FUNDAMENTALS OF FORCE CALIBRATION ½ DAY COURSE

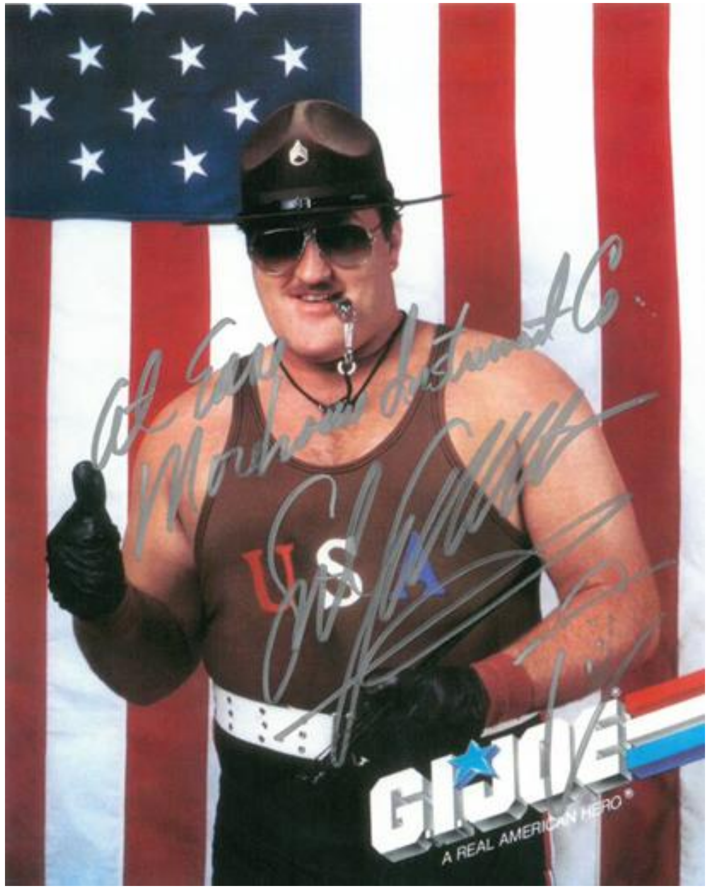
MHFORCE

Morehouse

THE FORCE IN CALIBRATION SINCE 1925

SCAN ME

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 2, 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 and will cover the importance of calibrating force measurement devices in the way they are being used to reduce measurement errors and lower uncertainty.

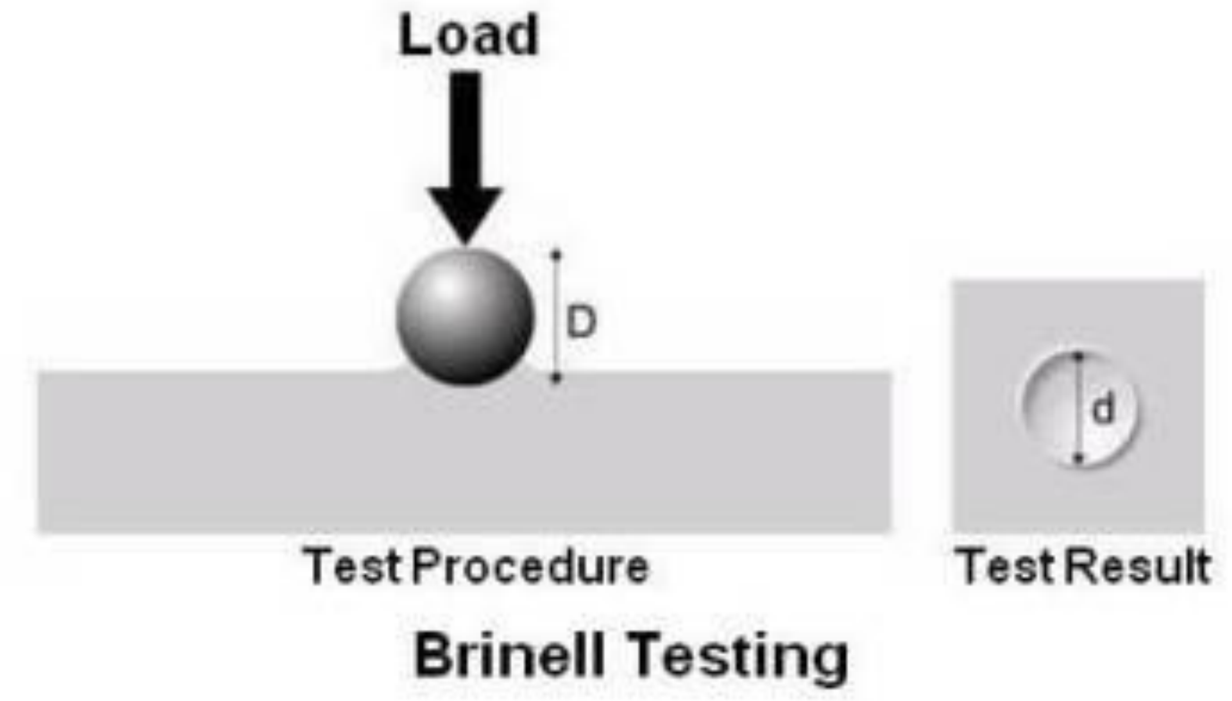
- There will be mini review sessions throughout today's session.

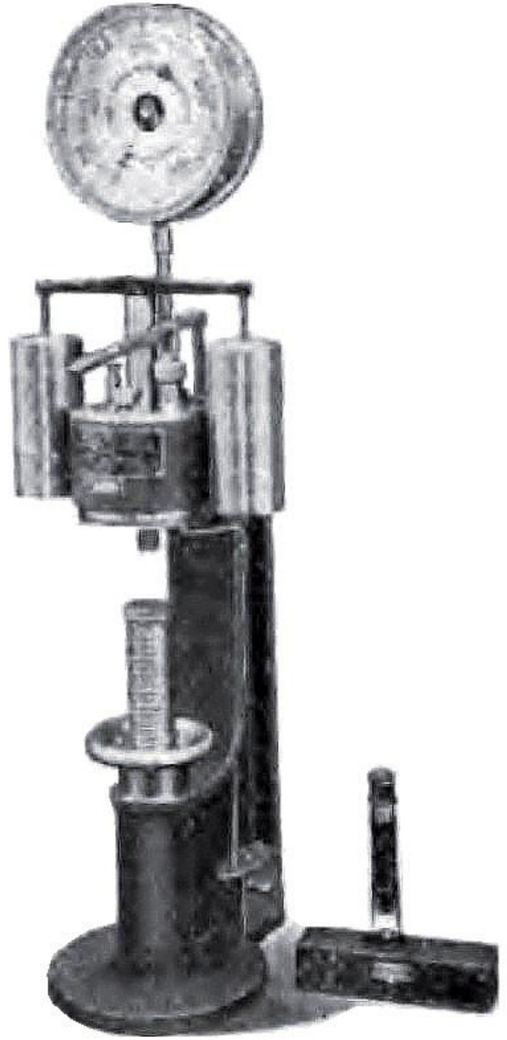
Course Agenda – Imagine Leaving This Session With Knowledge About All of the Information Below

- Company History – Introductions (10 minutes)
- Force Calibration
- Force Calibration Equipment
- Choosing the right load cell system
- Low-Capacity Force Measurements
- ASTM E74 (Brief Discussion)
- Potential Force Measurement errors
- TUR and Measurement Risk

Why we exist?

Why we exist?





1921 Brinell Hardness Machine

Company History

- 1920’s – Morehouse and the U.S. Bureau of Standards started to design and refine force calibration products (Proving Rings) for the purpose of generating 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

Morehouse
THE FORCE IN CALIBRATION SINCE 1925

Form 1a
11—5809

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

Informal Request
May 21, 1926

Bureau of Standards

Certificate

FOR

Proving Ring
No. 14

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

SUBMITTED BY W. E. Morehouse

B. S. No. 47197

COPY

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 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. 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 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.

Introductions

- Please state the following

- Name (Preferably your name)
- Experience level?
- A Question about Force Calibration you may have?

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!

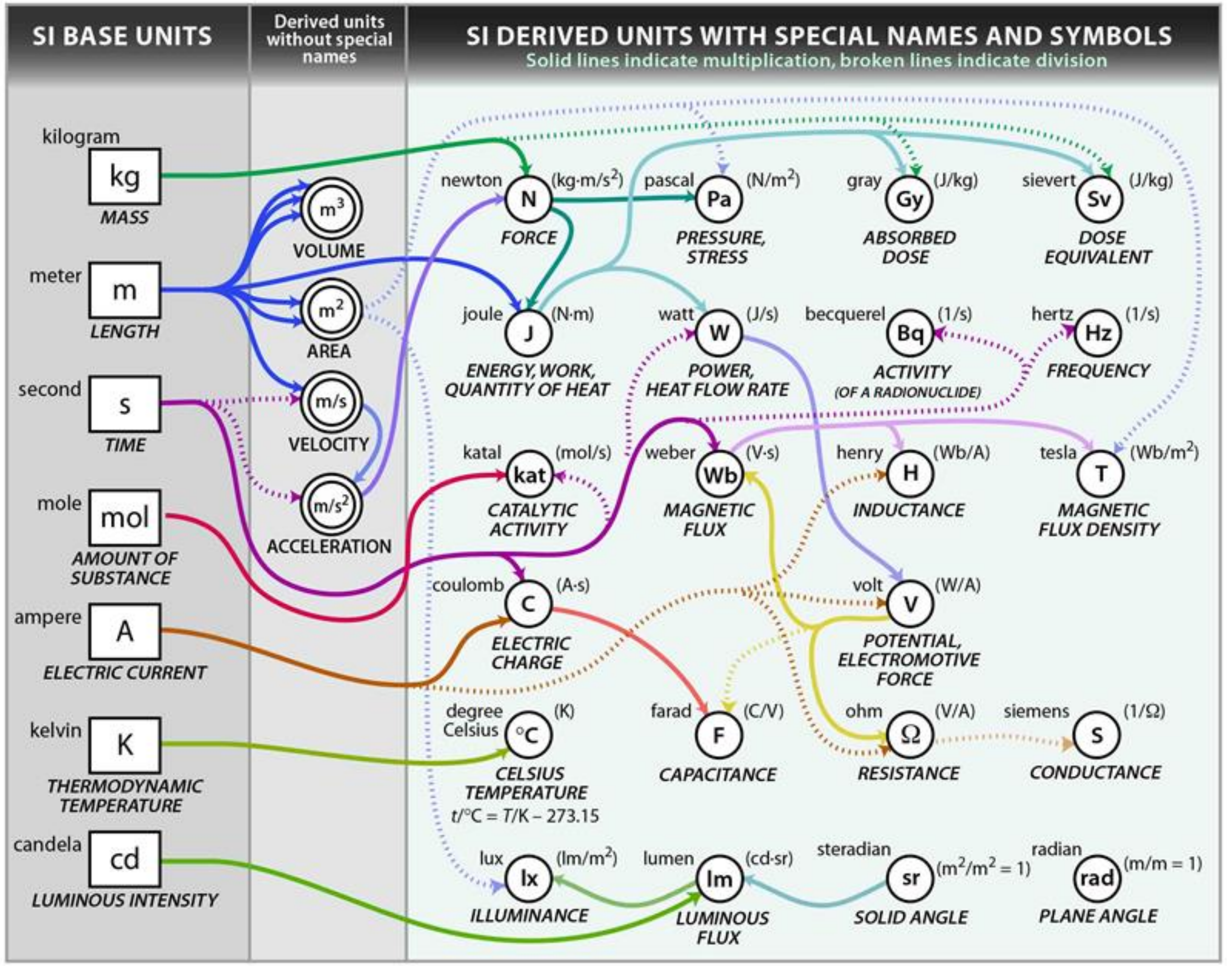
Learning Objectives

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

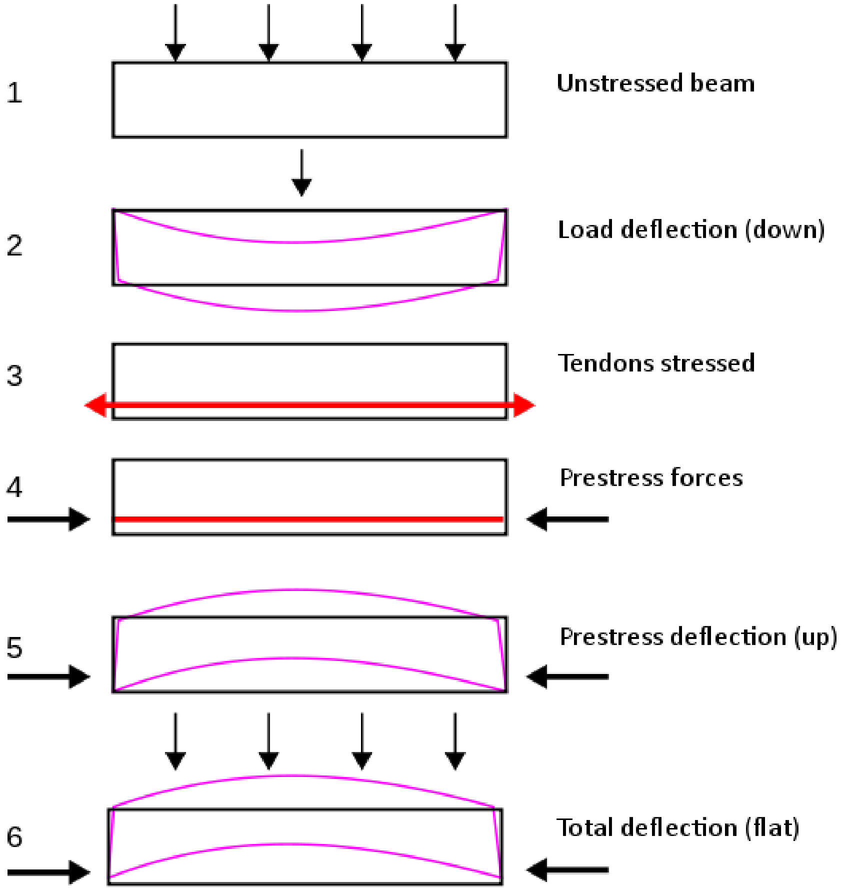
What **happens if we do not perform force measurements properly?**

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

What could happen if you fail to get the force measurement correct.



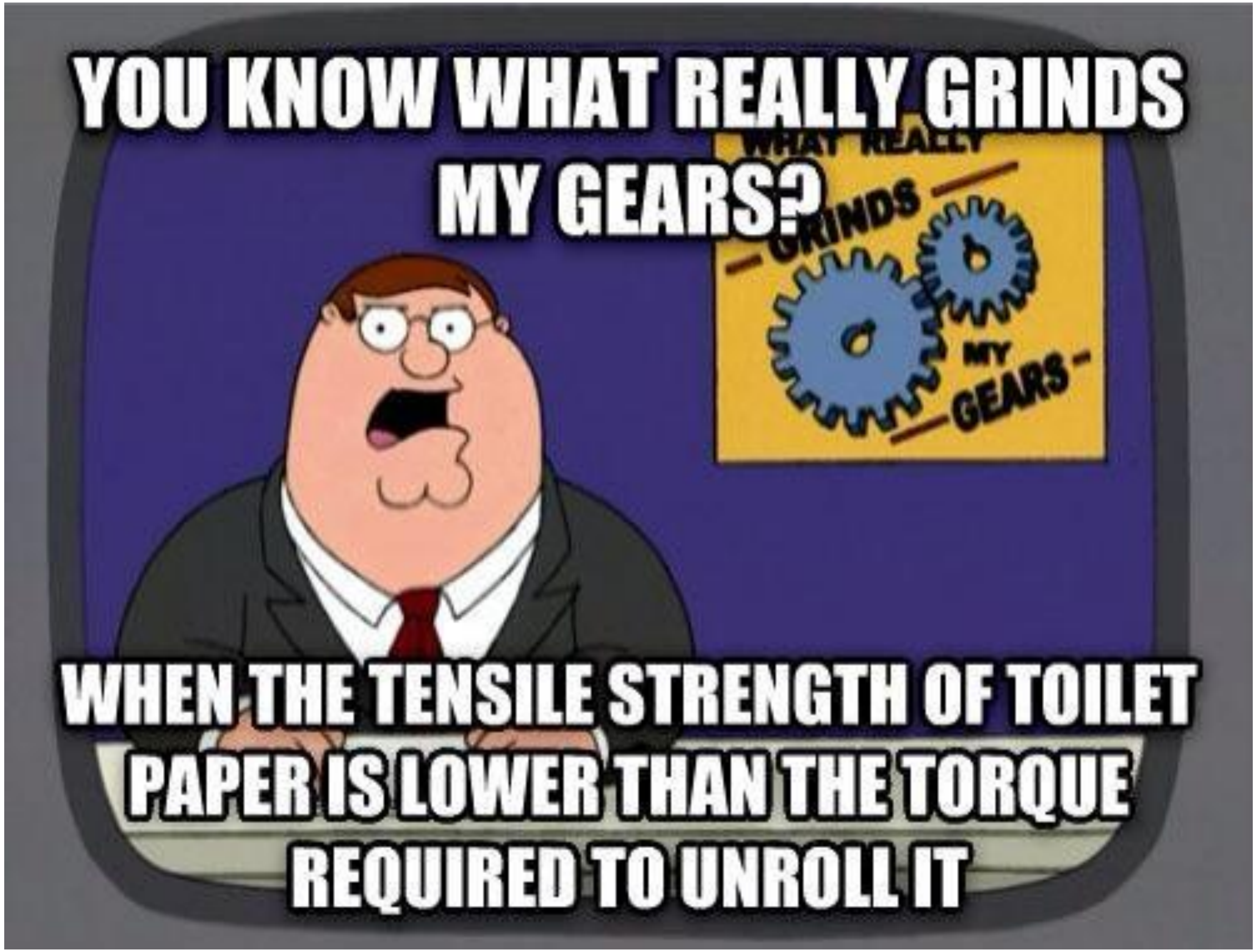
Force General information
Why is force measurement important?

- *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.

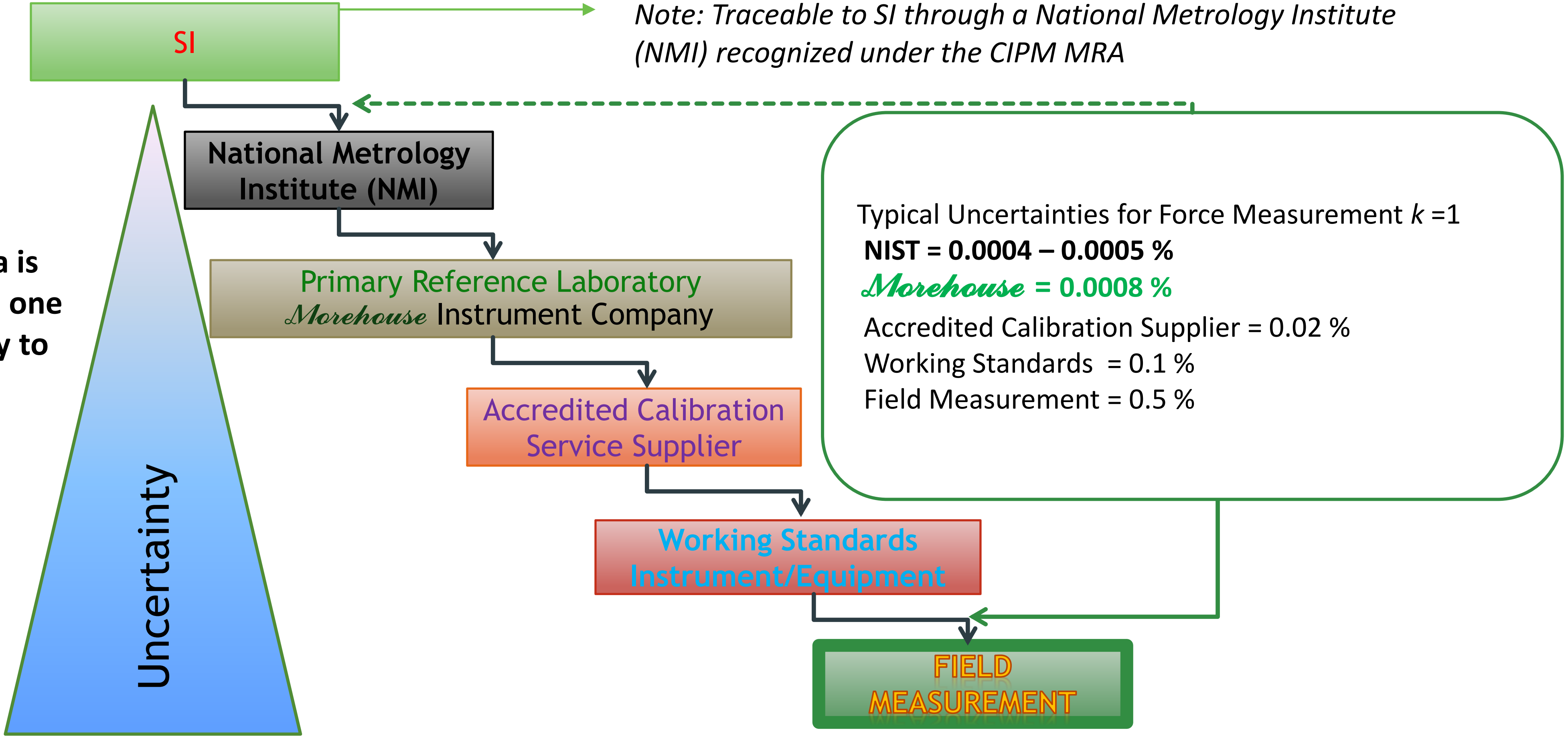
- These products may vary from the wood that was used to build your house to the cardboard that holds your toilet paper on the roll.


YOU KNOW WHAT REALLY GRINDS MY GEARS?
WHAT REALLY GRINDS MY GEARS
WHEN THE TENSILE STRENGTH OF TOILET PAPER IS LOWER THAN THE TORQUE REQUIRED TO UNROLL IT

Measurement Traceability and Uncertainties

Typical Metrological Traceability Uncertainties for Force Measurements

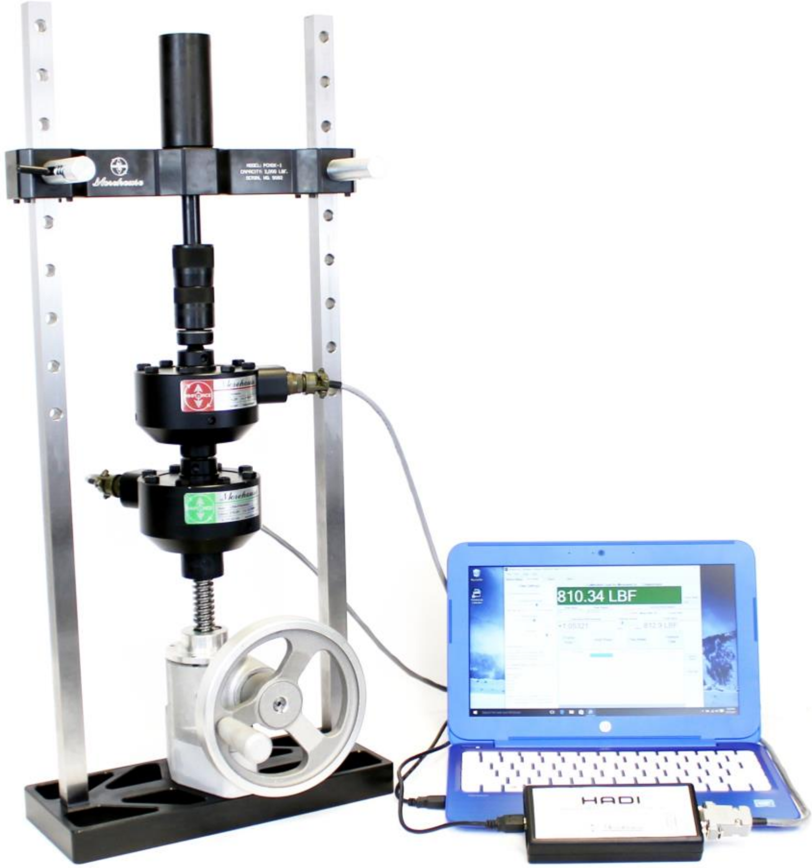
Measurement Uncertainty Data is cumulative from one level of hierarchy to another!



Force General information
Why is force measurement important?

Aircraft Weighing Applications

Force CMC's at Different Tiers



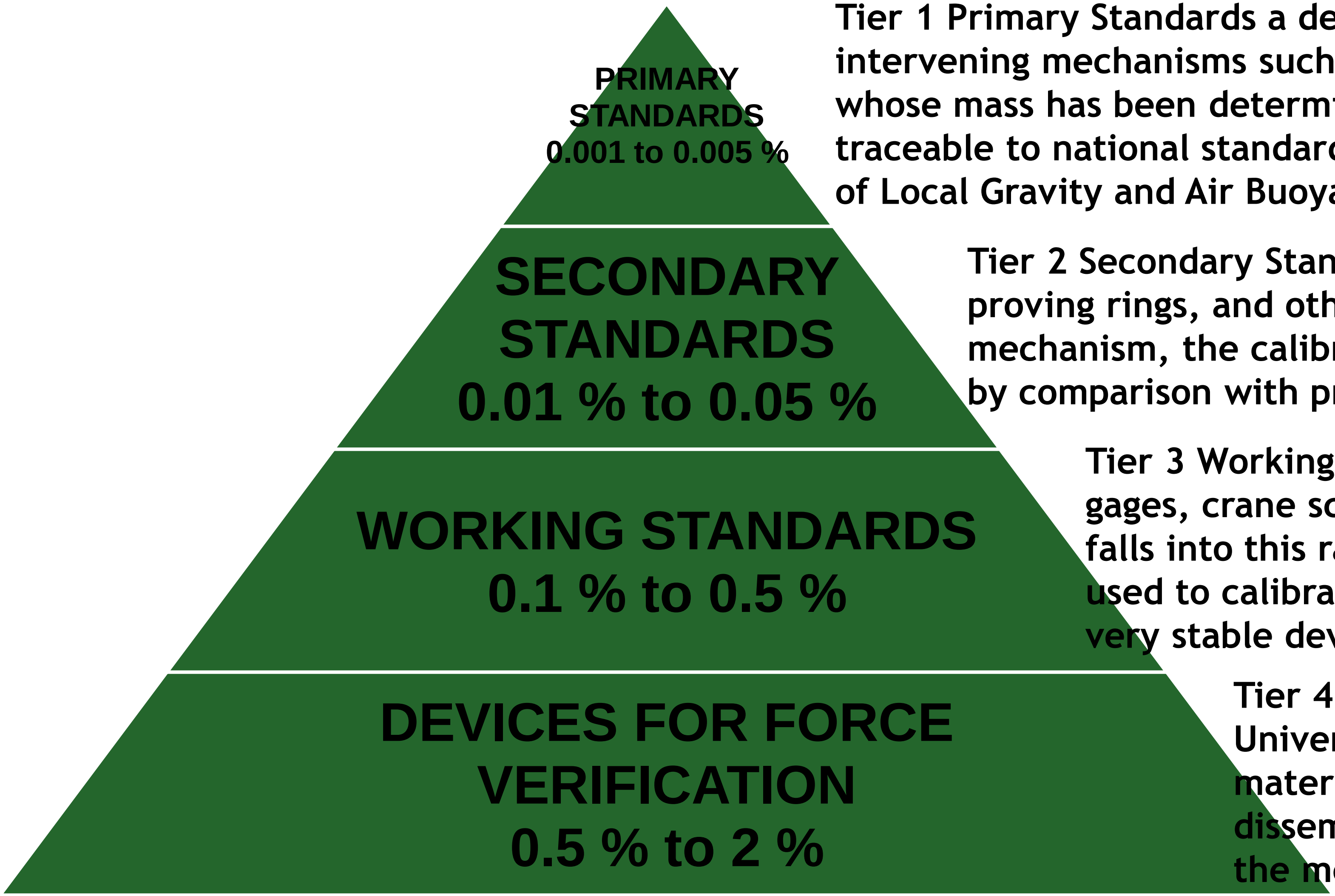
Tier 1: Primary Standard 0.0016 % used to calibrate Secondary Standards to Class AA

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

Force CMCs at Different Tiers

Tier 3 :Calibration of Working Standards using a Comparator (Morehouse Bench Top machine with load cell) to calibrate various equipment. CMCs typically vary from 0.03 % to 0.5 %.

Uncertainty Tiers For Force Calibration



Tier 1 Primary Standards 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. Require correction for the effects of Local Gravity and Air Buoyancy

Tier 2 Secondary Standards instruments such as load cells, proving rings, and other force measuring devices or a mechanism, the calibration of which has been established by comparison with primary force standards

Tier 3 Working Standards instruments such as load cells, force gages, crane scales, dynamometers, etc., Where the laboratory falls into this range largely depends on the reference standard used to calibrate the device. To achieve 0.1 % may require very stable devices and calibration by primary standards.

Tier 4 Devices for Force Verification instruments or Universal Testing Machines (UTM) used for testing material or verification of forces. Further dissemination of force is uncommon after this tier as the measurement uncertainty becomes quite large.

Note: All %'s are of applied force

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 CMC of Morehouse Machine, Tier 1 Calibration by Primary Standards Class AA loading Range Assigned, Tier 2 actual CMC of 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

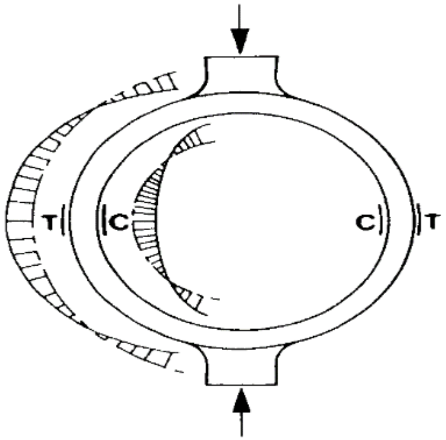
Reliability

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.

Morehouse
THE FORCE IN CALIBRATION SINCE 1925

THIS CALIBRATION DATA IS CERTIFIED TRACEABLE
TO THE
UNITED STATES NATIONAL INSTITUTE OF STANDARDS & TECHNOLOGY

08/05/03
MOREHOUSE PROVING RING NO-6803
CAPACITY 2,000 LBF COMPRESSION

CALIBRATION IN ACCORDANCE WITH ASTM METHOD E 74
COMPRESSION DATA FOR 23 DEGREES C

APPLIED LOAD	DEFLECTIONS OBSERVED DURING CALIBRATION			DEVIATION FROM FITTED CURVE			VALUES FROM FITTED CURVE
	RUN 1	RUN 2	RUN 3	RUN 1	RUN 2	RUN 3	
LBF	DIV	DIV	DIV	DIV	DIV	DIV	DIV
50.00	27.37	27.39	27.39	-0.02	0.00	0.00	27.39
200.00	108.72	108.76	108.76	-0.03	0.01	0.01	108.75
400.00	217.75	217.82	217.81	-0.10	-0.03	-0.04	217.85
600.00	327.68	327.78	327.67	0.01	0.11	0.00	327.67
800.00	438.30	438.24	438.22	0.11	0.05	0.03	438.19
1,000.00	549.43	549.49	549.48	0.00	0.06	0.05	549.43
1,200.00	661.25	661.25	661.33	-0.12	-0.12	-0.04	661.37
1,400.00	774.07	774.10	774.09	0.04	0.07	0.06	774.03
1,600.00	887.34	887.36	887.34	-0.05	-0.03	-0.05	887.39
1,800.00	1,001.41	1,001.41	1,001.39	-0.06	-0.06	-0.08	1,001.47
2,000.00	1,116.33	1,116.31	1,116.34	0.07	0.05	0.08	1,116.26

THE FOLLOWING CALIBRATION EQUATION, DESCRIBED IN SECTION 7.2 OF ASTM METHOD E74, HAS BEEN FITTED TO THE CALIBRATION DATA BY THE METHOD OF LEAST SQUARES.

DEFLECTIONS = (A) + (B)(LOAD) + (C)(LOAD SQUARED)

VALUES OF CONSTANTS ARE,

a = 0.3538256D+00
b = 0.5401942D+00
c = 0.8878805D-05

ASTM UNCERTAINTY = 0.28 = (2.4 TIMES S) IN LBF

07/27/2015 6803G2715

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

MODEL: 200
MOREHOUSE Proving Ring, SERIAL NO. 6803
2000.00 LBF Compression Calibrated to 2000.00 LBF

Calibration is in Accordance with ASTM E74-13
Ascending Compression DATA FOR 23.00 Degrees C

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	DIV	DIV	DIV	DIV	DIV	DIV	DIV
50	26.99	27.00	27.10	-0.11	-0.10	0.00	27.10
200	108.58	108.64	108.69	0.04	0.10	0.15	108.54
400	217.61	217.68	217.67	-0.11	-0.04	-0.05	217.72
600	327.70	327.66	327.66	0.11	0.07	0.07	327.59
800	438.08	438.10	438.14	-0.07	-0.05	-0.01	438.15
1000	549.41	549.43	549.37	0.01	0.03	-0.03	549.40
1200	661.39	661.31	661.29	0.05	-0.03	-0.05	661.34
1400	773.96	773.94	774.05	-0.01	-0.03	0.08	773.97
1600	887.28	887.42	887.36	-0.01	0.13	0.07	887.29
1800	1001.10	1001.10	1001.06	-0.19	-0.19	-0.23	1001.29
2000	1116.21	1116.08	1116.06	0.22	0.09	0.07	1115.99

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

Where: A0 4.50599168E-2
A1 5.40729401E-1
A2 8.62247087E-6

The following values as defined in ASTM E74-13 were determined from the calibration data.
Lower Limit Factor, LLF 0.459 LBF

Class A Loading Range 183.78 TO 2000.00 LBF

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

Page 2 of2

There are two certificates above. One is in 2003 and another one in 2015.

Proving Ring

2015	2003	% Diff
108.54	108.75	0.193 %
217.72	217.85	0.060 %
327.59	327.67	0.024 %
438.15	438.19	0.009 %
549.4	549.43	0.005 %
661.34	661.37	0.005 %
773.97	774.03	0.008 %
887.29	887.39	0.011 %
1001.29	1001.47	0.018 %
1115.99	1116.26	0.024 %

12 Year Change From Previous.

Note: Morehouse does not recommend 12-year calibration intervals.

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. Also, 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

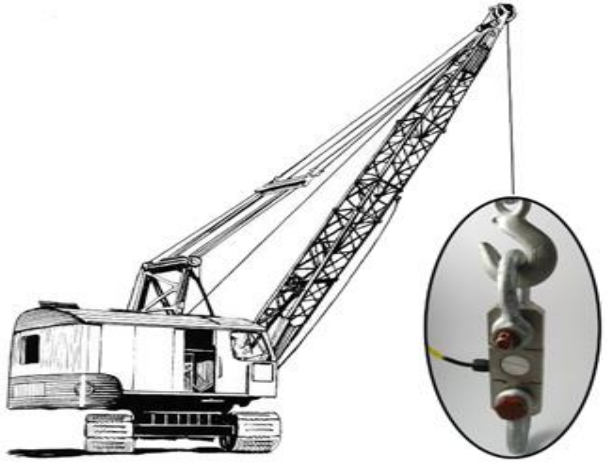
- Typically used for adjusting tension on guy wires, field testing chain, rope, wire, or anything requiring precision force or tension measurement.

