INTERNATIONAL STANDARD

**ISO 20312**

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# Petroleum and natural gas industries — Design and operating limits of drill strings with aluminium alloy components

*Industries du pétrole et du gaz naturel — Conception et limites de fonctionnement des garnitures de forage en alliage d'aluminium*



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## Foreword

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ISO 20312 was prepared by Technical Committee ISO/TC 67, *Materials, equipment and offshore structures for petroleum, petrochemical and natural gas industries*.

## Introduction

The function of this International Standard is to define operating limits of aluminium drill pipes and recommend design criteria for the drill stem containing such aluminium drill pipes. This International Standard contains formulas and figures to aid in the design and selection of equipment to meet a specific drilling condition.

In this International Standard, data are expressed in the International System of units (SI).

Users of this International Standard need to be aware that further or differing requirements could be needed for individual applications. This International Standard is not intended to inhibit a manufacturer from offering, or the purchaser from accepting, alternative equipment or engineering solutions for the individual application, particularly where there is innovative or developing technology. Where an alternative is offered, the manufacturer will need to identify any variations from this International Standard and provide details.

This International Standard includes provisions of various nature. These are identified by the use of certain verbal forms:

— “shall” is used to indicate that a provision is mandatory;

— “should” is used to indicate that a provision is not mandatory, but recommended as good practice;

— “may” is used to indicate that a provision is optional.

# Petroleum and natural gas industries — Design and operating limits of drill strings with aluminium alloy components

## 1 Scope

This International Standard applies to design and operating limits for drill strings containing aluminium alloy pipes manufactured in accordance with ISO 15546.

## 2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 9712, *Non-destructive testing — Qualification and certification of personnel*



ISO 15546, *Petroleum and natural gas industries — Aluminium alloy drill pipe*



ASNT Recommended Practice No. SNT-TC-1A, *Personnel Qualification and Certification in Non-destructive Testing*



## 3 Terms, definitions, symbols and abbreviated terms

### 3.1 Terms and definitions

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

**3.1.1**
**aluminium alloy pipe body**
aluminium alloy pipe formed by extrusion, including upsets and protector thickening

**3.1.2**
**aluminium alloy drill pipe**
aluminium alloy pipe body with threaded steel tool joints

**3.1.3**
**box**
tool joint part that has internal tool-joint thread

**3.1.4**
**buckling**
unstable lateral deflection of a drill stem component under compressive effective axial force

**3.1.5**
**corrosion**
adverse chemical alteration or destruction of a metal by air, moisture or chemicals

 

**3.1.6**
**critical buckling load**
load level associated with initiation of drill stem components buckling

**3.1.7**
**dogleg**
sharp change of direction in a well bore

**3.1.8**
**dogleg severity**
measure of the amount of change in the inclination and/or direction of a borehole, usually expressed in degrees per 30 m interval

**3.1.9**
**drill string**
complete assembly from the swivel or top drive to the drill bit, which can contain the kelly, drill pipes, subs, drill collars and other bottom hole assembly (BHA) members, such as stabilizers, reamers and junk baskets

**3.1.10**
**effective axial force**
force created by adverse combinations of axial load and pressure

**3.1.11**
**helical buckling**
buckling in which drill stem components form a helix or spiral shape



**3.1.12**
**manufacturer**
firm, company or corporation responsible for marking the product



NOTE Marking by the manufacturer warrants that the product conforms to this International Standard, and it is the manufacturer who is responsible for compliance with all of its applicable provisions.

**3.1.13**
**new class pipe**
wear-based classification of pipe not having been put in service

**3.1.14**
**pin**
tool joint part that has external tool-joint thread

**3.1.15**
**premium class, class 2 pipe**
wear-based classification of pipe worn to an extent listed in Tables 12 and 13

**3.1.16**
**sinusoidal buckling**
buckling of drill stem components in a sinusoidal shape

**3.1.17**
**slip area**
area within a small distance along the pipe body from the box end, clamped by the pipe slips during the pulling and running operations

**3.1.18**
**tool joint**
steel tool joint element for drill pipes consisting of two parts (pin and box)

 

**3.1.19**
**TT type thread**
trapezoidal-shaped thread connecting aluminium pipe body and steel joint

NOTE See ISO 15546.

