This following is of consideration for this comment only ballot:

The purpose of having a recommended practice for field verification of surface rotary torque measurements is to improve consistency and comparing of results.

This recommended practice **will not** address the accuracy required. Accuracy required should be per customer and their application. Accuracy should be part of contract terms (work order).

For consistency, the recommended practice should have a consistent method for calculating accuracy.

This recommended practice **will not** address the calibration and/or how to correct an accuracy issue. There can be many reasons why the accuracy is off. This recommended practice will not document all the potential issues and the respective corrective actions (which could include calibration).

Rely on our contractors/vendors with their expertise (OEM guides) for corrective actions. However, this recommended practice can be executed after the corrective action to check if the corrective action resolves customer’s accuracy requirement.

This recommended practice **will not** address the frequency or trigger events for field verification. There is still more data and learnings to help determine frequency and/or trigger events. Also, these may be different per system, etc.

**Surface Applied Rotary Torque Field Verification for Oil and Gas Well Drilling Operations**

**API RECOMMEND PRACTICE XX**

**XX EDITION, MONTH YEAR**
1. Scope

1.1. Coverage

The critical sensors on the drilling rig provide a picture of how the rig and the well are acting so that the appropriate measures can be taken to manage well control and operations. Using sensors that are out of application accuracy requirements may lead to inaccurate assessments of and actions to well control and operations.

The purpose of this document is to recommend practices and procedures for field verifying critical sensors (for surface applied rotary torque for drilling and not make up torque) in drilling operations to improve consistency. The practices/procedures may need to be adjusted as testing considerations for current and future surface applied rotary torque devices are further identified/understood. This document can serve as a starting point to further build specific device process/procedures.

Accuracy requirements are not defined in the recommended practice. See Section 1.3 Responsibility.

1.2. Applicability

These recommendations apply to rotary drilling rigs.

1.3. Responsibility

Responsibilities shall be defined as per the work contract. Communication, discussion, and agreement of data requirements during the contract phase is critical to ensure alignment on responsibilities.

During the contract phase, accuracy requirements are jointly agreed upon by the operator and drilling contractor based on the application needs (safety and performance) including on a risk basis.

- During the work phase, the accuracy results from field verification are compared against jointly agreed upon application accuracy requirements to determine path forwards. IADC Guidelines for Data Stewardship [1] and IADC Guidelines for Sensor Stewardship [2] may be consulted for further information on path forwards for data issues.

2. Normative Reference

The following referenced documents are indispensable for the application of this recommended practice. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced standard applies (including any addenda/errata).

API¹

Spec Q2  Quality Management Systems for Service Supply Organizations for the Petroleum and Natural Gas Industry

¹ American National Standards Institute, 11 West 42nd Street, New York, New York 10036
3. Terms, Definitions, and Abbreviations

3.1. Terms and Definitions

For the purpose of this document, the following terms and definitions apply.

3.1.1. accuracy
The degree to which the result of a measurement (observed value) conforms to the true value (correct value or standard)

3.1.2. drill pipe
Any tubular, shaft, or other device used to rotate the drill bit and circulate drilling fluid

3.1.3. drill string (work string)
Several sections or joints of drill pipe or tubing joined together for use in a wellbore.

3.1.4. driller
The person responsible for the operation of the drilling and hoisting equipment of the rig under normal conditions.

3.1.5. drilling contractor
The party that is responsible for the operation of the drilling unit for drilling of a well, wellbore, or section thereof

3.1.6. hysteresis
The phenomenon in which a value of a physical property lags behind changes in the effect causing it

3.1.7. levelness
The state of being level (horizontal plane which is perpendicular or normal to the local gravitational field).

3.1.8. location (well site or worksite)
The place where drilling is occurring.

3.1.9. Operator or operator representative
The party that is legally responsible for the construction of a well, wellbore, or section thereof.

3.1.10. qualified person/personnel
A person(s) who, by possession of a recognized degree, certificate, or professional standing, or who by knowledge, training, or experience, can successfully demonstrate the ability to solve or resolve problems relating to the subject matter or the work.
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3.1.11.  supervisor
Person who has been given the control, direction, or supervision of work performed by one or more personnel.

