitivity effect, the zero effect is minimal, with a change of 0.08 % R.O. per 100° F.

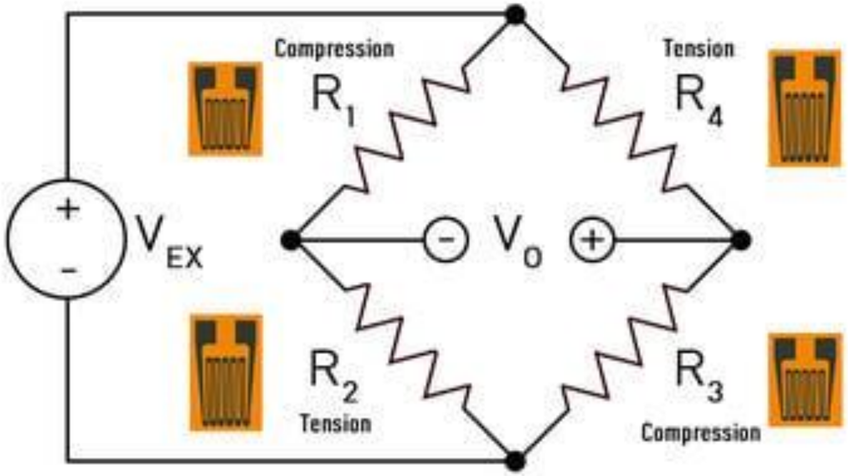
Electrical Specifications:

Input/Output Resistance (Ω): These parameters describe the electrical characteristics of the load cell. These values ensure the electrical compatibility of the load cell with measurement systems. More information on Input/Output resistance can be found here.

Sensitivity: Sensitivity is also referred to as Rated Output (R.O.) or Full-Scale Output (F.S.O or F.S.). Sensitivity defines the nominal output signal produced by the load cell for each volt of excitation voltage applied or. For example, for a 10,000 lbf capacity load cell, the sensitivity is 4 mV/V, meaning the output voltage would be 4 millivolts per volt of excitation.

Insulation Resistance (MegΩ @ 50 VDC): This parameter indicates how well the load cell's electrical circuits are isolated from its body, reducing the chances of electrical interference. With an insulation resistance of 5000 Megohms, the load cell is well-protected against electrical noise.

Load Cell Resistance



Many of today's load cells are designed with a **Wheatstone Bridge** Configuration.

A **Wheatstone bridge** circuit is composed of four resistive elements (strain gauges) that change resistance when a load is applied. The input load cell resistance and output load cell resistance are measured at different points in this circuit, which leads to inherent differences between the two.

- **Input Resistance**: This is the resistance measured between the two excitation terminals (often labeled as +EX and –EX). It represents the total resistance of the circuit that the excitation voltage is applied to and can be used to calculate nominal power consumption of the loadcell.
- **Output Resistance**: This is the resistance measured between the two signal terminals (often labeled as +SIG and –SIG). It represents the resistance through which the measurement signal (proportional to load) is obtained. This value normally has no effect on power consumption.

Ohms Law

$I = \frac{V}{\mathbf{R}}$ where *I* is the current, V is the Voltage, and R is the resistance.

This formula can be useful in calculating the load cell resistance.

We find that a 350 Ω load cell draws approximately 0.029 Amps.

$$I = \frac{10\ V}{350\ \mathbf{\Omega}} = 0.029\ A$$

While a 2800 Ω load cell draws approximately 0.0036 Amps.

$$I = \frac{10\ V}{2800\ \mathbf{\Omega}} = 0.0036\ A$$

Mechanical Specifications:

Safe Overload, % R.O.: This is the amount of overload a load cell can withstand without being damaged. In our example, the Morehouse load cell can handle overloads up to 150 % of its rated output without permanent damage.

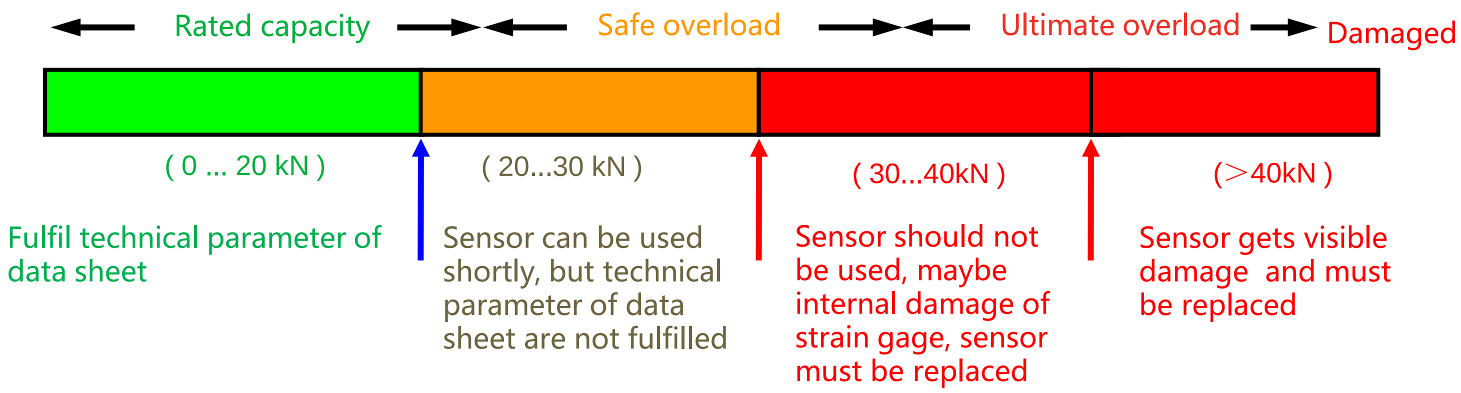
Weight and Material: The load cells are available in various capacities, ranging from grams to millions of lbf. Depending on the capacity, the load cells are made from aluminum or steel, affecting their weight and suitability for different applications. In our example, a 300 lbf load cell weighs around 3.8 lb., while a 200,000 lbf load cell weighs 171 lb.

Overload Technical data

Safe overload (120~150 %)： The maximum load in percent of rated capacity which can be applied without producing a permanent shift in performance characteristics behond those specified

Ultimate overload (200~300 %)： The maximum load in percent of rated capacity that can be applied without producing a structural failure

Example： sensor rated capacity 20kN,safe overload 150 %， ultimate overload 200 %



Additional Specifications:

What many specification sheets do not tell you.

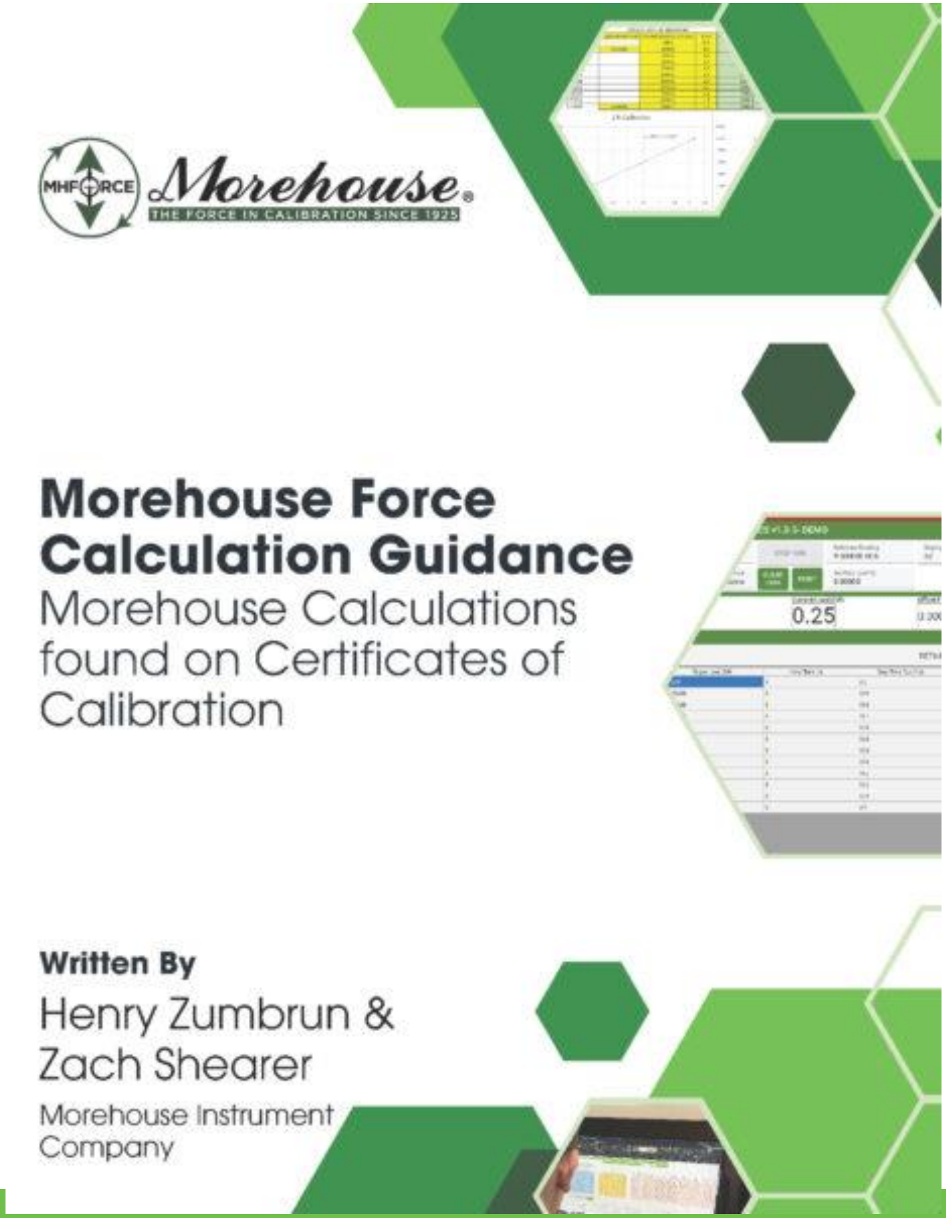
How good is the expected performance of the load cell.

Standard Features

- ASTM E74 performance. Lower Limit Factor (LLF) better than 0.005 %, Class A better than 2 %, and Class AA better than 10 % of capacity when used only in a single direction.[1]
- ISO 376 Class 00 from 5 % of capacity (Case C only, Case D varies by capacity)
- Compression and/or tension modes
- Capacities from 300–200,000 lbf, or equivalent kgf/Newton
- Calibration available to Primary deadweight standards
- Available accessories include Quick-Change Tension Members, custom-cut protective cases, and various indicators

Calculation Guidance

For further details on calculations related to these load cell specifications, you can refer to Morehouse's calculation guidance (Morehouse-Calculation-Guidance), which covers advanced topics such as non-linearity, hysteresis, and other force measurement-related factors, and the calculations used to determine many specifications.



Static Versus Dynamic Forces

Static Loading:

- The load is applied incrementally and held, allowing time for the system to stabilize and for the instrument to take a precise reading. Think deadweights applied individually to a force or torque transducer.
- Calibration systems under static conditions often offer lower measurement uncertainty because they eliminate variables like oscillations and transient forces.
- Time is typically not a major factor once stabilization has occurred. Typically, within 30 seconds.

Dynamic Loading:

- The load changes continuously, with little to no stabilization time, making precise measurements more challenging due to system inertia and response times. Think about a testing machine breaking a specimen.
- When the load is constantly changing, the measurement uncertainty can be affected by lag in the system's response or by transient errors due to the quick load changes (frequency response).
- Time is critical as the force changes over time, meaning the instrument's response time and ability to accurately track these changes will directly influence the measurement precision.

4 Steps for Choosing the Right Load Cell System

Step 1. Choose the right load cell for your needs

Step 2. Choose the right indicator

Step 3. Choose the right adapters

Step 4. Choose the right calibration provider

Shipping and Receiving

Recommended

The Good

The Bad

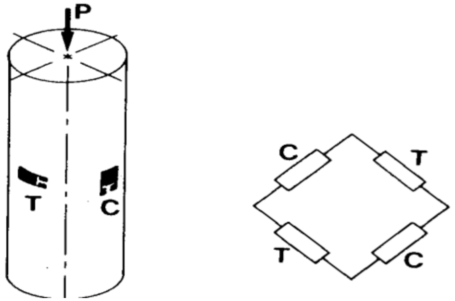
The Ugly

If the instrument is damaged during shipment, problems such as: lost calibration history, unrepairable scenarios, extra costs to repair, and claims may not be paid.

Types of Load Cells

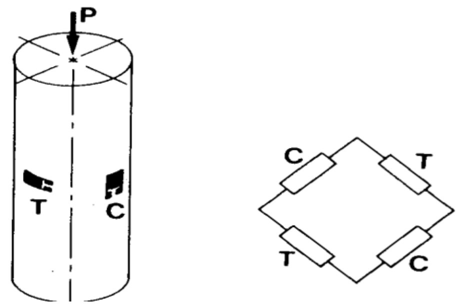
- Column Load Cell (Single-Column or High-Stress Load Cells)
- Multi-Column Load Cell
- S-Beam or S-Type
- Button or Pancake
- Shear Web

Column Load Cell



- The spring element is intended for axial loading and typically has a minimum of four strain gauges, two in the longitudinal direction and two oriented transversally to sense the Poisson strain.

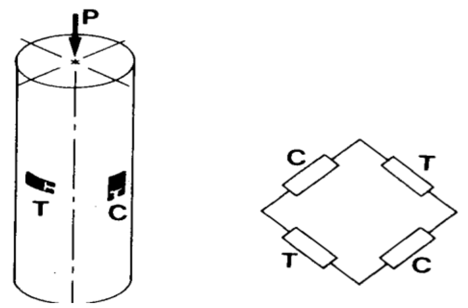
Column Load Cell



Advantages

- Physical size and weight - It is not uncommon to have a 1,000,000 LBF column cell weigh less than 100 lbs.

Column Load Cell



Disadvantages

- Reputation for inherent non-linearity. This deviation from linear behavior is commonly ascribed to the change in the cross-sectional area of the column (due to Poisson's ratio), which occurs with deformation under load.
- Sensitivity to off-center loading can be high, and the hardness of the loading pad can change output by as much as 0.5 %

Column Load Cell

The Data – Comparing Two Single Column Load Cells By Different Manufacturers

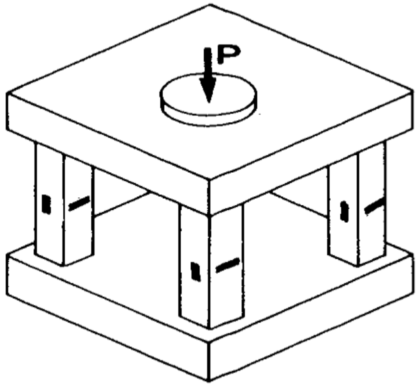
Disadvantages

- Larger creep characteristics than other cells and often do not return to zero as well as other cells. (ASTM Method A typically yields larger LLF)

Load Cell Type	Not-Morehouse
Single Column Example 1	
Force (lbf)	**RUN 1 DIV**
0	0
8000	28257
20000	70545
40000	141018
80000	281891
120000	422418
160000	562878
200000	703249
240000	843461
280000	983583
320000	1123296
360000	1263032
400000	1402542
0	**358**
Zero Return @ 30 Seconds	
0.0255%	

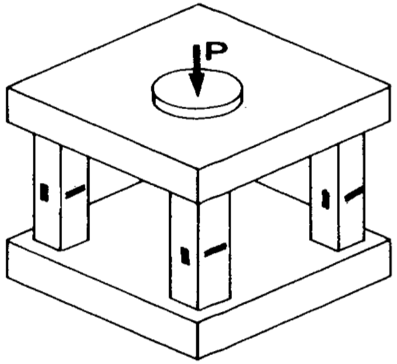
Load Cell Type	Not-Morehouse
Single Column Example 2	
Force (lbf)	**RUN 1 DIV**
0	0
9000	23818
20000	52914
40000	105795
80000	211662
120000	317377
160000	423042
200000	528730
240000	634303
280000	739846
320000	845413
360000	950778
400000	1056182
408000	**1077219**
0	89
Zero Return @ 30 Seconds	
0.0083%	

Multi - Column Load Cell



- In this type of design, the load is carried by four or more small columns, each with its own complement of strain gauges. The corresponding gauges from all the columns are connected in a series in the appropriate bridge arms.

Multi - Column Load Cell

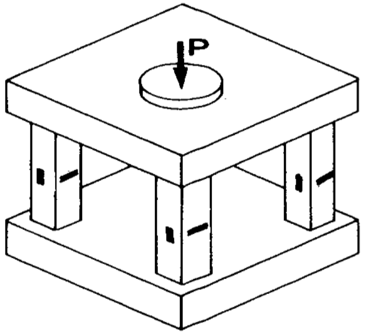


Advantages

- Multi-Column load cells can be more compact than high-stress column cells
- Improved discrimination against the effects of off-axis load components.

Multi - Column Load Cell

Advantages Continued



- These cells typically have less creep and have better zero returns than single-column cells.

- In many cases, a properly designed shear-web spring element can offer greater output, better linearity, lower hysteresis, and faster response.

Load Cell Type	Morehouse
Multi Column	
Force (lbf)	RUN 1
0	0.00000
30000	0.13488
72500	0.32570
134885.366	0.60543
202328.049	0.90747
269770.733	1.20905
337213.416	1.51025
404656.099	1.81108
472098.782	2.11154
539541.465	2.41160
606984.148	2.71113
674426.832	3.01045
0	-0.00001
Zero Return @ 30 Seconds	
0.0003%	

Multi - Column Load Cell

- Error associated with installing a non-flat base on a multi-column cell. This is an actual test result we observed on a Revere multi-column cell.

	Non-Flat Base	Flat Base
	Maximum Error	Maximum Error
Force Applied	In Rotation	In Rotation
	LBF	LBF
30000	12	4
150000	136	24
300000	342	68
	% error	% error
30000	0.040 %	0.013 %
150000	0.091 %	0.016 %
300000	0.114 %	0.023 %

Bottom Plates

- A flat bottom plate may be needed to improve performance. It is often not recommended the practice to load against the machine surface as it could be uneven, or the base of the load cell could deform the machine surface.

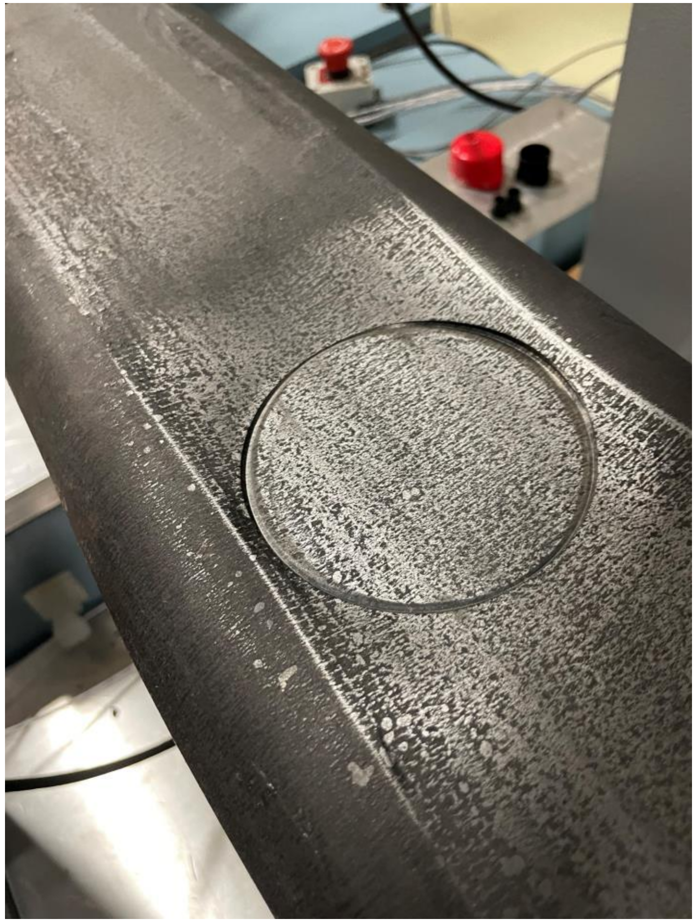
- Pictured left is a Morehouse 60K rod end-style load cell with spherical threaded adapter, top compression pad, and load cell base plate.

Morehouse Compression Adapters

- Pictured above is a Morehouse Concrete set with top and bottom bases.

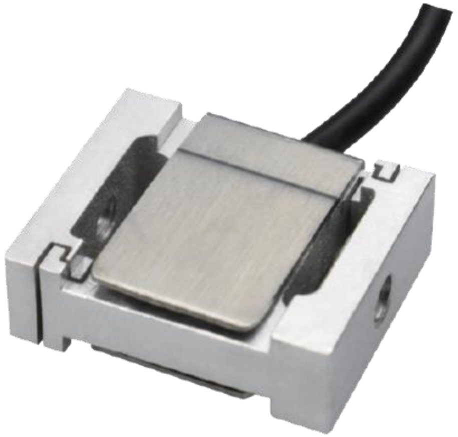
[Link to Concrete 600K set with adapters](#)

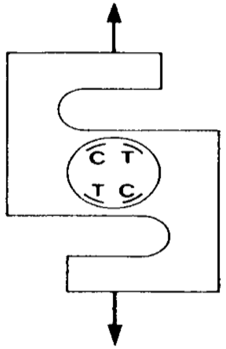
What Bottom Adapters Help Protect Against



Another Example of When Adapters are Not Used

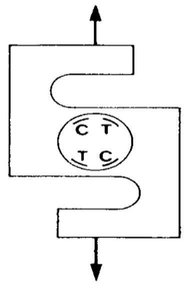
S-beam Load Cell





- This type of design is often used in weighing applications. There are four gauges placed inside the beam.

S-beam Load Cell

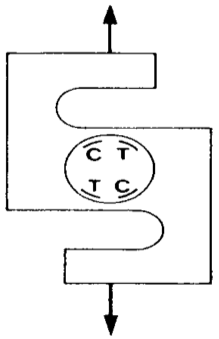


Advantages

- In general, linearity will be enhanced by minimizing the ratio of deflection (at rated load) to the length of the sensing beam, thus minimizing the change in the shape of the element.

- Ideal for measuring small forces (under 50 LBF) when physical weights cannot be used.

S-beam Load Cell



Disadvantages

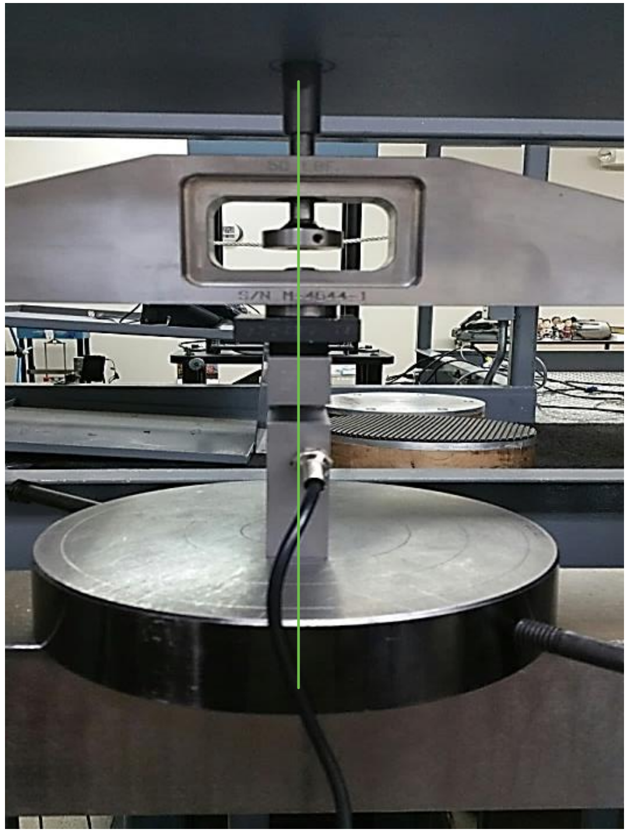
- These cells are very sensitive to off-axis loading - ideally suited for scales or tension applications.
- Compression output will be different if the cell is loaded through the threads versus flat against each base.

S-beam

Does anything look different when comparing these two pictures?

Misalignment on S-beam

Misalignment Demonstrating 0.752 % error

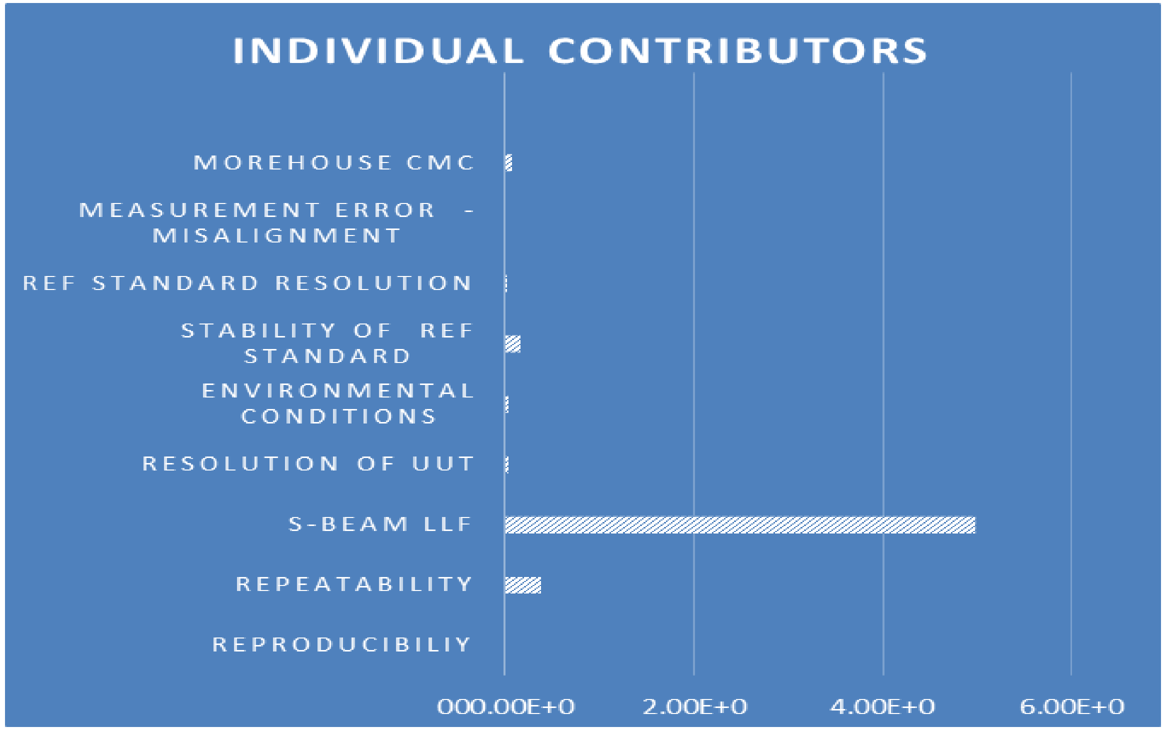


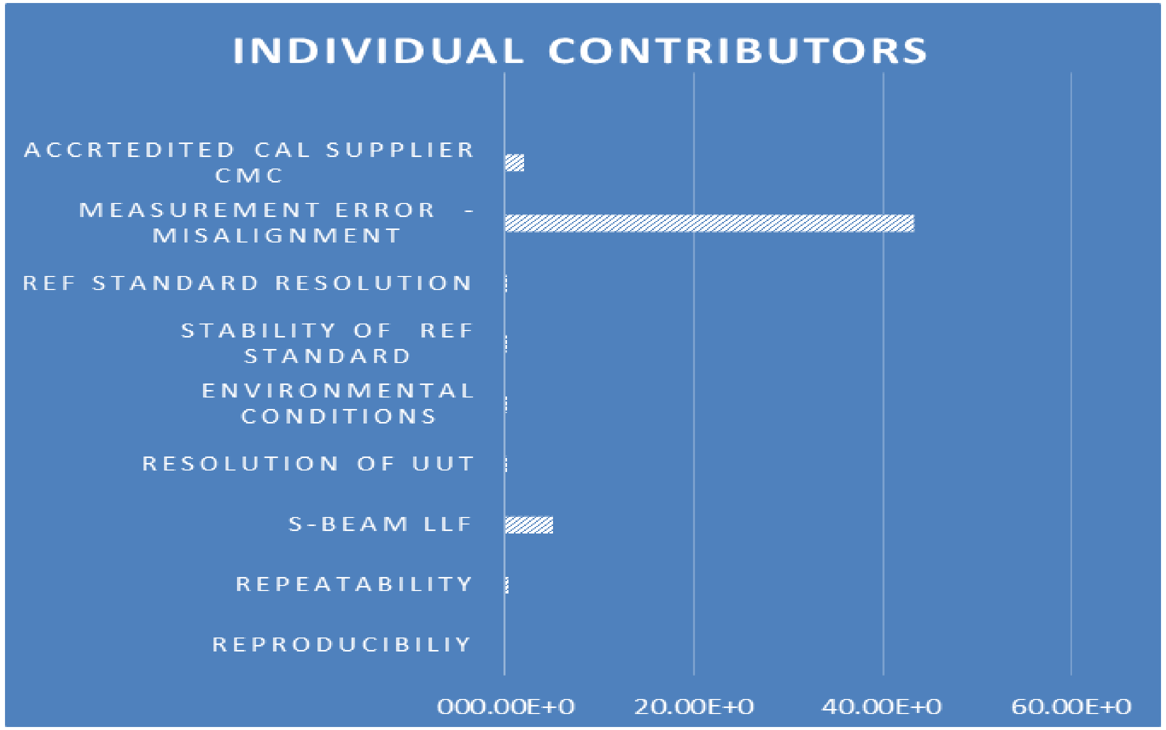
Output in mV/V
Aligned in machine
-1.96732 mV/V

