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Draft for ballot #5886

Field Verification of Rig Devices for Oil and Gas Well Drilling Operations

API RECOMMEND PRACTICE XX
XX EDITION, MONTH YEAR



AMERICAN PETROLEUM INSTITUTE

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1. Scope

1.1. Coverage

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

The purpose of this document is to provide recommended practices for the development of field verification procedures for critical drilling rig devices used in drilling operations. This is to promote and maintain the quality and consistency of field verification processes for device management and operational capabilities.

The critical drilling rig devices addressed in this recommended practice are for:

- 1) Surface applied rotary torque
- 2) Make up torque
- 3) Hook load
- 4) Rotational speed
- 5) Block Position
- 6) Pressure
- 7) Pump rate

The recommended practices may need to be adjusted as testing considerations for current and future devices are further identified and understood. This document provides field verification procedures incorporating device and test considerations based on recommended practices. These procedures can serve as a starting point to further build device specific field verification procedures by drilling contractors and service providers who will be conducting device field verification.

This recommended practice does:

- **NOT** define accuracy requirements. Accuracy requirements are per operator, application, drilling contractor, and service company. See Section 1.3 Responsibility.
- **NOT** address device calibration or define actions to correct accuracy issues (in respect to results of field verification and accuracy requirements). However, field verification can be performed after the corrective action to check if the corrective action resolves the accuracy issue.
- **NOT** address the frequency and/or trigger events for field verification. However, results from field verification can be used to determine the frequency and trigger events.

1.2. Applicability

These recommendations apply to rotary drilling rigs. Special considerations may have to be made for floating, slant, other non-traditional fixed rigs, and workover rigs.

1.3. Responsibility

Responsibilities are 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 should be 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 should be compared against jointly agreed upon application accuracy requirements to determine path forwards.

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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 Specification for Quality Management Systems for Service Supply Organizations for the Petroleum and Natural Gas Industries
- IADC²
IADC Rig Sensor Stewardship Guidelines

3. Terms, Definitions, and Abbreviations

3.1. Terms and Definitions

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

- 1)
accuracy
The degree to which the result of a measurement (observed value) compares to the true value (correct value or standard).
- 2)
drill pipe
A tubular, shaft, or other component used to transmit rotation to the drill bit and conduct drilling fluid.
- 3)
drill string (work string)
Several sections or joints of drill pipe or tubing joined together for use in a wellbore.
- 4)
driller
The person responsible for the operation of the drilling and hoisting equipment of the rig under normal conditions.
- 5)
drilling contractor
The party that is responsible for the operation of the drilling unit for drilling of a well, wellbore, or section thereof.
- 6)
hysteresis
The phenomenon in which a value of a physical property lags behind changes in the effect causing it.
- 7)
electronic drilling recorder
Also known as electronic data recorder. System for monitoring and recording data from operations.

¹ American Petroleum Institute

² International Association of Drilling Contractors

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8)

instrument

Measuring device used to gauge the level, position, speed, or other property.

9)

levelness

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

10)

operator

operator representative

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

11)

pipe slip

Mechanical device used to grip on the outside of drill pipe to hold it in place in respect to the hole.

12)

qualified person

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.

13)

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.

14)

red zone

Marked safety zones where access is limited during operations.

15)

surface applied rotary torque device

Device on a drilling rig that applies torque to the drill string. The torque is applied on surface.

NOTE: Examples are top drives and kelly drives.

16)

quill

A hollow shaft to/through which the drill string is connected to the surface applied rotary device.

NOTE: 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 and Symbols

BOP	Blowout preventer
C	Moment arm correction factor
EDR	Electronic Drilling Recorder/Electronic Data Recorder
OEM	Original Equipment Manufacturer
QMS	Quality Management System
rpm	revolutions per minute
USC	United States Customary System of units
$V_{full\ scale}$	Value of full-scale reading for device being field verified
V_{true}	Value of reading or calculation based on the calibrated test instrument
$V_{observed}$	Value of reading or calculation from device being field verified
% RD	accuracy as percentage of reading
% FS	accuracy as percentage of full scale
θ_H	moment arm horizontal angle
θ_V	moment arm vertical angle

4. Fundamental Equations

4.1. General

The accuracy of the critical rig devices may be 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.

As an example for torque, the following components may need to be considered:

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

4.2. Torque Equation #1 (Static)

Torque (T) is defined in the following Equation 4.2.1:

$$T = F \times d \quad \text{(Equation 4.2.1)}$$

Where:

T = torque, $N \cdot m$ (lbf·ft)

F = force applied, N (lbf)

d = perpendicular distance of force from the axis of rotation, m (ft)

4.3. Torque Equation #2 (Dynamic)

Torque (T) is defined in the following Equation 4.3.1:

$$T = \frac{dL}{dt} \quad (\text{Equation 4.3.1})$$

Where:

T = torque, $N \cdot m$ ($lbf \cdot ft$)

L = angular momentum = $I\omega$, $kg \cdot m^2/s$ ($lb \cdot ft^2/s$)

ω = angular velocity, rad/s (rad/s)

I = moment of inertia, $kg \cdot m^2$ ($lb \cdot ft^2$)

t = time, s (s)

4.4. Error Equations

Having consistent error equations facilitates the capability to compare the results of field verification and the acceptance criteria. The error calculations and respective nomenclature shall be in accordance with at least one of the following.

Error equations are defined in the following Equations 4.4.1, 4.4.2, and 4.4.3:

$$\text{Error} = V_{\text{observed}} - V_{\text{true}} \quad (\text{Equation 4.4.1})$$

$$\text{Reading percentage error} = \% \text{ RD} = (V_{\text{observed}} - V_{\text{true}}) / V_{\text{true}} \quad (\text{Equation 4.4.2})$$

$$\text{Full scale percentage error} = \% \text{ FS} = (V_{\text{observed}} - V_{\text{true}}) / V_{\text{full scale}} \quad (\text{Equation 4.4.3})$$

Where

V_{true} = Value of reading or calculation based on the calibrated test instrument

V_{observed} = Value of reading or calculation from device being field verified

$V_{\text{full scale}}$ = Value of full-scale reading for device being field verified

5. Safety

At a minimum, the following shall be adhered to by rig contractor, equipment owner, or service provider.

- 1) Necessary permits are acquired for respective work.
- 2) Equipment and system rating(s) are not exceeded.
- 3) Equipment and test instruments are in proper working conditions. Repair or replace, as necessary.
- 4) Rig maintenance is up to date per equipment owner's preventative maintenance program (quality management system) for a properly functioning and performing rig.
- 5) Guards, shields, and other protective devices are in place and functional unless required to be removed for testing with noted mitigating measures.
- 6) Threaded connections (if any) meet manufacturer's technical specifications.
- 7) Ropes, chains, tongs, pad eye, or other force transmission equipment are in proper working order and have been inspected per equipment owner's preventative maintenance program (quality management system).
- 8) Anchor points are rated for the anticipated applied loads.

Activities shall be stopped if any safety issues are identified.

During the execution of field verification tests, red zones should be identified to minimize unnecessary personnel in the working area.

6. Influences on readings

The following are some (but not all) items that can affect readings and can result in safety and accuracy issues. IADC Rig Sensor Stewardship Guidelines Section 3.11 Sensor Inaccuracies and Section 3.12 Basic Calibration and Validation Principles provide additional information on influences on readings.

