

# Directional Well Drill Pipe Grade Selection by Torque, Dogleg and Fatigue

Engineering matrix for selecting X95, G105 or S135 after the well trajectory, torque-drag load, dogleg bending, rotation exposure, connection capacity and fatigue-sensitive areas have been reviewed.

<b>Main question</b> Which load controls the drill pipe in each well section?	<b>Grades covered</b> X95, G105 and S135	<b>Decision route</b> Well section -> load path -> torque / dogleg / fatigue -> connection limit -> grade review
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## 1. API 5DP Strength Baseline

Grade	Minimum Yield Strength	Maximum Yield Strength	Minimum Tensile Strength	Directional-Well Review Position
<b>X95</b>	95 ksi / 655 MPa	125 ksi / 862 MPa	105 ksi / 724 MPa	Controlled directional sections with moderate torque, dogleg and rotation exposure.
<b>G105</b>	105 ksi / 724 MPa	135 ksi / 931 MPa	115 ksi / 793 MPa	Common higher-strength review grade for combined tension and torque with controlled fatigue demand.
<b>S135</b>	135 ksi / 931 MPa	165 ksi / 1,138 MPa	145 ksi / 1,000 MPa	Reviewed for long laterals, ERD and higher combined loading after connection and fatigue checks.

**Screening rule:** the grade number sets the pipe-body strength window. It does not establish connection torque capacity, dogleg fatigue life or internal clearance.

## 2. Load Path by Well Section

Directional-well selection should follow the most severe local load condition rather than total measured depth alone.

Well Section	Dominant Load	Main Risk	Required Review	Initial Grade Range
<b>Vertical section</b>	Axial tension and hook load	Insufficient tensile margin	Buoyed string weight, overpull and pipe-body tensile capacity	X95 / G105
<b>Build / drop section</b>	Tension plus repeated bending	Upset and connection fatigue	Dogleg severity, build rate, rotation time and transition-area stress	G105 / S135 plus fatigue review
<b>Hold section</b>	Tension, torque and drag	Connection-side loading	Pick-up / slack-off load, maximum rotary torque and shoulder contact	G105 / S135
<b>Horizontal lateral</b>	Sustained drag, rotation and contact	Cumulative fatigue and wear	Torque accumulation, rotary hours, contact force and tool joint condition	G105 / S135
<b>ERD interval</b>	Combined tension, torque, drag and bending	Reduced combined-load margin	Torque-tension envelope, buckling state, dogleg history and connection capacity	S135 or special route review

A joint can retain adequate axial tensile margin in the vertical section and still be limited by connection torque in the hold section or by repeated bending in the build section.

### 3. Torque-Drag Review and Combined-Load Effect

Torque-Drag Input	Engineering Meaning	Grade / Connection Effect
<b>Pick-up load</b>	Surface load while moving the string upward.	Supports drag calibration and upper-string tension review.
<b>Slack-off load</b>	Surface load while moving the string downward.	Shows frictional asymmetry and possible buckling / contact changes.
<b>Rotating load</b>	Axial load while the string is rotating.	Used with rotary torque to define combined operating demand.
<b>Sliding load</b>	Axial load without full-string rotation.	Can increase drag and compression in high-angle sections.
<b>Friction factor</b>	Calibrated contact-friction input in torque-drag models.	Changes predicted surface torque, drag and contact force.
<b>Maximum rotary torque</b>	Highest expected operational torque.	Reduces available tension in the combined-load envelope.
<b>Connection torque capacity</b>	Limit governed by thread, shoulder, tool joint dimensions and make-up condition.	A higher pipe-body grade does not increase this limit automatically.

Reference Condition	G105	S135	Technical Reading
<b>Pipe / connection</b>	5.000 in x 0.362 in, NC50, 80% inspection class	Same geometry and connection	Only the pipe-body grade changes.
<b>Assembly max tension at 0 torque</b>	436,100 lb	560,800 lb	S135 adds pipe-body combined-load margin at zero operational torque.
<b>Maximum MUT, friction factor 1.0</b>	30,700 ft-lb	30,700 ft-lb	The same NC50 connection retains the same recommended make-up torque.
<b>Assembly max tension near 9,500-9,600 ft-lb torque</b>	426,200 lb at 9,600 ft-lb	553,200 lb at 9,500 ft-lb	Operational torque reduces available tension in both grades.
<b>Assembly max tension near 24,000 ft-lb torque</b>	369,600 lb at 24,000 ft-lb	511,600 lb at 23,800 ft-lb	The S135 pipe body retains more combined-load margin, but the connection geometry is unchanged.

