Improve your Force Measurements

Presented by:
Henry Zumbrun
President, Morehouse Instrument Company
Hosted-PJLA , Tracy Szerszen, President

Tuesday, April 19, 2022
1:00-2:00 PM EDT

PJLA

Presentation Overview

PJLA

Hosted By-Tracy Szerszen
President
Perry Johnson Laboratory Accreditation (PJLA)

Discuss Force Measurements using ASTM E74 method

Tips and Challenges

Questions & Answers

Webinar Housekeeping

- This webinar will be recorded
- All PJLA webinars are made available on our website & YouTube channel
  - https://www.pjlabs.com/training/pjla-webinars/past-webinars
- All attendees are muted
- Please utilize the question tool bar to submit questions
  - To be answered at the end of presentation

Welcome
Henry Zumbrun, Morehouse Instrument Company

- President of Morehouse since 2013 and worked at Morehouse for more than 20 years. Henry has a passion for measurement accuracy and reducing risk associated with measurements that impact safety in our day to day lives.

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Improve Your Force Measurements

Tips to Improve Your Force Measurements

MHFORCE

Morehouse

THE FORCE IN CALIBRATION SINCE 1925

What Morehouse does

We are a manufacturing company that produces force calibration equipment and adapters, that are used in industry, to measure force.

We have state-of-the-art force and torque calibration laboratories and offer calibrations at a very high level of accuracy.

Our Purpose

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

Outcomes

The participant will be able to

- Know the right questions to start asking
- Know what constitutes good force measurement equipment
- Know the interactions of some adapters used for force calibration
- Know more about decision risk

Improve Your Force Measurements

Agenda

- ASTM E74 Common Standard Violations to Look For and Correct
- Asking the Right Questions
- The Importance of Adapters
- The Right Equipment
- The Right Calibration Provider for Your Equipment

Improve Your Force Measurements

Additional Material

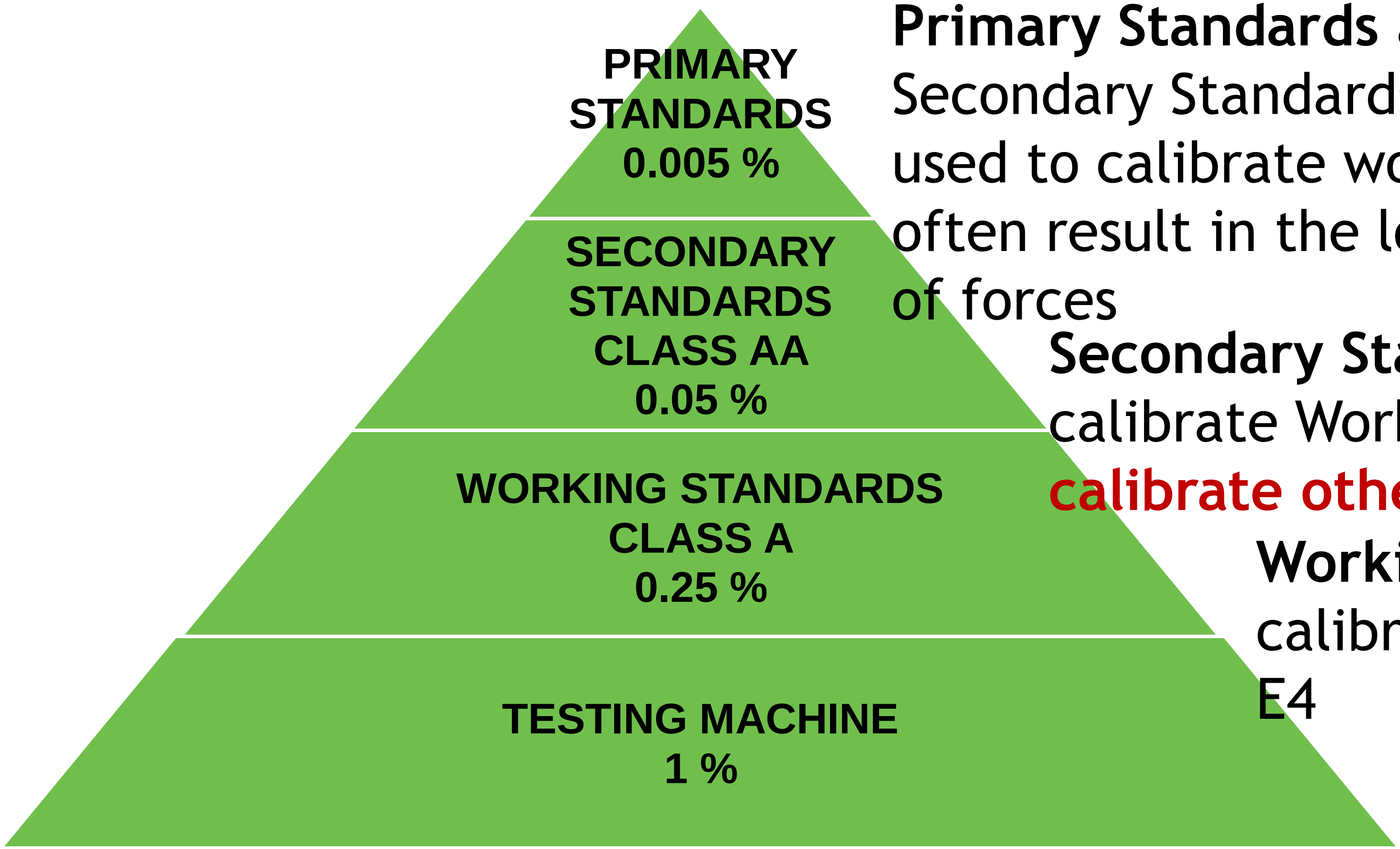
- **Technical Paper on Adapters**
- **Technical Paper on Uncertainty Propagation**
- **Technical Paper on ASTM E74 and ISO 376**
- **Technical Paper on Common Measurement Errors in Weighing**
- **PDF version of this presentation**

- **Website link @ https://mhforce.com/documentation-tools/?_sft_support-item-tag=technical-paper**

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.*

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 verified range of forces

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

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

- 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

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.*

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

ASTM E74 Calibration Procedure

- At least 30 force applications are required (we typically recommend 3 runs of 11 or 33 force applications)

- There should be at least one calibration force for each 10 % interval throughout the loading range and if the instrument is to be used below 10% of its capacity a low force should be applied.

Note: This low force must be greater than the resolution of the device multiplied by 400 for Class A or 2000 for Class AA devices

ASTM E74 Calibration Procedure

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

MHFORCE Morehouse THE FORCE IN CALIBRATION SINCE 1925

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

ASTM E74 Calibration Procedure

Criteria for Determining the LLF (Lower Limit Factor)

$$s_m = \sqrt{\frac{d_1{}^2 + d_2{}^2 + \ldots + d_n{}^2}{n - m - 1}}$$

- LLF = 2.4 * STD DEV (As defined above)
- Based on LLF or Resolution whichever is higher

NOTE: Any force-measuring instrument that is either modified or repaired should be recalibrated

Recalibration is required for a permanent zero shift exceeding 1.0 % of full scale

ASTM E74 Common Standard Violations to Look For and Correct

Calibration Interval Per ASTM E74-18 section 11.2.1

- *"Force-measuring instruments shall demonstrate changes in the calibration values over the range of use during the recalibration interval of less than 0.032 % of reading for force-measuring instruments and systems used over the Class AA verified range of forces and less than 0.16 % of reading for those instruments and systems used over the Class A verified range of forces"*

- 11.2.2 *"Force-measuring instruments not meeting the stability criteria of 11.2.1 shall be recalibrated at intervals that shall ensure the stability criteria are not exceeded during the recalibration interval"*

ASTM E74 Common Standard Violations to Look For and Correct

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

- Per Section 7.2.1 *"If the lower force limit of the verified range of forces of the force-measuring instrument (see 8.6.1) is 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 "*

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

POLYNOMIA

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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**.