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

Misalignment on 10,000 LBF S-beam

Misalignment Demonstrating 0.752 % Error

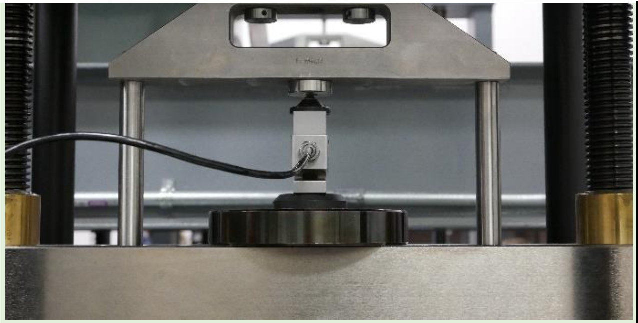
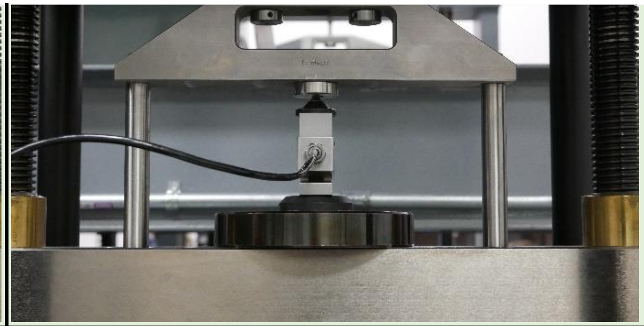
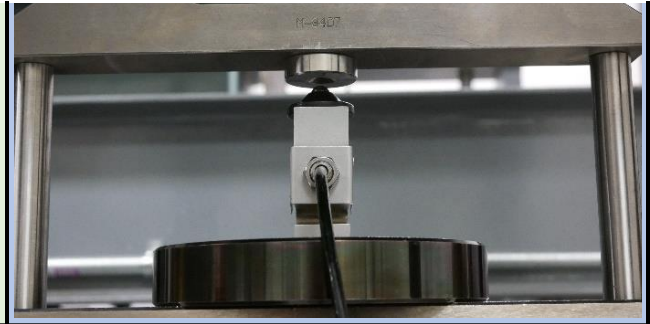




Output in mV/V
Aligned in the machine
-1.96732 mV/V
Expanded Uncertainty 9.95 LBF

Output in mV/V
Slightly misaligned in the machine
-1.98211 mV/V
Expanded Uncertainty 85.0 LBF

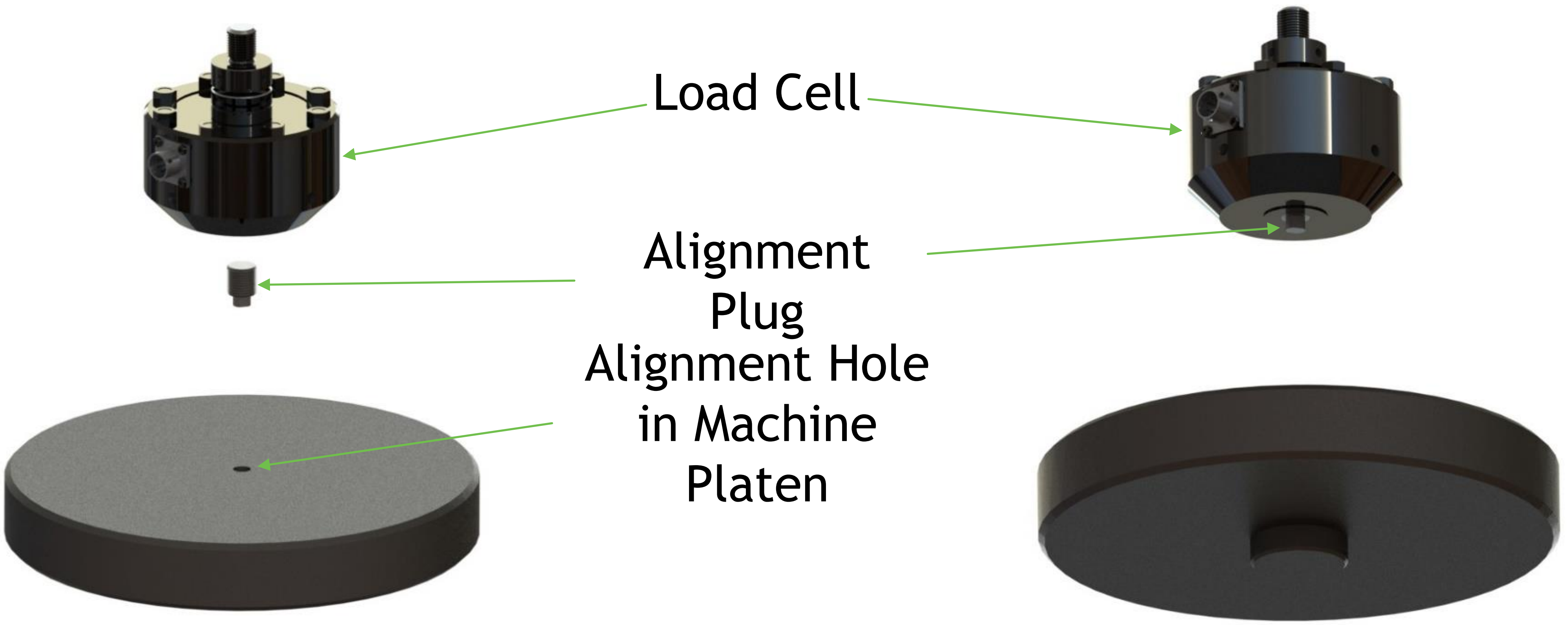
S-Beam Loading Errors


Instrument Reading Thread Loading Loose Both Ends Output in mV/V	Instrument Reading Thread Loading Tight Both Ends Output in mV/V	Instrument Reading Thread Loaded on Top / Flat Base Output in mV/V	Instrument Reading Flat on Flat Output in mV/V
1.50136	1.50241	1.50182	1.50721
3.00381	3.00581	3.00459	3.01326

Maximum Difference mV/V	Maximum Difference lbf	Maximum % Difference	Smallest % Diffference
0.00585	4.618066191	0.369%	0.029%
0.00945	7.459953077	0.298%	0.025%

Alignment Plugs Help Reduce Error



Button Load Cell

- This type of design is often used in weighing applications or when there is minimal room to perform a test. The load cells on the left exhibit high errors from any misalignment. A 0.1 % misalignment can produce a large cosine error. The cells on the right are generally a much better alternative though they are also a more expensive option. Some of these cells typically have errors anywhere from 1 % - 10 % of rated output when calibrated without proper adapters. The cells on the right are the exception, as they can be as good as 0.05 % or better.

Button Load Cell Calibration

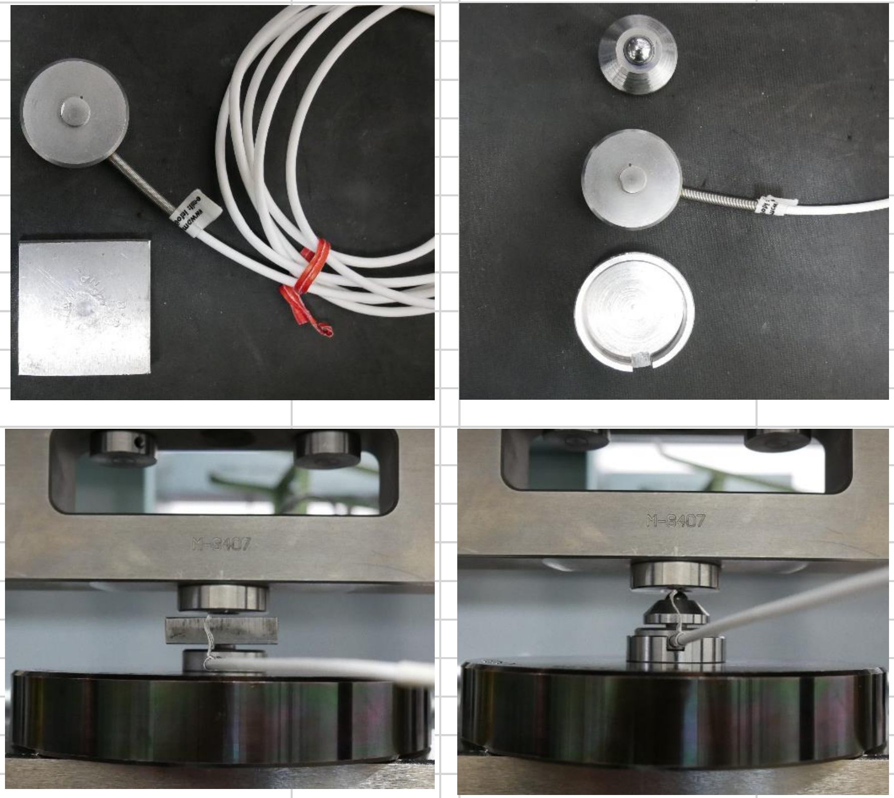
Does this setup look familiar?

Manually Aligned	Data
0 degree	2011
120 degree	1997
240 degree	2018
Average	2008.66667
Standard Deviation	10.6926766
Max Deviation	21
% Error	1.045%

Button Load Cell Calibration

Morehouse Button Load Cell Adapters improved the measurement result by 525 %

Standard Setup versus Morehouse Adapters in Morehouse Deadweight



Manually Aligned	Data
0 degree	2011
120 degree	1997
240 degree	2018
Average	2008.66667
Standard Deviation	10.6926766
Max Deviation	21
% Error	1.045%

Aligned with Adapter	Data
0 degree	2008
120 degree	2006
240 degree	2010
Average	2008
Standard Deviation	2
Max Deviation	4
% Error	0.199%

Button and Washer Load Cell

- Above are pictures of button load cell adapters.

Shear Web Load Cell

Integral Adapter

- This type of load cell is typically the most accurate when installed on a tapered base with an integral threaded rod installed. These cells typically have very low creep and are not as sensitive to off-axis loading as the other cells discussed.

Shear Web Load Cell

- These cells would be the recommended choice for force applications from 100 LBF through 100,000 LBF. After 100,000 LBF, the weight of the cell makes it very difficult to use as a field standard. A 100,000 LBF Shear Web cell weighs approximately 57 lbs, and a 200,000 LBF shear web cell weighs over 140 lbs.

Shear Web Load Cell

Why are shear web load cells the recommended choice for calibration standards for both lab and field use?

Load Cell Type	Morehouse
Precision Shear Web	
Force (lbf)	**RUN 1**
0	-0.00001
200	0.08218
500	0.20545
1000	0.41093
2000	0.82195
3000	1.23305
4000	1.64427
5000	2.05555
6000	2.46698
7000	2.87845
8000	3.28988
9000	3.70138
10000	4.11287
0	0.00005
Zero Return @ 30 Seconds	
0.0012%	

Misalignment S-Beam versus Shear web cell

S-BEAM WITH 0.75 % MISALIGNMENT ERROR VS MOREHOUSE WITH 0.0022 % ERROR

S-BEAM	10000	LBF	SERIAL NO	EXAMPLE
%	Force Applied	COMBINED UNCERTAINTY FOR K=2		
2.00%	200	0.89076%	1.782	LBF
10.00%	1000	0.86705%	8.671	LBF
20.00%	2000	0.86630%	17.326	LBF
30.00%	3000	0.86616%	25.985	LBF
40.00%	4000	0.86612%	34.645	LBF
50.00%	5000	0.86609%	43.305	LBF
60.00%	6000	0.86608%	51.965	LBF
70.00%	7000	0.86607%	60.625	LBF
80.00%	8000	0.86607%	69.286	LBF
90.00%	9000	0.86607%	77.946	LBF
100.00%	10000	0.86606%	86.606	LBF

MOREOUSE	10000	LBF	SERIAL NO	EXAMPLE
%	Force Applied	COMBINED UNCERTAINTY FOR K=2		
2.00%	200	0.20836%	0.417	LBF
10.00%	1000	0.04179%	0.418	LBF
20.00%	2000	0.02108%	0.422	LBF
30.00%	3000	0.01426%	0.428	LBF
40.00%	4000	0.01091%	0.436	LBF
50.00%	5000	0.00894%	0.447	LBF
60.00%	6000	0.00766%	0.460	LBF
70.00%	7000	0.00677%	0.474	LBF
80.00%	8000	0.00613%	0.490	LBF
90.00%	9000	0.00565%	0.508	LBF
100.00%	10000	0.00527%	0.527	LBF

Thread Depth Comparison - Shear Web Load Cell

0.25 " Backed Off	Integral Adapter Installed
	

Percent of Full Scale	Percentage Difference In Loading Conditions
10%	0.184%
50%	0.174%
100%	0.138%

Morehouse Budget Shear-Web cells

- Cost less than other shear web-type load cells.
- Easy for simple applications such as weighing, a test rig, E4, ISO 7500 field applications.
- Durability - Morehouse Budget Loadcells are manufactured using durable, corrosion-resistant materials and are designed to withstand harsh environments.
- Quick-Replacement – We keep these in stock.
- Applications where the load cell is calibrated “in-place” – are perfect to use in testing machines.

Thread Depth Comparison Two Different Shear Web Designs

MorehouseCalibration Grade		Morehouse Budget Load Cell	

MorehouseCalibration Grade

Full Scale %	% Difference
10%	0.184%
50%	0.174%
100%	0.138%

Morehouse Budget Load Cell

Full Scale %	% Difference
10%	-0.006%
50%	-0.014%
100%	-0.018%

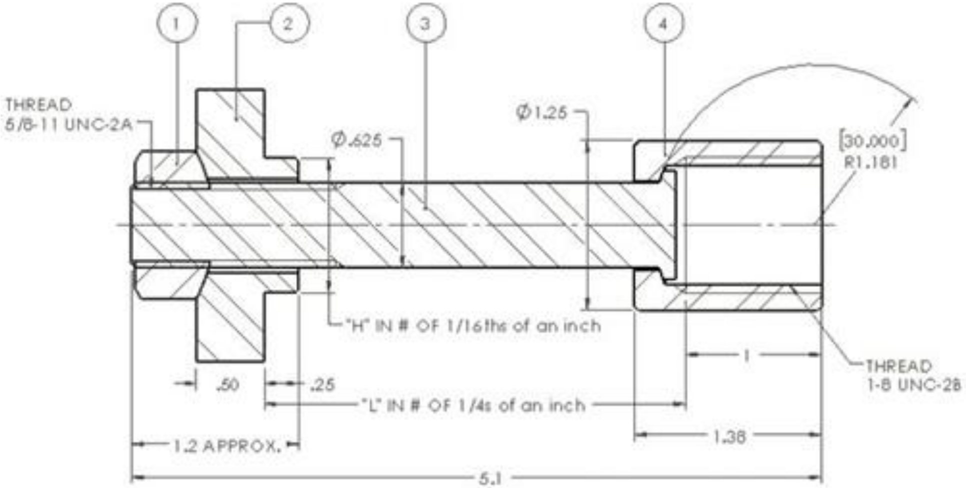
The Importance of Adapters

Keeping the line of force pure (free from eccentric forces) is key to the calibration of load cells. ASTM E74 does not address the various adapter types, but ISO 376 does.

Alignment is Key

- In compression, using a ball adapter (pictured right) if the machine has a ball adapter often yields the best results. If a ball adapter does not exist, a spherical alignment adapter (pictured left) will help align the force.
- From the previous slides, some load cells are just more sensitive to alignment and thread engagement issues making adapters even more critical.

ISO 376: 2011



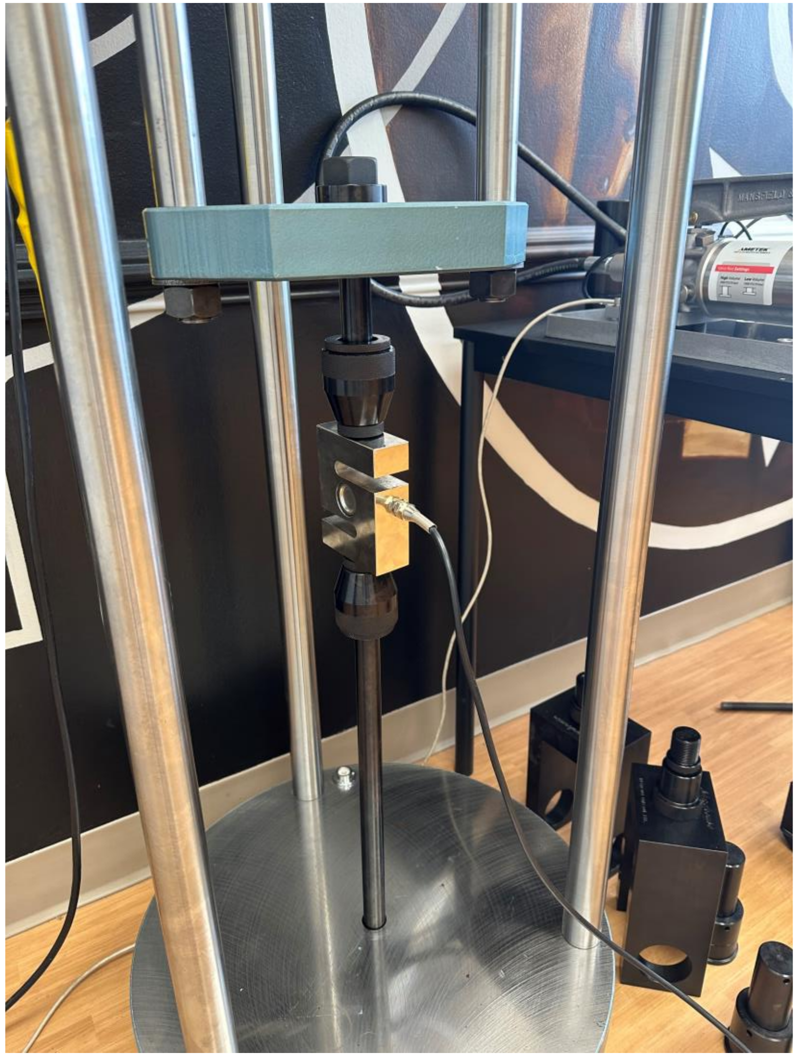
Even close to perfect machines can't fix bad adapters. ISO 376 tells us how to reduce that risk. Proper adaptor use in accordance with ISO 376 Annex A helps ensure the reliability of reported measurements.

A.4 Loading fittings

A.4.1 General

- 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.

Surface Finish of Parts

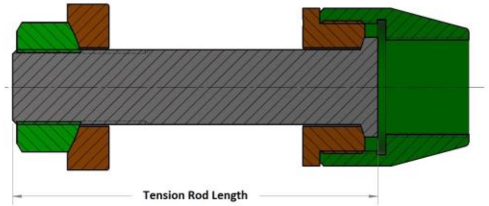


Reproducibility Study Rough Versus Smooth Finish							
Smooth Finish				Rough Finish			
0	120	180	Max % Error	0	120	180	Max % Error
10001.8	10001.8	10001.5	0.003%	10016.9	10009.2	10004.7	0.122%

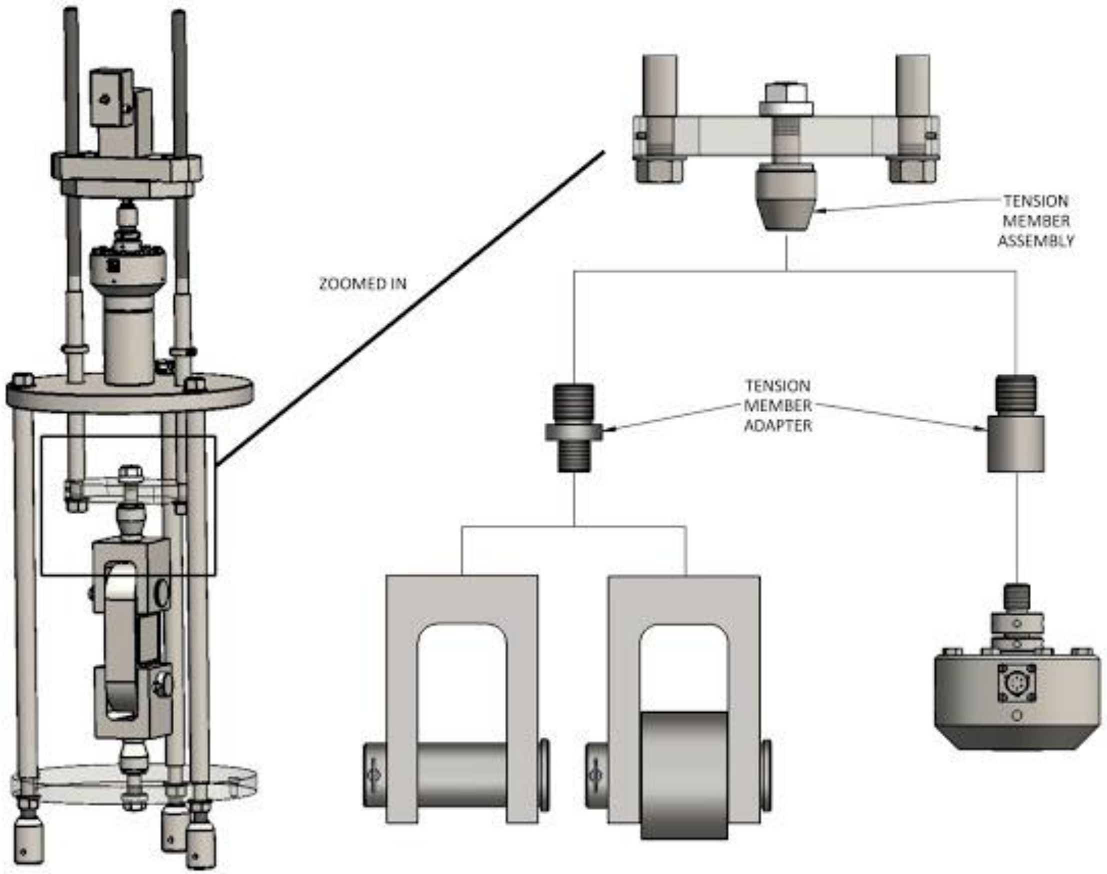
The Wrong Tension Adapters

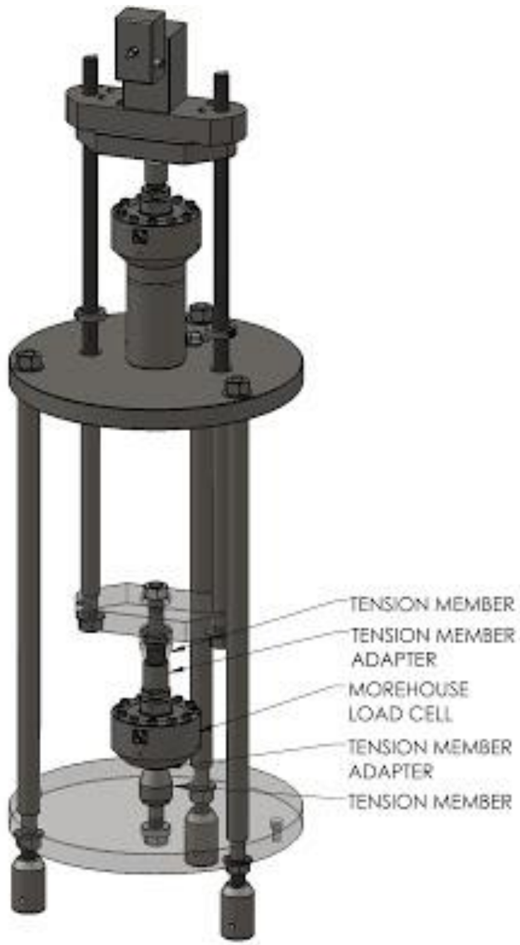
- If any of these looks like tension adapters in your calibration lab, there is a problem.
- Even straight-threaded rods can introduce misalignment issues as they can distort the line of force in non-Morehouse machines.
- Any machine misalignment of 0.01 degrees can affect the reproducibility of some load cells. Even our spherical adapters can only overcome about 0.1 degree of misalignment.

Morehouse Quick Change Adapters For Tension



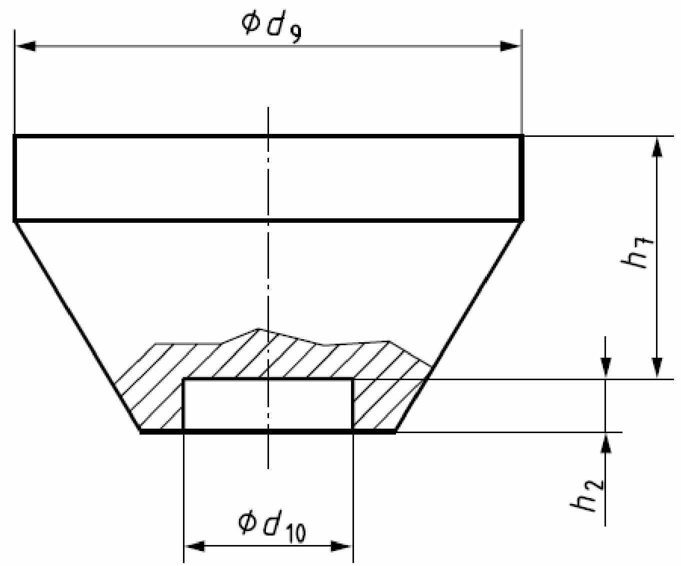
Morehouse Quick Change Tension Members with ISO Radius

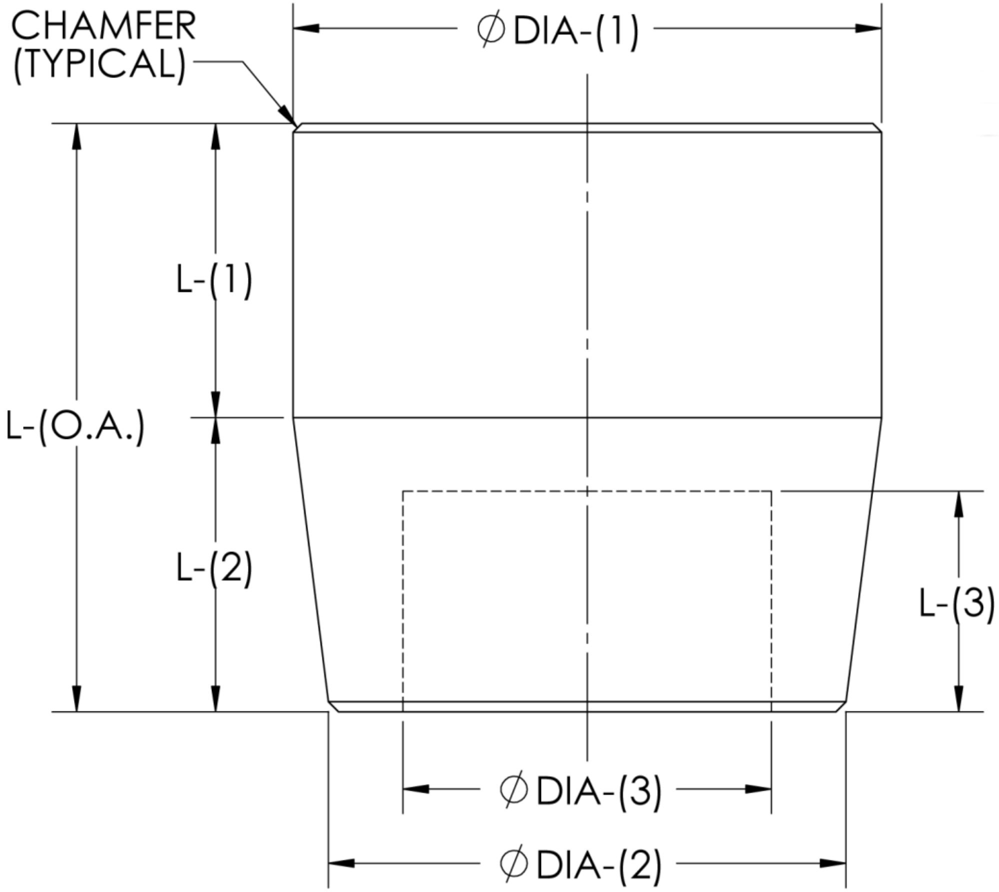




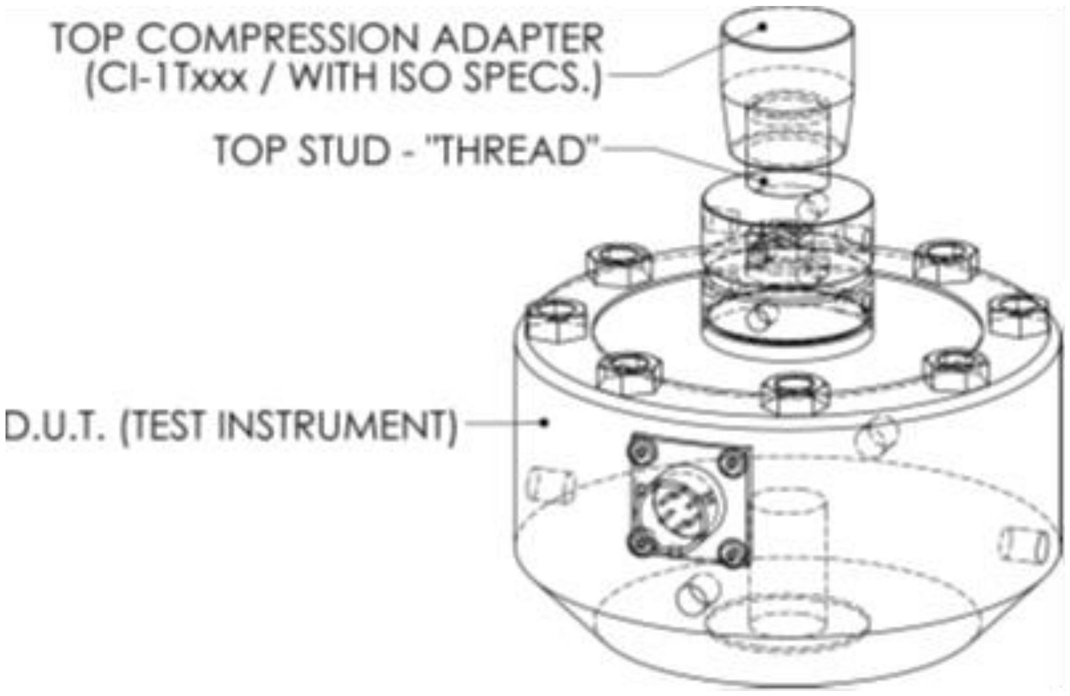
ISO 376 Compression Adapters

- Compressive force transducers should be fitted with one or two compression pads.



