

Drill Stem Performance Properties

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Drill Stem Performance Properties

1 Scope

This standard includes the performance properties for certain drill stem elements and gives general cautions regarding the use of the performance properties. The properties of drill pipe and tool joints, drill collars, heavy weight drill pipe, kellys, rock bits, and lift subs are given. Also provided are the properties of rotary shoulder connections and associated special processes, and break-in steps.

2 Normative References

This standard contains no normative references. For a list of associated documents, see the Bibliography.

3 Terms, Definitions, and Acronyms

3.1 Terms and Definitions

For the purposes of this document, the following definitions apply.

3.1.1

bending strength ratio

BSR

The ratio of the section modulus of a rotary shouldered box at the point in the box where the pin ends when made up divided by the section modulus of the rotary shouldered pin at the last engaged thread.

3.1.2

bevel diameter

The outer diameter of the contact face of the rotary shouldered connection.

3.1.3

bit sub

A sub, usually with 2 box connections, that is used to connect the bit to the drill string.

3.1.4

box connection

A threaded connection on oil country tubular goods (OCTG) that has internal threads.

3.1.5

calibration system

A documented system of gauge calibration and control.

3.1.6

Class 2

An API service classification for used drill pipe and tubing work strings.

3.1.7

cold working

Plastic deformation of metal at a temperature low enough to ensure or cause permanent strain.

3.1.8

corrosion

The alteration and degradation of material by its environment.

3.1.9**decarburization**

The loss of carbon from the surface of a ferrous alloy as a result of heating in a medium that reacts with the carbon at the surface.

3.1.10**dedendum**

The distance between the pitch line and root of thread.

3.1.11**drill collar**

Thick-walled pipe or tube designed to provide stiffness and concentration of weight at the bit.

3.1.12**drill pipe**

Drill pipe body with weld-on tool joints.

3.1.13**drill pipe body**

Seamless pipe with upset ends.

3.1.14**drill stem element**

All components of the drilling assembly below the swivel or top drive.

3.1.15**failure**

Improper performance of a device or equipment that prevents completion of its design function.

3.1.16**forging**

Plastically deforming metal, usually hot, into desired shapes with compressive force, with or without dies; a shaped metal part formed by the forging method.

3.1.17**kelly**

The square or hexagonal shaped steel pipe connecting the swivel to the drill string.

NOTE The kelly moves through the rotary table and transmits torque to the drill string.

3.1.18**last engaged thread**

The last thread on the pin engaged with the box or the box engaged with the pin.

3.1.19**makeup shoulder**

The sealing shoulder on a rotary shouldered connection.

3.1.20**minimum OD**

For tool joints on drill pipe with rotary shouldered connections, the minimum OD is the minimum box OD that will allow the connection to remain as strong as a specified percentage of the drill pipe tube in torsion.

3.1.21**pin end**

A threaded connection on OCTG that has external threads.

3.1.22**plain end**

Drill pipe, tubing, or casing without threads.

NOTE The pipe ends may or may not be upset.

3.1.23**premium class**

An API service classification for used drill pipe and tubing work strings.

3.1.24**quenched and tempered**

Quenching is the hardening of a ferrous alloy by austenitizing and then cooling rapidly enough so that some or all of the austenite transforms to martensite.

Tempering is the reheating of a quenched-hardened or normalized ferrous alloy to a temperature below the transformation range and then cooling at any rate desired.

3.1.25**range**

A length classification for OCTG.

3.1.26**recommended makeup torque**

The minimum amount of torque necessary to develop a specific tensile stress in the pin or compressive stress in the box.

NOTE This specific stress level is perceived as being sufficient in most drilling conditions to prevent downhole makeup and to prevent shoulder separation from bending loads, and to make sure normal weight drill pipe tool joints have sufficient tension capacity so that the drill pipe remains tube-weak in tension.

3.1.27**rotary shouldered connection**

A connection used on drill string elements that has coarse, tapered threads and sealing shoulders.

3.1.28**shear strength**

The stress required to produce fracture in the plane of cross section, the conditions of loading being such that the directions of force and of resistance are parallel and opposite although their paths are offset a specified minimum amount; the maximum load divided by the original cross-sectional area of a section separated by shear.

3.1.29**slip area**

The slip area is contained within a distance of 48 in. along the pipe body from the juncture of the tool joint OD and the elevator shoulder.

3.1.30**stress-relief feature**

A modification performed on rotary shouldered connections that removes the unengaged threads of the pin or box.

NOTE This process makes the joint more flexible and reduces the likelihood of fatigue cracking in this high-stress area.

3.1.31**tensile strength**

The maximum tensile stress that a material is capable of sustaining.

NOTE Tensile strength is calculated from the maximum load during a tension test carried to rupture and the original cross-sectional area of the specimen.

3.1.32**thread form**

The form of thread is the thread profile in an axial plane for a length of one pitch.

3.1.33**tolerance**

The amount of variation permitted.

3.1.34**tool joint**

Forged or rolled steel component for drill pipe designed to be welded to the drill pipe body and having an RSC.

3.1.35**upset**

A pipe end with increased wall thickness.

NOTE The outside diameter (OD) may be increased, or the inside diameter (ID) may be reduced, or both; upsets are usually formed by hot forging the pipe end.

3.2 Acronyms

BSR	bending strength ratio
IADC	International Association of Drilling Contractors
ID	inside diameter
OCTG	oil country tubular goods
OD	outside diameter
RSC	rotary shouldered connection
YS	yield strength

4 General Information**4.1 Safety Factors**

The values of performance properties included in this standard do not include factors of safety and are generally based on single loading conditions, tension only for example. In the design of drill stems, the effect of combined loading should be considered. Factors of safety should be used as considered necessary for the particular application.

4.2 Historical Precedent of Values

The values of performance properties included in this standard have been established over time. In some cases, they are different than if calculated using the methods provided within. Generally, these are very small differences that are insignificant. This is often due to using fewer significant figures and rounding at different stages. These values have historical precedent and are used elsewhere; therefore, they have been left unchanged unless found to be clearly in error.

4.3 Welding

Usually the materials used in the manufacture of downhole drilling equipment (tool joints, drill collars, stabilizers, and subs) are AISI 4135, 4137, 4140, or 4145 steels. These are alloy steels and are normally in the heat-treated state; these materials are not weldable unless proper procedures are used to prevent cracking and to recondition the sections where welding has been performed.

It should be emphasized that areas welded can only be reconditioned and cannot be restored to their original state free of metallurgical change unless a complete heat treatment is performed after welding, which cannot be done in the field. Performance properties in or near welded areas may be less than provided within this standard.

5 Properties of Drill Pipe and Tool Joints

The dimensional, mechanical, and performance properties of new and used drill pipe are presented in a series of tables (Table A.1 through Table A.4). Tables are also included listing these properties for tool joints used with new and used drill pipe. All of the properties and dimensional limits are based on tool joints for Grades E, X, G, S, and V, or SS grades in accordance with API 5DP. Properties and limits for SR 25 or other tool joints may be calculated using the methods in G.5 and G.8.

The torsional strength of a tool joint is a function of several variables. These include the strength of the steel, connection size, thread form, lead, taper, and coefficient of friction on mating surfaces, threads, or shoulders. The coefficient of friction for the purposes of this standard is assumed a constant; it has been demonstrated, however, that new tool joints and service temperature often affect the coefficient of friction of the tool joint system. While new tool joints typically exhibit a low coefficient of friction, service temperatures greater than 300 °F can dramatically increase or decrease the coefficient of friction depending primarily on thread compound.

The pin or box area, whichever controls, is the largest factor and is subject to the widest variation. The tool joint OD and ID largely determine the strength of the joint in torsion. The OD affects the box area and the ID affects the pin area. Choice of OD and ID determines the areas of the pin and box and establishes the theoretical torsional strength, assuming all other factors are constant.

The greatest reduction in theoretical torsional strength of a tool joint during its service life occurs with OD wear. At whatever point the tool joint box area becomes the smaller or controlling area, any further reduction in OD causes a direct reduction in torsional strength. If the box area controls when the tool joint is new, initial OD wear reduces torsional strength. If the pin controls when new, some OD wear may occur before the torsional strength is affected. Conversely, it is possible to increase torsional strength by making joints with oversize OD and reduced ID.

Dimensional limits and properties of used pipe are listed in Table A.3 and Table A.4. The tool joint to pipe torsional ratios that are used here (≥ 0.80) are recommendations only, and it should be realized that other combinations of dimensions may be used. A given assembly that is suitable for certain service may be inadequate for some areas and overdesigned for others.

Additionally, on used drill pipe the minimum tong space for pin tool joints shall be 75 % of the tool joint OD but not less than 4 in., and the box tong space shall not be less than L_{BC} (length of box connection) plus 1 in.

Figure A.1 through Figure A.25 show the theoretical torsional strength and recommended makeup torque curves of several commonly used tool joint connections over a wide range of IDs and ODs. Torsional strength is based on 120,000 psi minimum yield strength and calculated by Equation (G.10). Recommended makeup torque is based on 72,000 psi stress and calculated by Equation (G.11).

The theoretical torsional strength for a used tool joint is determined by taking the following steps.

- Select the appropriately titled curve for the size and type tool joint connection being studied.
- Extend a horizontal line from the OD under consideration to the curve and read the torsional strength representing the box.

- c) Extend a vertical line from the ID to the curve and read the torsional strength representing the pin.

The smaller of the two torsional strengths thus obtained is the theoretical torsional strength of the tool joint.