- 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.

Funny Story

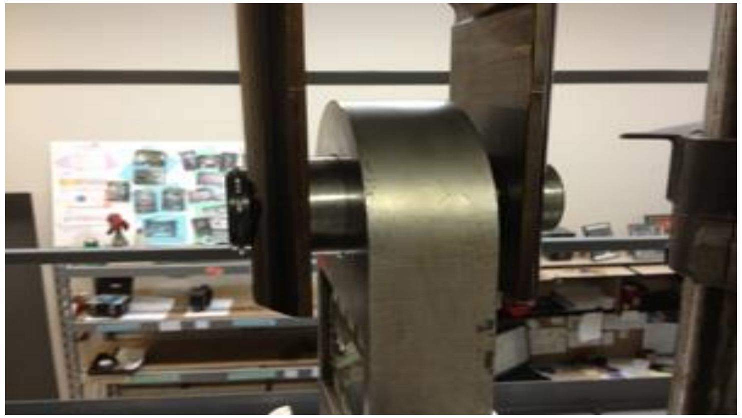
A dynamometer measures in-line force or tension by means of a load cell or mechanical scale installed between two shackles or hooks. Typically, the dynamometer is attached to a ratcheting cable puller on one end and a come-a-long on the other, allowing the cable to tightened while in place as shown in the picture.

Tension Links



- Typically used for lift tests, towing tension, cable tension, crane scale, hoist scale, and tensile testing systems.
- Calibration should be performed with the same load pins the end user is using with the device. Some links exhibit very high errors when substituting machined pins versus forged pins to perform the calibration.

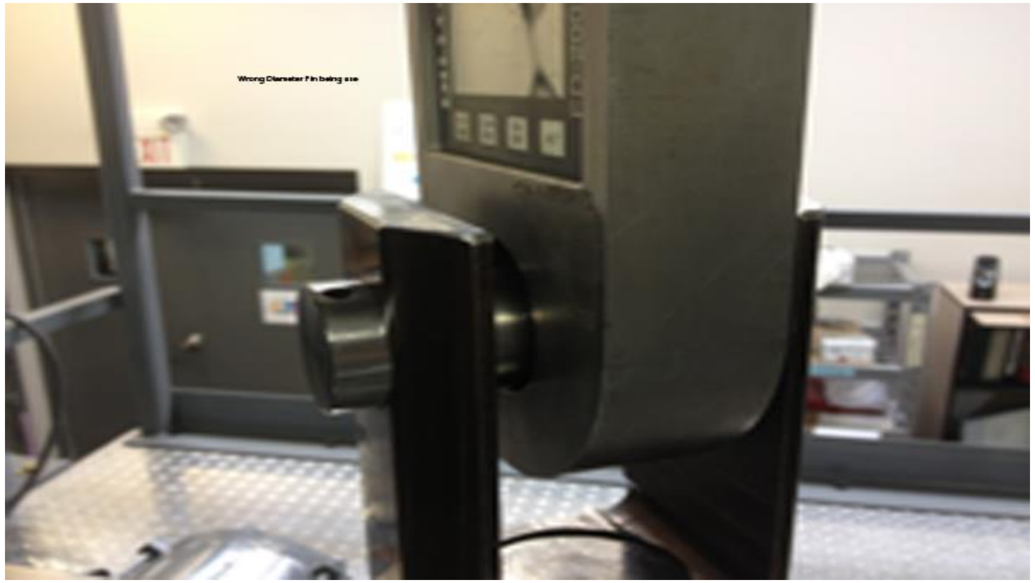
Tension Links Pin Diameter



- Do you think the output will vary?

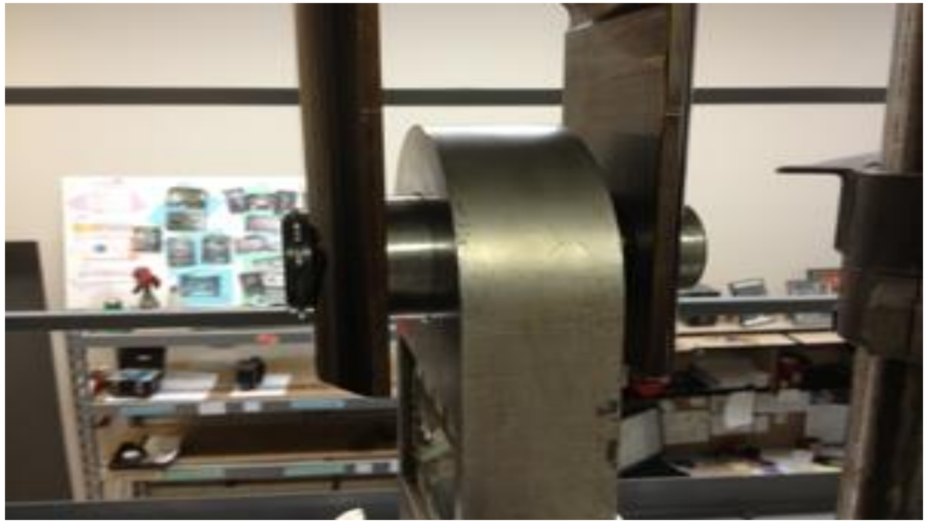
Tension Links PROPER PIN DIAMETER

- Loaded without the proper Pin Diameter to 50,000 LBF



Tension Links PROPER PIN DIAMETER

- Loaded with the proper Pin Diameter to 50,000 LBF



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.

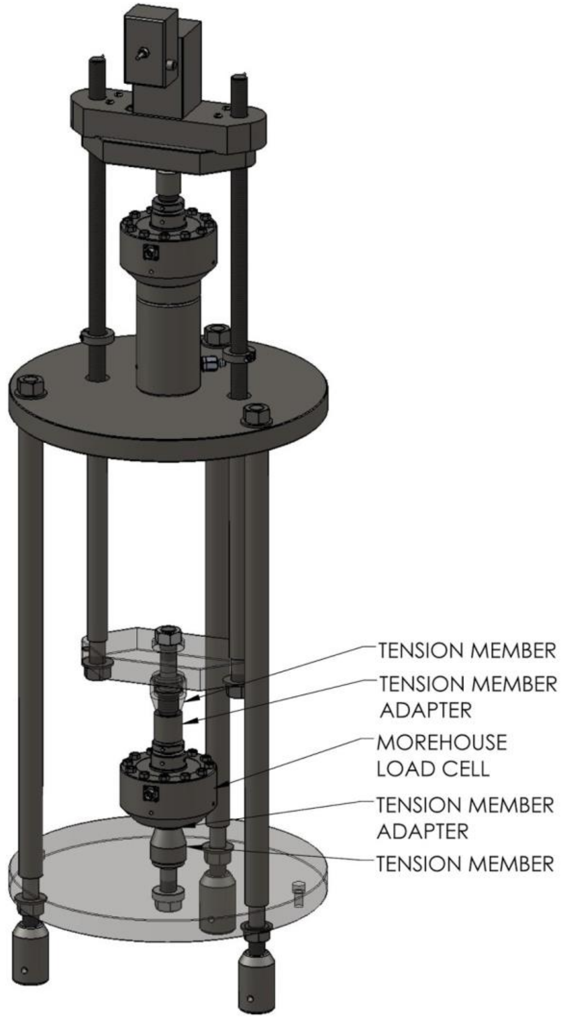
Tension Links PROPER PIN DIAMETER

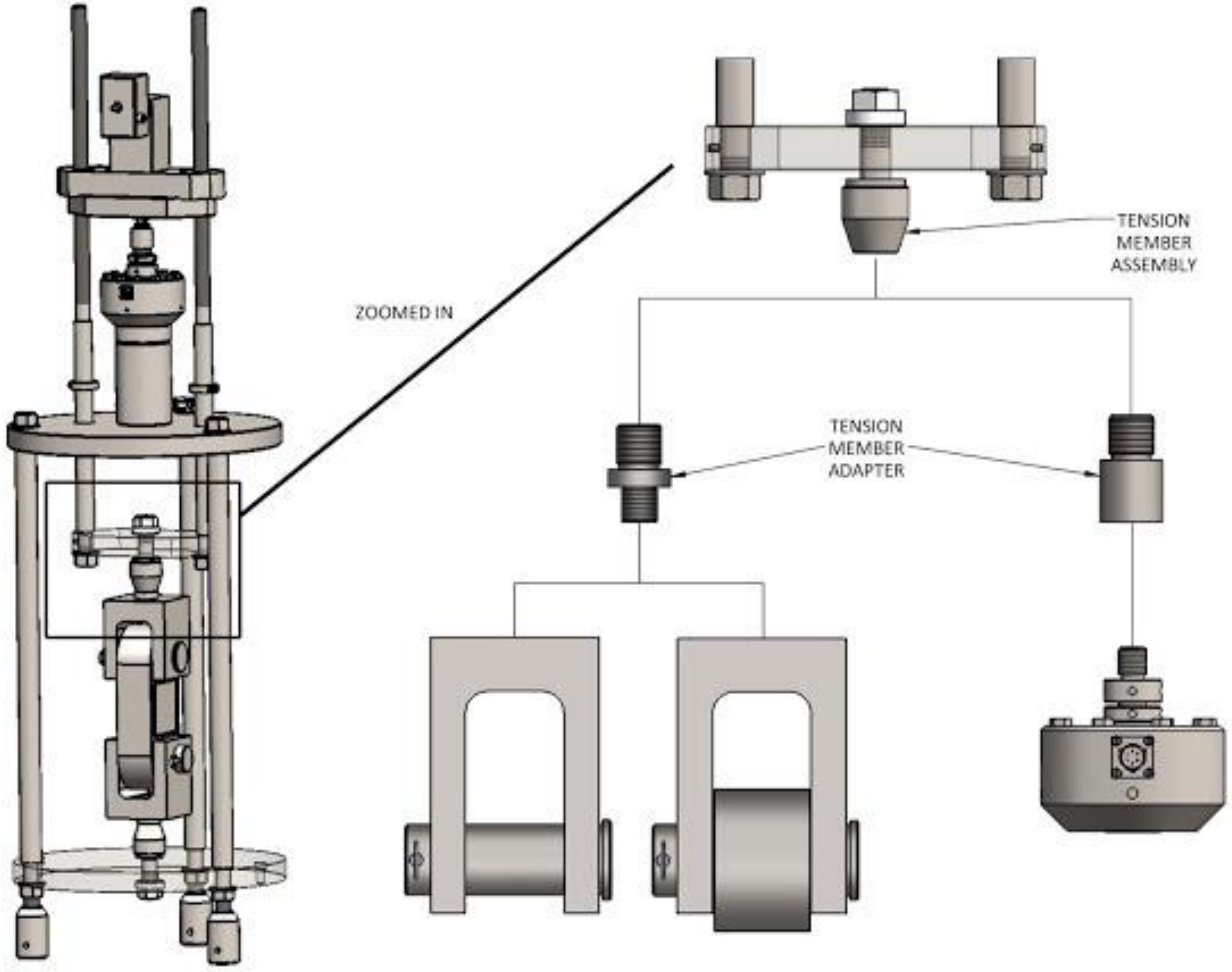
Pin B (2.0030 to 2.0060)	Pin A (2.0005 to 2.0045)
50,070	50,010
50,050	50,020
50,040	50,010
50,070	50,020
50,090	50,020
50,060	50,030
50,080	50,010
50,070	50,030
50,090	50,020
50,090	50,070
50,080	50,060
50,100	50,070
17.81640375	22.74696117
Out of 24 tests 13 did not meet spec ± 50	

Tension Link Calibration

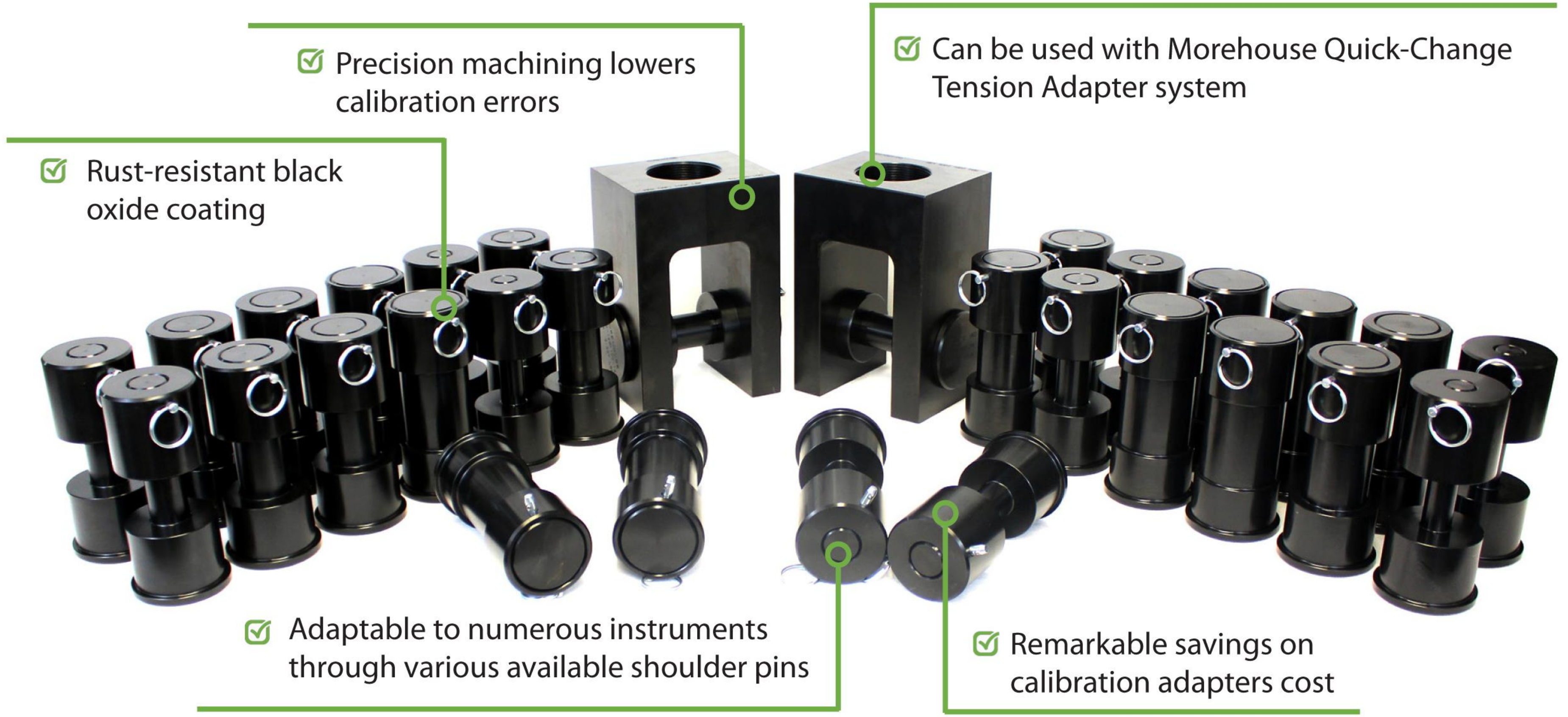
Discussion on tension link calibration and safety

Morehouse Quick-Change Adapter System





Proper Adapters for Tension Links



(U.S. Patent No 11,078,052)

Proper Adapters for Tension Links

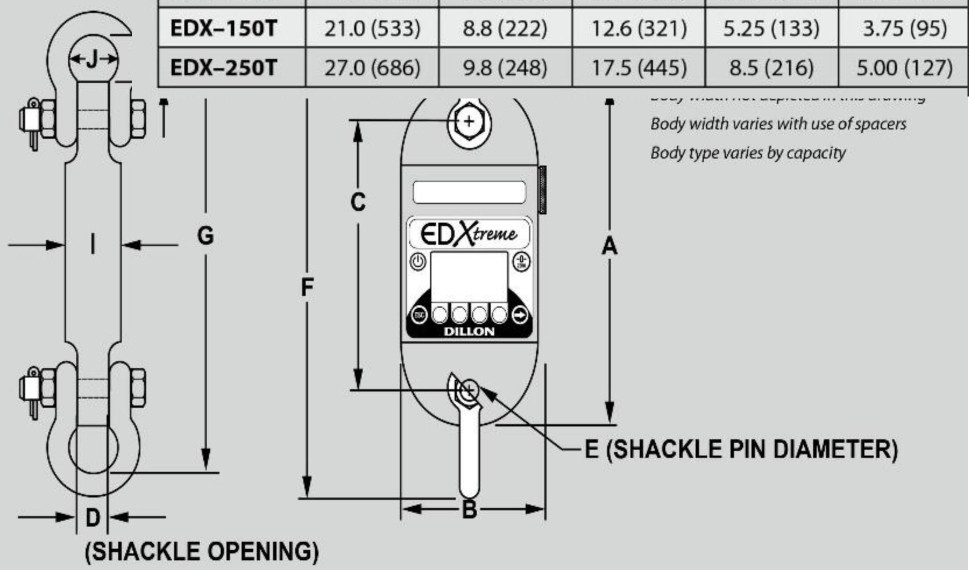
Dimensions inch

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)

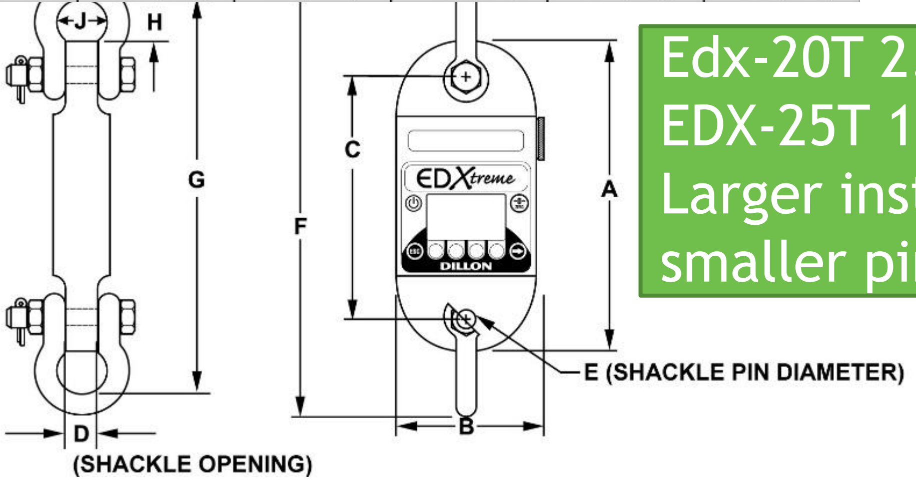
Model	A	B	C	D	E
EDX–1T	10.6 (269)	5.0 (127)	7.8 (198)	1.06 (26)	0.75 (19)
EDX–2T	10.6 (269)	5.0 (127)	7.8 (198)	1.06 (26)	0.75 (19)
EDX–5T	11.4 (289)	5.3 (135)	8.1 (206)	1.38 (35)	1.00 (25)
EDX–10T	11.5 (291)	5.3 (133)	7.9 (201)	1.97 (50)	1.38 (35)
EDX–25T	13.7 (348)	6.0 (152)	9.0 (229)	2.75 (70)	1.97 (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)



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)
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)

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

Tension Links
Good measurement practice

- This following summary is from Dillon.

- Using correctly sized pins is critical.

- If links are damaged, highly used, or worn, decrease the time between recalibrations.

- The same size and style of shackle and pin used during operation should be used for calibration.

- Other factors have a larger effect on accuracy than pin rotation.

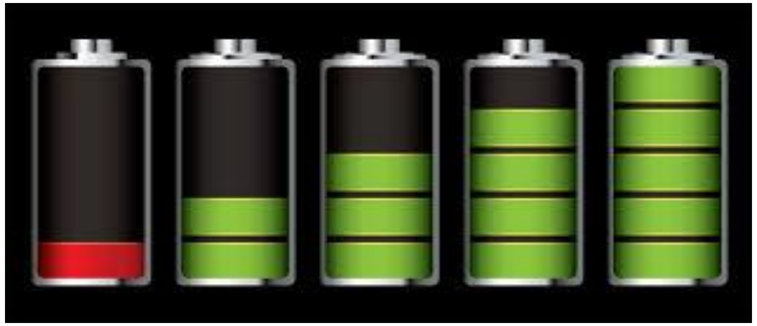
- Maintaining pin orientation may be best practice but is not required to stay in tolerance.

Crane Scale

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

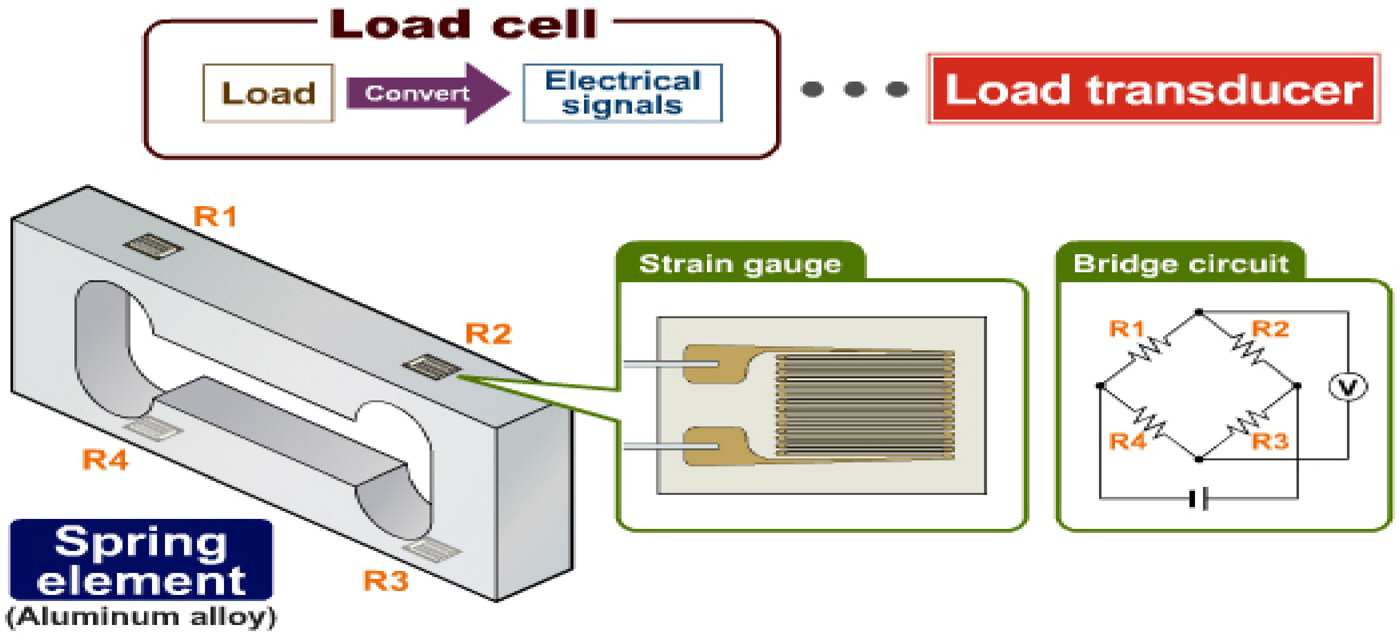
Thank you for thinking of us for your calibration work.

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.

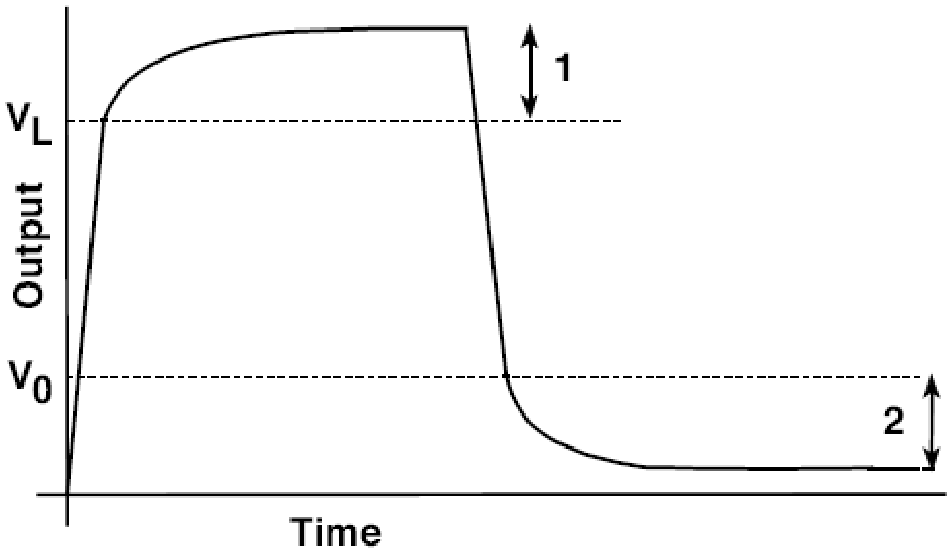
How Load Cells Work

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.

Load Cell Terms

Creep

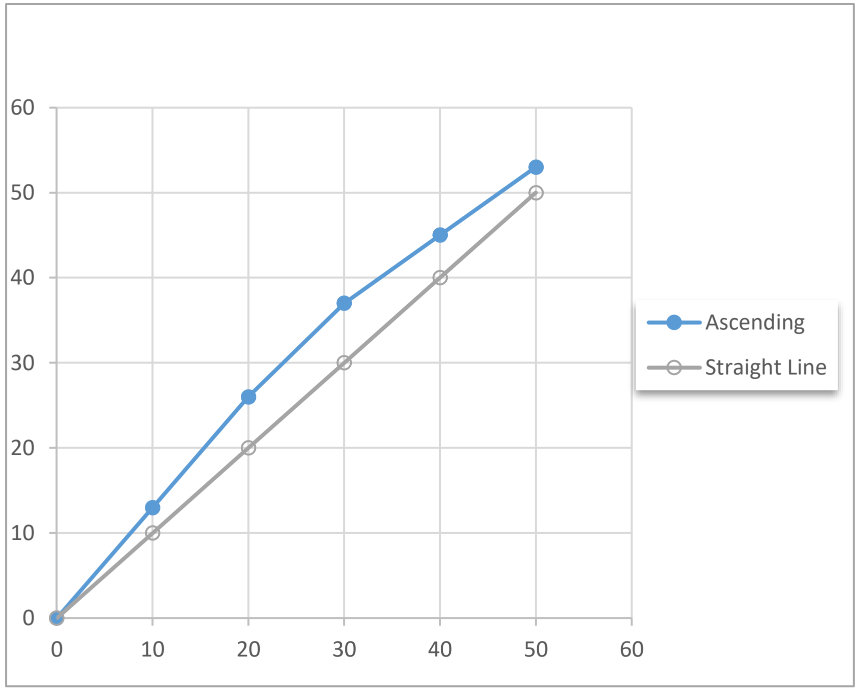
- The change in Load Cell Signal occurring with time while under load and with all environmental conditions remaining constant.



Load Cell Terms

Nonlinearity

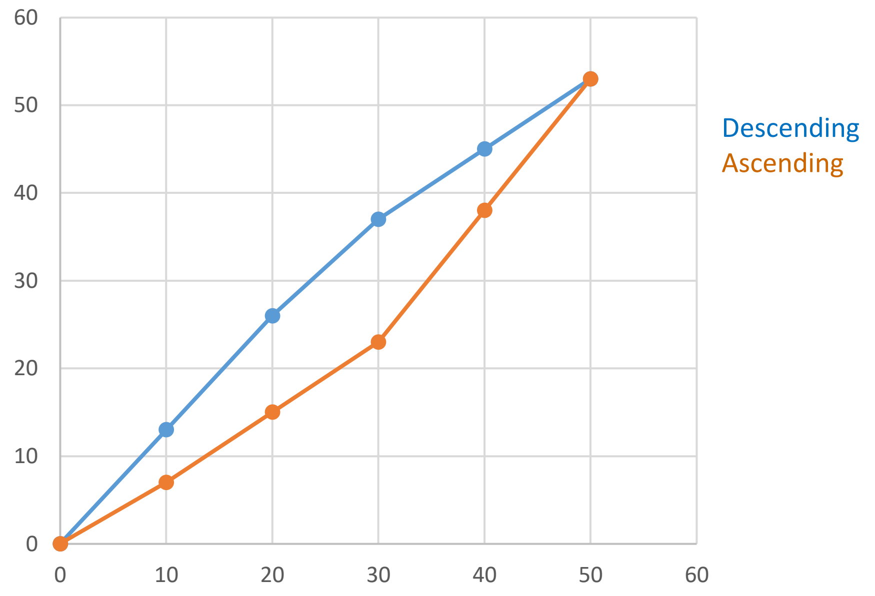
- The algebraic difference between OUTPUT at a specific load and the corresponding point on the straight line drawn between MINIMUM LOAD and MAXIMUM LOAD.
- Normally expressed in units of %FS. It is common for characterization to be measured at 40-60 %FS.



Load Cell Terms

Hysteresis

- The algebraic difference between OUTPUT at a given load descending from MAXIMUM LOAD and OUTPUT at the same load ascending from MINIMUM LOAD.
- Normally expressed in units of %FS. It is common for characterization to be measured at 40-60% FS.



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

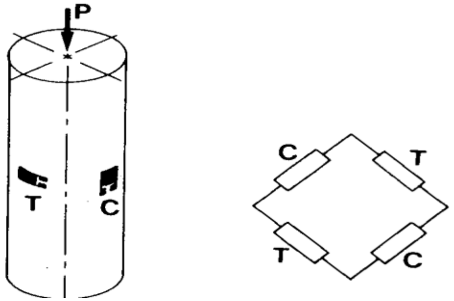
The Ugly

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

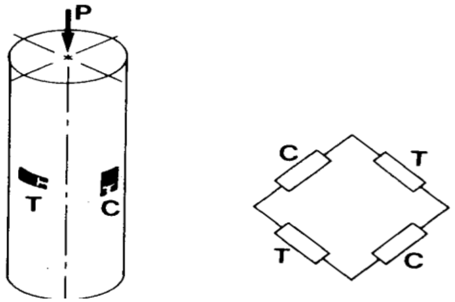
- Column Load Cell (Single-Column or High- Stress Load Cells)
- Multi-Column Load Cell
- S-Beam or S-Type
- Button or Pancake
- Shear Web

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.

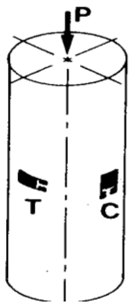
Column Load Cell

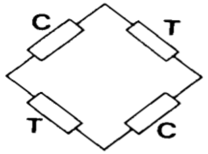


Advantages

- 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 hardness of 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

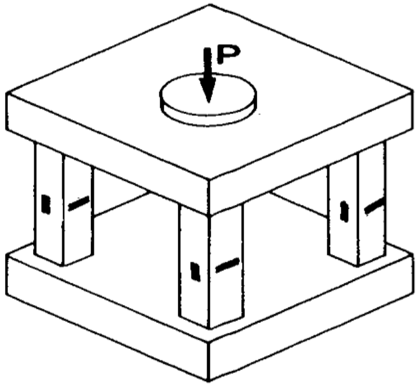
Disadvantages

- Larger creep characteristics than other cells and often do 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%	

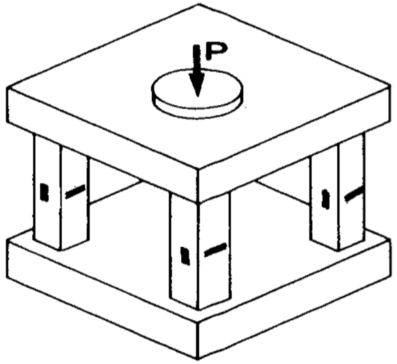
Load Cell Type	Not-Morehouse
Single Column Example 2	
Force (lbf)	**RUN 1 DIV**
0	0
9000	23818
20000	52914
40000	105795
80000	211662
120000	317377
160000	423042
200000	528730
240000	634303
280000	739846
320000	845413
360000	950778
400000	1056182
408000	**1077219**
0	89
Zero Return @ 30 Seconds	
0.0083%	

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.

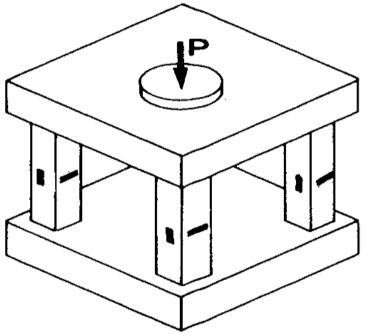
Multi - Column Load Cell



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.

Force Applied	Non-Flat Base Maximum Error In Rotation LBF	Flat Base Maximum Error In Rotation 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.

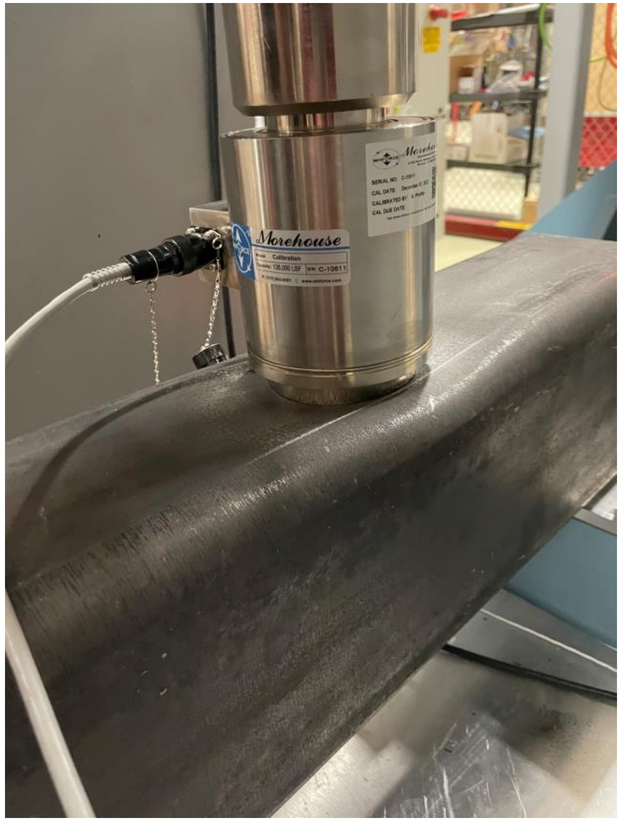
- Pictured left is a Morehouse 60K rod end style load cell with spherical threaded adapter, top compression pad and load cell base plate.