*The published reference values use a safety factor of 1.0 and uniform dimensions. Final design should use the applicable performance sheet, project design factor and current inspection data.*

## 4. Dogleg and Fatigue Control Matrix

Dogleg severity defines wellbore curvature, but fatigue damage also depends on axial load, rotation exposure, contact state and the position of each joint in the string.

Fatigue Control Point	Data to Review	Mechanism	Required Action
<b>Dogleg severity</b>	Inclination / azimuth change per survey interval; expressed as deg/100 ft or deg/30 m.	Increases curvature and alternating bending stress during rotation.	Identify high-DLS intervals and compare with axial tension and rotary exposure.
<b>Build rate / local tortuosity</b>	Planned build rate and short-interval survey changes.	Local curvature can exceed the average DLS represented by widely spaced surveys.	Use sufficient survey resolution and calibrated wellbore geometry.
<b>Rotation time / bending cycles</b>	Rotary hours, RPM and time spent across curved intervals.	Each revolution creates another bending-stress cycle.	Track cumulative exposure, not only peak stress.
<b>Axial load in the dogleg</b>	Tension or compression at the curved interval.	Changes bending stress distribution and contact behavior.	Use the local load state from the torque-drag model.
<b>Buckling / contact state</b>	Side force, sinusoidal or helical buckling indication.	Changes pipe curvature, wall contact and stress concentration.	Include stiff-string / buckling analysis for high-angle or compressive sections.
<b>Upset and friction-weld transition</b>	Geometry, NDT condition and previous fatigue exposure.	Section change creates a fatigue-sensitive transition.	Inspect and track high-exposure joints.
<b>Thread root / shoulder</b>	Thread gauge, shoulder contact, make-up history and damage.	Connection geometry experiences combined torque and bending.	Confirm connection condition before assigning high-torque service.

**Fatigue reading:** DLS alone is not a grade-selection number. The same DLS can produce different damage when axial load, pipe stiffness, contact state and accumulated rotations change.

### 5. Directional-Well Grade Boundary Matrix

Directional-Well Condition	Main Control Point	X95 Review	G105 Review	S135 / Special Review
<b>Short directional section, moderate dogleg</b>	Tensile margin and standard connection condition	Suitable when torque and bending exposure remain controlled.	Reviewed when X95 combined-load margin is limited.	Normally unnecessary unless another load controls.
<b>Higher torque, controlled fatigue</b>	Rotary torque, MUT and shoulder contact	Use only where connection and pipe-body margins remain adequate.	Common review grade.	Reviewed when torque-tension demand reduces G105 margin.
<b>Long horizontal section</b>	Torque-drag, rotary hours and cumulative fatigue	Usually limited to lower-load or shorter lateral conditions.	Suitable where cumulative fatigue and connection demand remain controlled.	Reviewed when long-lateral loading reduces G105 margin.
<b>Severe dogleg / high build rate</b>	Transition-area and connection-side fatigue	Grade alone is not sufficient.	Requires detailed fatigue review.	Higher strength does not replace fatigue management or inspection.
<b>ERD profile</b>	Combined tension, torque, drag, buckling and fatigue	Generally outside the normal X95 review window.	Can remain suitable in controlled ERD sections.	Common review when the combined-load margin exceeds G105 capability.
<b>Restricted bore / clearance</b>	Tool joint ID, upset type and drift diameter	Dimensional limit can control.	Dimensional limit can control.	Higher grade does not solve restricted clearance.

*These ranges are engineering screening boundaries rather than fixed API grade rules. Final selection requires the actual well trajectory, load model, pipe dimensions and certified assembly data.*