- 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

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

Calibration Standards Utilized

Cert. #	Manufacturer	Model #	Description	Cal Date	Due Date
2508330017	Interface, Inc.	1620AJH-25K	Gold Standard Load Cell	08/15/2013	08/15/2015
2737280059	General Radio	1434-B	Decade Resistor	04/23/2014	04/23/2015
2911710180	Agilent Technologi	34420A	Nanovolt/Micro-Ohmmeter	01/07/2015	07/07/2015

5000	-8.157	-8.159	-8.160	-8.159580	-0.003%	0.002580	0.000580	-0.000420
7500	-12.239							
10000	-16.320							
12500	-20.401							
15000	-24.486							
17500	-28.570							
20000	-32.655							
22500	-36.735							
25000	-40.819							

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

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

Lower Limit of Loading

Class AA = 8761.37 lbf

Class A = 2500 lbf

What's wrong here?

This is to certify that the equipment described below has been calibrated against [redacted] load cell standard, traceable to NIST dead weight standards. All readings are within a tolerance of +/-0.1% of applied load, or ± 5 lbs of capacity whichever is greater
Load cell calibration standards with serial № [redacted] was calibrated 13AUG2018. Next calibration due 13AUG2019
Accuracy of load cells used in the [redacted] calibration presses are maintained to better than +/-0.025% accuracy. These accuracies are determined by direct comparison to a basic standard certified by Morehouse Instrument Company, Inc. using dead weight machine traceable to NIST per ANSI/NCSL Z540-1 Certified in accordance with Sec. 7 of ASTM, Spec. E74-02 entitled "Standard Practice of Calibration of Force Measurement Instruments." The [redacted] calibration system conforms to Z540.1.

What's interesting is Morehouse does not perform calibrations for this company

- ASTM's current version is ASTM-18
- This company is using a company that has a CMC uncertainty of 0.037 % for the range used

ASTM E74 is not ISO 376

- The ISO 7500-1 Calibration and verification of static uniaxial testing machines requires standards to be calibrated in accordance with ISO 376. One cannot use ASTM E74 calibration to perform an ISO 7500 calibration.

- ISO 376 has several requirements that are not requirements of ASTM E74

COMPRESSION CALIBRATION DATA ANALYSIS

FORCE APPLIED	REPEATABILITY W/ ROTATION		REPEATABILITY W/O ROTATION		FIT ERROR		RESOLUTION		MACHINE UNCERTAINTY	
lbf	b (%)	CLASS	b' (%)	CLASS	f_c	CLASS	div	CLASS	%	CLASS
20.4	0.106	1	0	00	0.152	2	940	2	0.003	00
50	0.087	0.5	0.043	0.5	0.071	1	2302	0.5	0.002	00
100	0.043	00	0.043	0.5	0.039	0.5	4599	00	0.002	00
200	0.043	00	0	00	0.015	00	9200	00	0.002	00
300	0.036	00	0	00	0.005	00	13803	00	0.002	00
400	0.022	00	0.005	00	0.007	00	18404	00	0.002	00
500	0.022	00	0.004	00	0.001	00	23008	00	0.002	00
600	0.022	00	0.004	00	0.001	00	27611	00	0.002	00
700	0.012	00	0.003	00	0.002	00	32216	00	0.002	00
800	0.008	00	0	00	0.007	00	36822	00	0.002	00
900	0.012	00	0.002	00	0.005	00	41426	00	0.002	00
1000	0.011	00	0.004	00	0.001	00	46028	00	0.002	00
1020	0.002	00	0.004	00	0.006	00	46947	00	0.002	00

ZERO ERROR		
TEST RUN	f_0	CLASS
RUN 1	0	00
RUN 2	0	00
RUN 3	0.006	00
RUN 4	0.006	00

CREEP TEST RESULTS			
Force Held at Max Force for 90 Seconds	div	ERROR	CLASS
Output 30 Seconds after removing load:	4	0.0174 %	00
Output 300 Seconds after removing load:	12		

Combined Expanded Uncertainty Equation for Compression Calibration

The following linear equation has been fitted to the combined uncertainty and applied force values observed at calibration using the method of least squares:

Expanded Uncertainty (lbf)=	**$C_0+C_1 \times F$**
where: F=	**Force (lbf)**
Coefficient C_0=	0.060657438
Coefficient C_1=	9.84874E-05

ASTM E74 is not ISO 376

Table 2 — Characteristics of force-proving instruments

Class	Relative error of the force-proving instrument %						Expanded uncertainty of applied calibration force (95 % level of confidence)
	of reproducibility b	of repeatability b'	of interpolation f_c	of zero f_0	of reversibility v	of creep c	%
00	0,05	0,025	±0,025	±0,012	0,07	0,025	±0,01
0,5	0,10	0,05	±0,05	±0,025	0,15	0,05	±0,02
1	0,20	0,10	±0,10	±0,050	0,30	0,10	±0,05
2	0,40	0,20	±0,20	±0,10	0,50	0,20	±0,10

Force Uncertainty 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.

Measurement Uncertainty

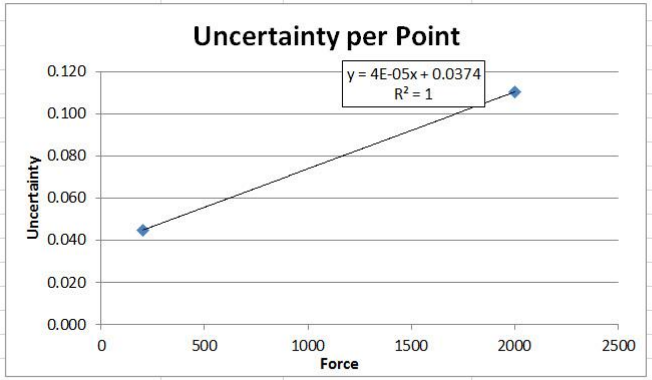
Morehouse Measurement Uncertainty Calibration and Measurement Capability Worksheet

Measurement Uncertainty Budget Summary

Laboratory	Morehouse								
Parameter	FORCE	Range	2K	Sub-Range	N/A				
Technician	HZ								
Date	8/10/2017	Standards Used	Ref S/N DEMOH1017 UUT S/N Test						
	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

https://mhforce.com/documentation-tools/?_sft_support-item-tag=guidance-document

Asking the Right Questions

Are you discussing customer requirements such as:

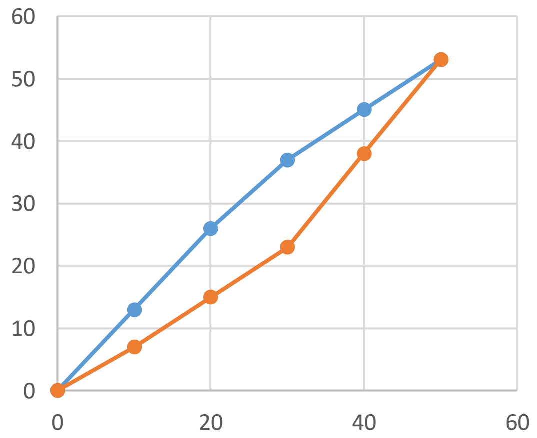
What type of calibration is needed?   Below are some force specific examples

- To What Capacity?
- What Mode or Modes Compression/Tension?
- To What Standard or Customer Request? – ASTM E74, ISO 376, Commercial 10 pt calibration, 5 pt calibration?
- What are the reporting expectations? SEB, Nonlinearity, Hysteresis
- Tolerance Requirements and Decision Rule? (A top 10 A2LA deficiency)
- Does the calibration require Ascending/Descending points?
- Do you have a calibration due date or frequency you want to be put on the certificate? - If in accordance with a standard, we can assign a due date, otherwise the customer is responsible for the due date.
- How is the instrument currently being used?
- Any additional requests?

