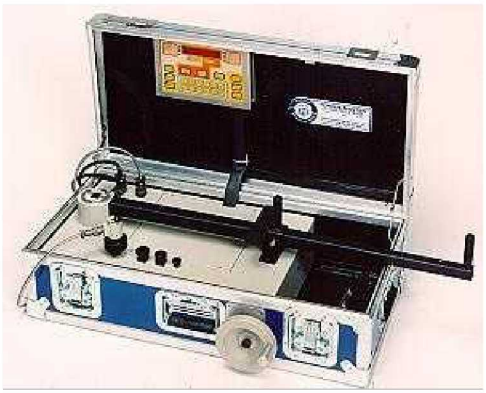
*Exceptional service in the national interest*

SAND2018-1631C

Sandia National Laboratories



# Calibration of Torque Instruments

Andrew Mackrory

Sandia National Laboratories

U.S. DEPARTMENT OF ENERGY | NNSA

Sandia National Laboratories is a multimission laboratory managed and operated by National Technology & Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International, Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.

# Disclaimer

- Certain commercial equipment, instruments, or materials are identified in this training in order to adequately describe the procedures. Such identification does not imply recommendation or endorsement by the author(s) or Sandia National Laboratories, nor does it imply that the materials or equipment identified are the only or best available for the purpose.
- This training course and the course materials do not constitute an official interpretation of any standard.
- Any views or opinions expressed by the presenter(s) are their own and do not reflect the views of Sandia National Laboratories.

# Acknowledgements


- Sandia National Laboratories supported the preparation and delivery of this training. Special thanks to Matt McLane, Carlos Mascarenas, Jeff Domain, and Rick Mertes
- Pat Pierce of AKO, Inc. arranged for the loan of the TSD 650 P Portable Torque Wrench Test System

# Introductions

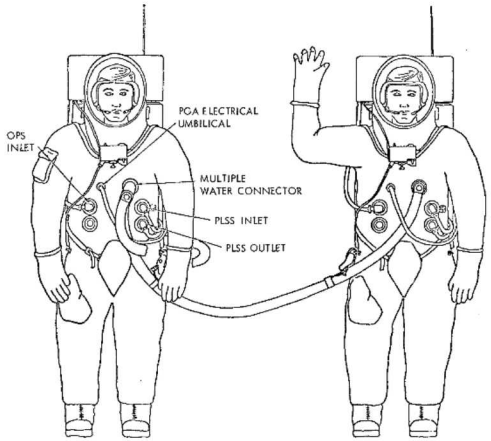
# Learning Objectives

- Vocabulary, definitions
- National and international standards
- Development of procedures
  - Hands-on calibration of torque wrenches
- Measurement uncertainty
- Other types of torque instruments
  - Calibration of torque testers

Sandia National Laboratories

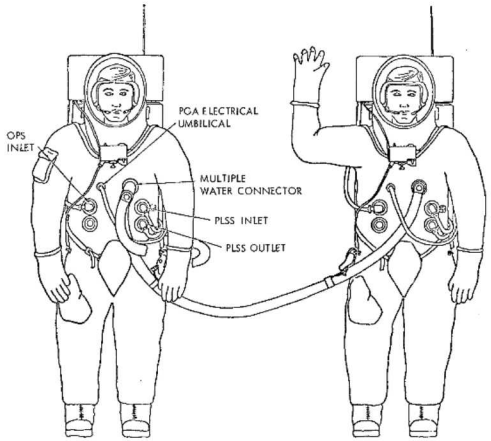
# SAFETY:
# MORE THAN JUST YOUR OWN

# Safety During Calibration




Buddy System

# Safety During Calibration




Buddy System

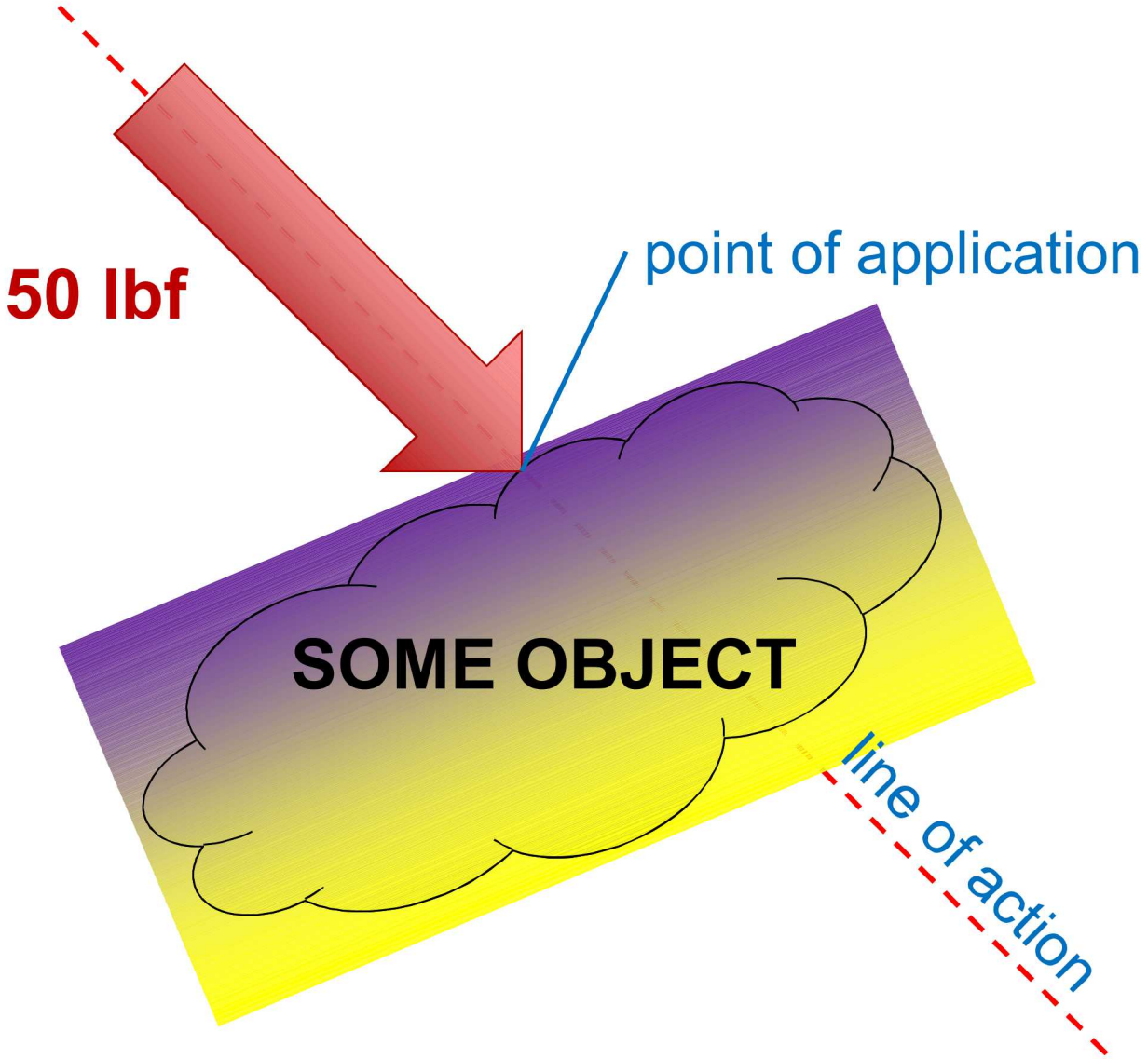
# Safety Due to Calibration

# Safety Due to Calibration

Sandia National Laboratories

# TORQUE FUNDAMENTALS: VOCABULARY AND DEFINITIONS

# Forces



# Force is not Mass

**1 kg**

**2.2 lbm**

**9.8 N**

**2.2 lbf**

**Mass**
**(amount of matter)**

**Weight**
**(a force)**

**1 kg**

**2.2 lbm**

**1.6 N**

**0.36 lbf**

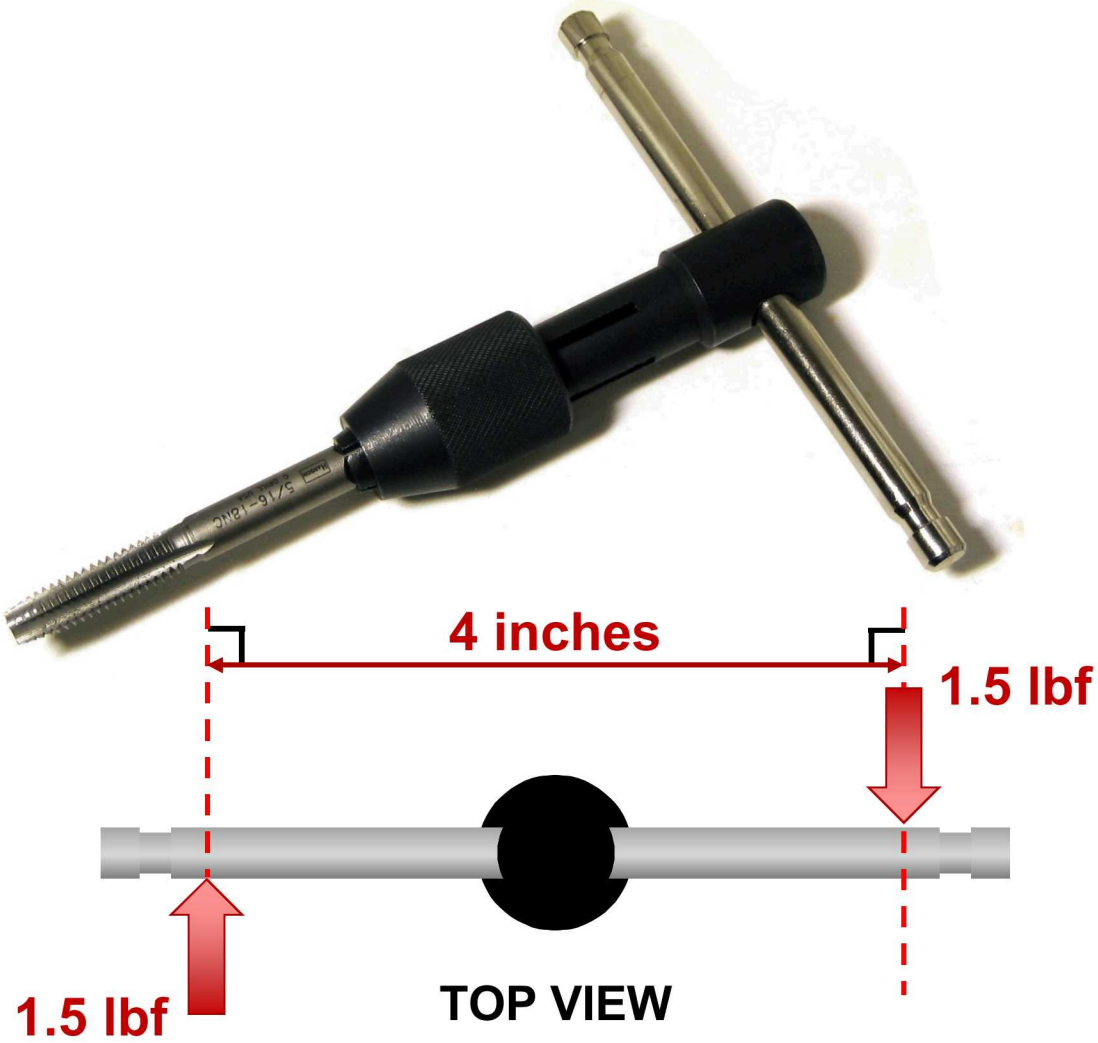
# Force Conversion Factors

Sandia National Laboratories

| To convert from | to | Multiply by |
|---|---|---|
| kilogram-force (kgf) | newton (N) | **9.80665** |
| ounce(avoirdupois) -force (ozf) | newton (N) | 0.2780139 |
| pound-force (lbf) | newton (N) | 4.448222 |
| newton (N) | kilogram-force (kgf) | 0.101972 |
| newton (N) | ounce(avoirdupois) -force (ozf) | 3.596942 |
| newton (N) | pound-force (lbf) | 0.2248089 |