It is emphasized that the values obtained from the curves are theoretical values of torsional strength. Tool joints in the field, subject to many factors not included in determination of points for the curves, may vary from these values.

The curves are most useful to show the relative torsional strengths of joints for variations in OD and ID, both new and after wear. In each case, the smaller value should be used.

The recommended makeup torque for a used tool joint is determined by taking the following steps.

- 1) Select the appropriately titled curve for the size and type tool joint connection being studied.
- 2) Extend a horizontal line from the OD under consideration to the curve and read the recommended makeup torque representing the box.
- 3) Extend a vertical line from the ID under consideration to the curve and read the recommended makeup torque representing the pin.

The smaller of the two recommended makeup torques thus obtained is the recommended makeup torque for the tool joint.

6 Properties of Drill Collars

6.1 Weight

Table B.1 contains steel drill collar weights for a wide range of OD and ID combinations, in both API and non-API sizes. Values in the table may be used to provide the basic information required to calculate the weights of drill collar strings that are not made up of collars having uniform and standard weights.

6.2 Makeup Torque

Recommended makeup torque values for rotary shouldered drill collar connections are listed in Table B.2. These values are listed for various connection styles and for commonly used drill collar OD and ID sizes. The table also includes a designation of the weak member (pin or box) for each connection size and style.

6.3 Bending Strength Ratio (BSR)

Many drill collar connection failures are a result of bending stresses rather than torsional stresses. Figure B.1 through Figure B.7 may be used for determining the most suitable connection to be used on new drill collars or for selecting the new connection to be used on collars that have been worn down on the OD. The curves were determined from BSRs calculated by using the section modulus (Z) as the measure of the capacity of a section to resist any bending moment to which it may be subjected. The effect of stress-relief features is disregarded. The BSR is calculated using Equation (G.12). The equation's derivation and an example of its use are included in G.6.

The following BSR ranges may be used as guidelines in specifying acceptable BSRs. These apply best to collars with a uniform OD and ID throughout the length of the collar.

- Collar OD smaller than 6 in. 1.80 to 2.50.
- Collar OD 6 in. to 8 in. 2.25 to 2.75.
- Collar OD larger than 8 in. 2.50 to 3.20.

Used drill collar dimensions are limited such that these BSR ranges are kept and by a makeup torque that is acceptable to the user.

The minimum BSR acceptable in one operating area may not be acceptable in another. Local operating practices experience based on recent predominance of failures and other conditions should be considered when determining the minimum acceptable BSR for a particular area and type of operation. For proprietary connections, consult the manufacturer's guidelines for determining bending-strength ratios.

Certain other precautions should be observed in using these charts. It is imperative that adequate shoulder width and area at the end of the pin be maintained. The calculations involving BSRs are based on standard dimensions for all connections.

Minor differences between measured ID and IDs in Figure B.1 through Figure B.7 are of little significance; therefore, select the figure with the ID closest to measured ID.

6.4 Elevator Grooves

There is no accepted way to reasonably determine the lifting capacity of the elevator groove shoulder. Even a small amount of wear can significantly reduce the lifting capacity. Therefore, elevator grooves should not be used for lifting.

7 Properties of Heavy Weight Drill Pipe

Table C.1 provides the performance properties for heavy weight drill pipe defined in API 7-1.

Table C.2 provides the dimensional limits and performance properties for used heavy weight drill pipe. Additionally, on used heavy weight drill pipe a minimum of 10 in. tong space shall be present at each end and eccentric wear on the center upset is limited to $\frac{1}{8}$ in. maximum.

For this purpose, eccentric wear is taken to be the difference between:

- the pad height from the tube OD, taken at the point where the pad height is the greatest, and
- the pad height from the tube OD, taken at the point where the pad height is the least.

NOTE Properties of heavy weight drill pipe products not defined in API 7-1 are not provided in this standard; contact the respective manufacturer for properties.

8 Properties of Kellys

8.1 General

Kellys are manufactured with one of two drive configurations, square or hexagonal. Dimensions are given in API 7-1. The performance properties of new kellys is given in Table D.1 and of re-machined kellys in Table D.2.

Square kellys are furnished as forged or machined in the drive section. On forged kellys, the drive sections are normalized and tempered, and the ends are quenched and tempered.

Hexagonal or fully machined square kellys are machined from round bars. Heat treatment may be either:

- full-length quenched and tempered before machining; or
- the drive section normalized and tempered, and the ends quenched and tempered.

It should be noted that fully quenched drive sections have higher minimum tensile yield strength than normalized drive sections when tempered to the same hardness level. For the same hardness level, the ultimate tensile strength may be considered as the same in both cases.

8.2 Selection Criteria

The following criteria should be considered in selecting square or hexagonal kellys.

- a) It may be observed from Table D.1 that the drive section of the hexagonal kelly is stronger than the drive section of the square kelly when the appropriate kelly is selected for a given casing size; e.g. a 4¹/₄-in. square kelly or a 5¹/₄-in. hexagonal kelly would be selected for use in 8⁵/₈-in. casing.

It may also be observed, however, that the connections on these two kellys are generally the same and unless the bores (IDs) are the same, the kelly with the smaller bore could be interpreted to have the greater pin tensile and torsional strength.

- b) For a given tensile load, the stress level is less in the hexagonal section.

Due to the lower stress level, the endurance limit of the hexagonal drive section is greater in terms of cycles to failure for a given bending load.

- c) Surface decarburization (decarb) is inherent in the as-forged square kelly, which further reduces the endurance limit in terms of cycles to failure for a given bending load. Hexagonal kellys and fully machined squares have machined surfaces and are generally free of decarb in the drive section.

It is impractical to remove the decarb from the complete drive section of the forged square kelly; however, the decarb should be removed from the corners in the fillet between the drive section and the upset to aid in the prevention of fatigue cracks in this area. Machining of square kellys from round bars could eliminate this undesirable condition.

- d) The life of the drive section is directly related to the kelly fit with the kelly drive. A square drive section normally will tolerate a greater clearance with acceptable life than will a hexagonal section. A diligent effort by the rig personnel to maintain minimum clearance between the kelly drive section and the bushing will minimize this consideration in kelly selection.

New roller bushing assemblies working on new kellys will develop wear patterns that are essentially flat in shape on the driving edge of the kelly. Wear patterns begin as point contacts of zero width near the corner. The pattern widens as the kelly and bushing begin to wear until a maximum wear pattern is achieved. The wear rate will be the least when the maximum wear pattern width is achieved.

Figure D.1 illustrates the maximum width flat wear pattern that could be expected on the kelly drive flats if the new assembly has clearances as shown in Table D.3. The information in Table D.3 and Figure D.1 and Figure D.2 may be used to evaluate the clearances between kelly and bushing. This evaluation should be made as soon as a wear pattern becomes apparent after a new assembly is put into service.

EXAMPLE At the time of evaluation, the wear pattern width for a 5¹/₄-in. hexagonal kelly is 1.00 in.

This could mean one of the following two conditions exist.

- 1) If the contact angle is less than 8 degrees 37 minutes, the original clearances were acceptable; in this case, the wear pattern is not fully developed.
- 2) If the contact angle is greater than 8 degrees 37 minutes, the wear pattern is fully developed; in this case, the clearance is greater than is recommended and would need to be corrected.

8.3 Extending Life of Kellys—Re-machining and Reversing Ends

8.3.1 Re-machining

Before attempting to re-machine a kelly, it should be fully inspected for fatigue cracks and also dimensionally checked to assure that it is suitable for re-milling. The strength of a re-machined kelly should be compared with the strength of the drill pipe with which the kelly is to be used. (See Table D.2 for drive section dimensions and strengths.)

8.3.2 Reversing Ends

Usually both ends of the kelly shall be butt welded (stubbed) for this to be possible as the original top is too short and the old lower end is too small in diameter for the connections to be reversed. The welds should be made in the upset portions on each end to ensure the tensile integrity and fatigue resistance capabilities of the sections. Proper heating and welding procedures shall be used to prevent cracking and to recondition the sections where welding has been performed.

8.4 Internal Pressure at Minimum Yield

The internal pressure at minimum yield for the drive section may be calculated from Equation (G.6).

9 Classification and Properties of Rock Bits

A classification system for designating roller cone rock bits was developed by the International Association of Drilling Contractors (IADC). The system designates bits according to the type of bit (steel tooth or insert), the type of formation drilled, and mechanical features of the bit, where the classification forms may be obtained from IADC.

a) Recommended Torque

Recommended torque for fixed cutter bits is shown in Table E.1. Recommended torque for roller cone bits is shown in Table E.2.

b) Common Bit Sizes

Common sizes for roller bits are listed in Table E.3. Common sizes for fixed cutter bits are listed in Table E.4. Other sizes may be available by request from the manufacturer.

10 Properties of Lift Subs—Yield Load

The yield load for lift subs manufactured according to API 7-1 is provided in Table F.1. A safety factor should be applied to determine the safe working load.

11 Properties of Rotary Shouldered Connections

11.1 Purpose

The threads on rotary shouldered connection do not form a seal but act as a jackscrew to force the shoulders together. By forcing the shoulders together under high load, the shoulders provide the necessary seal to prevent leakage.

The connection acts as a structural member in the drilling assembly. This means that the connection shall be strong in torsion, tension, and bending; strong in torsion to take the rotational forces as the bit turns, strong enough in tension to lift the drill string from the hole, and strong in bending strength to resist fatigue failures.