Asking the Right Questions

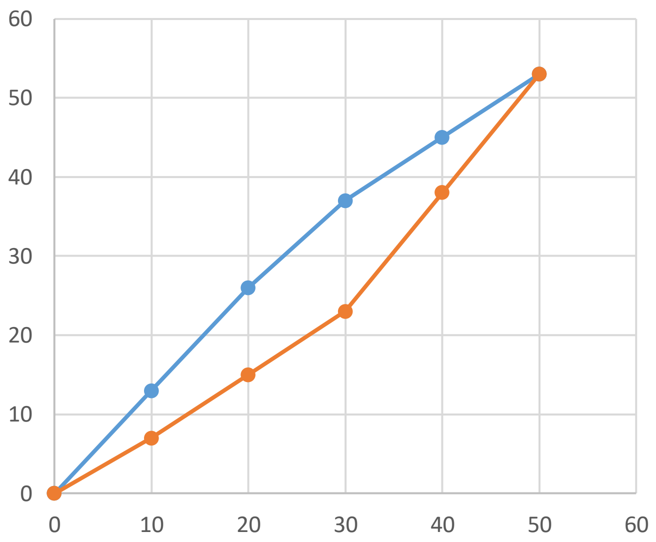
Does the calibration require Ascending/Descending points?

ASTM E74-18 section 7.4.1 “Force-measuring instruments are usually used under increasing forces, but if a force-measuring instrument is to be used under decreasing force, it shall be calibrated under decreasing forces as well as under increasing force.”



Asking the Right Questions

Does the calibration require Ascending/Descending points?



The difference in output on an ascending curved versus a descending curve can be quite different. A very good 100K load cell had an output of -2.03040 on the ascending curve and -2.03126 on the descending curve. Using the ascending only curve would result in an additional error of 0.042 %.

Asking the Right Questions

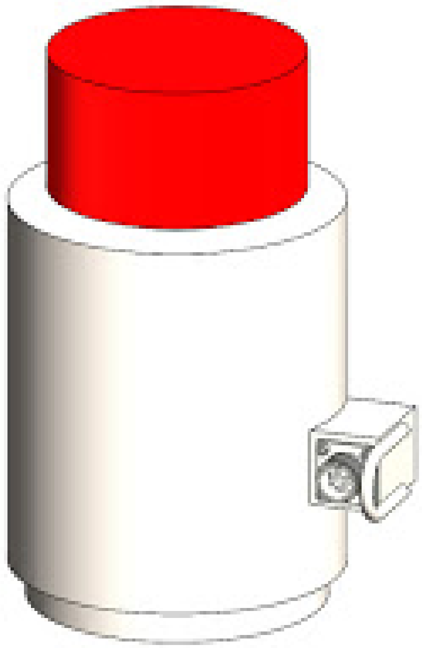
How is the instrument currently being used?

This can vary and have a lot of different scenarios. The most common are as follows:

- **What adapters are used with it?**
- **How is it loaded? Common questions are**
- **Is the force device loaded through the top shoulder or thread loaded? If thread loaded, how much engagement?**
- **Is the force device loaded through the bottom threads?**
- **Do you have a top block that can be sent with the Force Measuring Device?**

Asking the Right Questions

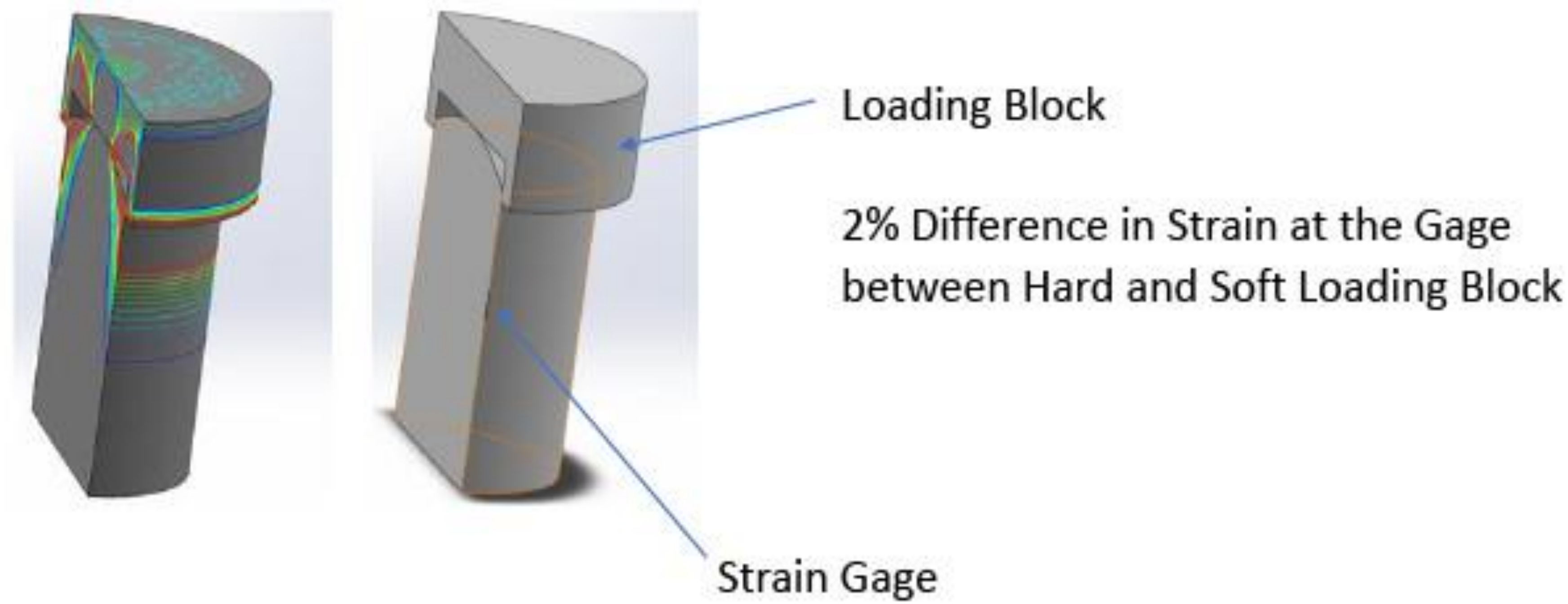
Do you have a top block that can be sent with the Force Measuring Device?



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%

Asking the Right Questions



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

Asking the Right Questions

Is the force device loaded through the top shoulder or thread loaded? If thread loaded, how much engagement?

Morehouse tested the same load cell with two different types of adaptors and recorded the readings with 10,000 LBF applied.

Output was 10,001.5 LB with 1.5” of engagement vs 9942.3 LBF with 0.5” engagement.
There was a difference of 59.2 LBF on a 10,000 LBF cell.
The error on this measurement was over 0.5 % on a device expected to be better than 0.025 % (20 times expected).