# Pure Torque

## Tap Wrench: Designed for **pure torque**

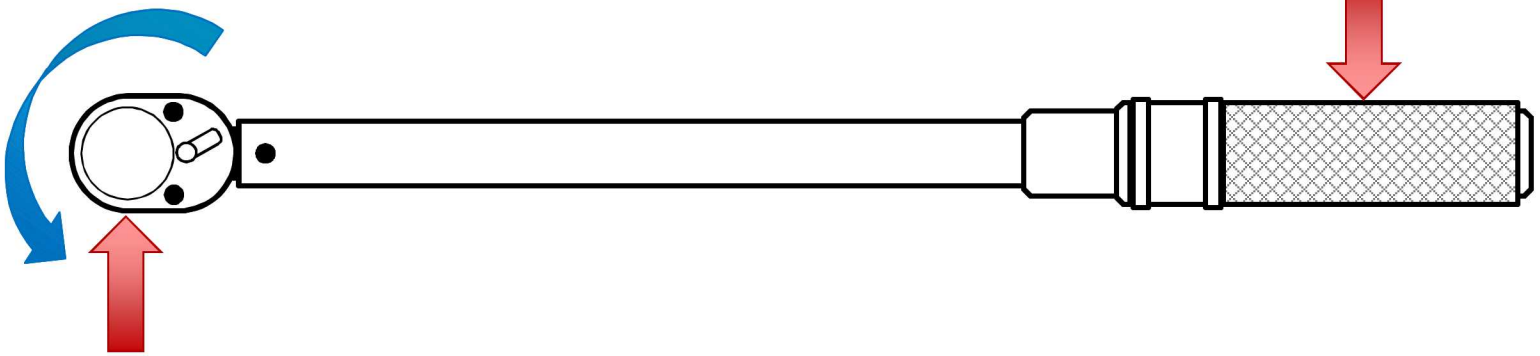


# Forces on a Torque Wrench

Sandia National Laboratories

**Torque of fastener on wrench**

**Force of hand on wrench**

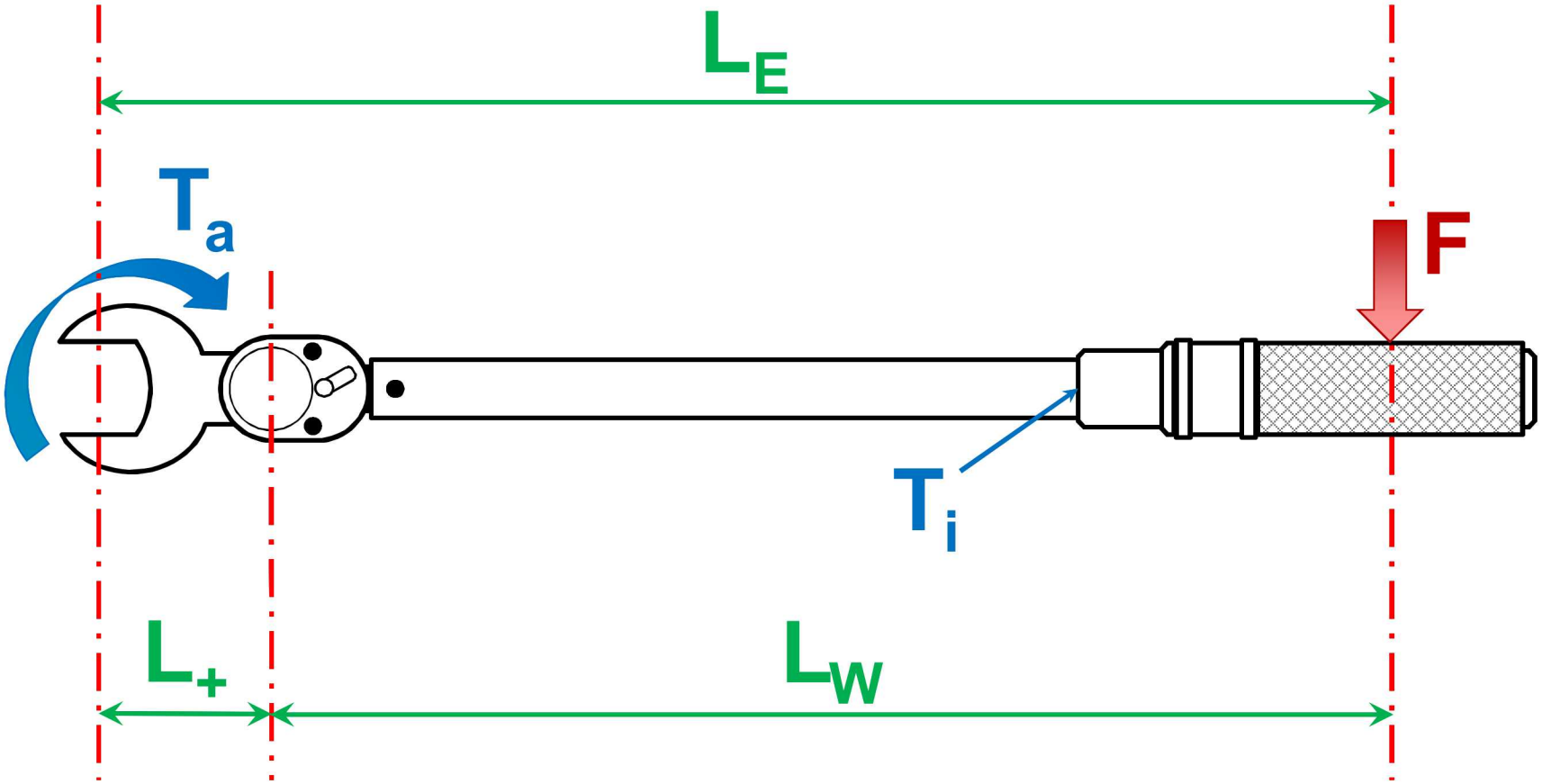


**Force of fastener on wrench**

# Forces on a Torque Wrench

# Extensions and Attachments

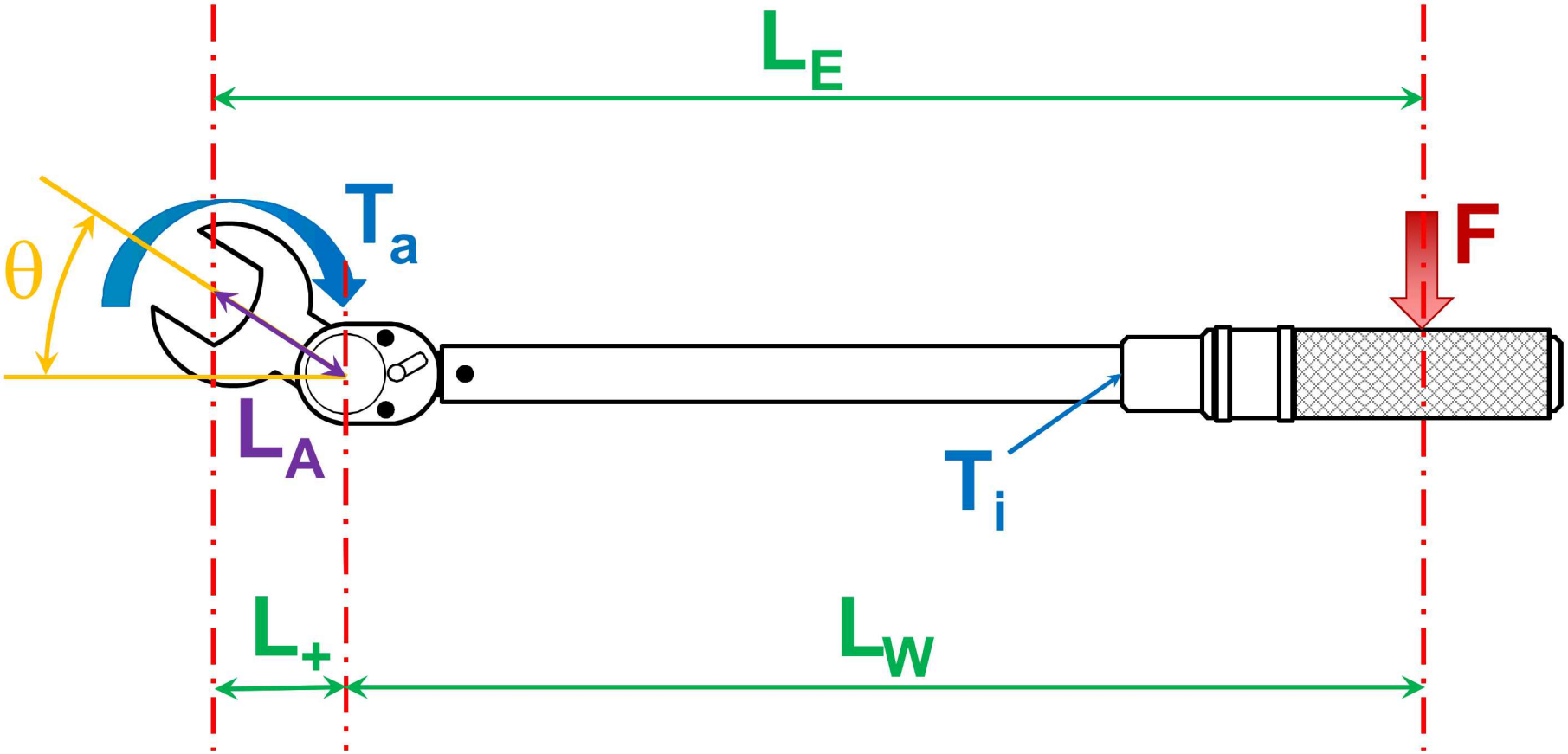
# Effect on Calibration 1




$$T_i = \frac{T_a \times L_W}{L_E}$$

$$T_a = \frac{T_i \times L_E}{L_W}$$

# Effect on Calibration 2




$$T_i = \frac{T_a \times L_W}{L_E}$$

$$T_a = \frac{T_i \times L_E}{L_W}$$

# Extensions and Attachments

# Handle Extensions (“cheater bars”)

# Torque Conversion Factors

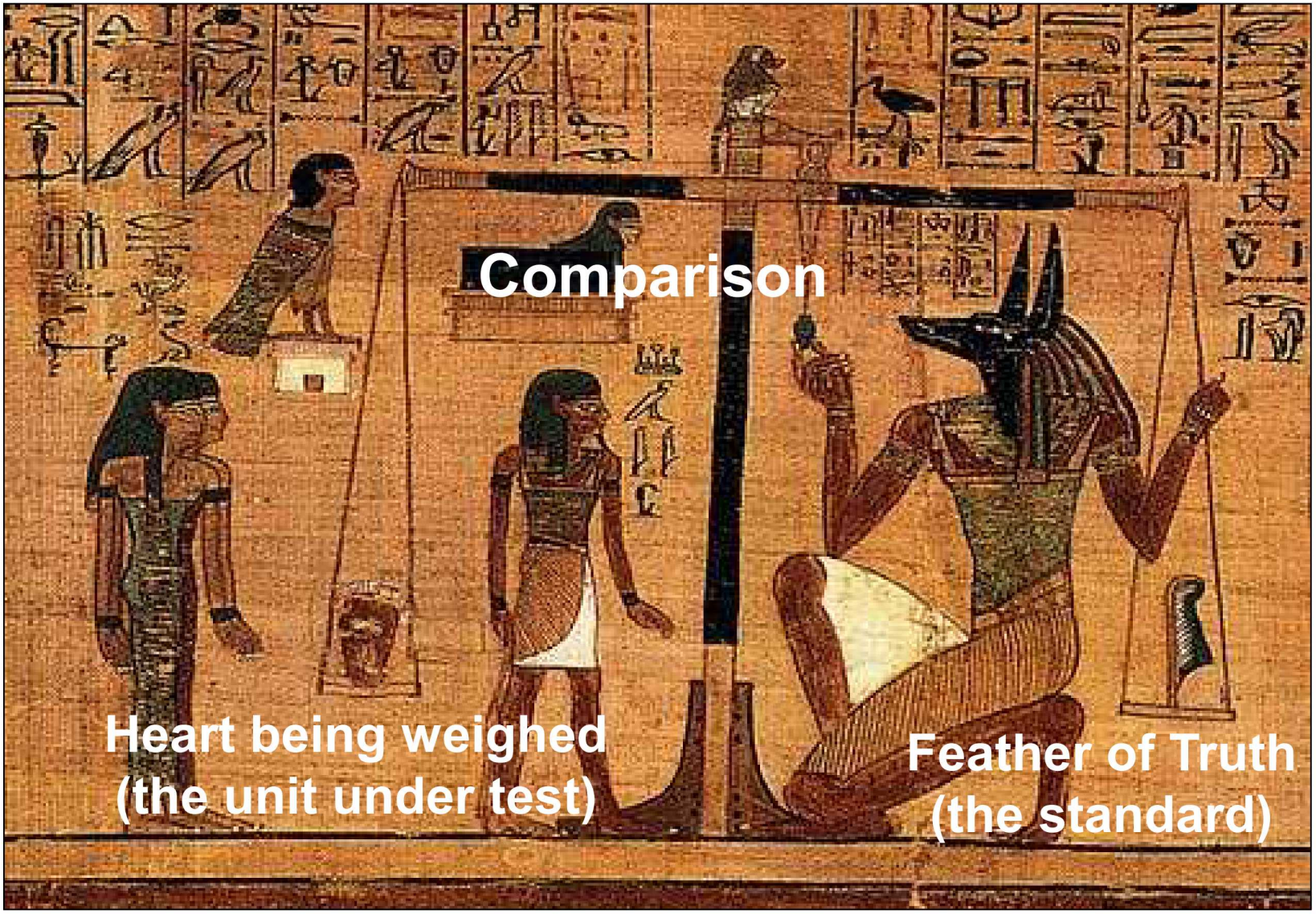
| To convert from | to | Multiply by* |
|---|---|---|
| kilogram-force meter (kgf·m) | newton-meter (N·m) | **9.80665** |
| ounce (avoirdupois)-force inch (ozf·in) | newton-meter (N·m) | 0.007061552 |
| ounce (avoirdupois)-force inch (ozf·in) | millinewton-meter (mN·m) | 7.061552 |
| pound-force foot (lbf·ft) | newton-meter (N·m) | 1.355818 |
| pound-force inch (lbf·in) | newton-meter (N·m) | 0.1129848 |

* To convert the other way, divide by the number shown

Sandia National Laboratories

# CALIBRATION FUNDAMENTALS

# What is Calibration?



# Traceability

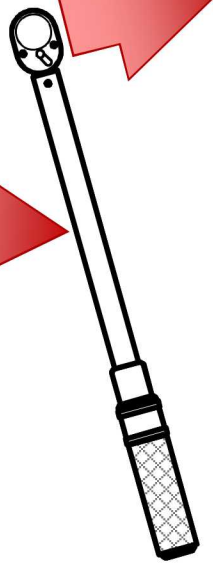
NIST
National Institute of Standards and Technology
U.S. Department of Commerce