- Operating Conditions/Loads
 - i. Operating temperatures.
 - ii. Operating angular velocities (rpm).
 - iii. Operating angular acceleration.
- Corrections
 - i. For top drives without direct torque control, torque correction may be required based on output rpm.
 - ii. Temperature and environmental effects.
 - iii. Moment arm length corrections due to horizontal and vertical angle deviations from 90° (see Annex M).
 - iv. Sensor offset.
 - v. Calibration factors.
- Electrical
 - i. Frays, scars, cuts, kinks, or other damage to cables that are part of the instrumentation and data aggregation system.
 - ii. Damaged junction boxes which allow water intrusion or other environmental elements in affecting wiring.
 - iii. 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.
 - iv. Inadequate bonding of variable frequency drives, silicon control rectifiers, generators, pumps, or other electrically connected skids.
 - v. Induced electrical noise from: bad connection, improper insulation or isolation, colocation of high-voltage and low-voltage conductors or other factors.

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- Hydraulic
 - i. Plugged filter, damaged pump, damaged valve, kinked hose, or orifice restricting flow of hydraulic fluid that could reasonably affect device performance.
- Mechanical
 - i. Direction of movement.
 - ii. Friction between bearings, sleeves, and sheaves.
 - iii. Weight of lines and fluids that can add additional tension.
 - iv. Worn dies resulting in slippage.
- Hysteresis
 - i. For the system, potential hysteresis effects from friction, viscous effects, and other damping whether mechanical or electrical.

Insertion or assembly of a test instrument into an electrical or mechanical system that is different from that which the test instrument was calibrated with can result in errors beyond those determined during calibration. Any such application should be carefully evaluated by qualified person to prevent unacceptable errors.

7. Documentation Review

Calibrated test instruments shall be used when verifying critical rig devices. The readings from the calibrated test instruments provide the reference to compare against the readings from the critical rig devices.

- 1) Calibration/validation documents shall be reviewed for test instruments. The frequency of test instrument calibration shall be per contractor/OEM QMS.
 - Some examples of test instruments are load cells, strain gauge data sub, pressure gauge, etc.

Test instruments shall be traceable to an international or national measurement standards; where no such standards exist, the basis used for calibration or verification shall be recorded per API Q2 – Section 5.8 Control of Testing, Measuring, Monitoring, and Detection Equipment.

At a minimum, the following information shall be recorded for each test instrument 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, if applicable (per customer/contractor/OEM agreement – contract)
 - Accuracy Basis (Full Scale or Reading)

- 2) Review previous verification results for the critical rig device.

8. Surface Applied Rotary Torque Field Verification

8.1. Objective

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

8.2. Considerations

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

- a. Operating torques (or from 20%-80% of device nominal range, whichever is greater).
- b. Operating temperatures (both environmental and device generated heat).
- c. Surface applied rotary torque device field verification tests noted in this recommended practice are static tests (the surface applied rotary torque 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 device field verification procedures.

8.2.1 Effect on surface applied rotary torque field 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) Error may vary on the range of operating torque; therefore, multiple test torques are recommended from the minimum to maximum expected operating torque.
- 3) Torque readings 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.

Note: For some surface applied rotary torque devices, this may be 700 to 800 N·m (500 to 600 lbf·ft). A minimum test torque of 4000 N·m (3,000 lbf·ft) 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.

8.2.2 Minimal to no effect on surface applied rotary torque verification

- 1) The surface applied rotary torque device verification tests noted in this recommended practice are static tests (the surface applied rotary device is not rotating).

Contrary to hydraulic surface applied rotary torque devices, the results of these static surface applied rotary torque verification tests may not be affected by cold oil temperatures when running in normal operating range; therefore, it is not specified to run the surface applied rotary torque device at typical operating rpm in order to be operating at a specified oil temperature (per OEM) for these surface applied rotary torque verification tests.

- 2) Ramp up and down rates to get to test torque has a fraction of a second effect prior to getting to stabilized static torque; therefore, ramp up and down rates are not specified.

8.3. Static Torque Procedure with Test Instrument – Load Cell

The below shall be followed for the procedure.

- 1) Personnel for the job:
 - Company representative (if Operator, this can be Well site supervisor, third party inspector, or other designated person)
 - Driller
- 2) Test equipment for the job (parties responsible for providing test equipment shall be agreed upon beforehand). See Table 1 and Table 2.

Table 1: Test Instruments for Static Torque Procedure with Test Instrument – Load Cell

Observed Property	Suggested Device(s)
Force	In-line Load Cell
Distance	Calibrated Tape Measure, Scale, or Other Length Measurement Instrument
Time	Stopwatch or Other Timer
Angle	Protractor or Quick Square

Table 2: Additional Tools for Static Torque Procedure with Test Instrument – Load Cell

Purpose	Suggested Device(s)
Connection to Surface Applied Rotary Torque Device	Pipe or sub with appropriate connection to connect surface rotary device to force measurement devices (load cells or other instrument(s))
Force Transmission	Tongs, Cables, Chains, etc.
Levelness	Spirit or Digital Level

- 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 torque device working operating torque min or 4000 N·m (3,000 lbf·ft), whichever is higher
 - Maximum torque to test = Surface applied rotary torque device working operating torque max

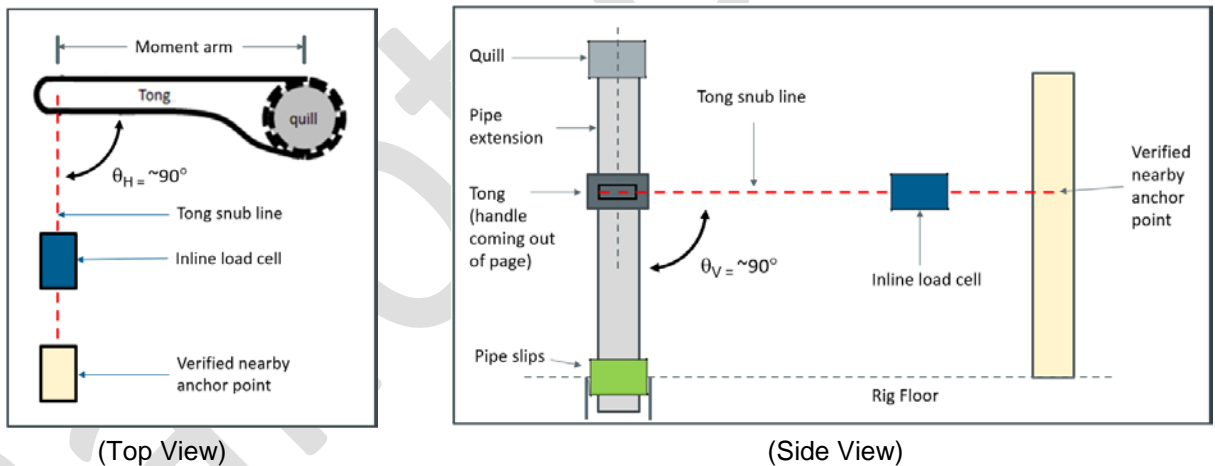
Note: It is recommended to test the device for its manufacturer's expected operating range. If drilling contractor/operator/OEM want to concentrate on a specific range, this can be adjusted.)

- 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 torque devices, this may be 700 to 800 N·m (500 to 600 lbf·ft). 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 load cell as true reference reading. See Figure 1.

- For top drives, make up pipe extension to quill on the top drive. (Use crossover if necessary.)
- Set pipe slips on pipe extension. (This will prevent the pipe extension from rotating. This is a static torque test.)
- Engage tong to the pipe extension at the output of the surface applied rotary torque device and make tong level with the plane of the rig floor.
- Affix approved tension device (i.e., tong snub line) with a calibrated in-line tension gage (load cell) to an anchor point of the rig that is approved for the maximum test load.
- Check that the approved load cell is:
 - i. aligned 90 degrees in respect to the handle of the tong
(Measure and record θ_H , moment arm horizontal angle in degrees.)
 - ii. level with the plane of the rig floor
(Measure and record θ_V , moment arm vertical angle in degrees.)
- Check that the output of the surface applied rotary device, the pipe extension, or any other rotating component is not in contact with other objects such that a portion of the output torque might be absorbed through friction or other loads.)
- Measure the distance from the center of the pipe extension to the tong snub line. This is the moment arm. Record the number in decimal units.