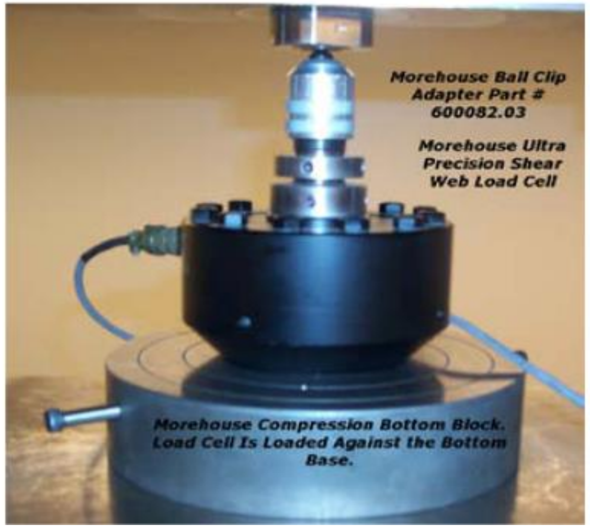
Proper Adapters Shear Web cells

Solution – Purchase and lock in an integral adapter

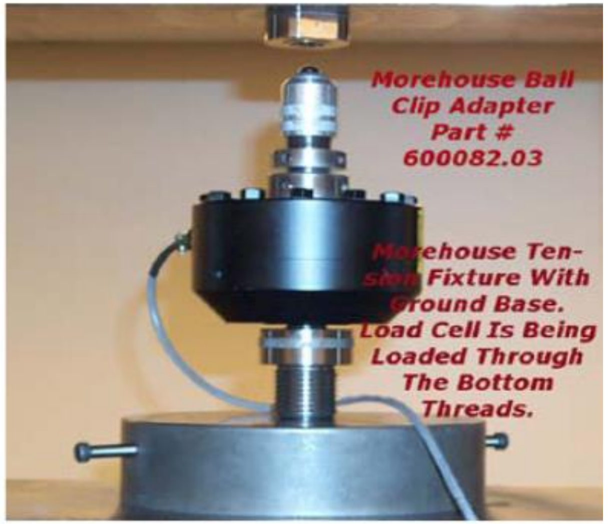
or pick a top adapter and always use and have the force measuring device calibrated with that top adapter. In this example, a spherical load button would be an excellent top adapter for this load cell.

Asking the Right Questions

Is the force device loaded through the bottom threads?



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



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.

Proper Adapters – Tension Links

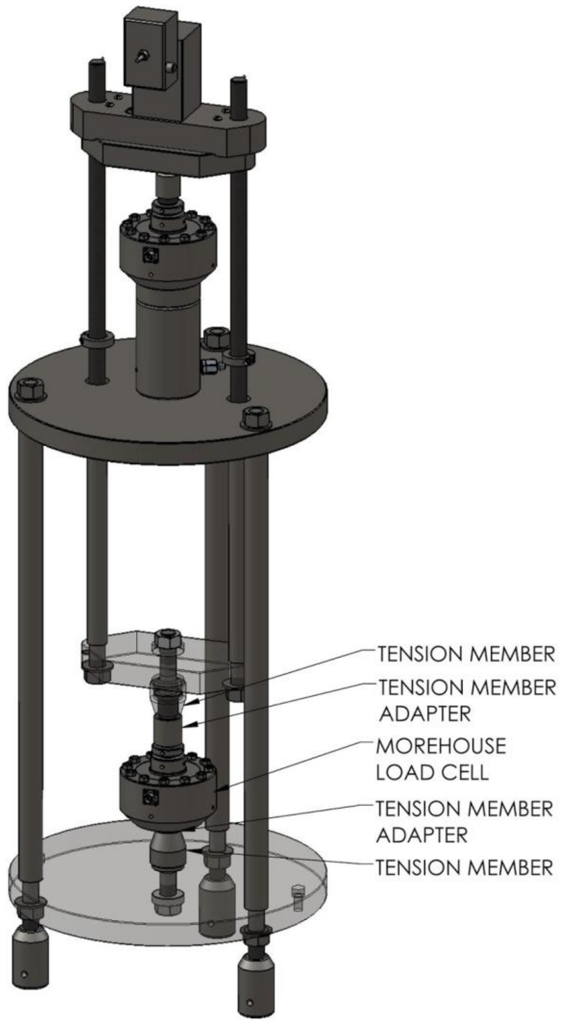
Tension Links Improper Vs Proper Pin Diameter

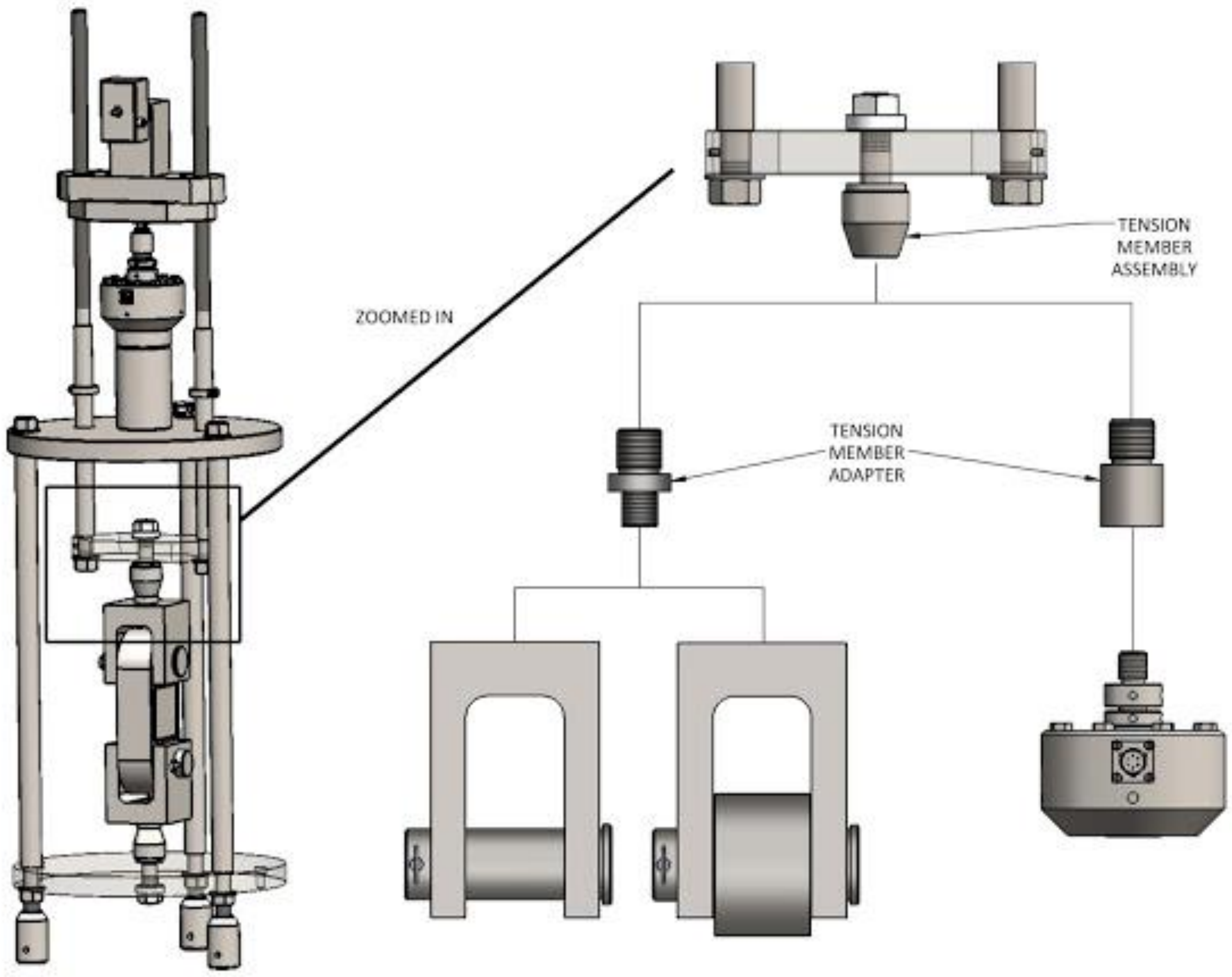
Difference of 860 LBF or 1.72 % error at 50,000 LBF from not using the proper size load pins.