NOTE Supervisors may be referred to as rig operators, operators, drillers, rig managers, company representative, and others depending on job and area.

3.1.12.  red zone
Marked safety zones where access is limited during operations.

3.1.13.  surface applied rotary device
Device on a drilling rig that applies torque to the drill string. The torque is applied on surface. Examples are top drives and kelly drives.

3.1.14.  quill
A coupling to/through which the drill string is connected to the surface applied rotary device.

A kelly drive does not have a quill. The kelly connects to the drill string via rotary shouldered connections on the kelly (and possibly valves and/or saver subs).

3.2.  Abbreviations

HPU  Hydraulic Power Unit
OEM  original equipment manufacturer
QMS  quality management system
RPM  revolutions per minute
SCR  silicon control rectifier
USC  United States Customary System of units
VFD  variable frequency drive
V\text{full scale}  full scale value
V\text{true}  true value
V\text{observed}  observed value
\% RD  accuracy as percentage of reading
\% FS  accuracy as percentage of full scale
4. Torque Equations

The accuracy of torque is based on the components (measurements or object properties) that are used to calculate it, so the accuracy of these components should be considered per the QMS.

1) force,
2) distance,
   or
3) time,
4) angular velocity,
5) moment of inertia

4.1. Torque Equation #1

Torque (T) is defined as:

\[ T = F \times d \]

Where:

- \( F \) = Force applied
- \( d \) = Perpendicular distance of force from the axis of rotation

4.2. Torque Equation #2

Torque (T) is defined as:

\[ T = \frac{dL}{dt} \]

Where:

- \( L \) = angular momentum = \( l\omega \)
- \( \omega \) = angular velocity
- \( l \) = moment of inertia
- \( t \) = time
5. **Safety**

1) Equipment/system rating(s) should not be exceeded.
2) Ensure equipment and test equipment are in proper working conditions. Repair or replace, as necessary.
   - Ensure rig maintenance is up to date per equipment owner’s preventative maintenance program (quality management system) for a properly functioning and performing rig.
   - Ensure that all threaded connections (if any) conform to QMS requirements.
   - Ensure that all ropes, chains, tongs, pad eye, or other force transmission equipment are in proper working order and have been inspected according to QMS and safety requirements.
   - Ensure that any anchor points are rated for the anticipated applied loads plus an appropriate safety factor.
3) During execution of field verification tests, be aware of red zones. Minimize unnecessary personnel in the working area.
4) Ensure all necessary permits are acquired for respective work.

6. **Influences on torque readings**

The following are some (but not all) items that may affect torque readings.

- **Operating Conditions/Loads**
  - Operating temperatures
  - Operating angular velocities (RPM)
  - Operating angular acceleration
- **Corrections**
  - For Top Drives without direct torque control, torque correction may be required based on torque RPM.
  - Temperature and environmental effects
  - Moment arm corrections due to horizontal and vertical angle deviations (see Appendix E)
- **Electrical**
  - Frays, scars, cuts, kinks or other damage to cables that are part of the instrumentation/data aggregation system
  - Damaged junction boxes which allow water intrusion or other environmental elements in affecting wiring
  - Improper grounding that may include insufficient number of grounding points, incorrect locations, driven-depth or water saturation for earth grounds, or other factors that affect the system’s ability to have a proper ground potential.
  - Inadequate bonding of VFD, SCR, Generator, Pump, or other electrically connected skids
  - Induced electrical noise from: bad connection, improper insulation or isolation, colocation of high-voltage and low-voltage conductors or other factors.
- **Hydraulic**
  - (If applicable) Plugged HPU filter restricting flow of hydraulic fluid that could reasonably affect tool performance
- **Hysteresis**
  - For the system, consider potential hysteresis effects which may be caused by friction, viscous effects, and other damping whether mechanical or electrical.
7. Documentation Review

When verifying rig instrumentation, it is required to have calibrated testing tools. The readings from the calibrated testing tools provide the reference to compare against the readings from the rig instrumentation.