Sandia National Laboratories

**NOTICE**

**TRAINED PERSONNEL ONLY**

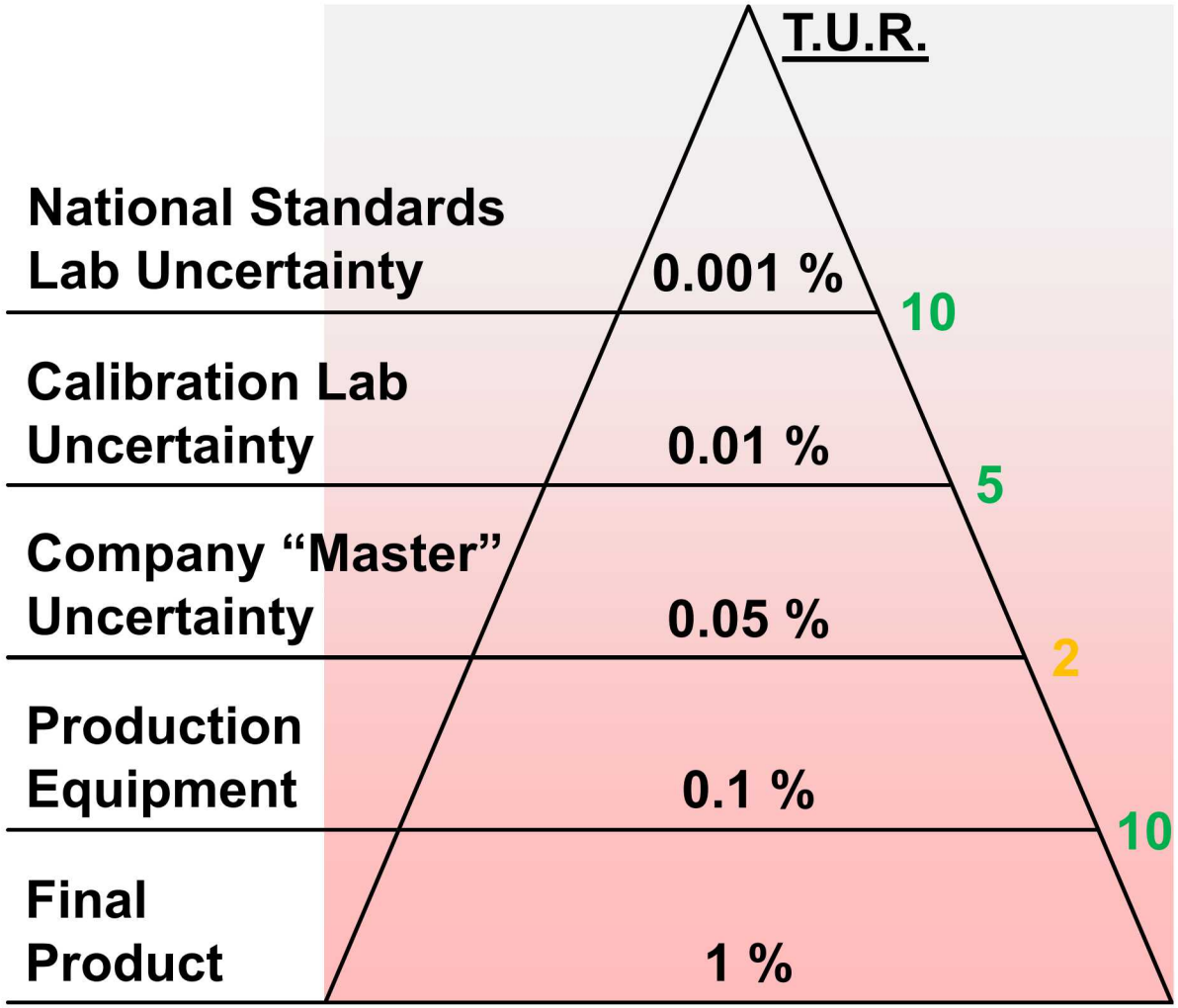




$U_{(k=2)}$

Each arrow represents a separate calibration certificate

# Measurement Uncertainty




**Generally Adequate:**

**Test Uncertainty Ratio (T.U.R.) of 4:1 (or higher)**

**1.5:1 < T.U.R. < 4:1**

**→ Apply guard banding**

**T.U.R. < 1.5:1**

**→ Calibration system is inadequate**

# Test Uncertainty Ratio 1

- You need to calibrate a torque wrench to ±4% of reading, your calibration system uncertainty is ±0.6% of reading
- Calculate the T.U.R.

$$T.U.R. = \frac{U_{certification}}{U_{cal.process}}$$

$$T.U.R. = \_\_\_\_\_$$

Is the calibration system adequate?

_____

# Test Uncertainty Ratio 2

- You need to calibrate a torque wrench to ±1% of reading, your calibration system uncertainty is ±0.4% of reading
- Calculate the T.U.R.

$$T.U.R. = \frac{U_{certification}}{U_{cal.process}}$$

$$T.U.R. = \_\_\_\_\_$$

Is the calibration system adequate?

_____

Sandia National Laboratories

# NATIONAL AND INTERNATIONAL STANDARDS

# ISO/IEC 17025

United States Department of Commerce
National Institute of Standards and Technology

NVLAP®

## Certificate of Accreditation to ISO/IEC 17025:2005

**NVLAP LAB CODE: 105002-0**

**Sandia National Laboratories**
Albuquerque, NM

*is accredited by the National Voluntary Laboratory Accreditation Program for specific services, listed on the Scope of Accreditation, for:*

**Calibration Laboratories**

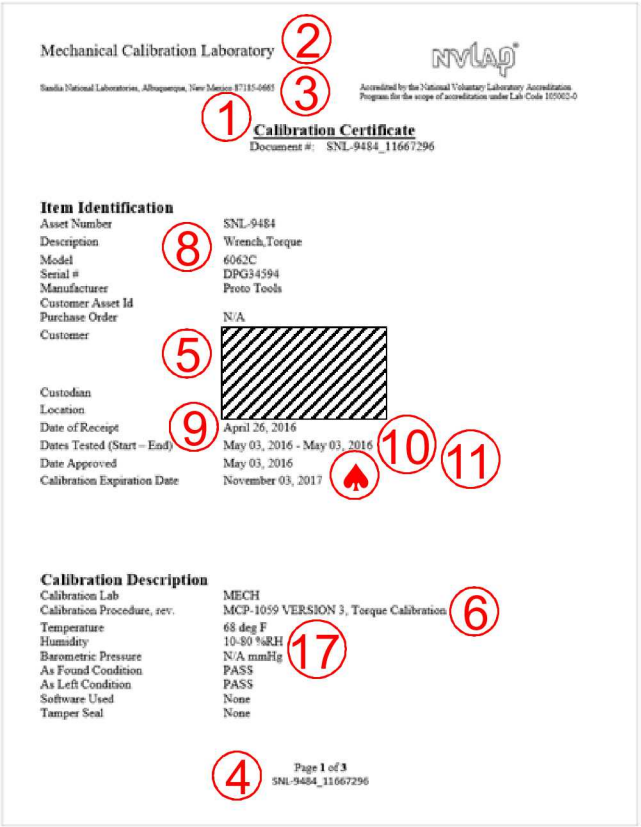
*This laboratory is accredited in accordance with the recognized International Standard ISO/IEC 17025:2005. This accreditation demonstrates technical competence for a defined scope and the operation of a laboratory quality management system (refer to joint ISO-ILAC-IAF Communique dated January 2009).*

2017-03-01 through 2018-03-31
*Effective Dates*

DEPARTMENT OF COMMERCE · UNITED STATES OF AMERICA ·

*For the National Voluntary Laboratory Accreditation Program*

# Certificate Requirements



Mechanical Calibration Laboratory

Sandia National Laboratories, Albuquerque, New Mexico 87185-0665

Accredited by the National Voluntary Laboratory Accreditation Program for the scope of accreditation under Lab Code 105002-0

**Calibration Certificate**

Document #: SNL-9484_11667296

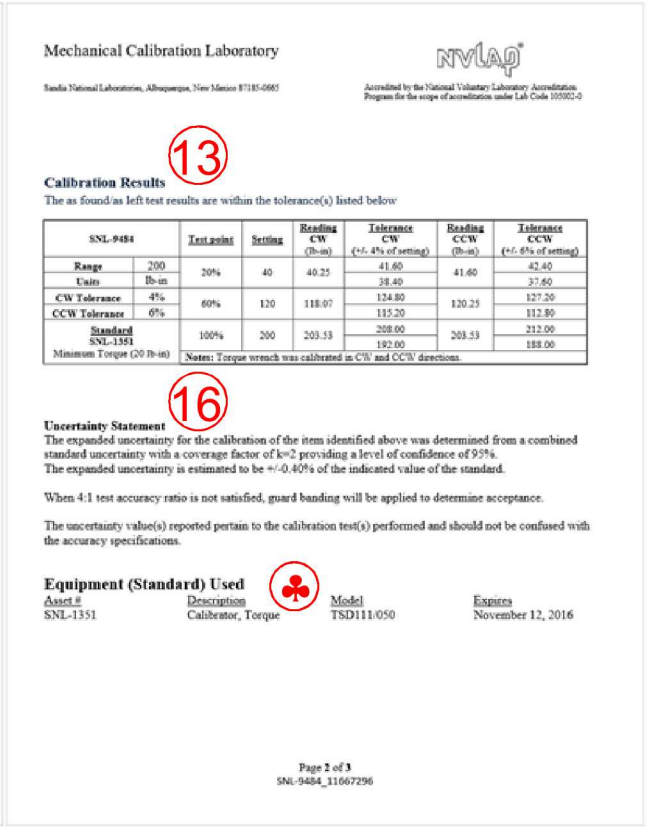
**Item Identification**

| | |
|---|---|
| Asset Number | SNL-9484 |
| Description | Wrench,Torque |
| Model | 6062C |
| Serial # | DPG34594 |
| Manufacturer | Proto Tools |
| Customer Asset Id | |
| Purchase Order | N/A |
| Customer | |
| Custodian | |
| Location | |
| Date of Receipt | April 26, 2016 |
| Dates Tested (Start – End) | May 03, 2016 - May 03, 2016 |
| Date Approved | May 03, 2016 |
| Calibration Expiration Date | November 03, 2017 |

**Calibration Description**

| | |
|---|---|
| Calibration Lab | MECH |
| Calibration Procedure, rev. | MCP-1059 VERSION 3, Torque Calibration |
| Temperature | 68 deg F |
| Humidity | 10-80 %RH |
| Barometric Pressure | N/A mmHg |
| As Found Condition | PASS |
| As Left Condition | PASS |
| Software Used | None |
| Tamper Seal | None |

Page 1 of 3
SNL-9484_11667296



Mechanical Calibration Laboratory

Sandia National Laboratories, Albuquerque, New Mexico 87185-0665

Accredited by the National Voluntary Laboratory Accreditation Program for the scope of accreditation under Lab Code 105002-0

**Calibration Results**

The as found/as left test results are within the tolerance(s) listed below

| SNL-9484 | | Test point | Setting | Reading CW (lb-in) | Tolerance CW (+/- 4% of setting) | Reading CCW (lb-in) | Tolerance CCW (+/- 6% of setting) |
|---|---|---|---|---|---|---|---|
| Range | 200 | 20% | 40 | 40.25 | 41.60 | 41.60 | 42.40 |
| Units | lb-in | | | | 38.40 | | 37.60 |
| CW Tolerance | 4% | 60% | 120 | 118.07 | 124.80 | 120.25 | 127.20 |
| CCW Tolerance | 6% | | | | 115.20 | | 112.80 |
| Standard SNL-1351 | | 100% | 200 | 203.53 | 208.00 | 203.53 | 212.00 |
| Minimum Torque (20 lb-in) | | Notes: Torque wrench was calibrated in CW and CCW directions. | | | 192.00 | | 188.00 |

**Uncertainty Statement**

The expanded uncertainty for the calibration of the item identified above was determined from a combined standard uncertainty with a coverage factor of k=2 providing a level of confidence of 95%.
The expanded uncertainty is estimated to be +/-0.40% of the indicated value of the standard.

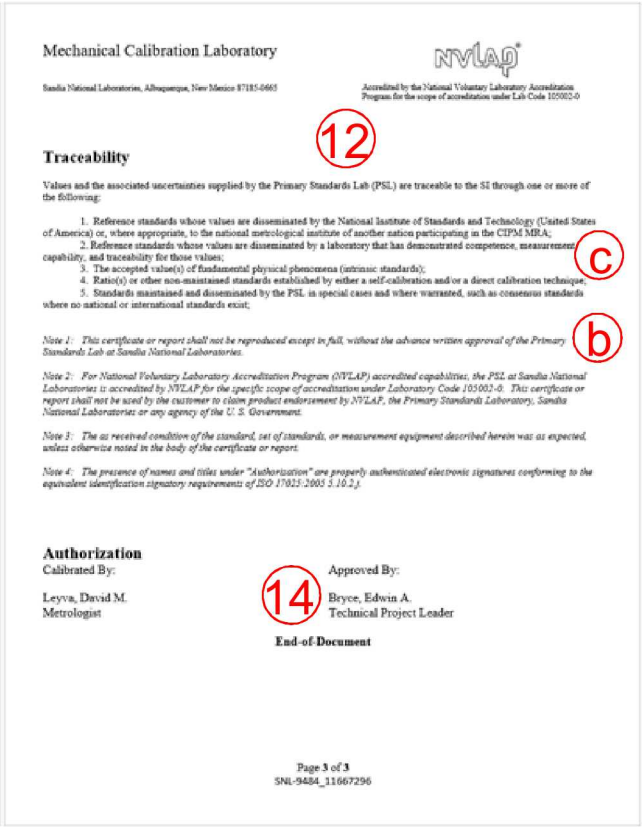
When 4:1 test accuracy ratio is not satisfied, guard banding will be applied to determine acceptance.

The uncertainty value(s) reported pertain to the calibration test(s) performed and should not be confused with the accuracy specifications.