The rotary shouldered connection is designed with the best overall combination of these functions to utilize the tensile and torsional strength of the steel, maximum possible stiffness, and shoulder sealing efficiency.

The ideal condition would be to have the connection as stiff and strong as the body of the drill stem member of which it is a part. Since this is not practical, design calculations are made to obtain the best balance between relative capacities of the box and pin to resist bending; the best torsional balance to give optimum shoulder load to prevent shoulder separation and to provide ample tensile load requirements.

The shoulders acting under high compressive load form the only sealing surface. All threads on rotary shouldered connections are purposely truncated to prevent interference between the thread crests and thread roots, in addition to providing a space for excess thread compound and foreign particles in the drilling fluid. The space between the box counterbore and pin base also serves this purpose.

NOTE This space between the box counterbore and pin base, as well as the space between the non-loaded thread flanks, forms a helical opening that follows the thread all the way to the bore of the connection.

The shoulders should always be treated with care and good rig practices to ensure proper sealing.

11.2 Interchangeable Connections

Many sizes and styles of connections are interchangeable with certain others. These conditions differ only in name and in some cases thread form. A table of interchangeable connections is provided in API 7-2.

11.3 Recommended Makeup Torque

Recommended makeup torque values for drill pipe tool joint connections are listed in Table A.2, Table A.3, and Table A.4 and also shown in Figure A.1 through Figure A.25.

Recommended makeup torques for drill collars connections are shown in Table B.2; these values are listed for various connection styles and for commonly used OD and ID sizes. Most of the other bottomhole assembly components (subs, reamers, stabilizers, and other tools between the drill pipe and the bit) should follow Table B.2 or manufacturer's recommendations.

Recommended makeup torques for drill bits are provided in Table E.1 and Table E.2. Makeup torque is calculated using Equation (G.11).

11.4 Torque to Yield

Torque to yield of drill pipe tool joint connections are listed in Table A.2, Table A.3, and Table A.4. Torque to yield is calculated using Equation (G.10).

11.5 Bending Strength Ratio (BSR)

The BSR for drill collar connections with a variety of ODs and IDs are shown in Figure B.1 through Figure B.7. The effect of stress-relief features is disregarded when calculating the BSR. The BSR is calculated using Equation (G.12). The equation's derivation and an example of its use are included in G.6.

11.6 Stress-relief Features

11.6.1 Relief Grooves

Stress is concentrated in the thread roots of rotary shouldered connections. Relief grooves were designed to remove the thread roots and spread the bending over a larger area. Original laboratory fatigue tests performed by several drill collar manufacturers in the 1950s demonstrated the beneficial effects of the stress-relief grooves at the pin shoulder and at the base of the box thread.

These laboratory tests indicated an improvement by raising the fatigue life of the connections by as much as fourfold to fivefold. Subsequent tests made under actual service conditions verified the improvement in fatigue life gained if these features are provided. Finite element analysis of pin stress-relief grooves in the 1990s further confirmed the benefit and established the groove length limits for new and used products.

11.6.2 Box Bore Back Relief Feature

The relief groove on the pin is easy to machine because the machinist can see their work. But machining the relief groove in the box presents problems. One of the problems of machining a relief groove in the box is the ability of the machinist to see over the thread crest and thus assure the surfaces of the groove were smooth and free of tool marks. The surface of relief features should be free of machining marks for benefits to be seen.

The bore back relief feature was designed to eliminate these problems. Instead of a groove, the bore back is cut as a cylinder with the taper of the threads causing the thread roots to gradually vanish at the back of the box.

The bore back is the preferred relief feature for the box, but the box relief groove is still available as an alternate.

11.7 Torsional Balance

Torsional balance exists for a connection when the box area, A_b , is equal to the pin area, A_p . It can be expressed as the A_b/A_p ratio, where $A_b/A_p = 1.00$ is balanced. This is ideal because the recommended makeup torque yields equal magnitude compressive stress in the box and tensile stress in the pin, and the maximum compressive stress in the box is achieved. It is this compressive stress that keeps the shoulders together.

An A_b/A_p ratio less than 1.00 is box-weak and will also have the maximum compressive stress in the box when made up to the recommended makeup torque. The stress in the box is equal to the makeup stress level, S .

An A_b/A_p ratio greater than 1.00 is pin-weak. As the ratio increases greater than 1.00, the compressive stress in the box decreases and it becomes increasingly more difficult to keep the shoulders from opening while rotating.

EXAMPLE If the A_b/A_p ratio is 1.20 on a drill collar connection, the average compressive stress in the box is reduced to 52,083 psi; and if the ratio is 1.50, the average compressive stress in the box will be further reduced to 41,667 psi. This may not be enough compression to offset the bending caused by rotation and other downhole conditions; where the result could be the shoulders open on the outer periphery, the thread compound is lost and galling of the shoulders and hard-to-break connections occur.

Warning—It is critical to follow proper makeup procedures and apply the correct amount of makeup torque if the A_b/A_p ratio is greater than 1.00.

If the ratio is greater than 1.20, it may be necessary to apply more makeup torque than that which is recommended in Table B.1. The exact amount depends upon the drilling conditions. Remember the recommended range is the tabulated value to plus 10 %. If galling still persists, increase the torque in 5 % increments until the problem disappears.

In large diameter drill collars, it is very difficult to select a connection where the A_b/A_p ratio is near 1.00 because the number of connections to select from is limited to a very few. The solution to this problem is to use the low torque feature to reduce box area.

11.8 Low Torque Feature

The low torque feature does not reduce the makeup required for the connection unless it is used on an OD smaller than the minimum OD for which it is recommended.

It does not change the BSR discussed in 11.5 if the OD is the same. But it does permit the use of BSRs as large as 3.40.

The torsional area of the box connections machined with the low torque feature is reduced because the counterbore is cut to a diameter larger than the counterbore on a standard “full faced” connection.

With the box torsional area reduced, the A_b/A_p ratio is reduced and the compressive stress in the shoulders is increased.

Caution—Connections with the low torque feature are not intended to be mated with connections with the standard “full face” because both the outside bevels and the counterbores are different. To mate such a difference will reduce the contact face by as much as 50 %, causing the shoulders to yield in compression.

11.9 Cold Working

Stress is concentrated in the thread roots of a rotary shouldered connection, and cyclic loading (bending while rotating) often results in fatigue. At about the same time research work was being performed on stress-relief features, laboratory investigations were done as to the benefits of cold working the thread roots. The conclusions of these tests indicated almost the same improvements could be achieved by cold working the thread roots of the thread.

Cold working the thread roots raises the fatigue life of the connection by as much as four times over the limit of a non-cold-worked thread. Cold working puts the thread root into a compressive state by yielding the surface of the thread root. With the surface in compression, the connection can withstand higher bending loads before fatigue begins.

Cold working can be applied by several methods: cold rolling under pressure with a roller shaped like the thread form (API 7CR), shot peening, or by working with a small special shaped air hammer.

The gauging of the connection should be done before cold working because the gauge standoff will change. But the process will not interfere with the makeup of the connection.

12 Connection Break-in

Based on field experience, it has been observed that used rotary shouldered connections are less likely to gall than new connections. It is believed that this is due to work hardening the connection surfaces. The process of connection break-in is a makeup and breakout of the connection under controlled conditions to provide surface work hardening prior to use.

Since many factors affect connection galling, connection break-in does not eliminate the possibility of galling. Connection break-in may be done on the rig, as an optional manufacturing step, or at a service facility. The following steps should be followed during break-in.

a) Preparation for Connection Break-in

- 1) Remove any storage or rust preventative coatings.
- 2) Make sure that the connections are free of dirt or other debris.
- 3) Thoroughly coat the threads and shoulders of both pin and box connections with a thread compound suitable for rotary shouldered connections.
- 4) Determine the recommended makeup torque of the connection as described in 11.3.

b) Connection Break-in at the Rig

- 1) Taking care to align the connection, stab and prepare to make up the connection slowly.

NOTE Galling may occur if not well aligned or spinning together with a chain or high-speed power spinner.

Then, using a calibrated torque gauge or line pull indicator, slowly make up to the recommended makeup torque; if using manual tongs, use both sets of tongs and keep lines at 90° for the final torque. Excessive

resistance or other signs that could indicate the possibility of galling may occur during both makeup and breakout.

- 2) Slowly break out the connection.
- 3) Wipe clean the pin and box connections and visually inspect for evidence of galling in the threads or sealing shoulders. If galling occurs, the connection shall be repaired in accordance with API 7G-2 prior to use.

c) Connection Break-in During Manufacturing

- 1) When performing break-in at the factory or service facility, the connection should be finished machined, inspected, cold rolled (if specified), and surface treatments applied (if required) prior to performing break-in of the connection.

NOTE Break-in will change thread gauge standoff.

- 1) Slowly make up three times to the recommended torque.
- 2) Between each makeup, break out only far enough to apply additional thread compound to the shoulders and last engaged threads.
- 3) Break out the connection after final makeup.
- 4) Wipe clean the pin and box and visually inspect for galling on the threads or shoulder; if galling occurs, the connection is rejected.