Figure 1: Example of a load cell setup



- 6) Test from minimum test torque to maximum test torque (4 test torques minimum).

Each test torque shall be conducted a minimum of one time.

Example of test torques are in Table 3.

Table 3: Example Test Torques

Torque #	Torque Example (Metric)	Torque Example (USC)
T1	4,000 N·m (minimum test torque)	3,000 lbf·ft (minimum test torque)
T2	14,000 N·m	10,000 lbf·ft
T3	28,000 N·m	20,000 lbf·ft
T4	40,000 N·m (max test torque)	30,000 lbf·ft (max test torque)

Record the following values in Annex A (Metric), Annex B (USC), or comparable table:

- Surface applied rotary torque device static torque reading, N·m (lbf·ft)
- Load cell force, N (lbf)
- Moment arm length, m (ft)
- θ_H , Moment arm horizontal angle, degrees (degrees)
- θ_V , Moment arm vertical angle, degrees (degrees)
- C, Moment arm length correction factor - See Annex M
- Calculated load cell torque, N·m (lbf·ft) = Load cell force, N (lbf) x Moment arm length, m (ft) x C

- 7) Calculate and record error.

Use Equations 4.4.1, 4.4.2, and/or 4.4.3.

- V_{observed} : Surface applied rotary torque device static torque reading
The device being field verified is the surface applied rotary torque device.
- V_{true} : Calculated load cell torque
The calibrated test instrument is the load cell.

8.4. Static Torque Procedure with Test Instrument – Strain gauge data sub

The below shall be followed for the procedure.

- 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 data sub technician
- 2) Test equipment required for the job (parties responsible for providing test equipment shall be agreed upon beforehand). See Table 4 and Table 5.

Table 4: Test Instruments for Static Torque Procedure with Test Instrument – Strain gauge data sub

Observed Property	Suggested Device(s)
Torque	Strain gauge data sub

Table 5: Additional Tools for Static Torque Procedure with Test Instrument – Strain gauge data sub

Purpose	Suggested Device(s)
Connection to Surface Applied Rotary Device	Pipe or sub with appropriate connection to connect surface applied rotary device to force measurement devices (strain gauge data sub or other instrument(s))
Force Transmission	Tong, Cables, Chains, etc.
Levelness	Spirit or Digital Level

- 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 torque device working operating torque min or 4000 N·m (3,000 lbf·ft), whichever is higher
 - Maximum torque to test = Surface applied rotary torque device working operating torque max

Note: 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 torque devices, this may be 700 to 800 N·m (500 to 600 lbf·ft). 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 strain gauge data sub as true reference reading.
 - Make up strain gauge data sub to surface applied rotary torque device per OEM requirements.
 - If top drive, make up pipe extension to quill on the top drive. (Use crossover if necessary.)
 - Set pipe slips on pipe extension. (This will prevent the pipe extension from rotating. This is a static torque test.)

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- Engage tong to pipe connected to the strain gauge data sub. Make tong 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 shall be conducted a minimum of one time.

Example of test torques are in Table 6.

Table 6: Example Test Torques

Torque #	Torque Example (Metric)	Torque Example (USC)
T1	4,000 N·m (minimum test torque)	3,000 lbf·ft (minimum test torque)
T2	14,000 N·m	10,000 lbf·ft
T3	28,000 N·m	20,000 lbf·ft
T4	40,000 N·m (max test torque)	30,000 lbf·ft (max test torque)

Record the following values in Annex C (Metric) , Annex D (USC), or comparable table:

- Surface applied rotary torque device static torque reading, N·m (lbf·ft)
- Strain gauge data sub static torque reading, N·m (lbf·ft)

7) Calculate and record error.

Use Equations 4.4.1, 4.4.2, and 4.4.3.

- V_{observed} : Surface applied rotary torque device static torque reading
The device being field verified is the surface applied rotary torque device.
- V_{true} : Calculated load cell torque
The calibrated test instrument is the strain gauge data sub.

9. Hydraulic Iron Roughneck Make Up Torque Field Verification

9.1. Objective

To have a consistent field verification method for make up torque.

9.2. Considerations

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

- a. Operating Torques (or from 20%-80% of device nominal range, whichever is greater)
- b. Operating temperatures (both environmental and device generated heat)

The following were considered for the development of the make up torque device verification procedures.

9.2.1 Effect on hydraulic iron roughneck make up torque field verification

- 1) The hydraulic torque gauge measures hydraulic pressure which is a representation of torque. Incorrect measurement of hydraulic pressure can result in erroneous torque readings; therefore, see section 9.2.
- 2) The tank line pressures affects the hydraulic pressure on the iron roughneck; therefore, see the torque gauge bias adjustment in section 9.2
- 3) 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.
- 4) Make up torque error may vary on the range of operating torque; therefore, multiple test torques are recommended from the minimum to maximum expected operating torque.
- 5) Worn dies/insert may result in slippage causing issues in readings.
- 6) Clamping force is the force applied to the tubular before any rotary torque is applied to make up a connection. If the test instrument is affected by clamping force, then residual torque from clamping should be excluded from the measurement of applied makeup torque. After clamping has fully ceased and before any rotary torque is applied, a tare should be applied to the test instrument, and it should read a static value of zero.

9.3. Hydraulic System Verification Procedure with Test Instrument – Hydraulic Pressure Test Gauge

The below shall be followed for the procedure.

- 1) Personnel required for the job:
 - Qualified Maintenance Technician
- 2) Test equipment required for the job (parties responsible for providing test equipment will need to be agreed upon beforehand). See Table 7 and Table 8.

Table 7: Test Instruments for Hydraulic System Verification Procedure with Test Instrument – Hydraulic Pressure Test Gauge

Observed Property	Suggested Device(s)
Pressure	Hydraulic Pressure Test Gauge

Table 8: Additional Tools for Hydraulic System Verification Procedure with Test Instrument – Hydraulic Pressure Test Gauge

Purpose	Suggested Device(s)
----------------	----------------------------

Connection to hydraulic system	Adaptors/Test Fittings
Pressure up hydraulic system	Hydraulic Hand Pump

- 3) If the Iron Roughneck has an OEM specified system pressure:
 - De-energize the hydraulic system and connect a hydraulic pressure test gauge to the test port or fitting specified by the OEM to test.
 - Energize the hydraulic system and record the system pressure.

- 4) Verify torque gauge accuracy.
 - De-energize the hydraulic system and isolate the hydraulic torque gauge from the Iron Roughneck hydraulic system.
 - Use necessary adaptors and test fittings to connect the hydraulic hand pump to the Iron Roughneck hydraulic torque gauge and the hydraulic pressure test gauge in a manner that pressure applied using the hand pump will be applied equally to the Iron Roughneck torque gauge and the test gauge.
 - If the Iron Roughneck torque gauge has a bias adjustment, verify using the test gauge that no pressure is applied, and then adjust the bias such that the torque gauge needle is aligned with zero on the gauge face.
 - Apply increasing pressure using the hydraulic hand pump, and record Iron Roughneck torque gauge and test gauge readings at a minimum of five values evenly spaced across the full scale of the Iron Roughneck torque gauge.
 - Remove pressure from the system. Disconnect the hand pump and test gauge.
 - Verify that the Iron Roughneck hydraulic system is still de-energized and reconnect the Iron Roughneck torque gauge in its standard operating configuration.
 - The table in Annex E or Annex F (Metric or USC) or comparable table can be used to record the values for:
 - i. Iron Roughneck hydraulic pressure reading, kPa (psi)
 - ii. Iron Roughneck hydraulic torque reading, N·m (lbf·ft)
 - iii. Hydraulic pressure test gauge reading, kPa (psi)
 - Calculate error values and record.