## 3.2 Symbols

$A$ factor depending on the failure theory selected for calculations and adjusted for anisotropy of drill pipe material

$A_b$ box cross-sectional area at 9,525 mm from the bearing face

$A_{dp}$ drill pipe cross-sectional area

$A_{OD}$ cross-sectional area circumscribed by pipe outside diameter

$A_p$ pin cross-sectional area at 15,875 mm from the bearing face

$A_{pb}$ cross-sectional area of pin $A_p$ or box $A_b$, whichever is smaller

$A_z$ cross-sectional area of drill pipe in upset part

$a_e$ coefficient of linear expansion of material



$a_w$ cross-sectional area of pipe wall with regard to pipe ovality

$B$ variable



$b$ strain reduction factor

$C$ pitch diameter of thread at gauge point

$c$ area coverage coefficient

$D_{dp}$ pipe body outside diameter

$D_h$ average diameter of the borehole at the regarded interval

$D_{max}$ maximum outside diameter of pipe

$D_{min}$ minimum outside diameter

$D_{pt}$ protector outside diameter

$D_{tj}$ tool joint outside diameter

$D_U$ outside diameter of drill pipe in upset part

$\overline{D}$ conventional outside diameter of drilling pipe with tool joint

$d_{dp}$ pipe body inside diameter

$d_p$ pin inside diameter

$E$ modulus of elasticity or Young's modulus

$F$ variable

$f$ friction factor

$g$ acceleration of gravity, 9,81m/s$^2$

$H$ thread height not truncated

$H_{\text{dm}}$ drilling mud depth

$h$ fluid depth

$h_{\text{DS}}$ drilling string setting depth

$h_{\text{K}}$ well depth at the upper limit of drill string section

$h_{\text{K}-1}$ well depth at the lower limit of drill string section

$I$ moment of inertia of the pipe body in regard to transverse axis (at bending)

$J$ drill pipe moment of inertia with respect to its diameter

$K$ transverse load factor



$k$ plastic-to-elastic-collapse ratio

$L$ strength-to-weight ratio



$L_{1/2}$ half the distance between tool joints

$L_{\text{Al}}$ strength-to-weight ratio of aluminium

$L_{\text{dp}}$ pipe length with tool joint (the distance between the tool joint box face and the pin shoulder)

$L_{\text{pc}}$ length of the pin that mates with the box

$L_{\text{s}}$ length of slip contact with drill pipe

$L_{\text{St}}$ strength-to-weight ratio of steel

$l_{\text{K}}$ length of section “K”

$M_{\text{B}}$ mass per unit length of plain end pipe body

$M_{\text{dp}}$ mass per unit length of drill pipe

$M_{\text{K}}$ mass per unit length of drill pipe in drill string section “K”

$m_{\text{b}}$ mass of plain end pipe body

$m_{\text{p}}$ mass gain due to protector thickening

$m_{\text{tj}}$ tool joint mass

$m_u$ mass gain due to upsets

$n$ number of the drill string sections

$O_i$ initial ovality

$P$ load applied to the drill string

$P_0$ collapse pressure

$P_c$ minimum collapse pressure for imperfect pipe

$P_e$ elastic bending pressure

$P_{ext}$ net external pressure

$P_{hel}$ helical buckling force

$P_i$ internal pressure

$P_{i\,y}$ internal yield pressure

$P_K$ tensile stress applied to the bottom cross-section



$P_{max}$ maximum tension yield strength of drill pipe body

$P_{sin}$ sinusoidal buckling force



$P_T$ effective tensile load on tubular

$P_y$ yield pressure with simultaneous tension

$P_z$ axis load when the stress in the body of the pipe chucked in the slips reaches yield strength

$p$ lead of thread

$Q_c$ box counter bore

$R$ dogleg severity radius at the beginning and the end of the build or drop interval