**Equipment (Standard) Used**

| Asset # | Description | Model | Expires |
|---|---|---|---|
| SNL-1351 | Calibrator, Torque | TSD111/050 | November 12, 2016 |

Page 2 of 3
SNL-9484_11667296



Mechanical Calibration Laboratory

Sandia National Laboratories, Albuquerque, New Mexico 87185-0665

Accredited by the National Voluntary Laboratory Accreditation Program for the scope of accreditation under Lab Code 105002-0

**Traceability**

Values and the associated uncertainties supplied by the Primary Standards Lab (PSL) are traceable to the SI through one or more of the following:

1. Reference standards whose values are disseminated by the National Institute of Standards and Technology (United States of America) or, where appropriate, to the national metrological institute of another nation participating in the CIPM MRA;
2. Reference standards whose values are disseminated by a laboratory that has demonstrated competence, measurement capability, and traceability for those values;
3. The accepted value(s) of fundamental physical phenomena (intrinsic standards);
4. Ratio(s) or other non-maintained standards established by either a self-calibration and/or a direct calibration technique;
5. Standards maintained and disseminated by the PSL in special cases and where warranted, such as consensus standards where no national or international standards exist;

*Note 1: This certificate or report shall not be reproduced except in full, without the advance written approval of the Primary Standards Lab at Sandia National Laboratories.*

*Note 2: For National Voluntary Laboratory Accreditation Program (NVLAP) accredited capabilities, the PSL at Sandia National Laboratories is accredited by NVLAP for the specific scope of accreditation under Laboratory Code 105002-0. This certificate or report shall not be used by the customer to claim product endorsement by NVLAP, the Primary Standards Laboratory, Sandia National Laboratories or any agency of the U.S. Government.*

*Note 3: The as received condition of the standard, set of standards, or measurement equipment described herein was as expected, unless otherwise noted in the body of the certificate or report.*

*Note 4: The presence of names and titles under "Authorization" are properly authenticated electronic signatures conforming to the equivalent identification signatory requirements of ISO 17025:2005 5.10.2.j.*

**Authorization**

Calibrated By:

Leyva, David M.
Metrologist

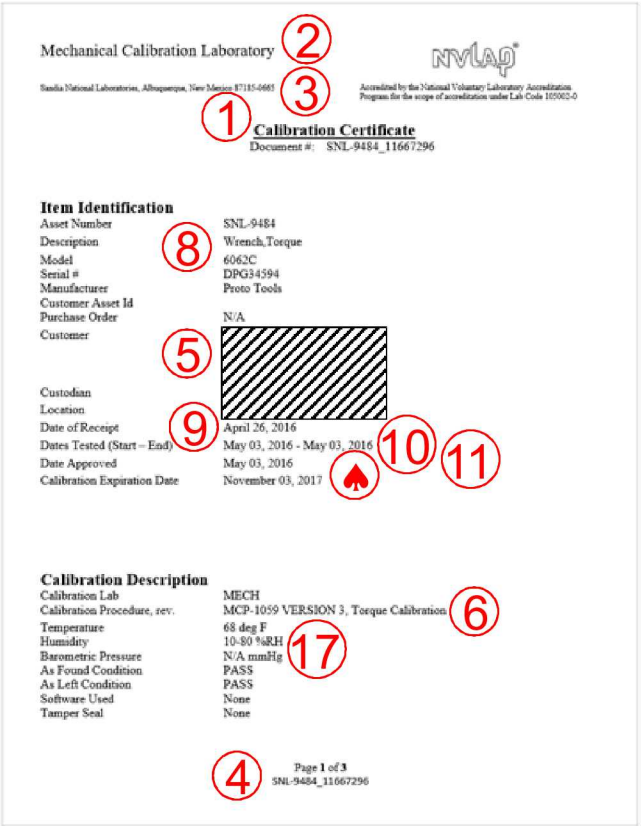
Approved By:

Bryce, Edwin A.
Technical Project Leader

**End-of-Document**

Page 3 of 3
SNL-9484_11667296

# Certificate Requirements



Mechanical Calibration Laboratory

Sandia National Laboratories, Albuquerque, New Mexico 87185-0665

Accredited by the National Voluntary Laboratory Accreditation Program for the scope of accreditation under Lab Code 105002-0

**Calibration Certificate**

Document #: SNL-9484_11667296

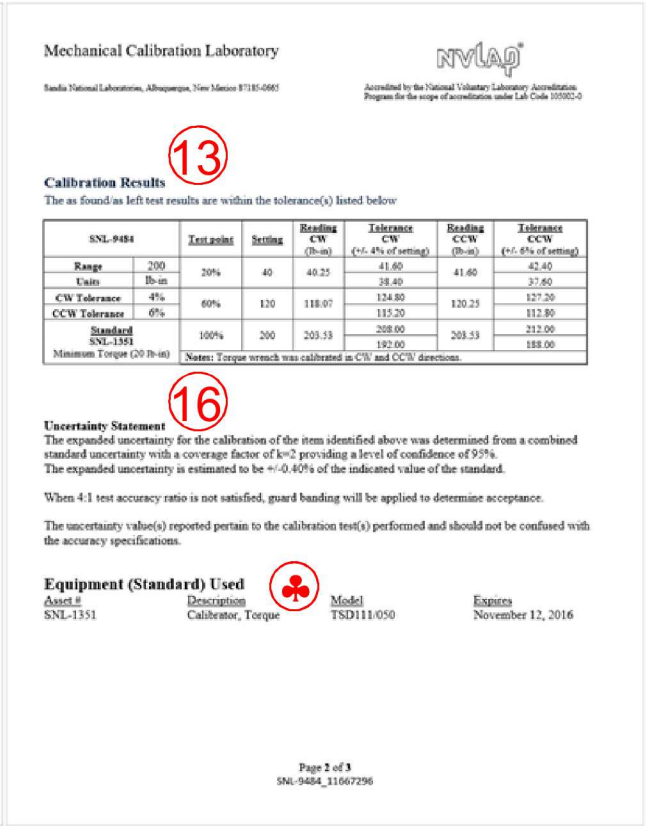
**Item Identification**

| | |
|---|---|
| Asset Number | SNL-9484 |
| Description | Wrench,Torque |
| Model | 6062C |
| Serial # | DPG34594 |
| Manufacturer | Proto Tools |
| Customer Asset Id | |
| Purchase Order | N/A |
| Customer | |
| Custodian | |
| Location | |
| Date of Receipt | April 26, 2016 |
| Dates Tested (Start – End) | May 03, 2016 - May 03, 2016 |
| Date Approved | May 03, 2016 |
| Calibration Expiration Date | November 03, 2017 |

**Calibration Description**

| | |
|---|---|
| Calibration Lab | MECH |
| Calibration Procedure, rev. | MCP-1059 VERSION 3, Torque Calibration |
| Temperature | 68 deg F |
| Humidity | 10-80 %RH |
| Barometric Pressure | N/A mmHg |
| As Found Condition | PASS |
| As Left Condition | PASS |
| Software Used | None |
| Tamper Seal | None |

Page 1 of 3
SNL-9484_11667296



Mechanical Calibration Laboratory

Sandia National Laboratories, Albuquerque, New Mexico 87185-0665

Accredited by the National Voluntary Laboratory Accreditation Program for the scope of accreditation under Lab Code 105002-0

**Calibration Results**

The as found/as left test results are within the tolerance(s) listed below

| SNL-9484 | | Test point | Setting | Reading CW (lb-in) | Tolerance CW (+/- 4% of setting) | Reading CCW (lb-in) | Tolerance CCW (+/- 6% of setting) |
|---|---|---|---|---|---|---|---|
| Range | 200 | 20% | 40 | 40.25 | 41.60 | 41.60 | 42.40 |
| Units | lb-in | | | | 38.40 | | 37.60 |
| CW Tolerance | 4% | 60% | 120 | 118.07 | 124.80 | 120.25 | 127.20 |
| CCW Tolerance | 6% | | | | 115.20 | | 112.80 |
| Standard SNL-1351 | | 100% | 200 | 203.53 | 208.00 | 203.53 | 212.00 |
| Minimum Torque (20 lb-in) | | Notes: Torque wrench was calibrated in CW and CCW directions. | | | 192.00 | | 188.00 |

**Uncertainty Statement**

The expanded uncertainty for the calibration of the item identified above was determined from a combined standard uncertainty with a coverage factor of k=2 providing a level of confidence of 95%.
The expanded uncertainty is estimated to be +/-0.40% of the indicated value of the standard.

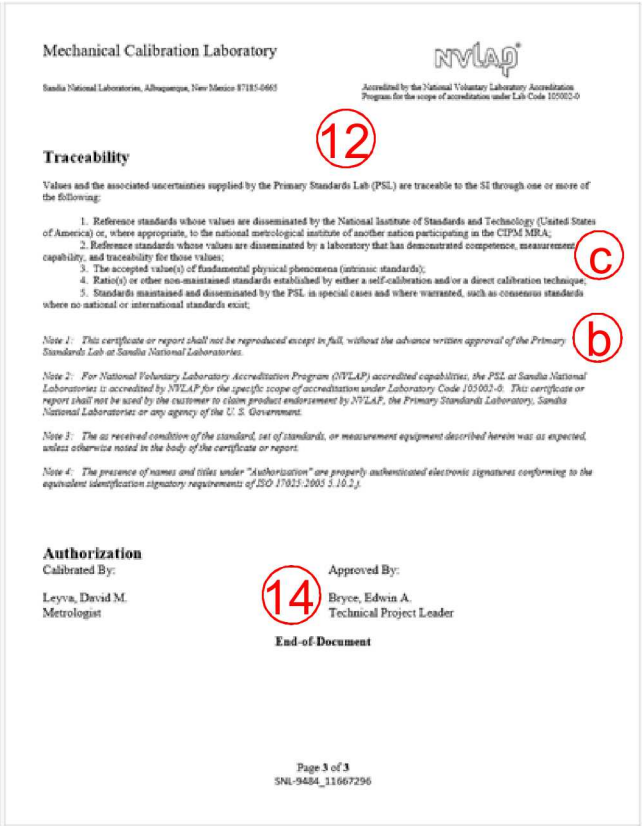
When 4:1 test accuracy ratio is not satisfied, guard banding will be applied to determine acceptance.

The uncertainty value(s) reported pertain to the calibration test(s) performed and should not be confused with the accuracy specifications.

**Equipment (Standard) Used**

| Asset # | Description | Model | Expires |
|---|---|---|---|
| SNL-1351 | Calibrator, Torque | TSD111/050 | November 12, 2016 |

Page 2 of 3
SNL-9484_11667296



Mechanical Calibration Laboratory

Sandia National Laboratories, Albuquerque, New Mexico 87185-0665

Accredited by the National Voluntary Laboratory Accreditation Program for the scope of accreditation under Lab Code 105002-0

**Traceability**

Values and the associated uncertainties supplied by the Primary Standards Lab (PSL) are traceable to the SI through one or more of the following:

1. Reference standards whose values are disseminated by the National Institute of Standards and Technology (United States of America) or, where appropriate, to the national metrological institute of another nation participating in the CIPM MRA;
2. Reference standards whose values are disseminated by a laboratory that has demonstrated competence, measurement capability, and traceability for those values;
3. The accepted value(s) of fundamental physical phenomena (intrinsic standards);
4. Ratio(s) or other non-maintained standards established by either a self-calibration and/or a direct calibration technique;
5. Standards maintained and disseminated by the PSL in special cases and where warranted, such as consensus standards where no national or international standards exist;

*Note 1: This certificate or report shall not be reproduced except in full, without the advance written approval of the Primary Standards Lab at Sandia National Laboratories.*

*Note 2: For National Voluntary Laboratory Accreditation Program (NVLAP) accredited capabilities, the PSL at Sandia National Laboratories is accredited by NVLAP for the specific scope of accreditation under Laboratory Code 105002-0. This certificate or report shall not be used by the customer to claim product endorsement by NVLAP, the Primary Standards Laboratory, Sandia National Laboratories or any agency of the U.S. Government.*

*Note 3: The as received condition of the standard, set of standards, or measurement equipment described herein was as expected, unless otherwise noted in the body of the certificate or report.*

*Note 4: The presence of names and titles under "Authorization" are properly authenticated electronic signatures conforming to the equivalent identification signatory requirements of ISO 17025:2005 5.10.2.j.*

**Authorization**

Calibrated By:

Leyva, David M.
Metrologist

Approved By:

Bryce, Edwin A.
Technical Project Leader

**End-of-Document**

Page 3 of 3
SNL-9484_11667296

# ASME B107.300-2010 (R2016)

- Torque Instruments
  - Hand Torque Tools (mechanical)
  - Electronic Torque Instruments
  - Electronic Tester, Hand Torque Tools
- Available from:

https://www.asme.org/products/codes-standards/b107300-2010-torque-instruments-(1)

- $43
- The purpose of the standard is to:
  - "define essential performance and safety characteristics"
  - "specify test methods to evaluate performance" (for example, calibration to evaluate accuracy)

