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TECHNICAL CIRCULAR 1

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Petroleum and natural gas industries — Materials for use in H_2S-containing environments in oil and gas production —

Part 3: Cracking-resistant CRAs (corrosion-resistant alloys) and other alloys

TECHNICAL CIRCULAR 1

Industries du pétrole et du gaz naturel — Matériaux pour utilisation dans des environnements contenant de l'hydrogène sulfuré (H_2S) dans la production de pétrole et de gaz —

Partie 3: ARC (alliages résistants a la corrosion) et autres alliages résistants à la fissuration

CIRCULAIRE TECHNIQUE 1

Technical Circular 1 to ISO 15156-3 was prepared by the ISO 15156 Maintenance Agency on behalf of Technical Committee ISO/TC 67, *Materials, equipment and offshore structures for petroleum, petrochemical and natural gas industries.*

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Foreword

The establishment of the ISO 15156 Maintenance Agency was confirmed by the ISO Technical Management Board in June 2007. A copy of the TMB Vote-Form Number: **34/2007** giving the rules of procedure for the maintenance agency can be obtained from the ISO TMB Secretariat. It is also available from the ISO 15156 website at www.iso.org/iso15156maintenance.

ISO 15156 series has, since publication, been amended by a number of Technical Corrigenda and Technical Circulars and consists of the following parts, under the general title *Petroleum and natural gas industries — Materials for use in H_2S-containing environments in oil and gas production*:

— *Part 1: General principles for selection of cracking-resistant materials (2015)*

— *Part 2: Cracking-resistant carbon and low alloy steels, and the use of cast irons (2015)*

— *Part 3: Cracking-resistant CRAs (corrosion-resistant alloys) and other alloys (2015)*

  — *Technical Circular 1, ISO 15156-3:2015/Cir.1:2016(E) (2016-04-06)*

As applicable, subsequent publications resulting in new editions of an individual part of ISO 15156, effectively replace the corresponding set of documents shown above. Information on the latest status of these documents can be obtained from www.iso.org/iso15156maintenance.

Changes to ISO 15156-3:2015 introduced by this Technical Circular 1, ISO 15156-3:2015/Cir.1:2016(E), are shown in the document below in blue.

Page 37, Table A.27 — Environmental and materials limits for martensitic precipitation-hardened stainless steels used for wellhead and christmas tree components (excluding bodies and bonnets), valves and chokes (excluding bodies and bonnets), and packers and other subsurface equipment

Replace Table A.27 with the following:

Table A.27 — Environmental and materials limits for martensitic precipitation-hardened stainless steels used for wellhead and christmas tree components (excluding bodies and bonnets), valves and chokes (excluding bodies and bonnets), and packers and other subsurface equipment

Individual alloy UNS number	Temperature max °C (°F)	Partial pressure H_2S p_{H_2S} max kPa (psi)	Chloride conc. max mg/l	pH	Sulfur-resistant?	Remarks
UNS S17400	See “Remarks” column	3,4 (0,5)	See “Remarks” column	≥4,5	NDS[a]	See [b]; the safe use limits on chloride and temperature have not been defined.
UNS S45000	See “Remarks” column	10 (1,5)	See “Remarks” column	≥3,5	NDS[a]	Any combination of temperature and chloride concentration occurring in production environments is acceptable.

For these applications, these materials shall also comply with the following:

a) wrought UNS S17400 precipitation-hardening martensitic stainless steels shall have a maximum hardness of 33 HRC and shall have been heat-treated in accordance with either 1) or 2), as follows:

1) double age-hardening process at 620 °C (1 150 °F):

— solution-anneal at (1 040 ± 14) °C [(1 900 ± 25) °F] and air-cool or liquid-quench to below 32 °C (90 °F);

— first precipitation-hardening cycle at (620 ± 14) °C [(1 150 ± 25) °F] for 4 h minimum at temperature, then air-cool or liquid-quench to below 32 °C (90 °F);

— second precipitation-hardening cycle at (620 ± 14) °C [(1 150 ± 25) °F] for 4 h minimum at temperature, then air-cool or liquid-quench to below 32 °C (90 °F).