Use Equations 4.4.1, 4.4.2, and 4.4.3.

 - V_{observed} : Pressure reading from iron roughneck torque gauge
The device being field verified is the iron roughneck torque gauge.
 - V_{true} : Pressure reading from hydraulic pressure test gauge
The calibrated test instrument is the hydraulic pressure test gauge.

- 5) If the Iron Roughneck has an OEM specified maximum tank return line pressure
 - De-energize the hydraulic system and connect a hydraulic pressure test gauge to the test port or fitting specified by the OEM to test.
 - Energize the hydraulic system, function test Iron Roughneck jaw actuation, wait 30 seconds, and record the tank return line pressure.

- 6) If the Iron Roughneck torque gauge has a bias adjustment:
 - Follow OEM recommendations to adjust the gauge bias for the observed tank line pressure.

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9.4. Static Torque Procedure with Test Instrument – Strain Gauge Data Sub

The below shall be followed for the procedure.

- 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 data sub technician
- 2) Test equipment required for the job (parties responsible for providing test equipment will need to be agreed upon beforehand). See Table 9 and Table 10.

Table 9: Test Instruments for Static Torque Procedure with Test Instrument – Strain Gauge Data Sub

Observed Property	Suggested Device(s)
Torque	Strain gauge data sub

Table 10: Additional Tools for Static Torque Procedure with Test Instrument – Strain Gauge Data Sub

Purpose	Suggested Device(s)
Replacement	Dies/inserts

- 3) Define torque test range based on iron roughneck expected operating range (min and max)
 - Minimum torque to test = Iron roughneck working operating torque min or 4000 N·m (3,000 lbf·ft), whichever is higher
 - Maximum torque to test = Iron roughneck working operating torque max

Note: 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.

Per OEM procedure, review reference minimum, optimum, and maximum torque requirements for the connection(s) to be used. Check that connection torque requirements are within torque testing range.

- 4) Check that dies/inserts are new for the testing (to prevent slippage which may cause issues during testing).
- 5) Set up Strain gauge data sub per OEM requirements.
- 6) Tare out clamping force if strain gauge data sub is affected by clamping force.
- 7) Test a minimum of 5 torque values (20%, 40%, 60%, 80%, 100% of maximum torque). Ramp up at a consistent ramp up/down rate – within 3 to 5 seconds.

Make the connection as per usual practice.

Each test torque will be conducted 3 cycles (low torque to high torque). (torque, release).

Example:

If the torques to test are 10, 15, 20, 25, and 30 klbf, the following would be the test sequence:

10, 15, 20, 25, 30; 10, 15, 20, 25, 30; 10, 15, 20, 25, 30

If after 2 cycles, the results are within accuracy requirements, then the remaining cycles do not have to be conducted. (This is to reduce unnecessary wear on the dies/inserts for the iron roughneck.)

- 8) Use the table in Annex G or Annex H (Metric or USC) or comparable to record the readings for:
- Strain gauge data sub - torque, N·m (lbf·ft)
 - Iron roughneck torque, N·m (lbf·ft)
- 9) Calculate error and record.

Use Equations 4.4.1, 4.4.2, and 4.4.3.

- V_{observed} : Iron roughneck torque
The device being field verified is the iron roughneck.
- V_{true} : Strain gauge data sub - torque
The calibrated test instrument is the strain gauge data sub.

10. Push Rod Cathead Make Up Torque Field Verification

10.1. Objective

To have a consistent field verification method for cathead make up torque.

10.2. Considerations

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

- a. Operating Torques (or from 20%-80% of device nominal range, whichever is greater)
- b. Operating temperatures (both environmental and device generated heat)

The following were considered for the development of the make up torque device verification procedures.

10.2.1 Effect on push rod cathead make up torque field 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.

10.3. Static Torque Procedure for Test Instrument – Load Cell (Test Fixture)

The below shall be followed for the procedure.

- 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). See Table 11 and Table 12.

Table 11: Test Instruments for Static Torque Procedure for Test Instrument – Load Cell (Test Fixture)

Observed Property	Suggested Device(s)
Force	Inline Load Cell
Time	Stopwatch or Other Timer

Table 12: Additional Tools for Static Torque Procedure for Test Instrument – Load Cell (Test Fixture)

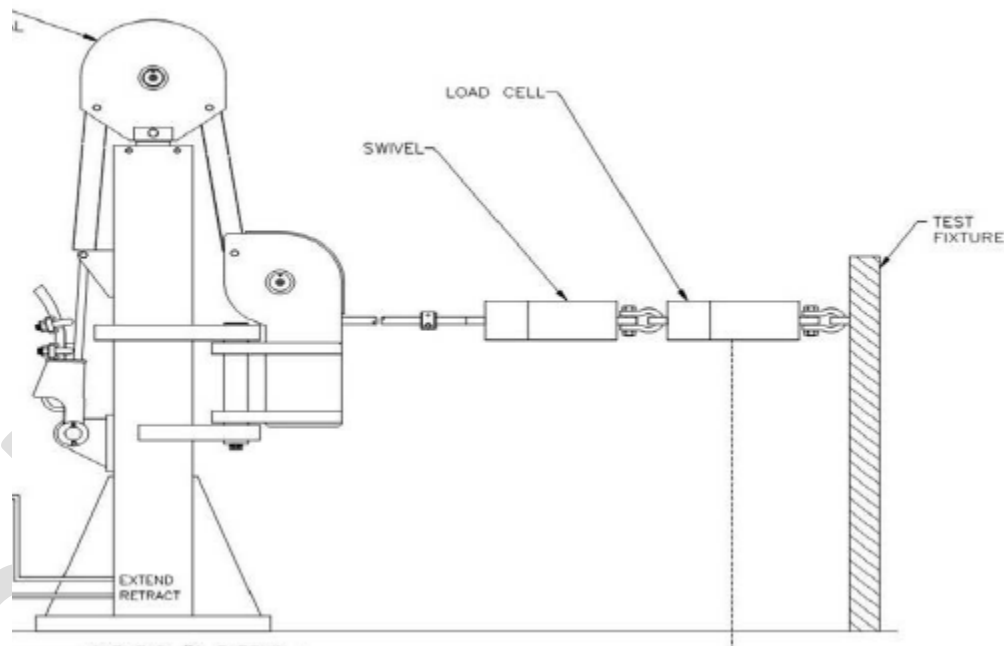
Purpose	Suggested Device(s)
Test Fixture (anchor point)	Pipe or sub with appropriate connection to connect to force measurement devices (load cells or other instrument(s))
Force Transmission	Tongs, Cables, Chains, etc...

- 3) Define pull force and torque test range based on expected tubular make up torque (min and max).
 - Minimum pull force load to test = Planned load for minimum make up torque with tongs in use or load required with tongs in use for 3000 ft-lb [4000 N-m] (whichever is higher)
 - Maximum pull force load to test = Planned load for maximum make up torque with tongs in use

Note: 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. Load test ranges based on torque required.

- 4) Stroke cylinder to check that the device is operating within the hydraulic pressure range specified (per OEM). (NOTE: Pull Force reported from the cathead can be significantly affected by cold/hot operating fluids and/or gear lubricants.)
 - Record any pull force & torque reported when functioning cathead with no load attached.
- 5) Set up Load Cell as true reference reading. See Figure 2.
 - Make up test fixture in rotary area as an anchor point for pull test.
 - Affix approved tension device (i.e., cables) with a calibrated in-line tension gage (load cell) to cathead pulling cable.

Figure 2: Example of a load cell setup with cathead and test fixture



(Note: Swivel is a recommended practice to minimize misalignment.)

- 6) Test from minimum test pull force to maximum pull force.
 - Apply test pull force at a consistent rate within 3 to 5 seconds.
 - Hold load for a minimum of 3 seconds and record applied values.
 - Conduct each pull test 3 times.