Out of Tolerance   Versus   In Tolerance

Note: Tension links of this design seem to exhibit similar problems. If you are unsure, TEST!

Proper Adapters





Proper Adapters for Tension Links
(U.S. Patent No 11,078,052)

- Precision machining lowers calibration errors
- Can be used with Morehouse Quick-Change Tension Adapter system
- Rust-resistant black oxide coating

- Adaptable to numerous instruments through various available shoulder pins
- Remarkable savings on calibration adapters cost

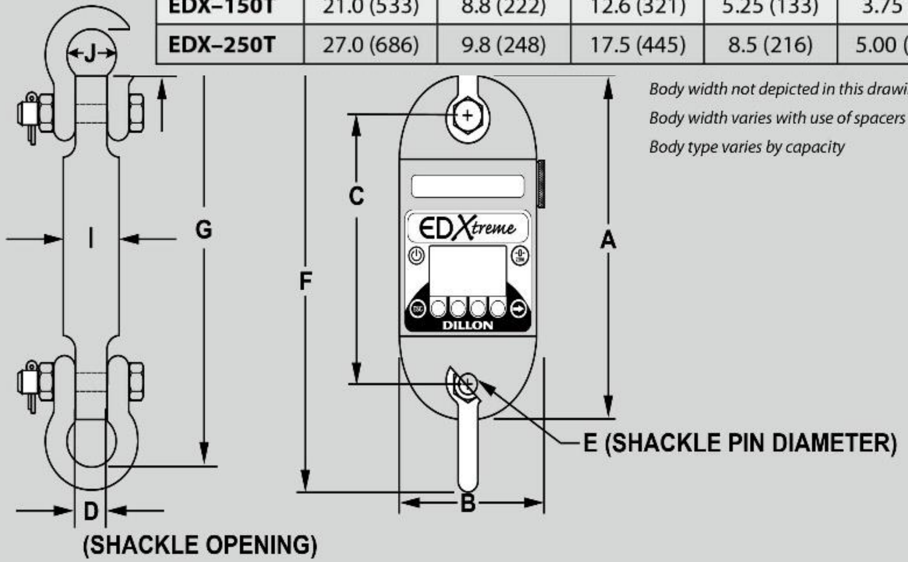
Proper Adapters for Tension Links

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

*Dimensions shown using

Dimensions inches (mm)

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

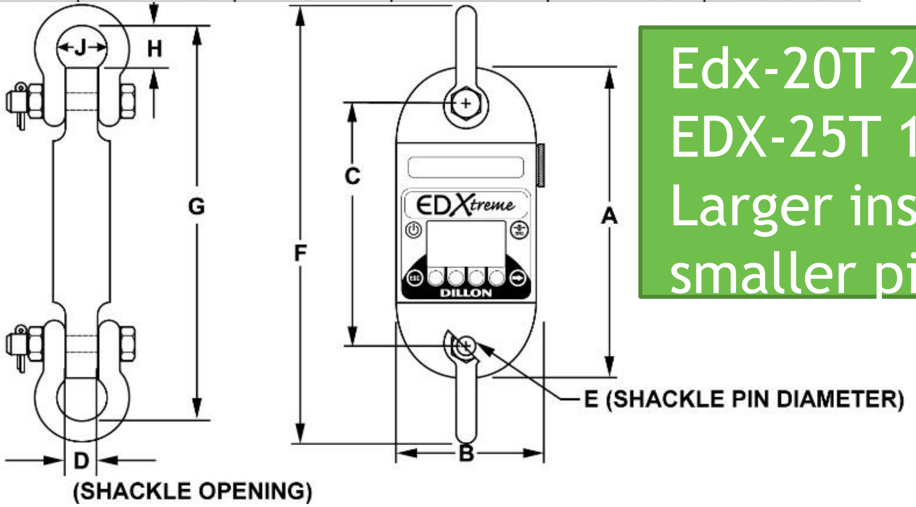


Body width not depicted in this drawing
Body width varies with use of spacers
Body type varies by capacity

Dimensions inches (mm)

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



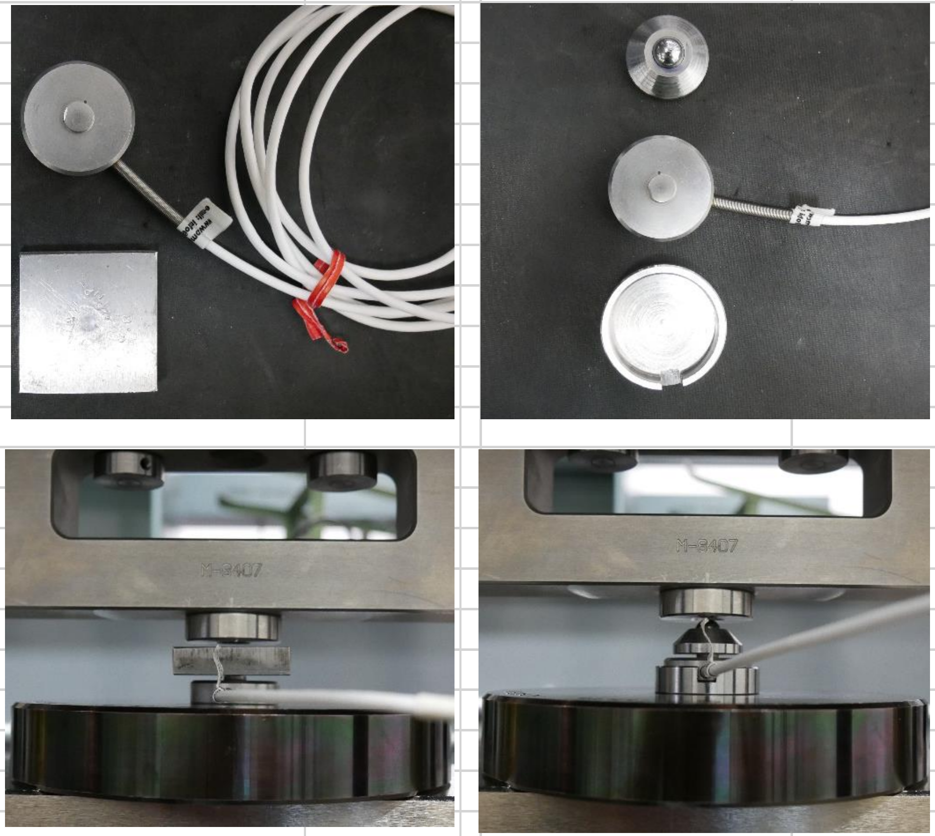
Edx-20T 2.0-inch pin
EDX-25T 1.97-inch pin
Larger instrument takes smaller pin!

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

Button Load Cell Calibration

Button Load Cell Adapters that better aligned the load cell 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%

Proper Adapters

We have a technical paper here on adapters

https://mhforce.com/wp-content/uploads/2021/04/Recommended-Compression-and-Tension-Adapters-for-Force-Calibration.pdf that won a best paper award at NCSLI.