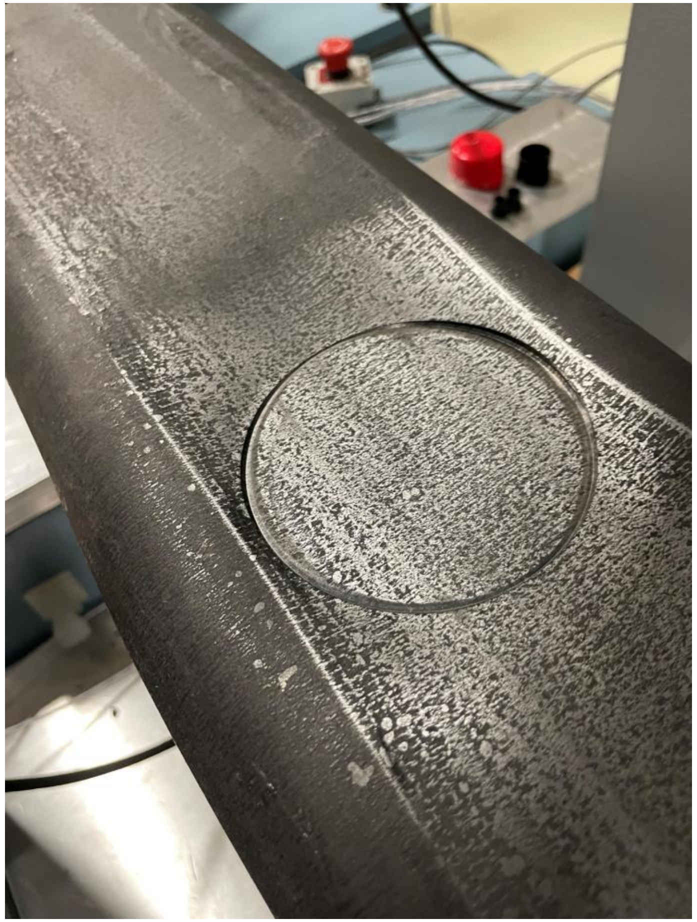
Morehouse Compression Adapters

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

[Link to Concrete 600K set with adapters]

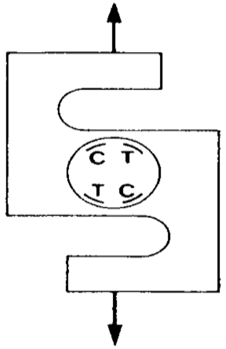
What Bottom Adapters Help Protect Against





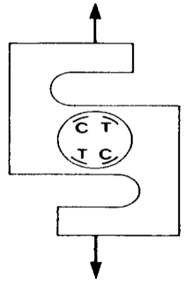
Another example of when adapters are not used

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

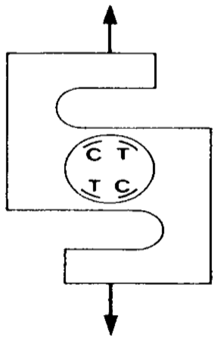


Advantages

- 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 shape of the element.

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

S-beam Load Cell



Disadvantages

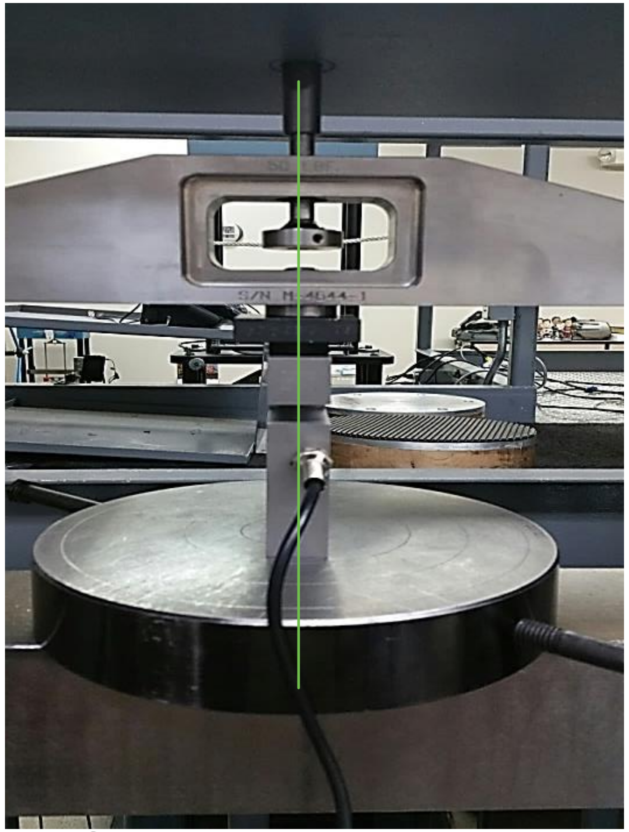
- These cells are very sensitive to off-axis loading - ideally suited for scales or tension applications.
- Compression output will be different if the cell is loaded through the threads versus flat against each base

S-beam

Does anything look different when comparing these two pictures?

Misalignment on S-beam

Misalignment Demonstrating 0.752 % error

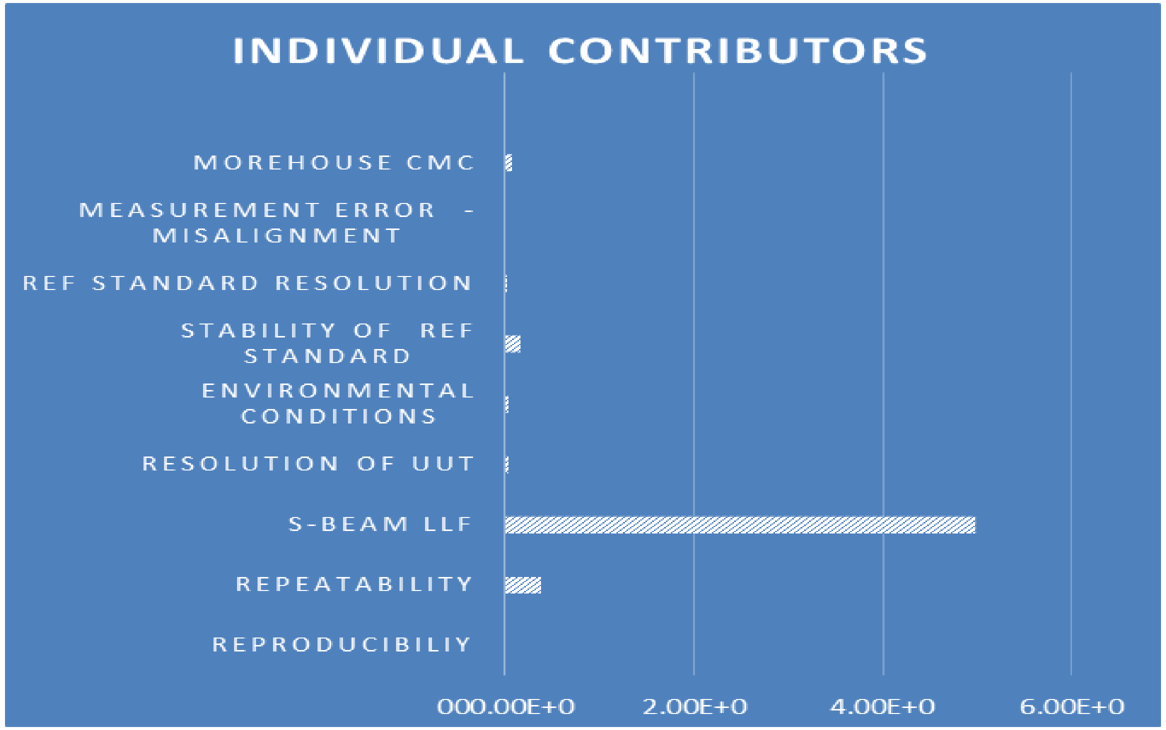


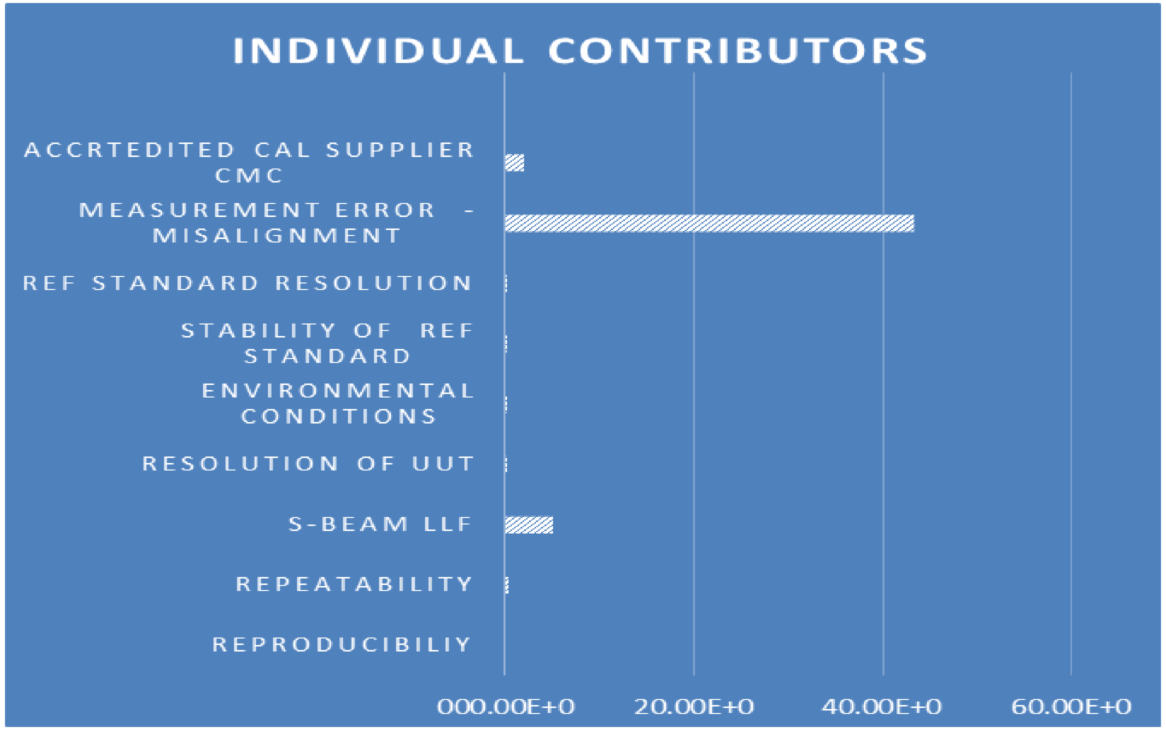
Output in mV/V
Aligned in machine
-1.96732 mV/V

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

Misalignment on 10,000 LBF S-beam

Misalignment Demonstrating 0.752 % Error

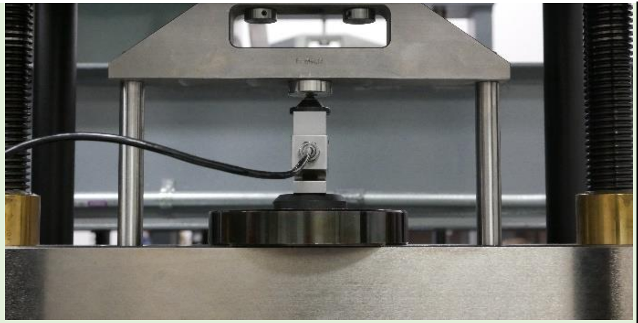
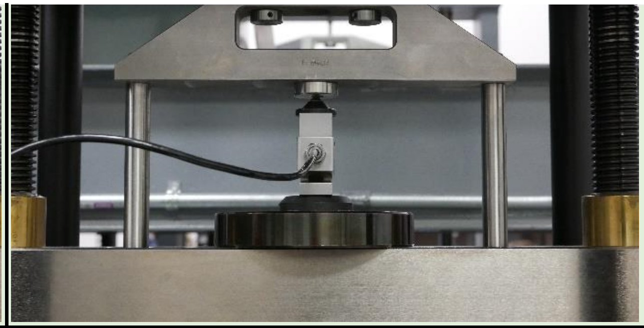
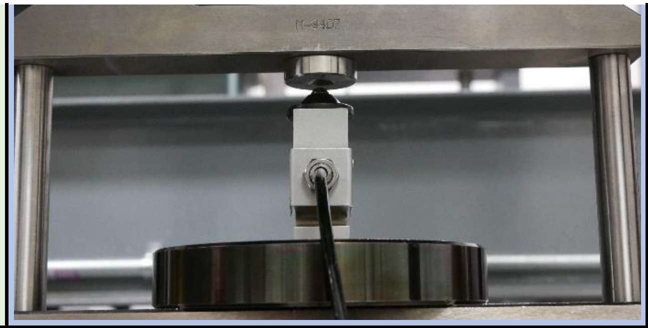




Output in mV/V
Aligned in machine
-1.96732 mV/V
Expanded Uncertainty 9.95 LBF

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

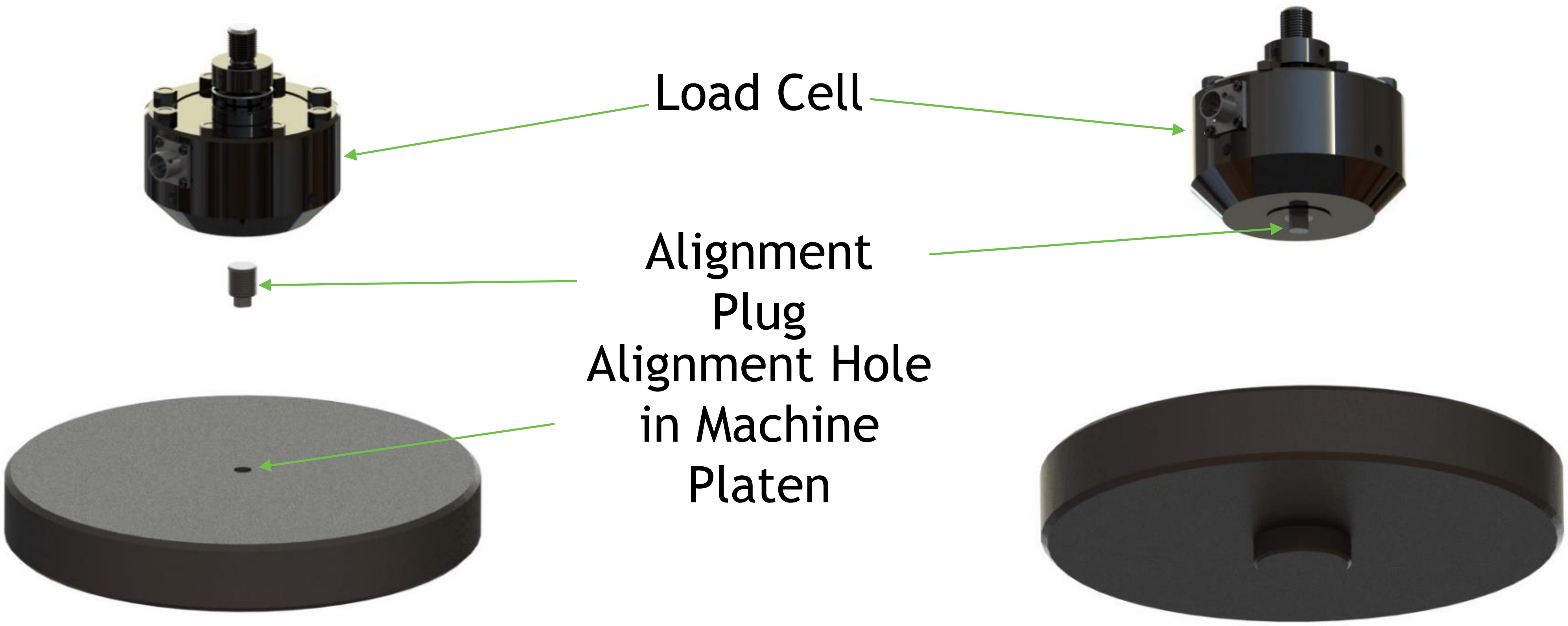
S-Beam Loading Errors

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 minimum 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

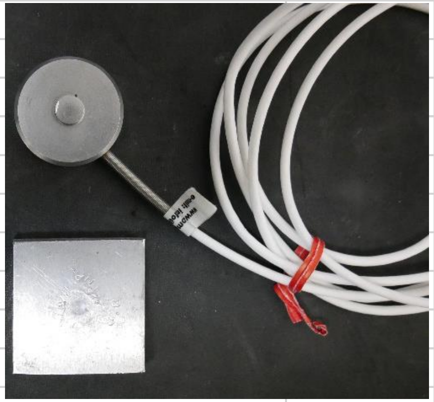
Does this setup look familiar?

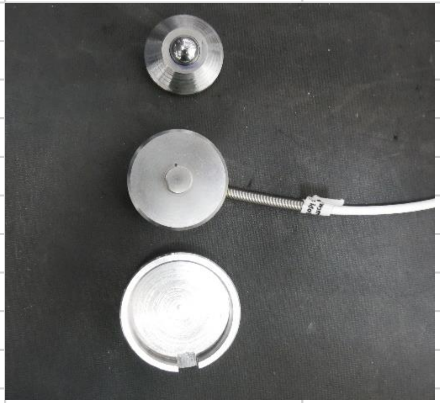
Manually Aligned	Data
0 degree	2011
120 degree	1997
240 degree	2018
Average	2008.66667
Standard Deviation	10.6926766
Max Deviation	21
% Error	1.045%

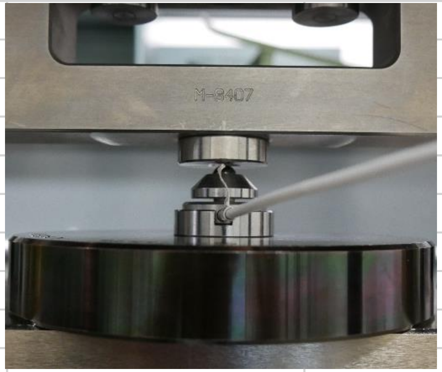
Button Load Cell Calibration

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

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 from 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” – these are perfect to use in testing machines.

The Importance of Adapters

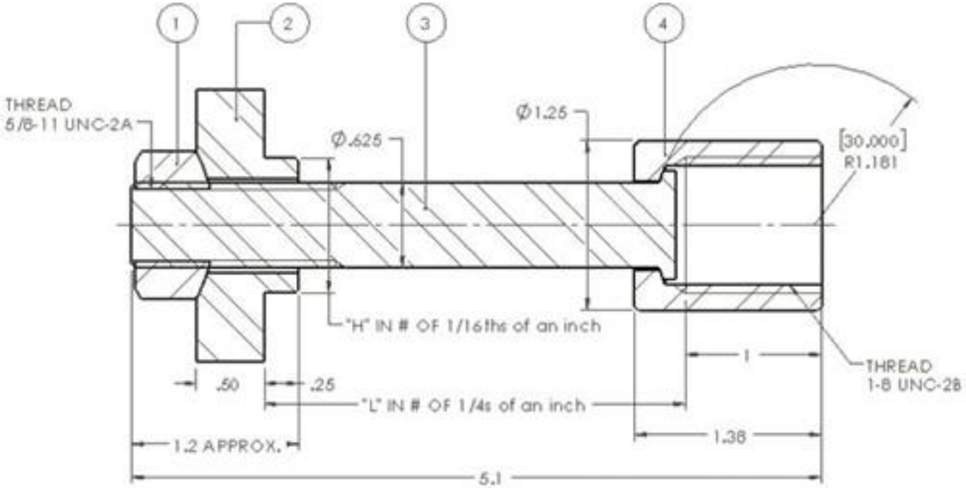
Keeping the line of force pure (free from eccentric forces) is key to the calibration of load cells. ASTM E74 does not address the various adapter types, but ISO 376 does.

MISALIGNED LOAD CELL!

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



ISO 376 recognizes the importance of adapters in reproducibility conditions of the measurement. 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

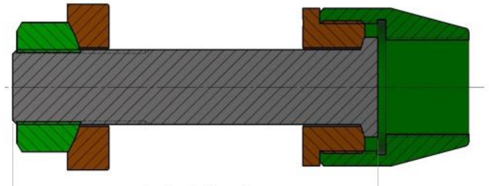
- Loading fittings should be designed in such a way that the line of force application is not distorted. As a rule, tensile force transducers should be fitted with two ball nuts, two ball cups and, if necessary, with two intermediate rings, while compressive force transducers should be fitted with one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

The Wrong Tension Adapters

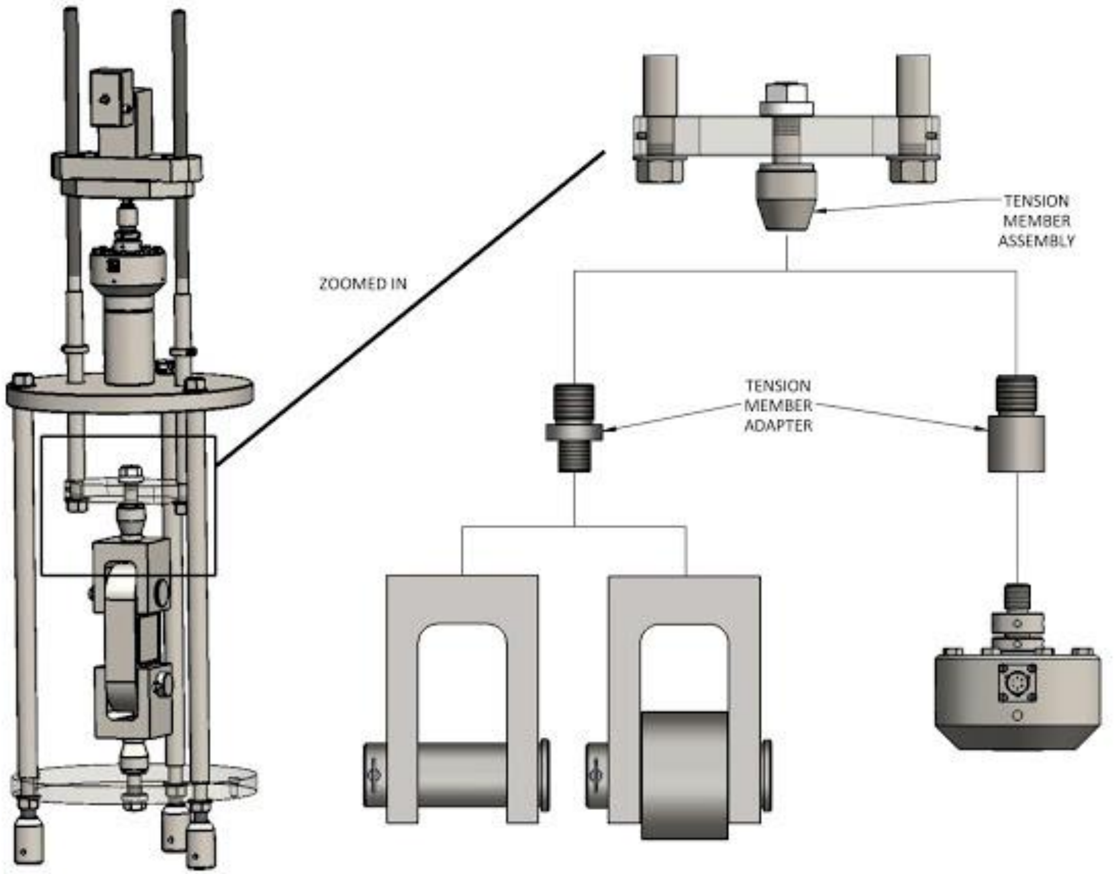


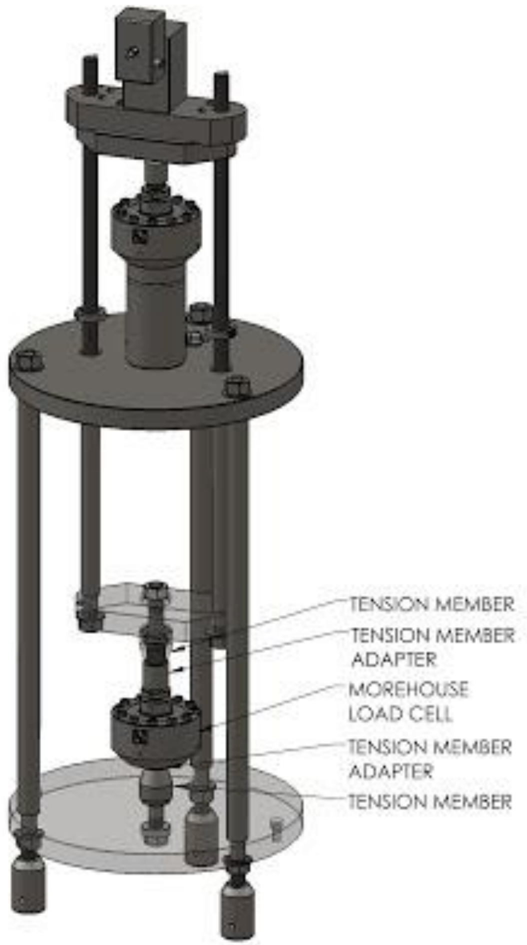
- If any of these looks like tension adapters in your calibration lab, there is a problem.
- Even straight threaded rod can introduce misalignment issues as they can distort the line of force in non-Morehouse machines.
- Any machine misalignment of 0.01 degrees can affect the reproducibility of some 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





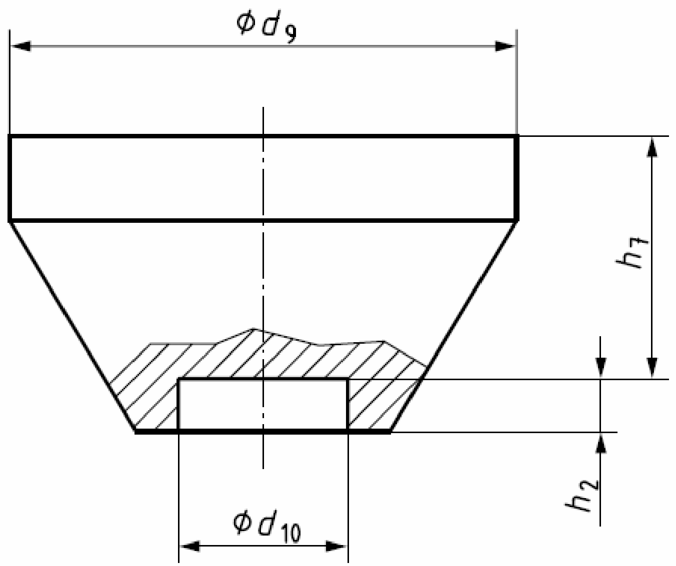
Morehouse Quick Change Adapters Value Kits

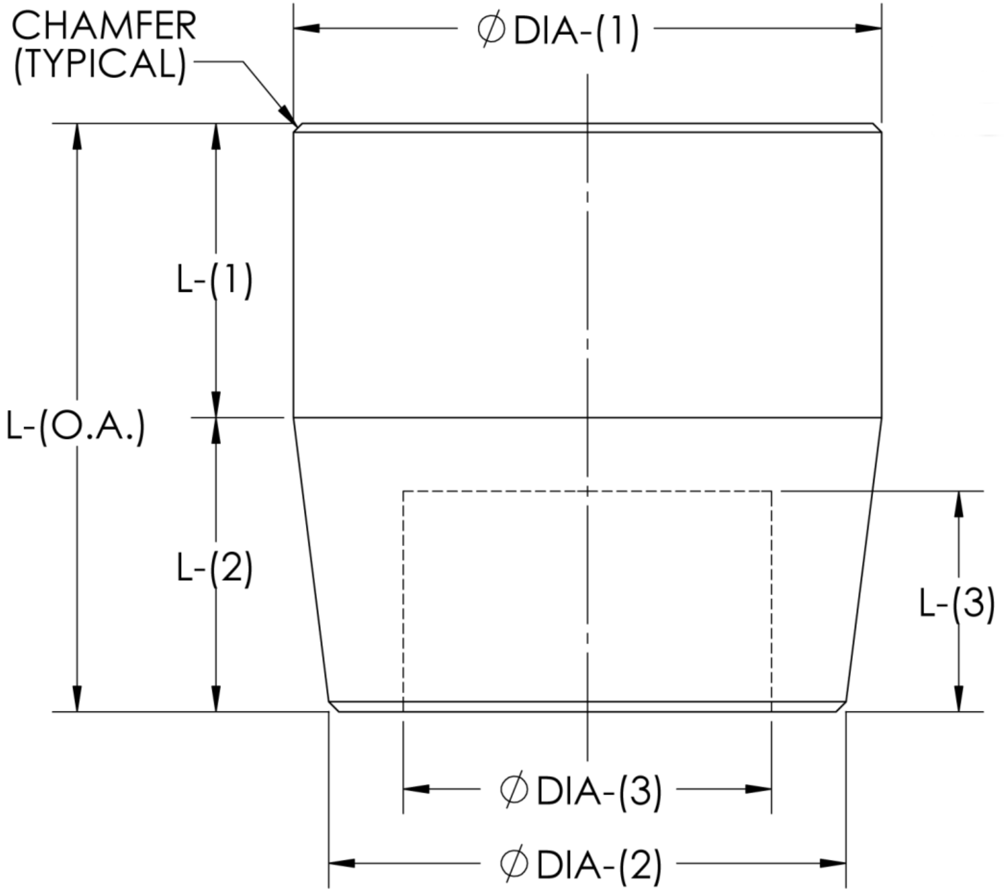
Value Kits offer:

- 20 % saving on the cost when ordered the full kit
- Reduce tension changeover time, and overall calibration cycle time
- Easier and faster setup for calibration technicians
- Improve alignment by using a spherical radius contact as defined by ISO 376
- Simplify setups by using one tension member with several adapters
- Fit for use with additional clevis assemblies to calibrate crane scales, and dynamometers
- Rust-resistance black oxide coating on all parts helps keep things clean

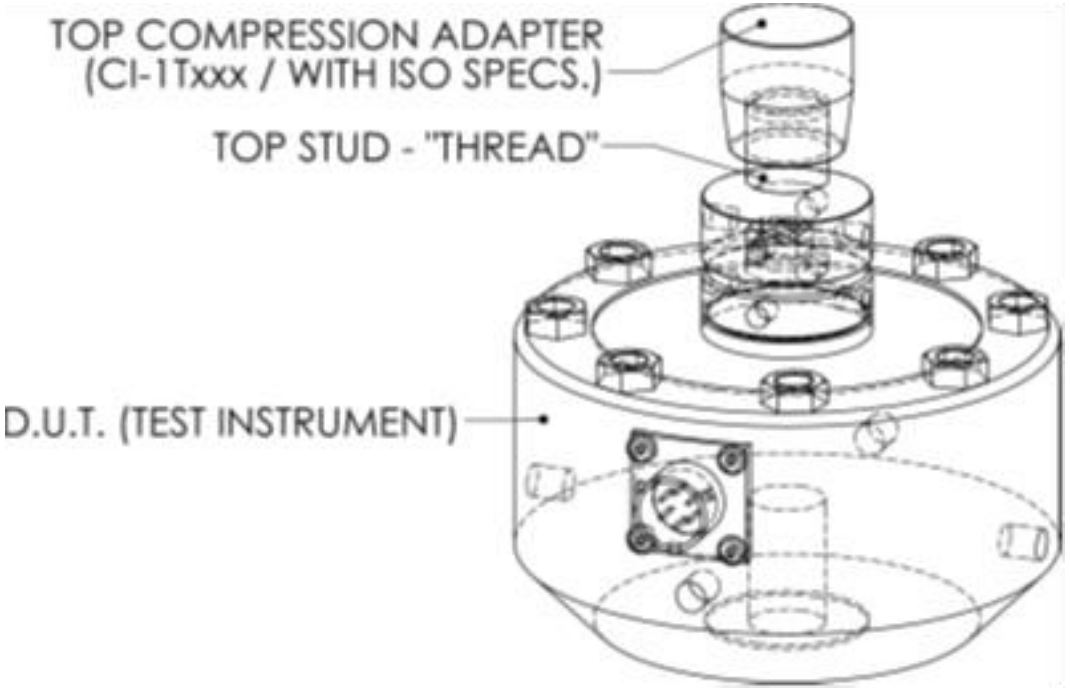
ISO 376 Compression Adapters

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



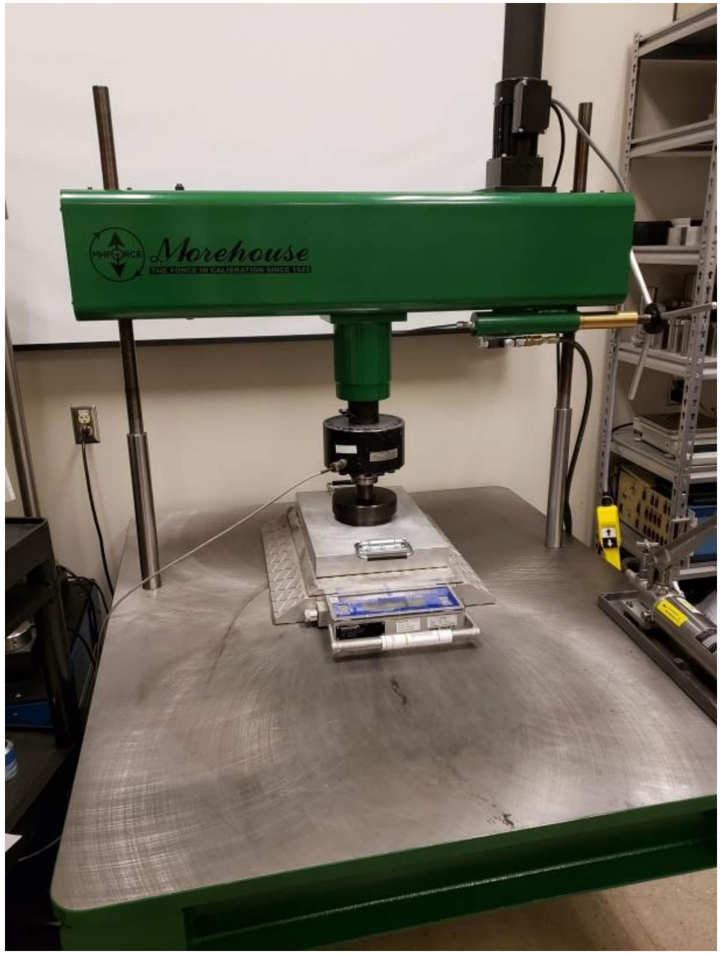


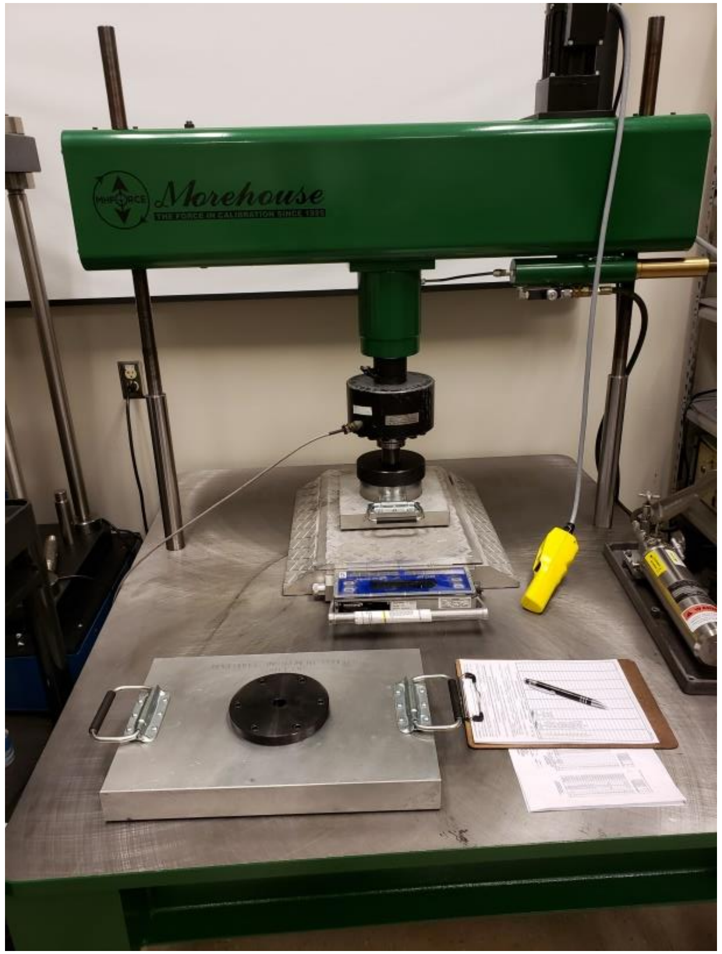
Morehouse Compression Adapters



- Pictured above are an ISO 376 recommended compression adapters

Truck Scales

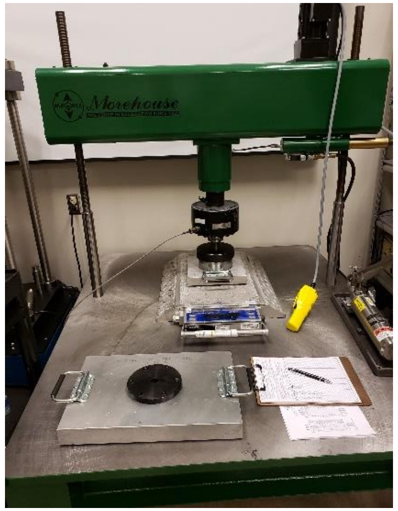




Pictures Showing Two Different Size Adapters.