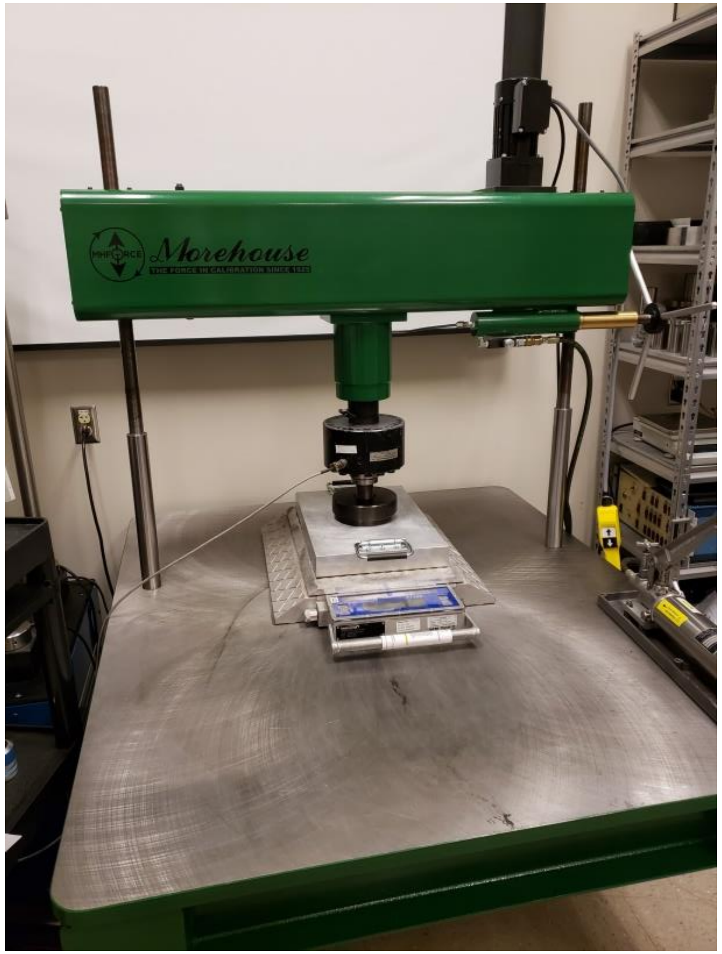


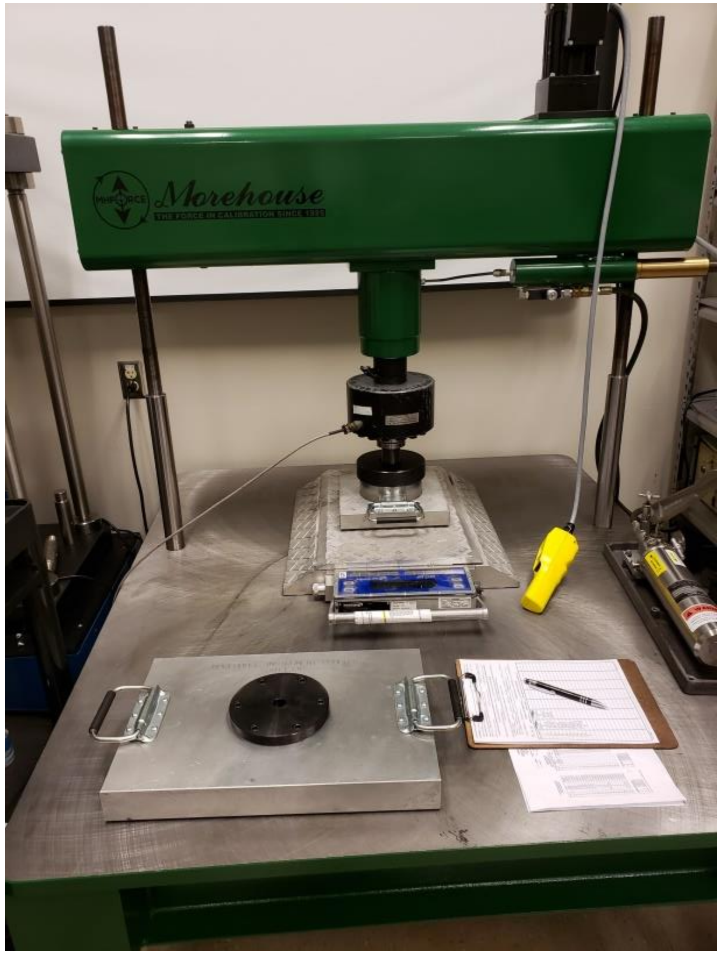
Morehouse Compression Adapters



- Pictured above are ISO 376 recommended compression adapters.

Truck Scales

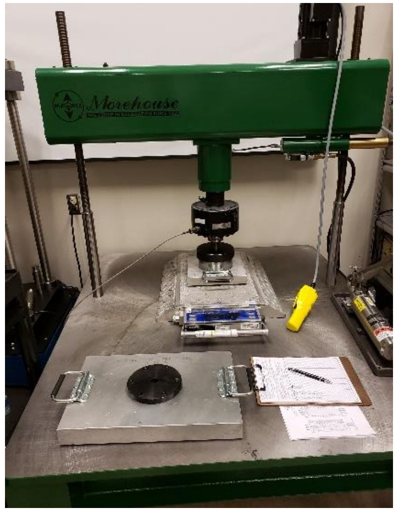




Pictures Showing Two Different Size Adapters.

Will there be a difference in the measured values?

Calibration of a Truck Scale



Notes: Calibration of a truck scale in our Morehouse USC-60 Scale Calibrating Machine. This test is comparing the difference in the footprint of different tires on the scale.

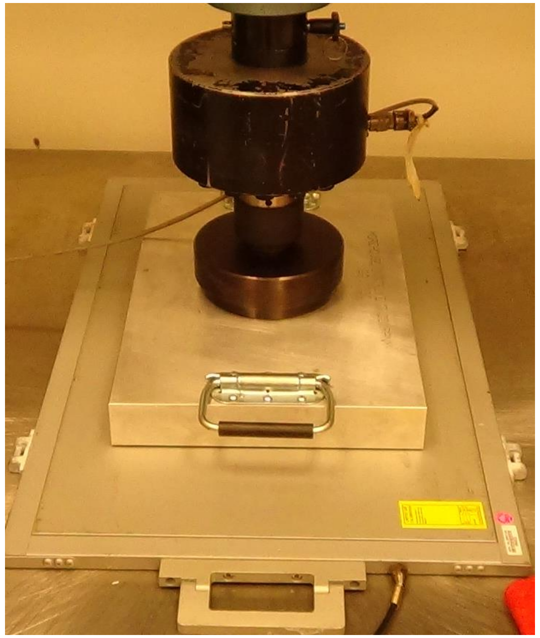
Force Applied lbf	Instrument Reading normal pad	Instrument Reading small pad	Difference in lbf	% Difference	Tolerance 1 % of Applied	Tolerance % by using different pads
2000	2000	2000	0	0.00%	20	0%
4000	4000	4000	0	0.00%	40	0%
6000	6020	6020	0	0.00%	60	0%
8000	8020	8020	0	0.00%	80	0%
10000	10040	9980	60	0.60%	100	60%
12000	12040	11980	60	0.50%	120	50%
14000	14060	13980	80	0.57%	140	57%
16000	16060	15960	100	0.63%	160	63%
18000	18060	17940	120	0.67%	180	67%
20000	20060	19920	140	0.70%	200	70%

Calibration of a Truck Scale

Difference in lbf	% Difference	Tolerance 1 % of Applied	Tolerance % by using different pads
0	0.00%	20	0%
0	0.00%	40	0%
0	0.00%	60	0%
0	0.00%	80	0%
60	0.60%	100	60%
60	0.50%	120	50%
80	0.57%	140	57%
100	0.63%	160	63%
120	0.67%	180	67%
140	0.70%	200	70%

Aircraft and Truck Scale Adapters

Morehouse has test truck and aircraft scales, and there is a large difference in output from using different-size plates.

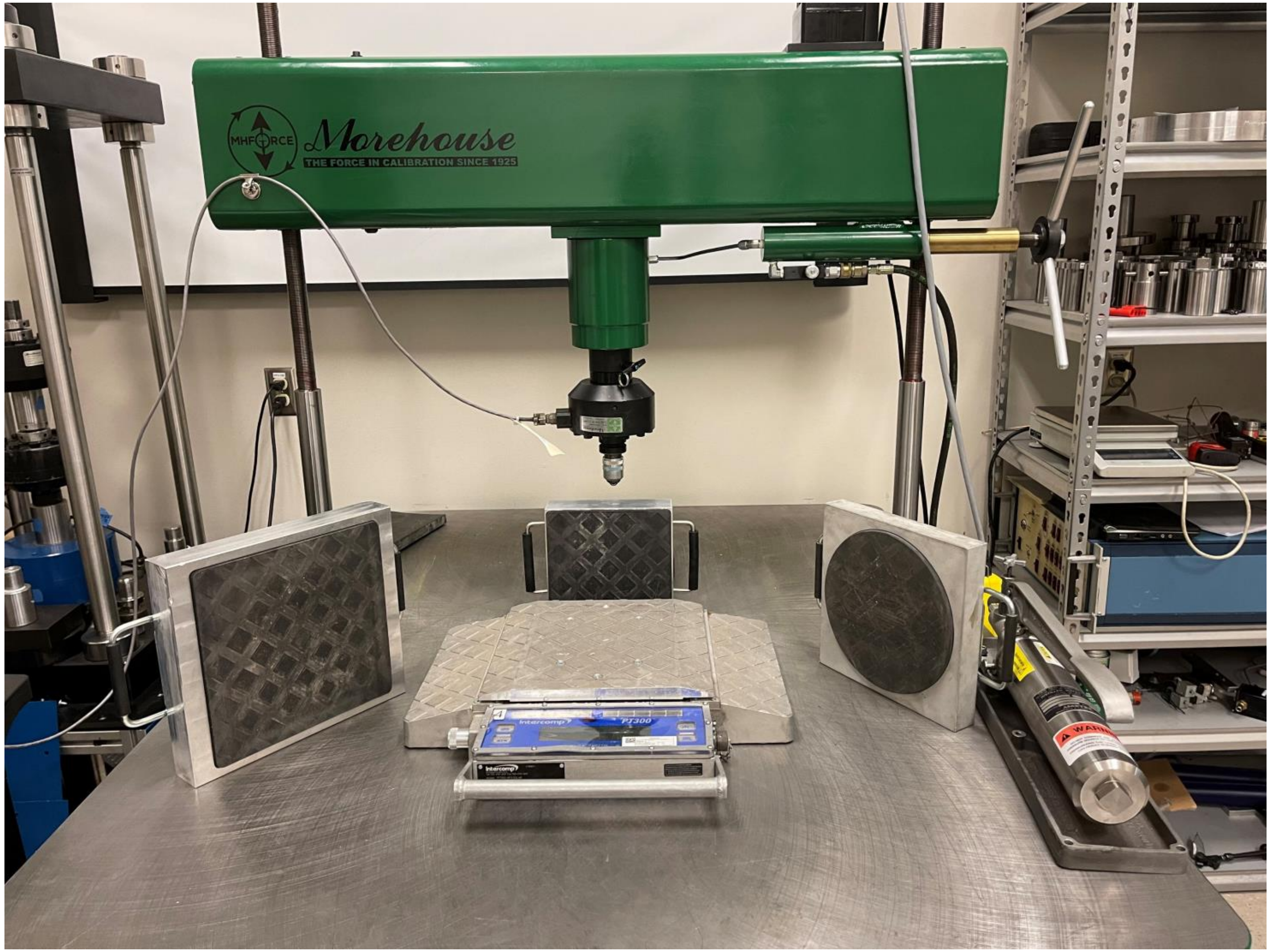


Force Applied lbf	Scale Reading w/ Large pad	Scale Reading w/ Small pad		
0	0	0	Diff in lbf	%
4000	3950	3980	-30	-0.759%
8000	7980	8030	-50	-0.627%
12000	11990	12020	-30	-0.250%
16000	15980	16090	-110	-0.688%
20000	19980	20140	-160	-0.801%
24000	23990	24210	-220	-0.917%
28000	27990	28270	-280	-1.000%
32000	31990	32350	-360	-1.125%
36000	35990	36460	-470	-1.306%
40000	40010	meter saturated		

Aircraft and Truck Scale Adapters

Truck and Aircraft Scales are typically used to weigh trucks and airplanes with the tires sitting on several scales. Any adapter used during calibration should be composed of the same type of rubber and should have the same footprint as the tire to ensure accurate results.

Truck Scales

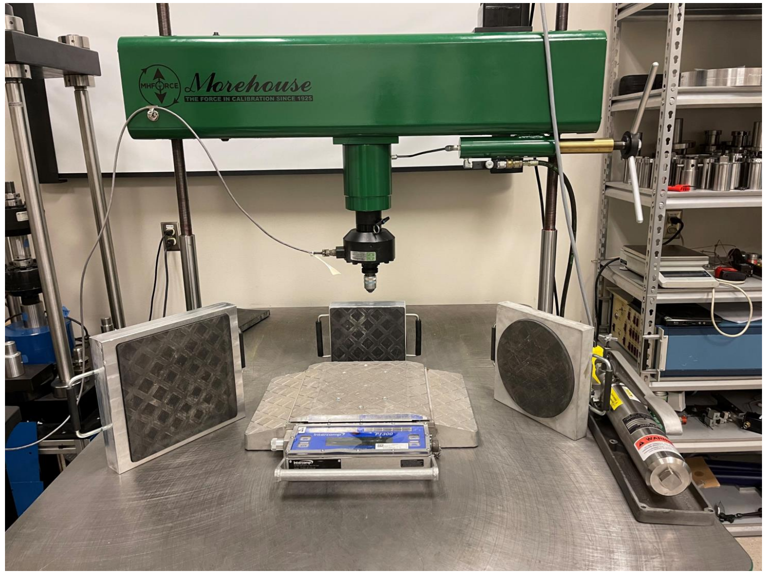


Pictures Showing Three Different Size Adapters Made by Morehouse.

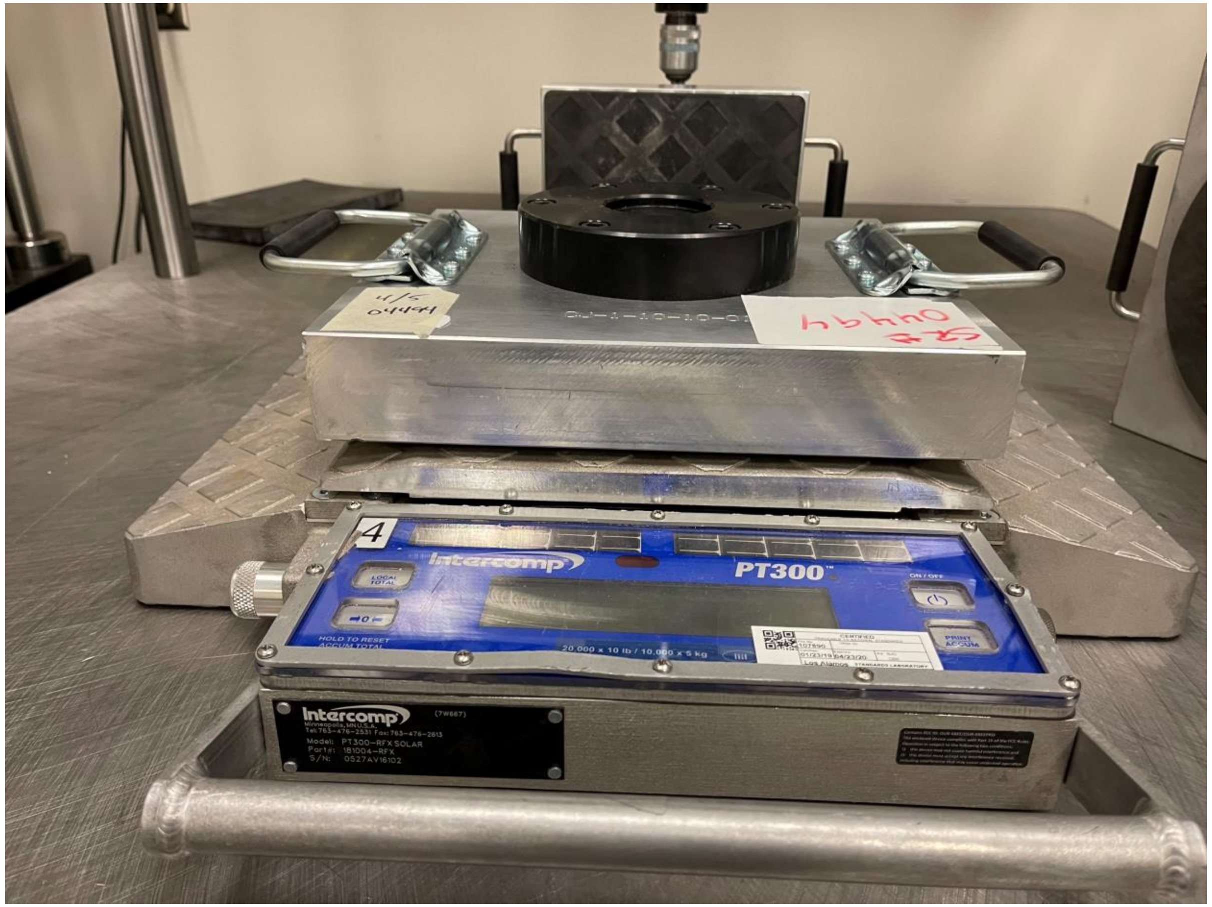
Will there be a difference in the measured values on a 10,000 lbf PT300 scale?

Calibration of a Truck Scale

PT 300 Example					
FORCE APPLIED	10 X 10 PAD READINGS	8 X 8 PAD READINGS	9" ROUND PAD READINGS	Maximum Difference	% Maximum
2000	2000	2000	2000	0	0.00%
4000	4040	3990	4000	50	1.25%
6000	6090	5990	5990	100	1.67%
8000	8130	7990	8000	140	1.75%
10000	10170	10000	10010	170	1.70%
12000	12190	12010	12000	190	1.58%
14000	14210	14010	14000	210	1.50%
16000	16230	16010	15990	240	1.50%
18000	18230	18010	17980	250	1.39%
20000	CAP	20000	19980	N/A	N/A



Calibration of a Truck Scale



Thoughts?

The Importance of Adapters

- Best practice is to send any top blocks or plates with the load cell being calibrated.
- Each load cell should have top blocks, and they should be ground flat.
- Using Tension Adapters with a steep spherical radius will provide a better vertical line of force, producing better results.

Questions on Adapters

- Did anyone learn anything new?
- Takeaways so far?

Choosing the Right Indicator

Choose the Right Indicator

Choosing the Right Indicator		
Does the indicator have to be better than 0.005 % ? Are you willing to use a computer to convert mV/V to Engineering Units ? Do you require portability without a power adapter? Do you have more than two load cells?	HADI	
Do you require portability without a power adapter? Do you only have one load cell or two one mode only load cells? Are you okay with close to direct reading? Do you want portability with batteries?	PSD	
Does the indicator have to be better than 0.005 % ? Do you have more than two load cells? Do you want to span mulitple calibration points?	4215	

These Indicators use Polynomial Coefficients to Correct Measurement Bias

Choose the Right Indicator

- Choose an indicator based on your accuracy and uncertainty requirements
- Choose based on wired or wireless
- Choose based on environmental conditions
- Choose based on four-wire or six-wire sensing
- Choose based on the ability to use coefficients
- Choose based on the price
- Choose based on ease of use
- Choose based on ruggedness
- Choose based on the number of load cells and channels required
- Is TEDS something you want or need?

What is Happening in Our World:

Market Misconceptions & Compliance Failures

- Programming the TEDS chip via a 2-PT linearization and not testing the actual performance of the load cell
- Breaking fundamental rules of metrological traceability, which requires all load cells and all indicators to be calibrated.

What is Happening in Our World:
Market Misconceptions & Compliance Failures

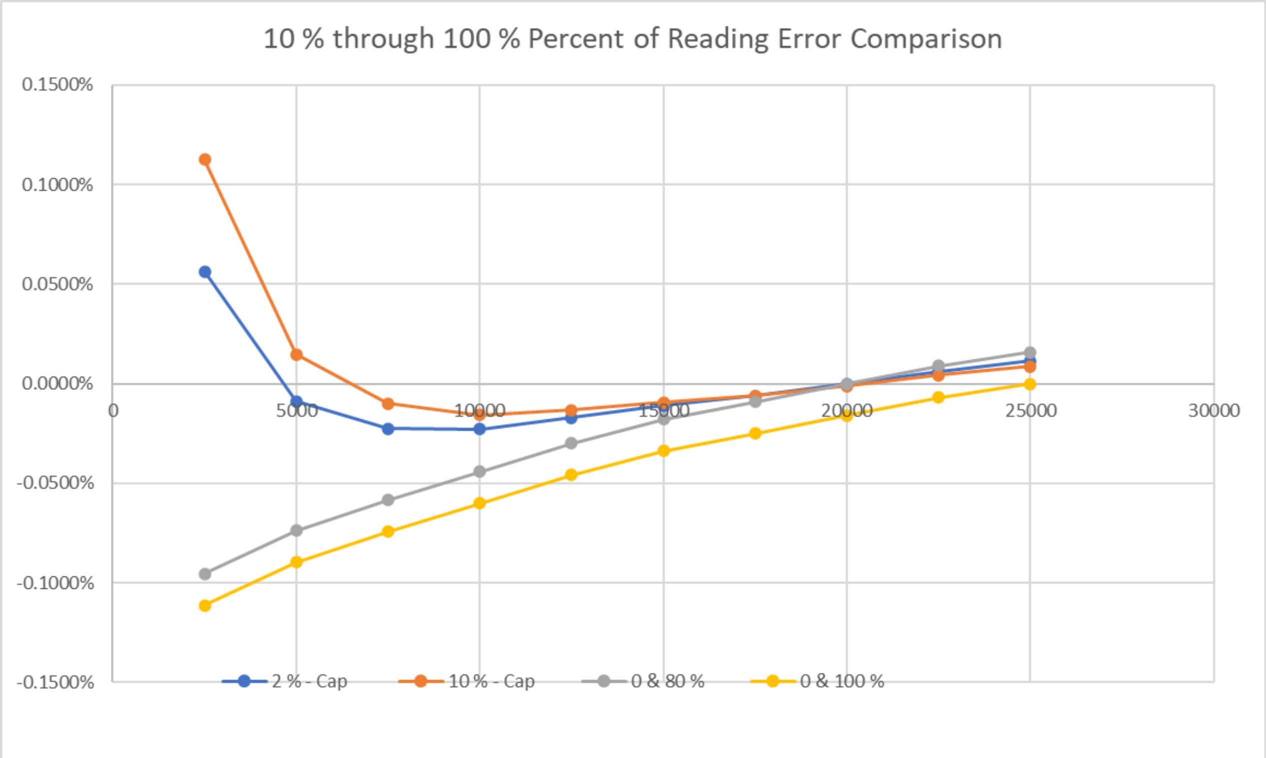
- People are confused and think TEDS will calibrate the load cell, yet it does not affect the bridge circuit. Instead, the memory chips store the information to allow the meter or DAQ to scale and linearize the output from the load cell.
- End-user confusion: End-users often purchase load cells with TEDS, expecting full calibration functionality, but receive incomplete or non-compliant systems.

How to implemented a TED’s System

TEDS Basic Templates

- **Template 33** for mV/V load cell (unamplified) Template 31 for 4-20mA or 0-20mA
- **Template 30** for voltage amplified. i.e. 0-5V, .5 to 10.5V, etc. 3)Linearization templates (optional)
- **Template 40** provides linearization data piecewise (shown below on a graph as a 4 pt Span point option.
- **Template 41** provides linearization data via a curve fit polynomial. (Ideally suited for using calibration information from Morehouse ASTM E74 or ISO 376 certificates, as well as any Tension and Compression load cell

Problems with 2 PT Linearization



This slide takes the same set of test data on a great shear web cell and compares a span adjustment versus multiple test points that only use a slope function (y=mx+b). Notice the maximum error is 0.1018 %

Force Applied	Error in %			
Force Applied	2 % - Cap	10 % - Cap	0 & 80 %	0 & 100 %
2500	0.0562%	0.1125%	-0.0955%	-0.1113%
5000	-0.0089%	0.0146%	-0.0738%	-0.0896%
7500	-0.0225%	-0.0100%	-0.0585%	-0.0744%
10000	-0.0227%	-0.0156%	-0.0443%	-0.0601%
12500	-0.0171%	-0.0133%	-0.0299%	-0.0458%
15000	-0.0109%	-0.0093%	-0.0180%	-0.0338%
17500	-0.0061%	-0.0061%	-0.0091%	-0.0249%
20000	-0.0002%	-0.0013%	0.0000%	-0.0158%
22500	0.0064%	0.0043%	0.0089%	-0.0069%
25000	0.0113%	0.0086%	0.0158%	0.0000%

No matter which 2 points you pick, the errors can be quite large! (0.1 %)

Force Applied	Measurement Value	Offset, Bias ,Systemic Measurement Error
10 000.00	10 009.00	+ 9
10 000.00	10 009.00	+ 9

When you know the value to generate 10 000.0 N is 10 0009.0 N.

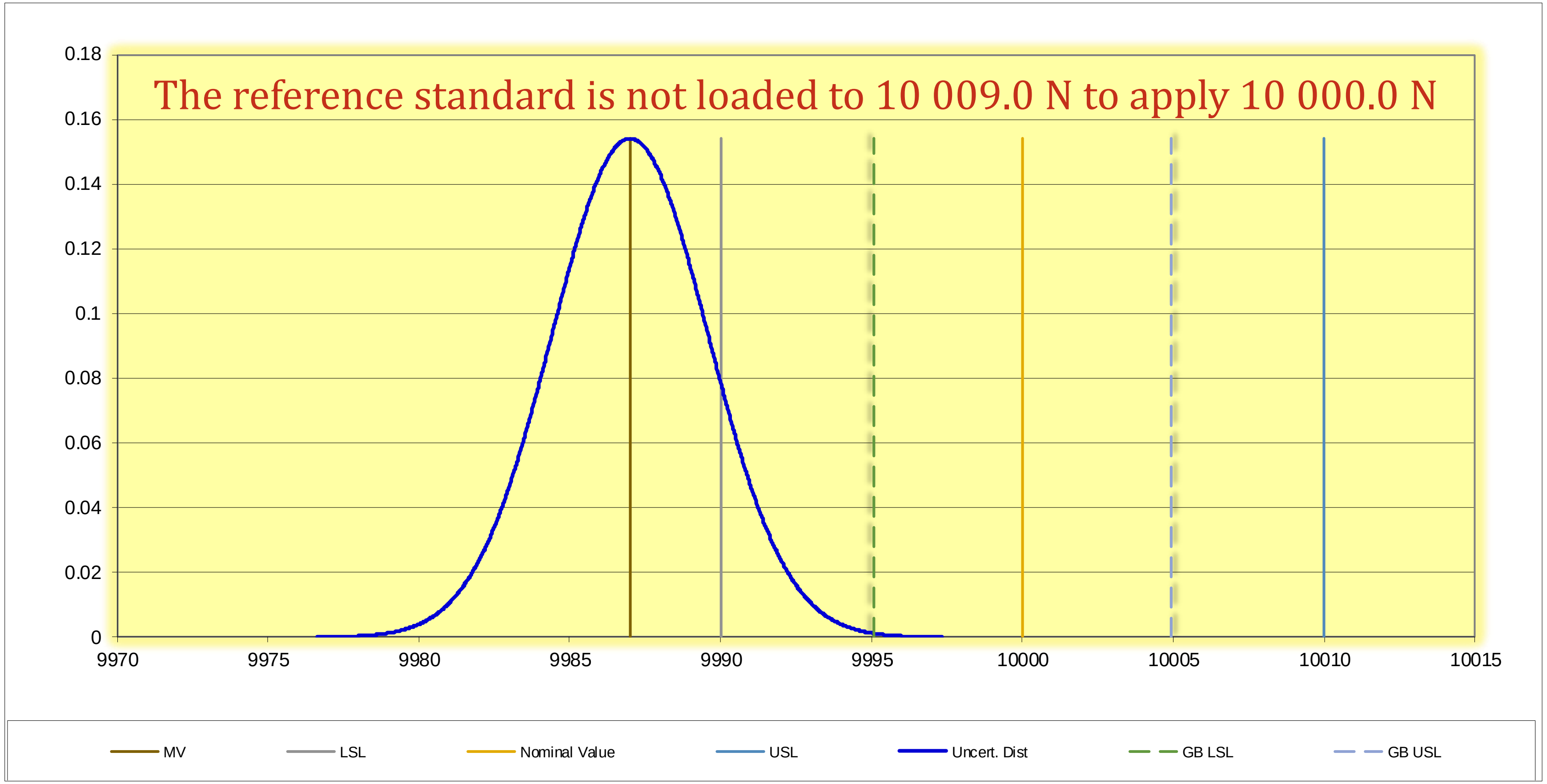
The right thing for the end-user to do is to load the device to 10 009.0 N to apply 10 000.0 N of force.

What Happens When We Do Not Correct the Bias?

MHFORCE Morehouse THE FORCE IN CALIBRATION SINCE 1925

Let us assume they do not do that and use this device to calibrate another 10,000 N instrument.