Next up we are going to discuss the right equipment

The Right Equipment

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

Note: All of the machines shown are designed with these 5 things in mind. They replicate how most instruments are used in the field

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

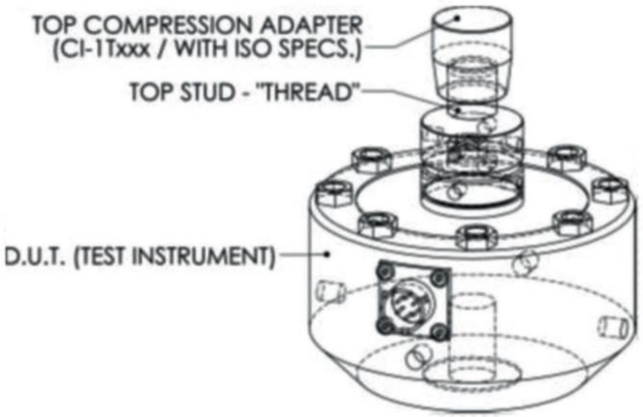
Torsion – the action of twisting or the state of being twisted. Free of torsion means free of being twisted when forces are applied

Pictured Right - Morehouse PCM-2K With Reference Load Cell. This machine have 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.

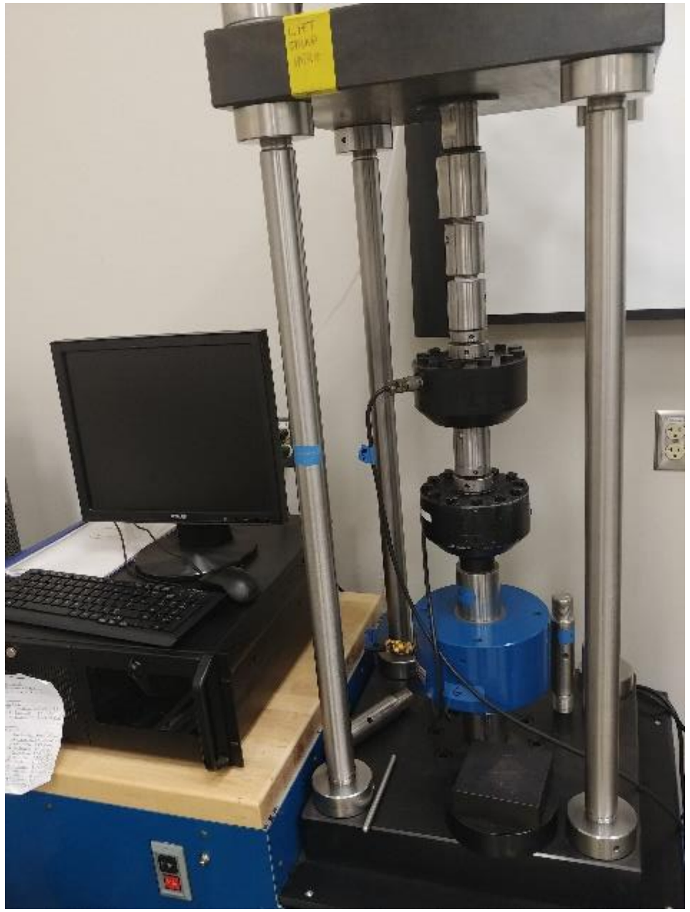
The Right Equipment

Replicates Field Use

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

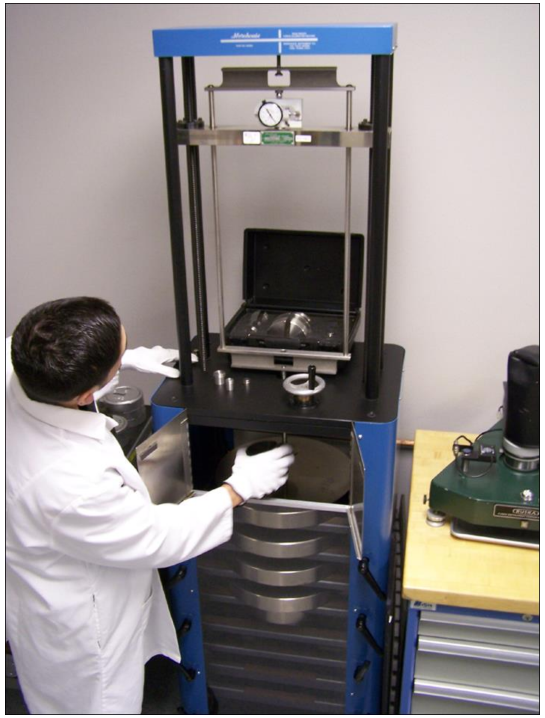


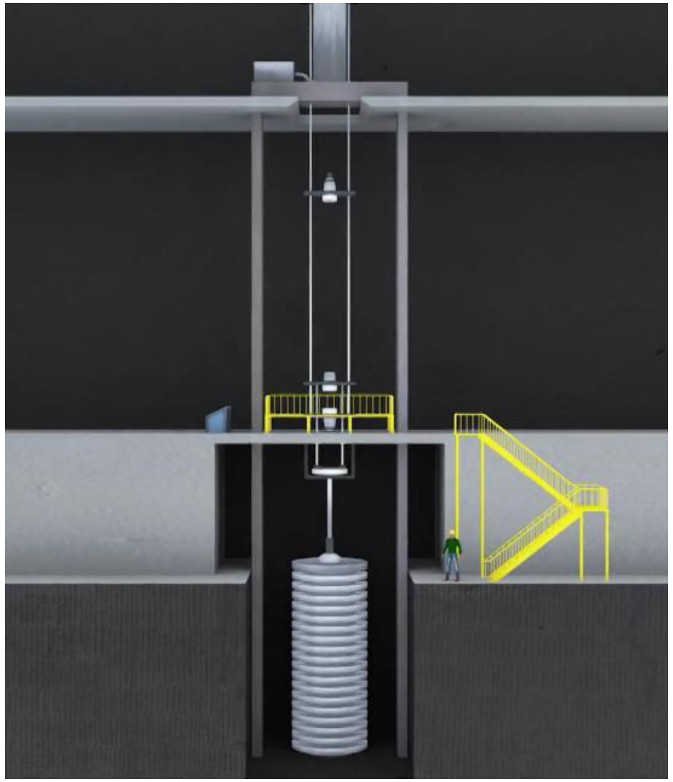
One of these does not replicate how the equipment is used in the field. Which One?