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.

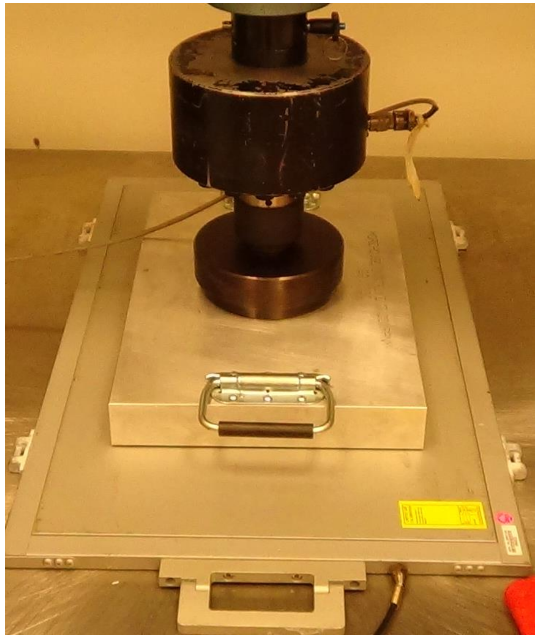
Force Applied lbf	Instrument Reading normal pad	Instrument Reading small pad	Difference in lbf	% Difference	Tolerance 1 % of Applied	Tolerance % by using different pads
2000	2000	2000	0	0.00%	20	0%
4000	4000	4000	0	0.00%	40	0%
6000	6020	6020	0	0.00%	60	0%
8000	8020	8020	0	0.00%	80	0%
10000	10040	9980	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

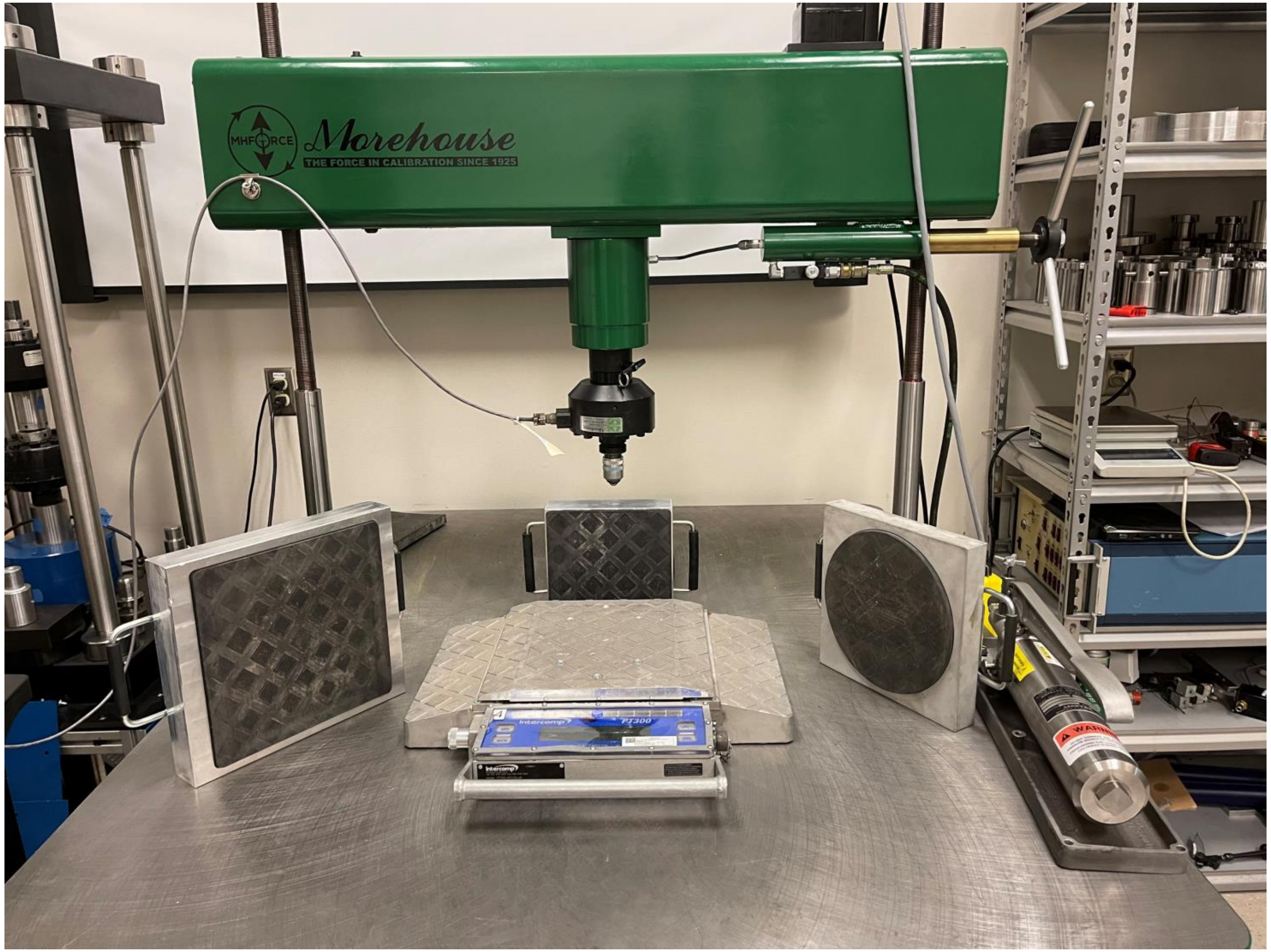


Force Applied lbf	Scale Reading w/ Large pad	Scale Reading w/ Small pad		
0	0	0	Diff in lbf	%
4000	3950	3980	-30	-0.759%
8000	7980	8030	-50	-0.627%
12000	11990	12020	-30	-0.250%
16000	15980	16090	-110	-0.688%
20000	19980	20140	-160	-0.801%
24000	23990	24210	-220	-0.917%
28000	27990	28270	-280	-1.000%
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

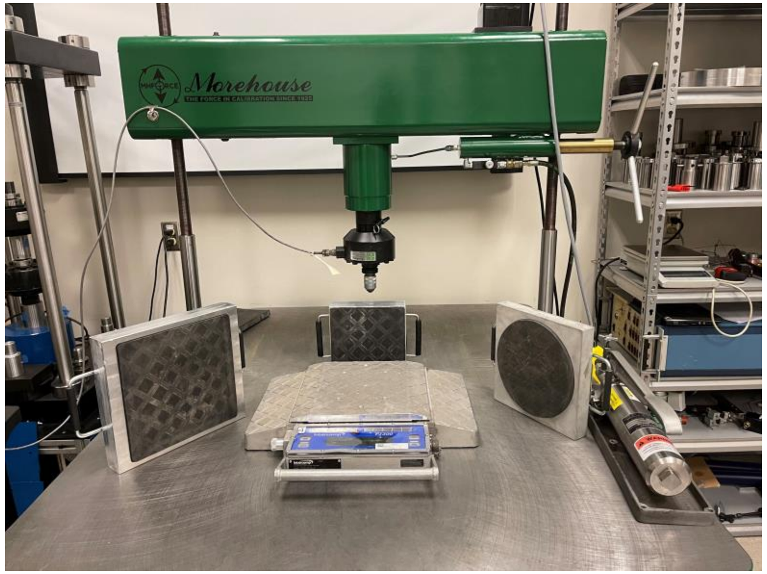


Pictures Showing three Different Size Adapters made by Morehouse.

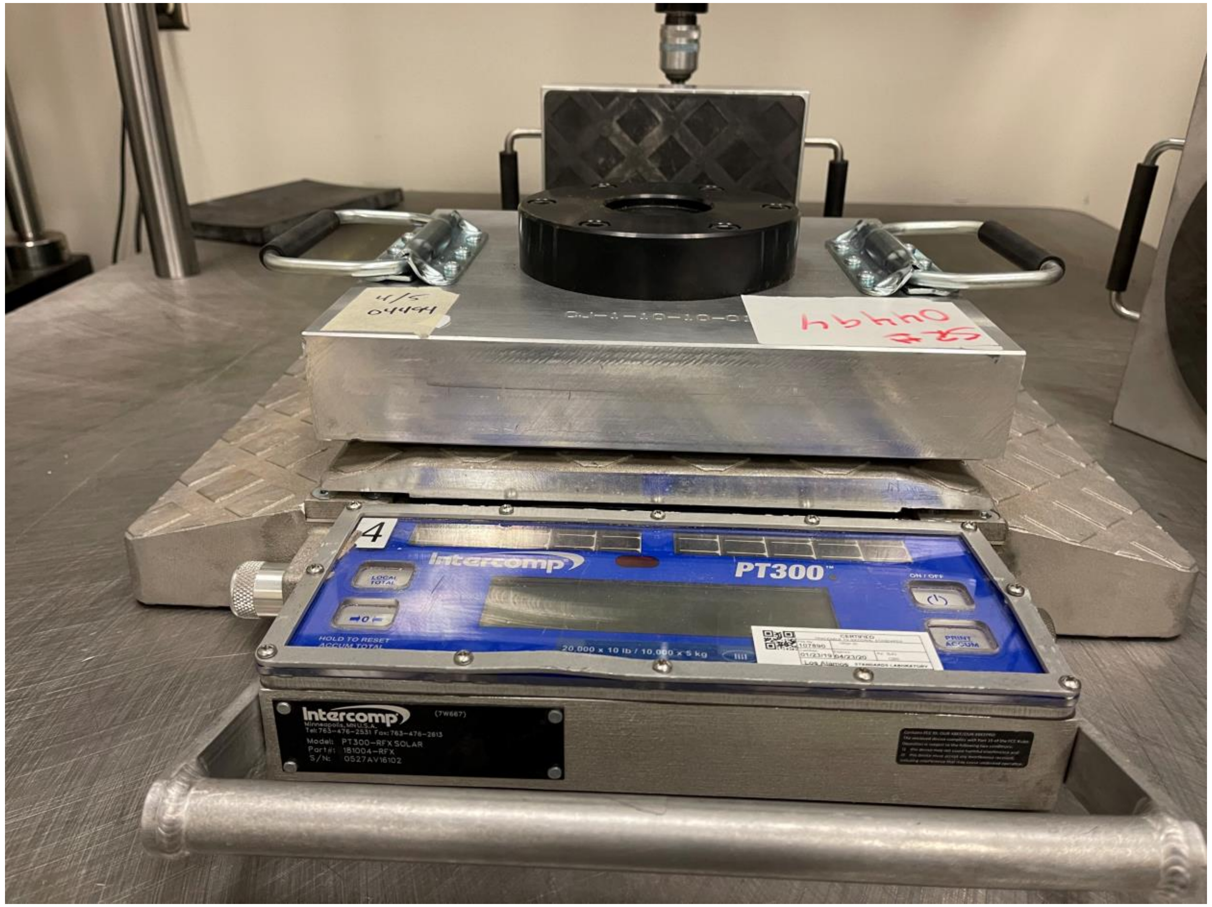
Will there be a difference in the measured values on a 10,000 lbf PT300 scale?

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?

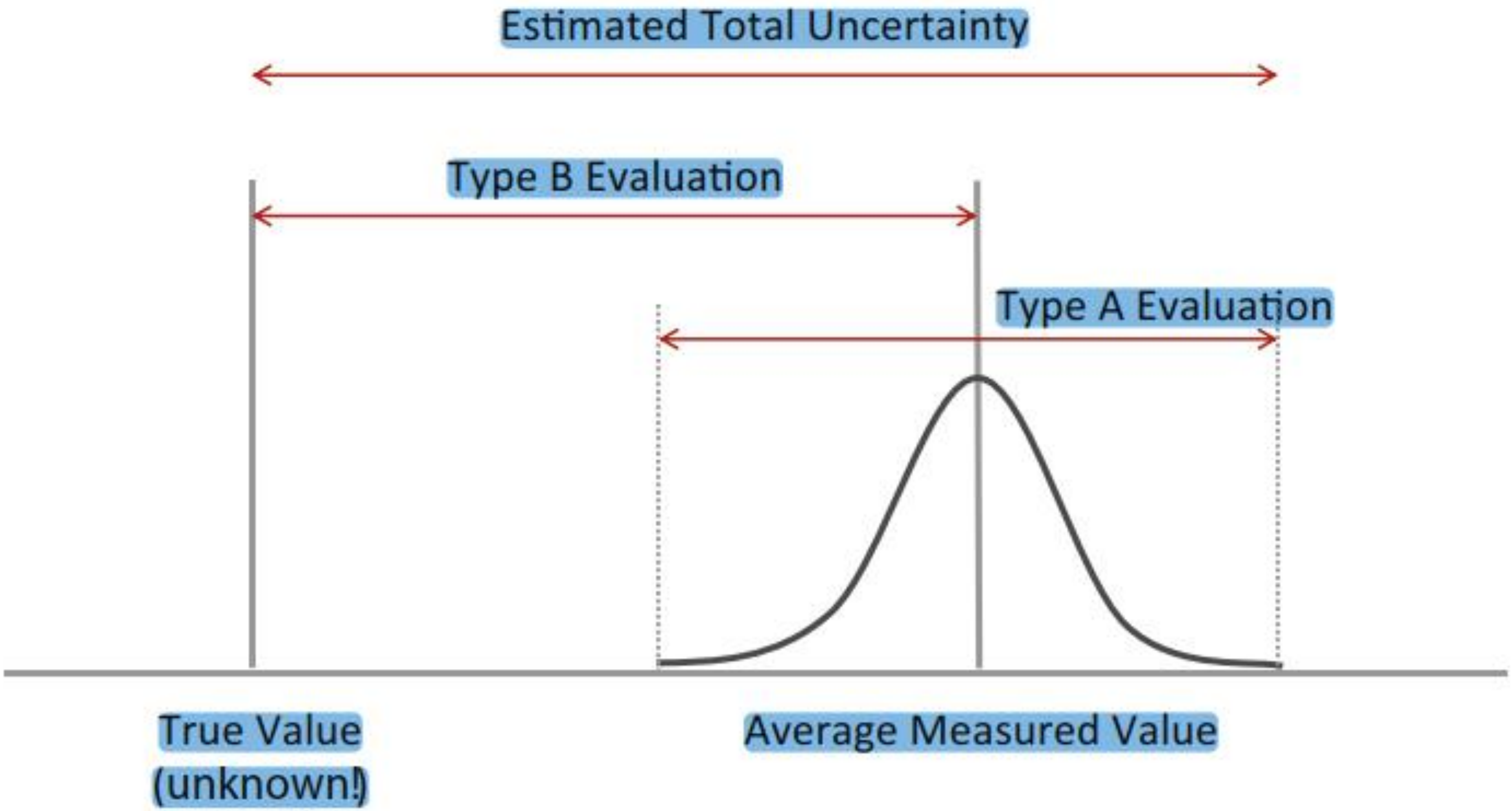
Choosing the right Indicator

Choose the right Indicator

<table>
<tr><th colspan="3">Choosing the Right Indicator</th></tr>
<tr><td>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?</td><td>HADI</td><td>
</td></tr>
<tr><td>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?</td><td>PSD</td><td>
</td></tr>
<tr><td>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?</td><td>4215</td><td>
</td></tr>
</table>

Need to use Coefficients to reduce measurement bias

When We Correct For a Known Bias



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

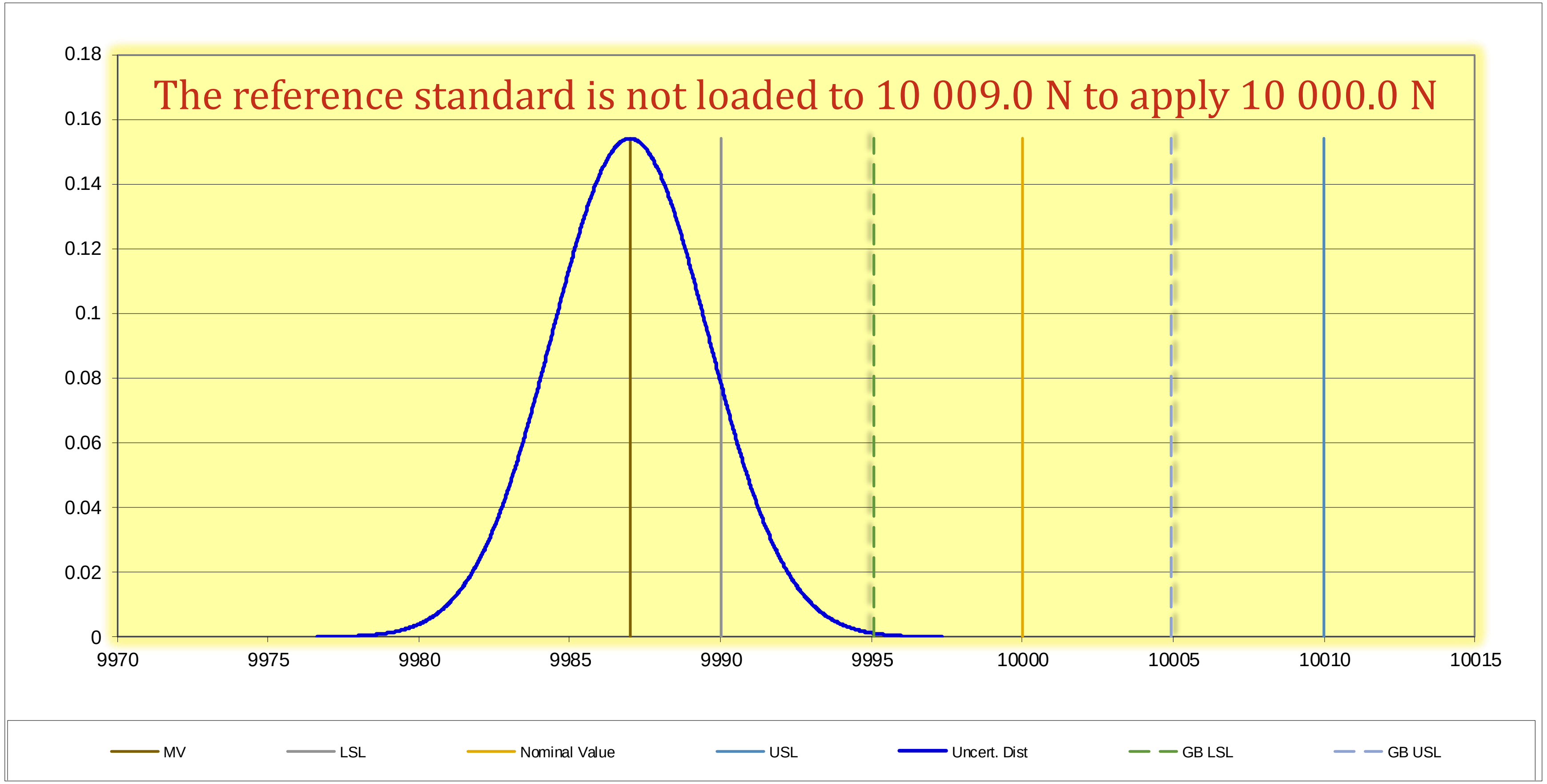
When you know the value to generate 10 000.0 N is 10 0009.0 N.

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?

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

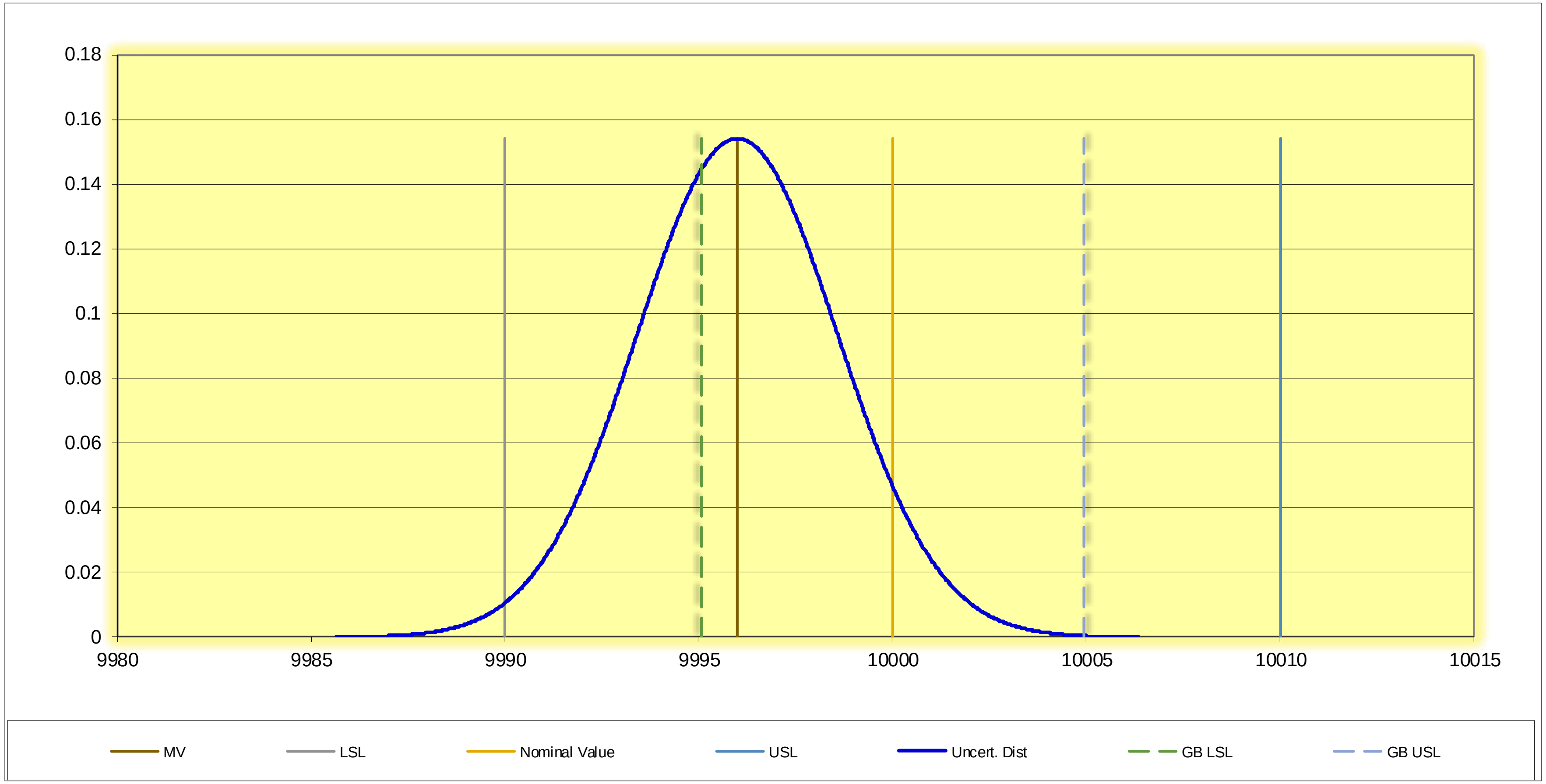
Nominal Value	**10000.0**
Lower specification Limit	9990.0
Upper Specification Limit	10010.0
Measured Value	**9987.0**
Measurement Error	-13.0
Std. Uncert. (k=1)	**2.589**
Total Risk	**87.67%**
Upper Limit Risk	0.000%
Lower Limit Risk	87.672%
TUR =	**1.931223436**
Cpk=	**-0.59120171**
TAR=	**3.99840064**
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.

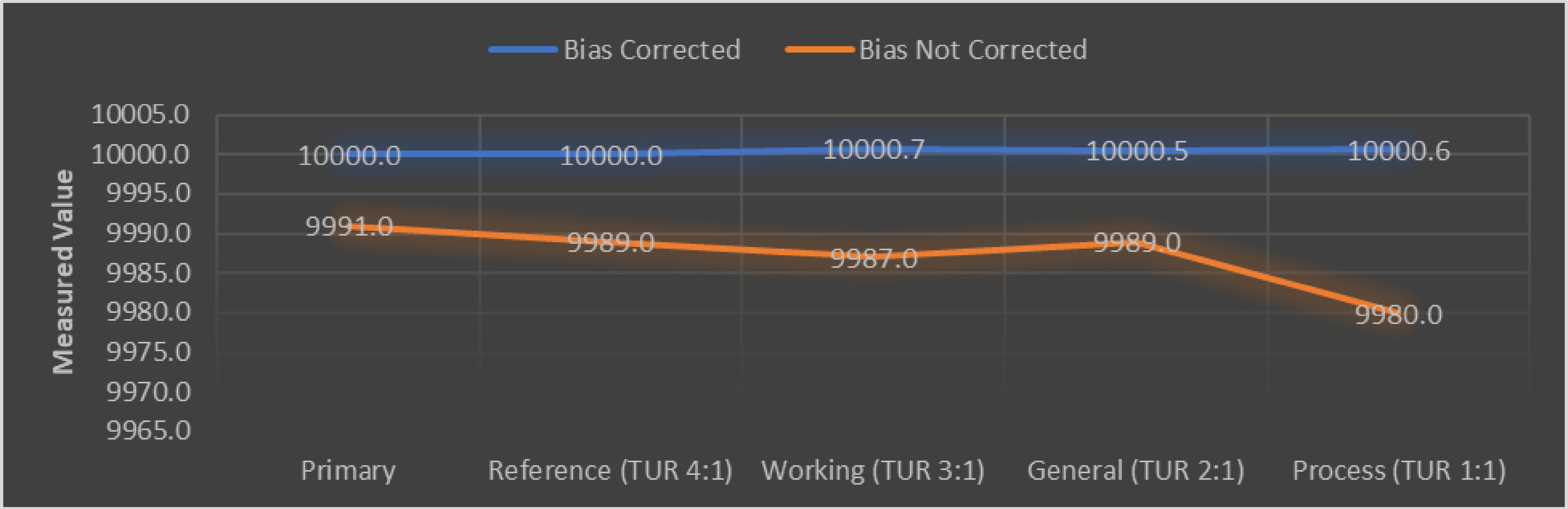
Nominal Value	**10000.0**
Lower specification Limit	9990.0
Upper Specification Limit	10010.0
Measured Value	**9996.0**
Measurement Error	-4.0
Std. Uncert. (k=1)	**2.589**
Total Risk	**1.02%**
Upper Limit Risk	0.000%
Lower Limit Risk	1.024%
TUR =	**1.931223436**
Cpk=	**1.182403422**
TAR=	**3.99840064**
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%**



What happens when we do not correct the bias?

	Measurement Uncertainty *k* = 2	BIAS Measured Value With Bias	BIAS CORRECTED Measured Value Bias Removed
Primary	0.17	9991.0	10000.0
Reference (TUR 4:1)	2.5	9989.0	10000.0
Working (TUR 3:1)	3.3	9987.0	10000.7
General (TUR 2:1)	5	9989.0	10000.5
Process (TUR 1:1)	10	9980.0	10000.6

Not correcting for Bias



The Figure above shows what happens when the reference laboratory does not correct for bias and applies 9,991.0 lbf and not 10,000.0 lbf.

In this scenario, instruments may have failed when they would have passed calibration.

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

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

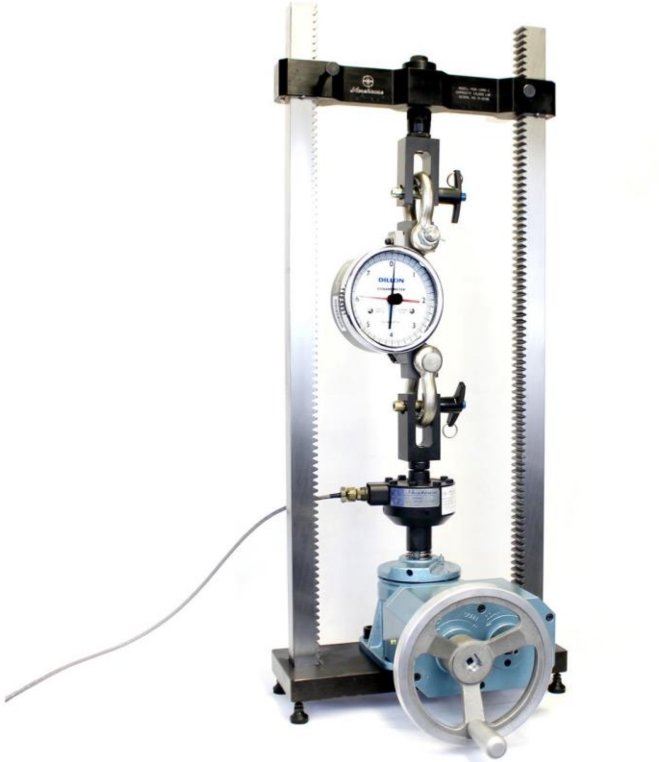
Stacking Weights Issues

- 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 %



Using Mass Instead of Force Weights

- It is very important that the gravitational value for the Laboratory is established. The effect of not doing this could be a variation in the force produced by the weight of perhaps 0.1 % or more of reading. It is therefore strongly recommended that you establish the local value of gravity (g) for your Laboratory and use weights that have been calibrated at that gravitational constant.

- The ideal solution is to have the gravity measured on site by the national geological survey agency.

Gravity Correction

- There are several formulae, usually based on latitude and sometimes altitude above sea level. These are quite inaccurate, often being incorrect by 800-900 milligals, or about 0.1 %. Obviously, these may be used if the stated uncertainty of a measurement is correspondingly coarse, but it’s not a good idea.

Converting Force (lbf) to Mass(lbs)

Exercise

Force = M x g / 9.80665 m/s^2 (1 – d/ D)

Where M = mass of weight, g = gravity at fixed location, d = air density, and D = material density

CM = Conventional Mass of the artifact. The conventional mass is defined as the mass of material of a specified density that would exactly balance the unknown object if the weighing were carried out at a temperature 20 °C in air of density 0.0012 g/cm3.

Additional Information

Using Mass Weights for Force

Converting Force (lbf) to Mass(lbs)

The Correct Method that should be used for weighing different material

- **Step 1. Obtain Measured Force Value**

  10,000 lbf

- **Step 2. Find the gravity at the location of the measurement**

  9.79620 m/s^2

- **Step 3. Find Air Density and Material Density (or use conventional mass formula)**

  For Denver, at around 24 degrees C Air Density may be estimated at 0.960 kg/m3 and Material density assuming Stainless Steel is 7916.453 kg /m3

- **Step 4. Use the following Formula**

  Mass = Force x 9.80665/(local gravity*(1-d/D)

Mass = 10,000 lbf x 9.80665/(9.79620*(1-0.960/7916.453))

Mass = 10,011.89 lbs

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 Weig	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

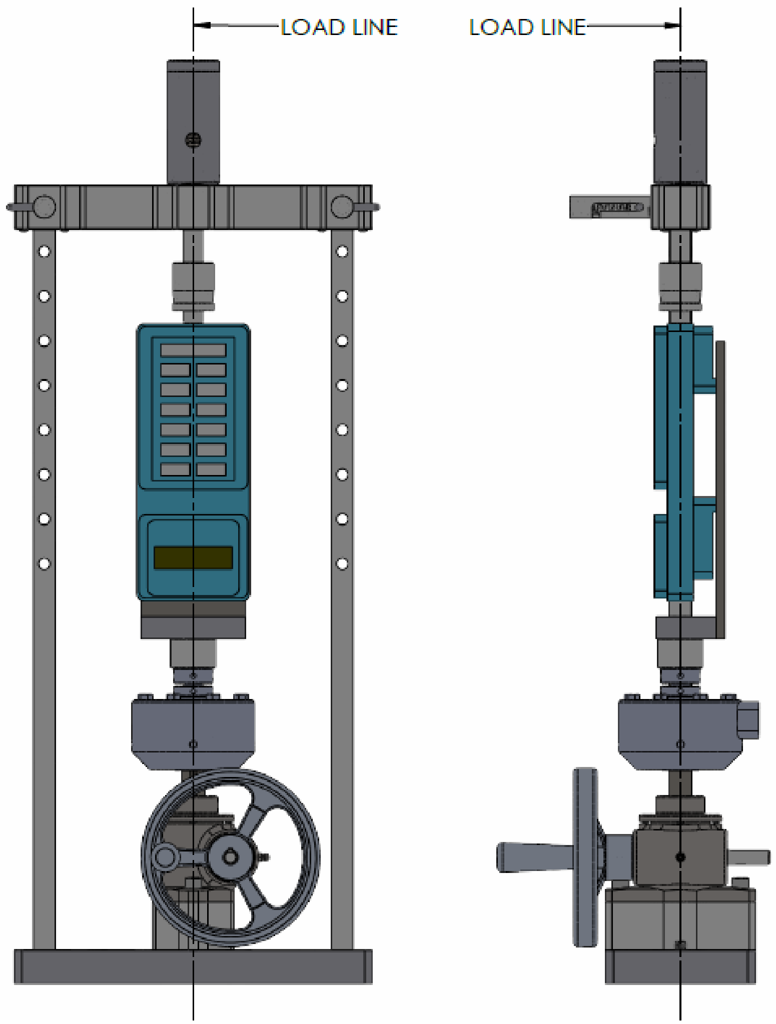
Enter Force Applied and Reduced Run Data From Certificate

	Tension Force to Mass												
Test Point #	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

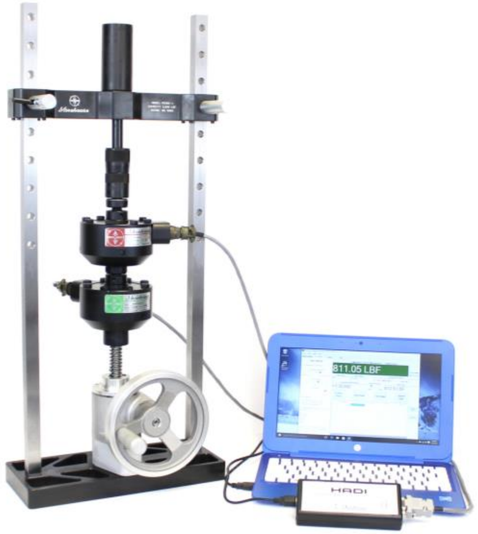
Alignment Issues

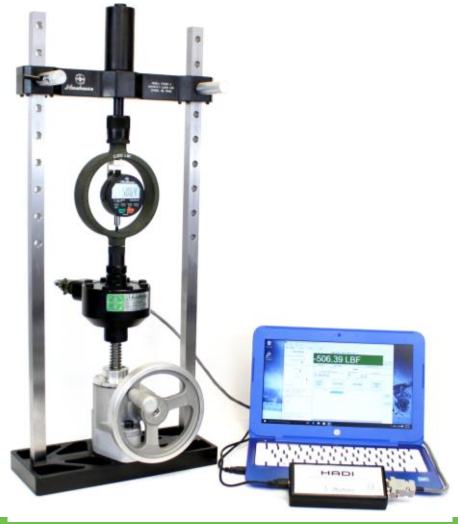
- Misalignment can cause errors that exceed 1 % of applied reading on certain load cells and other devices.
- Using the right adapters will help reduce these errors

PCM-2K Low Cost

- Low cost when compared to paying someone to manually lift weights onto a pan and take a reading
- Low cost when compared against technicians sustaining an injury
- Low Cost when compared against other systems that are not as versatile or have the proper adapters

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

- Is anyone calibrating cable tensiometers here?