Use the table in Annex I or Annex J (Metric or USC) or comparable to record the readings for:

- Cathead pull force, N (lbf)
- Load cell force, N (lbf)

- 7) Calculate error and record.

Use Equations 4.4.1, 4.4.2, and/or 4.4.3.

- V_{observed} : Cathead pull force
The device being field verified is the push rod cathead.
- V_{true} : Load cell force
The calibrated test instrument is the load cell.

10.4. Static Torque Procedure for Test Instrument – Load Cell (Tong arrangement)

The below shall be followed for the procedure.

- 1) Personnel for the job shall be:
 - 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). See Table 13 and Table 14.

Table 13: Test Instruments for Static Torque Procedure for Test Instrument – Load Cell (Tong arrangement)

Observed Property	Suggested Device(s)
Force	Inline Load Cell
Distance	Calibrated Tape Measure
Time	Stopwatch or Other Timer
Angle	Protractor or Quick Square

Table 14: Additional Tools for Static Torque Procedure for Test Instrument – Load Cell (Tong arrangement)

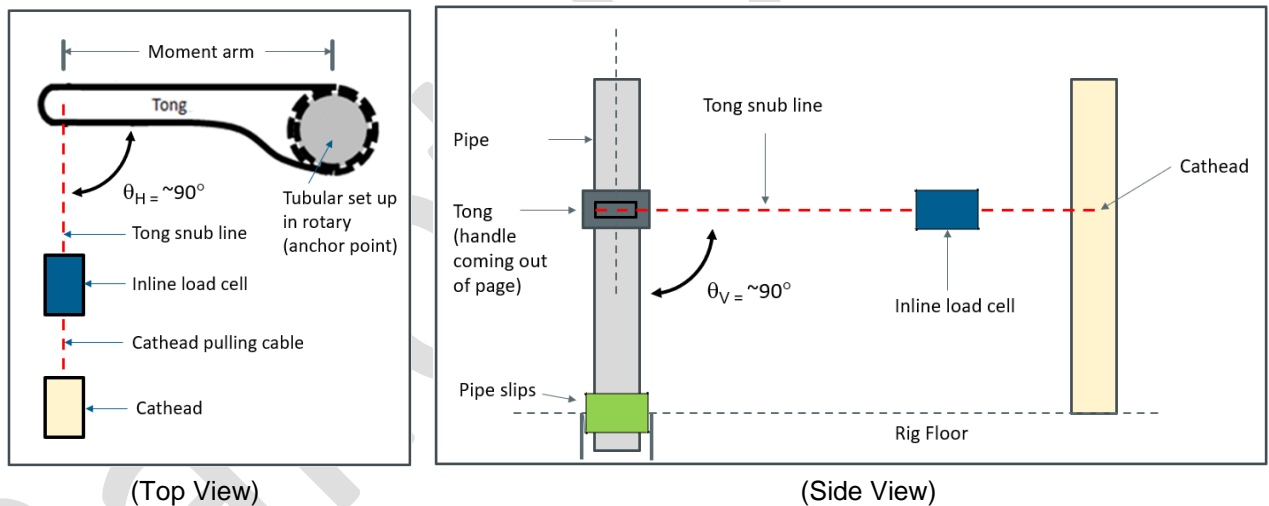
Purpose	Suggested Device(s)
Make Up Torque Connection	Pipe or sub with appropriate connection to connect surface rotary device to force measurement devices (load cells or other instrument(s))
Force Transmission	Tongs, Cables, Chains, etc...
Levelness	Spirit or Digital Level

- 3) Define pull force and torque test range based on expected tubular make up torque (min and max).
 - Minimum torque to test = Planned makeup torque minimum or 3000 ft-lb [4000 N-m] (whichever is higher)
 - i. Calculate minimum pull force to test by dividing minimum torque to test by moment arm.
 - Maximum torque to test = Planned makeup torque maximum
 - i. Calculate maximum pull force to test by dividing maximum torque to test by moment arm.

Note: 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.

- 4) Stroke cylinder to check that the device is operating within the hydraulic pressure range specified (per OEM). (NOTE: Pull Force reported from the cathead can be significantly affected by cold operating fluids and/or gear lubricants.)
 - Record any pull force & torque reported when functioning cathead with no load attached.
- 5) Set up Load Cell as true reference reading. See Figure 3.
 - Make up tubular in rotary area as an anchor point for pull test
 - Affix tongs to tubular anchor point
 - Affix approved tension device (i.e., cables) with a calibrated in-line tension gage (load cell) to tong and cathead pulling cable. Check that the approved tension device is:
 - i. within 90 degrees in respect to the tongs
(Measure and record θ_H , moment arm horizontal angle in degrees.)
 - ii. level with the plane of the rig floor
(Measure and record θ_V , moment arm vertical angle in degrees.)
 - Measure moment arm (the distance from the center of tubular to cable tie-on point).
 - i. Record the number in decimal units.
 - ii. Check that moment arm entered into rig control system equals measured moment arm

Figure 3: Example of a load cell setup



- 6) Test from minimum test pull force (minimum test torque) to maximum pull force (maximum test torque).
 - Apply test pull force (test torque) at a consistent rate within 3 to 5 seconds.
 - Hold load for a minimum of 3 seconds and record applied values.
 - Conduct each pull test 3 times.

Use the table in Annex K or Annex L (Metric or USC) or comparable to record the readings for:

- Moment arm length, m (ft)
- θ_H , Moment arm horizontal angle, degrees (degrees)
- θ_V , Moment arm vertical angle, degrees (degrees)
- C, Moment arm length correction factor - See Annex M
- Cathead pull force (lb or [N])

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- Calculated Cathead torque (ft-lb or $[N\cdot m]$) = Cathead pull force, N (lbf) x Moment arm length, m (ft) x C
- Load Cell Force (lb or $[N]$)
- Calculated load cell torque, $N\cdot m$ (lbf-ft) = Load cell force, N (lbf) x Moment arm length, m (ft) x C

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7) Calculate error and record.

Use Equations 4.4.1, 4.4.2, and 4.4.3.

- V_{observed} : Calculated Cathead torque
The device being field verified is the push rod cathead.
- V_{true} : Calculated load cell torque
The calibrated test instrument is the load cell.

11. Hook Load Field Verification

11.1. Objective

To have a consistent field verification method for hook load.

11.2. Considerations

Verification should be performed under the following conditions:

- a. The drill string should be in vertical and cased hole in order for the drill string to be free hanging and that there is no weight transfer.

The following were considered for the development of the hook load device verification procedures.

- 1) The weight of the traveling assembly is one known weight that can be used to verify weight measurements.
- 2) On the rig, there may be multiple systems that may be collecting hook load data. To align the various data collection systems, offsetting and scaling of the various systems shall be conducted.
- 3) Weight of hoses and fluid can affect hook load readings. Conducting tests at a consistent height can minimize the variability related to hose and fluid weight.

11.3. Procedure - Rig Control System and Electronic Data Recorder (EDR) Hook Load Reading Offsetting and Scaling and Single Point Hook Load Verification

The below shall be followed for the procedure.

Properly scaling shall be conducted on the high and low hook load readings on the Rig Control System and EDR. This is essential for these systems to provide accurate information about the depth, hook load, weight on bit, and other parameters.

Equipment manufacturer procedures shall be utilized when offsetting and scaling hook load.

1. Verify the drill string is free of obstructions and can be reciprocated.
2. Set the slips in the rotary and remove all string weight from the elevators.
3. Perform a single point hook load scaling in the Rig Control System by entering the weight of the traveling assembly. See Table 15 for an example of traveling assembly weights based on rig type.