1) Review calibration/validation documents for testing tools: (frequency of testing tool calibration per contractor/OEM QMS)
   - Some examples of tools used for surface applied rotary torque verification
     i. Test tool 1: Load cell (if used)
     ii. Test tool 2: Strain gauge torque sub (if used)

During any calibration/validation procedure, its respective documentation includes information to uniquely and unambiguously identify machines, tools, and instruments to ensure the traceability and trustworthiness of the observations and measurements resulting from the calibration/validation process. Test tools should be traceable to a national standard, body, or lab as per API Q2 – Section 5.8 Control of Testing, Measuring, Monitoring, and Detection Equipment.

The following information will be recorded for each testing tool for traceability:
   - Sensor Type
   - Make
   - Model
   - Serial Number
   - Last Calibration Date
   - Manufacturers recommended calibration frequency
   - Next Calibration Due Date
   - Manufacturers Specified Accuracy
     - Accuracy Basis (Full Scale or Reading)
   - Application Specified Accuracy (per customer/contractor/OEM agreement – contract)
     - Accuracy Basis (Full Scale or Reading)

2) Review previous verification results for the rig instrumentation.
   - Surface applied rotary torque
8. Procedure - Surface Applied Rotary Torque Verification

Objective: To have a consistent field verification method for surface applied rotary torque.

Basic Principles:

Verification should be performed under conditions which are similar to those reasonably expected during well work activities. This includes (but is not limited to):

b. Operating torques (or from 20%-80% of device nominal range, whichever is greater)
c. Operating temperatures (both environmental and device generated heat)
d. Surface applied rotary torque verification tests noted in this Recommended Practice are static tests (the surface applied rotary device is not rotating). If rotating field verification tests are developed, the following conditions should also be considered.
   i. Operating angular velocities (RPM)
   ii. Operating angular acceleration

The following were considered for the development of the surface applied rotary torque verification procedures.

Effect on surface applied rotary torque verification

1) Geometry of inline load readings for calculation of reference torque readings can result in erroneous reference readings; therefore, guidance is provided on levelness and moment arm angle.

2) Surface applied rotary torque error may vary on the range of operating torque; therefore, multiple test torques are recommended from the minimum to maximum expected operating torque.

3) Surface applied rotary torque verification below residual friction in the drive (torque reported by the drive at 50 rpm with no load attached) will be inaccurate and is not advised. (For some surface applied rotary devices, this may be 500 to 600 ft-lb [700 to 800 N-m].) A minimum test torque of 3,000 ft-lb [4000 N-m] is noted as a parameter in determining torque test range.

4) Any system that controls or modifies any properties measured during testing should be turned off if possible. This includes auto-drillers, soft-torque systems or other devices that influence torque output.

Minimal to no effect on surface applied rotary torque verification

1) The surface applied rotary torque verification tests noted in this Recommended Practice are static tests (the surface applied rotary device is not rotating).
   a. In respect to hydraulic surface applied rotary devices, the results of these static surface applied rotary torque verification tests are not affected by cold oil temperatures; therefore, it is unnecessary to run the surface applied rotary device at typical operating RPM to ensure the surface applied rotary device is operating at a specified oil temperature (per OEM) for these surface applied rotary torque verification tests.

2) Ramp up/down rates to get to test torque has a fraction of a second effect prior to getting to stabilized static torque; therefore, ramp up/down rates are not specified.
8.1. Testing Tool – Load Cell

1) Personnel required for the job:
   • Company representative (if Operator, this can be Well site supervisor, third party inspector, or other designated person)
   • Driller

2) Test equipment required for the job (parties responsible for providing test equipment will need to be agreed upon beforehand):

<table>
<thead>
<tr>
<th>Observed Property</th>
<th>Suggested Device(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Force</td>
<td>Inline Load Cell</td>
</tr>
<tr>
<td>Angular Velocity</td>
<td>Device Onboard Rotary Encoder</td>
</tr>
<tr>
<td>Distance</td>
<td>Calibrated Tape Measure</td>
</tr>
<tr>
<td>Time</td>
<td>Stopwatch or Other Timer</td>
</tr>
<tr>
<td>Angle</td>
<td>Protractor or Quick Square</td>
</tr>
</tbody>
</table>