2) modified double age-hardening process:

— solution-anneal at (1 040 ± 14) °C [(1 900 ± 25) °F], then air-cool or liquid-quench to below 32 °C (90 °F);

— first precipitation-hardening cycle at (760 ± 14) °C [(1 400 ± 25) °F] for 2 h minimum at temperature and air-cool or liquid-quench to below 32 °C (90 °F);

— second precipitation-hardening cycle at (620 ± 14) °C [(1 150 ± 25) °F] for 4 h minimum at temperature, then air-cool or liquid-quench to below 32 °C (90 °F).

b) wrought UNS S45000 molybdenum-modified martensitic precipitation-hardened stainless steel shall have a maximum hardness of 31 HRC (equivalent to 306 HBW for this alloy) and shall have undergone the following two-step heat-treatment procedure:

1) solution-anneal;

2) precipitation-harden at (620 ± 8) °C [(1 150 ± 15) °F] for 4 h minimum at temperature.

[a] No data submitted to ascertain whether these materials are acceptable for service in the presence of elemental sulfur in the environment.

[b] The use of UNS S17400 is restricted to those applications where the sustained stress is no more than 50 % of the specified minimum yield strength (SMYS) or 380 MPa (55 ksi), whichever is less. The use of UNS S17400 is acceptable for wellhead valve trim where the stem is subjected to higher stress levels for very short periods of time during actuation; other or longer stress duration applications are prohibited above 50 % of the specified minimum yield strength (SMYS) or 380 MPa (55 ksi), whichever is less.

Page 43, Table A.32 — Environmental and materials limits for precipitation-hardened nickel-based alloys (II) used for any equipment or component

Replace Table A.32 with the following:

Table A.32 — Environmental and materials limits for precipitation-hardened nickel-based alloys (II) used for any equipment or component

Individual alloy UNS number	Temperature max °C (°F)	Partial pressure H_2S pH_2S max kPa (psi)	Chloride conc. max mg/l	pH	Sulfur-resistant?	Remarks
N07718 N09925	232 (450)	200 (30)	See "Remarks" column	See "Remarks" column	No	Any combination of chloride concentration and *in situ* pH occurring in production environments is acceptable.
	204 (400)	1 400 (200)	See "Remarks" column	See "Remarks" column	No	
	199 (390)	2 300 (330)	See "Remarks" column	See "Remarks" column	No	
	191 (375)	2 500 (360)	See "Remarks" column	See "Remarks" column	No	
	149 (300)	2 800 (400)	See "Remarks" column	See "Remarks" column	No	
	135 (275)	See "Remarks" column	See "Remarks" column	See "Remarks" column	Yes	Any combination of hydrogen sulfide, chloride concentration, and *in situ* pH in production environments is acceptable.
N09925 (wrought, solution-annealed and aged)	205 (401)	3 500 (500)	180 000	See "Remarks" column	NDS[a]	Any *in situ* production environment pH is acceptable for $pCO_2 + pH_2S \leq$ 7 000 kPa (1 000 psi).
N09935	232 (450)	2 800 (400)	180 000	See "Remarks" column	NDS[a]	Any *in situ* production environment pH is acceptable for $pCO_2 + pH_2S \leq$ 8 300 kPa (1 200 psi)
N09945, N09946	232 (450)	3 500 (508)	139 000	See "Remarks" column	NDS[a]	Any *in situ* production environment pH is acceptable for $pCO_2 + pH_2S \leq$ 7 000 kPa (1 000 psi)
	205 (401)	3 500 (508)	180 000	See "Remarks" column	NDS[a]	

Table A.32 *(continued)*

Individual alloy UNS number	Temperature max °C (°F)	Partial pressure H_2S p_{H_2S} max kPa (psi)	Chloride conc. max mg/l	pH	Sulfur-resistant?	Remarks
N09945	177 (350)	7 700 (1 100)	125 000	See "Remarks" column	Yes[b]	Any *in situ* production environment pH is acceptable for p_{CO_2} such that: For p_{H_2S} < 5 800 kPa (842 psi): $p_{CO_2} + p_{H_2S} \leq$ 10 000 kPa (1 450 psi). For p_{H_2S} from 5 800 kPa to 7 700 kPa: $p_{CO_2} \leq$ 4 200 kPa (610 psi).

