

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

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

1 Scope

This document contains field verification procedures for critical drilling rig devices used in drilling operations. Its purpose 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:

- a) surface-applied rotary torque;
- b) make-up torque;
- c) hook load;
- d) rotational speed;
- e) block position;
- f) pressure; and
- g) pump rate.

This recommended practice does **NOT** address the following:

- accuracy requirements;

NOTE Accuracy requirements for a given application are determined by the operator, drilling contractor, and/or service company.

- device calibration or actions to correct accuracy issues (in respect to results of field verification and accuracy requirements);

NOTE Field verification can be performed after the corrective action to check if the corrective action resolves the accuracy issue.

- the frequency and/or trigger events for field verification.

NOTE Results from field verification can be used to determine the frequency and trigger events.

These procedures apply to rotary drilling rigs. Special considerations may have to be made for floating, slant, other nontraditional fixed rigs, and workover rigs.

2 Normative References

The following referenced document is indispensable for the application of this recommended practice. For a dated reference, only the edition cited applies. For an undated reference, the latest edition of the referenced standard applies (including any addenda/errata).

API Specification Q2, *Quality Management System Requirements for Service Supply Organizations for the Petroleum and Natural Gas Industries*

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) compares to the true value (correct value or standard).

3.1.2

drill pipe

A tubular, shaft, or other component used to transmit rotation to the drill bit and conduct 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 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

electronic drilling recorder

A system for monitoring and recording data from operations.

NOTE Also known as electronic data recorder.

3.1.8

instrument

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

3.1.9

levelness

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

3.1.10

operator

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

3.1.11

pipe slips

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

3.1.12**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.

3.1.16**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).

3.1.14**red zones**

Marked safety zones where access is limited during operations.

3.1.13**supervisor**

A person who has been given the control, direction, or supervision of work performed by one or more personnel.

NOTE Supervisors are also referred to as rig operators, operators, drillers, rig managers, company representatives, and others depending on job and area.

3.1.15**surface-applied rotary torque device**

A device on a drilling rig that applies torque on the surface to the drill string.

NOTE Examples are top drives and kelly drives.

3.2 Abbreviations and Symbols

BOP	blowout preventer
C	moment arm correction factor
EDR	electronic drilling recorder/electronic data recorder
OEM	original equipment manufacturer
rpm	revolutions per minute
QMS	quality management system
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 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 quality management system (QMS).

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

- a) force and distance for static torque;
- b) time, angular velocity, and moment of inertia for dynamic torque.

4.2 Static Torque Equation

Static torque (T_s) is defined in Equation (1):

$$T_s = F \times d \quad (1)$$

where

T_s is the static torque, in N·m (lbf·ft);

F is the force applied, in N (lbf);

d is the perpendicular distance of force from the axis of rotation, in m (ft).

4.3 Dynamic Torque Equation

Dynamic torque (T_d) is defined in Equation (2):

$$T_d = \frac{dL}{dt} \quad (2)$$

where

T_d is the dynamic torque, N·m (lbf·ft);

L is the angular momentum, $I\omega$, kg·m²/s (lb·ft²/s);

ω is the angular velocity, in rad/s (rad/s);

I is the moment of inertia, in kg·m² (lb·ft²);

t is the time, in seconds (s).

4.4 Error Equations

Having consistent error equations allows for comparison between 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 equations.

$$\text{Error} = V_{\text{observed}} - V_{\text{true}} \quad (3)$$

$$\text{Reading percentage error (\% RD)} = (V_{\text{observed}} - V_{\text{true}}) / V_{\text{true}} \quad (4)$$

$$\text{Full scale percentage error (\% FS)} = (V_{\text{observed}} - V_{\text{true}}) / V_{\text{full scale}} \quad (5)$$

where

- V_{true} is the value of reading or calculation based on the calibrated test instrument;
 V_{observed} is the value of reading or calculation from the device being field verified;
 $V_{\text{full scale}}$ is the value of full-scale reading for the device being field verified.

5 Safety

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

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

5.2 Activities shall be stopped if any safety issues are identified.

5.3 During the execution of field verification tests, red zone(s) should be identified to minimize unnecessary personnel in the working area.

6 Influences on Readings

6.1 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.

- a) operating conditions/loads:
 - 1) operating temperatures;
 - 2) operating angular velocities (rpm);
 - 3) operating angular acceleration.
- b) corrections:
 - 1) for top drives without direct torque control, torque correction may be necessary based on output rpm;
 - 2) temperature and environmental effects;

- 3) moment arm length corrections due to horizontal and vertical angle deviations from 90° (see [Annex B](#));
 - 4) sensor offset;
 - 5) calibration factors.
- c) electrical:
- 1) frays, scars, cuts, kinks, or other damage to cables that are part of the instrumentation and data aggregation system;
 - 2) damaged junction boxes that allow water intrusion or other environmental elements in affecting wiring;
 - 3) improper grounding that may include an 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;
 - 4) inadequate bonding of variable frequency drives, silicon control rectifiers, generators, pumps, or other electrically connected skids;
 - 5) induced electrical noise from: bad connection, improper insulation or isolation, colocation of high-voltage and low-voltage conductors.
- d) hydraulic: plugged filter, damaged pump, damaged valve, kinked hose, or orifice restricting flow of hydraulic fluid that could reasonably affect device performance.
- e) mechanical:
- 1) direction of movement;
 - 2) friction between bearings, sleeves, and sheaves;
 - 3) weight of lines and fluids that can add additional tension;
 - 4) worn dies resulting in slippage.
- f) hysteresis: for the system, potential hysteresis effects from friction, viscous effects, and other damping (mechanical or electrical).