Table 15: Example of traveling assembly weights based on Rig type

Rig Type	Weight of Traveling Assembly	
	Standard Model X Top Drive	Max Model X Top Drive
Rig example #1	187,000 N [42,000 lbf]	193,000 N [43,500 lbf]
Rig example #2	196,000 N [44,000 lbf]	202,000 N [45,500 lbf]
Rig example #3	191,000 N [43,000 lbf]	198,000 N [44,500 lbf]
Rig example #4	209,000 N [47,000 lbf]	216,000 N [48,500 lbf]
Rig example #5	187,000 N [42,000 lbf]	193,000 N [43,500 lbf]

4. Perform single point hook load verification based upon the weight of the traveling assembly.

Due to difference in weight of hoses and fluid at different heights, it is recommended to conduct this test at a consistent height and to account for hose and fluid weight for consistency. If the hook load measurement is not within acceptable error tolerance of the expected weight of traveling assembly/hose/fluid, follow up with corrective actions and repeat steps 3 and 4.

5. On the EDR, begin the two-point scaling by entering the low weight of the traveling assembly.
Note: This should match the Rig Control System hook load reading on the weight indicator.
6. Hoist the traveling assembly and drill string and remove the slips from the rotary table.
7. Return the traveling assembly and drill string to a neutral weight and allow the weight indicator to stabilize.
8. On the EDR, enter the high hook load reading displayed on the Rig Control System and complete the scaling process by pressing "enter".

Note: Hook load readings on the EDR and Rig Control System should be approximately the same weight.

11.4. Hook Load Verification Procedure between Rig Control System and EDR

The below shall be followed for the procedure.

1. Verify the drill string is free of obstructions and can be reciprocated.
2. Set the slips in the rotary and remove all string weight from the elevators.
3. Verify the Rig Control System and EDR are displaying the weight of the traveling assembly and read within acceptable error of one another.
4. Hoist the traveling assembly and drill string and remove the slips from the rotary table.
5. Verify the high weight of the Rig Control System and EDR are within acceptable error of one another.
6. If the low and/or high weights of the Rig Control System and EDR are outside of the acceptable ranges detailed above, rescale the hook load on the Rig Control System and EDR.

12. Rotational Speed Field Verification

12.1. Objective

To have a consistent field verification method for rotational speed.

12.2. Considerations

The following were considered for the development of the rotational speed field verification procedures.

- 1) Various instruments are available to measure rotational speed. Follow manufacturer instructions on proper use.
- 2) Rotational speed measurement should be independent of load if it is direct measurement from an encoder or similar.

12.3. Rotational Speed Procedure with Test Instrument - Digital Tachometer

The below shall be followed for the procedure.

- 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). See Table 16.

Table 16: Test Instruments for Rotational Speed Procedure with Test Instrument - Digital Tachometer

Observed Property	Suggested Device(s)
RPM	Digital Tachometer

Safety note: To avoid injuries, do not point the laser beam in eyes or look directly into the beam.

- 3) Attach reflective target on drill pipe connected top drive (per digital tachometer instructions). If the drill pipe is reflective, spray paint black prior to attaching the reflective target. (Follow manufacturer's instructions for proper set up.)
- 4) Set up digital tachometer to display RPM. Point digital tachometer at reflective target.
- 5) Request the top drive to rotate at test speeds (Example: 30, 60, 90, 120 RPM).
 - Await for steady state before starting the test
 - Run test for 1 minute. Record average RPM reading for the minute test.
- 6) Use the table in Annex N or comparable to record the readings for:
 - Top drive RPM
 - Digital tachometer RPM
- 7) Calculate error and record.
Use Equation 4.4.1.

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- V_{observed} : Top drive RPM
The device being field verified is the top drive.
- V_{true} : Digital tachometer RPM
The calibrated test instrument is the digital tachometer.

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12.4. Rotational Speed Procedure for Test Instrument - Strain gauge data sub

The below shall be followed for the procedure.

- 1) Personnel for the job:
 - Company representative (if Operator, this can be Well site supervisor, third party inspector, or other designated person)
 - Driller
 - Strain gauge data sub technician
- 2) Test equipment required for the job (parties responsible for providing test equipment will need to be agreed upon beforehand). See Table 17 and Table 18.

Table 17: Test Instruments for Rotational Speed Procedure for Test Instrument - Strain gauge data sub

Observed Property	Suggested Device(s)
RPM	Strain gauge data sub capable of reading up to 120 RPM

Table 18: Additional Tools for Rotational Speed Procedure for Test Instrument - Strain gauge data sub

Purpose	Suggested Device(s)
Display	Computer with software installed to wirelessly receive and output RPM reading from Strain Gauge Data Sub

- 3) Make up strain gauge data sub below top drive quill to recommended API makeup torque for connection used.
- 4) Request the top drive to rotate at test speeds (30, 60, 90, 120 RPM).
 - Await for steady state before starting the test
- 5) Use the table in Annex N or comparable to record the readings for:
 - Top drive RPM
 - Strain gauge data sub RPM
- 6) Calculate error and record.
Use Equation 4.4.1.
 - V_{observed} : Top drive RPM
The device being field verified is the top drive.
 - V_{true} : Strain gauge data sub RPM
The calibrated test instrument is the strain gauge data sub.

12.5. Rotational Speed Procedure for Test Instrument - Manual count

The below shall be followed for the procedure.

- 1) Personnel required for the job:
 - a. Company representative (if Operator, this can be Well site supervisor, third party inspector, or other designated person)
 - b. Driller
- 2) Test equipment required for the job (parties responsible for providing test equipment will need to be agreed upon beforehand). See Table 19 and Table 20.

Table 19: Test Instruments for Rotational Speed Procedure for Test Instrument - Manual count

Observed Property	Suggested Device(s)
Revolutions	Visual count
Time	Timer

Table 20: Additional Tools for Rotational Speed Procedure for Test Instrument - Manual count

Purpose	Suggested Device(s)
Marking device	Chalk, grease pencil, or other
Video recording device	Cellular phone camera or other

- 3) Make a chalk, grease pencil, or other mark on the quill or saver sub on the Top Drive.
- 4) Set a one-minute timer and request the top drive to rotate at test speeds (30, 60, 90, 120 RPM).
 - Await for steady state before starting the test
- 5) Count the number of revolutions in one minute.
 - At 120 RPM, it may be difficult to count. It may be necessary to use a recording device such as a cellular phone camera with slow motion video capture. Prior to spud, the rig floor has no NFPA hazardous or combustible materials classification, and electrical equipment may be used without permitting. If required, LEL (lower explosive limit) can be checked and continuously monitored.
- 6) Use the table in Annex N or comparable to record the readings for:
 - Top Drive RPM
 - Count of number of revolutions in one minute
- 7) Calculate error and record
Use Equation 4.4.1.
 - V_{observed} : Top drive RPM
The device being field verified is the top drive.
 - V_{true} : Count of number of revolutions in one minute
The calibrated test instrument is the count of number of revolutions in one minute.

13. Block Position Field Verification

13.1. Objective

To have a consistent field verification method for block position.

13.2. Considerations

The following were considered for the development of the block position field verification procedures.

- 1) Depending upon the test instrument being used to measure distance, error can be realized due to how the instrument is set up.

A consideration when determining the acceptable error for block position is that errors from block position are cumulative for bit depth and hole depth.

13.3. Procedure for Absolute Position (Blocks)

The below shall be followed for the procedure.

- 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). See Table 21.