$R_s$ variable

$R_t$ variable

$S_a$ mean axial stress

$S_b$ maximum permissible bending stress

$S_{DL}$ stress produced by the buoyant weight of the drill string below dogleg

$S_{rs}$ root truncation

$s$ bending strain experienced by tubular

$s_0$ critical bending strain

$T$ torque applied to the drill string

$T_j$ recommended make up torque for the aluminium drill pipes tool joints

$T_{max}$ maximum torsional yield strength of drill pipe body

$T_y$ torsional yield limit in connection

$t_{dp}$ wall thickness

$t_0$ operational temperature

$t_u$ wall thickness of drill pipe in upset part

$W_p$ polar sectional modulus of torsion of pipe body

$w_0$ weight per unit length of pipe in air

$w_{DL}$ buoyant weight of drill string section suspended below the dogleg

$w_m$ weight per unit length of pipe in mud

$Y_{min}$ minimum yield strength of material



$\alpha$ zenith angle of the borehole interval

$\alpha_0$ minimum zenith angle of the borehole

$\alpha_H$ zenith angle at the beginning of the build or drop interval

$\alpha_K$ zenith angle at the end of the build or drop interval

$\alpha_{SL}$ slips taper angle

$\bar{\alpha}$ average zenith angle of the borehole at build or drop interval

$\Delta$ taper

$\Delta L$ overall elongation of combined drill string

$\Delta l_{BHA}$ elongation under the weight of the downhole sections and BHA

$\Delta l_t$ thermal elongation

$\Delta l_w$ elongation of the relevant drill string section "K" under its own weight load

$\delta$ gap between borehole wall and the average outside diameter of drilling pipe

$\eta$ temperature gradient

$\Theta$ dogleg severity

$\theta$ half angle of thread

$\mu$ Poisson's ratio

$\mu_{SL}$ coefficient of friction between slips and master bushing

$\pi$ constant, $\pi$ = 3,141 812

$\rho_{Al}$ density of aluminium, 2 800 kg/m$^3$

$\rho_{dm}$ drilling mud density

$\rho_e$ equivalent density

$\rho_{St}$ density of steel, 7 850 kg/m$^3$

$\sigma$ level of normal stresses applied to the design sections of drill string

$\sigma_{-1}$ fatigue limit of the drill pipe

$\sigma_b$ pipe material ultimate strength

$\sigma_e$ equivalent stress

$\sigma_i$ allowable stress intensity calculated as adjusted to the normative safety factors

$\sigma_r$ reduced yield stress

$\tau$ level of tangential stresses applied to the drill string

$\tau_{min}$ shear stress, reaching minimum yield strength

$\varphi$ out-of-roundness function

$\psi$ imperfection function

$\psi_{SL}$ friction angle



## 3.3 Abbreviated terms

ADP aluminium alloy drill pipe

BHA bottom hole assembly

EU external upset

HWADP heavy wall aluminium drill pipe

HWSDP heavy weight steel drill pipe

HWDP heavy wall drill pipe

ID inside diameter

IU internal upset

OD outside diameter

ROP rate of penetration

RPM revolutions per minute

SDP steel drill pipe

TJ tool joint

WOB weight on bit

# 4 Properties of ADP and tool joints

## 4.1 General

Dimensional and mechanical properties of new ADP and tool joints shall be as specified in ISO 15546. The pipes may be with external or internal upset ends, and with protector thickening. Separate tables of the chapter include the data on the drill pipe torsional strength, tensile strength, and resistance against internal and external pressure.

## 4.2 New pipes and tool joints data

The new pipes and tool joint data properties are given in Tables 1 and 2.



## 4.3 Buoyant weight

The ADP buoyant weight of different length groups in the fluids of different density could be calculated by Equation (B.5). The equivalent density of new pipes is given in Tables 1 and 2. For mass calculation purposes, the assumed aluminium alloy density in Tables 1, 2, 5, 6 and 7 is 2 800 kg/m$^3$, and the steel density is 7 850 kg/m$^3$. If alloys of other density are used, a correcting factor shall be applied.



EXAMPLE

**Objective:** Calculate the weight of 1 m of ADP 147 × 11; 11,8 m long; with internal upset ends; with protector thickening in drilling mud with gravity 1 200 kg/m$^3$.

**Solution:** According to Table 2, the mass of 1 m of this pipe is 21,45 kg, equivalent density is 3 271 kg/m$^3$.

The weight in mud will be as follows:

$$w_\mathrm{m} = 21{,}45 \times 9{,}81 \times \left(1 - \frac{1\,200}{3\,271}\right) = 133{,}2\ \mathrm{N/m}$$

## 4.4 Mechanical properties

The mechanical properties of new pipe (tensional yield strength, torsional yield strength, internal yield and collapse pressure values) are given in Table 3. The properties correspond to the temperature of 20 °C. The “weak section” for the calculations was assumed to be the aluminium drill pipe body.

The mechanical properties of the premium class pipe are given in Table 4.

The mechanical properties of class 2 pipe are given in Table 5.

The wear classification of ADP is based on 8.3 and Table 12.