# Torque Instrument Classification

Sandia National Laboratories


①

②


③

# Torque Instrument Classification

Sandia National Laboratories

①

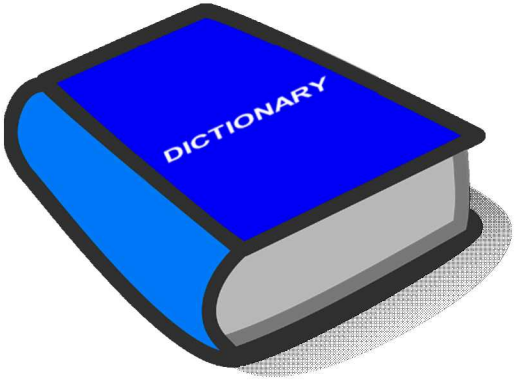
②

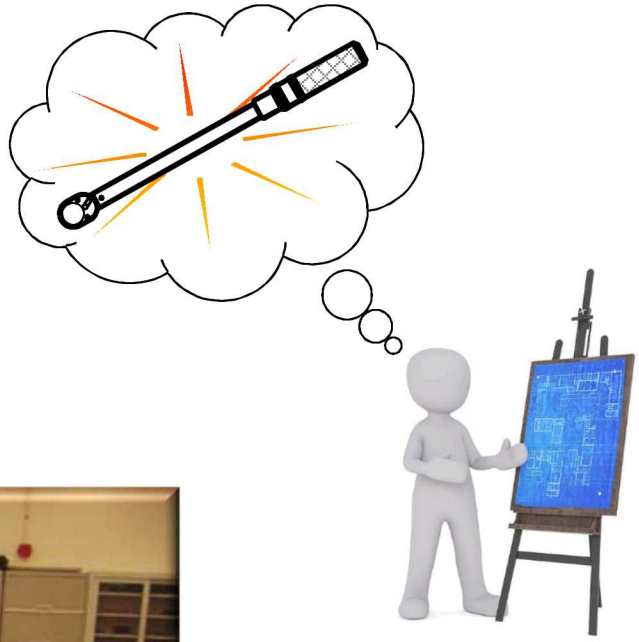

③


④

# Other Torque Wrench Features

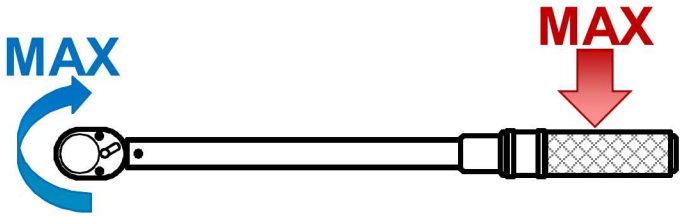
# ASME B107.300 – Other Content



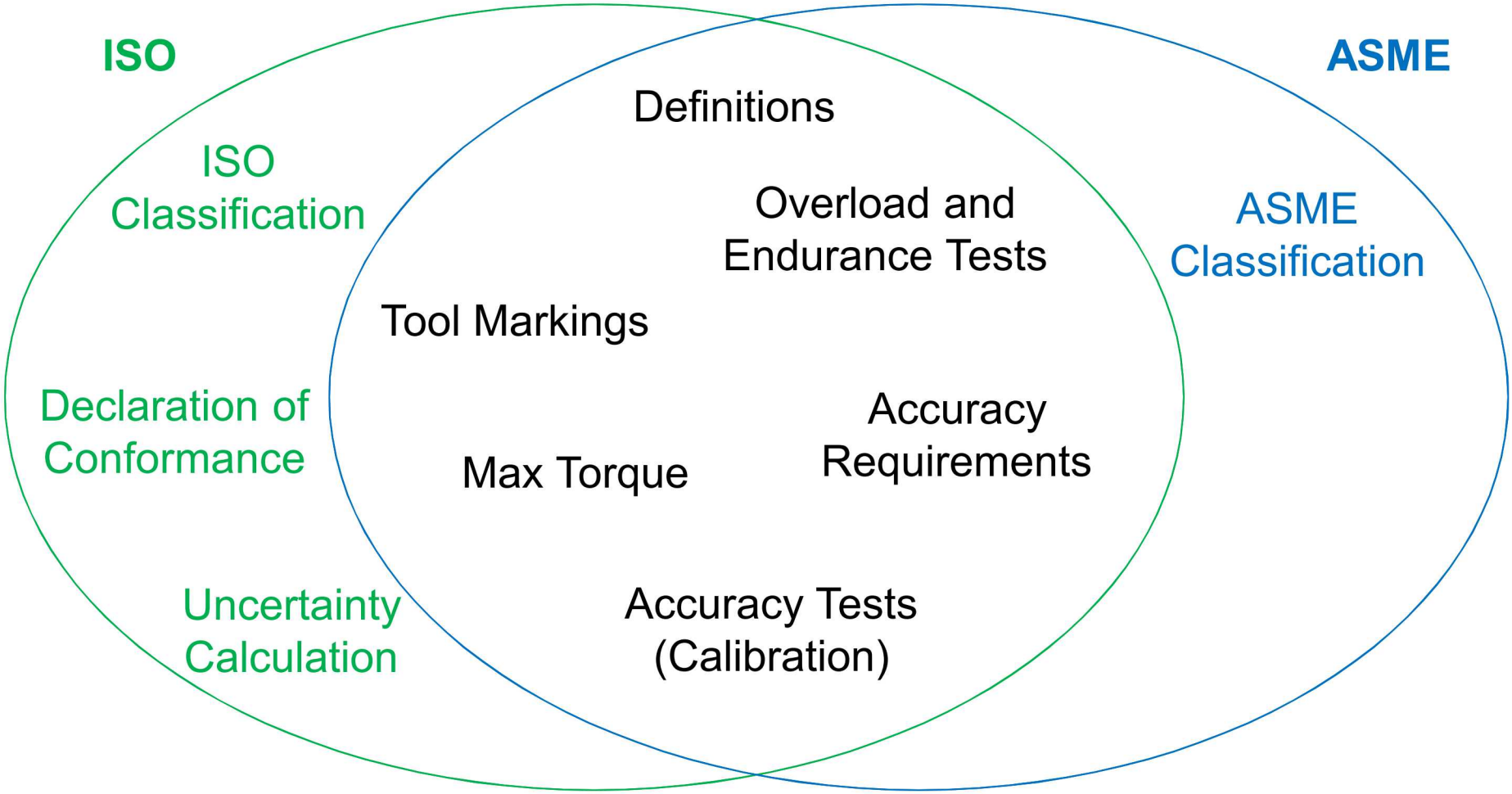




±4%

±6%

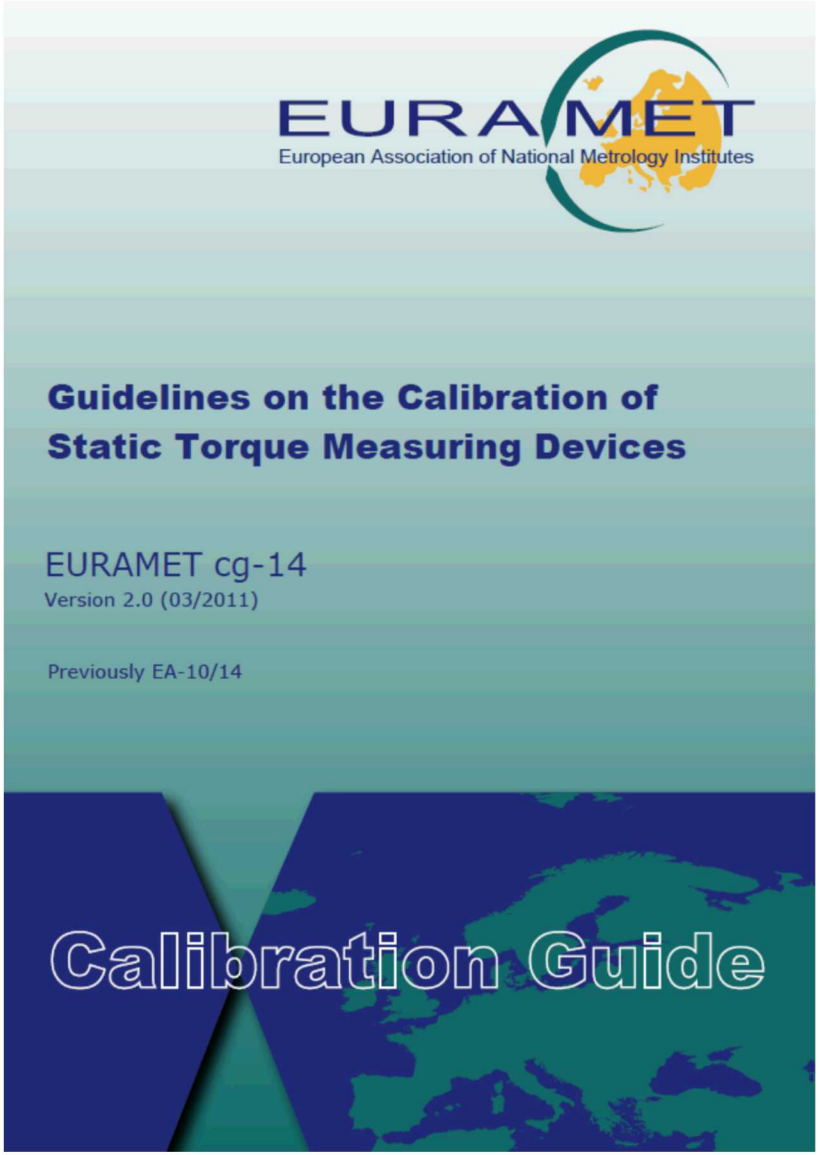


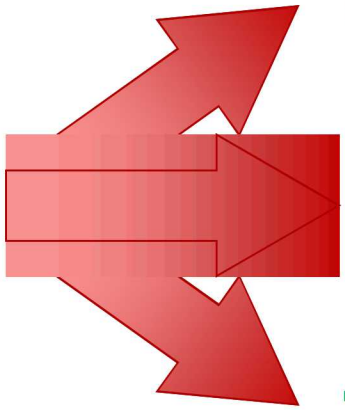
# ISO 6789 Parts 1 and 2 (2017)




**COMPARISON OF SCOPE**

# EURAMET cg-14



**Calibration**

**Uncertainty**

**Torque-specific Certificate Requirements**

Sandia National Laboratories

# DEVELOPING CALIBRATION PROCEDURES

# Step 1: Calibration Specifications

Sandia National Laboratories

**TORQUE SYSTEM ACCURACY:**

When TSD Transducer (s) are connected to and calibrated with approved Torque Transducer Calibration Systems and procedures, the minimum expected accuracy is +/- 1 division or count from 0 to 10% of the Transducer range and 0.1% IV (of indicated value) from 10% thru 100% of the Transducer Range. Each TSD Transducer has a minimum of 10,000 divisions or counts with full 12,000 and 16,000 count conversions.

**A.K.O. Inc.**

# Calibration Data Sheet

## Torque Instrument Calibration Data Sheet

*Example for NCSLI Technical Exchange, February 2018*

**Unit Under Test**

Manufacturer:
Model:
Serial Number:
Other Identifiers:
Condition, as received:
ASME Tool Classification:
Maximum Graduated Value:
Units:

Accuracy over 20 % to 100% of Rated Capacity

CW: % IV
CCW: % IV

**Calibration System**

Manufacturer:
Model:
Serial Number:
ASME Classification:

Transducers Used, Low to High Torque

| | | | |
|---|---|---|---|
| Manufacturer: | | | |
| Model: | | | |
| Serial Number: | | | |
| Calibration Date: | | | |
| Upper Range of Use: | | | |
| Units: | | | |
| Accuracy over Range of Use (% IV): | | | |
| Worst T.U.R. (CW and CCW): | | | |

**Test Conditions**

Date:
Procedure Used: ASME B107.300-2010 (B107.14)
Lab Temperature: °F
Lab Humidity: %RH

*CW = clockwise*
*CCW = counterclockwise*
*IV = indicated value*
*MIC = maximum instrument capacity*

*Tol. = tolerance*
*T.U.R. = test uncertainty ratio ( > 4:1 required)*
*%RH = percent relative humidity*

*This data sheet was prepared by Andrew Mackrory (Sandia National Laboratories) for instructional use only at the NCSLI Technical Exchange, February 2018. The author, Sandia National Laboratories, and NCSLI accept no liability for the use of this data sheet. It is the responsibility of class participants to check the data sheet for accuracy and conformance to applicable standards.*



**Calibration Process and Data - As Found**

Tool set to Maximum Graduated Value and operated 3 times in calibration direction (CW or CCW).
Tool set to Minimum Graduated Value and then set to first test point.
All setting adjustments are made by approaching target test value from below.
Tool operated 3 times at each test point before recording data.
Torque immediately removed from tool after taking a reading.

| Torque Setting - CW | Tol. Limits | | | Readings, | | | Max Deviation | |
|---|---|---|---|---|---|---|---|---|
| % of MIC | 0 | 0 | 0 | 4 | 5 | 6 | % of Tolerance | RESULT |
| 20% | 0 | 0 | 0 | | | | | |
| 60% | 0 | 0 | 0 | | | | | |
| 100% | 0 | 0 | 0 | | | | | |

| Torque Setting - CCW | Tol. Limits | | | Readings, | | | Max Deviation | |
|---|---|---|---|---|---|---|---|---|
| % of MIC | 0 | 0 | 0 | 4 | 5 | 6 | % of Tolerance | RESULT |
| 20% | 0 | 0 | 0 | | | | | |
| 60% | 0 | 0 | 0 | | | | | |
| 100% | 0 | 0 | 0 | | | | | |

**Adjustments Made:** No

**Calibration Data - As Left**

| Torque Setting - CW | Tol. Limits | | | Readings, | | | Max Deviation | |
|---|---|---|---|---|---|---|---|---|
| % of MIC | 0 | 0 | 0 | 4 | 5 | 6 | % of Tolerance | RESULT |
| 20% | 0 | 0 | 0 | | | | | |
| 60% | 0 | 0 | 0 | | | | | |
| 100% | 0 | 0 | 0 | | | | | |

| Torque Setting - CCW | Tol. Limits | | | Readings, | | | Max Deviation | |
|---|---|---|---|---|---|---|---|---|
| % of MIC | 0 | 0 | 0 | 4 | 5 | 6 | % of Tolerance | RESULT |
| 20% | 0 | 0 | 0 | | | | | |
| 60% | 0 | 0 | 0 | | | | | |
| 100% | 0 | 0 | 0 | | | | | |

**Condition, as left:**

**Notes:**
*(exclusions/additions/deviations)*

**Metrologist:**

*Unit Under Test (Make/Model/Serial):* / /

# Calibration Data Sheet

## Torque Instrument Calibration Data Sheet

*Example for NCSLI Technical Exchange, February 2018*

**Unit Under Test**

| | |
|---|---|
| Manufacturer: | Craftsman |
| Model: | unknown |
| Serial Number: | 4051182296 |
| Other Identifiers: | N/A |
| Condition, as received: | Set to 25 ft lb, graduation markings on handle nearly rubbed off, handle graduations do not line up with scale. |
| ASME Tool Classification: | Type II (Setting), Class A (graduated), Style 2 (ratcheting) |
| Maximum Graduated Value: | 75 |
| Units: | ft-lb |

Accuracy over 20 % to 100% of Rated Capacity

| | | |
|---|---|---|
| CW: | 4% | % IV |
| CCW: | 6% | % IV |

**Calibration System**

| | |
|---|---|
| Manufacturer: | AKO, Inc. |
| Model: | TSD 650-P |
| Serial Number: | 1138 |
| ASME Classification: | Type II (Hand actuated), Class A (0.25% accuracy) |

Transducers Used, Low to High Torque

| | | | |
|---|---|---|---|
| Manufacturer: | AKO, Inc. | AKO, Inc. | |
| Model: | TSD 821 | TSD 821 | |
| Serial Number: | 6272 | 6272 | |
| Calibration Date: | 22-Jan-2018 | 22-Jan-2018 | |
| Upper Range of Use: | 30 | 300 | |
| Units: | ft-lb | ft-lb | |
| Accuracy over Range of Use (% IV): | 0.13% | 0.10% | |
| Worst T.U.R. (CW and CCW): | 30.8:1 | 40:1 | |

**Test Conditions**

| | | |
|---|---|---|
| Date: | 9-Feb-2018 | |
| Procedure Used: | ASME B107.300-2010 (B107.14) | |
| Lab Temperature: | 72 | °F |
| Lab Humidity: | 40 | %RH |

*CW = clockwise*
*CCW = counterclockwise*
*IV = indicated value*
*MIC = maximum instrument capacity*

*Tol. = tolerance*
*T.U.R. = test uncertainty ratio ( > 4:1 required)*
*%RH = percent relative humidity*