6.2 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 evaluated by a qualified person to prevent unacceptable errors.

7 Documentation Review

7.1 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.

7.2 Calibration/validation documents shall be reviewed for test instruments.

7.3 The frequency of test instrument calibration shall be per the contractor/original equipment manufacturer (OEM) QMS.

EXAMPLE Load cells, strain gauge data sub, pressure gauge, etc.

7.4 Test instruments shall be traceable to an international or national measurement standard.



7.5 Where no measurement standards exist, the basis used for calibration or verification shall be recorded in accordance with API Q2, Section 5.8 (Control of Testing, Measuring, Monitoring, and Detection Equipment).

7.6 At a minimum, the following information shall be recorded for each test instrument for traceability:

- a) sensor type;
- b) make;
- c) model;
- d) serial number;
- e) last calibration date;
- f) manufacturer's recommended calibration frequency;
- g) next calibration due date;
- h) manufacturer's specified accuracy and accuracy basis (full scale or reading);
- i) application specified accuracy and accuracy basis (full scale or reading), if applicable (per customer/contractor/OEM agreement or contract).

7.7 Review previous verification results for the critical rig device.

8 Surface-applied Rotary Torque Field Verification

8.1 General

8.1.1 The objective of this section is to establish a consistent field verification method for surface-applied rotary torque.

8.1.2 Verification should be performed under conditions that are similar to those expected during well work activities. These include but are not limited to the following.

- a) operating torques (or from 20 % to 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:
 - operating angular velocities (rpm);
 - operating angular acceleration.

8.1.3 Operating torque error can vary; therefore, multiple tests from the minimum to the maximum expected operating torque should be performed.

8.1.4 Any system that can affect the 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 Considerations

8.2.1 Effect on Surface-applied Rotary Torque Field Verification

8.2.1.1 The geometry of inline load readings for the calculation of reference torque readings can result in erroneous reference readings; therefore, guidance is provided on levelness and moment arm angle.

8.2.1.3 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 can be 700 N·m to 800 N·m (500 lbf·ft to 600 lbf·ft). A minimum test torque of 4000 N·m (3000 lbf·ft) is noted as a parameter in determining torque test range.

8.2.2 Minimal to no Effect on Surface-applied Rotary Torque Verification

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

8.2.2.2 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 necessary to run the surface-applied rotary torque device at a specified oil temperature (per OEM) for these surface-applied rotary torque verification tests.

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

8.3 Static Surface-applied Rotary Torque Procedure with Test Instrument—Load Cell

The field verification procedure for static surface-applied rotary torque using a load cell shall be performed as follows.

- 1) Personnel required for the job include the following:
 - company representative (if operator, this can be well site supervisor, third-party inspector, or other designated person);
 - driller;
 - drill crew;
 - qualified personnel for load cell and test.
- 2) The parties responsible for providing test equipment shall be agreed upon beforehand. The equipment needed to perform this test includes:
 - a) a calibrated in-line load cell (for the force measurement);
 - b) a calibrated tape measure, scale, or other length measurement instrument (for the distance measurement);
 - c) a stopwatch or other timer (for elapsed-time measurement);
 - d) a protractor or quick square (for angle measurement);
 - e) a pipe or sub with appropriate connection to connect a surface rotary device to force measurement devices (load cells or other instrument(s));

- f) tongs, cables, chains, etc. (for force transmission);
 - g) a spirit or digital level (for levelness).
- 3) Define the torque test range based on surface-applied rotary drive expected operating range (minimum and maximum) for continuous torque (not intermittent torque).

— minimum torque to test = surface-applied rotary torque device working operating torque minimum or 4000 N·m (3000 lbf·ft), whichever is higher;

— maximum torque to test = surface-applied rotary torque device working operating torque maximum.

It is recommended to test the device for its manufacturer's expected operating range. If the drilling contractor/operator/OEM wants 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 N·m to 800 N·m (500 lbf·ft 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](#)):

- a) For top drives, make-up tubular to quill on the top drive. The tubular should be able to manage maximum torque to be tested.
- b) Prepare the rotary table and slip system to enable it to rotate freely. Set slips on the tubular (this is for centering the tubular in the rotary table).
- c) Engage the tong to the tubular at the output of the surface-applied rotary torque device and make the tong level with the plane of the rig floor (this is a static torque test).
- d) To prevent bending of the tubular, the tool joint on the tubular should be kept as close as possible to the pipe slips when applying torque with the tong(s) on the tool joint.

NOTE See API RP 7G for items that can affect tool joint height limitation.

- e) Affix approved tension device (i.e., tong snub line) with a calibrated in-line tension gauge (load cell) to an anchor point of the rig that is approved for the maximum test load.
- f) Check that the approved load cell is:
 - 1) aligned 90° in respect to the handle of the tong (measure and record θ_H , moment arm horizontal angle in degrees);
 - 2) level with the plane of the rig floor (measure and record θ_V , moment arm vertical angle in degrees.)
- g) Check that the output of the surface-applied rotary device, tubular, 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.
- h) Measure the distance from the center of the tubular to the tong snub line. This is the moment arm. Record the number in decimal units.