These materials shall also comply with the following:

a) wrought UNS N07718 shall be in any one of the following conditions:

1) solution-annealed to a maximum hardness of 35 HRC;
2) hot-worked to a maximum hardness of 35 HRC;
3) hot-worked and aged to a maximum hardness of 35 HRC;
4) solution-annealed and aged to a maximum hardness of 40 HRC.

b) wrought UNS N09925 shall be in any one of the following conditions:

1) cold-worked to a maximum hardness of 35 HRC;
2) solution-annealed to a maximum hardness of 35 HRC;
3) solution-annealed and aged to a maximum hardness of 38 HRC;
4) cold-worked and aged to a maximum hardness of 40 HRC;
5) hot-finished and aged to a maximum hardness of 40 HRC.

c) number-1 wrought UNS N09935 shall be in the solution annealed and aged condition to a maximum hardness of 34 HRC;

d) number-1 wrought UNS N09945 shall be in the solution annealed and aged condition to a maximum hardness of 42 HRC;

e) wrought UNS N09946 shall be in solution annealed and aged condition to a maximum hardness of 46 HRC.

[a] No data submitted to ascertain whether these materials are acceptable for service in the presence of elemental sulfur in the environment.

[b] Sulfur resistant as tested in accordance with Group 1 as defined in NACE Conference paper 95047 and EFC 17, Appendix S1.

Page 53, Table A.41 — Environmental and materials limits for titanium used for any equipment or component

Replace Table A.41 with the following:

Table A.41 — Environmental and materials limits for titanium used for any equipment or component

Individual alloy UNS number	**Temperature** max °C (°F)	**Partial pressure H_2S** p_{H_2S} max kPa (psi)	**Chloride conc.** max mg/l	**pH**	**Sulfur-resistant?**	**Remarks**
R50250 R50400 R56260 R53400 R56323 R56403 R56404 R58640	See “Remarks” column	See “Remarks” column	See “Remarks” column	See “Remarks” column	Yes	Any combination of temperature. pH_2S, chloride concentration, and *in situ* pH occurring in production environments is acceptable.
R55400	288 (550)	3 450 (500)	180 500	See “Remarks” column	Yes[a]	Any *in situ* production environment pH is acceptable for $p_{CO_2} + p_{H_2S} \leq 7\ 000$ kPa (1 000 psi)

These materials shall also comply with the following:

a) UNS R50250 and R50400 shall have a maximum hardness of 100 HRB;

b) UNS R56260 shall have a maximum hardness of 45 HRC and shall be in one of the three following conditions:

1) annealed;

2) solution-annealed;

3) solution-annealed and aged.

c) UNS R53400 shall be in the annealed condition. Heat treatment shall be annealing at (774 ± 14) °C [(1 425 ± 25) °F] for 2 h followed by air-cooling. Maximum hardness shall be 92 HRB;

d) UNS R56323 shall be in the annealed condition and shall have a maximum hardness of 32 HRC;

e) wrought UNS R56403 shall be in the annealed condition and shall have a maximum hardness of 36 HRC;

f) UNS R56404 shall be in the annealed condition and shall have a maximum hardness of 35 HRC;

g) UNS R58640 shall have a maximum hardness of 42 HRC;

h) UNS R55400 shall be used in the Solution-Treat plus Age (STA) condition, and have a maximum hardness of 41 HRC.

[a] Sulfur resistant as tested in accordance with Group 1 as defined in NACE Conference paper 95047 and EFC 17, Appendix S1.

Specific guidelines shall be followed for successful applications of each titanium alloy specified in this part of ISO 15156. For example, hydrogen embrittlement of titanium alloys can occur if these alloys are galvanically coupled to certain active metals (e.g. carbon steel) in H_2S-containing aqueous media at temperatures greater than 80 °C (176 °F). Some titanium alloys can be susceptible to crevice corrosion and/or SSC in chloride environments. Hardness has not been shown to correlate with susceptibility to SSC/SCC. However, hardness has been included for alloys with high strength to indicate the maximum testing levels at which failure has not occurred.