Annex A
(informative)

Properties of Drill Pipe and Tool Joints

Table A.1—New Drill Pipe Body Dimensional Data

(1)	(2)	(3)	(4)	(5)	(6)	(7)
Label 1 (in.) D_{dp}	Label 2	Plain End Weight ^a (lb/ft) w_{pe}	Wall Thickness (in.) t	ID ^b (in.) d_{dp}	Section Area Body of Pipe ^c (in. ²) A	Polar Sectional Modulus ^d (in. ³) Z
$2\frac{3}{8}$	4.85	4.43	0.190	1.995	1.3042	1.321
	6.65	6.26	0.280	1.815	1.8429	1.733
$2\frac{7}{8}$	6.85	6.16	0.217	2.441	1.8120	2.241
	10.40	9.72	0.362	2.151	2.8579	3.204
$3\frac{1}{2}$	9.50	8.81	0.254	2.992	2.5902	3.923
	13.30	12.31	0.368	2.764	3.6209	5.144
	15.50	14.63	0.449	2.602	4.3037	5.847
4	11.85	10.46	0.262	3.476	3.0767	5.400
	14.00	12.93	0.330	3.340	3.8048	6.458
	15.70	14.69	0.380	3.240	4.3216	7.157
$4\frac{1}{2}$	13.75	12.24	0.271	3.958	3.6004	7.184
	16.60	14.98	0.337	3.826	4.4074	8.543
	20.00	18.69	0.430	3.640	5.4981	10.232
	22.82	21.36	0.500	3.500	6.2832	11.345
5	16.25	14.87	0.296	4.408	4.3743	9.718
	19.50	17.93	0.362	4.276	5.2746	11.415
	25.60	24.03	0.500	4.000	7.0686	14.491
	TW 0.750	34.04	0.750	3.500	10.0138	18.651
$5\frac{1}{2}$	19.20	16.87	0.304	4.892	4.9624	12.221
	21.90	19.81	0.361	4.778	5.8282	14.062
	24.70	22.54	0.415	4.670	6.6296	15.688
	TW 0.500	26.70	0.500	4.500	7.8540	18.028
	TW 0.625	32.54	0.625	4.250	9.5720	21.020
	TW 0.750	38.05	0.750	4.000	11.1919	23.528
$5\frac{7}{8}$	23.4	21.26	0.361	5.153	6.2535	16.251
	26.3	24.20	0.415	5.045	7.1185	18.165
	TW 0.625	35.04	0.625	4.625	10.3084	24.523
	TW 0.750	41.05	0.750	4.375	12.0755	27.571
	TW 0.813	43.95	0.813	4.249	12.9289	28.922
$6\frac{5}{8}$	25.20	22.19	0.330	5.965	6.5262	19.572
	27.70	24.21	0.362	5.901	7.1227	21.156
	TW 0.522	34.02	0.522	5.581	10.0084	28.340
	TW 0.625	40.05	0.625	5.375	11.7810	32.356
	TW 0.750	47.06	0.750	5.125	13.8426	36.647
	TW 0.813	50.47	0.813	4.999	14.8445	38.585

^a Plain end weight is calculated using Equation (G.16).

^b $d_{dp} = D_{dp} - 2t$

^c $A = \frac{\pi}{4} (D_{dp}^2 - d_{dp}^2)$

^d $Z = \frac{\pi}{16} \frac{(D_{dp}^4 - d_{dp}^4)}{D_{dp}}$

Table A.2—New Drill Pipe Properties

Label 1	Label 2	Grade	Upset Type	RSC Type ^a	New Drill Pipe									
					Box OD (in.)	Pin ID (in.)	Approx. Mass (lb/ft)	Makeup Torque ^{b c} (ft-lb)	Tensile Yield Pipe Body (lb)	Tensile Yield Tool Joint (lb)	Torsional Yield Pipe Body (ft-lb)	Torsional Yield Tool Joint ^d (ft-lb)	Collapse Pressure Pipe Body (psi)	Max. Internal Pressure Pipe Body (psi)
2 ³ / ₈	4.85	E	EU	2 ³ / ₈ OH LW	3 ¹ / ₈	2	4.95	2,716 P	97,817	206,416	4,763	4,526 p	11,040	10,500
2 ³ / ₈	4.85	E	EU	2 ³ / ₈ SL H90	3 ¹ / ₄	2	5.05	3,042 P	97,817	202,670	4,763	5,075 p	11,040	10,500
2 ³ / ₈	4.85	E	EU	2 ³ / ₈ WO	3 ³ / ₈	2	5.15	2,541 P	97,817	195,677	4,763	4,235 p	11,040	10,500
2 ³ / ₈	4.85	E	EU	NC26	3 ³ / ₈	1 ³ / ₄	5.26	4,125 B	97,817	313,681	4,763	6,875 b	11,040	10,500
2 ³ / ₈	6.65	E	EU	2 ³ / ₈ OH LW	3 ¹ / ₄	1 ³ / ₄	6.89	3,783 B	138,214	294,620	6,250	6,305 b	15,599	15,474
2 ³ / ₈	6.65	E	IU	2 ³ / ₈ PAC *	2 ⁷ / ₈	1 ³ / ₈	6.71	2,803 P	138,214	238,504	6,250	4,672 P	15,599	15,474
2 ³ / ₈	6.65	E	EU	2 ³ / ₈ SL H90	3 ¹ / ₄	2	6.78	3,042 P	138,214	202,850	6,250	5,075 p	15,599	15,474
2 ³ / ₈	6.65	E	EU	NC26	3 ³ / ₈	1 ³ / ₄	7.02	4,125 B	138,214	313,681	6,250	6,875 b	15,599	15,474
2 ³ / ₈	6.65	X	EU	2 ³ / ₈ SL H90	3 ¹ / ₄	1 ¹³ / ₁₆	6.99	4,109 P	175,072	270,223	7,917	6,862 p	19,759	19,600
2 ³ / ₈	6.65	X	EU	NC26	3 ³ / ₈	1 ³ / ₄	7.11	4,125 B	175,072	313,681	7,917	6,875 b	19,759	19,600
2 ³ / ₈	6.65	G	EU	2 ³ / ₈ SL H90 *	3 ¹ / ₄	1 ¹³ / ₁₆	6.99	4,109 P	193,500	270,223	8,751	6,862 P	21,839	21,663
2 ³ / ₈	6.65	G	EU	NC26 *	3 ³ / ₈	1 ³ / ₄	7.11	4,125 B	193,500	313,681	8,751	6,875 b	21,839	21,663
2 ⁷ / ₈	6.85	E	EU	2 ⁷ / ₈ OH LW *	3 ³ / ₄	2 ⁷ / ₁₆	6.93	3,290 B	135,902	223,937	8,083	5,464 P	10,467	9,907
2 ⁷ / ₈	6.85	E	EU	2 ⁷ / ₈ SL H90	3 ⁷ / ₈	2 ⁷ / ₁₆	7.05	4,504 P	135,902	260,783	8,083	7,513 p	10,467	9,907
2 ⁷ / ₈	6.85	E	EU	2 ⁷ / ₈ WO	4 ¹ / ₈	2 ⁷ / ₁₆	7.31	4,209 P	135,902	277,553	8,083	7,015 p	10,467	9,907
2 ⁷ / ₈	6.85	E	EU	NC31	4 ¹ / ₈	2 ¹ / ₈	7.50	7,074 P	135,902	447,130	8,083	11,790 p	10,467	9,907
2 ⁷ / ₈	10.40	E	EU	2 ⁷ / ₈ OH SW *	3 ⁷ / ₈	2 ⁵ / ₃₂	10.59	5,194 P	214,344	345,566	11,554	8,659 P	16,509	16,526
2 ⁷ / ₈	10.40	E	IU	2 ⁷ / ₈ PAC *	3 ¹ / ₈	1 ¹ / ₂	10.27	3,424 P	214,344	272,938	11,554	5,706 P	16,509	16,526
2 ⁷ / ₈	10.40	E	EU	2 ⁷ / ₈ SL H90	3 ⁷ / ₈	2 ⁵ / ₃₂	10.59	6,732 P	214,344	382,765	11,554	11,227 p	16,509	16,526
2 ⁷ / ₈	10.40	E	IU	2 ⁷ / ₈ XH	4 ¹ / ₄	1 ⁷ / ₈	11.19	7,853 P	214,344	505,054	11,554	13,088 p	16,509	16,526
2 ⁷ / ₈	10.40	E	IU	NC26 *	3 ³ / ₈	1 ³ / ₄	10.35	4,125 B	214,344	313,681	11,554	6,875 B	16,509	16,526
2 ⁷ / ₈	10.40	E	EU	NC31	4 ¹ / ₈	2 ¹ / ₈	10.92	7,074 P	214,344	447,130	11,554	11,790 p	16,509	16,526
2 ⁷ / ₈	10.40	X	EU	2 ⁷ / ₈ SL H90 *	3 ⁷ / ₈	2 ⁵ / ₃₂	10.74	6,732 P	271,503	382,329	14,635	11,208 P	20,911	20,933
2 ⁷ / ₈	10.40	X	EU	2 ⁷ / ₈ SL H90	4	2	10.95	7,859 P	271,503	443,971	14,635	13,119 p	20,911	20,933
2 ⁷ / ₈	10.40	X	EU	NC31	4 ¹ / ₈	2	11.09	7,895 P	271,503	495,726	14,635	13,158 p	20,911	20,933