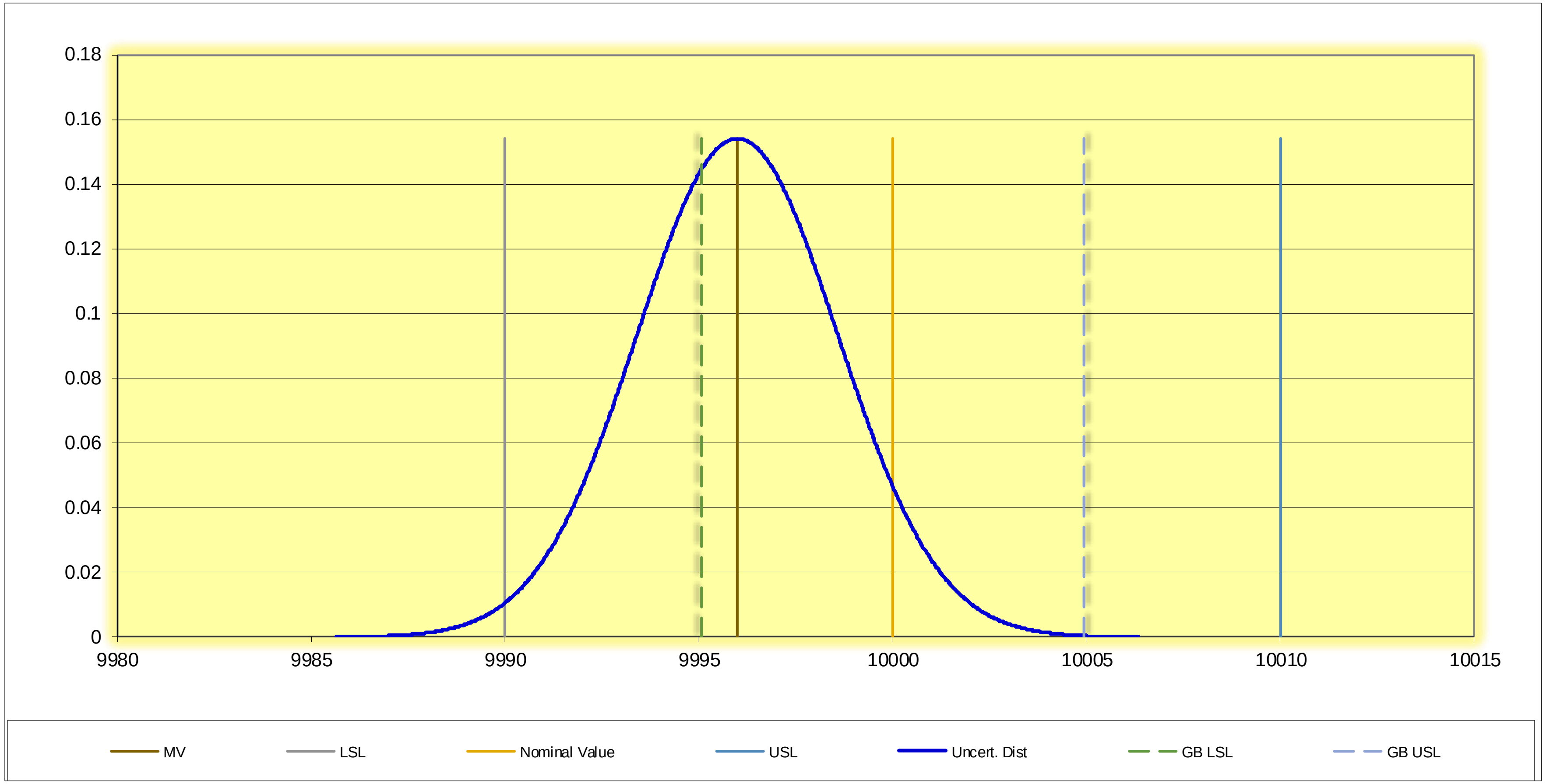
Nominal Value	**10000.0**
Lower specification Limit	9990.0
Upper Specification Limit	10010.0
Measured Value	**9987.0**
Measurement Error	-13.0
Std. Uncert. (k=1)	**2.589**
Total Risk	**87.67%**
Upper Limit Risk	0.000%
Lower Limit Risk	87.672%
TUR =	**1.931223436**
Cpk=	**-0.59120171**
TAR=	**3.99840064**
Simple Guard Band (Subtract Uncertainty)	
Guard Band LSL	**9995.178**
Guard Band USL	**10004.8219**
Percent of Spec	**48.22%**
Guard Band Limits for Risk of	**2.500%**
Guard Band LSL	**9995.074**
Guard Band USL	**10004.926**
Percent of Spec	**49.26%**



What Happens When We Correct the Bias?

The right thing for the end-user to do is to load the device to 10 009.0 N to apply 10 000.0 N of force. Let us assume they do not do that and use this device to calibrate another 10,000 N instrument.

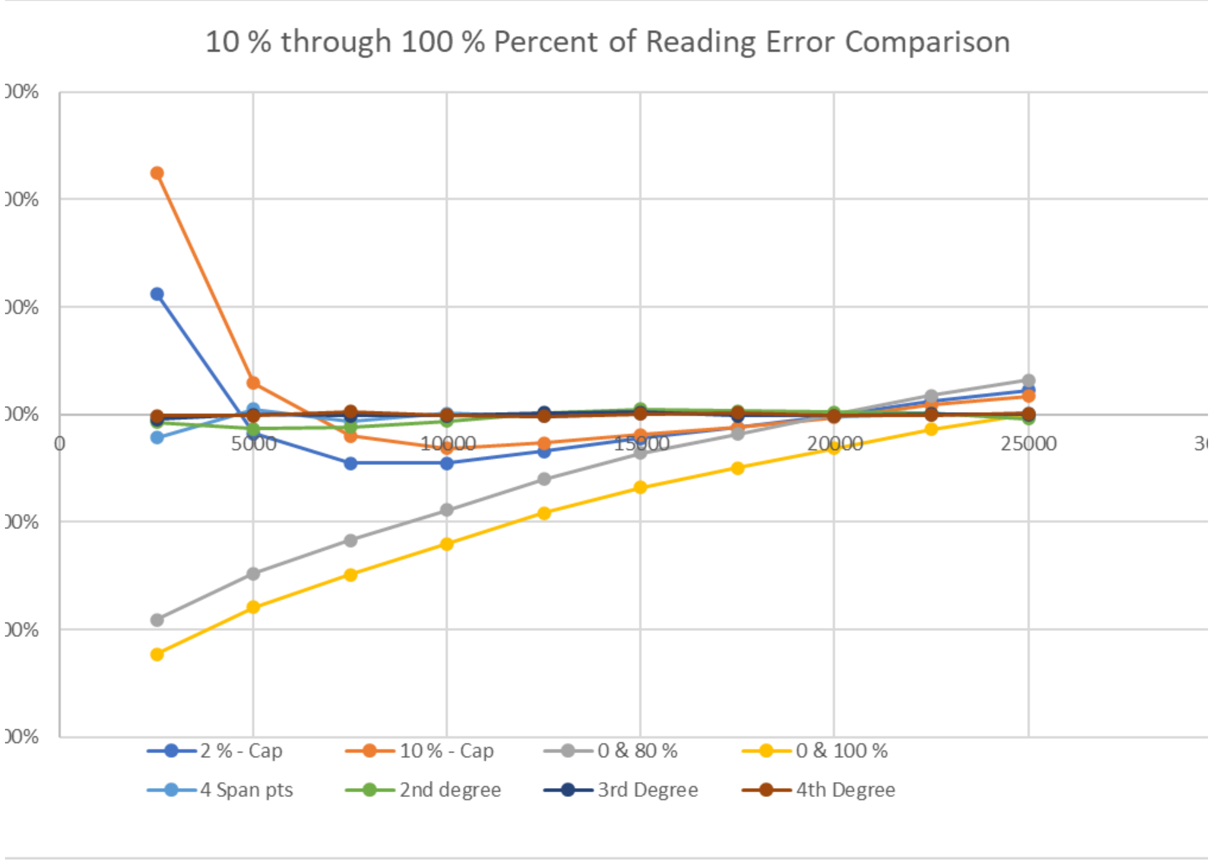
Nominal Value	**10000.0**
Lower specification Limit	9990.0
Upper Specification Limit	10010.0
Measured Value	**9996.0**
Measurement Error	-4.0
Std. Uncert. (k=1)	**2.589**
Total Risk	**1.02%**
Upper Limit Risk	0.000%
Lower Limit Risk	1.024%
TUR =	**1.931223436**
Cpk=	**1.182403422**
TAR=	**3.99840064**
Simple Guard Band (Subtract Uncertainty)	
Guard Band LSL	**9995.178**
Guard Band USL	**10004.8219**
Percent of Spec	**48.22%**
Guard Band Limits for Risk of	**2.500%**
Guard Band LSL	**9995.074**
Guard Band USL	**10004.926**
Percent of Spec	**49.26%**



Linearization Templates Comparison

Template	Purpose	Key Data Stored	Ideal Use Case
Template 40	Piecewise Linearization	Span points data (multiple points, 127)	Stepwise systems with moderate accuracy needs
Template 41	Polynomial Fit (Curve Fit)	Coefficients from ASTM E74 or ISO 376	High-accuracy metrology standards

Template Data Summary



- Template 33: Max Error ≈ 0.1018 %
- Template 40: Max Error ≈ 0.030 %
- Template 41: Max Error ≈ 0.0068 %

Calibration Strategy by Template

Template	Calibration Type	Steps Required	Notes
Template 33 or 40	One Mode (T or C)	1. As-Received Calibration 2. mV/V or A/D Reprogramming 3. As-Returned Calibration Needed for Measurement Error.	Might not be Cost-Effective 1.5x standard calibration cost
Template 41	One Mode (T or C)	1. Calibrate mV/V or A/D counts 2. Program polynomial coefficients	Best for ASTM E74 or ISO 376 calibrations

TEDS Templates: Which to Use and Why It Matters

📊 Template Comparison:
- Template 33: 2-Point Span — Simple, but high errors (up to 0.1%)
- Template 40: 4-Point Span — Better linearization, ~0.03% max error
- Template 41: Polynomial Fit — Best accuracy, errors in PPM

💡 Takeaway:
- Use Template 41 for high-precision applications (e.g., ASTM E74/ISO 376).
- Avoid relying solely on TEDS-enabled devices unless properly programmed.
- Always validate output and verify full-system calibration traceability.

Common Low Force Calibration Problems – Hand-Held Force Gauge

- Stacking Weights
- Off Center Loading
- Safety Issues

Common Low Force Calibration Problems – Hand-Held Force Gauge

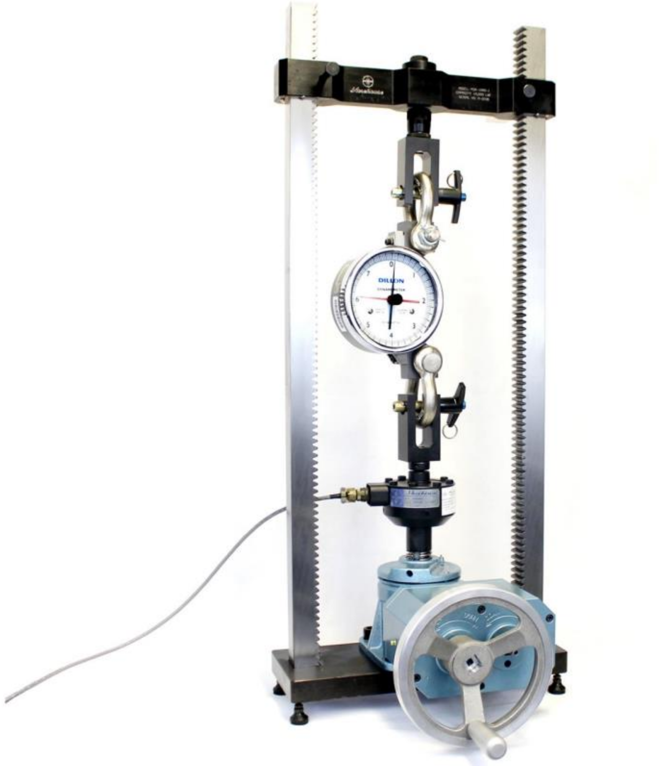
Stacking Weights Issues

- Slow and dangerous
- Ergonomic issue
- Often not corrected for force (corrections for force must include correcting for gravity, air density, and material density)

Common Low Force Calibration Problems – Hand-Held Force Gauge

Not Correcting Mass Weights To Force

- Morehouse Blog on Using Mass Weights
- Blog shows these errors to be from 0.05 % up to 0.185 %
- Extreme cases would be up to 0.53 %



Converting Force (lbf) to Mass (lbs)

Find the gravity at the location of the measurement

- Use https://www.geoplaner.com/ to get the Longitude and Latitude

- http://www.ngs.noaa.gov/TOOLS/Gravity/gravcon.html

Converting Force (lbf) to Mass (lbs)

Download our Morehouse Spreadsheet

https://mhforce.com/wp-content/uploads/2022/05/Force-to-Mass-2.xlsx

Enter Information in the Orange Cells			
Company Name	Calibrations R Us		
Date	4/20/2022		
Instrument Type	Load Cell		
Instrument Serial Number	U-7643		
Meter Serial Number	MY25245		
Force Units	lbf		
Location	New Jersey		
Mode Type	Tension		
Morehouse Ratio (Mass/Force)	1.000711725		
Gravity at Morehouse (m/s^2)	9.801158		
MH Air Density (g/cm^3)	0.001185		
MH Material Density (g/cm^3)	7.833400		
Gravity at Your Location (m/s^2)	9.792980		
Average Air Density at Your Location (	0.001225	0.001225	Density of air at normal pressure (1 atm) & temperature (68F)
Material Density of Your Weights (g/cm	8.000000	8	Stainless Steel Average Density for selected material
Optional Class Wt Error %	0.01%		

Force to Mass						
MH Force	MH Mass	ass Req'd at Customer S	ustomer Mass Weigh	rce Applied by Customer Wei	Gravity Error	Total Error Diff
250.0	250.1779	250.3873	250.00	249.61	-0.084%	0.1647%
500.0	500.3559	500.7746	500.00	499.23	-0.084%	0.1647%
1000.0	1000.7117	1001.5493	1000.00	998.45	-0.084%	0.1647%
1500.0	1501.0676	1502.3239	1500.00	1497.68	-0.084%	0.1647%
2000.0	2001.4234	2003.0985	2000.00	1996.91	-0.084%	0.1647%
2500.0	2501.7793	2503.8732	2500.00	2496.13	-0.084%	0.1647%
3000.0	3002.1352	3004.6478	3000.00	2995.36	-0.084%	0.1647%

Note: This sheet is to calculate potential differences from force to Mass. A full Measurement Uncertainty budget still needs to be created if using mass weights for a force application.

Mass Coefficients				
	Order			
	2	3	4	5
A_0	-4.28017E-06	-7.12494E-06	-1.15707E-05	-1.72357E-05
A_1	7.98787E-04	7.98797E-04	7.98818E-04	7.98853E-04
A_2	-1.21579E-12	-8.58256E-12	-3.58442E-11	-1.01520E-10
A_3	0.00000E+00	1.50456E-15	1.42060E-14	6.58274E-14
A_4	0.00000E+00	0.00000E+00	-1.94274E-18	-1.97050E-17
A_5	0.00000E+00	0.00000E+00	0.00000E+00	2.21192E-21
B_0	5.35835E-03	8.91967E-03	1.44851E-02	2.15766E-02
B_1	1.25190E+03	1.25188E+03	1.25185E+03	1.25179E+03
B_2	2.38547E-03	1.68395E-02	7.03274E-02	1.99182E-01
B_3	0.00000E+00	-3.69569E-03	-3.48940E-02	-1.61688E-01
B_4	0.00000E+00	0.00000E+00	5.97399E-03	6.05925E-02
B_5	0.00000E+00	0.00000E+00	0.00000E+00	-8.51495E-03

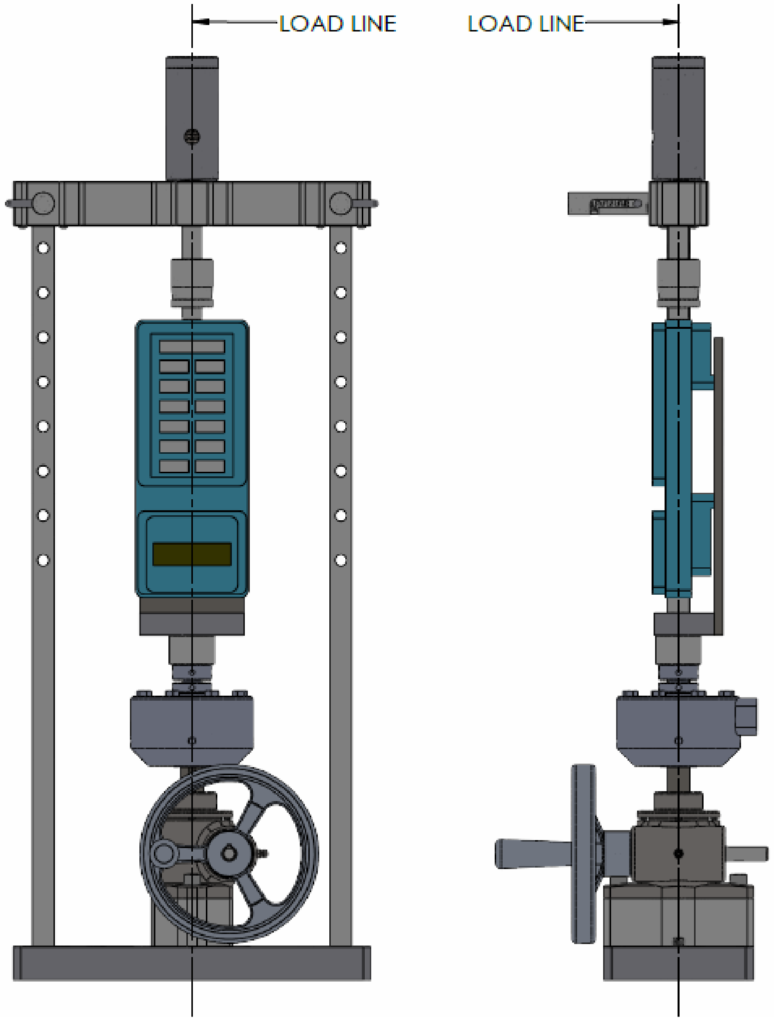
Enter Force Applied and Reduced Run Data From Certificate

Test Point #	Tension Force to Mass												
	Force Applied lbf	Fitted Curve or Average or Measured Output	MH Force Converted to Mass	Mass Req'd for Equivalent Force in Customer's Conditions	Difference in Mass Req'd at Different Locations	Customer's Mass Weight Values	Material Density Calibrations R Us	Air Density New Jersey	Gravity At New Jersey	Correction Factor Mass to Force	orce Adjusted fo Air Bouyancy & Gravity	Abs Difference in Force Applied by Customer Weight	dditional Max Erro In Mass Weight Class
1	250.0	0.20000	250.1779	250.3873	-0.084%	250.0	8.000000	0.001225	9.792980	0.998453	249.613284	0.15469%	0.01000%
2	500.0	0.40001	500.3559	500.7746	-0.084%	500.0	8.000000	0.001225	9.792980	0.998453	499.226568	0.15469%	0.01000%
3	1000.0	0.80002	1000.7117	1001.5493	-0.084%	1000.0	8.000000	0.001225	9.792980	0.998453	998.453136	0.15469%	0.01000%
4	1500.0	1.20003	1501.0676	1502.3239	-0.084%	1500.0	8.000000	0.001225	9.792980	0.998453	1497.679705	0.15469%	0.01000%
5	2000.0	1.60004	2001.4234	2003.0985	-0.084%	2000.0	8.000000	0.001225	9.792980	0.998453	1996.906273	0.15469%	0.01000%
6	2500.0	2.00005	2501.7793	2503.8732	-0.084%	2500.0	8.000000	0.001225	9.792980	0.998453	2496.132841	0.15469%	0.01000%
7	3000.0	2.40006	3002.1352	3004.6478	-0.084%	3000.0	8.000000	0.001225	9.792980	0.998453	2995.359409	0.15469%	0.01000%
8													
9													
10													
11													

Common Low Force Calibration Problems – Hand-Held Force Gauge

Off-Center Loading Issues

- Most hand-held force gauges require different centering fixtures for alignment - If the line of force is not pure, a large measurement error should be expected.



Adapters for Hand-Held Force Gauges

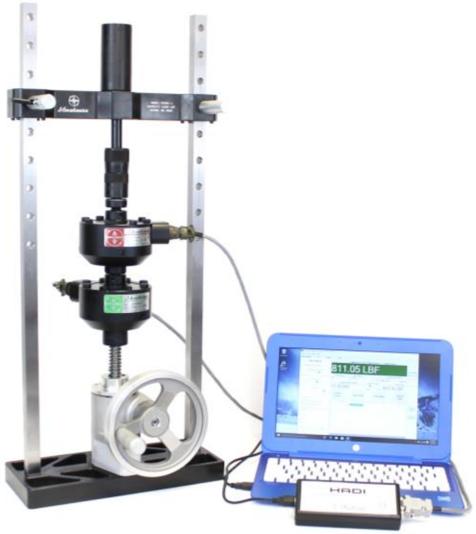
Morehouse L-Bracket kits are available for tension and compression calibration of handheld force gauges. These kits simplify setup and reduce errors with stacking weights. This kit can be used on both the Mechanical Tensiometer and PCM.

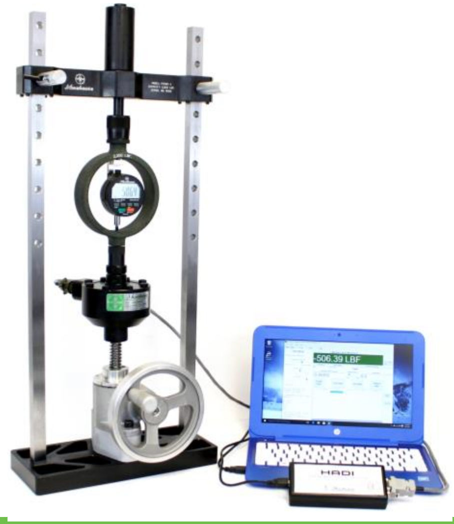
Common Low Force Calibration Problems - Alignment

Alignment Issues

- Misalignment can cause errors that exceed 1 % of applied reading on certain load cells and other devices.
- Using the right adapters will help reduce these errors.

PCM-2K High Value





- High-Value when compared to paying someone to manually lift weights or not getting the correct result by using the wrong adapters

- High-Value in terms of versatility – Can calibrate load cells, S-type load cells, force gauges, hand-held force gauges, button load cells, washer load cells, beam load cells

- High-Value in terms of accuracy – The system has an accuracy of better than 0.05 %. Better than 0.03 % is achievable.

Question

This International standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for t
Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.

INTERNATIONAL

Designation: E74 – 18

Standard Practices for
Calibration and Verification for Force-Measuring Instruments[1]

This standard is issued under the fixed designation E74; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the U.S. Department of Defense.

- Is anyone calibrating using the ASTM E74 standard?

Documents Referencing ASTM E74

AASHTO T22 - Standard Method of Test for Compressive Strength of Cylindrical Concrete Specimens

AASHTO T68 - Standard Method of Test for Tension Testing of Metallic Materials

ASTM E4 - Standard Practices for Force Verification of Testing Machines

ASTM C39 -Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens

ASTM E10 - Standard Test Method for Brinell Hardness of Metallic Materials

ASTM E18 – Standard Test Method for Rockwell Hardness of Metallic Materials

Note: This document requires calibration by Primary Standards in accordance with ASTM E74. It is important as only calibration laboratories with deadweights calibrated in accordance with the ASTM E74 requirements can calibrate these force measuring instruments and assign the Class AA verified range of forces as required by section A2.6.2.1.

Primary Force Standard (as defined by ASTM E74)

- Primary Force Standard – a deadweight force applied directly without intervening mechanisms such as levers, hydraulic multipliers, or the like, whose mass has been determined by comparison with reference standards traceable to national standards of mass
- To be classified as a primary standard, the masses of the weights shall be determined within 0.005 % of their values by comparison with reference standards traceable to the International System of Units (SI) for mass (ASTM E74-18 section 6.1.2)

Primary Force Standard (as defined by ASTM E74-18)

- Require correction for the effects of
- Local Gravity
- Air Buoyancy
- Must be adjusted to within 0.005 % or better (NIST weights are adjusted to within U = 0.0005 %, Morehouse U= 0.002 %)
- Per ASTM E74-18 section 6.1, *"weights shall be made of rolled, forged, or cast metal. Adjustment cavities should be closed by threaded plugs or suitable seals. External surfaces of weights shall have a Roughness Average of 3.2 µm or less as specified by ASME B46.1"* ***Note:*** *Stainless Steel preferred material*

Secondary Force Standard as defined by ASTM E74

- Secondary Force Standard – an instrument or mechanism, the calibration of which has been established by comparison with **primary force standards**.
- In order to perform calibrations in accordance with ASTM E74, your force standard must be calibrated with primary standards.

Examples of Secondary Standards in Machines

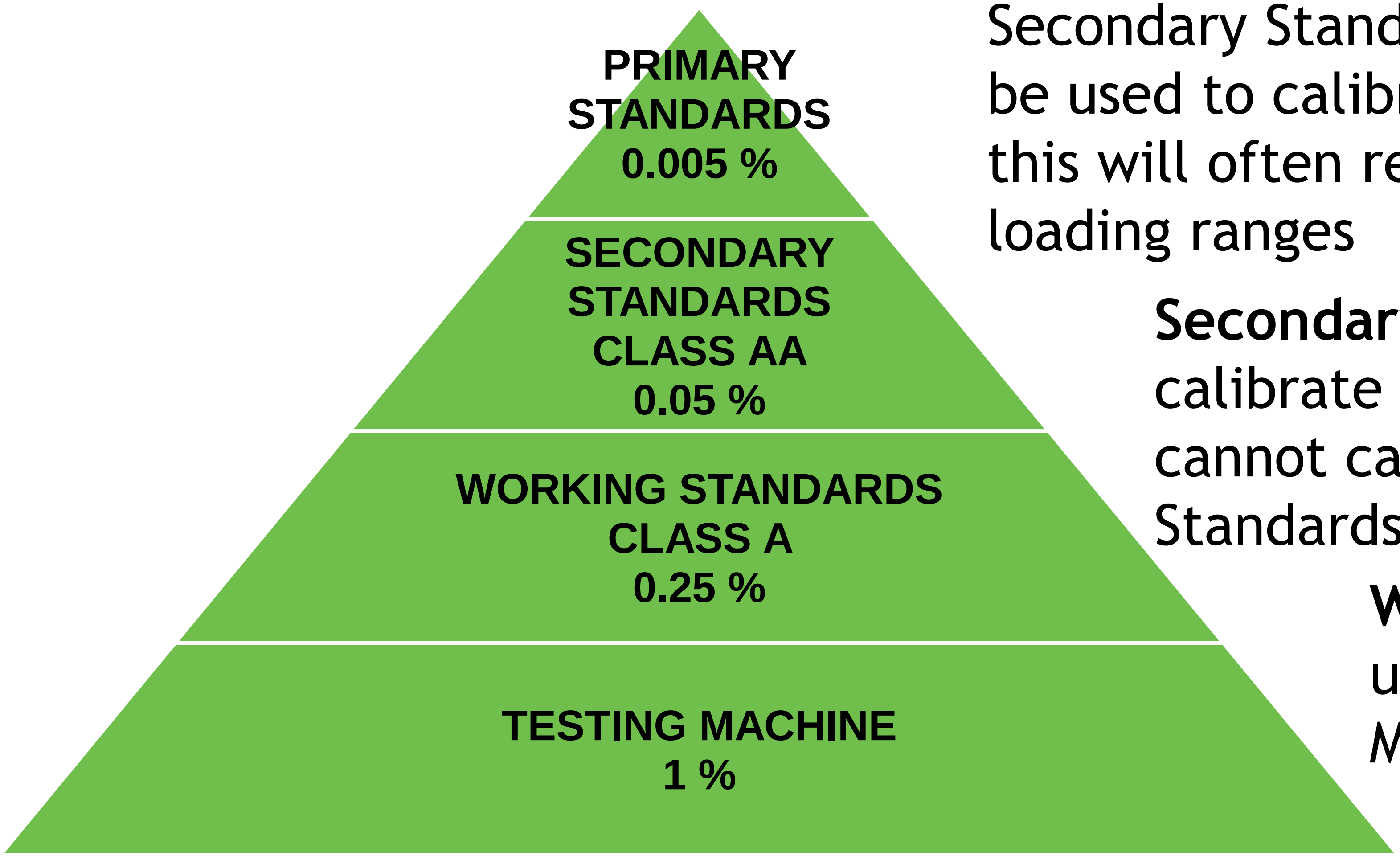
Secondary Force Standard as defined by ASTM E74

Secondary Force Standard – Range of use limited by the verified range of forces established by the standard

- ASTM E74 Class AA verified range of forces for calibration of secondary standard load cells. This is found by multiplying the lower limit factor by 2000 (0.05 %) 5:1 ratio
- ASTM E74 Class A verified range of forces for calibration of the testing machine . This is found by multiplying the lower limit factor by 400 (0.25 %) 4:1 ratio.

Range of use cannot be less than the lowest applied force. The Loading range cannot be less than 400 for Class A or 2000 for Class AA times the resolution.

Test Accuracy Ratio ASTM E74



Primary Standards are required to calibrate Secondary Standards. Primary Standards can be used to calibrate working standards, as this will often result in the lowest possible loading ranges

Secondary Standards are required to calibrate Working Standards. They cannot calibrate other Secondary Standards

Working Standards are used to calibrate Testing Machines to ASTM E4

ASTM E74 Calibration Procedure

- Allow UUT to come to room temperature
- Warm up Instrumentation
- Select 10-11 Test points
- Fixture UUT in Test Frame
- Exercise UUT 2-4 times
- Apply 1st series of forces (Run1)
- Rotate the UUT 120 degrees, if possible, for run 2
- Apply 2nd series of forces (Run2)
- *IF UUT IS COMPRESSION AND TENSION, SWITCH TO OTHER MODE AFTER FINISHING RUN 2 AND EXERCISE AND REPEAT THE ABOVE STEPS*
- Rotate the UUT another 120 degrees, if possible, for run 3
- Apply 3rd series of forces (Run3)

01/29/2016 U-SAMPLE

This Calibration Data is Certified Traceable to the United States National Institute of Standards & Technology

MODEL: ULTRA PRECISION
MOREHOUSE Load Cell, SERIAL NO. U-SMAPLE
10000.00 LBF Compression Calibrated to 10000.00 LBF
MOREHOUSE 4215, SERIAL NO. SAMPLE

Calibration is in Accordance with ASTM E74-13
Ascending Compression DATA

Applied Load	Deflection Values Per ASTM Method 8.1B Interpolated Zero			Deviation From Fitted Curve			Values From Fitted Curve
	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	
LBF	mV/V	mV/V	mV/V	mV/V	mV/V	mV/V	mV/V
200	-0.08103	-0.08101	-0.08101	-0.00001	0.00001	0.00001	-0.08102
1000	-0.40511	-0.40508	-0.40509	-0.00002	0.00001	0.00000	-0.40509
2000	-0.81030	-0.81026	-0.81029	-0.00002	0.00002	-0.00001	-0.81028
3000	-1.21560	-1.21556	-1.21559	-0.00001	0.00003	0.00000	-1.21559
4000	-1.62103	-1.62097	-1.62096	-0.00004	0.00002	0.00003	-1.62099
5000	-2.02650	-2.02650	-2.02648	-0.00002	-0.00002	0.00000	-2.02648
6000	-2.43210	-2.43202	-2.43205	-0.00004	0.00004	0.00001	-2.43206
7000	-2.83766	-2.83768	-2.83770	0.00004	0.00002	0.00000	-2.83770
8000	-3.24342	-3.24339	-3.24341	-0.00003	0.00000	-0.00002	-3.24339
9000	-3.64917	-3.64913	-3.64913	-0.00003	0.00001	0.00001	-3.64914
10000	-4.05493	-4.05491	-4.05489	-0.00002	0.00000	0.00002	-4.05491

The following polynomial equation, described in ASTM E74-13 has been fitted to the force and deflection values obtained in the calibration using the method of least squares.

response = A0 + A1(load) + A2(load)^2 + A3(load)^3

Where: A0 -1.83106052E-5
A1 -4.05005379E-4
A2 -6.6717265E-11
A3 1.8297849E-15

load = B0 + B1(response) + B2(response)^2 + B3(response)^3

Where: B0 -4.47730993E-2
B1 -2.46910115E+3
B2 -1.00215904E+0
B3 -6.79438426E-2

The following values as defined in ASTM E74-13 were determined from the calibration data.
Lower Limit Factor, LLF 0.132 LBF

Class A Loading Range 200.00 TO 10000.00 LBF

Morehouse Instrument Co., Inc.
1742 Sixth Ave., York, PA 17403
Phone 717/843-0081

ASTM E74 Calibration Data Analysis

- Deviations from the fitted curve
- These are the differences between the fitted curve and the observed values
- Standard Deviation is the square root of the sum of all the deviations squared/n-m-1

$$s_m = \sqrt{((d_1^2 + d_2^2 + .. + d_n^2)/(n\text{-}m\text{-}1))}$$

- N = sample size, m = the degree of polynomial fit
- Calibration equation Deflection or Response = A0+A1(load)+A2(load)^2+…A5(load)^5
- LLF is 2.4 times the standard deviation
- Class A range is 400 times the LLF. Class AA range is 2000 times the LLF.