*This data sheet was prepared by Andrew Mackrory (Sandia National Laboratories) for instructional use only at the NCSLI Technical Exchange, February 2018. The author, Sandia National Laboratories, and NCSLI accept no liability for the use of this data sheet. It is the responsibility of class participants to check the data sheet for accuracy and conformance to applicable standards.*



**Calibration Process and Data - As Found**

Tool set to Maximum Graduated Value and operated 3 times in calibration direction (CW or CCW).
Tool set to Minimum Graduated Value and then set to first test point.
All setting adjustments are made by approaching target test value from below.
Tool operated 3 times at each test point before recording data.
Torque immediately removed from tool after taking a reading.

| Torque Setting - CW | | Tol. Limits | | Readings, ft-lb | | | Max Deviation | |
|---|---|---|---|---|---|---|---|---|
| % of MIC | ft-lb | ft-lb | ft-lb | 4 | 5 | 6 | % of Tolerance | RESULT |
| 20% | 15 | 14.4 | 15.6 | 14.88 | 14.76 | 14.74 | 43% | PASS |
| 60% | 45 | 43.2 | 46.8 | 44.88 | 44.78 | 44.78 | 12% | PASS |
| 100% | 75 | 72 | 78 | 75.74 | 76.04 | 75.78 | 35% | PASS |

| Torque Setting - CCW | | Tol. Limits | | Readings, ft-lb | | | Max Deviation | |
|---|---|---|---|---|---|---|---|---|
| % of MIC | ft-lb | ft-lb | ft-lb | 4 | 5 | 6 | % of Tolerance | RESULT |
| 20% | 15 | 14.1 | 15.9 | 15.82 | 15.64 | 15.74 | 91% | PASS |
| 60% | 45 | 42.3 | 47.7 | 46.66 | 46.4 | 46.46 | 61% | PASS |
| 100% | 75 | 70.5 | 79.5 | 77.9 | 77.8 | 77.84 | 64% | PASS |

**Adjustments Made:** No

**Calibration Data - As Left**

| Torque Setting - CW | | Tol. Limits | | Readings, ft-lb | | | Max Deviation | |
|---|---|---|---|---|---|---|---|---|
| % of MIC | ft-lb | ft-lb | ft-lb | 4 | 5 | 6 | % of Tolerance | RESULT |
| 20% | 15 | 14.4 | 15.6 | N/A | N/A | N/A | | |
| 60% | 45 | 43.2 | 46.8 | N/A | N/A | N/A | | |
| 100% | 75 | 72 | 78 | N/A | N/A | N/A | | |

| Torque Setting - CCW | | Tol. Limits | | Readings, ft-lb | | | Max Deviation | |
|---|---|---|---|---|---|---|---|---|
| % of MIC | ft-lb | ft-lb | ft-lb | 4 | 5 | 6 | % of Tolerance | RESULT |
| 20% | 15 | 14.1 | 15.9 | N/A | N/A | N/A | | |
| 60% | 45 | 42.3 | 47.7 | N/A | N/A | N/A | | |
| 100% | 75 | 70.5 | 79.5 | N/A | N/A | N/A | | |

**Condition, as left:** Set to 10 ft-lb (minimum graduated value)

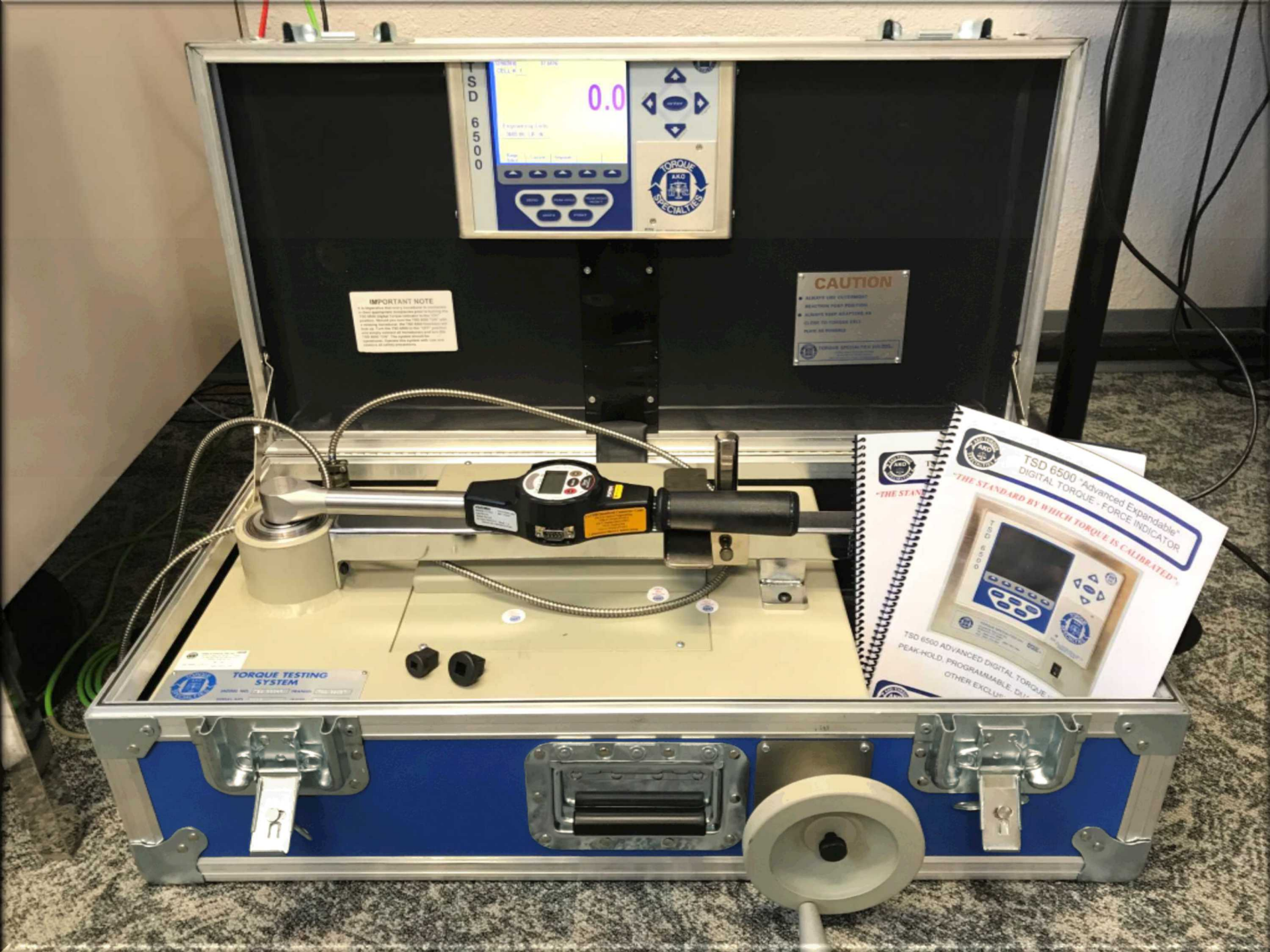
**Notes:** MIC taken from foot-pounds scale, which has slightly lower range than Nm scale. Wrench not adjusted per customer request.
*(exclusions/additions/deviations)*

**Metrologist:** Andrew Mackrory 9-Feb-2018

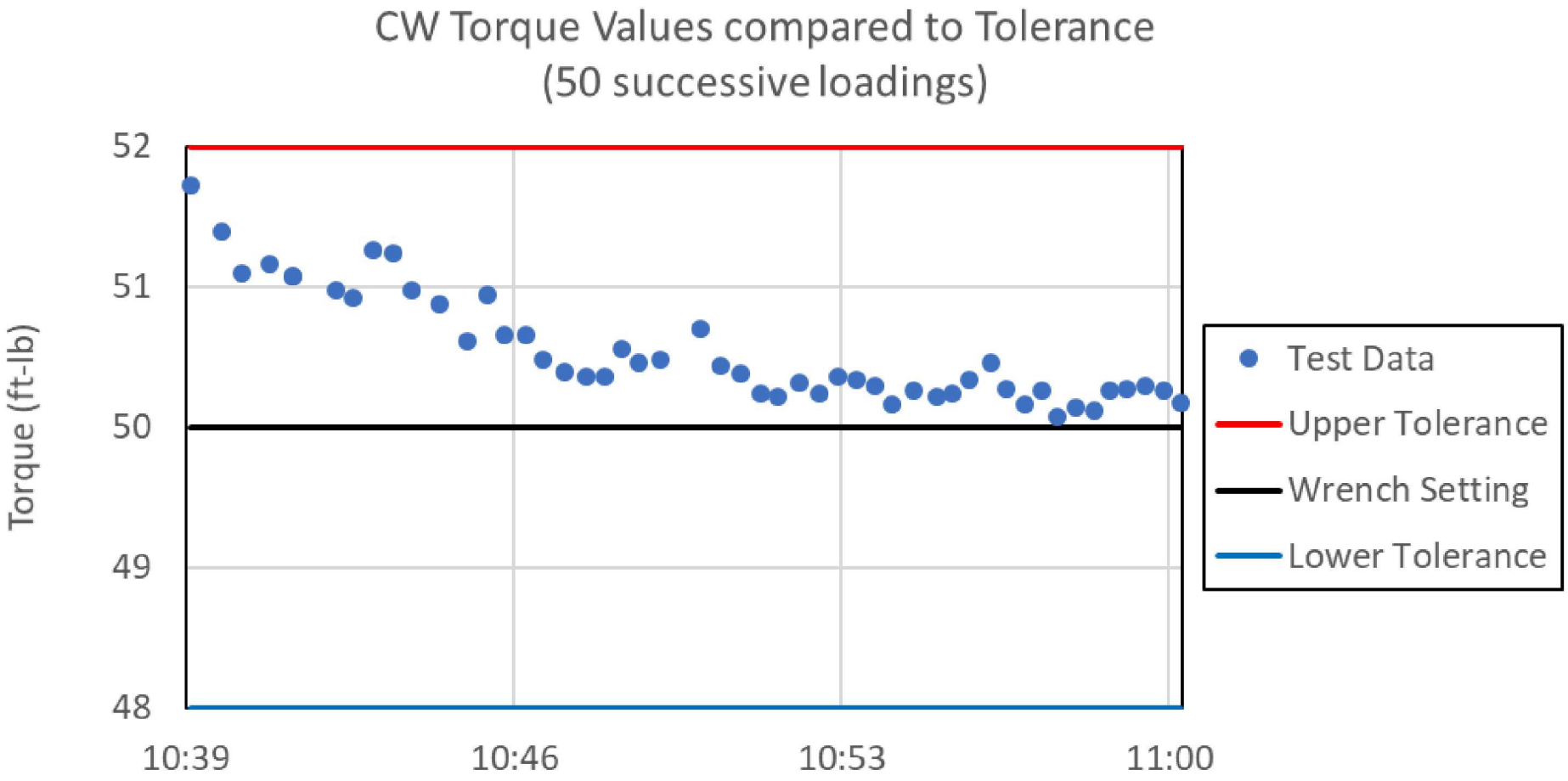
*Unit Under Test (Make/Model/Serial):* Craftsman / unknown / 4051182296

Sandia National Laboratories

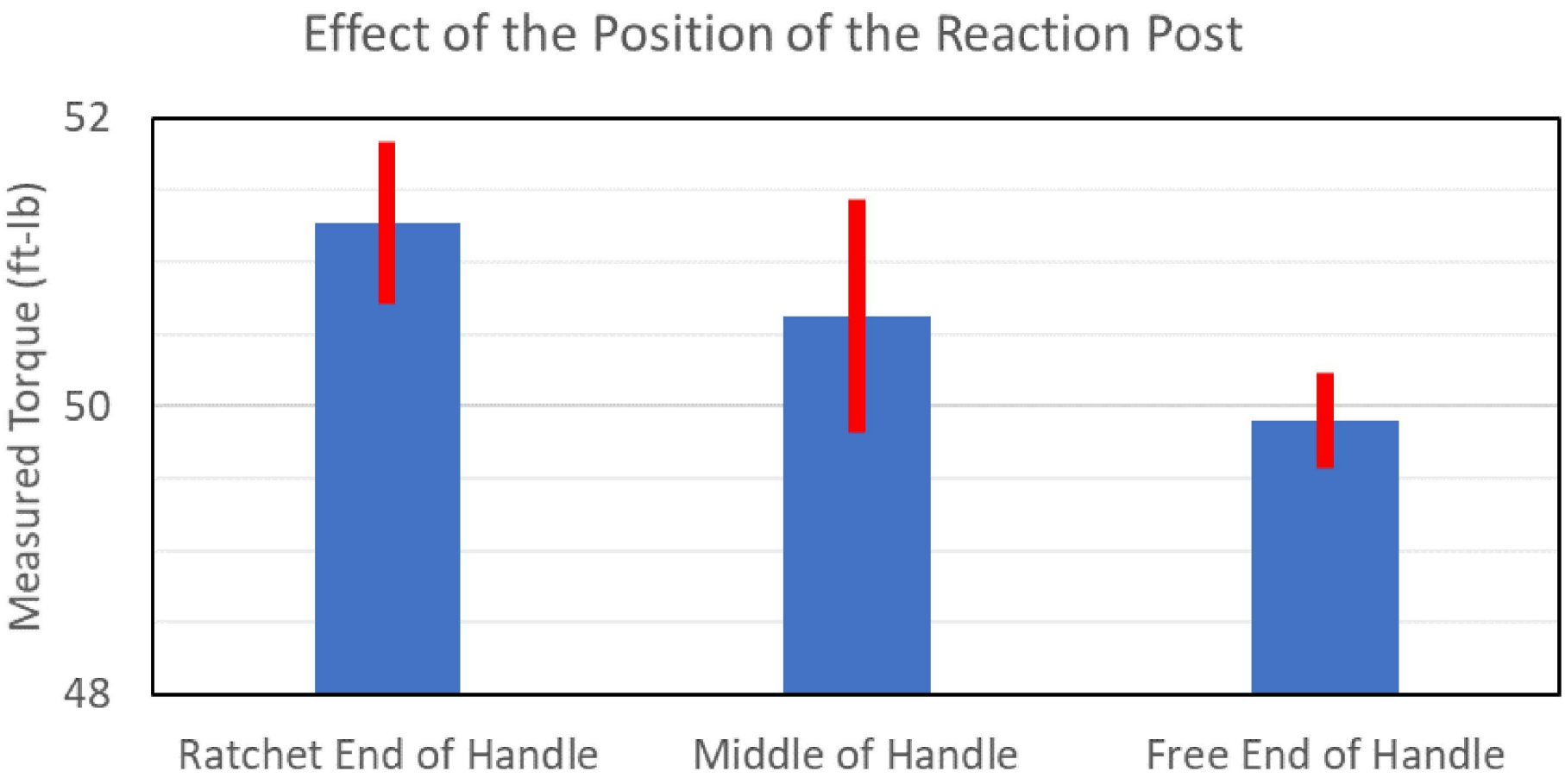
# HANDS-ON CALIBRATION


TSD 6500
0.0
TORQUE SPECIALTIES
IMPORTANT NOTE
CAUTION
TORQUE TESTING SYSTEM
TSD 6500 "Advanced Expandable"
DIGITAL TORQUE - FORCE INDICATOR
"THE STANDARD BY WHICH TORQUE IS CALIBRATED"