- What equipment is currently being used by your company to calibrate cable tensiometers?

- What are the current challenges to calibrate this equipment?

Mechanical Tensiometer

A cable tensiometer is a device with an accuracy specification that is typically 1-5 % of capacity force. They are used to check the tension of wire cables (typically used in aircraft rigging and textile manufacturer).

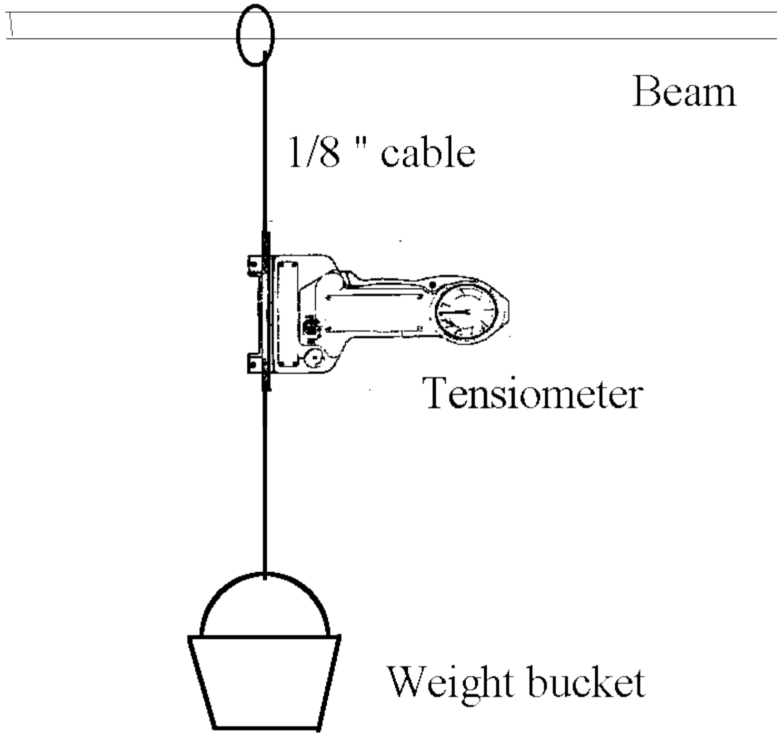
Mechanical Tensiometer
How They Work

They use a force gauge to react against the cable, via a riser, and display the result, through a gearbox, onto a dial scale. The dial is often just a linear scale numbered 0 through 100, a conversion table is then drawn up to convert the number to a meaningful result in lbf.

Mechanical Tensiometer
How They Work

Calibration is often done by loading to the same force point several times and taking an average of the readings. The tensiometers should be calibrated based on use and other factors. Some common problems to watch for are physical damage, overstretching of the spring (can happen when the correct riser is not installed for calibration), corrosion, and damaged risers.

Mechanical Tensiometer



Some calibration procedures may be very questionable. A common method of calibration is fixing one point of the cable and stacking weights, or even filling a bucket with the appropriate amount of weight to generate the force.

Note: Anyone think the bucket method is metrologically sound or would it pass an audit?

Mechanical Tensiometer Low Capacity

Mechanical Tensiometer Calibrator (model PCM-2MD-T1) is an easy-to-use solution for problems associated with calibrating force instruments and cable tension meters (tensiometers) propely up to 2000 lbf capacity.

This machine provides the user with fine and stable control on the applied force and offers a large working area which long enough to test tensiometers on standard cables lengths of 5 ft.

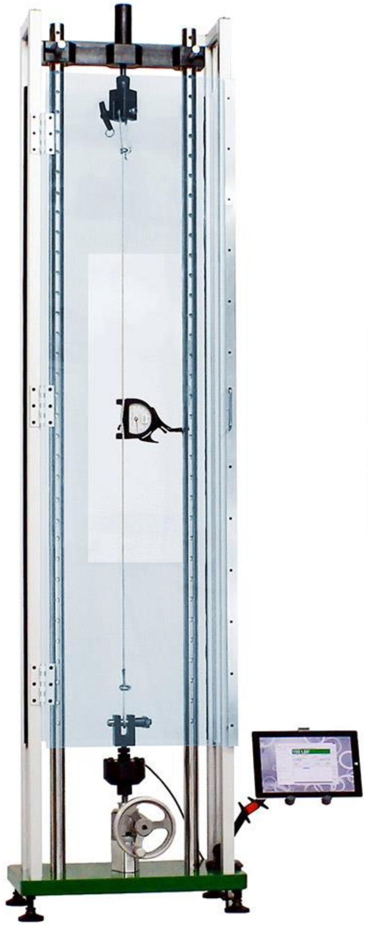
Smaller Models are also available.

Mechanical Tensiometer Low Capacity

The system is equipped with several time-saving features that enable a quality force calibration on a wide range of force sensors such as shear web load cells, S-type load cells, force gauges, button load cells, beam load cells, etc.

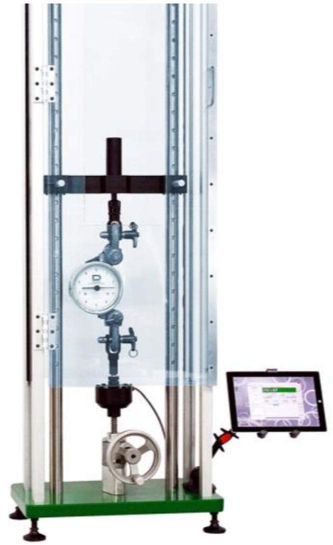
Mechanical Tensiometer

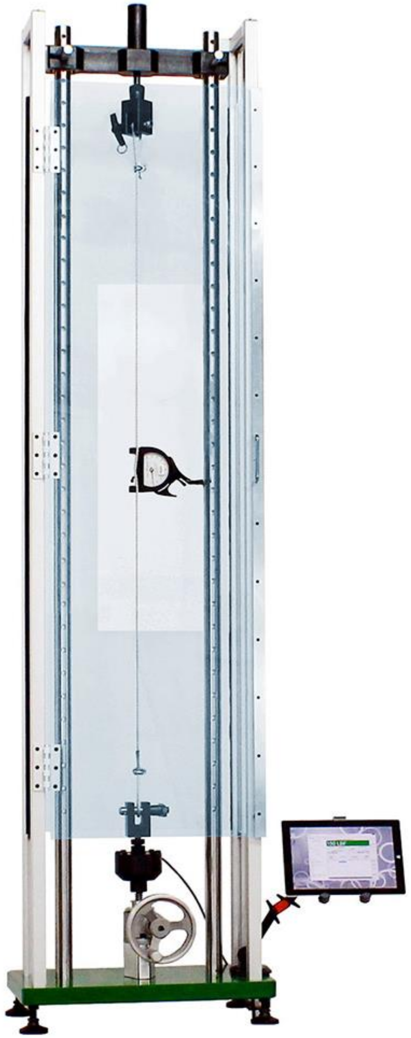
Low Cost



- Low cost when compared to paying someone to manually lift weights onto a pan and take a reading
- Low cost when compared to a $ 100,000.00 plus deadweight machine
- Low cost when compared against technicians sustaining an injury
- Low cost when comparing against a less accurate method of back calculating torque and not getting the right result

Mechanical Tensiometer High-Value





- High-Value when compared to paying someone to manually lift weights onto a pan and take a reading

- High-Value in terms of versatility – Can calibrate Dynamometers, 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 %

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.

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 a 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

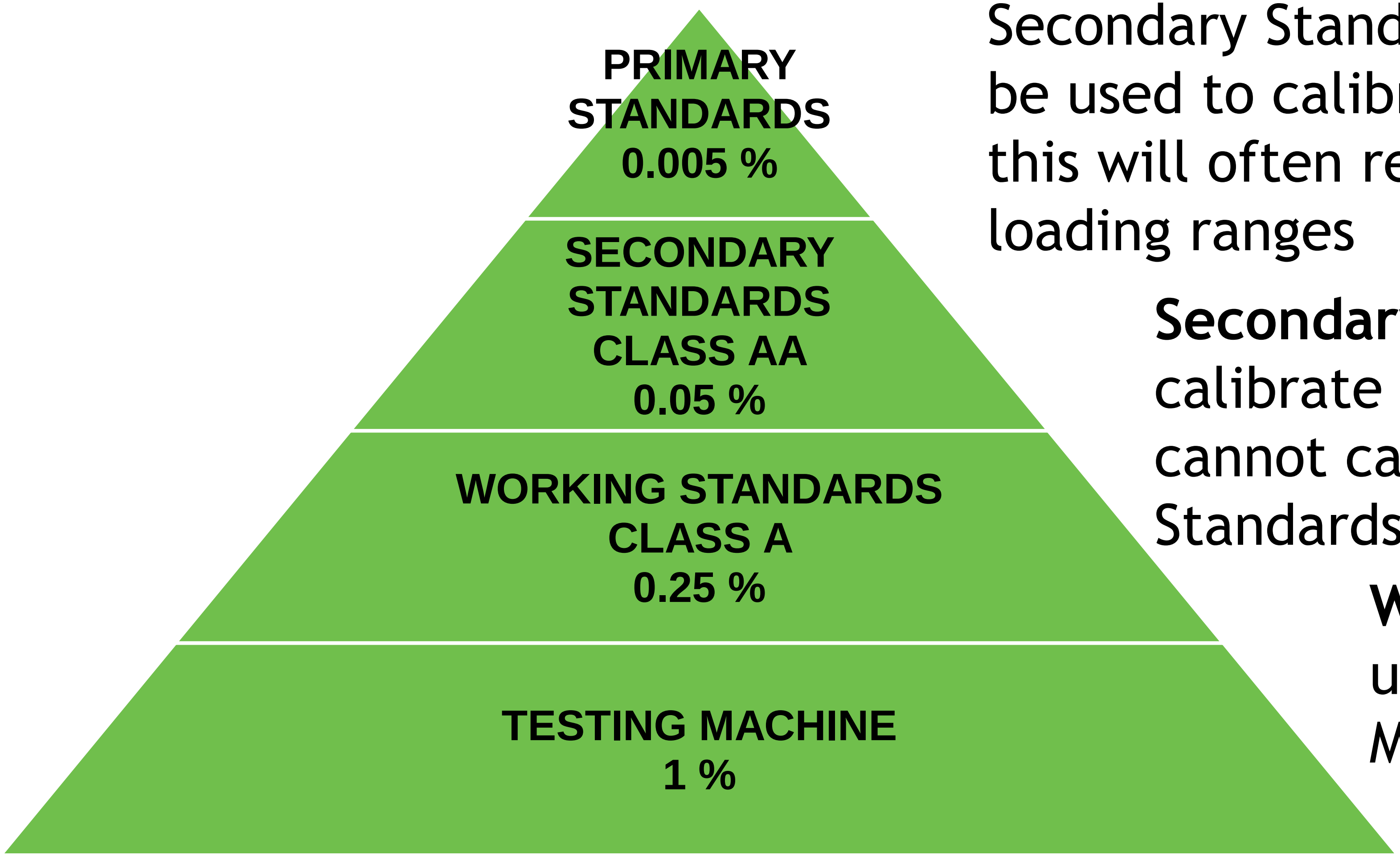
Secondary Force Standard as defined by ASTM E74

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 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. 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 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

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

- 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

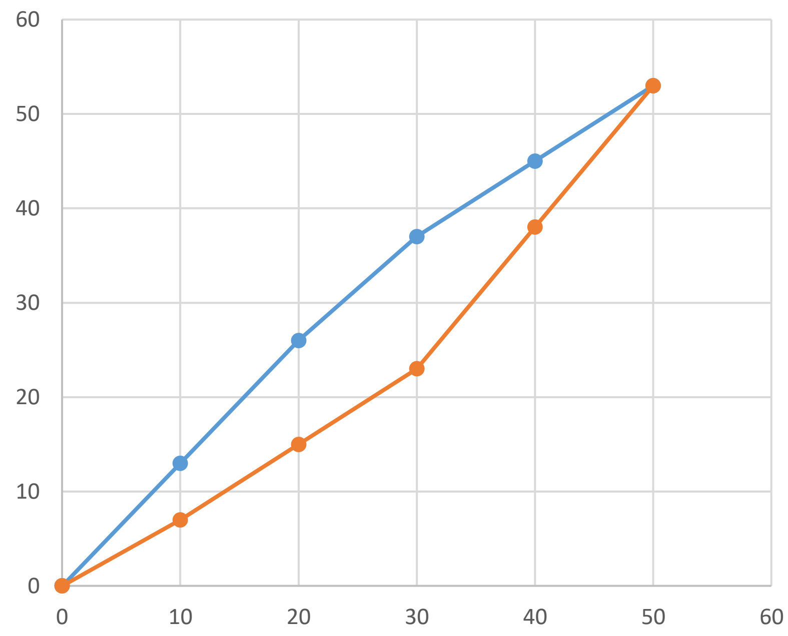
ASTM E74 Calibration Procedure

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.



MHFORCE Morehouse THE FORCE IN CALIBRATION SINCE 1925

ASTM E74 Calibration

- The Class A or Class AA verified range of forces cannot be less than the first applied **nonzero 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 than2 % (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 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 "*

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 98.2 % 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

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

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

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.

Calculating Force CMC's

Guidance Documents

- NCSLI RP-12 Determining and Rpt. Measurement Uncertainties (2013)
- Lack of proper guidance document for non-ASTM E74
- ASTM E74 Appendix combined with A2LA R205 Specific Requirements: Calibration Laboratory Accreditation Program

A2LA has an excellent guidance document G126Guidance on Uncertainty Budgets for Force Measuring Devices
https://a2la.qualtraxcloud.com/ShowDocument.aspx?ID=10227

Class Exercise

- What goes into a force uncertainty budget?

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.

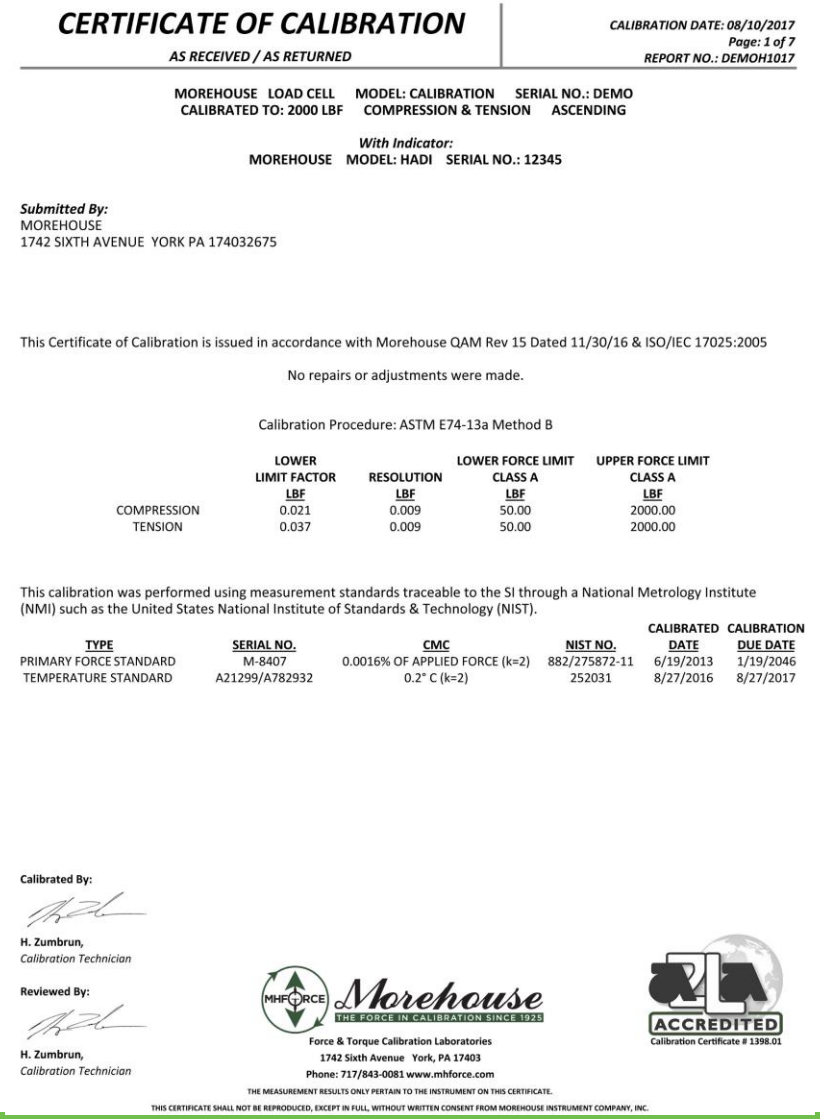
Uncertainty Budget for ASTM E74 Calibrations

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

Force	%	Eng. Units	Conv %	Force	MUST SELECT % 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

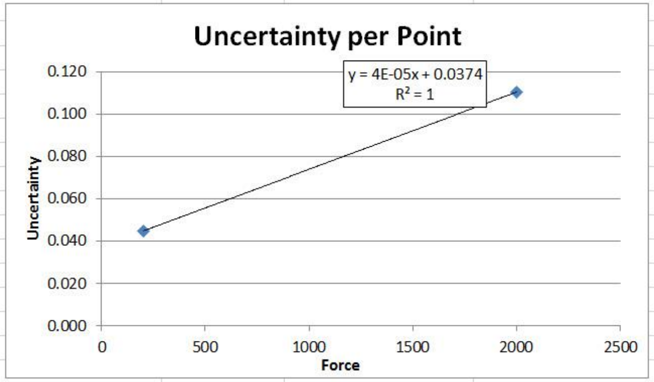
Morehouse Measurement Uncertainty Calibration and Measurement Capability Worksheet

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

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 towards where the force is being generated from.

Misalignment

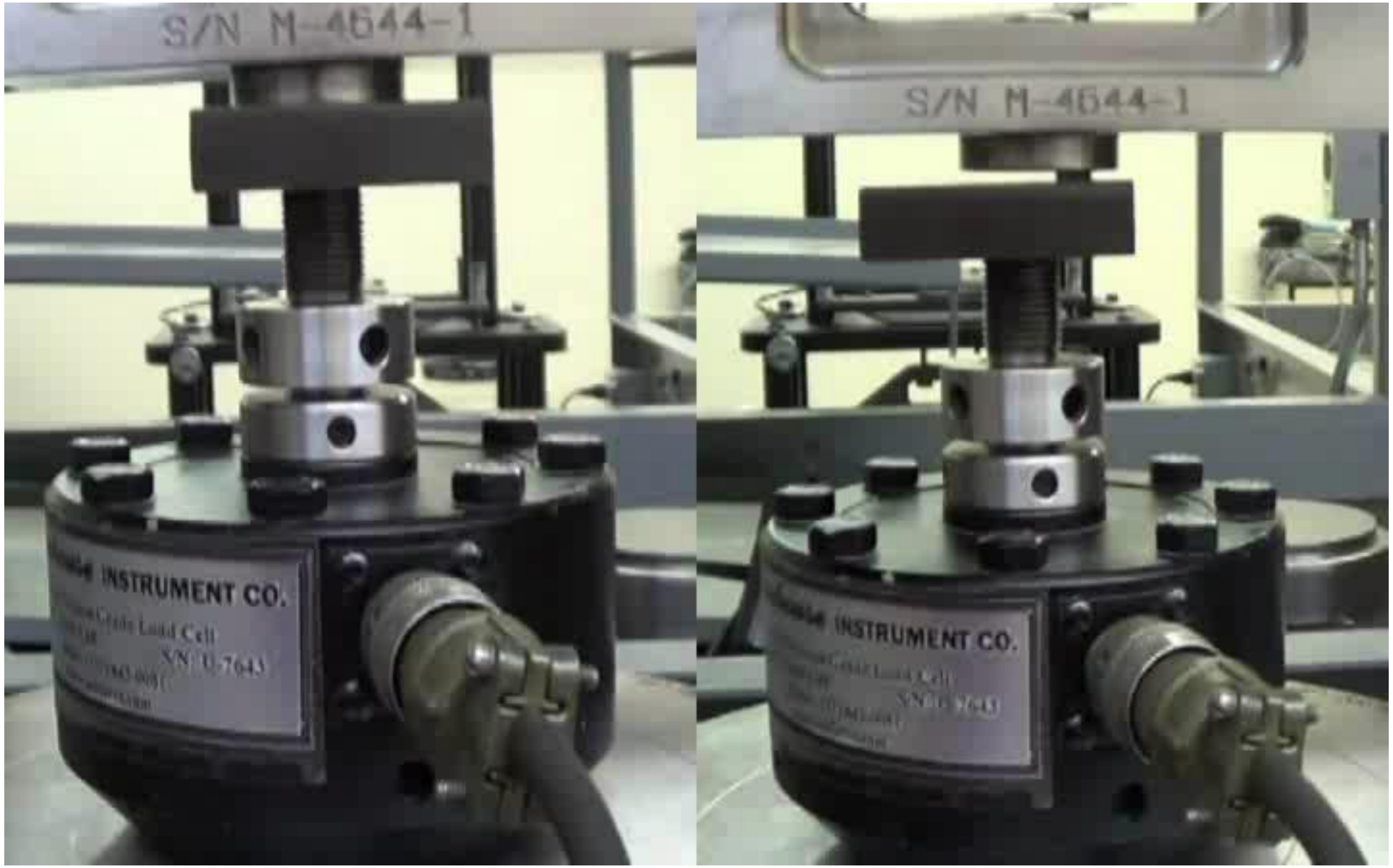
- For compression loading, a load pad or button can be used, and the surface should be ground flat.
- We have shown large deviations on ASTM E74 calibrations by using a beat-up, non-flat pad.
- For tension, it is recommended to use adapters with a spherical to reduce additional bending moments.

Misalignment

- A well aligned calibration machine may demonstrate bending less than 2 %.   Some transducers also specify this error. The % can usually be 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

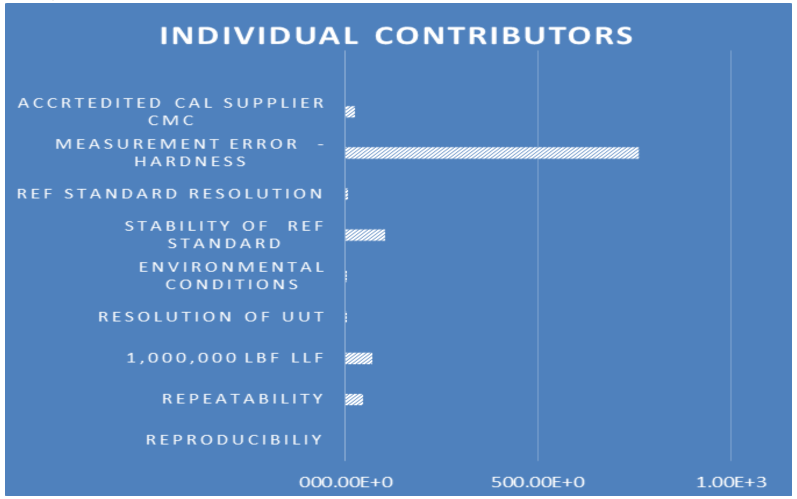
VERSUS MOREHOUSE WITH 0.0022 %

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 Adaptors

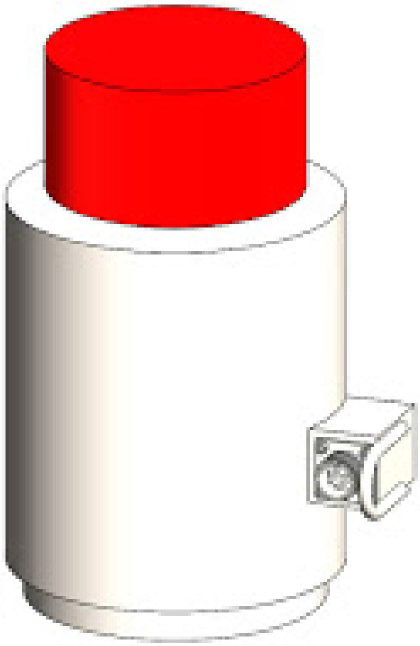
- Example: A customer brought in a 1,000,000 LBF load cell for calibration. Morehouse performed a calibration. The output of the load cell was recorded as 1,500 LBF higher than the previous calibration for a force applied 1,000,000 LBF.

- Is this a stability issue, or an adaptor 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 original top adaptor to 1,490 LBF using the newly fabricated adaptor.

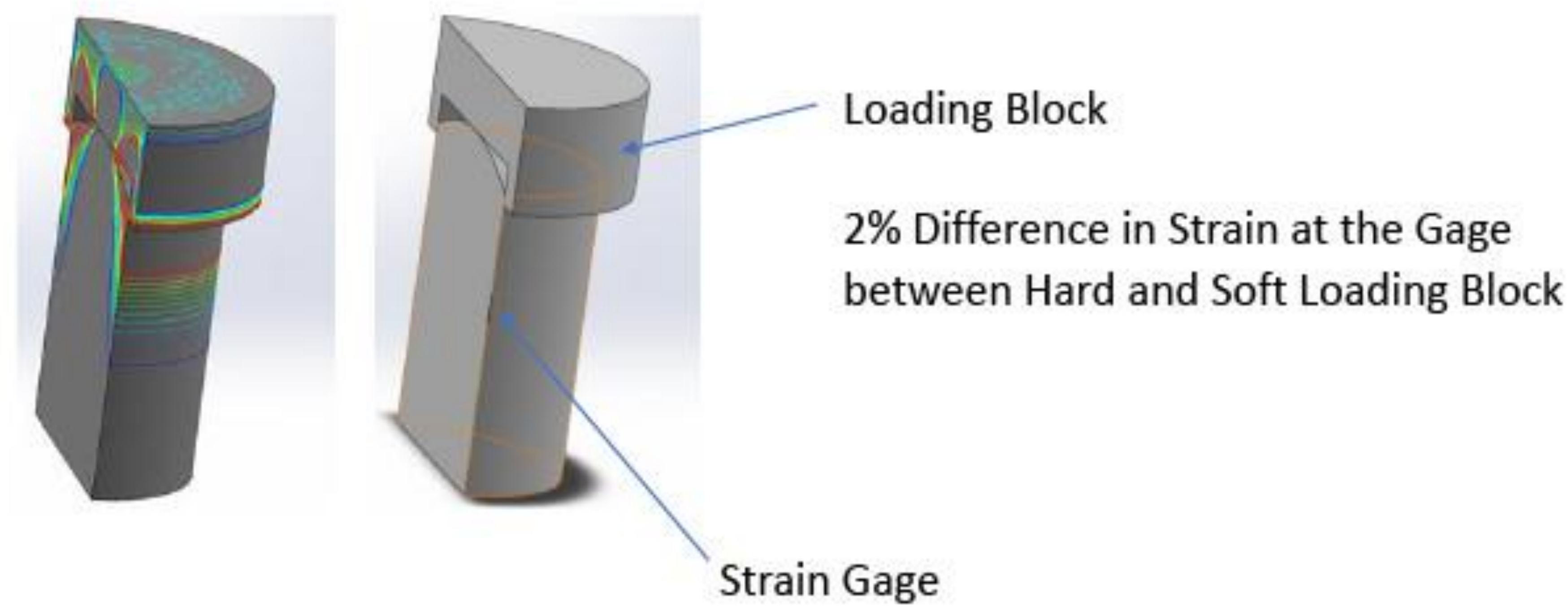
Different Hardness of Top Adaptors



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 Adaptors



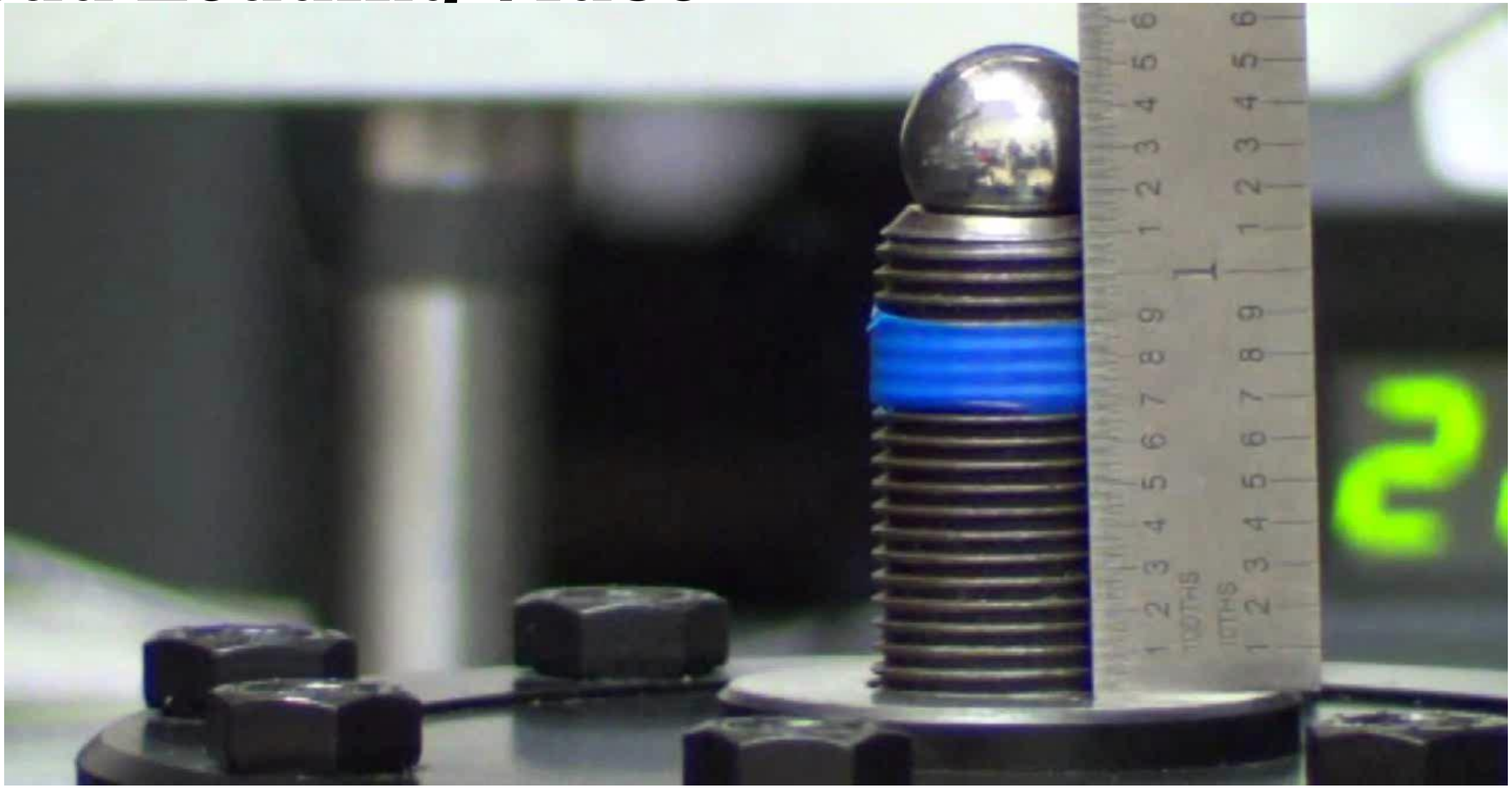
Materials with different hardness experience different amounts of lateral deflection under the same amount of load. Therefore, the varying hardness causes different amounts of stress between the block and the load cell. The above analysis shows steel to steel. It gets much worse if we use a softer material

Different Hardness of Top Adaptors

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



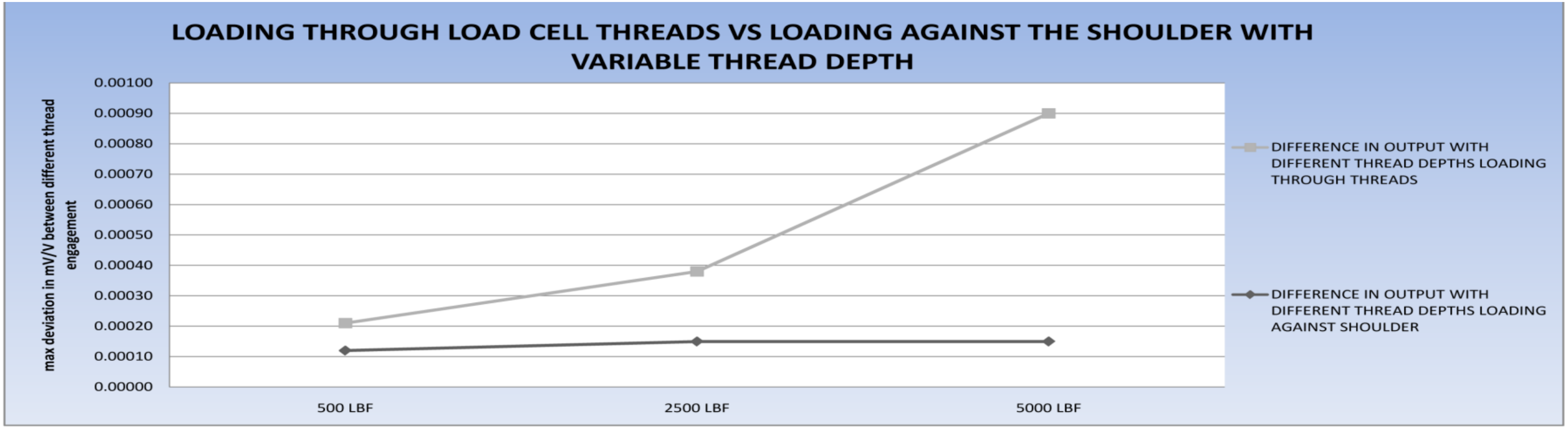
LOADING THROUGH THE THREADS POTENTIAL ERROR

On the left 0.034 % error added to the combined uncertainty vs Standard analysis on the same cell with 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

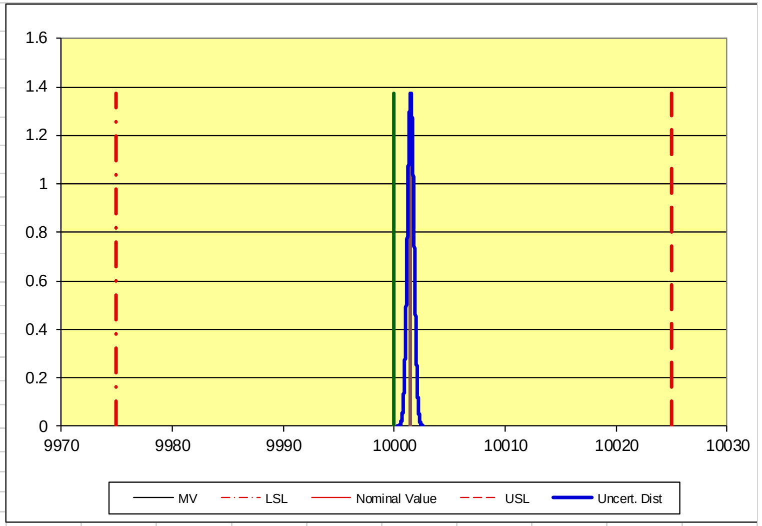
Have the calibration provider replicate how the device is being used

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?