Additional Tools

<table>
<thead>
<tr>
<th>Purpose</th>
<th>Suggested Device(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface Applied Rotary Connection</td>
<td>Pipe or sub with appropriate connection to connect surface rotary device to force measurement devices (load cells or other instrument(s))</td>
</tr>
<tr>
<td>Force Transmission</td>
<td>Tongs, Cables, Chains, etc…</td>
</tr>
</tbody>
</table>

3) Define torque test range based on surface applied rotary drive expected operating range (min and max) for continuous torque (not intermittent torque).
   • Minimum torque to test = Surface applied rotary device working operating torque min or 3,000 ft-lb [4000 N-m] (whichever is higher)
   • Maximum torque to test = Surface applied rotary device working operating torque max
   (It is recommended to test the device for its manufacturer’s expected operating range. If company/OEM want to concentrate on a specific range, this can be adjusted.)

   • Record the torque reported by the drive at 50 rpm with no load attached. This is the residual friction in the drive. Torque verification below this level will be inaccurate and is not advised. (For some surface applied rotary devices, this may be 500 to 600 ft-lb [700 to 800 N-m]. Refer to OEM guidelines.)

4) Turn OFF any system that controls or modifies any properties measured during testing, if possible. This includes auto-drillers, soft-torque systems or other devices that influence torque output.
5) Set up for Load Cell as true reference reading

- For top drives, make up pipe extension to quill on the top drive. (Use crossover if necessary).
- Affix tongs to surface applied rotary device. Ensure tongs are level with the plane of the rig floor.
- Affix approved tension device (i.e., cables) with a calibrated in-line tension gage (load cell) to a member of the rig that is approved for the maximum test load. Ensure that the approved tension device is:
  i. within 90 degrees in respect to the tongs
     (Measure $\varepsilon_H$, the horizontal angle deviation from 90 degrees.)
  ii. level with the plane of the rig floor
     (Measure $\varepsilon_V$, the vertical angle deviation from being level.)
- Measure the distance from the center of the pipe extension to the cables. This is the moment arm. Record the number in decimal units.

![Figure 4.1.1 Example of a load cell setup](image)
6) Test from minimum test torque to maximum test torque (4 test torques minimum).

Each test torque will be conducted a minimum of one time

Example of test torques:

<table>
<thead>
<tr>
<th>Test Torque</th>
<th>Torque Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>3,000 ft-lb</td>
<td>4,000 N-m</td>
</tr>
<tr>
<td>10,000 ft-lb</td>
<td>14,000 N-m</td>
</tr>
<tr>
<td>20,000 ft-lb</td>
<td>28,000 N-m</td>
</tr>
<tr>
<td>30,000 ft-lb (max)</td>
<td>40,000 N-m (max)</td>
</tr>
</tbody>
</table>

Use the table in APPENDIX A or APPENDIX B (USC or Metric) to record the values for:
- Surface Applied Rotary Drive Torque (ft-lb or N-m)
- Load Cell Force (lb or N)
- Moment Arm (ft or m)
- $\varepsilon_H$, Moment Arm Horizontal angle deviation from 90 degrees (degrees)
- $\varepsilon_V$, Moment Arm Vertical angle deviation from being level (degrees)
- C (Moment Arm Correction Factor – See Appendix E)
- Calculated Load Cell Torque (ft-lb or N-m) = Load Cell Force (lb or N) x Moment Arm (ft or m) x C

7) Calculate Error (Load Cell as true reference reading):

\[
\text{Error} = V_{true} - V_{observed}
\]

Percentage error = \% RD = \frac{\text{Error}}{V_{true}}

Full scale percentage error = \% FS = \frac{\text{Error}}{V_{full\,scale}}

Where
- $V_{true}$ = Calculated Load Cell Torque reading
- $V_{observed}$ = Surface Applied Rotary Drive Torque reading
- $V_{full\,scale}$ = Surface Applied Rotary Torque full scale reading
8.2. Testing Tool – Strain gauge torque sub