Page 80, Table D.9 — Chemical compositions of some precipitation-hardened nickel base alloys (see A.9)

Replace Table D.9 with the following:

Table D.9 — Chemical compositions of some precipitation-hardened nickel base alloys (see A.9)

UNS	C max[a] w_{C} %	Cr w_{Cr} %	Ni w_{Ni} %	Fe max[a] w_{Fe} %	Mn max[a] w_{Mn} %	Mo w_{Mo} %	Si max[a] w_{Si} %	Nb max[a] w_{Nb} %	Ti max[a] w_{Ti} %	Cu max[a] w_{Cu} %	Al max[a] w_{Al} %	Co max[a] w_{Co} %	N max[a] w_{N} %	B max[a] w_{B} %	P max[a] w_{P} %	S max[a] w_{S} %
N06625	0,10	20,0 to 23,0	Bal.[b]	5,0	0,50	8,0 to 10,0	0,50	3,15 to 4,15	0,40	—	0,40	—	—	—	0,015	0,015
N07022[e]	0,010	20,0 to 21,4	Bal.[b]	1,8	0,5	15,5 to 17,4	0,08	—	—	0,5	0,5	1,0	—	0,006	0,025	0,015
N07031	0,03 to 0,06	22,0 to 23,0	55,0 to 58,0	Bal.[b]	0,20	1,7 to 2,3	0,20	—	2,10 to 2,60	0,60 to 1,20	1,00 to 1,70	—	—	0,003 to 0,007	0,015	0,015
N07048	0,015	21,0 to 23,5	Bal.[b]	18,0 to 21,0	1,0	5,0 to 7,0	0,10	0,5	1,5 to 2,0	1,5 to 2,2	0,4 to 0,9	2,0	—	—	0,02	0,01
N07090	0,13	18,0 to 21,0	Bal.[b]	3,0	1,0	—	—	—	1,8 to 3,0	—	0,8 to 2,0	15,0 to 21,0	—	—	—	—
N07626	0,05	20,0 to 23,0	Bal.[b]	6,0	0,50	8,0 to 10,0	0,50	4,50 to 5,50	0,60	0,50	0,40 to 0,80	1,00	0,05	—	0,02	0,015
N07716	0,03	19,0 to 22,0	57,0 to 63,0	Bal.[b]	0,20	7,0 to 9,5	0,20	2,75 to 4,00	1,00 to 1,60	—	0,35	—	—	—	0,015	0,01
N07718	0,08	17,0 to 21,0	50,0 to 55,0	Bal.[b]	0,35	2,8 to 3,3	0,35	4,75 to 5,50	0,65 to 1,15	0,30	0,20 to 0,80	1,00	—	0,006	0,015	0,015
N07725	0,03	19,0 to 22,5	55,0 to 59,0	Bal.[b]	0,35	7,00 to 9,50	0,20	2,75 to 4,00	1,00 to 1,70	—	0,35	—	—	—	0,015	0,01
N07773	0,03	18,0 to 27,0	45,0 to 60,0	Bal.[b]	1,00	2,5 to 5,5	0,50	2,5 to 6,0	2,0	—	2,0	—	—	—	0,03	0,01
N07924[c]	0,020	20,5 to 22,5	52,0 min	7,0 to 13,0	0,20	5,5 to 7,0	0,20	2,75 to 3,5	1,0 to 2,0	1,0 to 4,0	0,75	3,0	0,20	—	0,030	0,005
N09777	0,03	14,0 to 19,0	34,0 to 42,0	Bal.[b]	1,00	2,5 to 5,5	0,50	0,1	—	—	0,35	—	—	—	0,03	0,01
N09925	0,03	19,5 to 23,5	38,0 to 46,0	22,0 min	1,00	2,50 to 3,50	0,50	0,50	1,90 to 2,40	1,50 to 3,00	0,10 to 0,50	—	—	—	—	0,03