Label 1	Label 2	Grade	Upset Type	RSC Type ^a	New Drill Pipe									
					Box OD (in.)	Pin ID (in.)	Approx. Mass (lb/ft)	Makeup Torque ^{b c} (ft-lb)	Tensile Yield Pipe Body (lb)	Tensile Yield Tool Joint (lb)	Torsional Yield Pipe Body (ft-lb)	Torsional Yield Tool Joint ^d (ft-lb)	Collapse Pressure Pipe Body (psi)	Max. Internal Pressure Pipe Body (psi)
2 ⁷ / ₈	10.40	G	EU	2 ⁷ / ₈ SL H90	4	2	10.95	7,859 P	300,082	443,971	16,176	13,119 p	23,112	23,137
2 ⁷ / ₈	10.40	G	EU	NC31	4 ¹ / ₈	2	11.09	7,895 P	300,082	495,726	16,176	13,158 p	23,112	23,137
2 ⁷ / ₈	10.40	S	EU	2 ⁷ / ₈ SL H90	4 ¹ / ₈	1 ⁵ / ₈	11.26	10,264 P	385,820	572,089	20,798	17,130 p	29,716	29,747
2 ⁷ / ₈	10.40	S	EU	NC31	4 ³ / ₈	1 ⁵ / ₈	11.55	10,086 P	385,820	623,844	20,798	16,809 p	29,716	29,747
3 ¹ / ₂	9.50	E	EU	3 ¹ / ₂ OH LW	4 ¹ / ₂	3	9.84	7,082 P	194,264	392,071	14,146	11,803 p	10,001	9,525
3 ¹ / ₂	9.50	E	EU	3 ¹ / ₂ OH LW	4 ³ / ₄	3	10.34	7,082 P	194,264	392,071	14,146	11,803 p	10,001	9,525
3 ¹ / ₂	9.50	E	EU	3 ¹ / ₂ SL H90	4 ⁵ / ₈	3	9.99	7,469 P	194,264	366,705	14,146	12,458 p	10,001	9,525
3 ¹ / ₂	9.50	E	EU	3 ¹ / ₂ WO	4 ³ / ₄	3	10.14	7,633 P	194,264	419,797	14,146	12,723 p	10,001	9,525
3 ¹ / ₂	9.50	E	EU	NC38	4 ³ / ₄	2 ¹¹ / ₁₆	10.60	10,843 P	194,264	587,308	14,146	18,071 p	10,001	9,525
3 ¹ / ₂	9.50	E	EU	NC38	4 ³ / ₄	3	10.34	7,595 P	194,264	419,797	14,146	12,657 p	10,001	9,525
3 ¹ / ₂	9.50	SS75	EU	NC38	4 ³ / ₄	2 ¹¹ / ₁₆	10.72	9,934 P	194,264	538,133	14,146	16,557 p	10,001	9,525
3 ¹ / ₂	13.30	E	EU	3 ¹ / ₂ H90	5 ¹ / ₄	2 ³ / ₄	14.37	14,043 B	271,569	664,050	18,551	23,443 p	14,113	13,800
3 ¹ / ₂	13.30	E	EU	3 ¹ / ₂ OH SW	4 ³ / ₄	2 ¹¹ / ₁₆	13.75	10,300 P	271,569	559,582	18,551	17,167 p	14,113	13,800
3 ¹ / ₂	13.30	E	EU	3 ¹ / ₂ XH	4 ³ / ₄	2 ⁷ / ₁₆	13.91	10,120 P	271,569	570,939	18,551	16,867 p	14,113	13,800
3 ¹ / ₂	13.30	E	IU	NC31 *	4 ¹ / ₈	2 ¹ / ₈	13.40	7,074 P	271,569	447,130	18,551	11,790 P	14,113	13,800
3 ¹ / ₂	13.30	E	EU	NC38	4 ³ / ₄	2 ¹¹ / ₁₆	13.96	10,843 P	271,569	587,308	18,551	18,071 p	14,113	13,800
3 ¹ / ₂	13.30	SS75	EU	NC38	4 ³ / ₄	2 ¹¹ / ₁₆	14.05	9,934 P	271,569	538,133	18,551	16,557 p	14,113	13,800
3 ¹ / ₂	13.30	X	EU	3 ¹ / ₂ H90	5 ¹ / ₄	2 ³ / ₄	14.60	14,043 B	343,988	664,050	23,498	23,443 p	17,877	17,480
3 ¹ / ₂	13.30	X	EU	3 ¹ / ₂ SL H90 *	4 ⁵ / ₈	2 ¹¹ / ₁₆	13.98	11,073 P	343,988	533,686	23,498	18,438 P	17,877	17,480
3 ¹ / ₂	13.30	X	EU	3 ¹ / ₂ SL H90	4 ³ / ₄	2 ⁹ / ₁₆	14.06	12,408 P	343,988	596,066	23,498	20,709 p	17,877	17,480
3 ¹ / ₂	13.30	X	EU	NC38	5	2 ⁹ / ₁₆	14.62	12,057 P	343,988	649,158	23,498	20,095 p	17,877	17,480
3 ¹ / ₂	13.30	SS95	EU	NC38	5	2 ¹ / ₈	14.91	14,577 P	343,988	772,236	23,498	24,294 p	17,877	17,480
3 ¹ / ₂	13.30	G	EU	3 ¹ / ₂ SL H90	4 ³ / ₄	2 ⁹ / ₁₆	14.06	12,408 P	380,197	596,066	25,972	20,709 p	19,758	19,320
3 ¹ / ₂	13.30	G	EU	NC38	5	2 ⁷ / ₁₆	14.72	13,221 P	380,197	708,063	25,972	22,035 p	19,758	19,320
3 ¹ / ₂	13.30	S	EU	3 ¹ / ₂ SL H90	5	2 ¹ / ₈	14.65	16,667 P	488,825	789,348	33,392	27,809 p	25,404	24,840
3 ¹ / ₂	13.30	S	EU	NC38	5	2 ¹ / ₈	14.93	15,902 P	488,825	842,440	33,392	26,503 P	25,404	24,840
3 ¹ / ₂	13.30	S	EU	NC40	5 ³ / ₈	2 ⁷ / ₁₆	15.13	17,858 P	488,825	897,161	33,392	29,764 p	25,404	24,840

Label 1	Label 2	Grade	Upset Type	RSC Type ^a	New Drill Pipe									
					Box OD (in.)	Pin ID (in.)	Approx. Mass (lb/ft)	Makeup Torque ^{b c} (ft-lb)	Tensile Yield Pipe Body (lb)	Tensile Yield Tool Joint (lb)	Torsional Yield Pipe Body (ft-lb)	Torsional Yield Tool Joint ^d (ft-lb)	Collapse Pressure Pipe Body (psi)	Max. Internal Pressure Pipe Body (psi)
3 1/2	13.30	V	EU	NC38 *	5	2 1/8	14.91	15,902 P	543,135	842,440	37,125	26,503 P	28,226	27,600
3 1/2	15.50	E	EU	NC38	5	2 9/16	16.58	12,057 P	322,775	649,158	21,086	20,095 p	16,774	16,838
3 1/2	15.50	SS75	EU	NC38	5	2 9/16	16.71	11,048 P	322,775	594,840	21,086	18,413 p	16,774	16,838
3 1/2	15.50	X	EU	NC38	5	2 7/16	16.84	13,221 P	408,848	708,063	26,708	22,035 p	21,247	21,328
3 1/2	15.50	SS95	EU	NC40	5 1/2	2 1/4	17.33	17,982 P	408,848	898,330	26,708	29,969 p	21,247	21,328
3 1/2	15.50	G	EU	NC38	5	2 1/8	17.06	15,902 P	451,885	842,440	29,520	26,503 p	23,484	23,573
3 1/2	15.50	G	EU	NC40	5 1/4	2 9/16	16.97	16,616 P	451,885	838,257	29,520	27,693 p	23,484	23,573
3 1/2	15.50	S	EU	NC38 *	5	2 1/8	17.05	15,902 P	580,995	842,440	37,954	26,503 P	30,194	30,308
3 1/2	15.50	S	EU	NC40	5 1/2	2 1/4	17.60	19,616 P	580,995	979,996	37,954	32,693 p	30,194	30,308
3 1/2	15.50	V	EU	NC40 *	5 1/2	2 1/4	17.33	19,616 P	645,555	979,996	42,197	32,694 P	33,549	33,675
4	11.85	E	IU	4 H90	5 1/2	2 13/16	13.00	21,185 P	230,755	913,708	19,474	35,308 p	8,381	8,597
4	11.85	E	EU	4 OH LW	5 1/4	3 15/32	12.10	13,186 P	230,755	621,357	19,474	21,903 p	8,381	8,597
4	11.85	E	EU	4 WO	5 1/4	3 7/16	12.91	17,186 P	230,755	782,987	19,474	28,643 p	8,381	8,597
4	11.85	E	EU	NC46	6	3 1/4	13.52	19,937 P	230,755	901,164	19,474	33,228 p	8,381	8,597
4	14.00	E	IU	4 H90	5 1/2	2 13/16	15.43	21,185 P	285,359	913,708	23,288	35,308 p	11,354	10,828
4	14.00	E	EU	4 OH SW	5 1/2	3 1/4	15.02	16,236 P	285,359	759,875	23,288	27,060 p	11,354	10,828
4	14.00	E	IU	4 SH *	4 5/8	2 9/16	14.35	9,016 P	285,359	512,035	23,288	15,026 P	11,354	10,828
4	14.00	E	IU	NC40	5 1/4	2 13/16	15.06	13,968 P	285,359	711,611	23,288	23,279 p	11,354	10,828
4	14.00	E	EU	NC46	6	3 1/4	15.91	19,937 P	285,359	901,164	23,288	33,228 p	11,354	10,828
4	14.00	SS75	EU	NC46	6	3 1/4	15.89	18,275 P	285,359	826,067	23,288	30,459 p	11,354	10,828
4	14.00	X	IU	4 H90	5 1/2	2 13/16	15.63	21,185 P	361,454	913,708	29,498	35,308 p	14,382	13,716
4	14.00	X	IU	NC40	5 1/4	2 11/16	15.29	15,319 P	361,454	776,406	29,498	25,531 p	14,382	13,716
4	14.00	X	EU	NC46	6	3 1/4	16.21	19,937 P	361,454	901,164	29,498	33,228 p	14,382	13,716
4	14.00	SS95	EU	NC46	6	3	16.08	21,448 P	361,454	961,058	29,498	35,747 p	14,382	13,716
4	14.00	G	IU	4 H90	5 1/2	2 13/16	15.63	21,185 P	399,502	913,708	32,603	35,308 p	15,896	15,159
4	14.00	G	IU	NC40	5 1/2	2 7/16	15.87	17,858 P	399,502	897,161	32,603	29,764 p	15,896	15,159