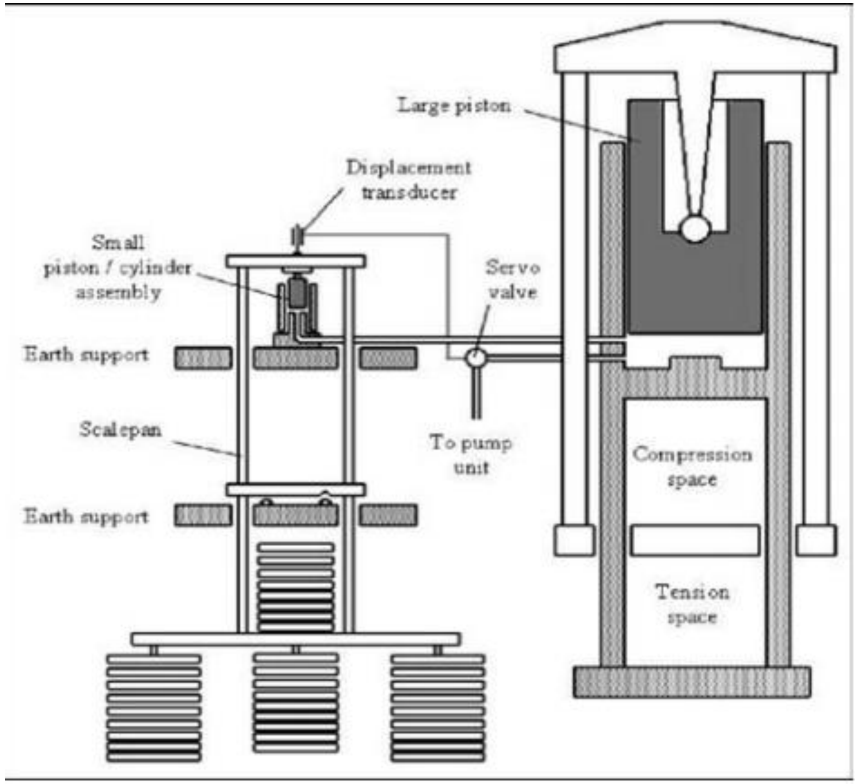


The Right Equipment

Replicates Field Use







The Right Equipment

Replicates Field Use

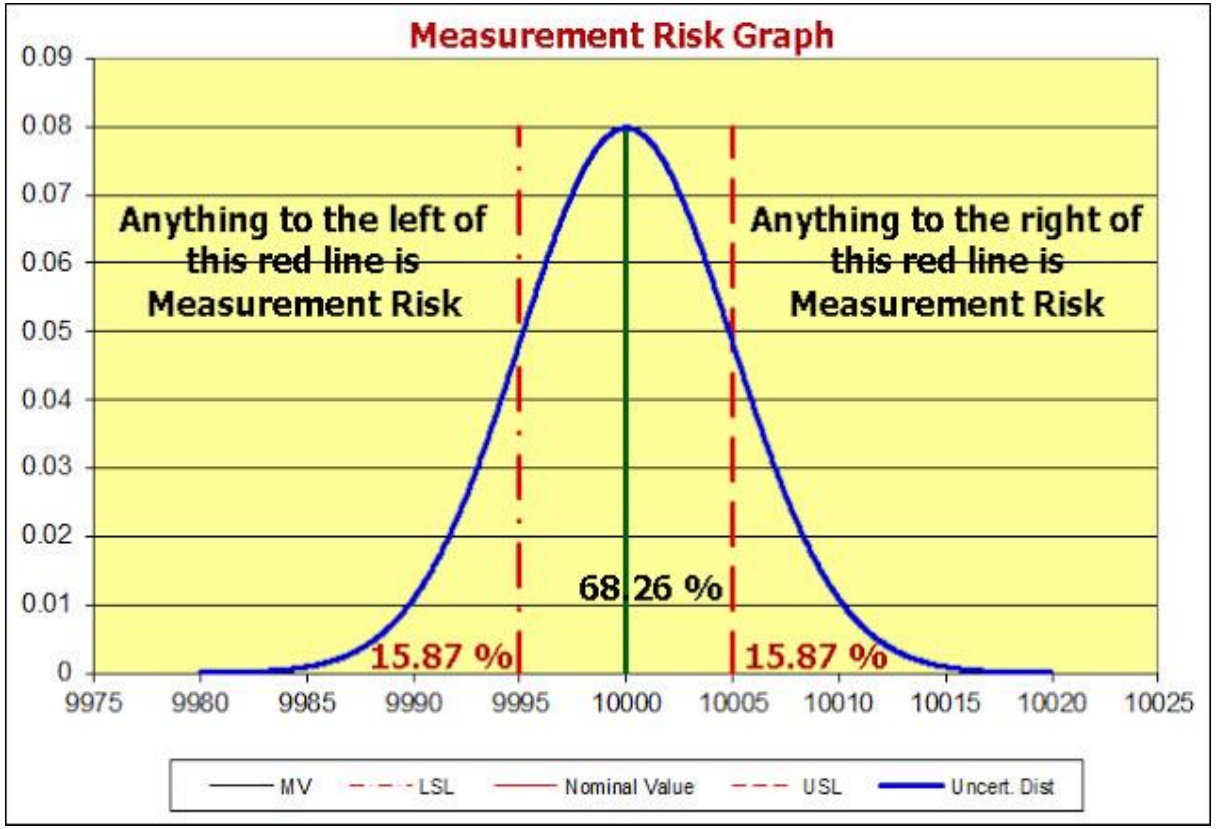
To Replicate Field Use for ASTM E4 & ISO 7500 Calibrations in These Types of Machines

- 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

The Right Calibration Provider

Has Uncertainties Low Enough to Meet Your Needs

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



Choose the Right Calibration Provider
(TUR Primary Standards Vs Secondary Standards)

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

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

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

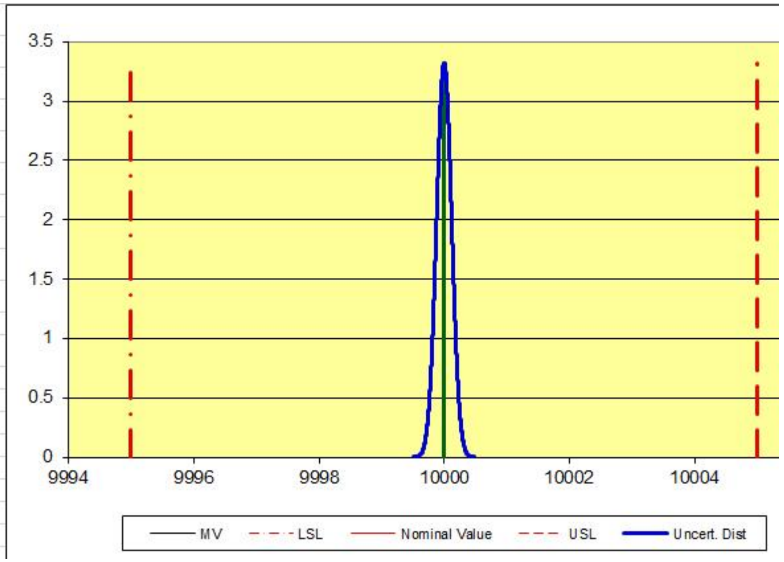
Morehouse CMC = 0.002 % of applied
One Sided Tolerance 5 lbf
Expanded U = 0.22 lbf
TUR = 22:1

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

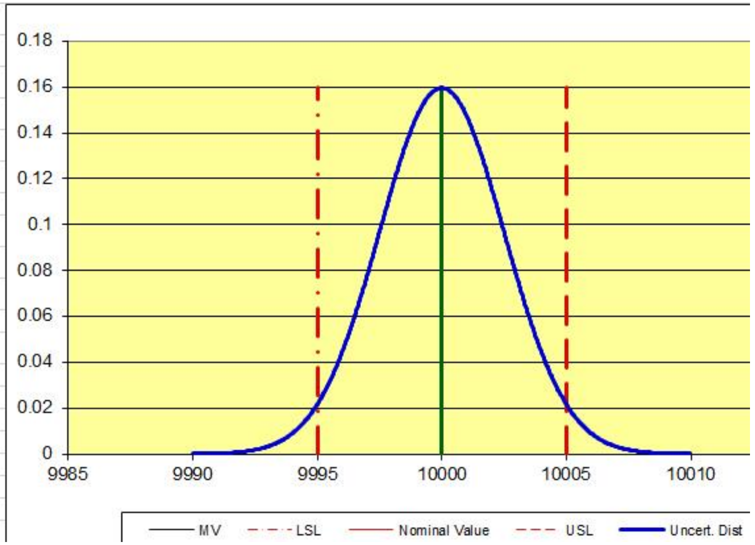
Competitor CMC = 0.05 % of applied
One Sided Tolerance 5 lbf
Expanded U = 5.0 lbf
TUR = 1:1