01/29/2016 U-SAMPLE

This Calibration Data is Certified Traceable to the United States National Institute of Standards & Technology

MODEL: ULTRA PRECISION
MOREHOUSE Load Cell, SERIAL NO. U-SMAPLE
10000.00 LBF Compression Calibrated to 10000.00 LBF
MOREHOUSE 4215, SERIAL NO. SAMPLE

Calibration is in Accordance with ASTM E74-13
Ascending Compression DATA

Applied Load	Deflection Values Per ASTM Method 8.1B Interpolated Zero			Deviation From Fitted Curve			Values From Fitted Curve
	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	
LBF	mV/V	mV/V	mV/V	mV/V	mV/V	mV/V	mV/V
200	-0.08103	-0.08101	-0.08101	-0.00001	0.00001	0.00001	-0.08102
1000	-0.40511	-0.40508	-0.40509	-0.00002	0.00001	0.00000	-0.40509
2000	-0.81030	-0.81026	-0.81029	-0.00002	0.00002	-0.00001	-0.81028
3000	-1.21560	-1.21556	-1.21559	-0.00001	0.00003	0.00000	-1.21559
4000	-1.62103	-1.62097	-1.62096	-0.00004	0.00002	0.00003	-1.62099
5000	-2.02650	-2.02650	-2.02648	-0.00002	-0.00002	0.00000	-2.02648
6000	-2.43210	-2.43202	-2.43205	-0.00004	0.00004	0.00001	-2.43206
7000	-2.83766	-2.83768	-2.83770	0.00004	0.00002	0.00000	-2.83770
8000	-3.24342	-3.24339	-3.24341	-0.00003	0.00000	-0.00002	-3.24339
9000	-3.64917	-3.64913	-3.64913	-0.00003	0.00001	0.00001	-3.64914
10000	-4.05493	-4.05491	-4.05489	-0.00002	0.00000	0.00002	-4.05491

The following polynomial equation, described in ASTM E74-13 has been fitted to the force and deflection values obtained in the calibration using the method of least squares.

response = A0 + A1(load) + A2(load)^2 + A3(load)^3

Where:
A0 -1.83106052E-5
A1 -4.05005379E-4
A2 -6.6717265E-11
A3 1.8297849E-15

load = B0 + B1(response) + B2(response)^2 + B3(response)^3

Where:
B0 -4.47730993E-2
B1 -2.46910115E+3
B2 -1.00215904E+0
B3 -6.79438426E-2

The following values as defined in ASTM E74-13 were determined from the calibration data.
Lower Limit Factor, LLF 0.132 LBF

Class A Loading Range 200.00 TO 10000.00 LBF

Morehouse Instrument Co., Inc.
1742 Sixth Ave., York, PA 17403
Phone 717/843-0081

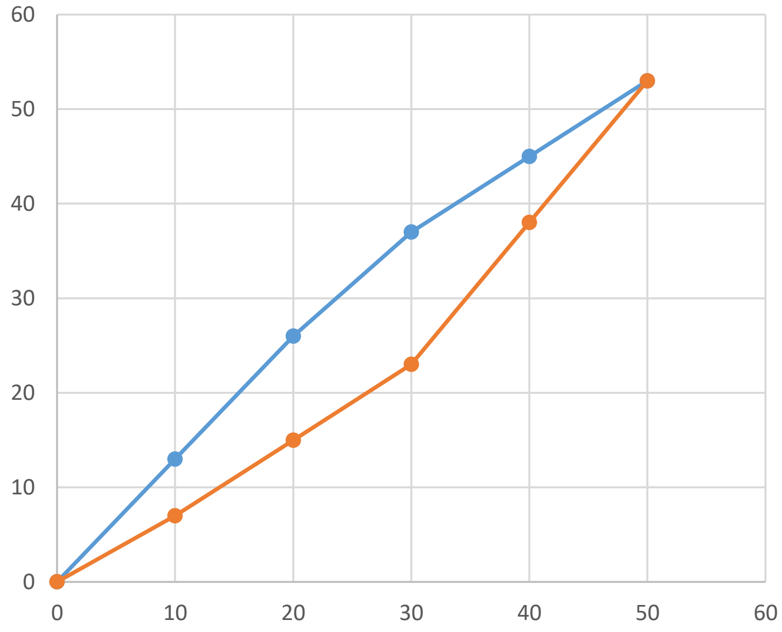
ASTM E74 Calibration Procedure

LOAD REVERSAL OR DESCENDING LOADING

- If a force-measuring device is to be used to measure forces during decreasing load sequences, then it must be calibrated in this manner.
- Separate calibration curves can be used for Ascending values and Descending Values.
- A combined curve may also be used though the STD DEV of the combined curve will be much higher than using separate curves.

ASTM E74 Calibration Procedure

- The LLF for a combined curve will typically be 3-4 larger than the LLF of an increasing-only calibration.
- A Descending Curve is only valid if the device is loaded to full capacity.
- An Ascending curve can be used for increasing calibration, and a combined curve would be recommended for any descending values, as the user would not have to apply the maximum force.



ASTM E74 Calibration

- The Class A or Class AA verified range of forces cannot be less than the first applied **non-zero force point** (400 x 0.132 = 52.8)
- Per Section 8.6.2 of ASTM E74-18, *"The verified range of forces shall not include forces outside the range of forces applied during the calibration. If the lower force limit is less than the lowest non-zero calibration force applied, then the lower force limit of the verified range of forces is equal to the lowest calibration force applied."*

01/29/2016 U-SAMPLE

This Calibration Data is Certified Traceable
to the
United States National Institute of Standards & Technology

MODEL: ULTRA PRECISION
MOREHOUSE Load Cell, SERIAL NO. U-SMAPLE
10000.00 LBF Compression Calibrated to 10000.00 LBF
MOREHOUSE 4215, SERIAL NO. SAMPLE

Calibration is in Accordance with ASTM E74-13
Ascending Compression DATA

Applied Load	Deflection Values Per ASTM Method 8.1B Interpolated Zero			Deviation From Fitted Curve			Values From Fitted Curve
	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	
LBF	mV/V	mV/V	mV/V	mV/V	mV/V	mV/V	mV/V
200	-0.08103	-0.08101	-0.08101	-0.00001	0.00001	0.00001	-0.08102
1000	-0.40511	-0.40508	-0.40509	-0.00002	0.00001	0.00000	-0.40509
2000	-0.81030	-0.81026	-0.81029	-0.00002	0.00002	-0.00001	-0.81028
3000	-1.21560	-1.21556	-1.21559	-0.00001	0.00003	0.00000	-1.21559
4000	-1.62103	-1.62097	-1.62096	-0.00004	0.00002	0.00003	-1.62099
5000	-2.02650	-2.02650	-2.02648	-0.00002	-0.00002	0.00000	-2.02648
6000	-2.43210	-2.43202	-2.43205	-0.00004	0.00004	0.00001	-2.43206
7000	-2.83766	-2.83768	-2.83770	0.00004	0.00002	0.00000	-2.83770
8000	-3.24342	-3.24339	-3.24341	-0.00003	0.00000	-0.00002	-3.24339
9000	-3.64917	-3.64913	-3.64913	-0.00003	0.00001	0.00001	-3.64914
10000	-4.05493	-4.05491	-4.05489	-0.00002	0.00000	0.00002	-4.05491

The following polynomial equation, described in ASTM E74-13 has been fitted to the force and deflection values obtained in the calibration using the method of least squares.

response = A0 + A1(load) + A2(load)^2 + A3(load)^3

Where:
A0 -1.83106052E-5
A1 -4.05005379E-4
A2 -6.6717265E-11
A3 1.8297849E-15

load = B0 + B1(response) + B2(response)^2 + B3(response)^3

Where:
B0 -4.47730993E-2
B1 -2.46910115E+3
B2 -1.00215904E+0
B3 -6.79438426E-2

The following values as defined in ASTM E74-13 were determined from the calibration data.
Lower Limit Factor, LLF 0.132 LBF

Class A Loading Range 200.00 TO 10000.00 LBF

Morehouse Instrument Co., Inc.
1742 Sixth Ave., York, PA 17403
Phone 717/843-0081
Fax 717/846-4193

Page 2 of3

ASTM E74 Calibration

- It is recommended that the lower force limit be not less than 2 % (1⁄50) of the capacity of the instrument.

- Per Section 7.2.1, *"If the lower force limit of the verified range of forces of the force-measuring instrument (see 8.6.1) is anticipate to be less than one-tenth of the maximum force applied during calibration, then forces should be applied at or below this lower force limit. In no case should the smallest force applied to be below the lower force limit of th force-measuring instrument as defined by the values: 400 x resolution for Class A verified range of forces, 2000 x resolution for Class AA verified range of forces "*

Applied Load	Deflection Values Per ASTM Method 8.1B Interpolated Zero		
	Run 1	Run 2	Run 3
LBF	mV/V	mV/V	mV/V
200	-0.08103	-0.08101	-0.08101
1000	-0.40511	-0.40508	-0.40509
2000	-0.81030	-0.81026	-0.81029
3000	-1.21560	-1.21556	-1.21559
4000	-1.62103	-1.62097	-1.62096
5000	-2.02650	-2.02650	-2.02648
6000	-2.43210	-2.43202	-2.43205
7000	-2.83766	-2.83768	-2.83770
8000	-3.24342	-3.24339	-3.24341
9000	-3.64917	-3.64913	-3.64913
10000	-4.05493	-4.05491	-4.05489

Example of not following the standard

What's Wrong Here?

PERFORMANCE

TEST LOAD APPLIED (lbf)	Recorded Readings (Lb) Run 1	Run 2	Run 3	Fitted	Error 1	Error 2	Error 3
0	0.0	0.0	0.0	0.05	0.05	0.05	0.05
500	499.9	499.8	500.3	500.06	0.16	0.26	-0.24
1000	1000.1	1000.1	1000.3	999.94	-0.16	-0.16	-0.36
2000	1999.4	1999.3	1999.5	1999.52	0.12	0.22	0.02
3000	2999.1	2999.0	2999.2	2999.08	-0.02	0.08	-0.12
4000	3998.7	3998.6	3999.0	3998.84	0.14	0.24	-0.16
5000	4998.8	4998.8	4999.0	4998.89	0.09	0.09	-0.11
6000	5999.2	5999.3	5999.5	5999.26	0.06	-0.04	-0.24
7000	6999.7	6999.9	7000.2	6999.86	0.16	-0.04	-0.34
8000	8000.4	8000.4	8000.7	8000.51	0.11	0.11	-0.19
9000	9000.7	9000.8	9001.0	9000.95	0.25	0.15	-0.05
10000	10000.5	10000.8	10001.3	10000.81	0.31	0.01	-0.49
4000	4001.5	4001.4	4001.4				
0	-0.2	0.0	0.0				

POLYNOMIAL COEFFICIENTS FOR ASCENDING FITTED CURVE

Coefficients*		Inverse**	
Coefficient A0=	5.072350e-002	Coefficient A0=	-5.091823e-002
Coefficient A1=	1.000166e+000	Coefficient A1=	9.998345e-001
Coefficient A2=	-3.470746e-007	Coefficient A2=	3.466446e-007
Coefficient A3=	7.319854e-011	Coefficient A3=	-7.312871e-011
Coefficient A4=	-3.939503e-015	Coefficient A4=	3.935937e-015

Standard Deviation	=	0.20026	lbf
Standard Deviation / Span	=	0.00200	%
Lower Limit Factor	=	0.48	lbf
Class A Lower Limit	=	192.3	lbf

*Reading = A0 + A1*Load + A2*Load^2 + A3*Load^3 + A4*Load^4
**Load = IA0 + IA1*Reading + IA2*Reading^2 + IA3*Reading^3 + IA4*Reading^4

Per Section 8.6 of ASTM E74-18, *"The verified range of forces shall not include forces outside the range of forces applied during the calibration."*

ASTM E74 Calibration (Do Not)

Do Not assign a Class A or Class AA verified range of forces below the first non-zero force point. Note: We have observed numerous labs violating this rule!

- Per Section 8.6.2 of ASTM E74-18, *"The verified range of forces shall not include forces outside the range of forces applied during the calibration. If the lower force limit is less than the lowest non-zero calibration force applied, then the lower force limit of the verified range of forces is equal to the lowest calibration force applied."*
- Per Section 7.2.1 of ASTM E74-18 states, *"If the lower force limit of the verified range of forces of the force-measuring instrument (see 8.6.1) is anticipated to be less than one tenth of the maximum force applied during calibration, then forces should be applied at or below this lower force limit. In no case should the smallest force applied be below the lower force limit of the force-measuring instrument as defined by the values: 400 x resolution for Class A verified range of forces 2000 x resolution for Class AA verified range of forces "*

Calibration In Accordance with ASTM E74

Secondary Force Standard – an instrument or mechanism, the calibration of which has been **established by comparison with primary force standards**.

Criteria for Lower Load Limit

- LLF = 2.4 * STD DEV – This corresponds to a 98.36 % Confidence Level
- Based on LLF or Resolution, whichever is higher
- Class A 400 times the LLF or resolution
- Class AA 2000 times the LLF or resolution

CLASS AA? THIS IS NOT CORRECT. THE CALIBRATION LAB IS USING A LOAD CELL TO ASSIGN A CLASS AA LOADING RANGE

Calibration Standards Utilized

Cert. #	Manufacturer	Model #	Description	Cal Date	Due Date
2508330017	Interface, Inc.	1620AJH-25K	Gold Standard Load Cell	08/15/2013	08/15/2015
2911710179	Agilent Technologi	34420A	Nanovolt/Micro-Ohmmeter	01/07/2015	07/07/2015

17500	-28.570	-28.!
20000	-32.655	-32.(
22500	-36.735	-36.:
25000	-40.819	-40.!

Deflections = (A) + (B) * (Load) + (C)

Values of constants are:
A = 1.3403263E-03
B = -1.6319647E-03
C = -4.3885004E-11

Class AA = 8761.37 lbf

Class A = 2500 lbf

ASTM E74 Calibration (Do Not)

Do Not Assign a Class AA verified range of forces unless you are calibrating with primary standards accurate to better than 0.005 %

Do Not Assign a Class A verified range of forces unless you are calibrating the device using a secondary standard that was calibrated directly by primary standards.

Note: A force-measuring instrument with Class A **verified range of forces** cannot assign Class A **verified range of forces**.

Note: A force measuring instrument with Class AA **verified range of forces** cannot assign Class AA **verified range of forces**.

Force Uncertainty Budget for ASTM E74 Calibrations

Type A Uncertainty Contributors

1) ASTM lower limit factor (LLF) reduced to 1 Standard Deviation (ASTM LLF is reported with k= 2.4)
2) Repeatability of the Best Existing Device
3) Repeatability and Reproducibility

Type B Uncertainty Contributors

1) Resolution of the Best Existing Device
2) Reference Standard Resolution* *If Applicable*
3) Reference Standard Uncertainty
4) Reference Standard Stability
5) Environmental Factors
6) Other Error Sources

Do not use SEB, Nonlinearity, or Hysteresis as they are not appropriate contributors when following the ASTM E74 standard.

Uncertainty Budget for ASTM E74 Calibrations

We will need the following:

1. Calibration Report for the Device, which needs to include Measurement Uncertainty
2. The uncertainty of the instrument(s) that were used to perform the calibration (Uref)
3. Calibration History (if available)
4. Manufacturer's Specification Sheet (For Environmental)
5. Error Sources, if known

The end user will then have to conduct the following tests:

1. Repeatability study
2. R & R between technicians
3. Complete Proficiency Testing Requirements

CERTIFICATE OF CALIBRATION

AS RECEIVED / AS RETURNED

CALIBRATION DATE: 08/10/2017
Page: 1 of 7
REPORT NO.: DEMOH1017

MOREHOUSE LOAD CELL MODEL: CALIBRATION SERIAL NO.: DEMO
CALIBRATED TO: 2000 LBF COMPRESSION & TENSION ASCENDING

With Indicator:
MOREHOUSE MODEL: HADI SERIAL NO.: 12345

Submitted By:
MOREHOUSE
1742 SIXTH AVENUE YORK PA 174032675

This Certificate of Calibration is issued in accordance with Morehouse QAM Rev 15 Dated 11/30/16 & ISO/IEC 17025:2005

No repairs or adjustments were made.

Calibration Procedure: ASTM E74-13a Method B

	LOWER LIMIT FACTOR LBF	RESOLUTION LBF	LOWER FORCE LIMIT CLASS A LBF	UPPER FORCE LIMIT CLASS A LBF
COMPRESSION	0.021	0.009	50.00	2000.00
TENSION	0.037	0.009	50.00	2000.00

This calibration was performed using measurement standards traceable to the SI through a National Metrology Institute (NMI) such as the United States National Institute of Standards & Technology (NIST).

TYPE	SERIAL NO.	CMC	NIST NO.	CALIBRATED DATE	CALIBRATION DUE DATE
PRIMARY FORCE STANDARD	M-8407	0.0016% OF APPLIED FORCE (k=2)	882/275872-11	6/19/2013	1/19/2046
TEMPERATURE STANDARD	A21299/A782932	0.2° C (k=2)	252031	8/27/2016	8/27/2017

Calibrated By:
H. Zumbrun,
Calibration Technician

Reviewed By:
H. Zumbrun,
Calibration Technician

Morehouse
THE FORCE IN CALIBRATION SINCE 1925
Force & Torque Calibration Laboratories
1742 Sixth Avenue York, PA 17403
Phone: 717/843-0081 www.mhforce.com

ACCREDITED
Calibration Certificate # 1398.01

THE MEASUREMENT RESULTS ONLY PERTAIN TO THE INSTRUMENT ON THIS CERTIFICATE.
THIS CERTIFICATE SHALL NOT BE REPRODUCED, EXCEPT IN FULL, WITHOUT WRITTEN CONSENT FROM MOREHOUSE INSTRUMENT COMPANY, INC.

Measurement Uncertainty

Morehouse has prepared a Measurement Uncertainty Calibration and Measurement Capability Excel Worksheet for anyone needing to calculate Measurement Uncertainty.

Morehouse Measurement Uncertainty Calibration and Measurement Capability Worksheet

START ON THIS SHEET AND FILL IN ONLY LIGHT GREY BOXES

SECTION 1 DATA ENTRY — **NOTE: ONLY ENTER INFORMATION IN LIGHT GREY BOXES**

Laboratory	Morehouse		
Technician Initials	HZ		All information entered must converted to like units.
Date:	8/10/2017		This spreadsheet is provided by Morehouse Instrument Company
Range	2K		It is to be used as a guide to help calculate CMC
Standards Used Ref and UUT	Ref S/N DEMOH1017 UUT S/N Test		
Resolution UUT	0.01	LBF	This is the resolution of the Unit Under Test you are Using for the Repeatability Study (What you are testing)

REFERENCE STANDARD INFORMATION

ASTM E74 LLF	0.021	LBF	* This is your ASTM E74 LLF Found on Your ASTM E74 Report. It will be converted to a pooled std dev
Resolution of Reference	0.009	LBF	This should be found on your calibration report.
Temperature Spec per degree C %	0.0015%		This is found on the load cell specification sheet. Temperature Effect on Sensitivity, % RDG/100 F
Max Temperature Variation per degree C of Environment	1		During a typical calibration in a tightly controlled the temperature varies by no more than 1 degree C.
Morehouse CMC (REF LAB)	0.0016%		This is the CMC statement for the range calibrated found on the certificate of calibration. Leave blank if entering Eng. Units
Non ASTM or ISO 376 (TOLERANCE,NL,SEB)	0	%	If non ASTM E74 or ISO 376 use this field & use Tolerance with nonlinearity or SEB if making ascending and descending measurements
Miscellaneous Error	0.003	%	This can be creep, side load sensitivity or other known error sources. Enter and select Eng. Units or %
Conv Repeatability Data To Eng. Units	NO		

Ref Standard Stability

	FORCE APPLIED	Change From Previous %	Interpolation Value	Actual LBF	Temperature Effect 0.000015
1	200	0.0100%	0.02	0.02	0.003
2	2000	0.0100%	0.02	0.2	0.03
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					

ISO 376 UNCERTAINTY COEFFICIENTS

C0	C1	C2
0.1	0.00071	

Expanded Uncertainty = C0 + (C1 * F) + (C2 * F)^2

Where F = Force Applied, C0 = Intercept, C1 = Slope

Repeatability of UUT

	Applied	Run1	Run2	Run3	Run4	Average	Resolution	STD DEV	CONVERTED
1	200.00	200.00	199.99	200.02	200.01	200.005	1	0.01290994	0.01290994
2	2000.00	2000.07	2000.00	2000.05	2000.03	2000.0375	1	0.02986079	0.02986079
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									
						Avg Std Dev of Runs		0.02300362	0.02300362

Ref Laboratory Uncertainty Per Point — **MUST SELECT**

Force	%	Eng. Units	Conv %	Force	% or Eng.
200	0.0016%		0.000016	200	%
2000	0.0016%		0.000016	2000	%
	0.0016%		0.000016		%
	0.0016%		0.000016		%
	0.0016%		0.000016		%
	0.0016%		0.000016		%
	0.0016%		0.000016		%
	0.0016%		0.000016		%
	0.0016%		0.000016		%
	0.0016%		0.000016		%
	0.0016%		0.000016		%
	0.0016%		0.000016		%

Measurement Uncertainty

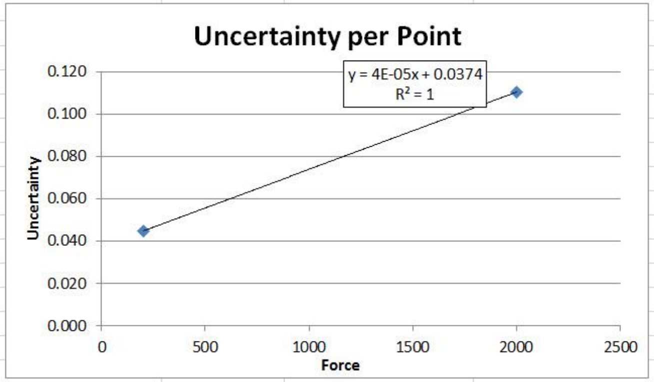
Morehouse Measurement Uncertainty Calibration and Measurement Capability Worksheet

Measurement Uncertainty Budget Summary

Laboratory	Morehouse								
Parameter	FORCE	**Range**	2K	**Sub-Range**	N/A				
Technician	HZ	**Standards Used**	Ref S/N DEMOH1017 UUT S/N Test						
Date	8/10/2017								
	Applied	**Expanded Uncertainty**	**Expanded Uncertainty %**		**Slope**	**Intercept**		**Enter Force Value Below**	**Estimated Expanded**
1	200	0.04468	0.02234%						
2	2000	0.11028	0.00551%		**3.64433E-05**	**0.03739**			
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									

Note: Force value should be entered between the segmented ranges above to calculate MU per point

Note: This is a summary sheet for all test points



Uncertainty Per Point Fit Coefficients	
a5=	2.04996E-18
a4=	0
a3=	0
a2=	0
a1=	0
a0=	0.04467848

$$U = a_5\,F^5 + a_4\,F^4 + a_3\,F^3 + a_2\,F^2 + a_1\,F + a_0$$

https://mhforce.com/wp-content/uploads/2021/04/CMC-CALCULATIONS-FOR-FORCE-MEASUREMENTS.xlsx

Learning Objectives

By the end of this section, you should be able to:

- Identify potential force measurement errors
- Implement proper force calibration techniques as discussed and demonstrated in the class

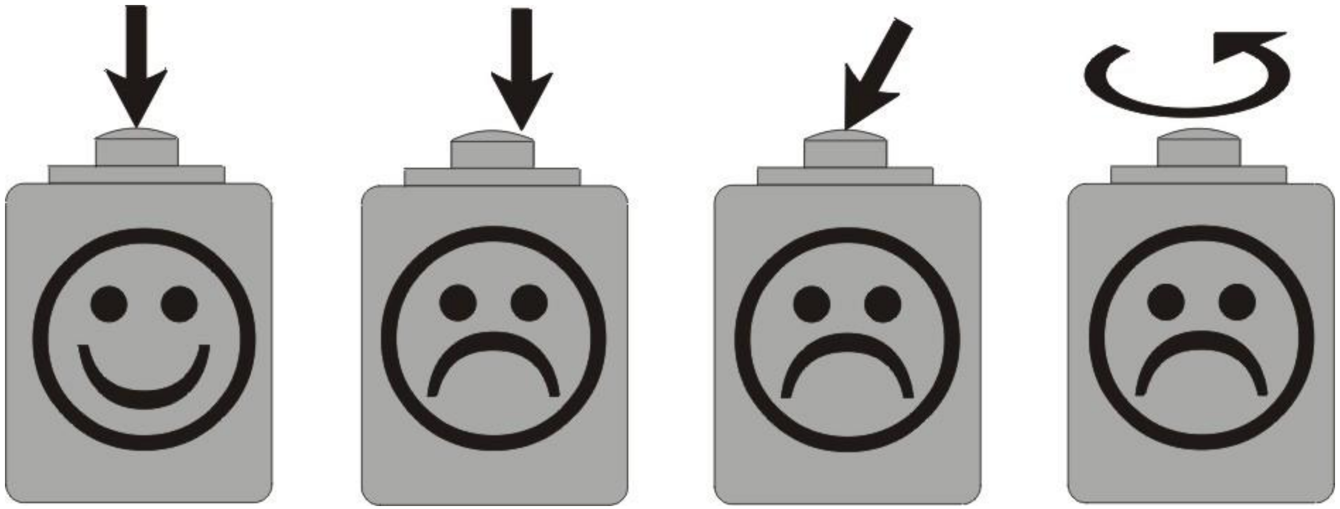
Force Potential Measurement Errors

- Cable Stiffness and Mounting
- Using Mass Weights instead of Force Weights
- Misalignment
- Different Hardness of Top Adapters
- Thread Depth – Shoulder Loading Versus Thread Loading
- Loading Through the Bottom Threads in Compression
- Cable Length
- Bolting Load Cells and Torque
- Tare Loads
- Other Error Sources

How to get a reliable test result.

To receive a reliable test result the load must be introduced centric and axial to the load cell. Side load, Eccentric forces or torque forces will influence the test result negative and might cause damage to the sensor

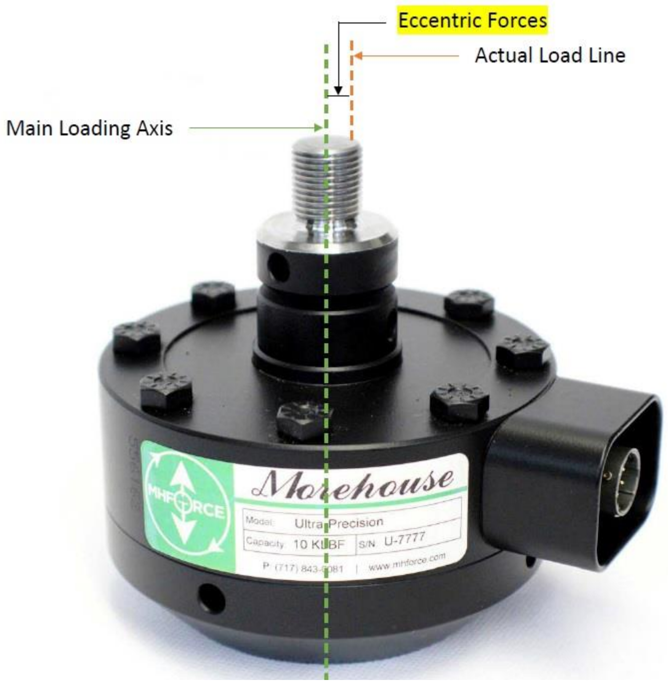
- Axial load: A load applied along or parrallel to and concentric with the primary axis
- Side load: Any load acting 90 degrees to the primary axis at the point of axial load application
- Eccentric load: Any load applied parrallel but not concentric with the primary axis



Cable Stiffness and Mounting

Cable Stiffness may influence the measurement if it provides a parallel load path. On smaller cells, this effect can be very significant.

It is often recommended that the transducer be oriented so that the "live end" is mounted toward where the force is being generated from.