Label 1	Label 2	Grade	Upset Type	RSC Type ^a	New Drill Pipe									
					Box OD (in.)	Pin ID (in.)	Approx. Mass (lb/ft)	Makeup Torque ^{b c} (ft-lb)	Tensile Yield Pipe Body (lb)	Tensile Yield Tool Joint (lb)	Torsional Yield Pipe Body (ft-lb)	Torsional Yield Tool Joint ^d (ft-lb)	Collapse Pressure Pipe Body (psi)	Max. Internal Pressure Pipe Body (psi)
4	14.00	G	EU	NC46	6	3 ¹ / ₄	16.21	19,937 P	399,502	901,164	32,603	33,228 p	15,896	15,159
4	14.00	S	IU	4 H90	5 ¹ / ₂	2 ¹³ / ₁₆	15.63	21,180 P	513,646	913,708	41,918	35,308 p	20,141	19,491
4	14.00	S	IU	NC40	5 ¹ / ₂	2	16.14	21,758 P	513,646	1,080,135	41,918	36,262 p	20,141	19,491
4	14.00	S	EU	NC46	6	3	16.44	23,399 P	513,646	1,048,426	41,918	38,998 p	20,141	19,491
4	14.00	V	EU	NC46	6	3	16.08	23,398 P	570,720	1,048,427	46,604	38,997 p	21,915	21,656
4	15.70	E	IU	4 H90	5 ¹ / ₂	2 ¹³ / ₁₆	17.09	21,185 P	324,118	913,708	25,810	35,308 p	12,896	12,469
4	15.70	E	IU	NC40	5 ¹ / ₄	2 ¹¹ / ₁₆	16.80	15,319 P	324,118	776,406	25,810	25,531 p	12,896	12,469
4	15.70	E	EU	NC46	6	3 ¹ / ₄	17.54	19,937 P	324,118	901,164	25,810	33,228 p	12,896	12,469
4	15.70	X	IU	4 H90	5 ¹ / ₂	2 ¹³ / ₁₆	17.23	21,185 P	410,550	913,708	32,692	35,308 p	16,335	15,794
4	15.70	X	IU	NC40	5 ¹ / ₂	2 ⁷ / ₁₆	17.52	17,858 P	410,550	897,161	32,692	29,764 p	16,335	15,794
4	15.70	X	EU	NC46	6	3	18.03	23,399 P	410,550	1,048,427	32,692	38,997 p	16,335	15,794
4	15.70	X	EU	NC46	6	3 ¹ / ₄	17.80	19,937 P	410,550	901,164	32,692	33,228 p	16,335	15,794
4	15.70	G	IU	4 H90	5 ¹ / ₂	2 ¹³ / ₁₆	17.23	21,185 P	453,765	913,708	36,134	35,308 p	18,055	17,456
4	15.70	G	IU	NC40	5 ¹ / ₂	2 ⁷ / ₁₆	17.52	17,859 P	453,765	897,161	36,134	29,764 p	18,055	17,456
4	15.70	G	EU	NC46	6	3	18.03	23,399 P	453,765	1,048,427	36,134	38,997 p	18,055	17,456
4	15.70	G	EU	NC46	6	3 ¹ / ₄	17.80	19,937 P	453,765	901,164	36,134	33,228 p	18,055	17,456
4	15.70	S	IU	NC46	6	2 ⁵ / ₈	18.23	26,982 B	583,413	1,247,230	46,458	44,978 b	23,213	22,444
4	15.70	S	EU	NC46	6	2 ⁷ / ₈	18.13	25,038 P	583,413	1,117,640	46,458	41,729 p	23,213	22,444
4	15.70	S	EU	NC46	6	3	18.02	23,398 P	583,413	1,048,426	46,458	38,998 p	23,213	22,444
4 ¹ / ₂	13.75	E	IU	4 ¹ / ₂ H90	6	3 ¹ / ₄	15.23	23,120 P	270,034	938,403	25,907	38,544 p	7,173	7,904
4 ¹ / ₂	13.75	E	EU	4 ¹ / ₂ OH SW	5 ³ / ₄	3 ³¹ / ₃₂	14.04	12,407 P	270,034	554,844	25,907	20,678 p	7,173	7,904
4 ¹ / ₂	13.75	E	EU	4 ¹ / ₂ WO	6 ¹ / ₈	3 ⁷ / ₈	14.77	19,290 P	270,034	848,619	25,907	33,492 p	7,173	7,904
4 ¹ / ₂	13.75	E	IU	NC46	6	3 ³ / ₈	15.12	18,117 P	270,034	823,115	25,907	30,195 p	7,173	7,904
4 ¹ / ₂	13.75	E	EU	NC50	6 ⁵ / ₈	3 ³ / ₄	15.90	22,362 P	270,034	939,096	25,907	37,269 p	7,173	7,904
4 ¹ / ₂	16.60	E	IEU	4 ¹ / ₂ FH	6	3	18.14	20,620 P	330,558	976,156	30,807	34,367 p	10,392	9,829
4 ¹ / ₂	16.60	E	IEU	4 ¹ / ₂ H90	6	3 ¹ / ₄	17.92	23,126 P	330,558	938,403	30,807	38,544 p	10,392	9,829
4 ¹ / ₂	16.60	E	EU	4 ¹ / ₂ OH SW	5 ⁷ / ₈	3 ³ / ₄	17.07	16,162 P	330,558	713,979	30,807	26,936 p	10,392	9,829

Label 1	Label 2	Grade	Upset Type	RSC Type ^a	New Drill Pipe									
					Box OD (in.)	Pin ID (in.)	Approx. Mass (lb/ft)	Makeup Torque ^{b c} (ft-lb)	Tensile Yield Pipe Body (lb)	Tensile Yield Tool Joint (lb)	Torsional Yield Pipe Body (ft-lb)	Torsional Yield Tool Joint ^d (ft-lb)	Collapse Pressure Pipe Body (psi)	Max. Internal Pressure Pipe Body (psi)
4 1/2	16.60	E	IEU	NC38 *	5	2 11/16	16.79	10,842 P	330,558	587,308	30,807	18,071 P	10,392	9,829
4 1/2	16.60	E	IEU	NC46	6 1/4	3 1/4	18.39	19,937 P	330,558	901,164	30,807	33,228 p	10,392	9,829
4 1/2	16.60	E	EU	NC50	6 5/8	3 3/4	18.49	22,361 P	330,558	939,096	30,807	37,269 p	10,392	9,829
4 1/2	16.60	SS75	IEU	NC46	6 1/4	3 1/4	18.61	18,275 P	330,558	826,067	30,807	30,459 p	10,392	9,829
4 1/2	16.60	SS75	EU	NC50	6 5/8	3 3/4	18.48	20,499 P	330,558	860,838	30,807	34,164 p	10,392	9,829
4 1/2	16.60	X	IEU	4 1/2 FH	6	2 3/4	18.70	23,695 P	418,707	1,111,637	39,022	39,491 p	12,765	12,450
4 1/2	16.60	X	IEU	4 1/2 FH	6	3	18.33	20,620 P	418,707	976,156	39,022	34,367 p	12,765	12,450
4 1/2	16.60	X	IEU	4 1/2 H90	6	3	18.47	26,969 P	418,707	1,085,391	39,022	44,938 p	12,765	12,450
4 1/2	16.60	X	IEU	4 1/2 H90	6	3 1/4	18.11	23,120 P	418,707	938,403	39,022	38,544 p	12,765	12,450
4 1/2	16.60	X	IEU	NC46	6 1/4	3	18.63	19,937 B	418,707	1,048,426	39,022	38,998 p	12,765	12,450
4 1/2	16.60	X	EU	NC50	6 5/8	3 3/4	18.86	22,361 P	418,707	939,095	39,022	37,269 p	12,765	12,450
4 1/2	16.60	SS95	IEU	NC46	6 1/4	2 3/4	18.97	24,397 P	418,707	1,085,249	39,022	40,661 p	12,765	12,450
4 1/2	16.60	SS95	EU	NC50	6 5/8	3 1/2	18.70	24,452 P	418,707	1,017,426	39,022	40,753 p	12,765	12,450
4 1/2	16.60	G	IEU	4 1/2 FH	6	2 3/4	18.70	23,695 P	462,781	1,111,637	43,130	39,491 p	13,825	13,761
4 1/2	16.60	G	IEU	4 1/2 FH	6	3	18.33	23,695 P	462,781	976,156	43,130	34,367 p	13,825	13,761
4 1/2	16.60	G	IEU	4 1/2 H90	6	3	18.33	26,969 P	462,781	1,085,665	43,130	44,948 p	13,825	13,761
4 1/2	16.60	G	IEU	NC46	6 1/4	3	18.63	23,399 P	462,781	1,048,426	43,130	38,998 p	13,825	13,761
4 1/2	16.60	G	EU	NC50	6 5/8	3 3/4	18.86	22,361 P	462,781	939,095	43,130	37,269 p	13,825	13,761
4 1/2	16.60	SS105	IEU	NC46	6 1/4	2 3/4	18.97	24,397 P	462,781	1,085,249	43,130	40,661 p	13,825	13,761
4 1/2	16.60	S	IEU	4 1/2 FH	6 1/4	2 1/2	19.19	26,528 P	595,004	1,235,337	55,453	44,214 p	16,773	17,693
4 1/2	16.60	S	IEU	4 1/2 H90	6	3	18.33	26,963 P	595,004	1,085,665	55,453	44,948 p	16,773	17,693
4 1/2	16.60	S	IEU	NC46	6 1/4	2 3/4	18.84	26,615 P	595,004	1,183,908	55,453	44,359 p	16,773	17,693
4 1/2	16.60	S	EU	NC50	6 5/8	3 1/2	19.13	26,674 P	595,004	1,109,920	55,453	44,456 p	16,773	17,693
4 1/2	16.60	V	IEU	NC46 *	6 1/4	2 3/4	18.97	26,615 P	661,110	1,183,908	61,651	44,358 P	18,106	19,658
4 1/2	16.60	V	EU	NC50 *	6 5/8	3 1/2	18.70	26,675 P	661,110	1,109,920	61,651	44,458 P	18,106	19,658
4 1/2	20.00	E	IEU	4 1/2 FH	6	3	21.64	20,620 P	412,358	976,156	36,901	34,367 p	12,964	12,542