1) Personnel required for the job:
   - Company representative (if Operator, this can be Well site supervisor, third party inspector, or other designated person)
   - Driller
   - Strain gauge torque sub technician

2) Test equipment required for the job (parties responsible for providing test equipment will need to be agreed upon beforehand):

<table>
<thead>
<tr>
<th>Observed Property</th>
<th>Suggested Device(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Torque</td>
<td>Strain gauge torque sub</td>
</tr>
</tbody>
</table>

Additional Tools

<table>
<thead>
<tr>
<th>Purpose</th>
<th>Suggested Device(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface Applied Rotary Connection</td>
<td>Pipe or sub with appropriate connection to connect surface applied rotary device to force measurement devices (strain gauge torque sub or other instrument(s))</td>
</tr>
<tr>
<td>Force Transmission</td>
<td>Tongs, Cables, Chains, etc.</td>
</tr>
</tbody>
</table>

3) Define torque test range based on surface applied rotary device expected operating range (min and max) for continuous torque (not intermittent torque).
   - Minimum torque to test = Surface applied rotary device working operating torque min or 3,000 ft-lb [4000 N-m] (whichever is higher)
   - Maximum torque to test = Surface applied rotary device working operating torque max
     (It is recommended to test the device for its manufacturer’s expected operating range. If company/OEM want to concentrate on a specific range, this can be adjusted.)

   - Record the torque reported by the drive at 50 rpm with no load attached. This is the residual friction in the drive. Torque verification below this level will be inaccurate and is not advised. (For some surface applied rotary devices, this may be 500 to 600 ft-lb [700 to 800 N-m]. Refer to OEM guidelines.)

4) Turn OFF any system that controls or modifies any properties measured during testing, if possible. This includes auto-drillers, soft-torque systems or other devices that influence torque output.

5) Set up for strain gauge torque sub as true reference reading
   - Make up strain gauge torque sub to surface applied rotary drive per OEM requirements
   - If top drive, make up pipe extension to quill on the top drive. (Use crossover if necessary).
   - Affix tongs to pipe connected to the strain gauge torque sub. Ensure tongs are level with the plane of the rig floor.
   - Affix approved tension device (i.e., cables) to a member of the rig that is approved for the maximum test load.

6) Test from minimum test torque to maximum test torque (4 test torques minimum).
Each test torque will be conducted a minimum of one time.

Example of test torques:

<table>
<thead>
<tr>
<th>Test Torque</th>
<th>Torque Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>3,000 ft-lb (min)</td>
<td>4,000 N-m (min)</td>
</tr>
<tr>
<td>10,000 ft-lb</td>
<td>14,000 N-m</td>
</tr>
<tr>
<td>20,000 ft-lb</td>
<td>28,000 N-m</td>
</tr>
<tr>
<td>30,000 ft-lb (max)</td>
<td>40,000 N-m (max)</td>
</tr>
</tbody>
</table>

Use the table in APPENDIX C or APPENDIX D (USC or Metric) to record the values for:

- Surface Applied Rotary Drive Torque (ft-lb or [N-m])
- Strain gauge torque Sub Torque (ft-lb or [N-m])

7) Calculate Error

\[
\text{Error} = V_{\text{true}} - V_{\text{observed}}
\]

\[
\text{Percentage error} = \% \text{ RD} = \left( \frac{V_{\text{true}} - V_{\text{observed}}}{V_{\text{true}}} \right) \times 100 \%
\]

\[
\text{Full scale percentage error} = \% \text{ FS} = \left( \frac{V_{\text{true}} - V_{\text{observed}}}{V_{\text{full scale}}} \right) \times 100 \%
\]

Where

- \( V_{\text{true}} \) = Strain gauge torque sub reading
- \( V_{\text{observed}} \) = Surface applied rotary device torque reading
- \( V_{\text{full scale}} \) = Surface applied rotary device torque full scale reading
Appendix A – INFORMATIVE – Surface Applied Torque Verification with Load Cell – Table to Record Readings (USC)