Table 21: Test Instruments for Procedure for Absolute Position (Blocks)

Observed Property	Suggested Device(s)
Distance	Calibrated Tape Measure (can be same tool for strapping pipe), Laser measurement device, or Other Length Measurement Instrument

- 3) Choose a random height at which to position the top drive in the derrick. Measure from a standardized location chosen by the rig such as the bottom of the elevators or pipe handler.
- 4) Use an approved measurement device to measure the actual height in the derrick and record the set-point and observed position.
 - If measurement device is a tape measure, check that it is in tension.
- 5) Repeat Steps 3 and 4 using no fewer than 3 points, preferably dividing the derrick into thirds (at each new wrap of the drum).
- 6) Use the table in Annex O or Annex P (Metric or USC) or comparable to record the readings for:
 - Block Position, m [ft]
 - Calibrated tool distance measurement, m [ft]
- 7) Calculate error and record.
Use Equation 4.4.1 and 4.4.2

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- V_{observed} : Block position reading
The device being field verified is the block position encoder.
- V_{true} : Calibrated tool distance measurement
The calibrated test instrument is the approved measurement device.

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13.4. Procedure for Encoder Check (Blocks)

The below shall be followed for the procedure.

- 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). See Table 22.

Table 22: Test Instruments for Procedure for Encoder Check (Blocks)

Observed Property	Suggested Device(s)
Distance	Calibrated Tape Measure (can be same tool for strapping pipe), Laser measurement device, or Other Length Measurement Instrument

- 3) Align a static part of the top drive or traveling block (i.e., bottom of the bails, quill, bottom of the sheaves) with the top of the measuring device. Record for use in step 6.
- 4) Record reading on electronic data recorder (before reading for the encoder).
- 5) Move the top drive up and down the derrick until at least 1000 ft of travel has been achieved (typically 5 times up and 5 times down).
- 6) Return the system to its original position with respect to the measurement device.
- 7) Use the table in Annex Q or Annex R (Metric or USC) or comparable to record the readings for:
 - Encoder before reading, m [ft]
 - Encoder after reading, m [ft]
 - Difference between after and before reading on encoder, m [ft] = Encoder after reading – Encoder before reading
- 8) Calculate error and record.
Use Equation 4.4.1 and 4.4.2
 - V_{observed} : Difference between after and before reading on encoder
The device being field verified is the encoder.
 - V_{true} : Calibrated tool distance measurement
The calibrated test instrument is the approved measurement device.

14. Pressure Field Verification

14.1. Objective

To have a consistent field verification method for pressure.

14.2. Considerations

The following were considered for the development of the pressure field verification procedures.

- 1) To optimize timing, pressure sensors field verification is coordinated with BOP testing.

14.3. Pressure Procedure for Test Instrument - Pressure Device

The below shall be followed for the procedure.

- 1) Personnel required for the job:
 - Company representative (if Operator, this can be Well site supervisor, third party inspector, or other designated person)
 - BOP tester
- 2) Test equipment required for the job (parties responsible for providing test equipment will need to be agreed upon beforehand). See Table 23 and Table 24.

Table 23: Test Instruments for Pressure Procedure for Test Instrument - Pressure Device

Observed Property	Suggested Device(s)
Pressure	Calibrated Pressure Device

Table 24: Additional Tools for Pressure Procedure for Test Instrument - Pressure Device

Purpose	Suggested Device(s)
Connection to hydraulic system	Adaptors/Test Fittings

- 3) All pressure sensors to be verified by BOP tester(s), in conjunction with BOP testing.
- 4) The following minimum set of gauges should be tested every rig-up:
 - Choke Panel Gauge
 - Choke Manifold Gauge
 - Casing (annular) Gauge
 - Any other gauge(s) material to well control operations
- 5) The following gauges are to be verified at the same time:
 - ALL rig-owned gauges and any other gauge(s) connected to the stand pipe and providing data to remote viewers or other users should be tested and recorded as well.
- 6) After the BOP test, tie test into the circulating system and prepare a fresh chart.

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- 7) Test circulating system and all gauges to 50% and 100% of maximum expected working pressure (or as advised by company representative). Pressure should be held for 10 minutes or until transients no longer influence the pressure reading, whichever is longer. Pressure should be static over the duration of the test.
- 8) Use the table in Annex S to record the readings.
- 9) Calculate error and record.
Use Equation 4.4.1, 4.4.2, and 4.4.3
 - V_{observed} : Well control and Standpipe pressure readings
The devices being field verified are the rig pressure instruments.
 - V_{true} : Calibrated pressure device from BOP tester
The calibrated test instrument is the approved pressure device.

15. Pump Rate Output Volume Field Verification

15.1. Objective

To have a consistent field verification method for pump rate.

15.2. Considerations

The following were considered for the development of the pump rate verification procedures.

- 1) Pumping at atmospheric pressure versus under pressure can result in differences in pump efficiencies.
- 2) Fluid consistency can affect pumping efficiencies and volume measurements. Foamed fluids are not recommended for the test.

15.3. Pump Rate Output Volume Procedure for Test Instrument - Tank Pit Volume

The below shall be followed for the procedure.

- 1) Personnel 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). See Table 25.

Table 25: Test Instruments for Pump Rate Output Volume Procedure for Test Instrument - Tank Pit Volume

Observed Property	Suggested Device(s)
Volume	Tank pit – calibrated volume

- 3) With the necessary valves/gates open and/or closed, transfer a pre-determined amount of liquid from one tank/pit to another. It is recommended to not use foamed fluids for the test.
- 4) Repeat the test no fewer than 3 times.
- 5) Use the table in Annex S to record the readings.
 - Display reading of volume pumped by flow rate device
 - Volume reading based upon level reading change in tank pit
- 6) Calculate error and record.
Use Equation 4.4.1, 4.4.2, and 4.4.3
 - V_{observed} : Volume pumped
The device being field verified is the drilling fluid flow rate device.
 - V_{true} : Calibrated Tank Pit Volume
The calibrated test instrument is the tank pit volume.

NOTE: This method is only performed at atmospheric pressures. Calculated efficiencies or errors may not be the same under actual operating pressures.

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Ballot Draft

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Annex A – INFORMATIVE – Surface Applied Rotary Torque Device Verification with Load Cell – Table to Record Readings (Metric)

Residual friction torque reading = _____ N·m

For section 8.3 Test Instrument – Load Cell

Moment Arm = _____ m (decimal)

θ_H , Moment arm horizontal angle = _____ degrees

θ_v , Moment arm vertical angle = _____ degrees

C, Moment arm correction factor = _____ unitless (from Annex M based on θ_H and θ_V)

Calculated Load Cell torque (N·m) = Load cell force (N) x Moment arm length (m) x C

	Planned Test Torque N-m	READING Surface Applied Rotary Torque Device, Torque N-m				READING					Error
						Load cell Force (N)					Allowed +/-
	1	2	3	4	1	2	3	4	Error in N-m		
1											
2											
3											
4											
5											
6											
7											
8											
9											

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Annex B – INFORMATIVE – Surface Applied Rotary Torque Device Verification with Load Cell – Table to Record Readings (USC)

Residual friction torque reading = _____ lbf·ft

For section 8.3 Test Instrument – Load Cell

Moment arm length = _____ ft (decimal)

θ_H , Moment arm horizontal angle = _____ degrees

θ_v , Moment arm vertical angle = _____ degrees

C, Moment arm correction factor = _____ unitless (from Annex M based on θ_H and θ_V)

Calculated Load Cell torque (lbf·ft) = Load cell force (lbf) x Moment arm length (ft) x C

	Planned Test Torque lbf-ft	READING Applied Rotary Device Torque ft-lb				READING				Error	
						Load cell Force (lb)				Allowed +/-	
											Calc Torque (lbf-ft)
		1	2	3	4	1	2	3	4	Error in lbf-ft	
1											
2											
3											
4											
5											
6											
7											
8											
9											

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Annex C – INFORMATIVE – Surface Applied Rotary Torque Device Field Verification with Strain Gauge Data Sub – Table to Record Readings (Metric)

Residual friction torque reading = _____ N·m

For section 8.4 Test Instrument – Strain Gauge Data Sub

[illegible]