Misalignment

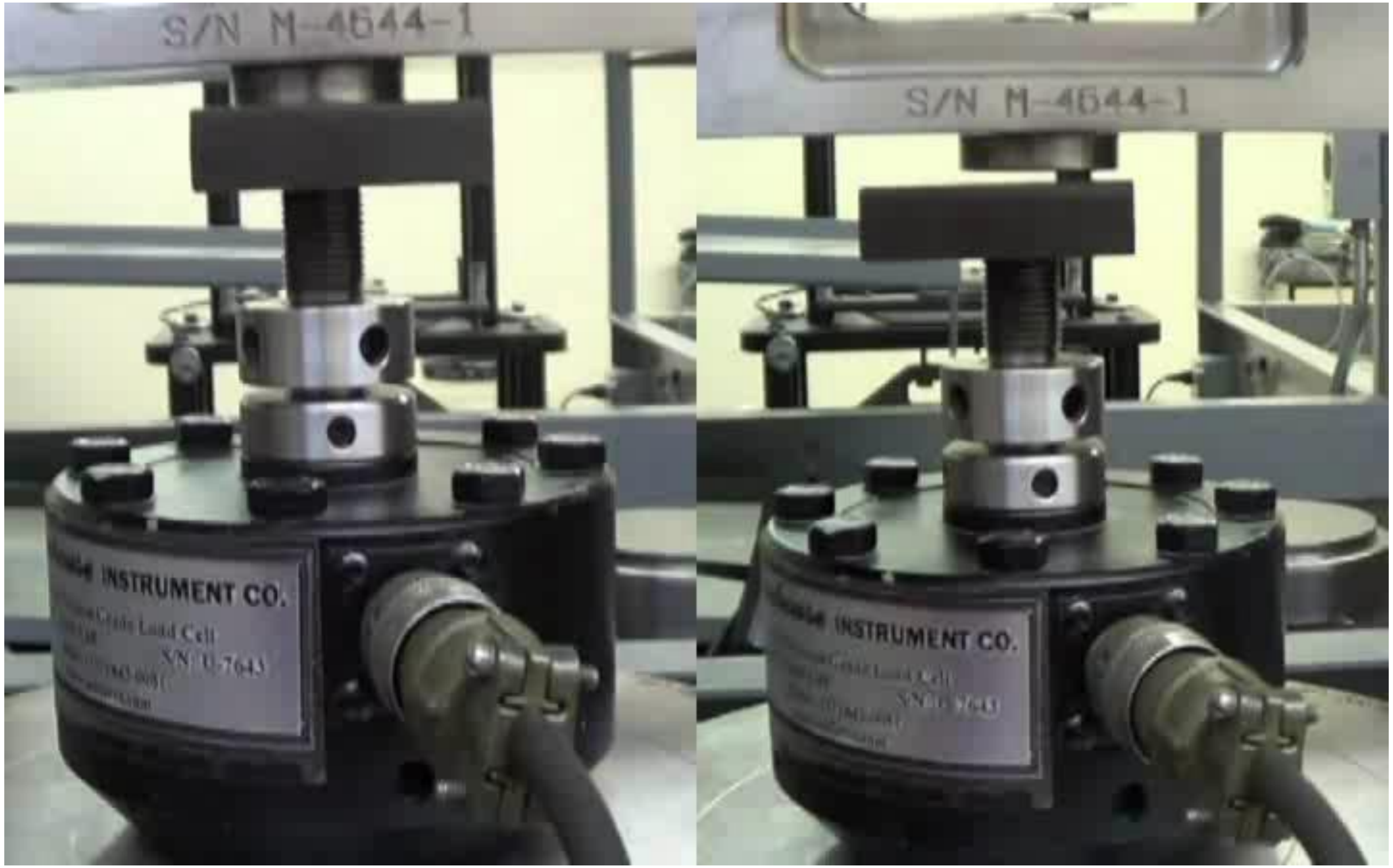
- For compression loading, a load pad or button can be used, and the surface should be ground flat.
- We have shown large deviations on ASTM E74 calibrations by using a beat-up, non-flat pad.
- For tension, it is recommended to use adapters with a spherical to reduce additional bending moments.

Misalignment

- A well-aligned calibration machine may demonstrate bending of less than 2 %. Some transducers also specify this error. The % is usually found on the load cell spec sheet under Side Load Sensitivity.
- The use of proper calibration adapters is required to minimize this error.

- Morehouse UCM 1/16-inch possible misalignment.

Misalignment Shear Web Cell Video



Misalignment Shear Web Cell

Note: From the previous video with the S-beam cell, the error observed was 0.75 % on the S-Type cell and 0.0022 % on the Morehouse Shear Web cell.
Assume both load cells had an ASTM E74 LLF = 0.5 LBF

S-BEAM WITH 0.75 %

S-BEAM	10000	LBF	SERIAL NO	EXAMPLE
%	Force Applied	COMBINED UNCERTAINTY FOR K=2		
2.00%	200	0.89076%	1.782	LBF
10.00%	1000	0.86705%	8.671	LBF
20.00%	2000	0.86630%	17.326	LBF
30.00%	3000	0.86616%	25.985	LBF
40.00%	4000	0.86612%	34.645	LBF
50.00%	5000	0.86609%	43.305	LBF
60.00%	6000	0.86608%	51.965	LBF
70.00%	7000	0.86607%	60.625	LBF
80.00%	8000	0.86607%	69.286	LBF
90.00%	9000	0.86607%	77.946	LBF
100.00%	10000	0.86606%	86.606	LBF

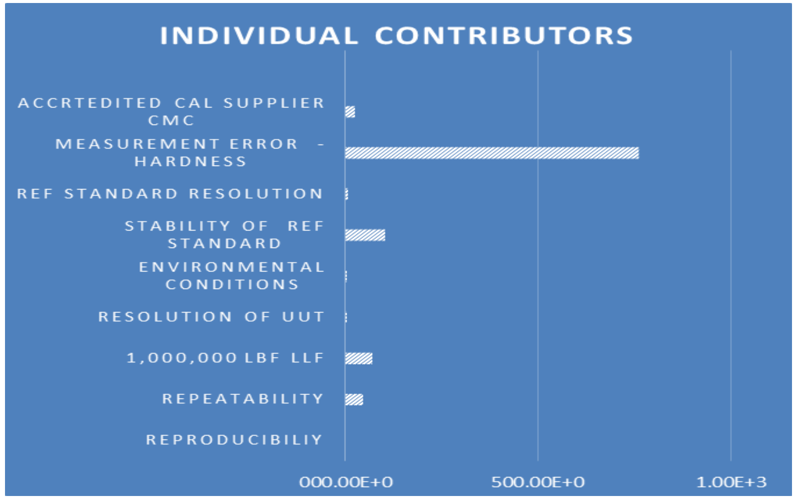
VERSUS MOREHOUSE WITH 0.0022 %

MOREOUSE	10000	LBF	SERIAL NO	EXAMPLE
%	Force Applied	COMBINED UNCERTAINTY FOR K=2		
2.00%	200	0.20836%	0.417	LBF
10.00%	1000	0.04179%	0.418	LBF
20.00%	2000	0.02108%	0.422	LBF
30.00%	3000	0.01426%	0.428	LBF
40.00%	4000	0.01091%	0.436	LBF
50.00%	5000	0.00894%	0.447	LBF
60.00%	6000	0.00766%	0.460	LBF
70.00%	7000	0.00677%	0.474	LBF
80.00%	8000	0.00613%	0.490	LBF
90.00%	9000	0.00565%	0.508	LBF
100.00%	10000	0.00527%	0.527	LBF

Different Hardness of Top Adapters

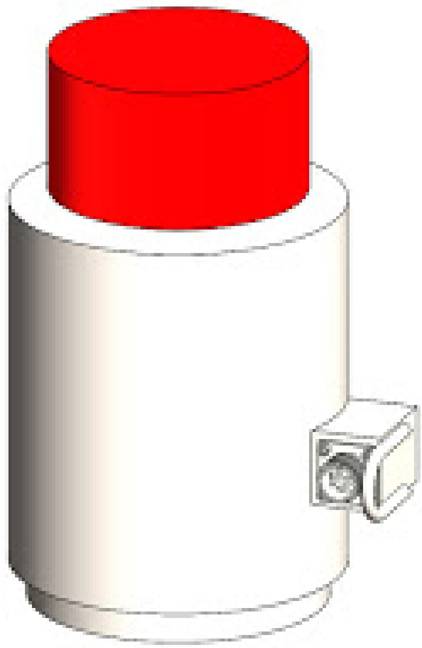
- Example: A customer brought in a 1,000,000 LBF load cell for calibration. Morehouse performed a calibration. The output of the load cell was recorded as 1,500 LBF higher than the previous calibration for a force applied 1,000,000 LBF.

- Is this a stability issue or an adapter issue?
- After calling the customer, we were informed a new top loading block was supplied with this load cell for the current calibration. When we told them what was happening, they sent the original top-loading block. When tested, the original block resulted in an output of 1,000,180 LBF when loaded to 1,000,000 LBF.



When using the new adaptor and figuring the measurement error between the different top blocks (adaptors), Expanded Uncertainty would have increased from **269 LBF** with the original top adapter to 1,490 LBF using the newly fabricated adapter.

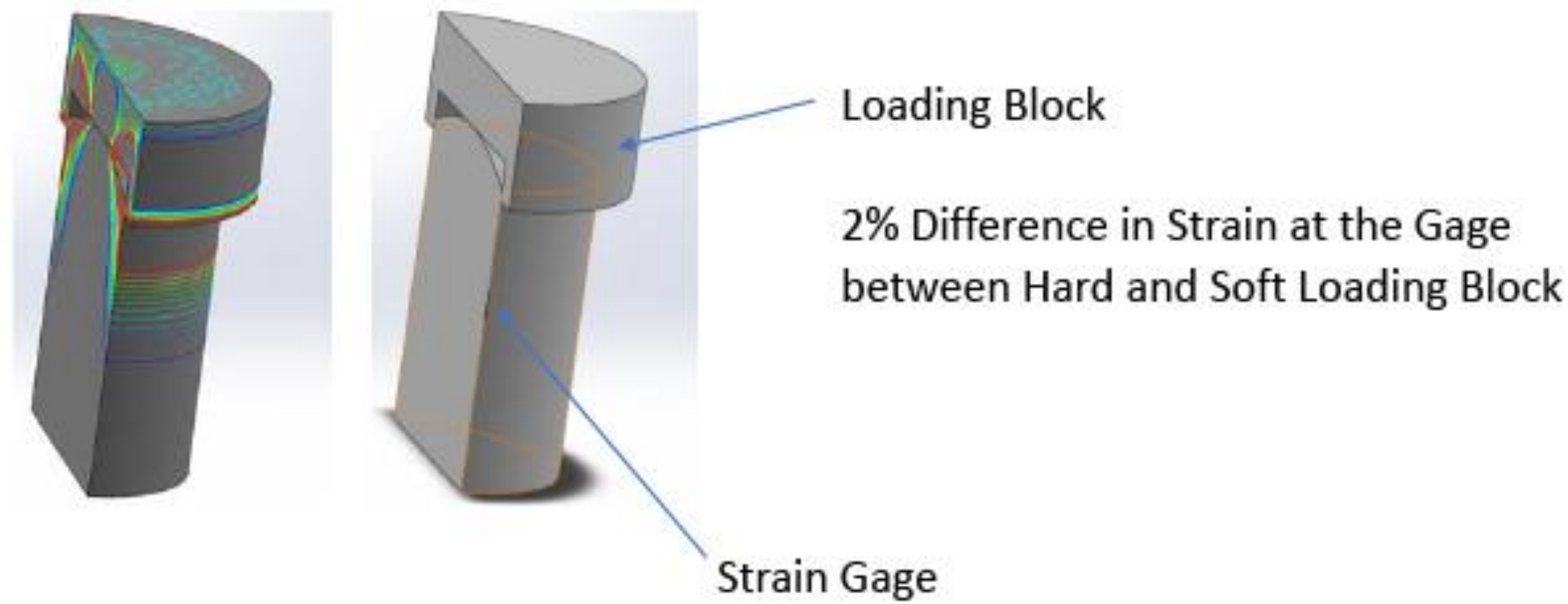
Different Hardness of Top Adapters



Different hardness of top adapters on column load cells can produce errors as high as 0.3 %

6/23/2017		6/23/2017		
4340 Top Block		Hardened Top Block		Difference
0	120	0	120	
-48968	-48960	-49120	-49109	-0.307%
-244290	-244308	-244990	-244971	-0.279%
-487279	-487320	-488596	-488570	-0.263%

Different Hardness of Top Adapters



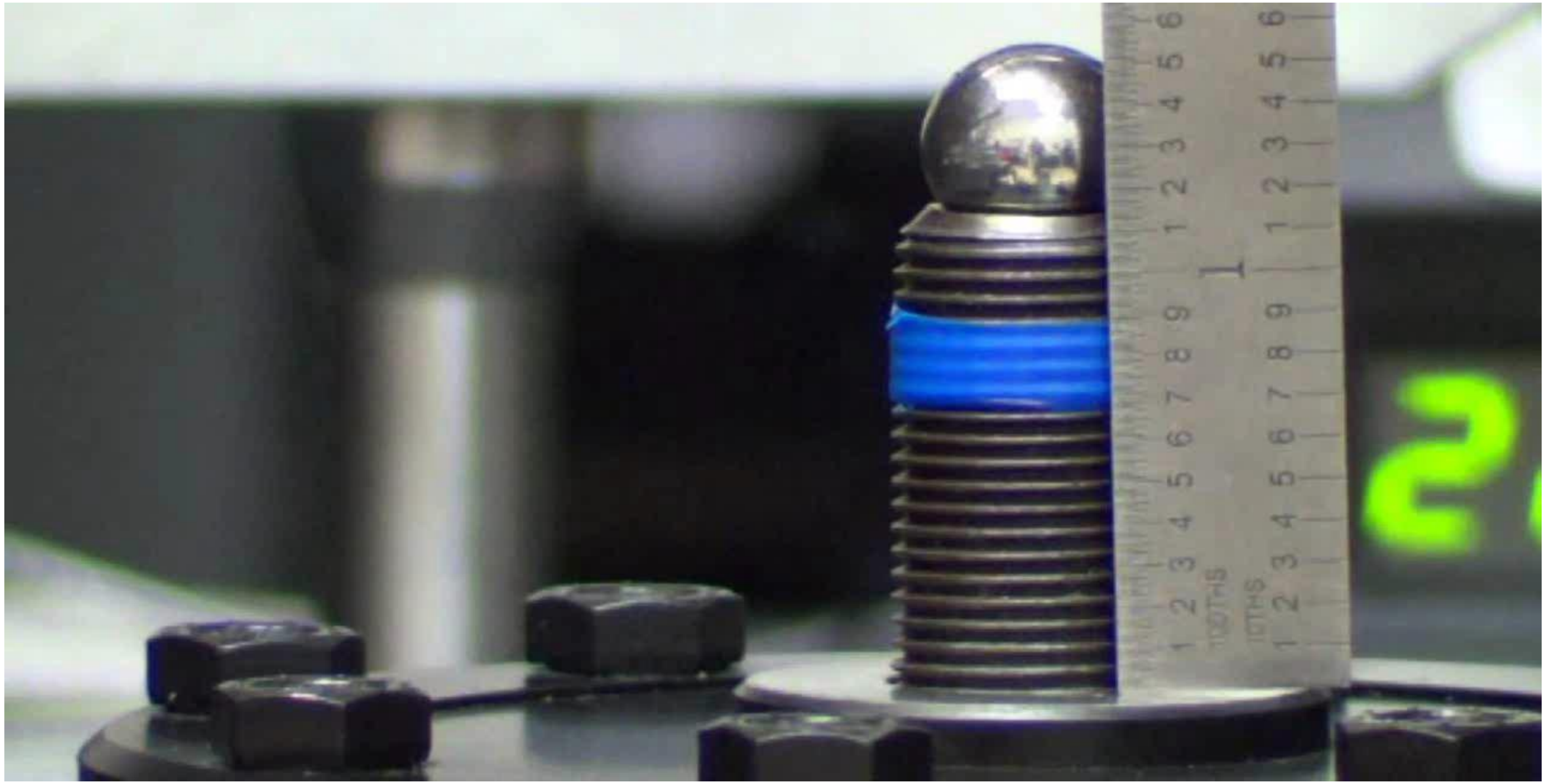
Materials with different hardness experience different amounts of lateral deflection under the same amount of load. Therefore, the varying hardness causes different amounts of stress between the block and the load cell. The above analysis shows steel to steel. It gets much worse if we use a softer material.

Different Hardness of Top Adapters

FORCE APPLIED	FITTED CURVE HARD BLOCK WITH AGILENT	FITTED CURVE SOFT BLOCK WITH AGILENT	Difference in %
10000	-0.40489	-0.4049	-0.002
20000	-0.80979	-0.8098	-0.001
30000	-1.21476	-1.21476	0.000
40000	-1.61983	-1.61983	0.000
50000	-2.02501	-2.02501	0.000
60000	-2.43031	-2.4303	0.000
70000	-2.83569	-2.83568	0.000
80000	-3.24113	-3.24111	-0.001
90000	-3.64657	-3.64655	-0.001
100000	-4.05196	-4.05192	-0.001

Morehouse Shear web cells are much more forgiving regarding the hardness of top adapters. Typically, we find errors to be below 0.005 % of applied force.

Thread Depth – Shoulder Loading Versus Thread Loading Video



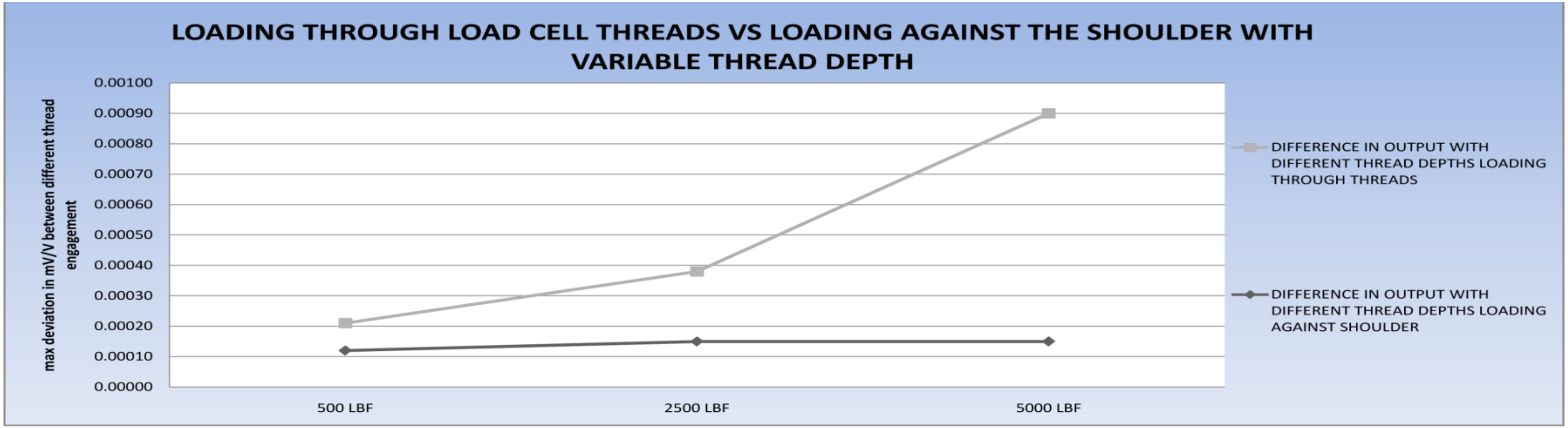
LOADING THROUGH THE THREADS POTENTIAL ERROR

On the left 0.034 % error added to the combined uncertainty vs Standard analysis on the same cell with an integral adapter locked into place

MOREOUSE	10000	LBF	SERIAL NO	EXAMPLE
%	Force Applied	COMBINED UNCERTAINTY FOR K=2		
2.00%	200	0.21201%	0.424	LBF
10.00%	1000	0.05728%	0.573	LBF
20.00%	2000	0.04449%	0.890	LBF
30.00%	3000	0.04169%	1.251	LBF
40.00%	4000	0.04067%	1.627	LBF
50.00%	5000	0.04019%	2.009	LBF
60.00%	6000	0.03992%	2.395	LBF
70.00%	7000	0.03976%	2.783	LBF
80.00%	8000	0.03966%	3.172	LBF
90.00%	9000	0.03958%	3.563	LBF
100.00%	10000	0.03953%	3.953	LBF

INTEGRAL ADAPTER LOCKED INTO PLACE CMC	
0.417	LBF
0.417	LBF
0.419	LBF
0.421	LBF
0.424	LBF
0.428	LBF
0.434	LBF
0.440	LBF
0.446	LBF
0.454	LBF
0.462	LBF

Shoulder Loading Versus Thread Loading



Proper Adapters Shear Web Cells

Solution – Purchase and lock in an integral adapter or pick a top adapter and always use and have the force measuring device calibrated with that top adapter. In this example, a Morehouse spherical load button would be an excellent top adapter for this load cell.

Different Thread Depths On a Non-Shear Web Cell

- What about non-shear web type cells?
- The different thread length of adapters may increase or decrease the amount of strain.

Measurement Risk

Have the calibration provider replicate how the device is being used

This is a Sensotec Model RFG/F226-01 load cell. I did a test with two different types of adapters and recorded the readings (10,001.5 vs 9942.3).
There was a difference of 59.2 LBF on a 10,000 LBF cell.

This is a Sensotec Model RFG/F226-01

Different type adapters. (1.5” engagement versus 0.5 “ engagement)

Measurement Risk

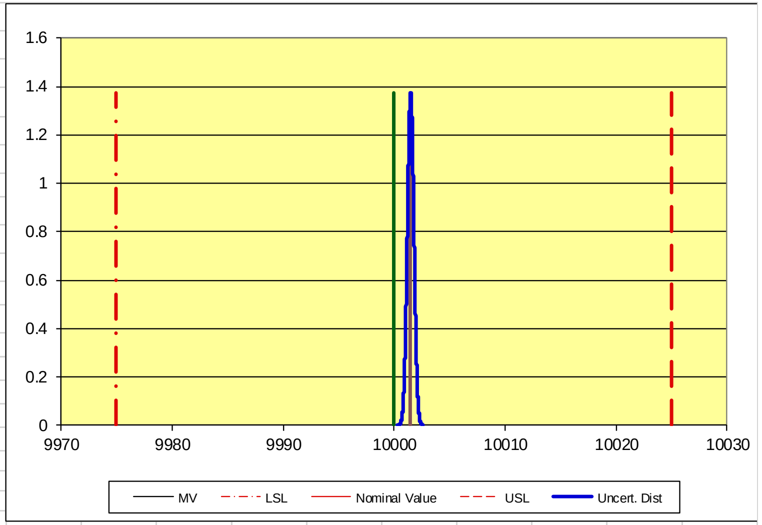
Have the calibration provider replicate how the device is being used

This is a Sensotec Model RFG/F226-01 load cell. I did a test with two different types of adapters and recorded the readings (10,001.5 vs 9942.3).

What is the probability of the measurement being within 0.25 % if the top adapter is changed out?

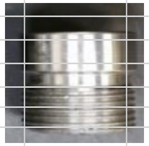
Well within 0.25 %

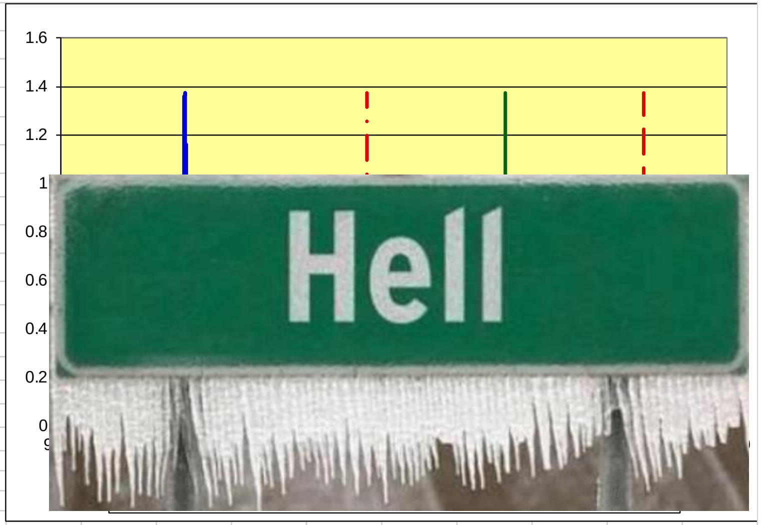
Nominal Value	10000
Lower specification Limit	9975
Upper Specification Limit	10025
Measured Value	10001.5
Measurement Error	1.5
Std. Uncert. (k=1)	0.29
Total Risk	0.00%
Upper Limit Risk	0.00%
Lower Limit Risk	0.00%
TUR =	**43.1034**



No where near 0.25 %

Nominal Value	10000
Lower specification Limit	9975
Upper Specification Limit	10025
Measured Value	9942.3
Measurement Error	-57.7
Std. Uncert. (k=1)	0.29
Total Risk	100.00%
Upper Limit Risk	0.00%
Lower Limit Risk	100.00%
TUR =	**43.1034**





Different Thread Depths on a Non-Shear Web Cell

Discussion

How should we handle this known problem with a customer load cell?

a) Call the Customer
b) Document it
c) Send a Postcard
d) Hire an Attorney
e) Do Nothing

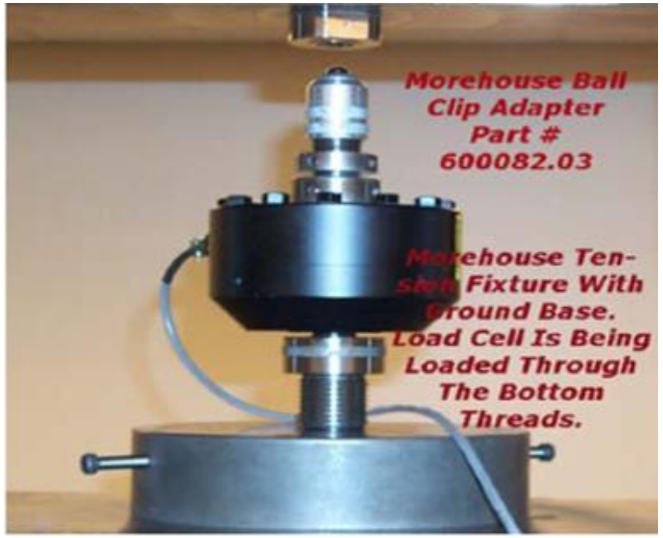
Different Thread Depths on a Non-Shear Web Cell

Solution.

Called the customer and asked for adapters (contract review).
The customer instructed us to do what we thought was best. Everything was documented, and we put this on the certificate

The above-identified instrument was calibrated in accordance with ASTM International's (American Society for Testing and Materials) standard E74-18 entitled, "Standard Practice of Calibration of Force-Measuring Instruments...", "As Returned". We could not provide an "As Received" calibration because the indicator had to be set up prior to calibration. Note: In compression, the adaptor was threaded tight against the top of the load cell. An adaptor used by Morehouse Instrument Company was threaded approximately 1.5 inches for tension and compression. The zero return values were taken approximately 30 seconds after the load was released.

Loading Through the Bottom Threads in Compression



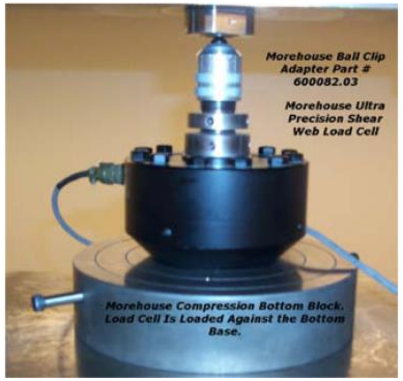
Do you think these loading profiles create a different result?

Loading Through the Bottom Threads in Compression

COMPRESSION LOADING OF LOAD CELLS LOADING AGAINST THE BASE OF THE LOAD CELL VERSUS LOADING THROUGH THE BOTTOM THREADS

THIS TEST WAS DONE TO SHOW THE POTENTIAL DIFFERENCE IN OUTPUT BY LOADING A SHEAR WEB LOAD CELL AGAINST THE BASE OF THE LOAD CELL VESUS LOADING THROUGH THE BOTTOM THREADS

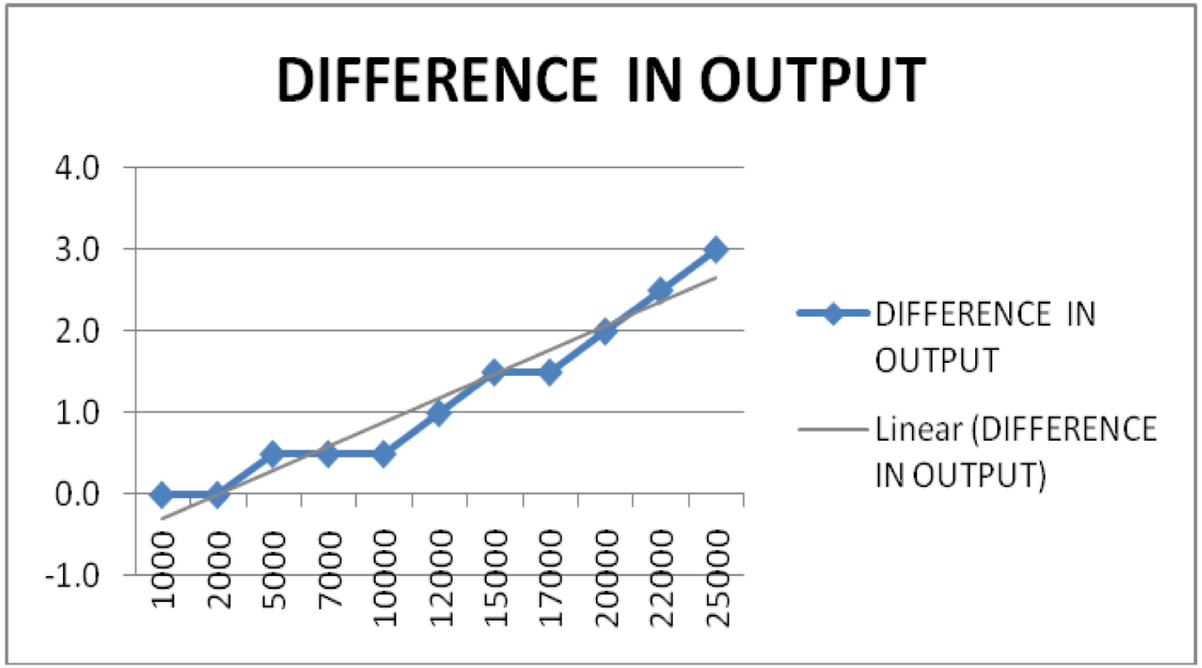
THE TEST INSTRUMENT USED WAS A MOREHOUSE ULTRA PRECISION LOAD CELL AND A MOREHOUSE 4215 METER
THE FORCE WAS APPLIED TO THE LOAD CELL USING MOREHOUSE 120,000 LB DEAD WEIGHT MACHINE S/N M-7471
THE WEIGHTS IN THIS MACHINE WERE CALIBRATED DIRECTLY BY NIST AND ARE ACCURATE TO .0015% OF APPLIED FORCE.
AN ASTM-E74 CALIBRATION WAS PERFORMED ON THE LOAD CELL AND THE UNCERTAINTY OF THE LOAD CELL WAS DETERMINED TO BE .798 LBF
FOR THE PURPOSE OF THIS TEST THE LOAD CELL WAS KEPT AT THE SAME ORIENTATION, ONLY THE BOTTOM ADAPTERS WERE CHANGED



FORCE APPLIED LBF	LOAD CELL OUTPUT LOADED AGAINST BOTTOM BASE	LOAD CELL OUTPUT LOADED AGAINST BOTTOM THREADS
1000	**999.0**	**999.0**
2000	**1998.0**	**1998.0**
5000	**4996.0**	**4996.5**
7000	**6995.0**	**6995.5**
10000	**9994.5**	**9995.0**
12000	**11994.0**	**11995.0**
15000	**14993.5**	**14995.0**
17000	**16993.5**	**16995.0**
20000	**19994.0**	**19996.0**
22000	**21994.0**	**21996.5**
25000	**24994.0**	**24997.0**

Loading Through the Bottom Threads in Compression

FORCE APPLIED LBF	DIFFERENCE IN OUTPUT	% DIFF
1000	0.0	0.000
2000	0.0	0.000
5000	0.5	0.010
7000	0.5	0.007
10000	0.5	0.005
12000	1.0	0.008
15000	1.5	0.010
17000	1.5	0.009
20000	2.0	0.010
22000	2.5	0.011
25000	3.0	0.012



CONCLUSION:

FOR THIS SHEAR WEB LOAD CELL, AS THE COMPRESSION FORCE APPLIED INCREASES THE STRAIN ON THE LOAD CELL IS GREATER WHEN LOADING THROUGH THE BOTTOM THREADS AS COMPARED WITH LOADING DIRECTLY AGAINSE THE BASE.