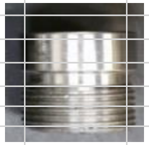
Well within 0.25 %

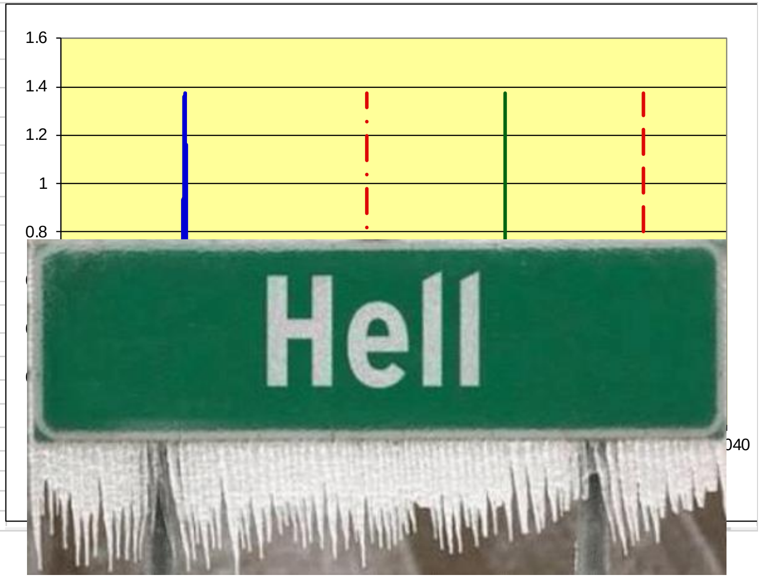
Nominal Value	10000
Lower specification Limit	9975
Upper Specification Limit	10025
Measured Value	10001.5
Measurement Error	1.5
Std. Uncert. (k=1)	0.29
Total Risk	0.00%
Upper Limit Risk	0.00%
Lower Limit Risk	0.00%
TUR =	43.1034



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?

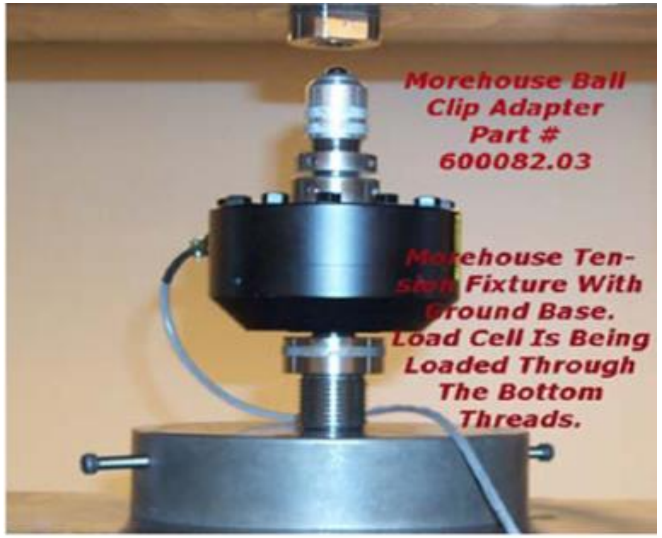
a) Call the Customer
b) Document it
c) Send a Postcard
d) Hire an Attorney
e) Do Nothing

Different Thread Depths on a Non-Shear Web Cell

Solution.
Called the customer and asked for adapters (contract review)
Customer instructed us to do what we thought was best. Everything was documented and we put this on the certificate per ISO/IEC 17025 5.10.1 paragraph 2.

The above identified instrument was calibrated in accordance with ASTM International's (American Society for Testing and Materials) standard E74-13a 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. This calibration is in conformance with the requirements of Morehouse QAM Rev. 12.1, dated 05/02/14, ISO/IEC 17025.

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

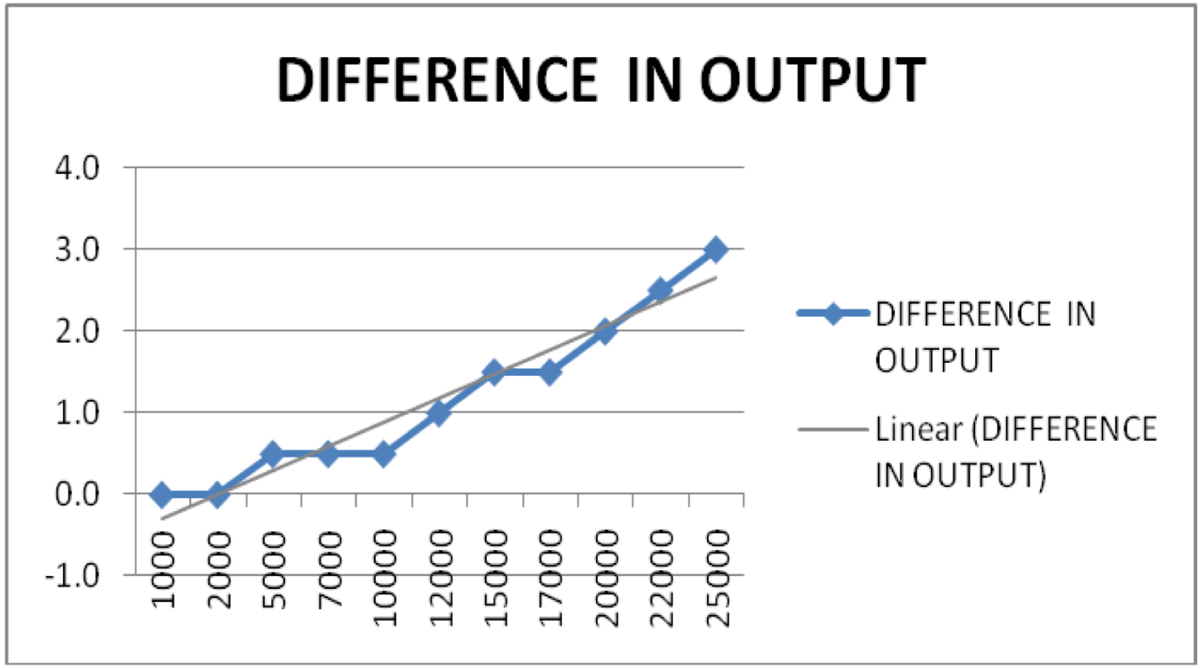
THIS TEST WAS DONE TO SHOW THE POTENTIAL DIFFERENCE IN OUTPUT BY LOADING A SHEAR WEB LOAD CELL AGAINST THE BASE OF THE LOAD CELL VESUS LOADING THROUGH THE BOTTOM THREADS

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

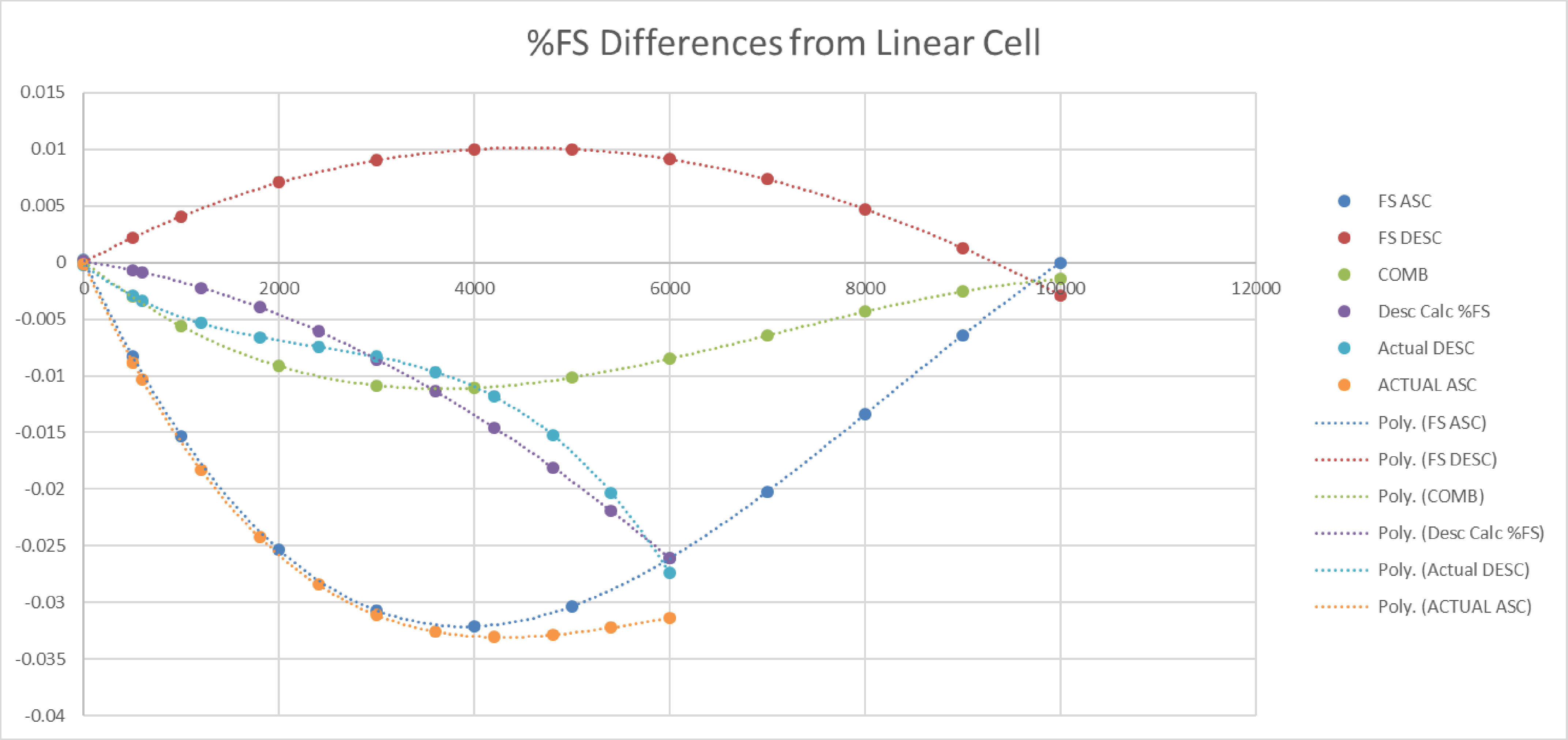
MOREHOUSE	10000	LBF	SERIAL NO	EXAMPLE
%	Force Applied	COMBINED UNCERTAINTY FOR K=2		
2.00%	200	0.20880%	0.418	LBF
10.00%	1000	0.04396%	0.440	LBF
20.00%	2000	0.02510%	0.502	LBF
30.00%	3000	0.01972%	0.592	LBF
40.00%	4000	0.01745%	0.698	LBF
50.00%	5000	0.01629%	0.815	LBF
60.00%	6000	0.01563%	0.938	LBF
70.00%	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.

Not Using Different Curves for Decreasing Forces

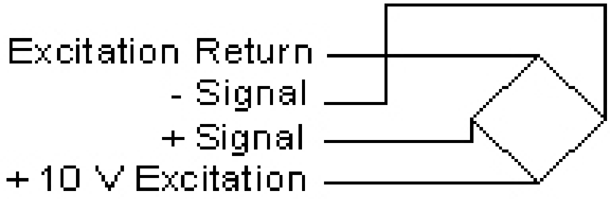


Cable Length Error

- Load cells used with meters that have a 4-wire configuration are subject to additional error. 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.

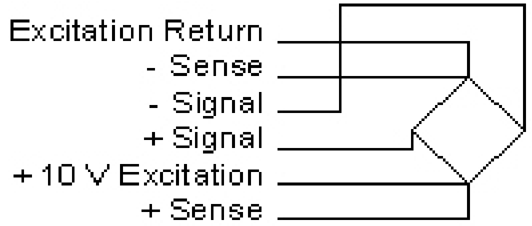
Cable Length Error

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.



MHFORCE Morehouse THE FORCE IN CALIBRATION SINCE 1925

Cable Length Conclusion

On the left 0.106 % error added to the combined uncertainty vs Standard analysis on the same cell with 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

Torque and Bolting A Load Cell

- Below are raw calibration numbers on a load cell that was sent into us for calibration. Notice the large deviations at higher capacities.

POSITION	LOAD APPLIED LBF.	NORMALIZED MEASURED DATA TEMP. OF 23 DEG. CELSIUS RUN 1 DIV	RUN 2 DIV	RUN 3 DIV	DEVIATION FROM CALCULATED FITTED CURVE RUN 1 DIV	RUN 2 DIV	RUN 3 DIV	VALUES FROM FITTED CURVE DIV
1	1000.00000	0.40797	0.00000	0.00000	0.00016	0.00000	0.00000	0.40781
2	2000.00000	0.81595	0.00000	0.00000	-0.00001	0.00000	0.00000	0.81595
3	3000.00000	1.22395	0.00000	0.00000	-0.00012	0.00000	0.00000	1.22406
4	4000.00000	1.63198	0.00000	0.00000	-0.00016	0.00000	0.00000	1.63214
5	5000.00000	2.04007	0.00000	0.00000	-0.00011	0.00000	0.00000	2.04018
6	6000.00000	2.44816	0.00000	0.00000	-0.00003	0.00000	0.00000	2.44818
7	7000.00000	2.85622	0.00000	0.00000	0.00007	0.00000	0.00000	2.85615
8	8000.00000	3.26430	0.00000	0.00000	0.00022	0.00000	0.00000	3.26408
9	9000.00000	3.67234	0.00000	0.00000	0.00036	0.00000	0.00000	3.67198
10	10000.00000	4.07944	0.00000	0.00000	-0.00040	0.00000	0.00000	4.07984
11	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
12	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
13	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
14	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
15	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
16	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
17	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
18	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000

10 PTS

Unct = 1.43

0.00016
-0.00001
-0.00012
-0.00016
-0.00011
-0.00003
0.00007
0.00022
0.00036
-0.00040
0.00000

Torque and Bolting A Load Cell

- Since this is a rather uncommon occurrence we began troubleshooting.
- We used a load cell tester and found all load cell readings were good.
- We then proceeded to check each bolt and found that 2 bolts did not have the appropriate torque applied.

Torque and Bolting A Load Cell

- We re-torqued the 2 bolts and reran the calibration. New LLF = 0.441 LBF vs OLD LLF = 1.43 LBF

- The deviations from the fitted curve became much better and the standard deviation was approximately 3 times smaller when the bolts were torqued in properly

before	after
0.00016	0.00008
-0.00001	0.00002
-0.00012	-0.00006
-0.00016	-0.00008
-0.00011	-0.00010
-0.00003	-0.00003
0.00007	0.00001
0.00022	0.00003
0.00036	0.00006
-0.00040	0.00009
0.00000	-0.00010

10/15/2013 Final CAL BOLTS WERE RE TORQUED P-8488J1513

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

2nd Degree This morning

MODEL: PRECISION
MOREHOUSE Load Cell, SERIAL NO. P-8488
10000.00 LBF Tension Calibrated to 10000.00 LBF
MOREHOUSE DSCUSB, SERIAL NO. 16883738

Interface 470706A

Calibration is in Accordance with ASTM E74-13
Tension 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	0.08159	0.08158	0.08159	0.00008	0.00007	0.00008	0.08151
1000	0.40792	0.40792	0.40791	0.00002	0.00002	0.00001	0.40790
2000	0.81584	0.81586	0.81585	-0.00006	-0.00004	-0.00005	0.81590
3000	1.22381	1.22383	1.22381	-0.00008	-0.00006	-0.00008	1.22389
4000	1.63180	1.63185	1.63183	-0.00010	-0.00005	-0.00007	1.63190
5000	2.03987	2.03991	2.03990	-0.00003	0.00001	0.00000	2.03990
6000	2.44792	2.44797	2.44794	0.00001	0.00006	0.00003	2.44791
7000	2.85595	2.85597	2.85599	0.00003	0.00005	0.00007	2.85592
8000	3.26400	3.26404	3.26403	0.00006	0.00010	0.00009	3.26394
9000	3.67205	3.67205	3.67206	0.00009	0.00009	0.00010	3.67196
10000	4.07989	4.07979	4.07985	-0.00010	-0.00020	-0.00014	4.07999

Note: Bolts were re torqued

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

Where:
A0 -8.49155569E-5
A1 4.07987171E-4
A2 1.9876956E-12

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

Where:
B0 2.08138035E-1
B1 2.45105748E+3
B2 -2.92640181E-2

The following values as defined in ASTM E74-13 were determined from the calibration data.
Lower Limit Factor, LLF 0.461 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

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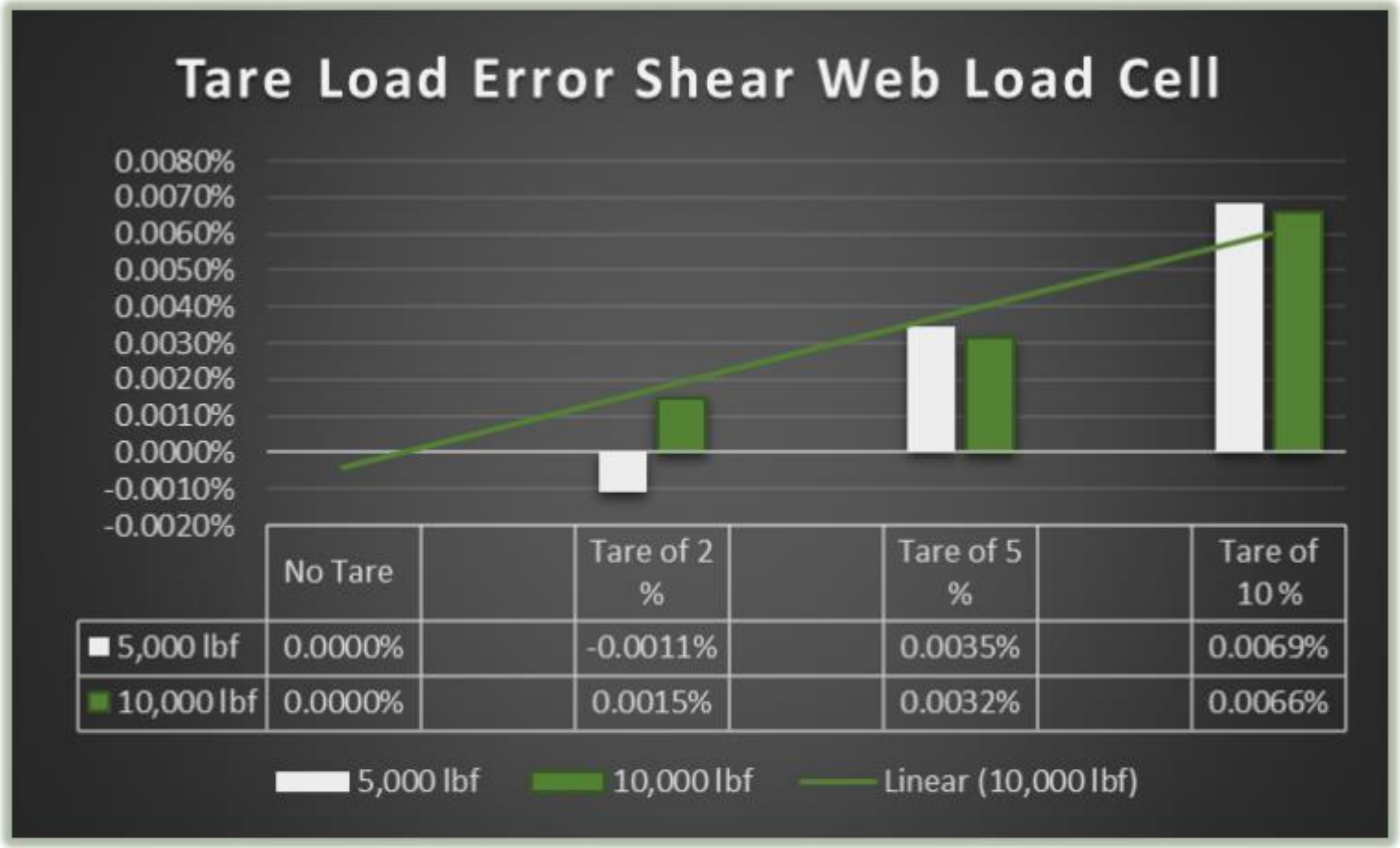
10 Volt Versus 5 Volt DC Excitation

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/

Other Error Sources

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

Risk Management

- The laboratory must plan and implement actions to address risks and opportunities.
- The laboratory is responsible for deciding which risks and opportunities need to be addressed

Risk = Probability x Impact

Risk Management 2017

ISO/IEC 17025 Risk Evolution	
2005 Managed Risk Policies Procedures Job Descriptions Top Management QM, TM	2017 Risk & Opportunity Management requires Documented Info Processes Decision Rules

2017 focuses more on minimizing a labs risk exposure and many of the ‘should’ references are replaced with shall

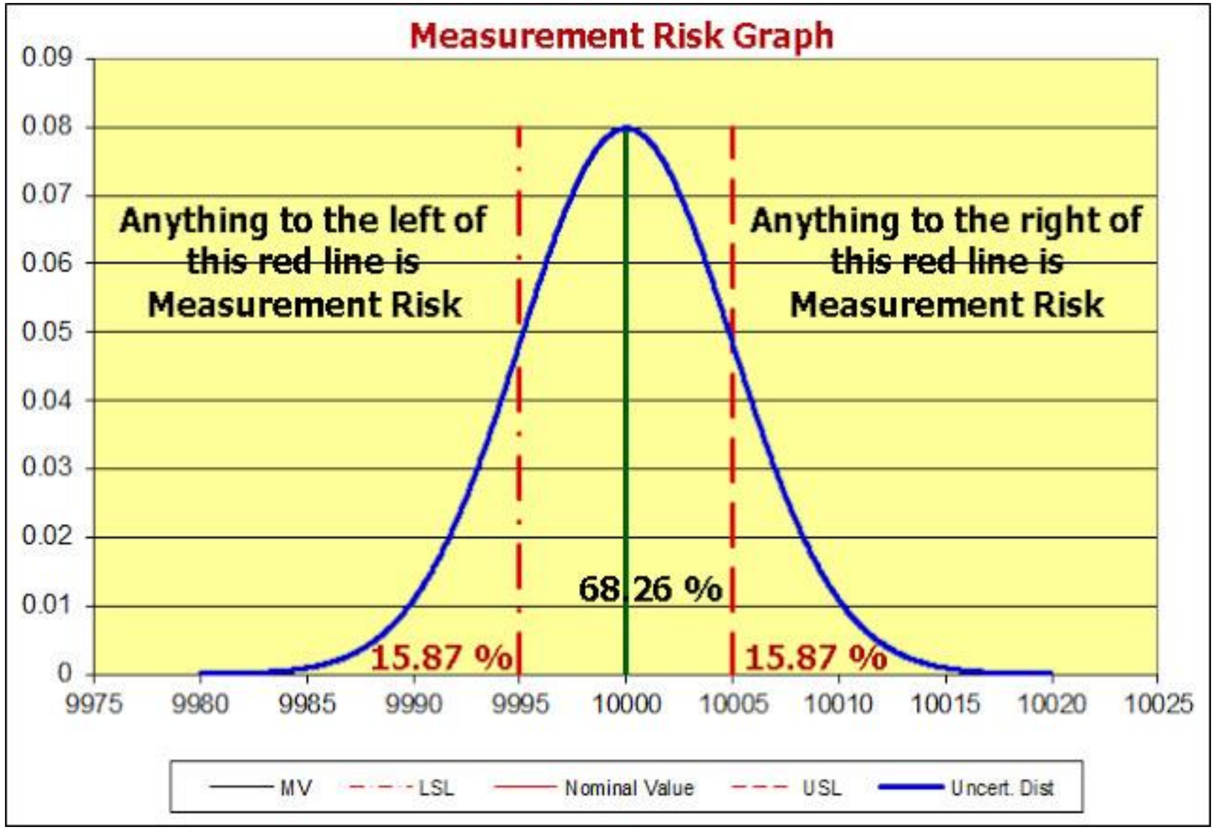
Risk Management Decision Rules

- 7.8.6.1 When a statement of conformity to a specification or standard for test or calibration is provided, the laboratory shall document the decision rule employed, taking into account the level of risk (such as false accept and false reject and statistical assumptions) associated with the decision rule employed and apply the decision rule
- 7.8.6.2 The laboratory shall report on the statement of conformity such that the statement clearly identifies –a) to which results the statement applies; and –b) which specifications, standard or parts thereof are met or not met; –c) **the decision rule applied** (unless it is inherent in the requested specification or standard)

Risk Management Decision Rules

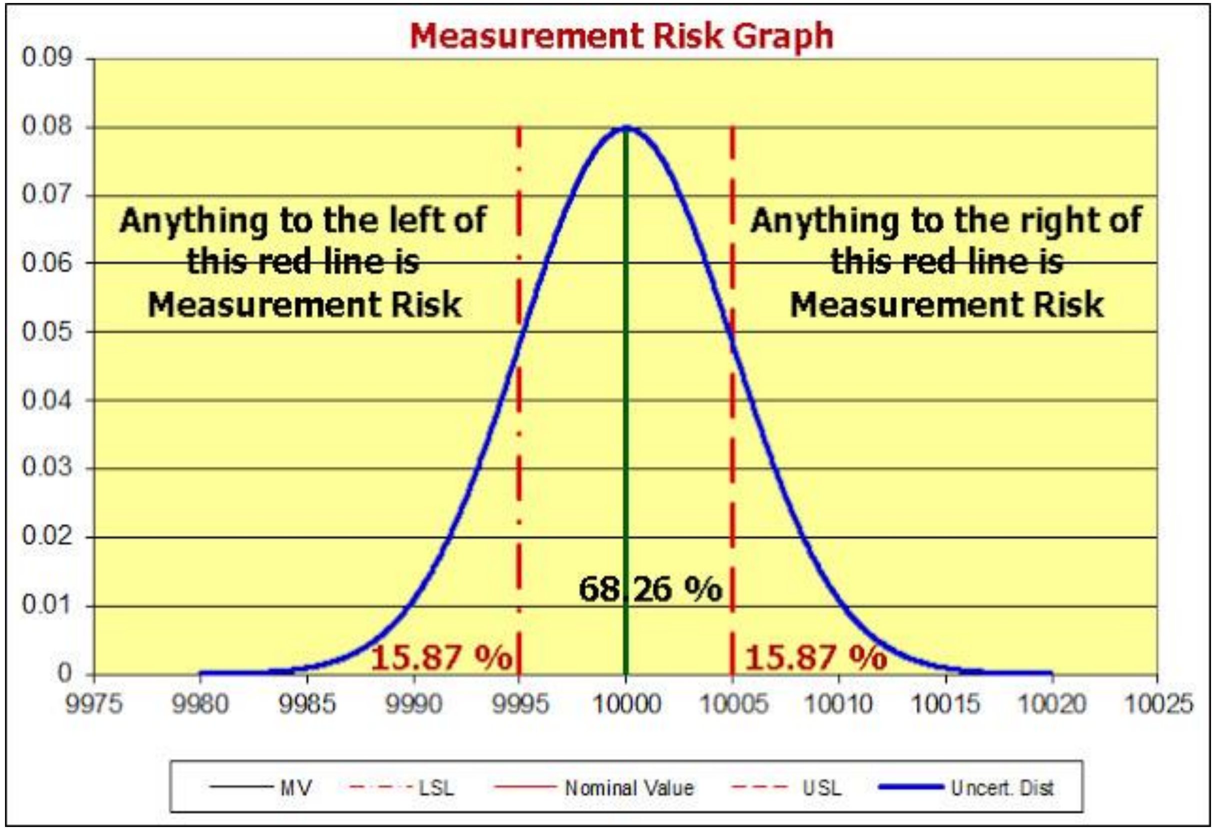
ANSI/NCSLI Z540.3-2006 defines 3.5 Measurement decision risk as probability that an incorrect decision will result from a measurement.

ISO/IEC 17025: 2017 Section 3.7 defines a decision rule as a rule that describes how measurement uncertainty is accounted for when stating conformity with a specified requirement



Measurement Related Terms

ANSI/NCSLI Z540.3-2006 defines 3.5 Measurement decision risk as probability that an incorrect decision will result from a measurement.



Is anyone okay with 31.74 % risk?

Risk Management Decision Rules

FORCE APPLIED lbf	RUN 1 MEASURED OUTPUT lbf	ACCEPTANCE LIMIT UPPER lbf	ACCEPTANCE LIMIT LOWER lbf	EXPANDED UNCERTAINTY lbf	TUR	PFA	COMPLIANCE PASS/FAIL
0	0						
10000	10050	10100	9900	31	3.23:1	0.063%	Pass
20000	20000	20100	19900	31	3.23:1	0.000%	Pass
30000	30050	30100	29900	31	3.23:1	0.063%	Pass
40000	40050	40100	39900	31	3.23:1	0.063%	Pass
50000	50050	50100	49900	31	3.23:1	0.063%	Pass
60000	60050	60100	59900	31	3.23:1	0.063%	Pass
70000	70000	70100	69900	31	3.23:1	0.000%	Pass
80000	80050	80100	79900	31	3.23:1	0.063%	Pass
90000	90000	90100	89900	31	3.23:1	0.000%	Pass
100000	100050	100100	99900	31	3.23:1	0.063%	Pass
0	0						

RESOLUTION: 50.00 lbf

SPECIFIED TOLERANCE: +/- 0.1% FULL SCALE FROM 0 lbf TO 100000 lbf

Example of a Morehouse Certificate using documenting the decision rule applied

Measurement Related Terms

Test Uncertainty Ratio: The ratio of the span of the tolerance of a measurement quantity subject to calibration, to twice the 95 % expanded uncertainty of the measurement process used for calibration.

- NOTE: This applies to two-sided tolerances.

$$\text{T.U.R.} = \frac{\text{U.U.T. Tolerance}}{\text{Calibration Process Uncertainty}}$$

TUR

$$\text{T.U.R.} = \frac{\text{U.U.T. Tolerance}}{\text{Calibration Process Uncertainty}}$$

$$\text{TUR} = \frac{\text{Span of the } \pm \text{Tolerance}}{2 \text{ x } k_{95\%}\left(\sqrt[2]{\left(\frac{\text{CMC}}{k_{\text{CMC}}}\right)^2 + \left(\frac{\text{Resolution}_{\text{UUT}}}{\sqrt[2]{12}}\right)^2 + \left(\frac{\text{Repeatability}_{\text{UUT}}}{1}\right)^2 + \cdots (u_{Other})^2}\right)}$$

CPU = 2 * Expanded Uncertainty per ILAC P14

U = Expanded Uncertainty
CMC = Reference labs Calibration and Measurement Capability
Res = Resolution of Unit Under Test (U.U.T)
Rep = Repeatability of U.U.T.

TUR Morehouse Vs Typical Force Lab

$$TUR = \frac{\text{Span of the } \pm \text{UUT Tolerance}}{2 \text{ x } k_{95\%}(\text{Calibration Process Uncertainty})}$$

$$TUR = \frac{\text{Span of the } \pm \text{Tolerance}}{2 \text{ x } k_{95\%}\left(\sqrt[2]{\left(\frac{CMC}{k_{CMC}}\right)^2 + \left(\frac{Resolution_{UUT}}{\sqrt[2]{12}}\right)^2 + \left(\frac{Repeatability_{UUT}}{1}\right)^2 + \cdots (u_{Other})^2}\right)}$$

10,000 lbf device accurate to 0.05 % of full scale with a 0.01 lbf Resolution and 0.05 lbf Repeatability

Morehouse CMC = 0.002 % of applied
One Sided Tolerance 5 lbf
Expanded U = 0.22 lbf
T.U.R = 22:1

10,000 lbf device accurate to 0.05 % of full scale with a 0.01 lbf Resolution and 0.1 lbf Repeatability

Competitor CMC = 0.05 % of applied
One Sided Tolerance 5 lbf
Expanded U = 5.0 lbf
T.U.R = 1:1

Measurement Risk & Uncertainty

How to lower both

- Use the right calibration provider and have them replicate how the device is being used
- Have competent technicians
- Use the right equipment this includes adapters
- Lower your uncertainties through using a calibration provider with lower uncertainties

Note: There is quite a bit of difference between force measurement labs with CMCs of 0.1 %, 0.05 %, 0.02 %, 0.01 %, 0.005 % and 0.002 % of applied force.

How Good Does Your Calibration Provider Have to Be? (T.U.R. Table)

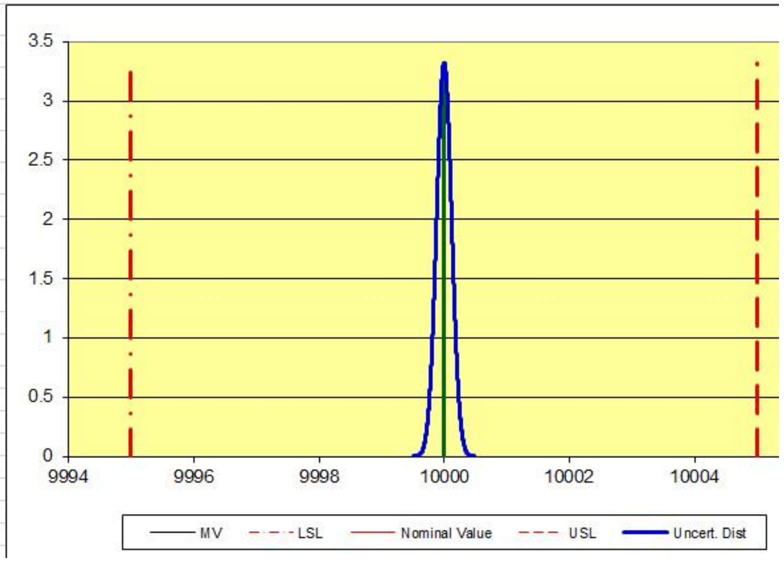
Calibration Standard Required			Tolerance Required					
			0.010%	0.020%	0.050%	0.100%	0.200%	0.500%
Deadweight	Calibration Lab Capability (CMC)	0.002%	4.329	8.657	21.644	43.287	86.575	216.437
Deadweight		0.005%	1.949	3.897	9.743	19.486	38.972	97.429
Deadweight / Lever		0.010%	0.993	1.987	4.967	9.934	19.868	49.669
High End Load Cell		0.020%	0.499	0.998	2.496	4.992	9.983	24.958
High End Load Cell		0.050%	0.200	0.400	1.000	1.999	3.999	9.997
Good Load Cell		0.100%	0.100	0.200	0.500	1.000	2.000	5.000

This table is based on a Calibration Grade Load Cell with 0.01 lbf Resolution; 0.1 lbf Repeatability.