Residual friction torque reading = _________ ft-lb

For section 8.1 Testing Tool – Load Cell
Moment Arm = ____________ ft (decimal)
Calculated Load Cell torque (ft-lb) = Load Cell Force (lb) x Moment Arm (ft) x Moment Arm Correction Factor

<table>
<thead>
<tr>
<th>Planned Test Torque ft-lb</th>
<th>READING Applied Rotary Device Torque ft-lb</th>
<th>READING Moment Arm (decimal)</th>
<th>READING ε_H (degree)</th>
<th>READING ε_V (degree)</th>
<th>READING Moment Arm Correction Factor</th>
<th>READING Load Cell Force (lb)</th>
<th>READING Load Cell Torque (ft-lb)</th>
<th>Error</th>
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</table>
Appendix B – INFORMATIVE – Surface Applied Torque Verification with Load Cell – Table to Record Readings (Metric)

Residual friction torque reading = __________ N-m

For section 8.1 Testing Tool – Load Cell

Moment Arm = __________ m (decimal)

Calculated Load Cell torque (N-m) = Load Cell Force (N) x Moment Arm (m) x Moment Arm Correction Factor

<table>
<thead>
<tr>
<th>Planned Test Torque N-m</th>
<th>READING Applied Rotary Device Torque N-m</th>
<th>READING Moment Arm (decimal m)</th>
<th>READING δH (degrees)</th>
<th>READING δV (degrees)</th>
<th>READING Moment Arm Correction Factor</th>
<th>READING Load Cell Force (N) Calculation Req'd</th>
<th>Error %</th>
<th>Allowed Error %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
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</tbody>
</table>
Appendix C – INFORMATIVE – Surface Applied Torque Verification with Strain Gauge Torque Sub – Table to Record Readings (USC)

Residual friction torque reading = __________ ft-lb

For section 8.2 Testing Tool – Strain Gauge Torque Sub

<table>
<thead>
<tr>
<th>Planned Test Torque ft-lb</th>
<th>READING Applied Rotary Device Torque ft-lb</th>
<th>READING Strain Based Gauge Torque ft-lb</th>
<th>Error Allowed ft-lb</th>
<th>Error ft-lb</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
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<tr>
<td></td>
<td>2</td>
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<td>4</td>
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</table>
Appendix D – INFORMATIVE – Surface Applied Torque Verification with Strain Gauge Torque Sub – Table to Record Readings (Metric)

Residual friction torque reading = __________ N-m

For section 8.2 Testing Tool – Strain Gauge Torque Sub

<table>
<thead>
<tr>
<th>Planned Test Torque Nm</th>
<th>READING Applied Rotary Device Torque Nm</th>
<th>READING Strain Based Gauge Torque Nm</th>
<th>Error in Nm</th>
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Appendix E – NORMATIVE – Moment Arm Correction

Table 1—Correction Factor (C) for Calculation of Effective Moment Arm Length when Horizontal (ε_H) and Vertical (ε_V) Errors (in degrees) are Present

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<th>5</th>
<th>6</th>
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<td>0.97</td>
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<td>0.86</td>
<td>0.84</td>
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<td>0.93</td>
<td>0.91</td>
<td>0.90</td>
<td>0.88</td>
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<td>0.88</td>
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</table>
1. Measure the distance from the center of the sub or quill to the chains. This is the moment arm. Record the number in decimal units (feet or $[\text{meters}]$) and calculate the required tension required to achieve desired testing torque(s).

   a. **NOTE:** $T_{\text{applied}} = T LC$ where:
      
      i. $T_{\text{applied}} = \text{Torque applied}$
      
      ii. $T = \text{Tension measured by load cell}$
      
      iii. $L = \text{Length of moment arm shown in Figure 1}$
      
      iv. $C = \text{Correction Factor from Table 1}$
ibliography

[1] IADC Guidelines for Data Stewardship