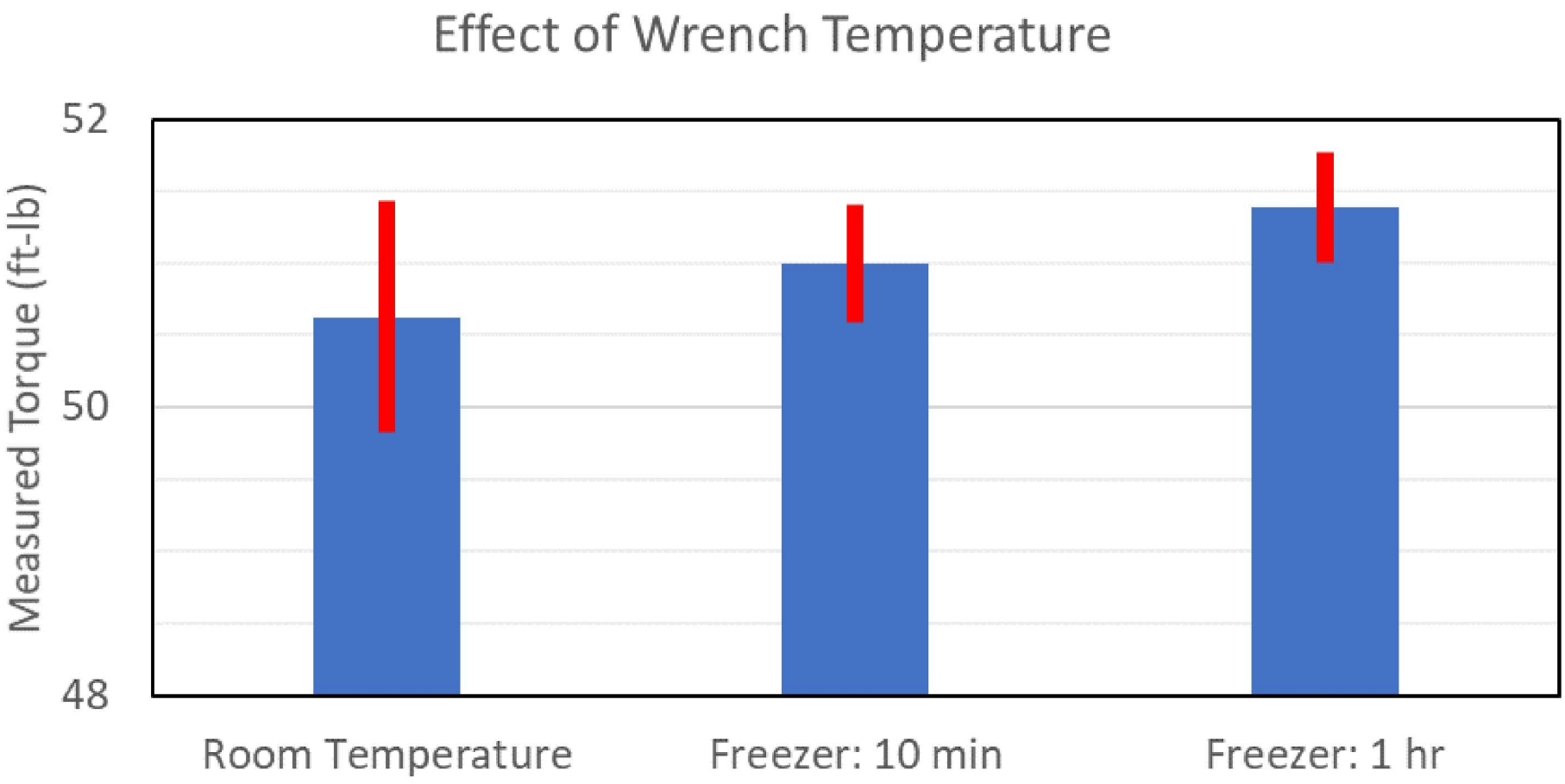
# Why Exercise a Wrench?