## 6. Dimensional and Connection Limits

Review Item	Technical Function	Directional-Well Risk	Verification
<b>Pipe OD / wall thickness</b>	Define pipe-body area, stiffness and hydraulic bore.	Wear reduces tensile and torsional capacity.	Measured minimum wall and inspection class.
<b>IU / EU / IEU upset</b>	Define end geometry and local internal / external clearance.	Transition geometry affects bending stiffness and fatigue concentration.	Dimensional report and transition-area NDT.
<b>Tool joint OD</b>	Supports connection strength and shoulder area.	External wear reduces connection / elevator margin.	Measured OD, wear table and shoulder inspection.
<b>Tool joint ID</b>	Defines bore area and tool passage.	Restricted bore can control hydraulics or downhole tool clearance.	Measured ID and drift confirmation.
<b>Drift diameter</b>	Confirms minimum internal passage through the assembly.	Grade upgrade does not correct a blocked tool path.	Recorded drift test.
<b>Recommended make-up torque</b>	Establishes connection preload and shoulder contact.	Incorrect make-up changes combined-load performance.	MUT procedure and tong record where required.
<b>Thread gauge / profile</b>	Confirms connection geometry.	Wear or damage increases local stress and connection risk.	Gauge result and visual / MPI inspection.
<b>Shoulder contact</b>	Transfers compressive and torsional load.	Poor contact reduces torque-transfer reliability.	Shoulder condition and make-up inspection.

**Assembly rule:** select the grade only after the pipe body, upset transition, tool joint and connection are confirmed to support the same combined load path.

## 7. Final Selection Flow and Verification Package

<b>Define well sections</b>	Vertical, build, hold, drop, horizontal lateral and ERD interval.
<b>Calibrate torque-drag inputs</b>	Pick-up, slack-off, rotating / sliding loads, friction factor and contact state.
<b>Identify fatigue-critical intervals</b>	Dogleg severity, local tortuosity, rotation time, axial load and buckling state.
<b>Set the initial grade range</b>	X95, G105 or S135 based on the combined-load margin.
<b>Check dimensions and connection</b>	OD / wall, upset, tool joint ID / OD, drift, MUT, threads and shoulder.
<b>Verify records</b>	MTC, tensile, dimensional, NDT, thread, shoulder and final release data.

Record / Check	What It Confirms
<b>Pipe marking + heat number</b>	Grade, size, connection and traceable production identity.
<b>MTC + tensile report</b>	Chemical and mechanical-property basis for X95, G105 or S135.
<b>Dimensional inspection</b>	OD, wall, upset, tool joint ID / OD and drift path.
<b>NDT report</b>	Pipe body, weld and transition-area defect inspection.
<b>Thread / shoulder inspection</b>	Gauge result, thread condition, shoulder contact and connection acceptance.
<b>Torque-drag and fatigue file</b>	Well section loads, operational torque, dogleg history and cumulative exposure.
<b>Final release record</b>	Links the selected grade and complete inspection package to the delivered drill pipe.

**Final technical note:** directional-well grade selection is governed by the lowest verified margin in the load path. Higher pipe-body strength is useful only when torque, fatigue, connection and clearance limits remain compatible.

## 8. Technical Reference Notes and Use Limits

Reference Basis	Data Used in This PDF	Application Limit
API RP 7G addendum	Pipe-body tension, pure torsion and tension-torsion calculation framework.	Use the applicable current edition and project-approved design method.
API 5DP grade values	X95, G105 and S135 mechanical strength windows.	Grade values do not replace dimensional, connection or fatigue review.
SPE torque-drag research	Directional and deep-well contact, friction, torque and drag behavior.	Model results depend on calibrated friction, trajectory and operating state.
SPE / technical fatigue studies	Cyclic bending, dogleg exposure, local curvature and cumulative fatigue.	DLS alone is not a fatigue acceptance limit; cumulative exposure must be assessed.
2025 G105 / S135 NC50 performance sheets	Same-geometry combined-load values at 80% inspection class.	Published values use uniform dimensions and a safety factor of 1.0 unless stated otherwise.

Use Limit	Required Engineering Check
No fixed DLS-to-grade rule	Combine dogleg severity with axial load, pipe stiffness, rotary exposure and contact state.
No fixed torque-to-grade rule	Compare operational torque with the pipe-body and connection combined-load envelope.
No depth-only grade selection	Use the actual trajectory, hook load, torque-drag output and connection capability.
No nominal-dimension assumption	Use measured wall, tool joint dimensions, wear condition and inspection class.
No grade-only fatigue conclusion	Review transition geometry, rotary hours, bending cycles, thread / shoulder condition and NDT history.

**Final decision rule:** select X95, G105 or S135 only after the governing well section, combined torque-tension demand, cumulative fatigue exposure, dimensional limits and inspection evidence are reviewed as one drill pipe assembly.

*Reference basis: API RP 7G drill pipe tension / torsion formulas; API 5DP grade mechanical values; SPE torque-drag and drillstring fatigue studies; public 2025 G105 and S135 NC50 performance sheets at 80% inspection class.*