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Annex D – INFORMATIVE – Surface Applied Rotary Torque Device Field Verification with Strain Gauge Data Sub – Table to Record Readings (USC)

Residual friction torque reading = _____ lbf·ft

For section 8.4 Test Instrument – Strain Gauge Data Sub

[illegible]

Annex E – INFORMATIVE– Iron Roughneck Hydraulic System Verification – Table to Record Readings (Metric)

System pressure = _____ kPa

Tank return line pressure = _____ kPa (Bias adjustment required)

	Planned Hydraulic Pressure kPa	READING Torque gauge - Pressure kPa	READING Torque gauge - Torque N-m	READING Hydraulic Pressure Test Gauge kPa	Error Allowed +/- Error in kPa
1					
2					
3					
4					
5					
6					
7					
8					
9					

Annex F – INFORMATIVE– Iron Roughneck Hydraulic System Verification – Table to Record Readings (USC)

System pressure = _____ psi

Tank return line pressure = _____ psi (Bias adjustment required)

	Planned Hydraulic Pressure psi	READING Torque gauge - Pressure psi	READING Torque gauge - Torque lbf-ft	READING Hydraulic Pressure Test Gauge psi	Error
					Allowed +/-
					Error in psi
1					
2					
3					
4					
5					
6					
7					
8					
9					

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Annex G – INFORMATIVE– Iron Roughneck Torque Verification – Table to Record Readings (Metric)

[illegible]

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Annex H – INFORMATIVE– Iron Roughneck Torque Verification – Table to Record Readings (USC)

[illegible]

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Annex I – INFORMATIVE– Cathead Force Verification – Table to Record Readings (Metric)

[illegible]

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Annex J – INFORMATIVE– Cathead Force Verification – Table to Record Readings (USC)

[illegible]

Annex K – INFORMATIVE– Cathead Torque Verification with Load Cell – Table to Record Readings (Metric)

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Annex L – INFORMATIVE– Cathead Torque Verification with Load Cell – Table to Record Readings (USC)

For section 9.3 Test Instrument – Load Cell

Moment arm length = _____ ft (decimal)

θ_H , Moment arm horizontal angle = _____ degrees

θ_v , Moment arm vertical angle = _____ degrees

C, Moment arm correction factor = _____ unitless (from Annex M based on θ_H and θ_V)

Calculated Load Cell torque (lbf·ft) = Load cell force (lbf) x Moment arm length (ft) x C

	Planned Test Torque lbf-ft	READING Make Up Torque Device, Torque lbf-ft				READING				Error
						Load cell Force (lbf)				Allowed
						Calc Torque (lbf-ft)				+/-
		1	2	3	4	1	2	3	4	Error in lbf-ft
1										
2										
3										
4										
5										
6										
7										
8										
9										

Annex M – NORMATIVE – Moment Arm Length Correction

Torque calculation is based on moment arm length that is perpendicular to the applied force. The following may be used to correct moment arm length when the moment arm horizontal and vertical angles are not 90°.

Moment arm length correction factor (C) is defined as:

$$C = \sin(\theta_H) \times \sin(\theta_V) \quad (\text{Equation E.1})$$

Where:

C = moment arm correction factor, unitless

θ_H = moment arm horizontal angle, degrees (degrees)

θ_V = moment arm vertical angle, degrees (degrees)

Table E.1—Correction Factor (C) for Calculation of Effective Moment Arm Length given Horizontal (θ_H) and Vertical (θ_V) Angles (in degrees)

		θ_H (degrees)																				
		80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
θ_V (degrees)	80	0.97	0.97	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.97	0.97
	81	0.97	0.98	0.98	0.98	0.98	0.98	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.98	0.98	0.98	0.98	0.97
	82	0.98	0.98	0.98	0.98	0.98	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.98	0.98	0.98	0.98	0.98
	83	0.98	0.98	0.98	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.98	0.98	0.98
	84	0.98	0.98	0.98	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.98	0.98	0.98
	85	0.98	0.98	0.99	0.99	0.99	0.99	0.99	0.99	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.99	0.99	0.99	0.99	0.98	0.98
	86	0.98	0.99	0.99	0.99	0.99	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.99	0.99	0.99	0.99	0.98
	87	0.98	0.99	0.99	0.99	0.99	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.99	0.99	0.99	0.99	0.98
	88	0.98	0.99	0.99	0.99	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.99	0.99	0.99	0.98
	89	0.98	0.99	0.99	0.99	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.99	0.99	0.99	0.98
	90	0.98	0.99	0.99	0.99	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.99	0.99	0.99	0.98
	91	0.98	0.99	0.99	0.99	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.99	0.99	0.99	0.98
	92	0.98	0.99	0.99	0.99	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.99	0.99	0.99	0.98
	93	0.98	0.99	0.99	0.99	0.99	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.99	0.99	0.99	0.98
	94	0.98	0.99	0.99	0.99	0.99	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.99	0.99	0.99	0.98
	95	0.98	0.98	0.99	0.99	0.99	0.99	0.99	0.99	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.99	0.99	0.99	0.99	0.98	0.98
96	0.98	0.98	0.98	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.98	0.98	0.98	
97	0.98	0.98	0.98	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.98	0.98	0.98	
98	0.98	0.98	0.98	0.98	0.98	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.98	0.98	0.98	0.98	0.98	
99	0.97	0.98	0.98	0.98	0.98	0.98	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.98	0.98	0.98	0.98	0.98	0.97	
100	0.97	0.97	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.97	0.97	

From Table E.1, if the moment arm angles (horizontal and vertical) are within +/-4° of 90°, the correction factor is 1.00 which means no correction is required since the correction is less than 0.5% (for correction factors rounded to the nearest hundredth).

Torque corrected ($T_{\text{corrected}}$) with moment arm length correction is defined as:

$$T_{\text{corrected}} = F \times L \times C \quad (\text{Equation E.2})$$

Where:

$T_{\text{corrected}}$ = Corrected torque with moment arm length correction, N·m (lbf·ft)

F = Load cell force reading, N (lbf)

L = Length of moment arm, m (ft)

C = Moment arm length correction, unitless – per Table E.1 or Equation E.1

Annex N – INFORMATIVE– Rotational Speed – Table to Record Readings

Error Allowed

RPM (+/-)

		Column 1	Column 2	
	Planned	READING	READING	Error
	Test RPM	Top Drive RPM	True RPM	(Column 1- Column 2) RPM
1	30			
2	60			
3	90			
4	120			

Annex O – INFORMATIVE– Absolute Block Position – Table to Record Readings (Metric)

Error Allowed

m (+/-)

	Column 1	Column 2	Column 3
	READING Measurement M	READING Block position m	DIFFERENCE Column 1-Column 2 m
1			
2			
3			

Annex P – INFORMATIVE– Absolute Block Position – Table to Record Readings (USC)

Error Allowed

ft (+/-)

	Column 1	Column 2	Column 3
	READING Measurement Ft	READING Block position ft	DIFFERENCE Column 1-Column 2 ft
1			
2			
3			

Annex Q – INFORMATIVE– Encoder Check – Table to Record Readings (Metric)

Error Allowed

	% (+/-) of total distance traveled
	Total distance traveled, m

	Column 1	Column 2	Column 3	
	READING (Before) Encoder M	READING (After) Encoder m	DIFFERENCE Column 1-Column 2 m	% error
1				

Annex R – INFORMATIVE– Encoder Check – Table to Record Readings (USC)

Error Allowed

	% (+/-) of total distance traveled
	Total distance traveled, ft

	Column 1	Column 2	Column 3	
	READING (Before) Encoder Ft	READING (After) Encoder ft	DIFFERENCE Column 1-Column 2 ft	% error
1				

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Annex S – INFORMATIVE– Pressure Verification – Table to Record Readings

[illegible]