LOADING THIS LOAD CELL THROUGH THE BOTTOM THREADS RESULTED IN AN ERROR OF 3 LBF AT CAPACITY WHICH IS A DIFFERENCE OF ALMOST 4 TIMES THE ORIGINAL ASTM-E74 UNCERTAINTY THAT WAS CALCULATED FROM LOADING AGAINST THE LOAD CELL BASE.

IT IS IMPORTANT THE END USER UNDERSTAND AND REPLICATE HOW THE CALIBRATION LABORATORY CALIBRATED THE FORCE MEASURING INSTRUMENT TO ENSURE ACCURATE FORCE MEASUREMENTS.

Loading Through the Bottom Threads in Compression

Potential Error due to loading through the bottom threads versus flat

0.012 % Error with different adapters vs loading against the base

MOREHOUSE	10000	LBF	SERIAL NO	EXAMPLE
%	Force Applied	COMBINED UNCERTAINTY FOR K=2		
2.00%	200	0.20880%	0.418	LBF
10.00%	1000	0.04396%	0.440	LBF
20.00%	2000	0.02510%	0.502	LBF
30.00%	3000	0.01972%	0.592	LBF
40.00%	4000	0.01745%	0.698	LBF
50.00%	5000	0.01629%	0.815	LBF
60.00%	6000	0.01563%	0.938	LBF
70.00%	7000	0.01521%	1.065	LBF
80.00%	8000	0.01494%	1.195	LBF
90.00%	9000	0.01475%	1.327	LBF
100.00%	10000	0.01461%	1.461	LBF

MOREHOUSE	10000	LBF	SERIAL NO	EXAMPLE
%	Force Applied	COMBINED UNCERTAINTY FOR K=2		
2.00%	200	0.20834%	0.417	LBF
10.00%	1000	0.04171%	0.417	LBF
20.00%	2000	0.02093%	0.419	LBF
30.00%	3000	0.01403%	0.421	LBF
40.00%	4000	0.01061%	0.424	LBF
50.00%	5000	0.00857%	0.428	LBF
60.00%	6000	0.00723%	0.434	LBF
70.00%	7000	0.00628%	0.440	LBF
80.00%	8000	0.00558%	0.446	LBF
90.00%	9000	0.00504%	0.454	LBF
100.00%	10000	0.00462%	0.462	LBF

Morehouse Threaded Adapters

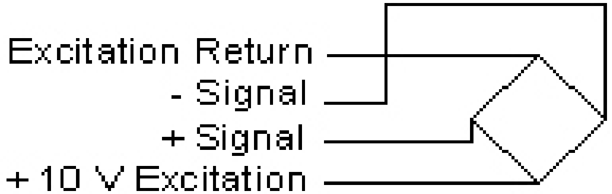
- Morehouse Threaded Adapters can be used for loading though the threads in compression and/or tension if needed.

Cable Length Error

- Load cells used with meters that have a 4-wire configuration are subject to additional errors. This is because of voltage drop over cable lengths and the effect on thermal span characteristics of the load cell, as temperature changes can alter cable resistance.

Cable Length Error

- Substitution of a 4-wire cable at a given length with another 4-wire cable of a different length or gauge will produce additional errors. (Recalibration will be required)



What you need to know about 4 wire systems.

1. If you damage or replace your cable, the system may need to be calibrated immediately following replacement or repair.
2. Operating at different temperatures will change the resistance, which will cause a voltage drop, resulting in a change of measured output.
3. Cable substitution will result in an additional error and should be avoided.
4. Cables used for 4-wire systems should have an S/N or a way to make sure the same cable stays with the system it was calibrated with. - This would be a Good Measurement Practice Technique Morehouse highly recommends.

Temperature Effects on Cables

- Since cable resistance is a function of temperature, the cable response to temperature change affects the thermal span characteristics of the load cell/cable system. For 6-wire systems, this effect is eliminated.

- For non-standard 4-wire cable lengths, there will be an effect on thermal span performance.

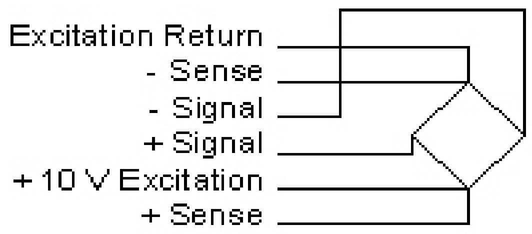
Cable Length Error

If using a 6-wire meter and wired properly, this error becomes minimalized.

- With a 6-wire setup, the sense lines are separate from the excitation lines, thereby eliminating effects due to variations in lead resistance.
- This allows long cable runs in outdoor environments with extreme temperatures.

Cable Length Error (6 wire it makes sense)

- Wiring a 6-wire cable for sense is as easy as running two lines from the load cell's positive excitation pin and two wires from the load cell's negative excitation pin; the remaining 2 wires are run to positive and negative sense.



Cable Length Conclusion

On the left 0.106 % error added to the combined uncertainty vs Standard analysis on the same cell with a 6-wire cable

MOREOUSE	10000	LBF	SERIAL NO	EXAMPLE
%	Force Applied	COMBINED UNCERTAINTY FOR K=2		
2.00%	200	0.24164%	0.483	LBF
10.00%	1000	0.12931%	1.293	LBF
20.00%	2000	0.12418%	2.484	LBF
30.00%	3000	0.12320%	3.696	LBF
40.00%	4000	0.12286%	4.914	LBF
50.00%	5000	0.12270%	6.135	LBF
60.00%	6000	0.12261%	7.357	LBF
70.00%	7000	0.12256%	8.579	LBF
80.00%	8000	0.12253%	9.802	LBF
90.00%	9000	0.12251%	11.026	LBF
100.00%	10000	0.12249%	12.249	LBF

6 Wire Cable CMC

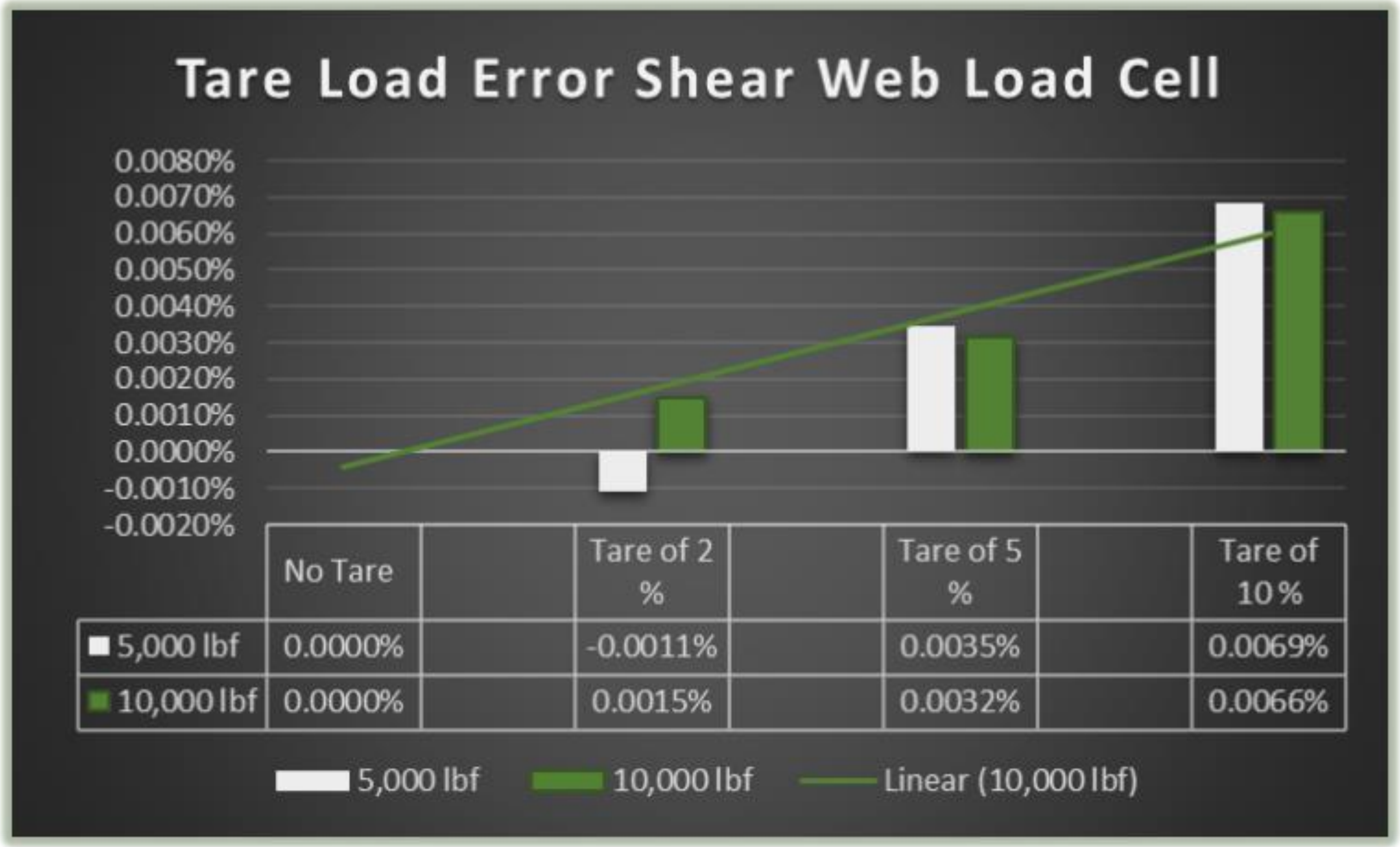
0.417 LBF
0.417 LBF
0.419 LBF
0.421 LBF
0.424 LBF
0.428 LBF
0.434 LBF
0.440 LBF
0.446 LBF
0.454 LBF
0.462 LBF

10 Volt Versus 5 Volt DC Excitation

MODEL: ULTRA PRECISION
MOREHOUSE Load Cell, SERIAL NO. U-7643
10000.00 LBF Compression Calibrated to 10000.00 LBF
MOREHOUSE 4215, SERIAL NO. 61120

	10 VOLT DC EXCITATION	5 VOLT DC EXCITATION		
Applied Load	Values from Fitted Curve	Values from Fitted Curve	Change from Previous	% Change from Previous
200	-0.08219	-0.08217	-0.000020	0.024
1000	-0.41091	-0.41092	0.000010	-0.002
3000	-1.23302	-1.23311	0.000090	-0.007
5000	-2.05548	-2.05567	0.000190	-0.009
7000	-2.87821	-2.87849	0.000280	-0.010
9000	-3.70110	-3.70146	0.000360	-0.010
600	-0.24654	-0.24654	0.000000	0.000
2000	-0.82191	-0.82196	0.000050	-0.006
4000	-1.64421	-1.64435	0.000140	-0.009
6000	-2.46682	-2.46706	0.000240	-0.010
8000	-3.28964	-3.28997	0.000330	-0.010
10000	-4.11258	-4.11296	0.000380	-0.009

Tare Load Errors

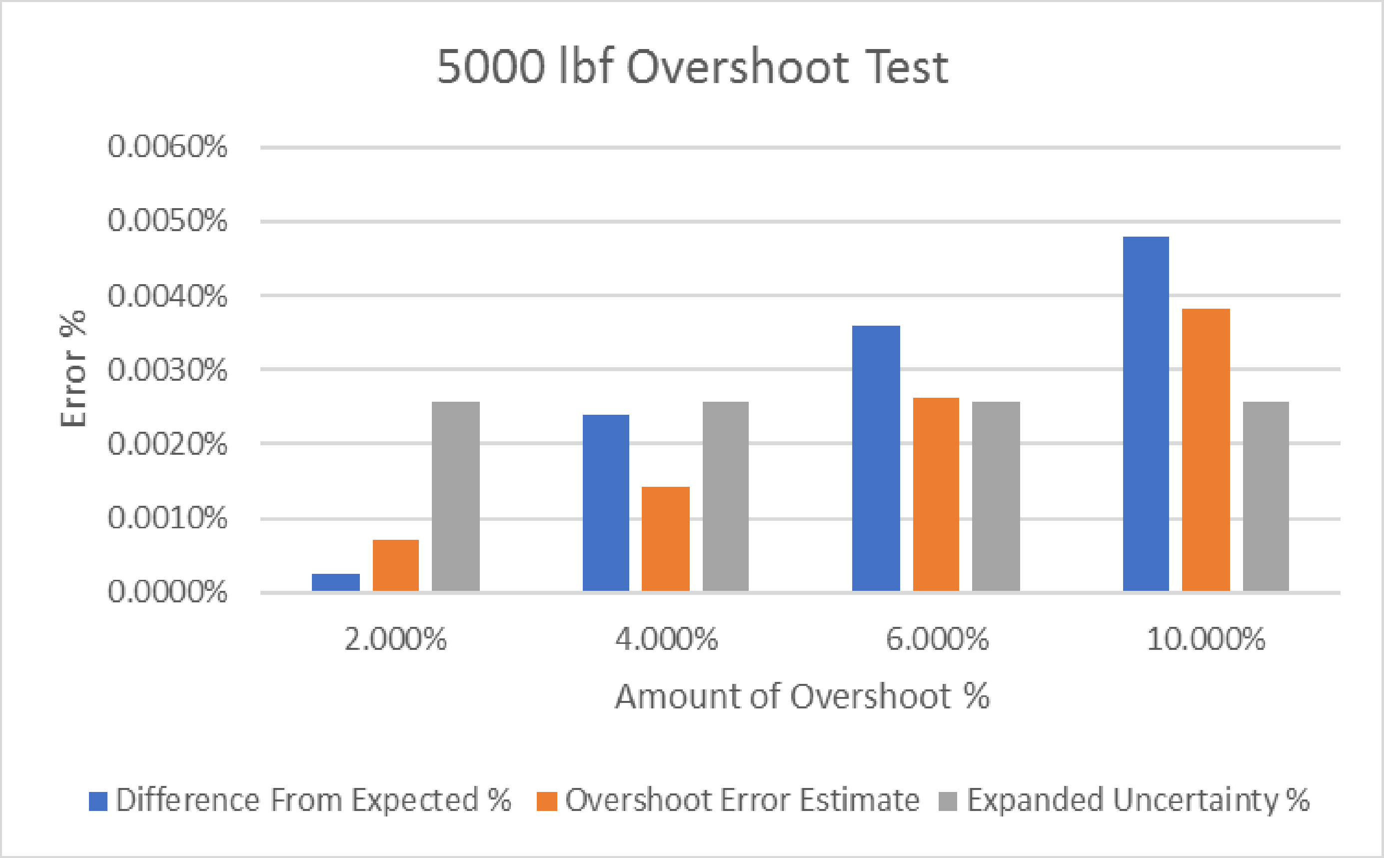


	No Tare	Tare of 2 %	Tare of 5 %	Tare of 10 %
5,000 lbf	0.0000%	-0.0011%	0.0035%	0.0069%
10,000 lbf	0.0000%	0.0015%	0.0032%	0.0066%

- https://mhforce.com/how-to-correct-for-tare-weight-when-using-load-cells-or-proving-rings/

Overshooting a Force Point

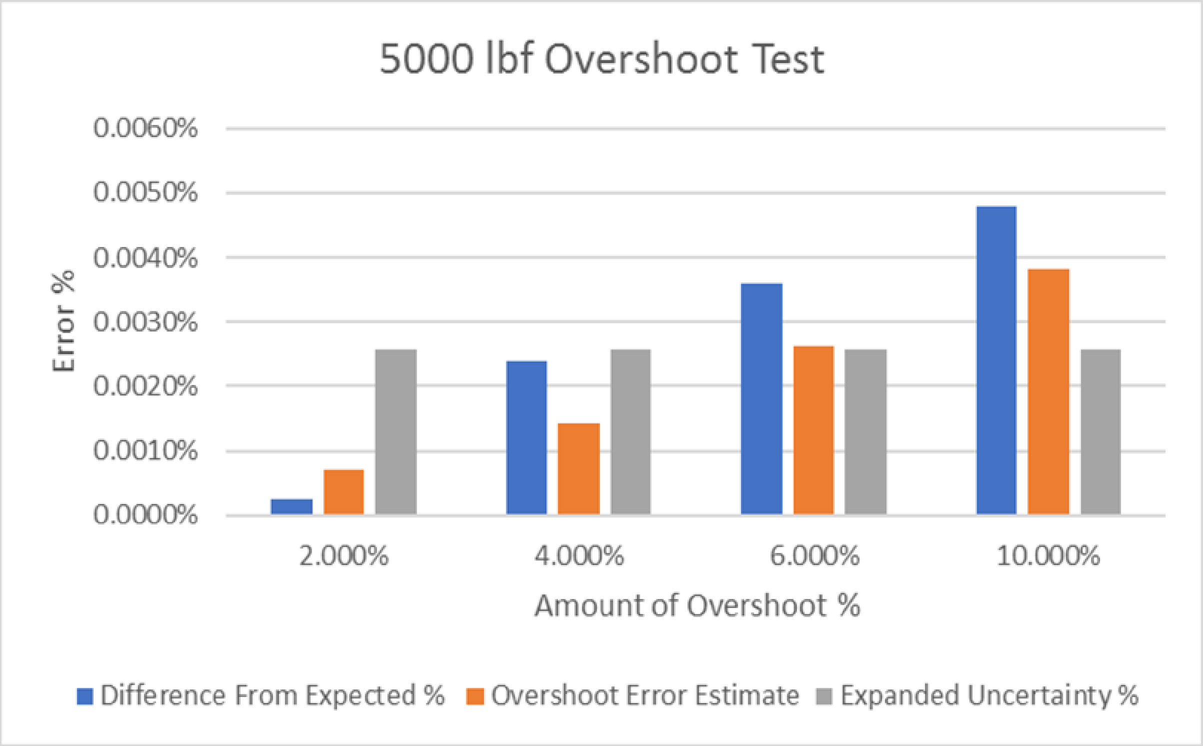
Force Applied	% Overshoot	Output	Diff from expected %	Repeatability Error %	Overshoot Error Estimate
5000	0%	-4.18260	0	0.0010%	
5000	2%	-4.18259	0.0002%	0.0010%	-0.0007%
5000	4%	-4.1827	0.0024%	0.0010%	0.0014%
5000	6%	-4.18275	0.0036%	0.0010%	0.0026%
5000	10%	-4.1828	0.0048%	0.0010%	0.0038%



Overshooting a Force Point

% Overshoot	Difference From Expected %	Overshoot Error Estimate	Expanded Uncertainty %	Combined Uncertainty	Difference
2.000%	0.0002%	0.0007%	0.0026%	0.0029%	0.0004%
4.000%	0.0024%	0.0014%	0.0026%	0.0038%	0.0013%
6.000%	0.0036%	0.0026%	0.0026%	0.0058%	0.0033%
10.000%	0.0048%	0.0038%	0.0026%	0.0081%	0.0055%

$$u = \sqrt{(\frac{CMC}{k})^2 + (\frac{Res}{3.464})^2 + (\frac{Rep}{1})^2}$$



More Info can be found here


With Morehouse's newly automated system, my technician rarely overshoots test points!
Must be nice . . .


PROUDLY
MADE IN THE USA

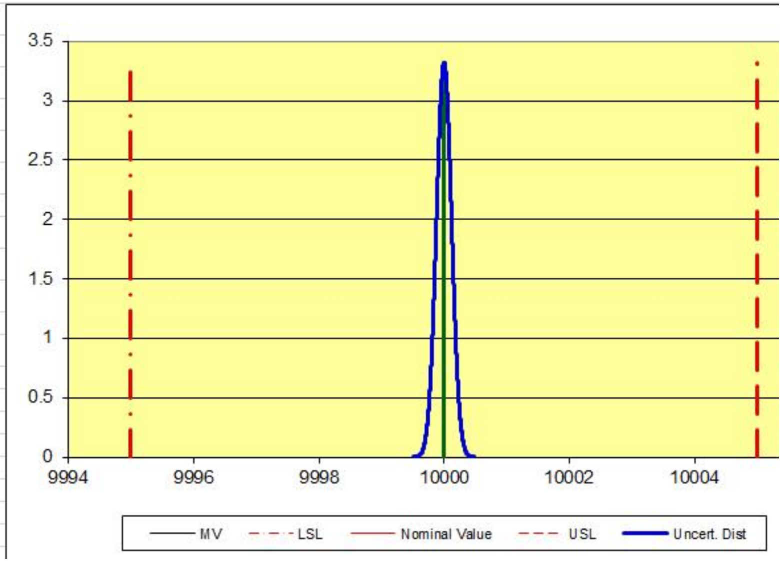
Other Error Sources

- Time differences in calibrations
- Drift of Calibration Standards with Time

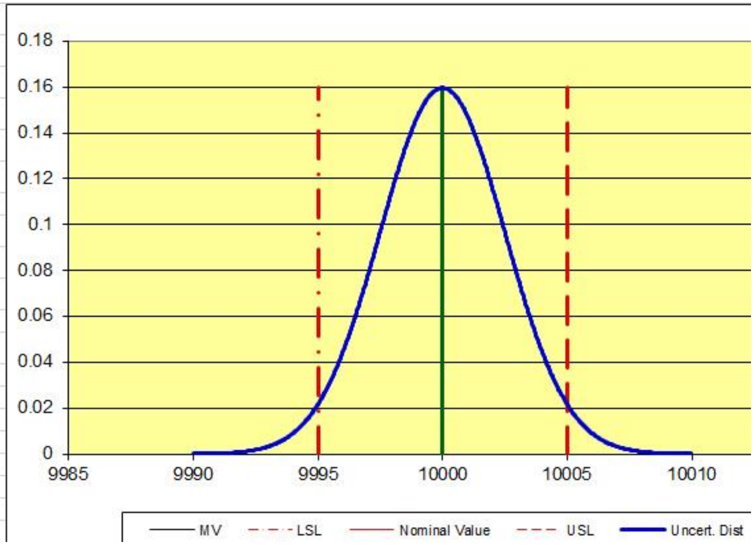
Morehouse
THE FORCE IN CALIBRATION SINCE 1925

Why is Measurement Uncertainty Important?

Nominal Value	10000
Lower specification Limit	9995
Upper Specification Limit	10005
Measured Value	10000
Measurement Error	0
Std. Uncert. (k=1)	0.12
Total Risk	0.00%
Upper Limit Risk	0.00%
Lower Limit Risk	0.00%
TUR =	20.8333



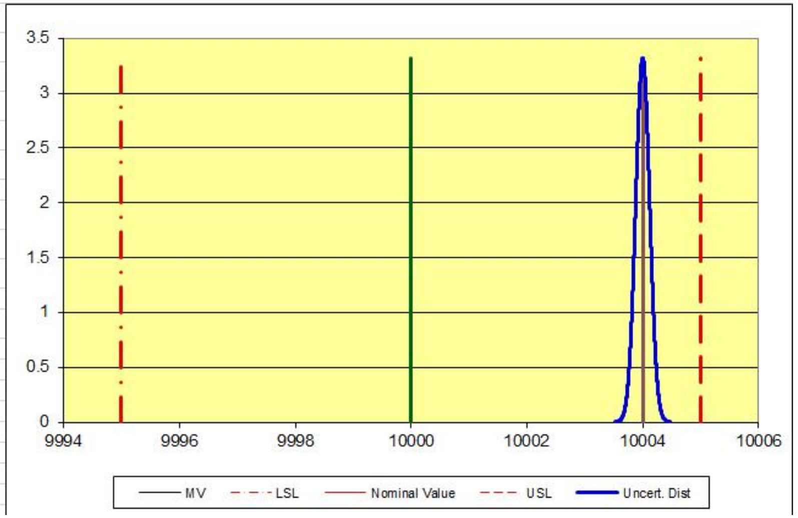
Nominal Value	10000
Lower specification Limit	9995
Upper Specification Limit	10005
Measured Value	10000
Measurement Error	0
Std. Uncert. (k=1)	2.5
Total Risk	4.55%
Upper Limit Risk	2.28%
Lower Limit Risk	2.28%
TUR =	1



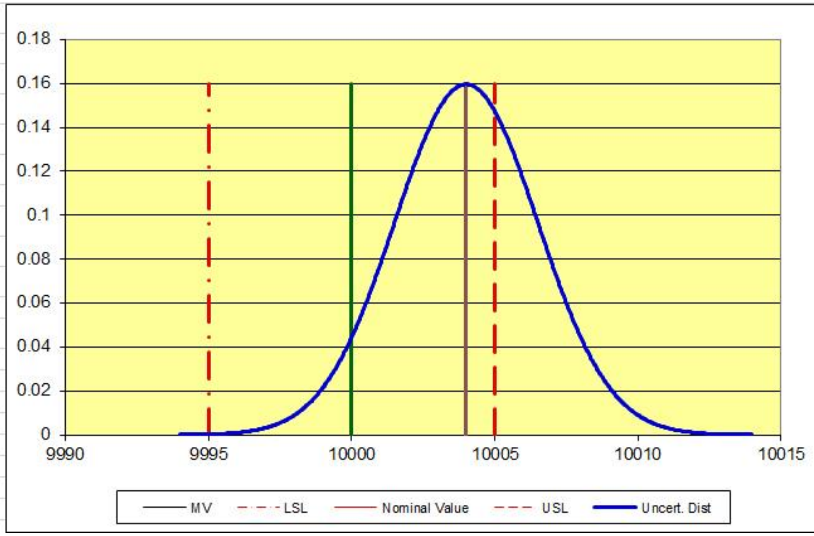
Notice the instrument reads 10,000 lbf when 10,000 lbf was applied. In this specific risk example, only the calibration provider with the lower measurement uncertainty can make the claim that the instrument is in tolerance if the requirement is less than a 2 % PFA.

Morehouse Vs Typical Force Lab

Nominal Value	10000
Lower specification Limit	9995
Upper Specification Limit	10005
Measured Value	10004
Measurement Error	4
Std. Uncert. (k=1)	0.12
Total Risk	0.00%
Upper Limit Risk	0.00%
Lower Limit Risk	0.00%
TUR =	20.8333



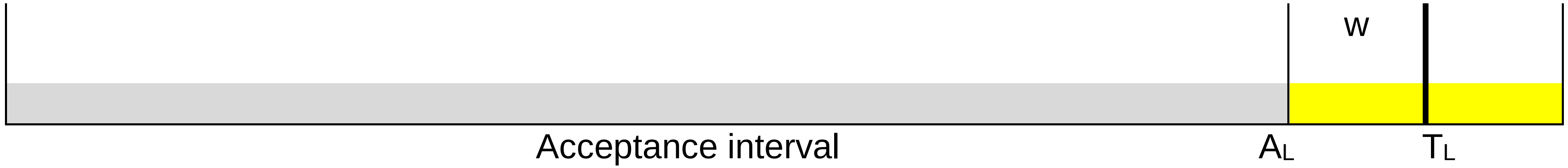
Nominal Value	10000
Lower specification Limit	9995
Upper Specification Limit	10005
Measured Value	10004
Measurement Error	4
Std. Uncert. (k=1)	2.5
Total Risk	34.47%
Upper Limit Risk	34.46%
Lower Limit Risk	0.02%
TUR =	1



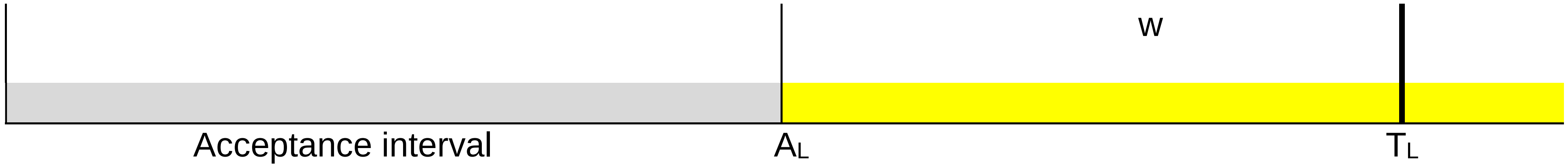
When the measured value is changed to 10,004 lbf, most people would think the device is still in tolerance. When Morehouse calibrates it, it is. When the lab with a CMC of 0.05 % calibrates it, the risk goes from 4.66 % to 34.47 %.