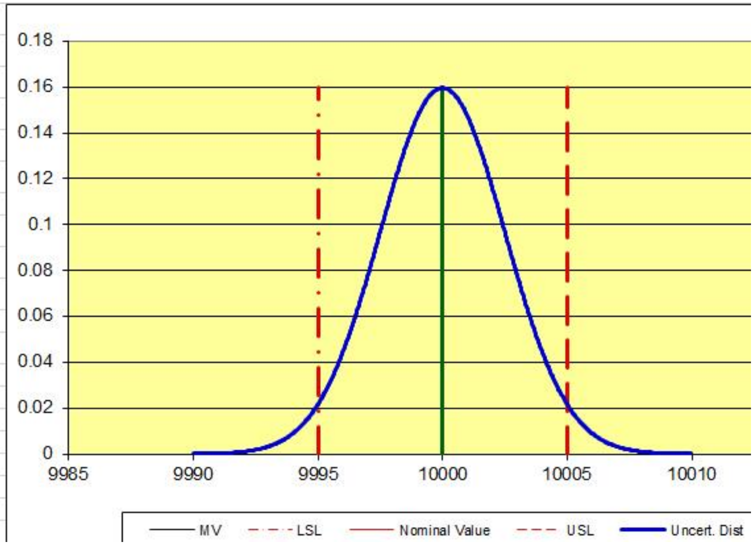
Anything in Red would have too much measurement risk.

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



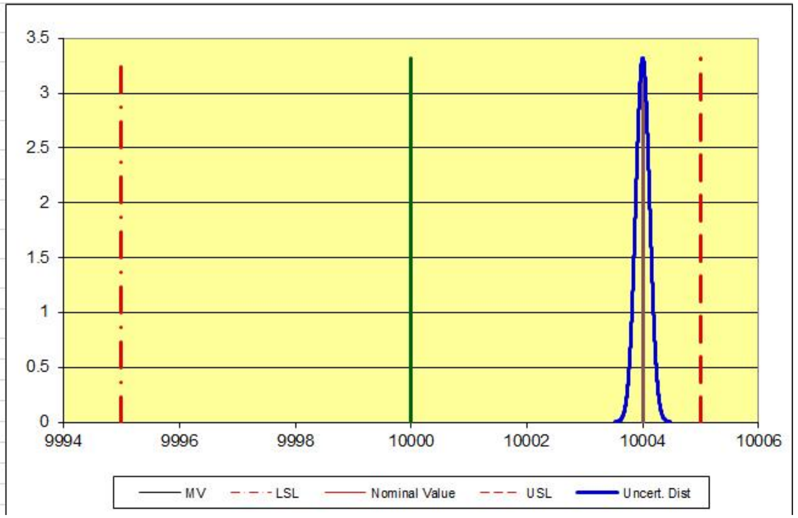
Nominal Value	10000
Lower specification Limit	9995
Upper Specification Limit	10005
Measured Value	10000
Measurement Error	0
Std. Uncert. (k=1)	2.5
Total Risk	4.55%
Upper Limit Risk	2.28%
Lower Limit Risk	2.28%
TUR =	1



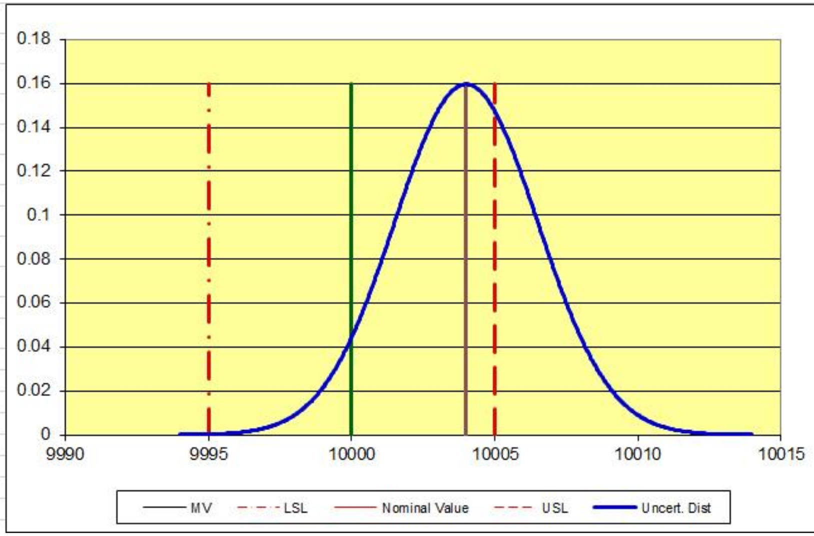
Notice the instrument reads 10,000 lbf when 10,000 lbf was applied. In this example, only the calibration provider with the lower measurement uncertainty can make the claim that the instrument is in tolerance if the requirement is less than a 2 % PFA.

T.U.R. 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 %.

ANSI/NCSL Z540.3 Method 5 Versus Method 6

The people who wrote the standard used 95.45 % as the confidence level which in most cases has a coverage factor of 2.

100 – 95.45 = 4.55
4.55/2 = 2.275

Notice: The risk is 2.275 % or less when we enter 996.002 as the measured value

At 95 % or 2.5 % our limits would become

Guard Band Limits to Assure less than 2.5 % RISK	
Guard Band LSL	995.982
Guard Band USL	1004.018

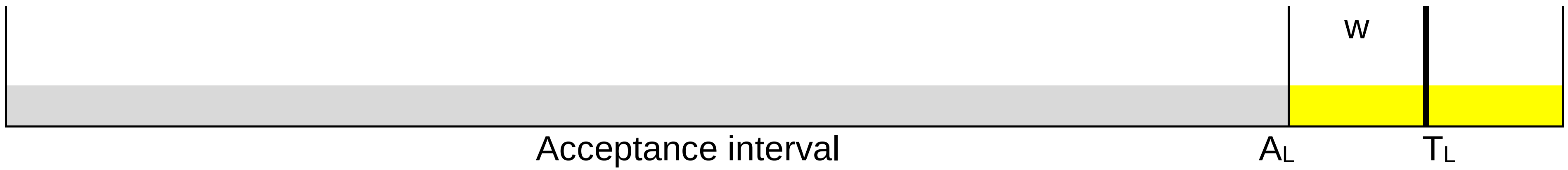
Nominal Value	1000
Lower specification Limit	995
Upper Specification Limit	1005
Measured Value	996.002
Measurement Error	3.998
Std. Uncert. (k=1)	0.50

Total Risk	2.27%
Upper Limit Risk	0.00%
Lower Limit Risk	2.27%

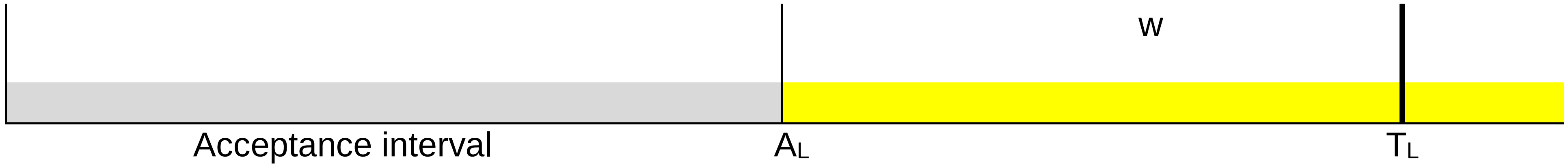
TUR =	4.991686956
Simple Guard Band with Subtraction Uncertainty Only	
Guard Band LSL	996.002
Guard Band USL	1003.998
Guard Band Limits to Assure less than 2 % RISK	
Guard Band LSL	996.029
Guard Band USL	1003.971

Large versus Small Expanded Unc

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

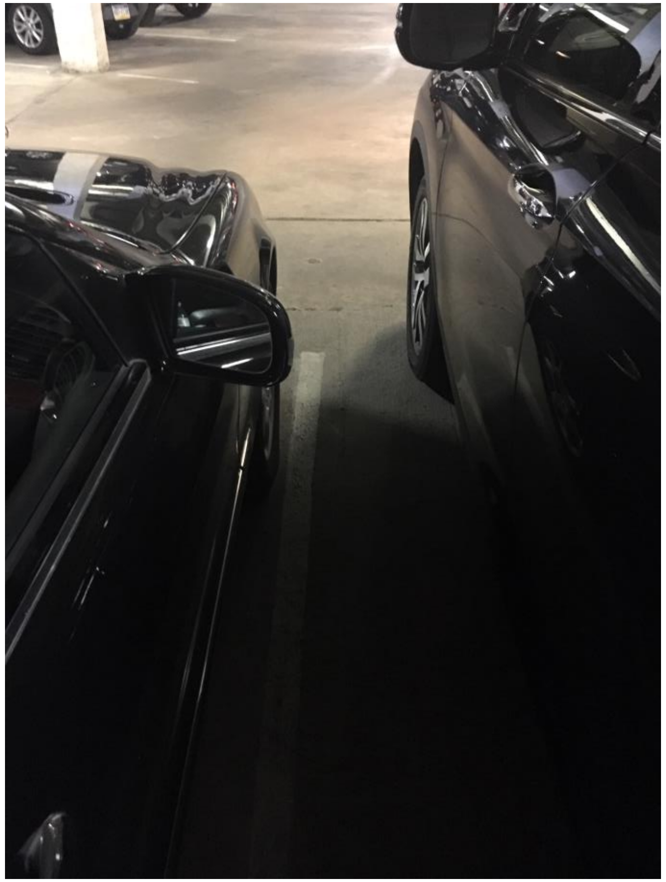


B) Large relative expanded uncertainty U=(T/2) and w=U



The lab with the smaller uncertainties will produces larger TUR's, giving you more space to be in tolerance!

The lab with the larger uncertainties will produces smaller TUR's, giving you less space to be in tolerance!



Measurement Risk

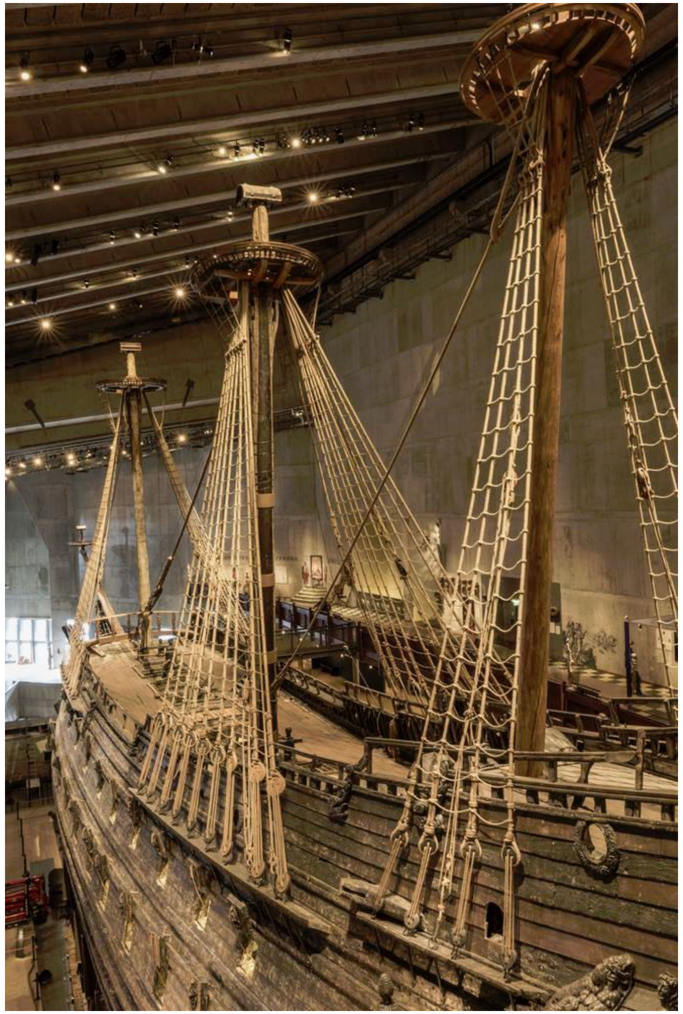
- Have you, or any of your technicians, ever overloaded a load cell?
- Have you, or someone you know, ever used the wrong equipment to try to accomplish a certain task?
- Have you signed a certificate you were unsure about?
- Do you know of any bad measurement practices in your organization that are not being corrected, or do complaints fall on deaf ears?
- How about your calibration provider: Have they ever admitted to making a mistake? If the problem was not corrected, did it just go away?

We are not perfect, but we can mitigate measurement risk by making better measurements, and by replicating the proper use of all instruments to lessen the possibility of devastating errors.

Why Measurements Matter

The Swedish warship Vasa, which famously sank in 1628 less than a mile into its maiden voyage, was built asymmetrically.

Archaeologists have found four rulers used by the workers, two turned out to be based on Swedish feet with 12 inches (30.48cm). The other two used Amsterdam feet, with 11 inches (27.94cm).



Why Measurements Matter

Why Calibration Matters

Measurement Risk

Measurement Risk

You can see the crash in this video for yourself but let us tell you about the findings of the subsequent investigation. There were **two intertwined causes of the crash.** Heavy rains before takeoff caused fuel to get into data sensors which were responsible for calculating speed and altitude among other things.

Measurement Risk

This mixture of water and fuel caused condensation to build up on the sensors which were near the planes surface. When maintenance crew were calibrating them before the flight, they were unaware of this build up **causing them to calibrate them wrong.**

It's only a 2-billion-dollar mistake

3 Rules to Lessen Your Measurement Risk

Rule #1. Know the Right Requirements - This first rule involves knowing what is needed to accomplish the task at hand.

Rule # 2. Choose the Right Equipment – Always choose Measuring and Test Equipment that can achieve the measurement tolerance required.

Rule # 3. Have the Right Processes – This last rule requires having a training program and proof of training (records) to validate the individuals performing the calibration or using the equipment.

3 Rules to Lessen Your Measurement Risk

Rule #1. Know the Right Requirements -This first rule involves knowing what is needed to accomplish the task at hand.

- The more accurate the system, the higher the costs will be to procure the equipment, and have it calibrated.
- For most tests, a T.U.R. of 4:1 will meet the guidelines set fourth in ANSI Z540.1 of ensuring that the total risk is less than 4 %.
- If the requirement is 0.1 % of applied, and the stability of the device is 0.2 % over a one-year period, the device would need to have the calibration interval shortened.

What happens when Rule #1 is not followed

BP Texas Refinery Moments before and immediately after the explosion

Knowing The Right Requirements

The Accident:

- Distillation tower and attached blow down drum overfilled
- ~7600 gallons flammable liquid released
- Liquid ignited by an idling diesel truck

Proximate cause:

- High-level alarm malfunctioned
- Level transmitter miscalibrated
  - Outdated 1975 data sheet
  - Level transmitter indicated liquid level falling
  - Level actually rising rapidly

Knowing The Right Requirements

Root causes:

- Cost-cutting, production pressures, and failure to invest
- Lack of preventative maintenance and safety training
- Procedural workarounds to compensate for the deteriorating equipment

The Cost:

- 15 deaths,
- 180 injured
- Over $2 billion, including lawsuits

The Aftermath

Special Thank You to Scott Mimbs for providing this example

3 Rules to Lessen Your Measurement Risk

Rule # 2. Choose the Right Equipment – Always choose Measuring and Test Equipment that can achieve the measurement tolerance required.

- If you need to certify that an instrument is within a tolerance of 1 %, you cannot use a standard with a 1 % tolerance to perform the calibration.
- Several manufacturers do not understand T.U.R and do not include the instrument's resolution or repeatability, or the reference standard used to perform the calibration, in their accuracy claims.
- On most of these instruments, no reference standard in the world may lower the risk if the instrument shows any bias.

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 T.U.R. 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 instruments 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

The right equipment for force is going to be

Square- for Force Machines this is about having four right angles.

Pictured Right – Morehouse 10,000 lbf Benchtop Machine. The adjustable beam and bottom base form the 4 right angles. This reduces the chance of misalignment. The bottom screw is aligned to the top beam to keep the line of force as plumb as possible.

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

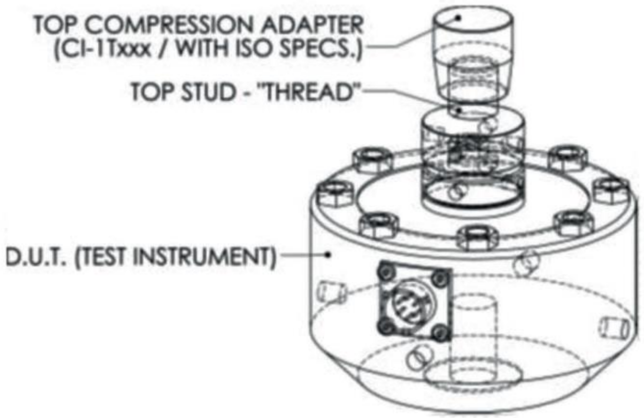
Torsion – the action of twisting or the state of being twisted. Free of torsion means free of being twisted when forces are applied

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.

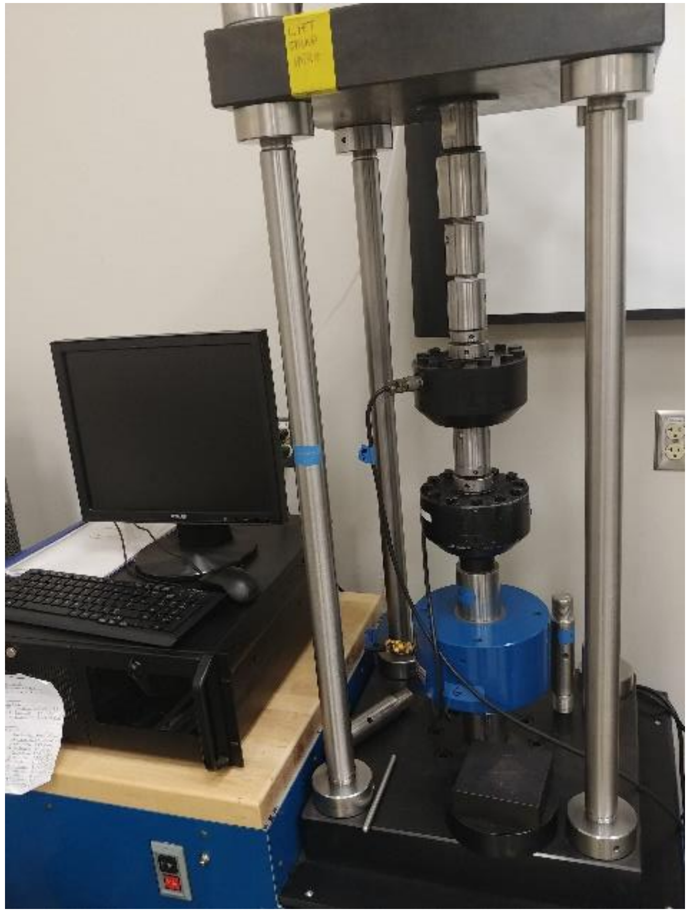
The Right Equipment

Replicates Field Use

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

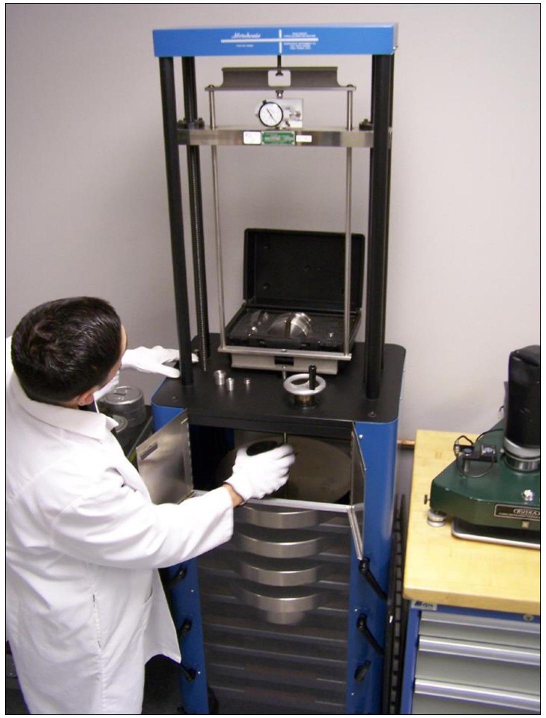


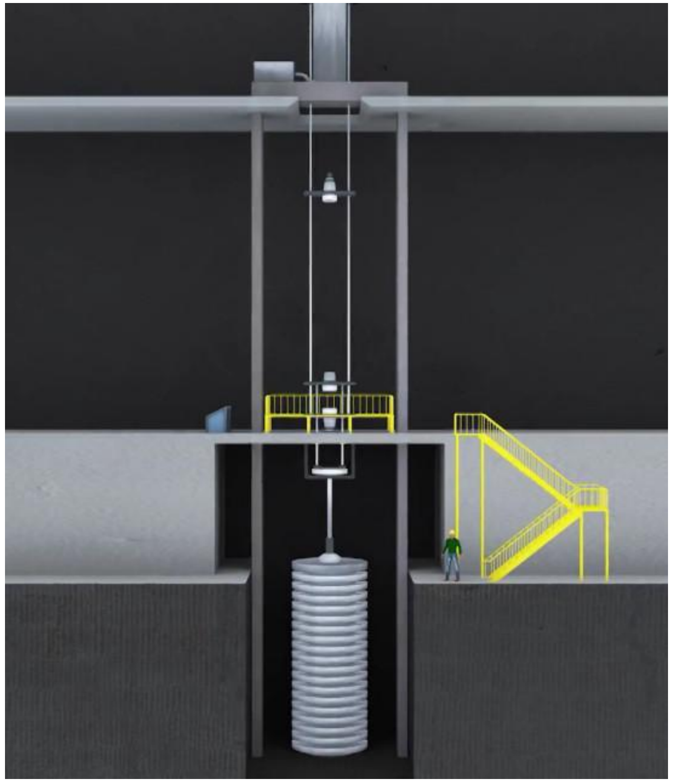
One of these does not replicate how the equipment is used in the field. Which One?

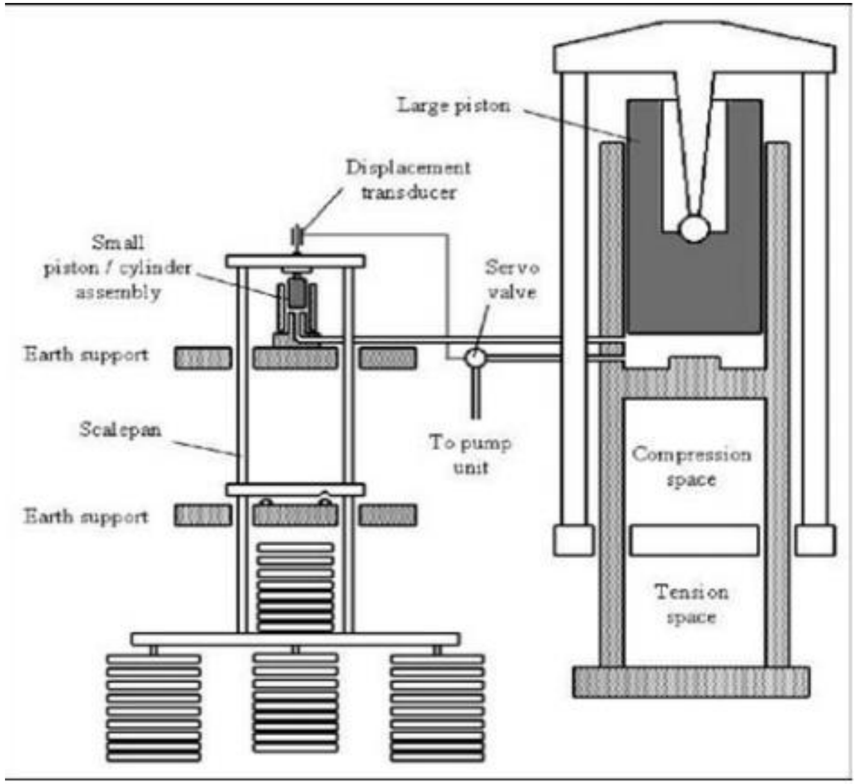


The Right Equipment

Replicates Field Use







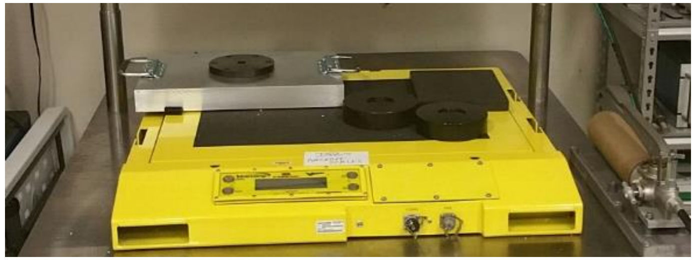
The Right Equipment

Replicates Field Use

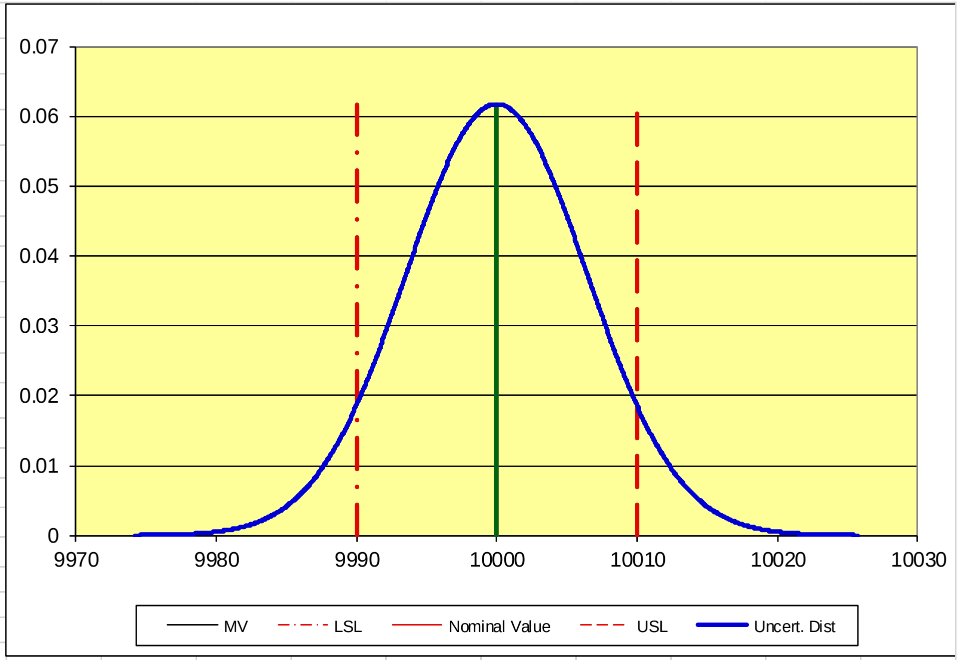
To Replicate Field Use for ASTM E4 & ISO 7500 Calibrations in These Types of Machines

- 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 than what is shown here

Choosing The Right Equipment



Nominal Value	10000
Lower specification Limit	9990
Upper Specification Limit	10010
Measured Value	10000
Measurement Error	0
Std. Uncert. (k=1)	6.45
Total Risk	12.10%
Upper Limit Risk	6.05%
Lower Limit Risk	6.05%
TUR =	**0.77519**



This is the calibration of an Intercomp Scale in our 804000 Press. The scale is repeatable within 10 lbf * and has a resolution of 10 lbf. No matter what reference standard is used, the Total Risk will always be higher than 10 %

* Note: Unless actions are taken to reduce the repeatability or resolution.

Choosing The Right Equipment

$$\text{TUR} = \frac{\text{Span of the} \pm \text{Tolerance}}{2 \text{ x } k_{95\%} \left(\sqrt[2]{\left(\frac{CMC}{k_{CMC}}\right)^2 + \left(\frac{\text{Resolution}_{UUT}}{\sqrt[2]{12}}\right)^2 + \left(\frac{\text{Repeatability}_{UUT}}{1}\right)^2 + \cdots (u_{Other})^2} \right)}$$

Let's break down the Scale

- U.U.T. Tolerance = 0.1 % of Applied 10 lbf, (USL – LSL)/2 ((10,010 – 9,990)/2) = **10 lbf**
- CMC = Variable CMC's
- Ures = **10 lbf**
- Urep = This is found by taking standard deviation of several test points. **5.774**

Urep	
Force Applied	Instrument Reading
10000	10000
10000	9990
10000	10000
10000	9990
STD DEV	5.773502692

Choosing The Right Equipment

- Let's break down the Intercomp Scale
- U.U.T. Tolerance= 10 lbf, (USL – LSL)/2
- CMC = Variable CMC's
- Ures = 10
- Urep = 5.774

$$TUR = \frac{UUT\ Tolerance}{k\ x\ \sqrt[2]{\left(\frac{CMC}{k}\right)^2 + \left(\frac{UUT_{Resolution}}{\sqrt{12}}\right)^2 + \left(\frac{UUT_{Repeatability}}{1}\right)^2}}$$

Capacity	Req Tolerance	LSL	USL	Res UUT	Rep UUT	CMC	Std Unc	Exp Unc	TUR
10000	0.100%	9990	10010	10	5.774	0.000%	6.46	12.91	0.775
10000	**0.100%**	**9990**	**10010**	**10**	**5.774**	0.002%	**6.46**	**12.91**	**0.774**
10000	0.100%	9990	10010	10	5.774	0.005%	6.46	12.92	0.774
10000	0.100%	9990	10010	10	5.774	0.025%	6.58	13.15	0.760
10000	0.100%	9990	10010	10	5.774	0.050%	6.92	13.85	0.722
10000	0.100%	9990	10010	10	5.774	0.100%	8.17	16.33	0.612

How can we fix this?

Raise the Tolerance?

Capacity	Req Tolerance	LSL	USL	Res UUT	Rep UUT	CMC	Std Unc	Exp Unc	TUR
10000	0.520%	9948	10052	10	5.774	0.000%	6.46	12.91	4.028
10000	**0.520%**	**9948**	**10052**	**10**	**5.774**	0.002%	**6.46**	**12.91**	**4.027**
10000	0.520%	9948	10052	10	5.774	0.005%	6.46	12.92	4.025
10000	0.520%	9948	10052	10	5.774	0.025%	6.58	13.15	3.954
10000	0.520%	9948	10052	10	5.774	0.050%	6.92	13.85	3.756
10000	0.520%	9948	10052	10	5.774	0.100%	8.17	16.33	3.184

Improve Repeatability Only ?

Capacity	Req Tolerance	LSL	USL	Res UUT	Rep UUT	CMC	Std Unc	Exp Unc	TUR
10000	0.100%	9990	10010	10	0	0.000%	2.89	5.77	1.732
10000	**0.100%**	**9990**	**10010**	**10**	**0**	0.002%	**2.89**	**5.78**	**1.731**
10000	0.100%	9990	10010	10	0	0.005%	2.90	5.80	1.726
10000	0.100%	9990	10010	10	0	0.025%	3.15	6.29	1.589
10000	0.100%	9990	10010	10	0	0.050%	3.82	7.64	1.309
10000	0.100%	9990	10010	10	0	0.100%	5.77	11.55	0.866

Improve Resolution and Repeatability ?

Capacity	Req Tolerance	LSL	USL	Res UUT	Rep UUT	CMC	Std Unc	Exp Unc	TUR
10000	0.100%	9990	10010	2	0	0.000%	0.58	1.15	8.660
10000	**0.100%**	**9990**	**10010**	**2**	**0**	0.002%	**0.59**	**1.17**	**8.533**
10000	0.100%	9990	10010	2	0	0.005%	0.63	1.26	7.947
10000	0.100%	9990	10010	2	0	0.022%	1.24	2.48	4.025
10000	0.100%	9990	10010	2	0	0.050%	2.57	5.13	1.949
10000	0.100%	9990	10010	2	0	0.100%	5.03	10.07	0.993

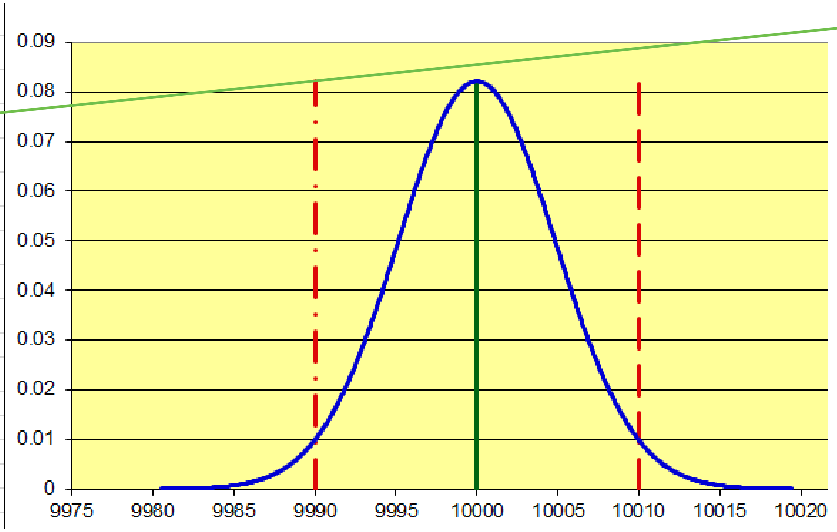
A TUR better than 4:1 would have minimal risk assuming the location of the measurement is within the guard band limits.

With a 2 lbf resolution and a CMC of 0.022 %, a 4:1 TUR could be achieved

How can we fix this?