Table D.9 *(continued)*

UNS	C max[a] w_C %	Cr w_{Cr} %	Ni w_{Ni} %	Fe max[a] w_{Fe} %	Mn max[a] w_{Mn} %	Mo w_{Mo} %	Si max[a] w_{Si} %	Nb max[a] w_{Nb} %	Ti max[a] w_{Ti} %	Cu max[a] w_{Cu} %	Al max[a] w_{Al} %	Co max[a] w_{Co} %	N max[a] w_N %	B max[a] w_B %	P max[a] w_P %	S max[a] w_S %
N09935[d]	0,030	19,5 to 22,0	34,0 to 38,0	Bal.[b]	1,0	3,0 to 5,0	0,50	0,20 to 1,0	1,80 to 2,50	1,0 to 2,0	0,50	1,0	—	—	0,02 5	0,00 1
N09945	0,005 to 0,04	19,5 to 23,0	45,0 to 55,0	Bal.[b]	1,0	3,0 to 4,0	0,5	2,5 to 4,5	0,5 to 2,5	1,5 to 3,0	0,01 to 0,7	—	—	—	0,03	0,03
N09946	0,005 to 0,030	19,5 to 22,5	50,0 to 55,0	Bal.[b]	1,0	3,0 to 4,0	0,5	3,5 to 4,5	0,5 to 2,5	1,5 to 3,0	0,01 to 0,7	—	—	—	0,03	0,03
N05500	0,25	—	63,0 to 70,0	2,00	1,50	—	0,50	—	0,35 to 0,85	Bal.[b]	2,30 to 3,15	—	—	—	—	—
N07750	0,08	14,0 to 17,0	70,0 min	5,0 to 9,0	1,00	—	0,50	0,70 to 1,20	2,25 to 2,75	0,5	0,40 to 1,00	—	—	—	—	0,01

[a] Min indicates minimum percentage mass fraction. Where a range is shown, it indicates min to max percentage mass fractions.

[b] "Bal." is the balance of composition up to 100 %.

[c] Additional elements by mass fraction: w_W = 0,5 % max and w_{Mg} = 0,005 0 % max.

[d] Additional elements by mass fraction: w_W = 1,0 % max.

[e] Additional elements by mass fraction: w_{Ta} = 0,2 % max and w_W = 0,8 % max.

Page 83, Table D.11 — Chemical compositions of some titanium alloys (see A.11)

Replace Table D.11 with the following:

Table D.11 — Chemical compositions of some titanium alloys (see A.11)

UNS	Al max[a] w_{Al} %	V max[a] w_V %	C max[a] w_C %	Cr max[a] w_{Cr} %	Fe max[a] w_{Fe} %	H max[a] w_H %	Mo max[a] w_{Mo} %	N max[a] w_N %	Ni w_{Ni} %	Sn max[a] w_{Sn} %	Zr max[a] w_{Zr} %	Other max[a] w %	Ti
R50250	—	—	0,10	—	0,20	0,015	—	0,03	—	—	—	O 0,18	Bal.[b]
R50400	—	—	0,10	—	0,30	0,015	—	0,03	—	—	—	O 0,25	Bal.[b]
R56260	6	—		—	—	—	6	—	—	2	4	—	Bal.[b]
R53400	—	—	0,08	—	0,30	0,015	0,2 to 0,4	0,03	0,6 to 0,9	—	—	O 0,25	Bal.[b]
R56323	2,5 to 3,5	2,0 to 3,0	0,08	—	0,25	0,015	—	0,03	—	—	—	O 0,15, Ru 0,08 to 0,14	Bal.[b]
R56403	5,5 to 6,75	3,5 to 4,5	0,10	—	0,40	0,0125	—	0,05	0,3 to 0,8	—	—	O 0,20, Pd 0,04 to 0,08, Residuals[c]	Bal.[b]
R56404	5,5 to 6,5	3,5 to 4,5	0,08	—	0,25	0,015	—	0,03	—	—	—	O 0,13, Ru 0,08 to 0,14	Bal.[b]
R58640	3	8	—	6	—	—	4	—	—	—	4	—	Bal.[b]
R55400	5,2 to 5,8	5,3 to 6,1	0,03	—	0,22	0,015	1,0 to 1,5	0,05	—	—	4,0 to 4,5	O 0,12, Pd 0,04 to 0,08	Bal.[b]

[a] Where a range is shown, it indicates min to max percentage mass fractions.

[b] “Bal.” is the balance of composition up to 100 %.

[c] Residuals each 0,1 % max mass fraction, total 0,4 % ma. mass fraction.