Large versus Small Expanded Uncertainty

A) Small relative expanded uncertainty U =T/10 and w=U

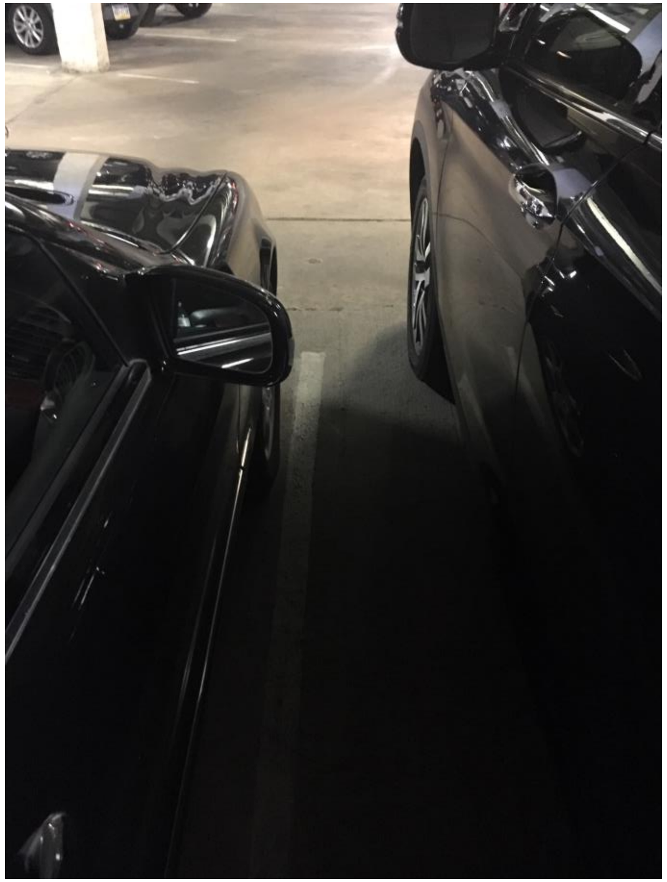


B) Large relative expanded uncertainty U=(T/2) and w=U



The lab with the smaller uncertainties will typically produce larger TURs, giving you more space to be in tolerance!

The lab with the larger uncertainties will typically produce smaller TURs, giving you less space to be in tolerance!



Why Measurements Matter

Your Calibration Provider Cannot Help Unless You

Choose the Right Equipment – Always choose Measuring and Test Equipment that can achieve the measurement tolerance required.

- Several manufacturers do not understand Guardbanding and setting the proper acceptance limits and do not include the instrument’s resolution or repeatability or the reference standard used to perform the calibration in their accuracy claims. This results in accuracy claims that are not achievable when including the instrument's resolution and repeatability
- On most of these instruments, no reference standard in the world will lower the risk if the instrument shows any bias.

The Right Equipment for Force

The right equipment for force is going to be made to minimize off-center loading, bending, and torsion. To do this force machines need to be:

1. Plumb
2. Level
3. Square
4. Rigid
5. Free of Torsion

The Right Equipment

The right equipment for force is going to be:

Plumb-exactly vertical or true.

Pictured Right – Morehouse 1,000 lbf automated deadweight machine that is plumb. In this machine, the weights hang in a vertical direction, and if they are out of plumb, they will introduce misalignment through the vertical line of force.

The Right Equipment

The right equipment for force is going to be:

Level-a device for establishing a horizontal line or plane by means of a bubble in a liquid that shows adjustment to the horizontal by movement to the center of a slightly bowed glass tube.

Pictured Right – Morehouse 100,000 lbf UCM. The upper and lower platen are ground flat, and the adjustable feet allow the end user to obtain a level condition. If level is not achieved, errors from misalignment will happen.

The Right Equipment

Rigid – not flexible. If the loading surface starts to bend, all sorts of alignment errors can happen, which will impact the results.

Pictured Right - Morehouse USC-60K With Reference Load and Morehouse 4215 Indicator – the top and bottom plates are reinforced to keep the machine from bending.

The Right Equipment

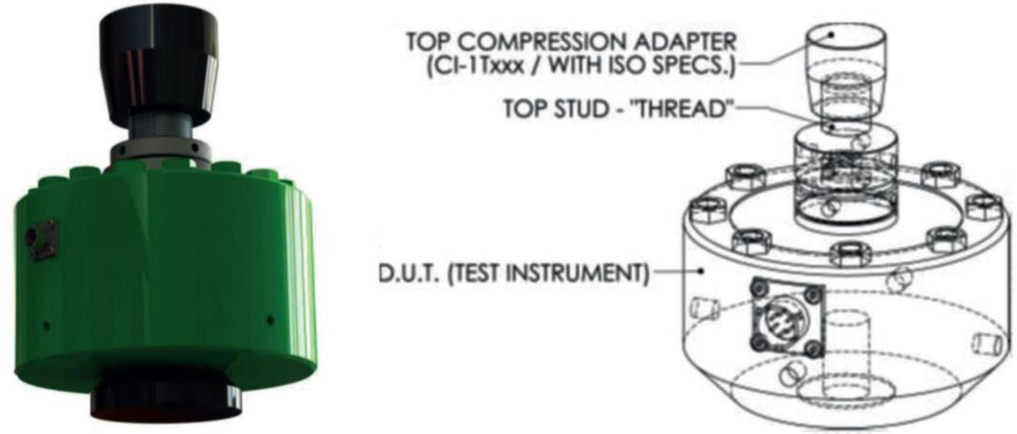
Torsion – the action of twisting or the state of being twisted. Free of torsion means free of being twisted when forces are applied.

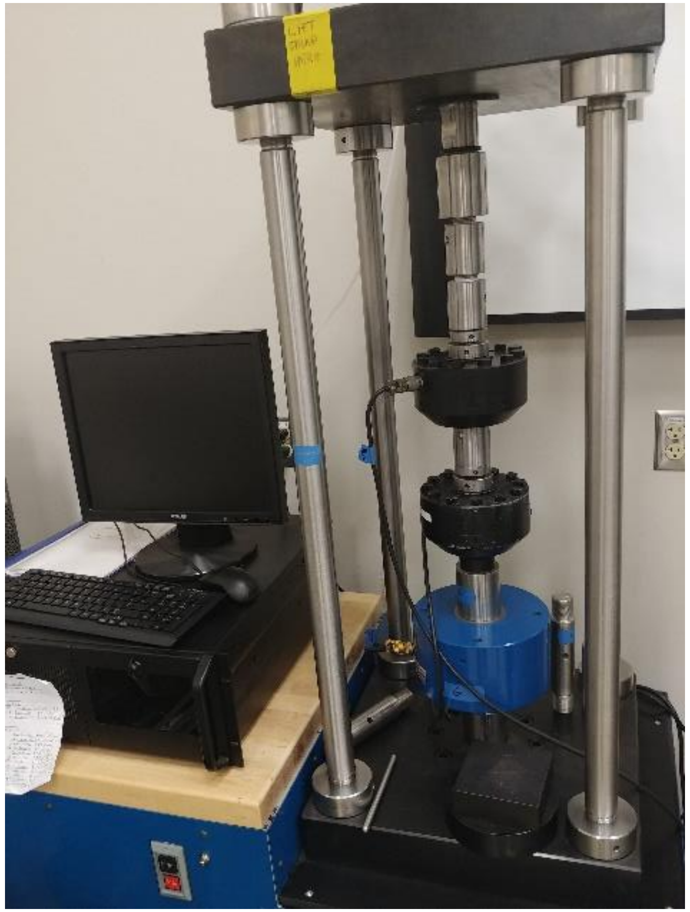
Pictured Right - Morehouse PCM-2K With Reference Load Cell. This machine has special bearings to keep things from twisting. Before putting in the bearings, the measurement errors were higher than 0.1 %. when we added the bearings, the errors became less than 0.02 %, which is better than most transfer standard-type machines.

The Right Equipment

Replicates Field Use

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

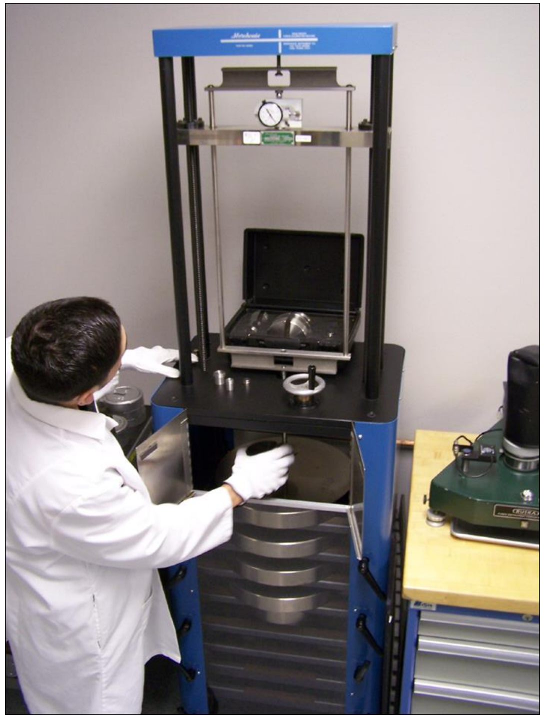


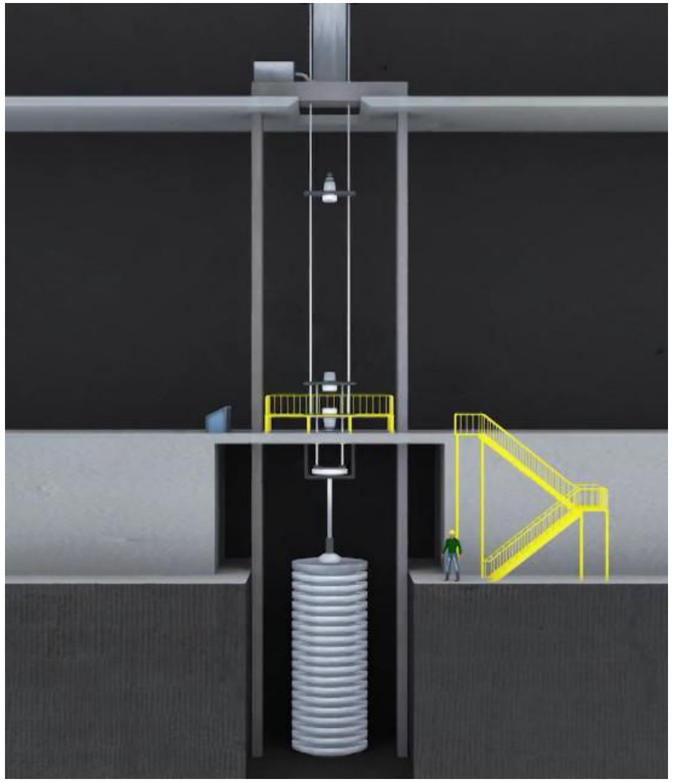


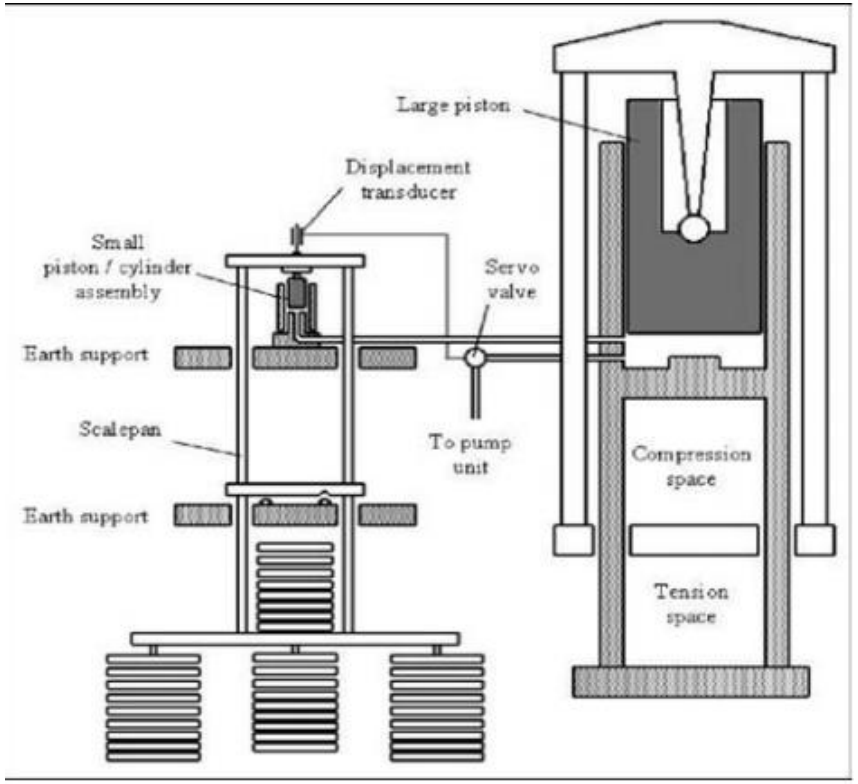
One of these does not replicate how the equipment is used in the field. Which One?

The Right Equipment

Replicates Field Use







The Right Equipment

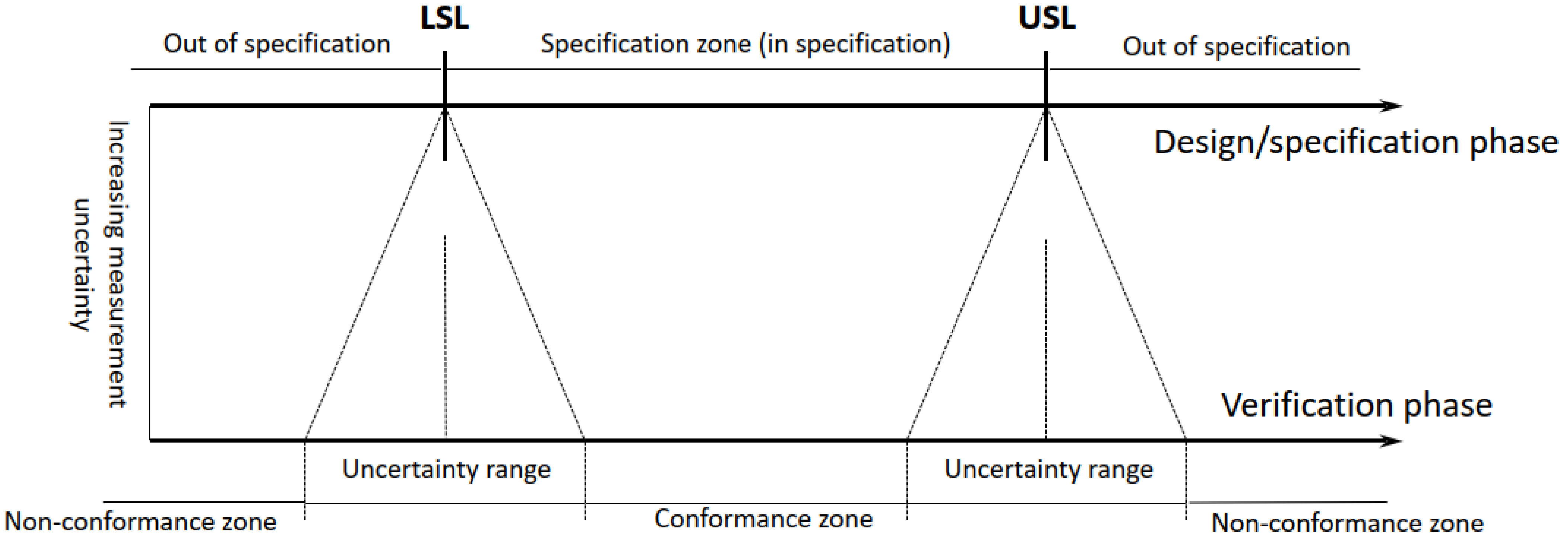
Replicates Field Use

To Replicate Field Use for ASTM E4 & ISO 7500 Calibrations in These Types of Machines

- The Calibration Laboratory Should Not Perform Compression and Tension Calibration in the Same Setup (Common Practice, as it is much quicker).
- They should use the Customer's Top Blocks and make Separate Compression Setups.
- In Compression, they Should Require a Baseplate to Load Against.
- For tension calibration, if the end user is calibrating per ISO 7500, they should use adapters recommended per the ISO Annex, which would be different from what is shown here.

Choosing The Right Equipment

The Reference Equipment chosen could affect your ability to issue a conformity statement of “Pass”



The Right Processes?

Torque Measurement

Intercomp TL8500™ Tension Link Dynamometers are used by Texas oil field companies to measure the torquing force being applied to equipment. As this equipment is being serviced and assembled, these precision measurement devices play a vital role in ensuring proper specifications are being achieved while also improving operational efficiency and safety.

> "Our customers love the precision they get from the Intercomp TL8500™ Tension Links," said John Marquis, Sales Director for Industrial Scale Company, Inc. "Before, there wasn't any way to know how much torque was being applied, but now they can ensure they are meeting the required specifications."

The TL8500™ Tension Links have also yielded increased operational efficiency by reducing the staff and equipment required to perform these types of jobs.

"One of the main reasons Intercomp TL8500™'s are being used is due to the optional audible alarm available," continued Marquis, "Combined with their large, easy-to-read display, knowing when the optimal force reading has been reached is now be a one man job."

A large display and an audible alarm let workers know when the optimal torque has been reached.

A large, backlit, LCD display and long battery life make the TL8500™ Tension Link a top choice for many different applications and industries.

Torque= lift force x Sin(t) x wrench length
t = angle and assuming 45 degrees based on visual from picture, sine would be square root of 2 divided by 2 or about 0.71 (This equate to about 29 % error in the torque measurement). If the angle where 90 degrees, the sine error goes away.

Anyone this this is a good way to accurately measure torque?

Example of not following the standard

What's Wrong Here?

PERFORMANCE

TEST LOAD APPLIED (lbf)	Recorded Readings (Lb) Run 1	Run 2	Run 3	Fitted	Error 1	Error 2	Error 3
0	0.0	0.0	0.0	0.05	0.05	0.05	0.05
500	499.9	499.8	500.3	500.06	0.16	0.26	-0.24
1000	1000.1	1000.1	1000.3	999.94	-0.16	-0.16	-0.36
2000	1999.4	1999.3	1999.5	1999.52	0.12	0.22	0.02
3000	2999.1	2999.0	2999.2	2999.08	-0.02	0.08	-0.12
4000	3998.7	3998.6	3999.0	3998.84	0.14	0.24	-0.16
5000	4998.8	4998.8	4999.0	4998.89	0.09	0.09	-0.11
6000	5999.2	5999.3	5999.5	5999.26	0.06	-0.04	-0.24
7000	6999.7	6999.9	7000.2	6999.86	0.16	-0.04	-0.34
8000	8000.4	8000.4	8000.7	8000.51	0.11	0.11	-0.19
9000	9000.7	9000.8	9001.0	9000.95	0.25	0.15	-0.05
10000	10000.5	10000.8	10001.3	10000.81	0.31	0.01	-0.49
4000	4001.5	4001.4	4001.4				
0	-0.2	0.0	0.0				

POLYNOMIAL COEFFICIENTS FOR ASCENDING FITTED CURVE

Coefficients*	Inverse**
Coefficient A0= 5.072350e-002	Coefficient A0= -5.091823e-002
Coefficient A1= 1.000166e+000	Coefficient A1= 9.998345e-001
Coefficient A2= -3.470746e-007	Coefficient A2= 3.466446e-007
Coefficient A3= 7.319854e-011	Coefficient A3= -7.312871e-011
Coefficient A4= -3.939503e-015	Coefficient A4= 3.935937e-015

Standard Deviation	=	0.20026	lbf
Standard Deviation / Span	=	0.00200	%
Lower Limit Factor	=	0.48	lbf
Class A Lower Limit	=	192.3	lbf

*Reading = A0 + A1*Load + A2*Load^2 + A3*Load^3 + A4*Load^4
**Load = IA0 + IA1*Reading + IA2*Reading^2 + IA3*Reading^3 + IA4*Reading^4

Per Section 8.6 of ASTM E74-18 *"The verified range of forces shall not include forces outside the range of forces applied during the calibration."*

Force Measurement Tiers and Calibration Uncertainty

📐 Understanding the Hierarchy:
- Tier 1: Primary Standards (deadweight) — CMC as low as 0.0016%
- Tier 2: Secondary Standards — Calibrated using Tier 1
- Tier 3: Working Standards — Calibrated by Tier 2, used in the field
- Tier 4: Field Verification/Test Machines — Typically, much higher uncertainty

📊 Uncertainty Propagation:
Measurement uncertainty accumulates from Tier 1 → Tier 4. Proper traceability and equipment selection are key to minimizing total system uncertainty.

Load Cell System and Measurement Risk Conclusion

- Choose the right load cell for your application. An S-Beam load cell is not going to perform well as a standard for doing ASTM E4 calibrations in compression.
- Know what the manufacturer considered when they set the unit specifications.
- Choosing a readout that is stable with enough resolution is going to yield the best results.
- None of this matters if your calibration provider cannot calibrate to the accuracy required or if they do not follow published standards.

Questions (True or False)

Pin Size on a tension link can affect output?

The flatness of the bottom adapter can affect the reproducibility of load cells?

A 1,000,000 lbf column load cell will typically weigh less than 50 lbs.

Most button load cells can achieve better than 0.5 % of full-scale reproducibility.

Repeatability can often be improved by taking more measurements?

Questions (Multiple Choice)

What Load Cells are more sensitive to off axis loading?

a) S-beam

b) Button Type

c) Single Column

d) All of the above

Conclusion

Please join us in educating the people who underestimate the importance of following the standards, asking the right questions, and using the proper machines and adapters.

Using what was presented today, you can help us create a safer world by helping companies improve their force measurements.

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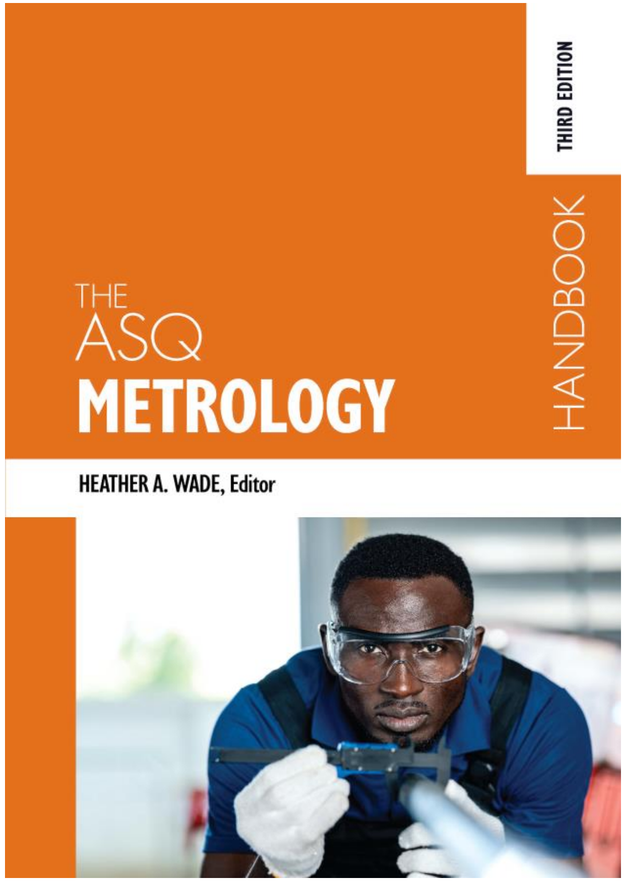
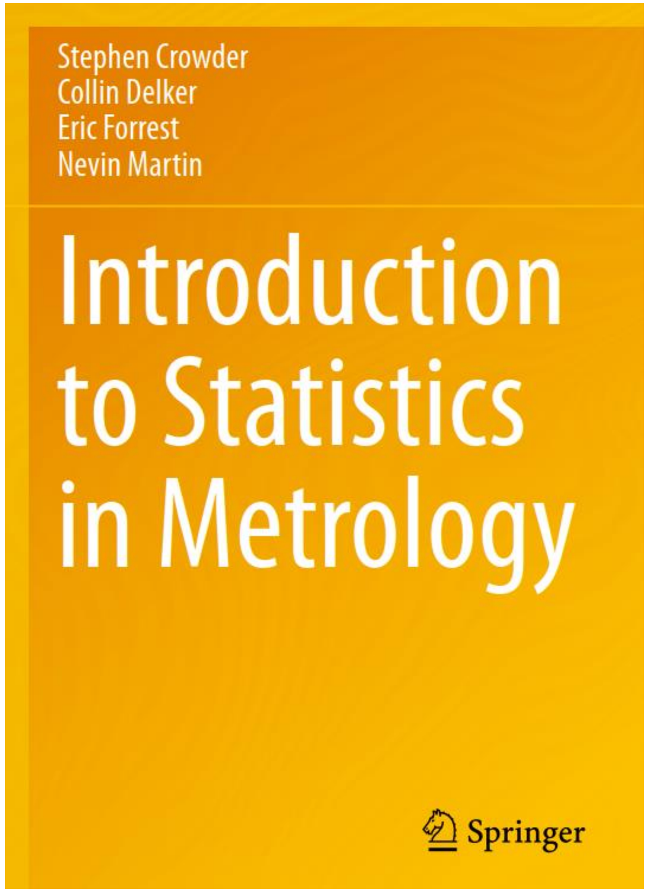
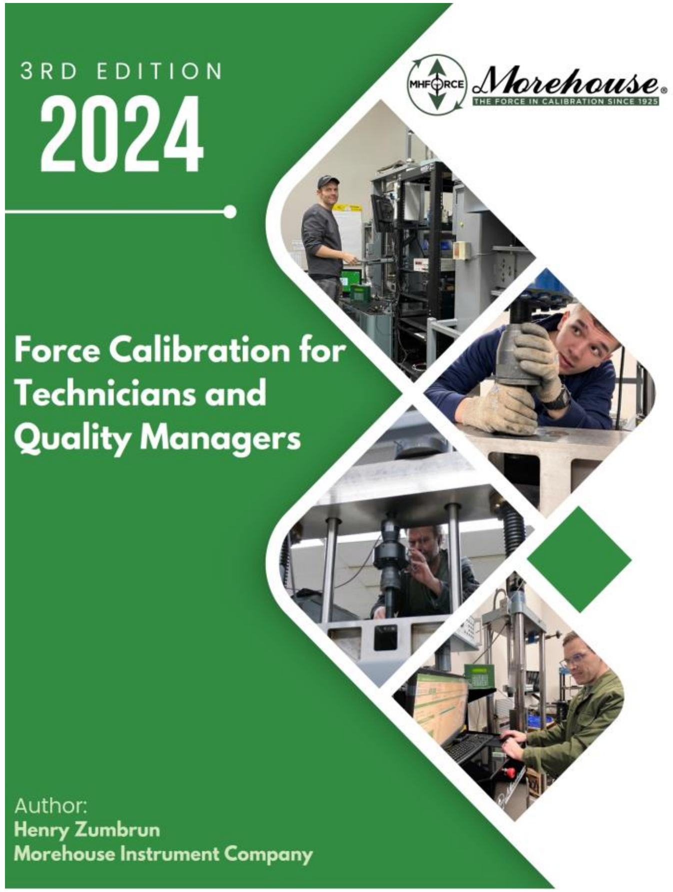
We create a better safer world by helping companies improve their force and torque measurements

Recommended Reading

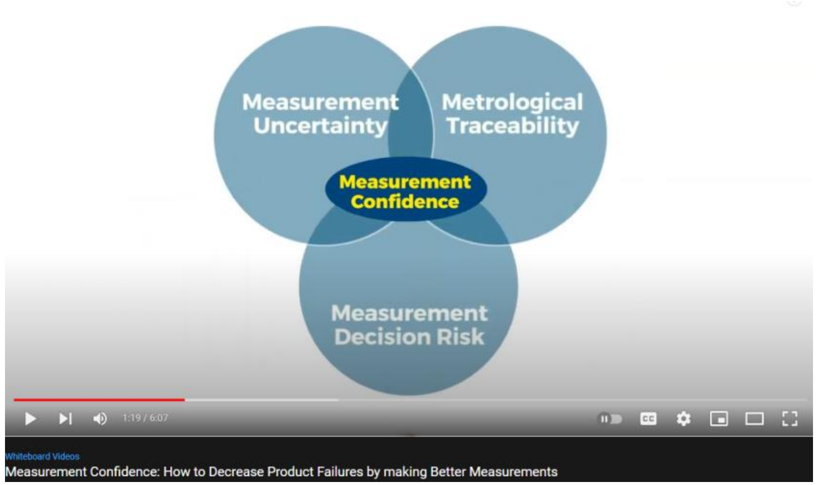






[Free Download: Force Calibration eBook 2024 Edition (mhforce.com)]

Want More Information?



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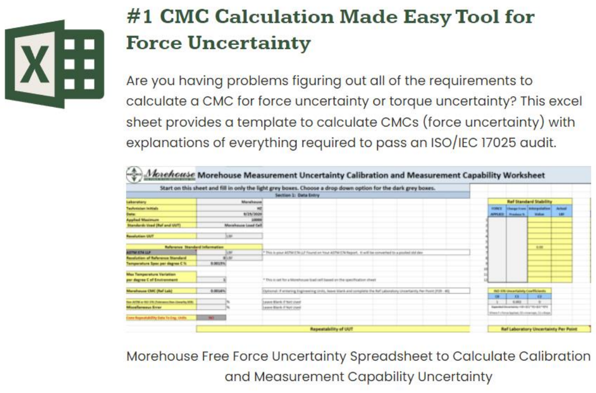

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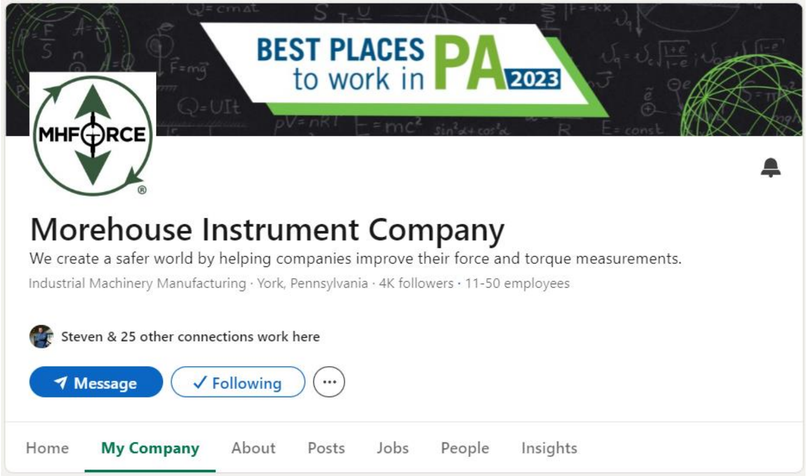

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