Label 1	Label 2	Grade	Upset Type	RSC Type ^a	New Drill Pipe									
					Box OD (in.)	Pin ID (in.)	Approx. Mass (lb/ft)	Makeup Torque ^{b c} (ft-lb)	Tensile Yield Pipe Body (lb)	Tensile Yield Tool Joint (lb)	Torsional Yield Pipe Body (ft-lb)	Torsional Yield Tool Joint ^d (ft-lb)	Collapse Pressure Pipe Body (psi)	Max. Internal Pressure Pipe Body (psi)
4 1/2	20.00	E	IEU	4 1/2 H90	6	3	21.64	26,969 P	412,358	1,085,665	36,901	44,948 p	12,964	12,542
4 1/2	20.00	E	IEU	NC46	6 1/4	3	22.14	23,399 P	412,358	1,048,426	36,901	38,998 p	12,964	12,542
4 1/2	20.00	E	EU	NC50	6 5/8	3 5/8	22.13	24,549 P	412,358	1,025,980	36,901	40,915 p	12,964	12,542
4 1/2	20.00	SS75	IEU	NC46	6 1/4	3	18.61	21,448 P	412,358	961,058	36,901	35,747 p	12,964	12,542
4 1/2	20.00	SS75	EU	NC50	6 5/8	3 5/8	22.16	22,504 P	412,358	940,482	36,901	37,507 p	12,964	12,542
4 1/2	20.00	X	IEU	4 1/2 FH	6	2 1/2	22.39	26,528 P	522,320	1,235,337	46,741	44,214 p	16,421	15,886
4 1/2	20.00	X	IEU	4 1/2 H90	6	3	21.91	26,969 P	522,320	1,085,391	46,741	44,938 p	16,421	15,886
4 1/2	20.00	X	IEU	4 1/2 H90	6	3 1/4	21.78	23,120 P	522,320	938,403	46,741	38,544 p	16,421	15,886
4 1/2	20.00	X	IEU	NC46	6 1/4	2 3/4	22.64	26,615 P	522,320	1,183,908	46,741	44,359 p	16,421	15,886
4 1/2	20.00	X	EU	NC50	6 5/8	3 1/2	22.60	26,674 P	522,320	1,109,920	46,741	44,456 p	16,421	15,886
4 1/2	20.00	SS95	IEU	NC46	6 1/4	2 1/4	22.59	29,589 P	522,320	1,301,233	46,741	49,315 p	16,421	15,886
4 1/2	20.00	SS95	EU	NC50	6 5/8	3	22.66	31,645 P	522,320	1,298,206	46,741	52,741 p	16,421	15,886
4 1/2	20.00	G	IEU	4 1/2 FH	6	2 1/2	22.39	26,528 P	577,301	1,235,337	51,661	44,214 p	18,149	17,558
4 1/2	20.00	G	IEU	4 1/2 H90	6	3	22.00	26,963 P	577,301	1,085,665	51,661	44,948 p	18,149	17,558
4 1/2	20.00	G	IEU	NC46	6 1/4	2 1/2	22.83	29,578 P	577,301	1,307,608	51,661	49,297 p	18,149	17,558
4 1/2	20.00	G	EU	NC50	6 5/8	3 1/2	22.60	26,674 P	577,301	1,109,920	51,661	44,456 p	18,149	17,558
4 1/2	20.00	SS105	IEU	NC46	6 1/4	2 1/4	22.59	29,589 P	577,301	1,301,233	51,661	49,315 p	18,149	17,558
4 1/2	20.00	S	IEU	NC46	6 1/4	2 1/4	23.00	32,279 P	742,244	1,419,527	66,421	53,800 p	23,335	22,575
4 1/2	20.00	S	EU	NC50	6 5/8	3	23.07	34,520 P	742,244	1,416,225	66,421	57,534 p	23,335	22,575
4 1/2	20.00	V	IEU	NC46 *	6 1/4	2 1/4	22.59	32,279 P	824,715	1,419,527	73,846	53,799 P	25,927	25,083
4 1/2	20.00	V	EU	NC50 *	6 5/8	3	22.66	34,521 P	824,715	1,416,225	73,846	57,536 P	25,927	25,083
4 1/2	22.82	E	IEU	NC46	6 1/4	3	24.56	23,398 P	471,239	1,048,426	40,912	38,998 p	14,815	14,583
4 1/2	22.82	E	EU	NC50	6 5/8	3 5/8	24.11	24,550 P	471,239	1,025,980	40,912	40,915 p	14,815	14,583
4 1/2	22.82	X	IEU	4 1/2 FH	6 1/4	2 1/4	25.13	29,113 P	596,903	1,347,256	51,821	48,522 p	18,765	18,472
4 1/2	22.82	X	IEU	NC46	6 1/4	2 3/4	24.77	26,615 P	596,903	1,183,908	51,821	44,359 p	18,765	18,472
4 1/2	22.82	X	EU	NC50	6 5/8	3 1/2	24.24	26,675 P	596,903	1,109,920	51,821	44,456 p	18,765	18,472
4 1/2	22.82	G	IEU	NC46	6 1/4	2 1/2	24.96	29,578 P	659,734	1,307,608	57,276	49,297 p	20,741	20,417