 

Mechanical properties of aluminium drill pipe bodies can be affected by exposure at elevated temperature (see 5.3).

**Table 1 — Dimensional and mass properties of new drill pipe with external upset ends**

| Outside diameter, mm | Wall thickness, mm | Plain pipe mass per 1 linear metre, kg/m | Mass gain due to upset, kg | Mass gain due to protector thickening, kg | | Tool joint | | | Tool joint mass, kg | Mass per linear metre including all upsets, protector thickening, and tool joint[a], kg/m | | | Equivalent density of pipe with tool joints[b], kg/m³ | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Range | | OD, mm | Minimum ID, mm | Thread | | Length range[c] | | | Length range[c] | | |
| | | | | 2 | 3 | | | | | 1 | 2 | 3 | 1 | 2 | 3 |
| 90 | 8 | 5,77 | 4,00 | — | — | 118 | 68 | NC 38 | 19,5 | 9,56 | 8,26 | 7,76 | 3 552 | 3 336 | 3 244 |
| 114 | 10 | 9,15 | 7,77 | — | — | 155 | 95 | NC 50 | 38,6 | 16,63 | 14,06 | 13,08 | 3 688 | 3 444 | 3 337 |
| 129 | 9 | 9,50 | 21,97 | — | — | 172 | 112 | 5 1/2 FH | 46,0 | 20,46 | 16,69 | 15,26 | 3 652 | 3 447 | 3 351 |
| | | | | 9,57 | 13,99 | | | | | — | 17,71 | 16,45 | — | 3 402 | 3 318 |
| 131 | 13 | 13,49 | 22,32 | — | — | 178 | 105 | 5 1/2 FH | 46,0 | 24,51 | 20,72 | 19,28 | 3 477 | 3 298 | 3 219 |
| | | | | 17,29 | 25,27 | | | | | — | 22,55 | 21,43 | — | 3 251 | 3 185 |
| 133 | 11 | 11,80 | 17,10 | — | — | 172 | 112 | 5 1/2 FH | 46,0 | 21,98 | 18,48 | 17,15 | 3 577 | 3 371 | 3 279 |
| | | | | 13,37 | 19,53 | | | | | — | 19,90 | 18,81 | — | 3 323 | 3 245 |
| 140 | 13 | 14,52 | 9,72 | — | — | 172 | 112 | 5 1/2 FH | 46,0 | 23,51 | 20,42 | 19,25 | 3 513 | 3 307 | 3 220 |
| | | | | 20,51 | 29,98 | | | | | — | 22,59 | 21,79 | — | 3 251 | 3 180 |
| 147 | 11 | 13,16 | 29,26 | — | — | 195 | 124 | 6 5/8 FH | 65,2 | 28,40 | 23,16 | 21,16 | 3 676 | 3 464 | 3 365 |
| | | | | 10,37 | 15,15 | | | | | — | 24,25 | 22,45 | — | 3 427 | 3 338 |
| 151 | 13 | 15,78 | 23,69 | — | — | 195 | 124 | 6 5/8 FH | 65,2 | 30,12 | 25,19 | 23,31 | 3 611 | 3 399 | 3 304 |
| | | | | 28,54 | 41,72 | | | | | — | 28,21 | 26,85 | — | 3 323 | 3 249 |
| 155 | 15 | 18,47 | 18,02 | — | — | 195 | 124 | 6 5/8 FH | 65,2 | 31,90 | 27,28 | 25,53 | 3 554 | 3 344 | 3 253 |
| | | | | 22,80 | 33,32 | | | | | — | 29,69 | 28,35 | — | 3 292 | 3 216 |
| 164 | 9 | 12,27 | 31,69 | — | — | 203 | 124 | 6 5/8 FH | 66,5 | 28,11 | 22,66 | 20,59 | 3 711 | 3 499 | 3 398 |
| | | | | 19,39 | 28,34 | | | | | — | 24,71 | 22,99 | — | 3 428 | 3 345 |
| 168 | 11 | 15,19 | 25,51 | — | — | 203 | 124 | 6 5/8 FH | 66,5 | 30,03 | 24,93 | 22,99 | 3 635 | 3 421 | 3 324 |
| | | | | 15,89 | 23,23 | | | | | — | 26,61 | 24,96 | — | 3 374 | 3 290 |

a Value is calculated by Equation (B.3).

b Value is calculated by Equation (B.4).

c ADP length ranges are defined by ISO 15546.