TUR Primary Standards vs Secondary Standards

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



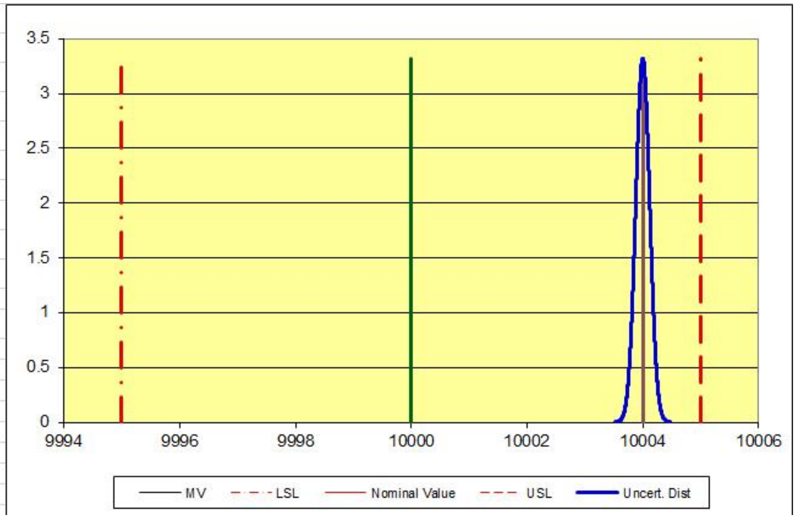
Nominal Value	10000
Lower specification Limit	9995
Upper Specification Limit	10005
Measured Value	10000
Measurement Error	0
Std. Uncert. (k=1)	2.5
Total Risk	4.55%
Upper Limit Risk	2.28%
Lower Limit Risk	2.28%
TUR =	1



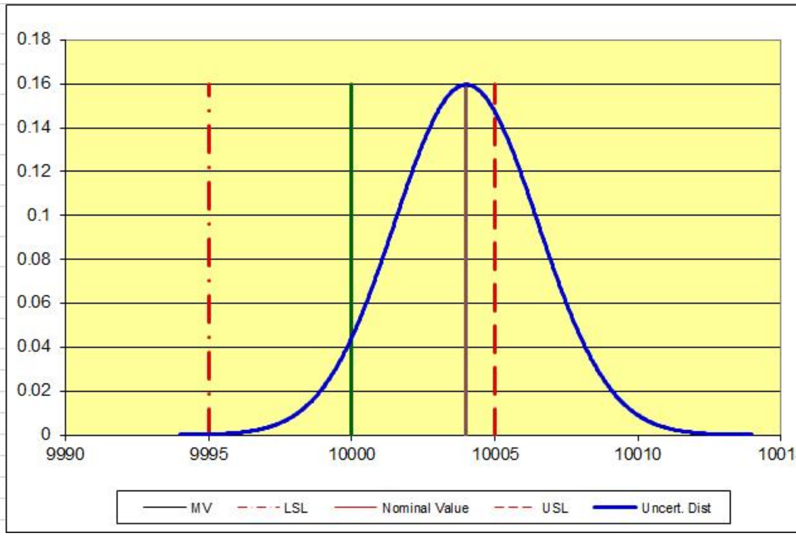
Notice the instrument read 10,000 lbf when 10,000 lbf was applied. What do you think happens when we move the location of the measurement to 10,004?

TUR Primary Standards vs Secondary Standards

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**

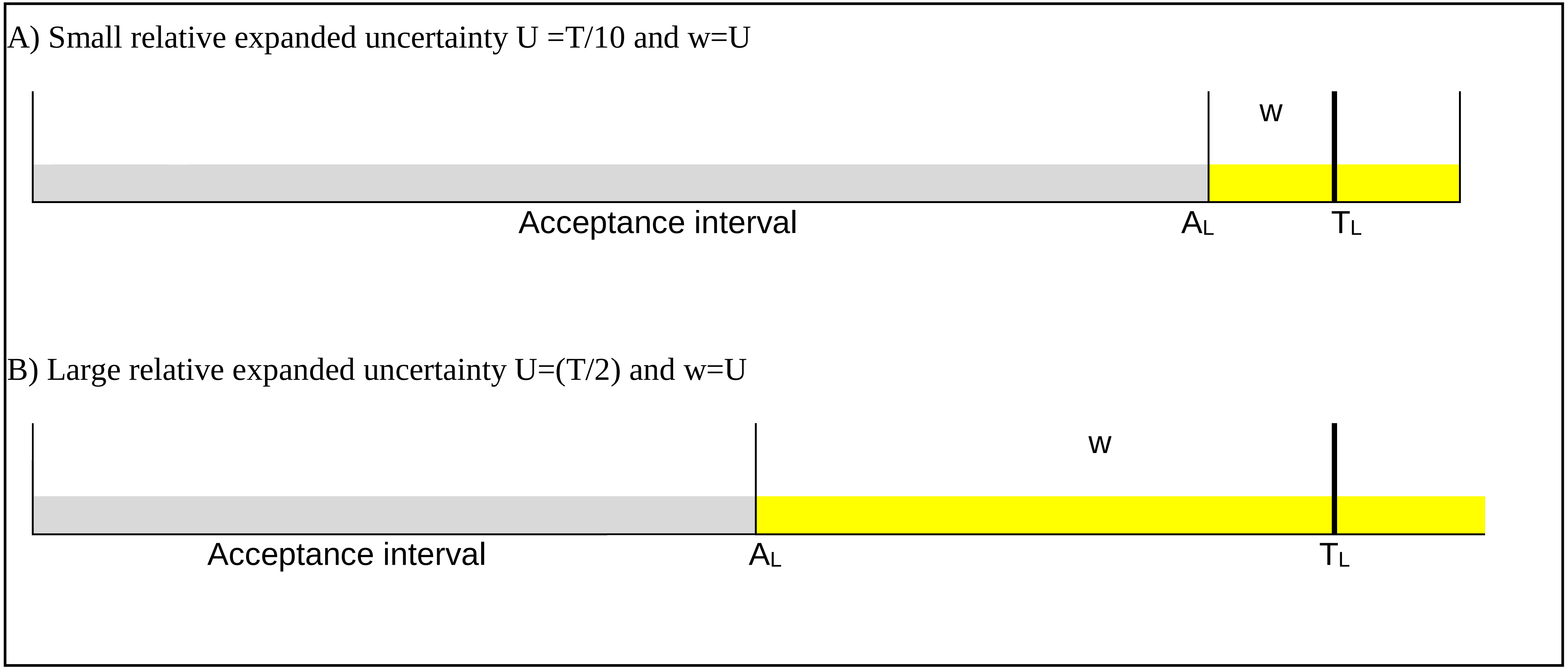


Nominal Value	10000
Lower specification Limit	9995
Upper Specification Limit	10005
Measured Value	10004
Measurement Error	4
Std. Uncert. (k=1)	2.5
Total Risk	34.47%
Upper Limit Risk	34.46%
Lower Limit Risk	0.02%
TUR =	**1**



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 Uncertainty of 0.05 % calibrates it, the risk goes from 4.55 % to 34.47 %.

Large versus Small Expanded Unc



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
- Asks the right questions to help their customers make better force measurements!

The Right Calibration Provider

Morehouse has reference force standards with calibration and measurement capabilities of better than 0.002 % to conduct many tests on adapters and provide solutions that improve measurements for our customer base.

- The frightening part of this is that not everyone in the industry realize they have these errors.
- Can you imagine the company making critical measurements using a machine that is not plumb, level, square, rigid, free of torsion, and does not replicate end-use conditions?
- How about weighing something like a ton of uranium with the wrong pin size using a tension link?

These measurements matter and the errors can be significant!

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.

Morehouse

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

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Time for Questions and Answers

PJLA

Join us for our Next Webinar

Friday, April 29, 2022 – 1:00pm EST

A Look at ISO/IEC 17025:2017 – Requirements Concerning Document Control and Control of Records

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Thank You!

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