We need to figure out how to lower the uncertainty and adjust the acceptance limits to limit lower and upper risk to less than ± 2 %

Nominal Value	10000
Lower specification Limit	9990
Upper Specification Limit	10010
Measured Value	10000
Measurement Error	0
Std. Uncert. (k=1)	4.86
Total Risk	3.96%
Upper Limit Risk	1.98%
Lower Limit Risk	1.98%
TUR =	**1.02881**



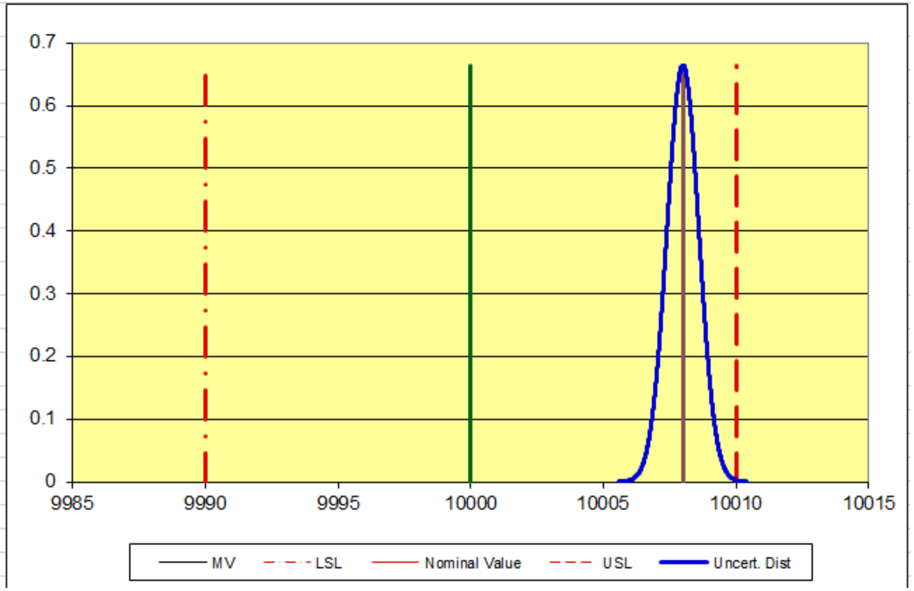
This assumes the location of the measurement is perfect.

Capacity	Req Tolerance	LSL	USL	Res UUT	Rep UUT	CMC	Std Unc	Exp Unc	TUR	U & L RISK	One Sided
10000	0.100%	9990	10010	10	3.77	0.000%	4.75	9.50	1.053	3.53%	1.76%
10000	**0.100%**	**9990**	**10010**	**10**	**3.77**	0.002%	4.75	9.50	**1.053**	3.53%	1.76%
10000	0.100%	9990	10010	10	3.77	0.005%	4.75	9.51	1.052	3.53%	1.76%
10000	0.100%	9990	10010	10	3.77	0.025%	4.91	9.82	1.018	4.17%	6.43%
10000	0.100%	9990	10010	10	3.77	0.050%	5.37	10.73	0.932	6.26%	3.13%
10000	0.100%	9990	10010	10	3.77	0.100%	6.90	13.79	0.725	14.73%	7.36%

Urep	
Force Applied	Instrument Reading
10000	10000
10000	10000
10000	10000
10000	9990
10000	10000
10000	10000
10000	10000
STD DEV	3.77964473

Choosing The Right Equipment

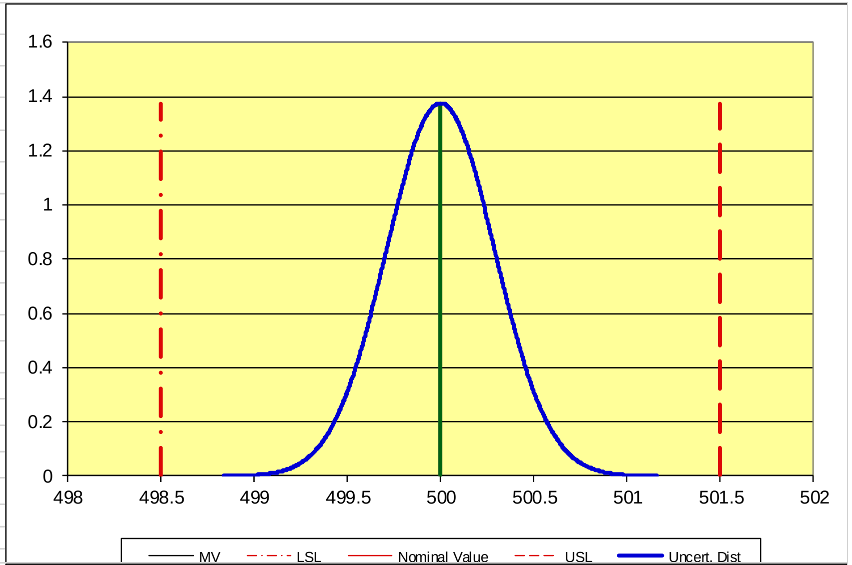
Nominal Value	10000
Lower specification Limit	9990
Upper Specification Limit	10010
Measured Value	10008
Measurement Error	8
Std. Uncert. (k=1)	0.6
Total Risk	0.04%
Upper Limit Risk	0.04%
Lower Limit Risk	0.00%
TUR =	**8.33333**



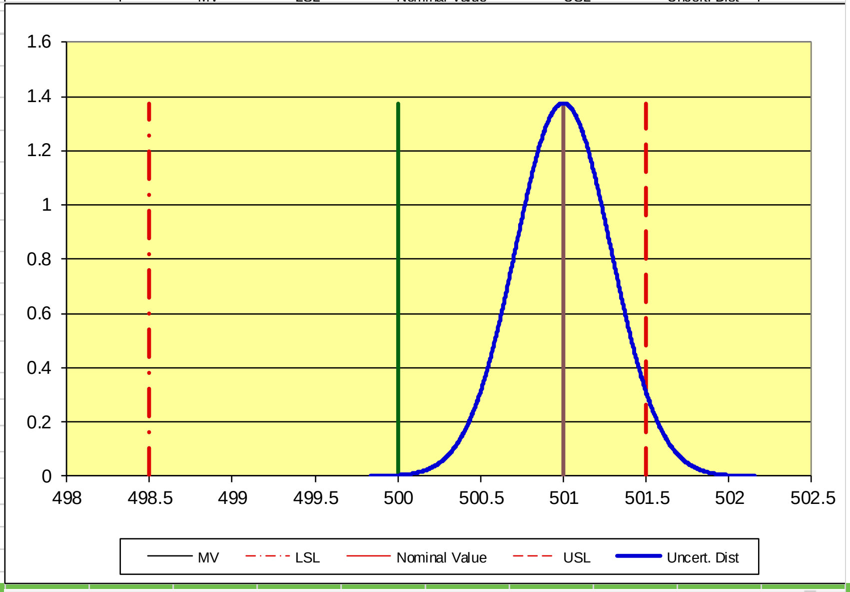
The only way to lower the Total Risk is to buy a scale with a better repeatability & resolution or change the method (lower the acceptance limits). Evaluating all components in a system is critical.

Choosing The Right Equipment

Nominal Value	500
Lower specification Limit	498.5
Upper Specification Limit	501.5
Measured Value	500
Measurement Error	0
Std. Uncert. (k=1)	0.29
Total Risk	0.00%
Upper Limit Risk	0.00%
Lower Limit Risk	0.00%
TUR =	2.58621



Nominal Value	500
Lower specification Limit	498.5
Upper Specification Limit	501.5
Measured Value	501
Measurement Error	1
Std. Uncert. (k=1)	0.29
Total Risk	4.23%
Upper Limit Risk	4.23%
Lower Limit Risk	0.00%
TUR =	2.58621



MSI PORTA-WEIGHT – Some accuracy specifications are 0.1 % of applied and other are 0.1 % of applied +/- 1 count.

Specification on this model is 0.1 % of applied +/- 1 count

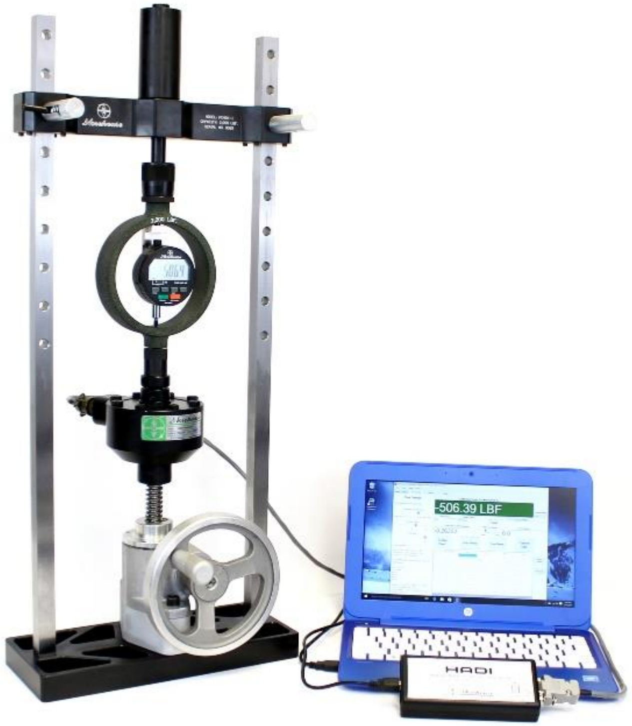
Location of the measurement is key.

Great Equipment. Just Remember that location of the measurement is key!

Choosing The Right Equipment

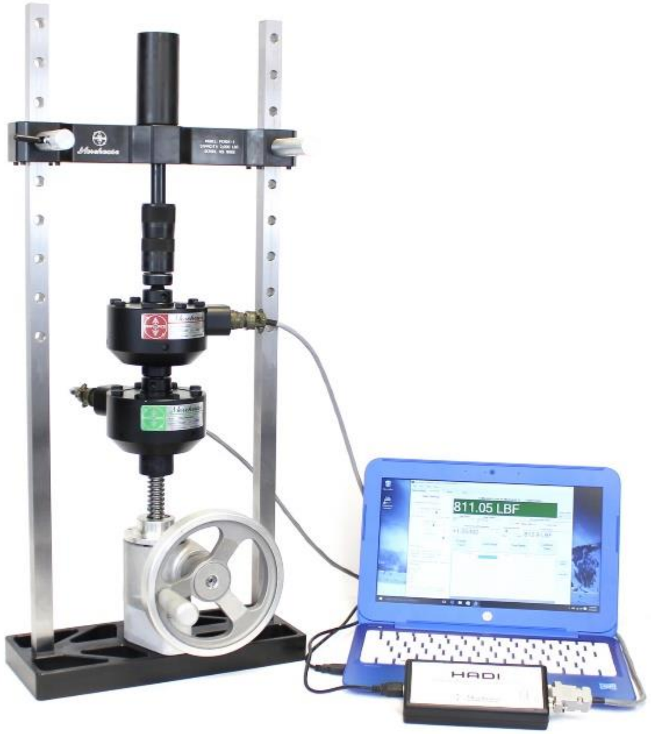
Morehouse 2K-PCM W/ Ultra Precision Load Cell

Is the PCM accurate enough to calibrate the UUT in each of the following scenarios using Method 5? Typical Calibration and Measurement Capability is 0.02 % of applied force



UUT 0.5 % of full scale

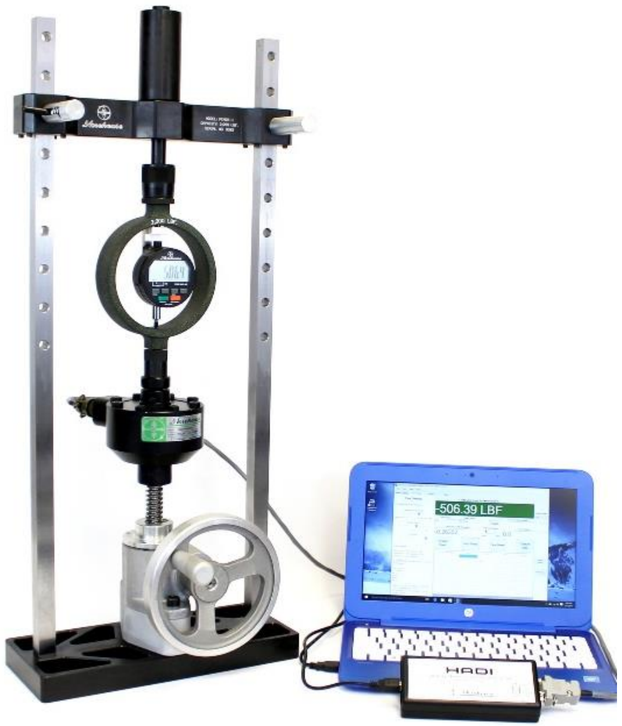
UUT 0.1 % of full scale



UUT 0.025 % of full scale

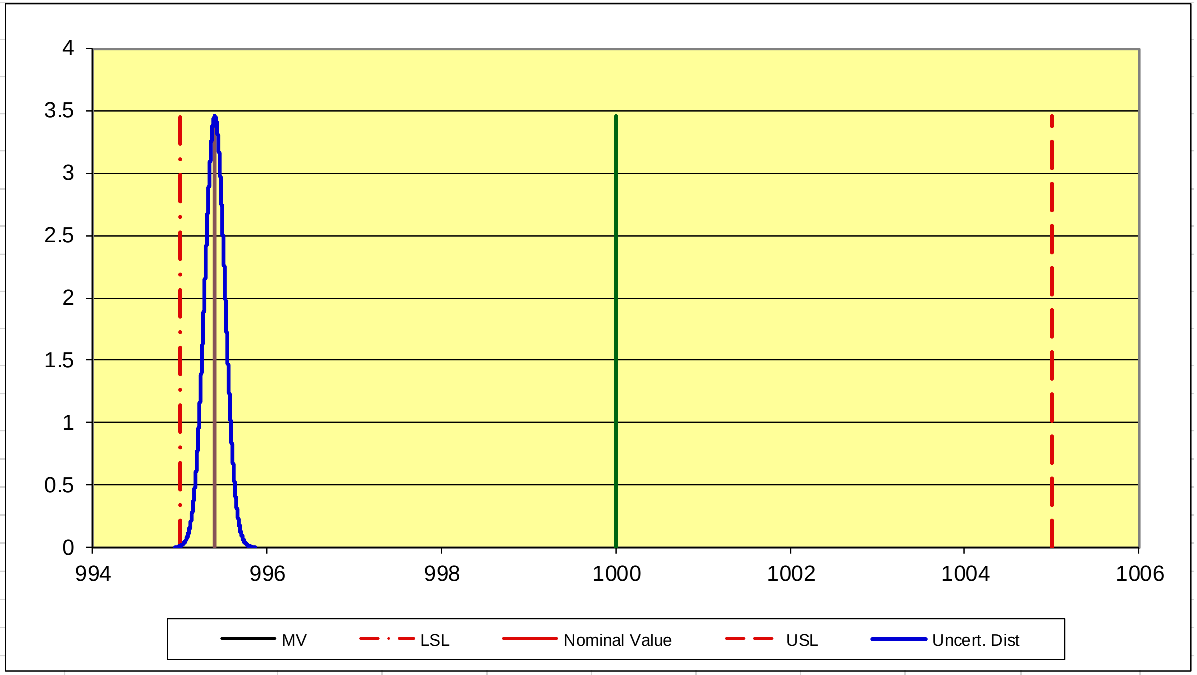
Choosing The Right Equipment
Morehouse 2K-PCM W/ Ultra Precision Load Cell

With a CMC of 0.02 % and a UUT resolution of 0.2 lbf as long as the UUT reads between 995.4 and 1004.6, the system would be accurate enough to calibrate the UUT.



1000 lbf Digital Force Gage UUT 0.5 % of full scale

Nominal Value	1000
Lower specification Limit	995
Upper Specification Limit	1005
Measured Value	995.4
Measurement Error	-4.6
Std. Uncert. (k=1)	0.12
Total Risk	0.03%
Upper Limit Risk	0.00%
Lower Limit Risk	0.03%
TUR =	**21.65047632**

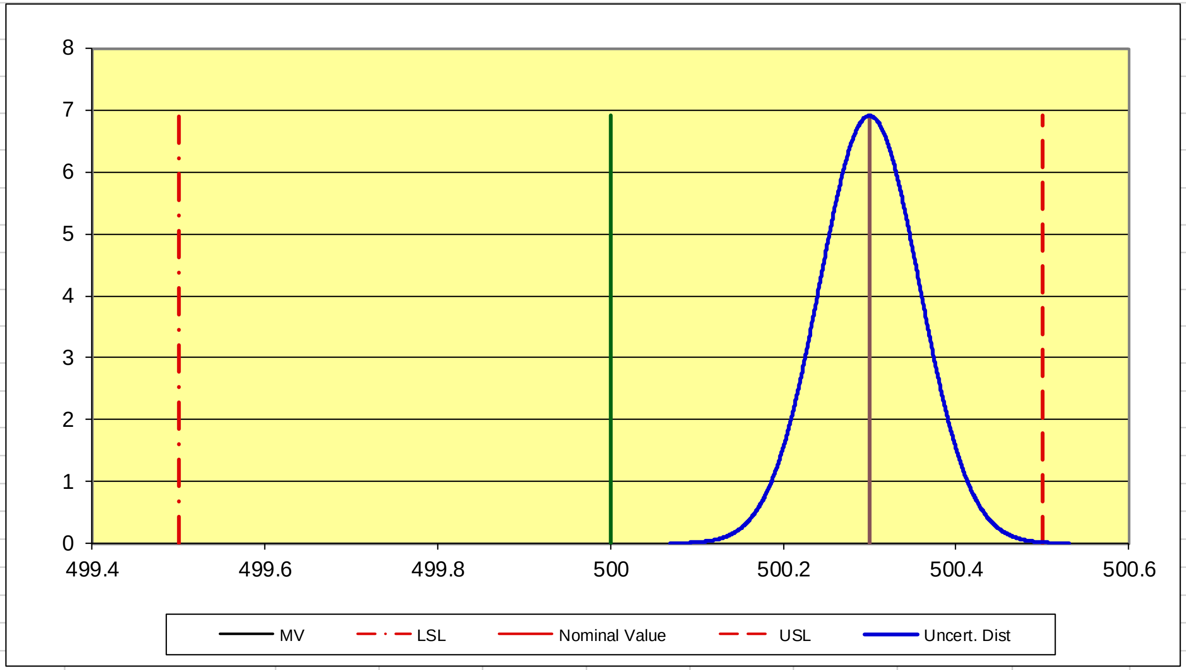


Choosing The Right Equipment
Morehouse 2K-PCM W/ Ultra Precision Load Cell

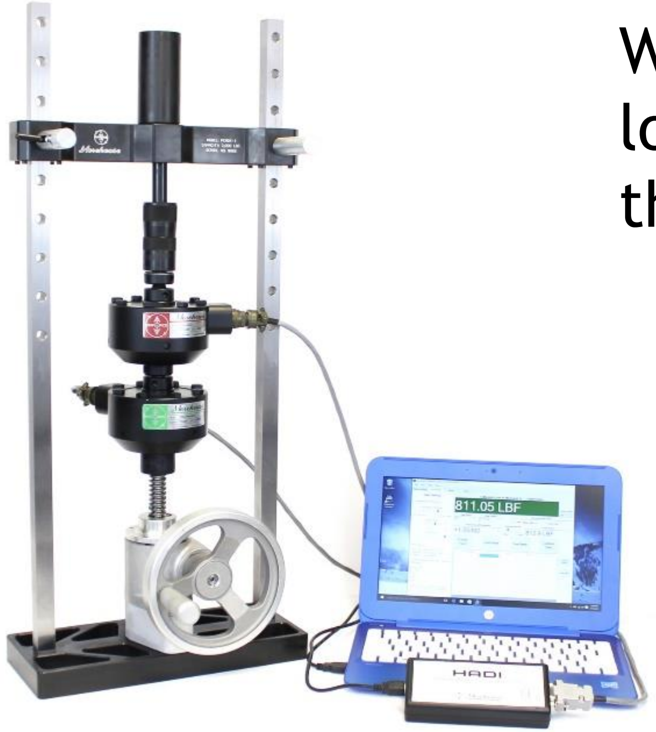
500 lbf Digital Force Gage UUT 0.1 % of full scale

With a CMC of 0.02 % and a UUT resolution of 0.1 lbf as long as the UUT reads between 499.7 and 500.3, the system would be accurate enough to calibrate the UUT.

Nominal Value	500
Lower specification Limit	499.5
Upper Specification Limit	500.5
Measured Value	500.3
Measurement Error	0.3
Std. Uncert. (k=1)	0.06
Total Risk	0.03%
Upper Limit Risk	0.03%
Lower Limit Risk	0.00%
TUR =	**4.330095263**



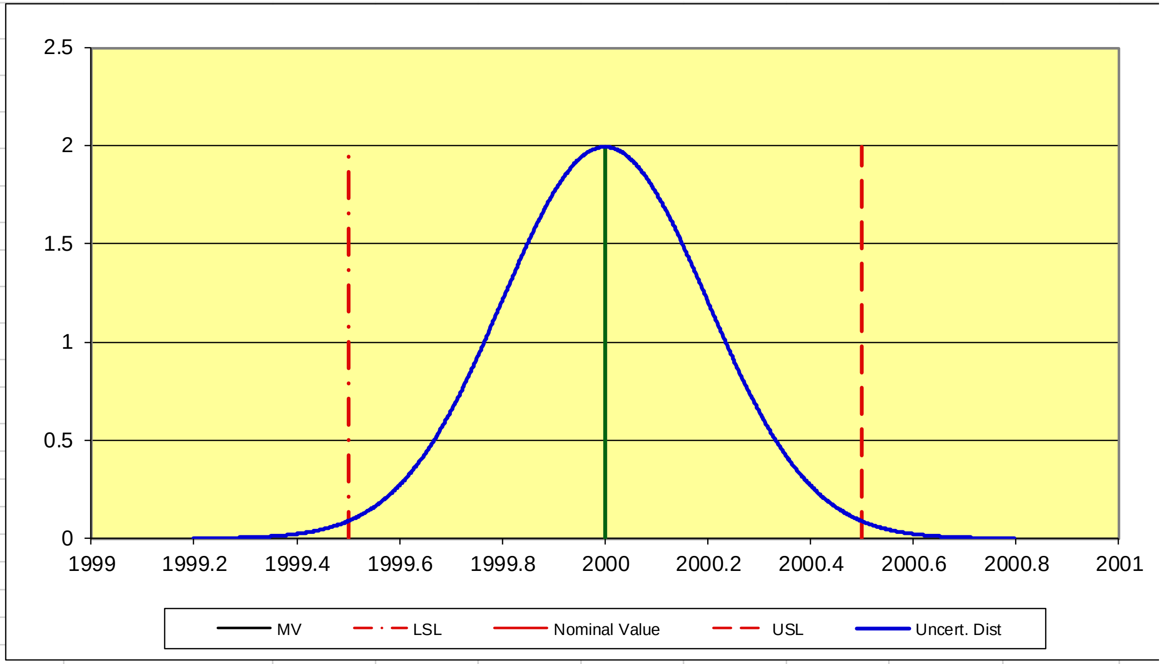
Choosing The Right Equipment
Morehouse 2K-PCM W/ Ultra Precision Load Cell



2000 lbf Load Cell UUT with a tolerance of 0.025 % of full scale

With a CMC of 0.02 % and a UUT resolution of 0.01 lbf as long as the UUT reads between 1999.91 lbf and 2000.09, the system would be accurate enough to calibrate the UUT.

Nominal Value	2000
Lower specification Limit	1999.5
Upper Specification Limit	2000.5
Measured Value	2000
Measurement Error	0
Std. Uncert. (k=1)	0.20
Total Risk	1.24%
Upper Limit Risk	0.62%
Lower Limit Risk	0.62%
TUR =	**1.249869804**



Method 6 would allow between 1999.66 and 2000.34 to pass!

Choosing The Right Equipment

$$\text{T.U.R.} = \frac{\text{U.U.T. Tolerance}}{2\,x\sqrt{\left(\frac{CMC}{k}\right)^2 + \left(\frac{Res}{3.464}\right)^2 + \left(\frac{Rep}{1}\right)^2}}$$

The Reference Equipment chosen could affect the T.U.R. in the following ways:

1. It can raise or lower the T.U.R.
2. Different equipment types have different CMC's which will raise or lower the T.U.R.
3. Different reference standards can make the repeatability of the UUT better or worse. (An example of this would be hydraulic versus deadweight) The stability of the hydraulics would factor into the CMC.
4. Different reference standards have different resolution (deadweight has 0, while a 60K load cell may have 0.15 lbf)
5. Changing the reference standard type will change the process, resulting in an increase or decrease in the CMC.

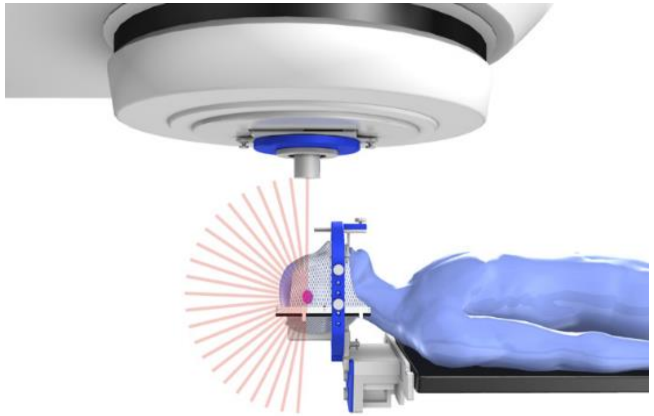
3 Rules to Lessen Your Measurement Risk

- **Rule # 3. Have the Right Processes** – This last rule requires having a training program and proof of training (records) to validate the individuals performing the calibration or using the equipment.
- It is important to maintain and follow procedures that adequately support the end-product performance
- There should be a process in place that ensures all aspects of the standards are being carefully satisfied in the calibration process
- Use of Proper Adapters and making sure the instrument's calibration matches how it is being used in the field or lab.

The Right Processes?

The Right Processes?

Incorrectly calibrated radiation treatment system overdosed 152 cancer patients



- CoxHealth of Springfield, MO inadvertently overdosed 152 cancer patients, 76 of which received up to 70 % higher than prescribed dosages
- The device, a BrainLAB stereotactic radiation system used to treat areas 1.1 centimeters or smaller, was initially incorrectly calibrated by the CoxHealth chief physicist in 2004
- The error went undetected for five years, until September 2009 when another CoxHealth physicist received training on the BrainLAB system
- Although the calibration error was corrected, as of February 2012, the CoxHealth BrainLAB program remains suspended while lawsuits are settled

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."

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

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, 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."*

The Right Calibration Provider

Not Following The ASTM E74 Standard

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
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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
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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

Some calibration providers claim zero can be used as the first calibrated test point.

This is not true. In the ASTM E74-18 standard the following sections point to this not being allowed.

- Per Section 7.2.1 of ASTM E74-13a states *"In no case should the smallest force applied be below the lower limit of the instrument as defined by the values: 400 x resolution for Class A loading range & 2000 x resolution for Class AA loading range" In this example the resolution is 0.1 lbf,*

We have a full webinar on ASTM E74 Explained

The Right Calibration Provider

Huntington Ingalls Industries

Supplier Performance Scorecard

RECEIVED
APR 24 2017
MOREHOUSE INSTRUMENT CO.

Ingalls Supplier ID 850300

4/11/2017

MOREHOUSE INSTRUMENT CO INC

This report represents your current performance scorecard for the Huntington Ingalls Industries during the period shown below. Your overall score is based on a double weighted method. Your raw performance score and weighted point score are shown. If a value of "N/A" is reflected the score was not used to develop your overall total. Details of Material deliveries and/or Quality defects follow if your Quality or Delivery score is less than 100.

Should you have any questions or require review of suspect data please contact us within 30 days following the original issue date. Your request should be addressed to SSSupRatings@hii-ingalls.com.

Gwen Wilkerson, Director, Supply Chain Material Aquisition, Ingalls

Current period data for 6 month period - October 2016-March 2017

SITE/CRITERIA	Quality	Weighted Quality	Delivery	Weighted Delivery	Responsiveness	Bonus	Total Score
Ingalls	100.00	60.00	100.00	40.00	N/A	N/A	100.00
Newport News	Supplier not used by Newport News during this scoring period						

Performance Trends based on previous scorecards

SITE	Quality	Delivery	Total
Ingalls	Static	Static	Static
Newport News	Newport News N/A		

Commodity Group Comparison

# of Similar Suppliers
9
Average Score of Similar Suppliers
90.60

Total Receipts During Scoring Period
2

Legend for Scores

	Quality	Delivery	Overall
Blue	>=98	>=95	>=98
Green	95-97.99	90-94.99	95-97.99
Yellow	90-94.99	85-89.99	65-94.99
Red	<90	<85	<65

The Right Calibration Provider

- Has a measurement process uncertainty capable of meeting your needs and follows published standards
- Replicates how the instrument is being used
- Uses the right adapters to ensure results are repeatable
- Has competent technicians with training records
- Follows published standards
- Reports measurement uncertainty correctly
- Is rated highly and is reliable for on-time delivery

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 matter 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 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

Questions (Multiple Choice)

What three things below make up expanded uncertainty?

a) Resolution of UUT

b) Repeatability of UUT

c) Tolerance

d) Calibration and Measurement Capability of the Reference Lab

$$U = 2 * \sqrt{\left(\frac{CMC}{2}\right)^2 + \left(\frac{Res}{3.464}\right)^2 + \left(\frac{Rep}{1}\right)^2}$$

Wrap Up

- Additional Questions
- What has been beneficial?
- Takeaways from today?

Conclusion

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

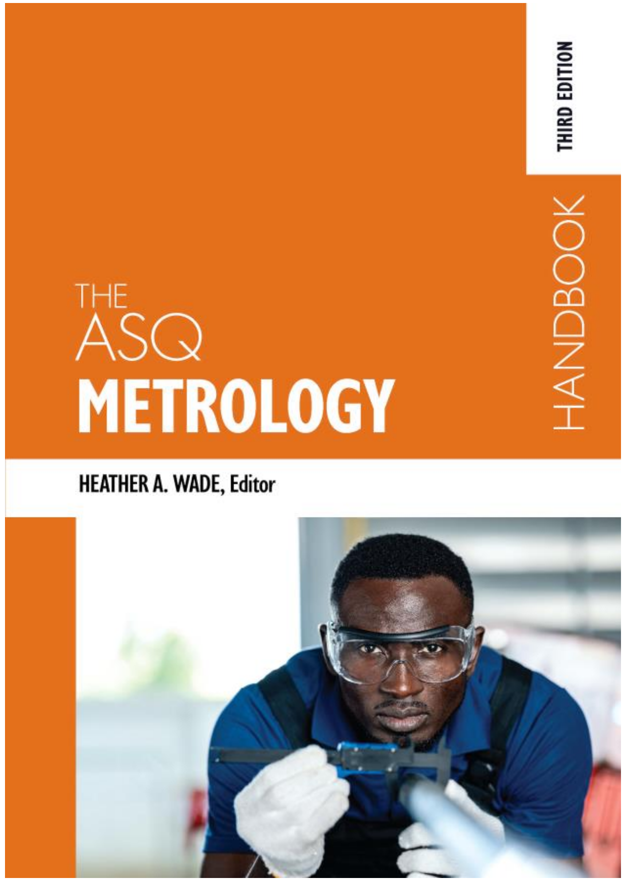
Using what was presented today, you can help us create a safer world by helping companies improve their force measurements.

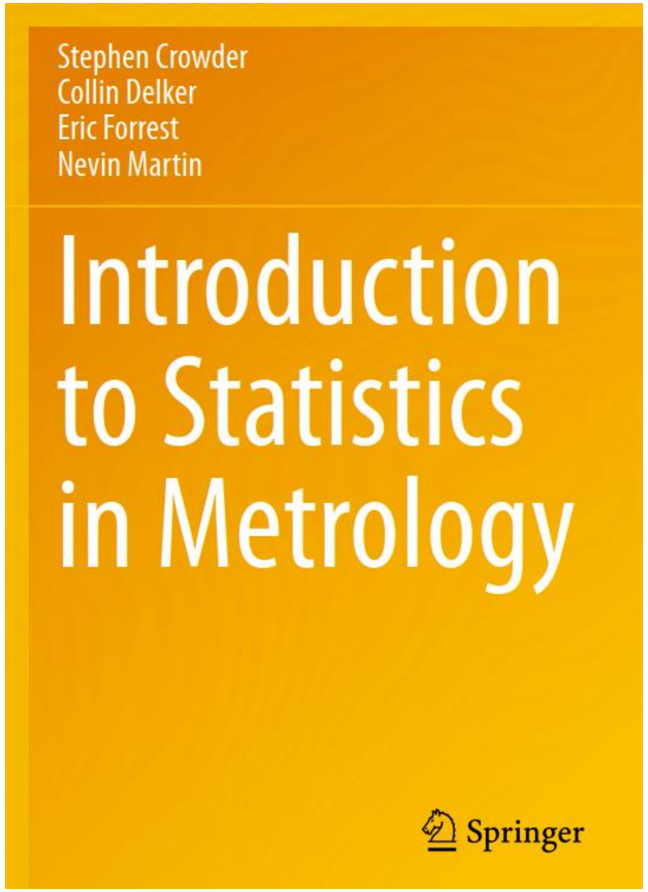
MHFORCE

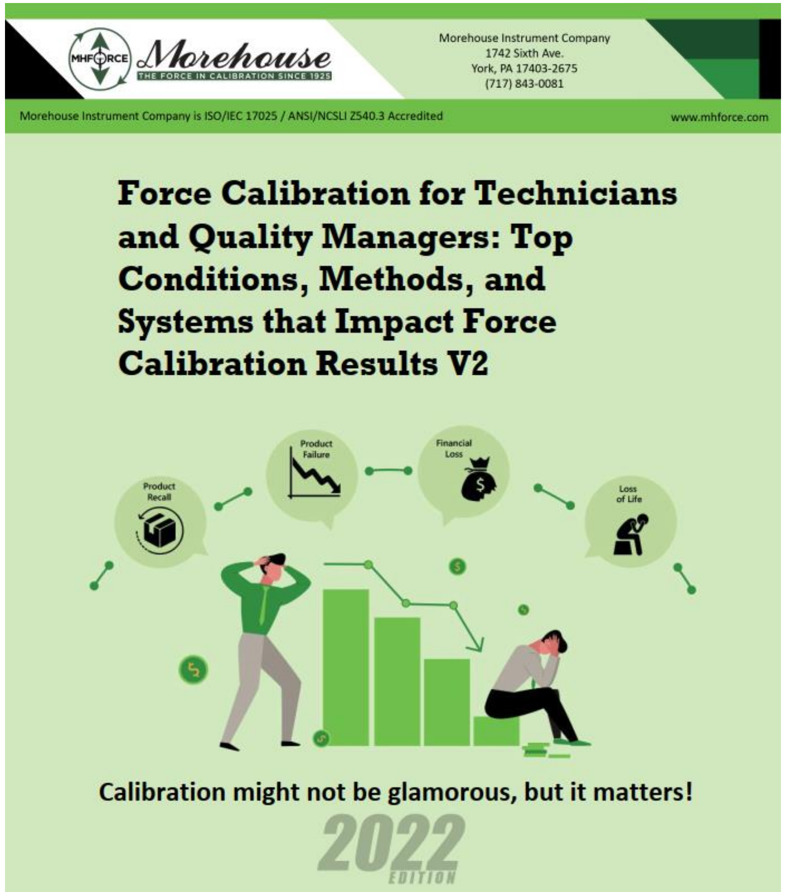
Morehouse

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

Recommended Reading







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Contact Us

Morehouse Instrument Company
1742 6th Ave
York, PA 17403

717 843 0081 Main

info@mhforce.com

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