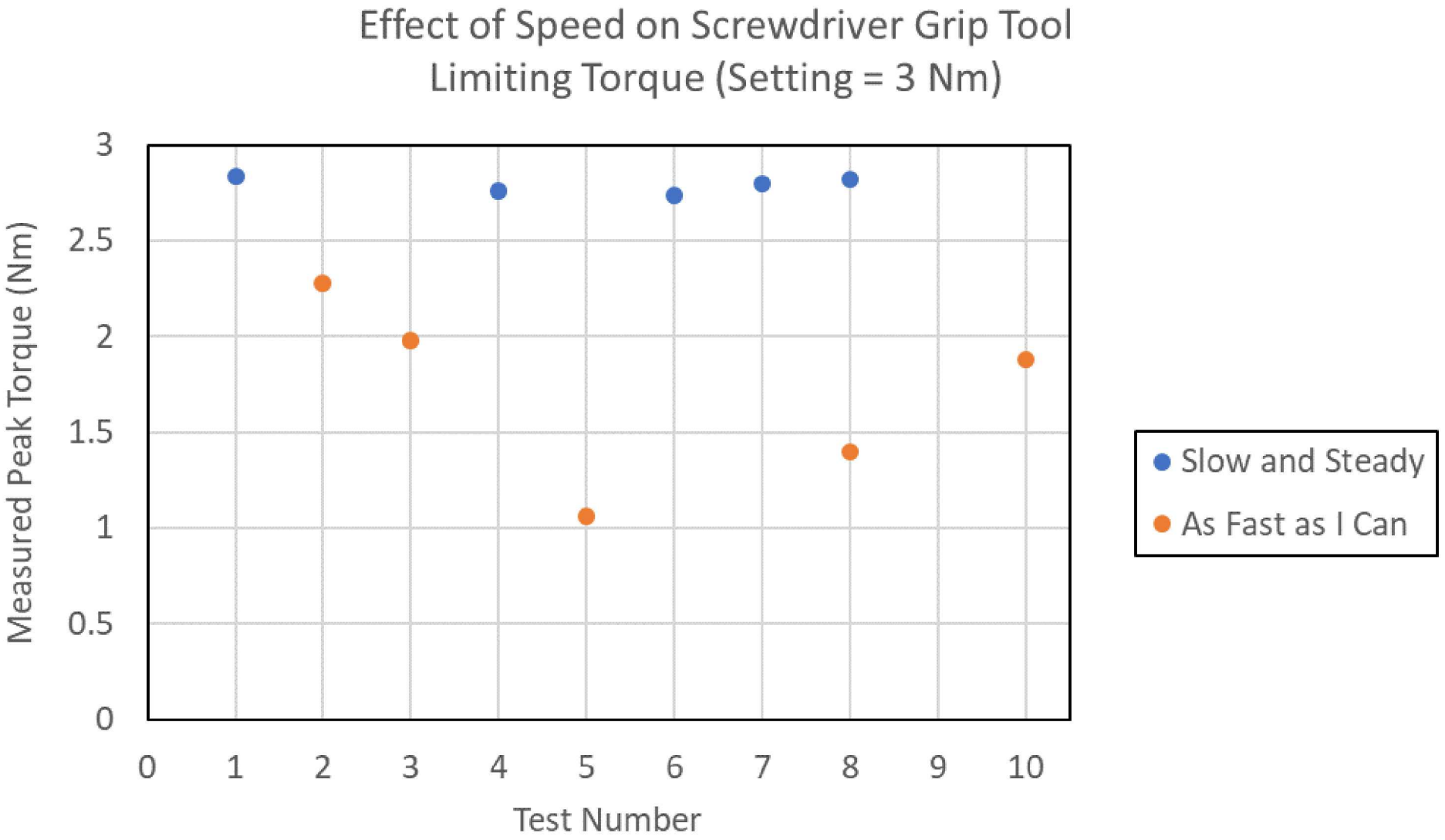
# Middle of the Handle



# Temperature



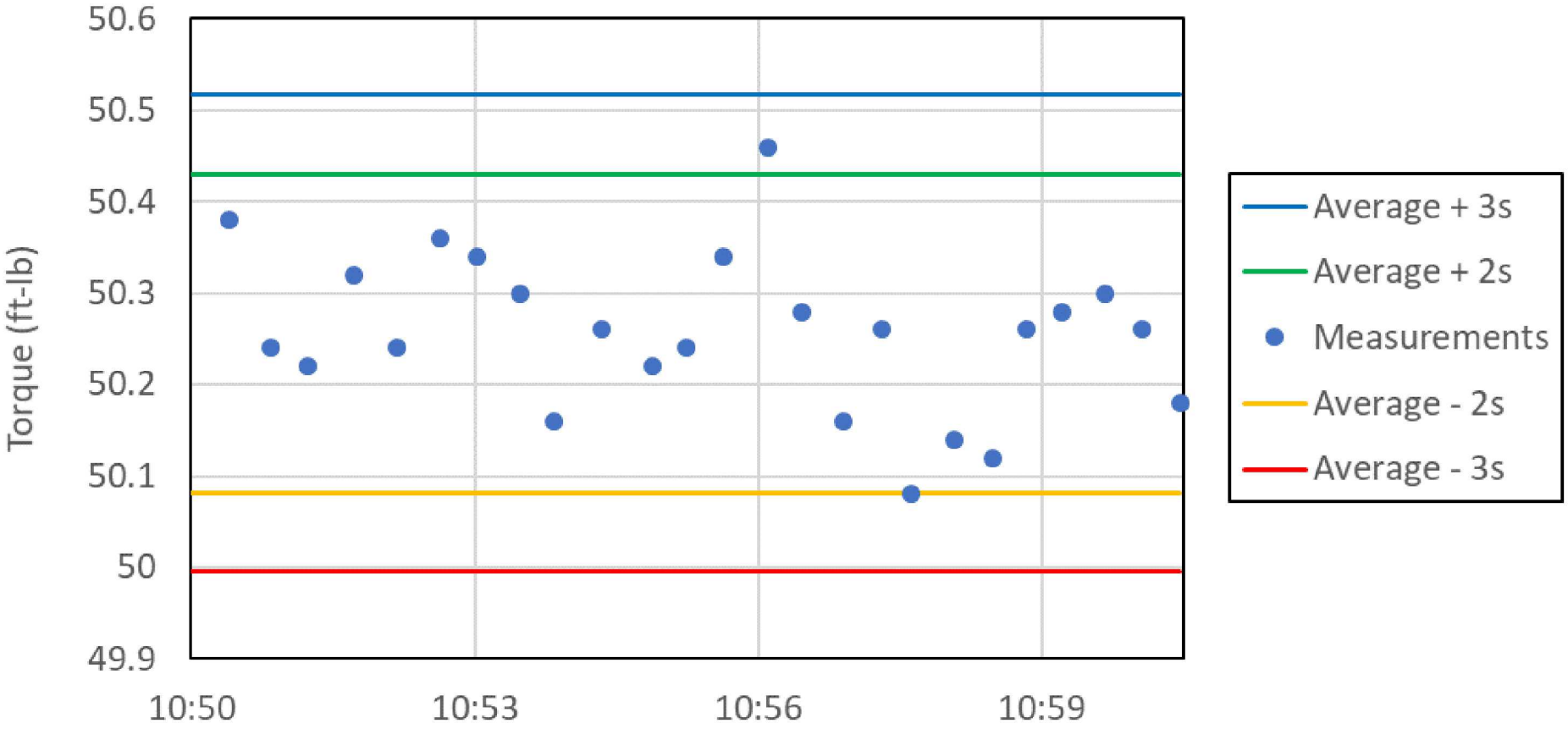
# Speed of Torque Application



Sandia National Laboratories

# ADJUSTMENT

# Don’t chase your tail…



Sandia National Laboratories

# DATA ANALYSIS: PASS OR FAIL?

# Pass or Fail?

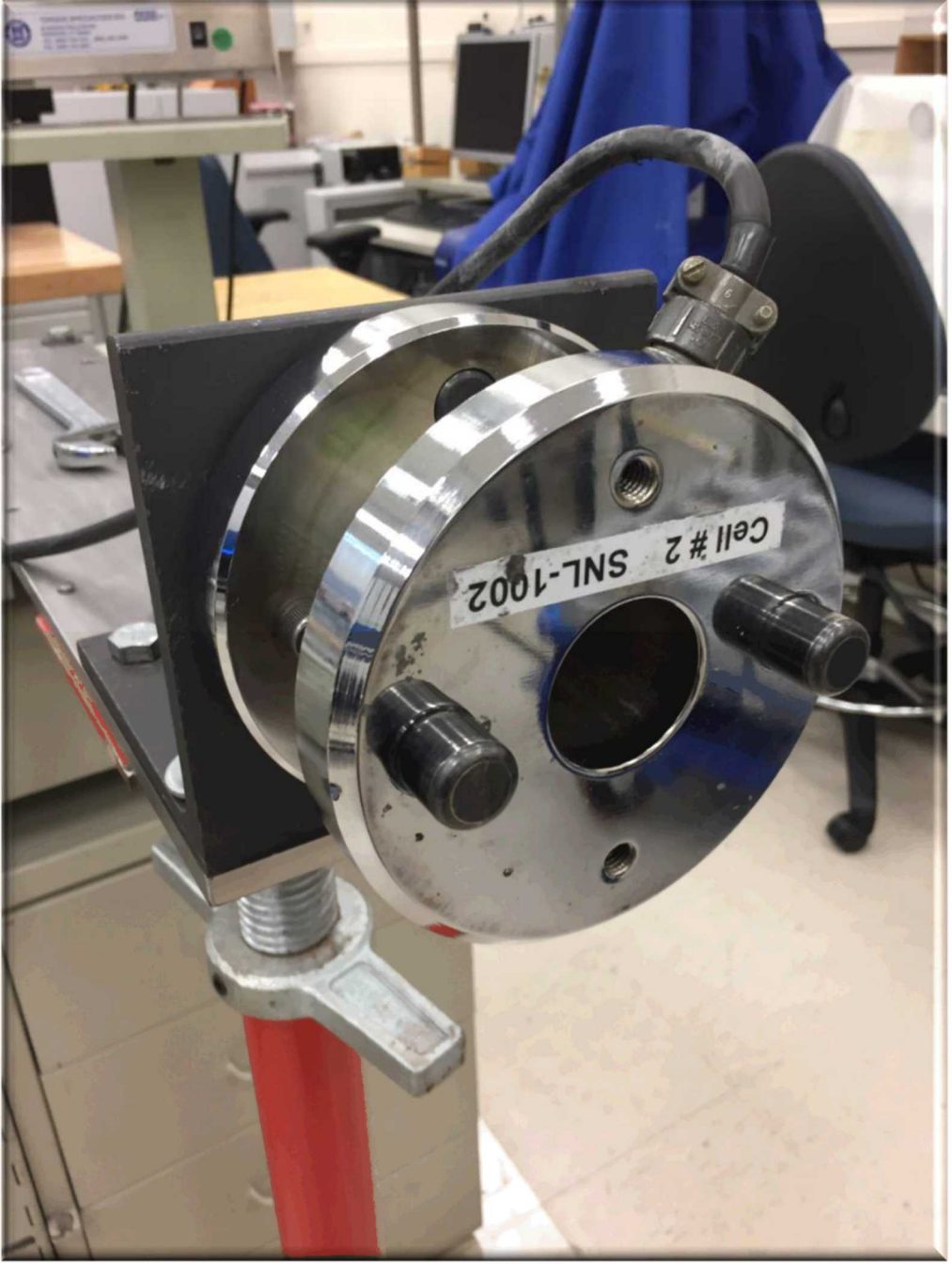
Sandia National Laboratories

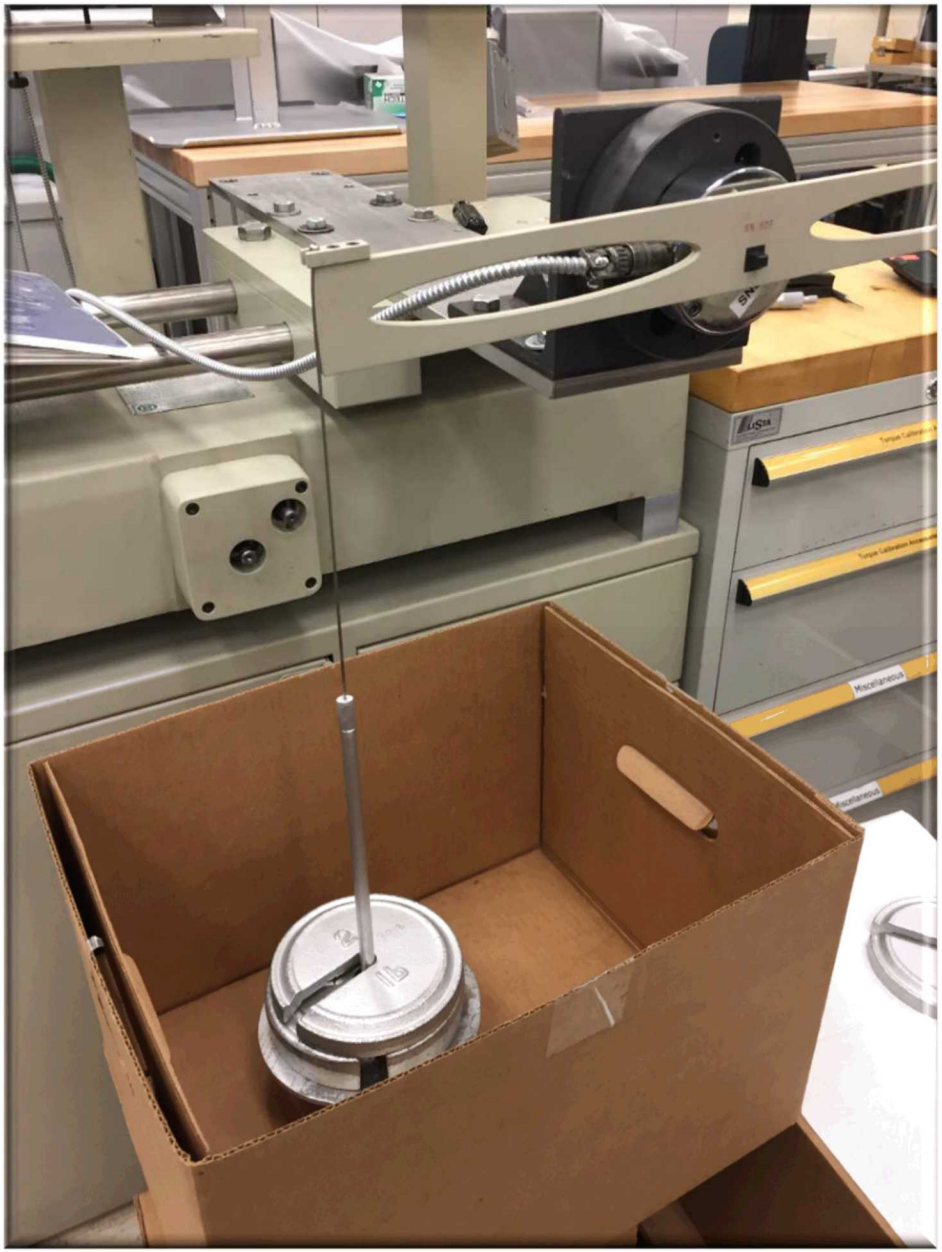
**For a Type II, Class A, Style 1 Wrench, determine the result of calibration:**

| Wrench Setting (lbf-ft) | Measured Torque (lbf-ft) | Determine PASS/FAIL |
|---|---|---|
| 100 | 103.6 | |
| 100 | 95.7 | |
| 60 | 62.8 | |

Sandia National Laboratories

# CALIBRATION OF TORQUE TESTERS


Cell # 2 SNL-1002




81.19
CDI TORQUE
25 - 250 IN.LB.

Sandia National Laboratories

# MEASUREMENT UNCERTAINTY FOR TORQUE WRENCH CALIBRATION

# Sources of Uncertainty

# What Does the Customer Need?

# Gage R&R

3×

# Uncertainty Budget

| Quantity | evaluation of standard uncertainty | standard uncertainty in N·m | relative standard uncertainty in % |
|---|---|---|---|
| Repeatability in unchanged mounting position $b'$ | type A | $u_{b'} = \frac{b'}{s\sqrt{2}}$ | $w_{b'} = \frac{b'}{\sqrt{2}} \cdot \frac{100}{\overline{X}}$ |
| Reproducibility in different mounting positions $b$ | type A | $u_b = \frac{b}{s\sqrt{n}}$ | $w_b = \frac{b}{\sqrt{n}} \cdot \frac{100}{\overline{X}}$ |
| Deviation resulting from fitting curve $f_a$ | type B with triangular distribution | $u_{fa} = \frac{\lvert f_a \rvert}{s\sqrt{6}}$ | $w_{fa} = \frac{\lvert f_a \rvert}{\sqrt{6}} \cdot \frac{100}{X_a}$ |
| Resolution $r$ | type B with rectangular distribution | $u_r = \frac{r}{\sqrt{12}}$ | $w_r = \frac{r}{\sqrt{12}} \cdot \frac{100}{M_k}$ |
| Reference torque | type B | $u_{tcm}$ | $w_{tcm}$ |

# Uncertainty Statement

The single biggest problem in communication is the illusion that it has taken place

- George Bernard Shaw

Sandia National Laboratories

# SETTING A CALIBRATION INTERVAL

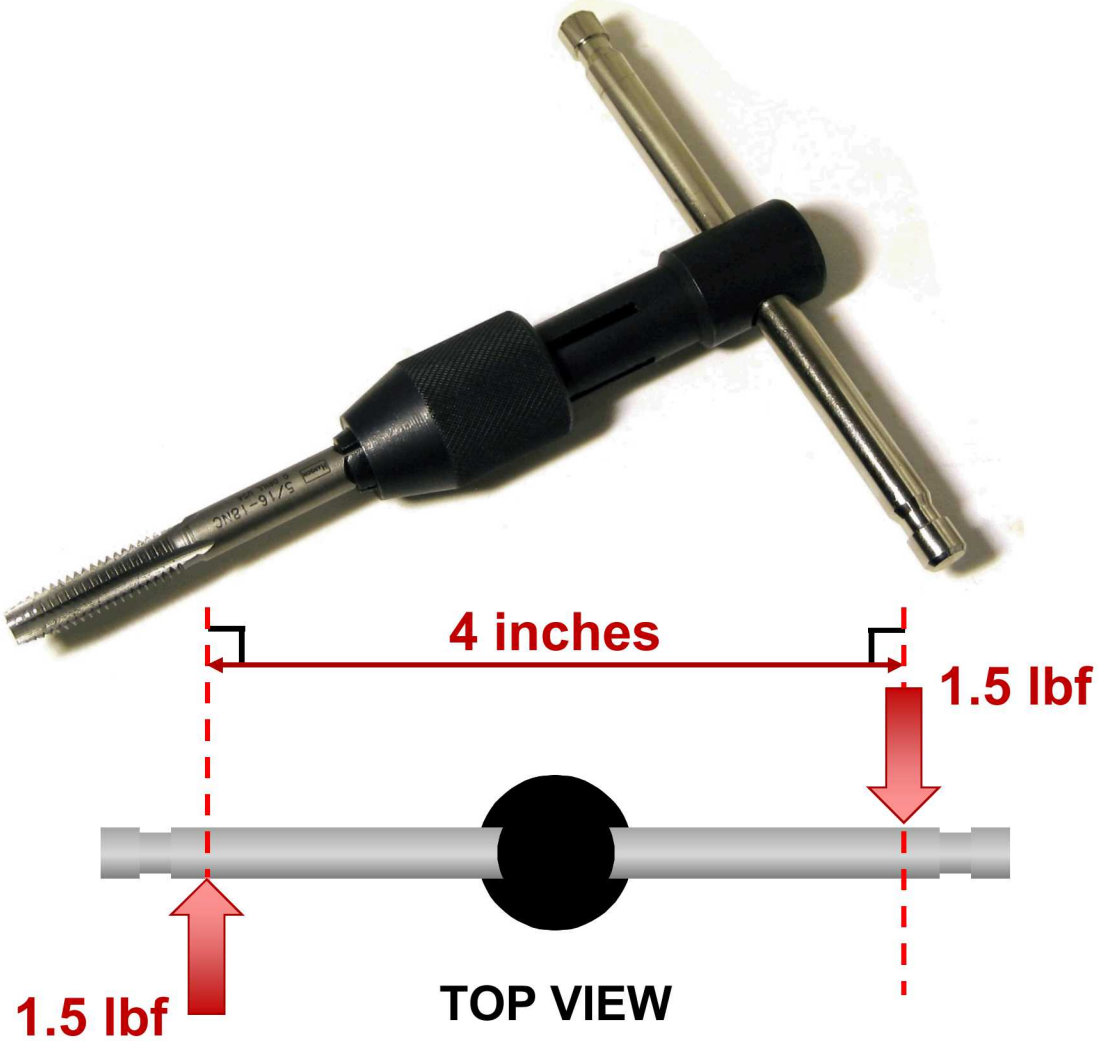
# Calibration Intervals

Sandia National Laboratories

# THE ANSWERS IN THE BACK

# Pure Torque

## Tap Wrench: Designed for **pure torque**




Calculating the torque on the tap:

1. Select the center of tap as the axis

2. 1.5 lbf × 2 in = +3 lbf-in
3. 1.5 lbf × 2 in = +3 lbf-in
4. Total: +6 lbf-in

# Pass or Fail?

Sandia National Laboratories

**For a Type II, Class A, Style 1 Wrench, determine the result of calibration:**

| Wrench Setting (lbf-ft) | Measured Torque (lbf-ft) | Determine PASS/FAIL |
|---|---|---|
| 100 | 103.6 | PASS |
| 100 | 95.7 | FAIL |
| 60 | 62.8 | FAIL |

Sandia National Laboratories

# GUARD BANDING

# T.U.R. and Guard Banding

- You need to calibrate something to ±1% of reading, your calibration system uncertainty is ±0.4% of reading
- Calculate the T.U.R.

$$T.U.R. = \frac{U_{certification}}{U_{cal.process}}$$

$$T.U.R. = \frac{1}{0.4} = 2.5$$

**1.5:1 < T.U.R. < 4:1**

**→ apply guard banding**

# T.U.R. and Guard Banding

- The guard banding equation to give new limits for acceptance:

$$Adjusted\ Limit = \sqrt{1 - \frac{1}{T.U.R.^2}} \times Limit$$

- Calculate the limits for acceptance for the example on the last slide:

$$Adjusted\ Limit = \sqrt{1 - \frac{1}{2.5^2}} \times \text{1\% of reading}$$

$$Adjusted\ Limit = \underline{\quad 0.91 \quad}\ \%\ \text{of reading}$$

# T.U.R. and Guard Banding

$$Adjusted\ Limit = \underline{\quad 0.91 \quad}\ \%\ \text{of reading}$$

| Item Setpoint (units) | Measured Value (units) | Allowable Deviation (units) | Determine PASS/FAIL |
|---|---|---|---|
| 100 | 101 | 0.91 | FAIL |
| 100 | 99.2 | 0.91 | PASS |
| 50 | 50.5 | 0.455 | FAIL |
| 50 | 50.4 | 0.455 | PASS |