Label 1	Label 2	Grade	Upset Type	RSC Type ^a	New Drill Pipe									
					Box OD (in.)	Pin ID (in.)	Approx. Mass (lb/ft)	Makeup Torque ^{b c} (ft-lb)	Tensile Yield Pipe Body (lb)	Tensile Yield Tool Joint (lb)	Torsional Yield Pipe Body (ft-lb)	Torsional Yield Tool Joint ^d (ft-lb)	Collapse Pressure Pipe Body (psi)	Max. Internal Pressure Pipe Body (psi)
4 ¹ / ₂	22.82	G	EU	NC50	6 ⁵ / ₈	3 ¹ / ₄	24.72	30,731 P	659,734	1,268,963	57,276	51,217 p	20,741	20,417
4 ¹ / ₂	22.82	S	EU	NC50	6 ⁵ / ₈	2 ³ / ₄	25.41	38,037 P	848,230	1,551,706	73,641	63,393 p	26,667	26,250
5	19.50	E	IEU	5 ¹ / ₂ FH	7	3 ³ / ₄	22.32	37,749 B	395,595	1,448,407	41,167	62,903 b	9,962	9,503
5	19.50	E	IEU	NC50	6 ⁵ / ₈	3 ³ / ₄	21.37	22,361 P	395,595	939,095	41,167	37,269 p	9,962	9,503
5	19.50	X	IEU	5 ¹ / ₂ FH	7	3 ³ / ₄	22.58	37,749 B	501,087	1,448,407	52,144	62,903 b	12,026	12,037
5	19.50	X	IEU	5 H90	6 ¹ / ₂	3 ¹ / ₄	21.93	30,732 P	501,087	1,176,265	52,144	51,220 p	12,026	12,037
5	19.50	X	IEU	NC50	6 ⁵ / ₈	3 ¹ / ₂	21.89	26,674 P	501,087	1,109,920	52,144	44,456 p	12,026	12,037
5	19.50	G	IEU	5 ¹ / ₂ FH	7	3 ³ / ₄	22.58	37,749 B	553,833	1,448,407	57,633	62,903 b	12,999	13,304
5	19.50	G	IEU	5 H90	6 ¹ / ₂	3	22.15	34,805 P	553,833	1,323,527	57,633	58,008 p	12,999	13,304
5	19.50	G	IEU	NC50	6 ⁵ / ₈	3 ¹ / ₄	22.14	30,730 P	553,833	1,268,963	57,633	51,217 p	12,999	13,304
5	19.50	S	IEU	5 ¹ / ₂ FH	7 ¹ / ₄	3 ¹ / ₂	23.44	43,328 P	712,070	1,619,231	74,100	72,213 p	15,672	17,105
5	19.50	S	IEU	NC50	6 ⁵ / ₈	2 ³ / ₄	22.58	38,036 P	712,070	1,551,706	74,100	63,393 p	15,672	17,105
5	25.60	E	IEU	5 ¹ / ₂ FH	7	3 ¹ / ₂	28.32	37,742 B	530,144	1,619,231	52,257	62,903 b	13,500	13,125
5	25.60	E	IEU	NC50	6 ⁵ / ₈	3 ¹ / ₂	27.37	26,674 P	530,144	1,109,920	52,257	44,456 p	13,500	13,125
5	25.60	SS75	IEU	5 ¹ / ₂ FH	7	3 ¹ / ₂	28.29	34,603 B	530,144	1,484,295	52,257	57,672 b	13,500	13,125
5	25.60	SS75	IEU	NC50 *	6 ⁵ / ₈	3 ¹ / ₂	27.36	24,452 P	530,144	1,017,426	52,257	40,753 P	13,500	13,125
5	25.60	X	IEU	5 ¹ / ₂ FH	7	3 ¹ / ₂	28.56	37,742 B	671,515	1,619,231	66,192	62,903 b	17,100	16,625
5	25.60	X	IEU	NC50	6 ⁵ / ₈	3	28.09	34,520 P	671,515	1,416,225	66,192	57,534 b	17,100	16,625
5	25.60	SS95	IEU	5 ¹ / ₂ FH	7 ¹ / ₄	3 ¹ / ₄	29.08	43,300 B	671,515	1,630,084	66,192	72,167 b	17,100	16,625
5	25.60	G	IEU	5 ¹ / ₂ FH	7 ¹ / ₄	3 ¹ / ₂	29.13	43,328 P	742,201	1,619,231	73,159	72,213 p	18,900	18,375
5	25.60	G	IEU	NC50	6 ⁵ / ₈	2 ³ / ₄	28.30	38,036 P	742,201	1,551,706	73,159	63,393 b	18,900	18,375
5	25.60	S	IEU	5 ¹ / ₂ FH	7 ¹ / ₄	3 ¹ / ₄	29.40	47,230 B	954,259	1,778,274	94,062	78,716 b	24,300	23,625
5	25.60	V	IEU	5 ¹ / ₂ FH *	7 ¹ / ₄	3 ¹ / ₄	29.08	47,237 B	1,060,290	1,778,274	104,577	78,728 B	27,000	26,250
5	TW 0.750	SS95	IEU	5 ¹ / ₂ FH	7 ¹ / ₄	3 ¹ / ₄	38.44	43,300 B	951,314	1,630,084	85,247	72,167 b	24,225	24,938
5	TW 0.750	V	IEU	5 ¹ / ₂ FH *	7 ¹ / ₄	3 ¹ / ₄	38.44	47,237 B	1,502,074	1,778,274	134,600	78,728 B	38,250	39,375
5 ¹ / ₂	21.90	E	IEU	5 ¹ / ₂ FH	7	4	23.81	33,412 P	437,116	1,265,802	50,710	55,687 p	8,413	8,615
5 ¹ / ₂	21.90	SS75	IEU	5 ¹ / ₂ FH	7	4	24.10	30,627 P	437,116	1,160,318	50,710	51,045 p	8,413	8,615

Label 1	Label 2	Grade	Upset Type	RSC Type ^a	New Drill Pipe									
					Box OD (in.)	Pin ID (in.)	Approx. Mass (lb/ft)	Makeup Torque ^{b c} (ft-lb)	Tensile Yield Pipe Body (lb)	Tensile Yield Tool Joint (lb)	Torsional Yield Pipe Body (ft-lb)	Torsional Yield Tool Joint ^d (ft-lb)	Collapse Pressure Pipe Body (psi)	Max. Internal Pressure Pipe Body (psi)
5 ¹ / ₂	21.90	X	IEU	5 ¹ / ₂ FH	7	3 ³ / ₄	24.43	37,742 B	553,681	1,448,407	64,233	62,903 b	10,019	10,912
5 ¹ / ₂	21.90	X	IEU	5 ¹ / ₂ H90	7	3 ¹ / ₂	24.80	34,820 P	553,681	1,268,877	64,233	58,033 p	10,019	10,912
5 ¹ / ₂	21.90	SS95	IEU	5 ¹ / ₂ FH	7 ¹ / ₂	3	26.12	47,720 P	553,681	1,765,075	64,233	79,534 p	10,019	10,912
5 ¹ / ₂	21.90	G	IEU	5 ¹ / ₂ FH	7 ¹ / ₄	3 ¹ / ₂	25.28	43,328 P	611,963	1,619,231	70,994	72,213 p	10,753	12,061
5 ¹ / ₂	21.90	S	IEU	5 ¹ / ₂ FH	7 ¹ / ₂	3	26.39	52,059 P	786,809	1,925,536	91,278	86,765 p	12,679	15,507
5 ¹ / ₂	21.90	V	IEU	5 ¹ / ₂ FH	7 ¹ / ₂	3	26.12	52,058 P	874,230	1,925,536	101,482	86,764 p	13,476	17,230
5 ¹ / ₂	24.70	E	IEU	5 ¹ / ₂ FH	7	4	26.33	33,412 P	497,222	1,265,802	56,574	55,687 p	10,464	9,903
5 ¹ / ₂	24.70	SS75	IEU	5 ¹ / ₂ FH	7	4	26.57	30,627 P	497,222	1,160,318	56,574	51,045 p	10,464	9,903
5 ¹ / ₂	24.70	X	IEU	5 ¹ / ₂ FH	7 ¹ / ₄	3 ¹ / ₂	27.77	43,328 P	629,814	1,619,231	71,660	72,213 p	12,933	12,544
5 ¹ / ₂	24.70	SS95	IEU	5 ¹ / ₂ FH	7 ¹ / ₂	3	28.57	47,720 P	629,814	1,765,075	71,660	79,534 p	12,933	12,544
5 ¹ / ₂	24.70	G	IEU	5 ¹ / ₂ FH	7 ¹ / ₄	3 ¹ / ₂	27.77	43,328 P	696,111	1,619,231	79,204	72,213 p	14,013	13,865
5 ¹ / ₂	24.70	S	IEU	5 ¹ / ₂ FH	7 ¹ / ₂	3	28.87	52,059 P	894,999	1,925,536	101,833	86,765 p	17,023	17,826
5 ¹ / ₂	24.70	V	IEU	5 ¹ / ₂ FH *	7 ¹ / ₂	3	28.57	52,058 P	994,440	1,925,536	113,217	86,764 P	18,389	19,807
5 ¹ / ₂	TW 0.500	V	IEU	5 ¹ / ₂ FH *	7 ¹ / ₄	3 ¹ / ₂	31.11	43,327 P	1,178,097	1,619,231	130,109	72,212 P	24,793	23,864
5 ¹ / ₂	TW 0.625	V	IEU	5 ¹ / ₂ FH *	7 ¹ / ₄	3 ¹ / ₈	36.67	47,237 B	1,435,806	1,853,377	151,702	78,728 B	30,217	29,830
5 ¹ / ₂	TW 0.750	V	IEU	5 ¹ / ₂ FH *	7 ¹ / ₂	3	42.24	52,058 P	1,678,789	1,925,536	169,802	86,764 P	35,331	35,795
5 ⁷ / ₈	23.40	E	IEU	5 ¹ / ₂ FH	7	4	25.40	33,412 P	469,013	1,265,801	58,640	55,686 p	7,453	8,065
5 ⁷ / ₈	23.40	X	IEU	5 ¹ / ₂ FH	7 ¹ / ₄	3 ¹ / ₂	26.44	43,327 P	594,083	1,619,231	74,278	72,212 p	8,774	10,216
5 ⁷ / ₈	23.40	G	IEU	5 ¹ / ₂ FH	7 ¹ / ₄	3 ¹ / ₂	26.44	43,327 P	656,619	1,619,231	82,096	72,212 p	9,362	11,291
5 ⁷ / ₈	23.40	S	IEU	5 ¹ / ₂ FH *	7 ¹ / ₄	3	26.88	47,237 B	844,224	1,925,536	105,553	78,728 B	10,820	14,517
5 ⁷ / ₈	23.40	V	IEU	5 ¹ / ₂ FH *	7 ¹ / ₄	3	26.88	47,237 B	938,026	1,925,536	117,281	78,728 B	11,380	16,130
5 ⁷ / ₈	26.30	E	IEU	5 ¹ / ₂ FH	7	3 ¹ / ₄	28.80	37,749 B	533,890	1,778,274	65,548	62,915 b	9,559	9,271
5 ⁷ / ₈	26.30	X	IEU	5 ¹ / ₂ FH	7 ¹ / ₄	3 ¹ / ₂	29.10	43,327 P	676,261	1,619,231	83,027	72,212 p	11,502	11,744
5 ⁷ / ₈	26.30	G	IEU	5 ¹ / ₂ FH *	7 ¹ / ₄	3 ¹ / ₂	29.10	43,327 P	747,446	1,619,231	91,767	72,212 P	12,414	12,980
5 ⁷ / ₈	26.30	S	IEU	5 ¹ / ₂ FH *	7 ¹ / ₂	3 ¹ / ₄	29.89	47,845 P	961,002	1,778,274	117,986	79,742 P	14,888	16,688
5 ⁷ / ₈	26.30	V	IEU	5 ¹ / ₂ FH *	7 ¹ / ₂	3 ¹ / ₄	29.89	47,845 P	1,067,780	1,778,274	131,096	79,742 P	15,979	18,543