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Guidance on Practice for Materials Selection and Specification for Subsea Equipment

GP 36-20

**BP GROUP
ENGINEERING TECHNICAL PRACTICES**

Foreword

This is the first issue of Engineering Technical Practice (ETP) BP Guidance on Practice GP 36-20.

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1. Scope

- a. This GP specifies requirements for selection and specification of materials for construction of oil and gas production equipment that is fully immersed in seawater and installed at or above seabed, including water, gas, and chemical injection systems and their associated controls.
- b. The following items are outside the scope of this GP:
 1. Drilling, well tubulars and completion equipment below the hangers.
 2. Items used only for deployment, retrieval, or maintenance of permanently installed facilities.
 3. Structural items and steel fabrications (see GN 18-002).
 4. Topside equipment (see GP 36-40).
 5. Flexible pipe (see GIS 78-17).

This GP is not an alternative to involvement of suitably qualified metallurgical, materials, welding, and corrosion specialists in subsea projects. The complexity of some issues involved is such that this GP cannot always provide definitive recommendations. The requirement for expert advice on materials issues will remain while deriving Site Technical Practices (STPs) from this GP.

Many associated topics that could affect materials performance and equipment integrity are not addressed in any detail in this document but are covered in other GPs, including:

- *Welding and cladding procedures (refer to category 18 and 42 documents).*
- *Non-destructive examination requirements.*
- *Quality assurance/quality control (QA/QC) procedures during component manufacture.*
- *Verification and validation testing of assembled equipment.*
- *Chemical treatment of hydrotest fluids (refer to GP 06-29).*
- *External coating and cathodic protection designs (refer to category 06 documents).*
- *Thermal insulation (refer to GN 36-009 and GN 36-010 for guidance).*
- *Methods of equipment deployment to avoid seawater ingress.*
- *Subsea connection procedures to avoid or minimise seawater ingress.*

2. Normative references

The following normative documents contain requirements that, through reference in this text, constitute requirements of this technical practice. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this technical practice are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies.

BP

GIS 43-311	Manufacture of Longitudinal or Helical Seam Submerged Arc Welded Linepipe in Grades up to X80.
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GIS 43-312	Manufacture of High Frequency Induction (HFI) or Electric Resistance Welded (ERW) Linepipe in Grades up to X70.
GIS 43-313	Manufacture of Seamless Linepipe in Grades up to X80.
GIS 43-314	Manufacture of 13% Chromium Seamless Linepipe.
GIS 43-315	Manufacture of 22% Cr and 25% Cr Duplex Stainless Steel Seamless Linepipe.
GIS 43-316	Manufacture of CRA Clad or Lined Steel Pipe.
GIS 43-317	Manufacture of Carbon Steel Induction Bends for Pipelines to ISO 15590 in Grades up to X80.
GIS 43-318	Manufacture of Carbon Steel Fittings for Pipelines to ISO 15590 in Grades up to X80.
GIS 43-319	Manufacture of Carbon Steel Flanges for Pipelines to ISO 15590 in Grades up to X80.
GIS 43-352	Guidance on Industry Standard for EN ISO 14723 Subsea Pipeline Valves.
GIS 78-019	Design of Subsea Control Umbilicals to ISO 13628 Part 5.
GN 06-001	BP Erosion Guidelines.
GN 06-002	Corrosion Prediction Modelling.
GN 18-002	Selection and Fabrication of Structural Steel for Manifolds, PLETS and Other Subsea Equipment
GN 18-003	Deposition of CRA Weld Overlay in Tubulars and Other Components
GN 36-001	Requirements for Alloy 718 Equipment.
GN 36-003	Non-metallic Materials Selection.
GN 36-005	Guidelines for Avoiding Gas Decompression Damage of Elastomer Seals.
GN 36-006	Status of Plastic Liner Technology for Flowline Applications.
GN 36-007	Guideline for Compatibility Testing of Non-metallic Materials within Subsea Chemical Delivery Systems.
GN 36-012	Specification for Titanium Risers and Forged Components for Use with Workover, Top Tensioned, and Catenary Riser Systems: 110 and 135 ksi SMYS Titanium Forgings.
GN 65-706	Dynamic Riser Materials.
GP 06-14	Erosion and Erosion Corrosion Control.
GP 06-20	Materials for Sour Service.
GP 06-29	Corrosion Protection during Hydrotesting.
GP 18-04	Selection and Specification of Duplex Stainless Steels.
GP 43-31	Linepipe Material Selection and Procurement.
GP 65-73	Design of Steel Catenary Risers
GP 78-10	Design and Installation of Subsea Manifolds

American Petroleum Institute (API)

API RP 15S	Recommended Practice for Qualification of Spoolable Reinforced Plastic Line Pipe.
API Spec 5L	Specification for Line Pipe (ISO 3183-1 and 3183-2, BS ISO 3183-3 and BS EN 10208-1, 10208-2 and 10208-3).
API Spec 6A	Specification for Wellhead and Christmas Tree Equipment (ISO 10423).



API Spec 6A718	Specification of Nickel Base Alloy 718 (UNS N07718) for Oil and Gas Drilling and Production Equipment.
API Spec 17D	Specification for Subsea Wellhead and Christmas Tree Equipment (ISO 13628-4).
API Spec 17E	Specification for Subsea Production Control Umbilicals.

American Society of Mechanical Engineers (ASME)

ASME B31.8	Gas Transmission and Distribution Piping Systems.
ASME B16.34	Valves - Flanged, Threaded, and Welding End.

American Society for Testing and Materials (ASTM)

ASTM A182	Standard Specification for Forged or Rolled Alloy and Stainless Steel Pipe Flanges, Forged Fittings, and Valves and Parts for High-Temperature Service.
ASTM A194	Standard Specification for Carbon and Alloy Steel Nuts for Bolts for High-Pressure or High-Temperature Service, or Both.
ASTM A265	Standard Specification for Nickel and Nickel-Base Alloy-Clad Steel Plate.
ASTM A269	Standard Specification for Seamless and Welded Austenitic Stainless Steel Tubing for General Service.
ASTM A312	Standard Specification for Seamless and Welded Austenitic Stainless Steel Pipe.
ASTM A320	Standard Specification for Alloy-Steel and Stainless Steel Bolting Materials for Low-Temperature Service.
ASTM A333	Standard Specification for Seamless and Welded Steel Pipe for Low-Temperature Service.
ASTM A350	Standard Specification for Carbon and Low-Alloy Steel Forgings, Requiring Notch Toughness Testing for Piping Components.
ASTM A352	Standard Specification for Steel Castings, Ferritic and Martensitic for Pressure Containing Parts Suitable for Low Temperature Service.
ASTM A358	Standard Specification for Electric-Fusion-Welded Austenitic Chromium Nickel Stainless Steel Pipe for High-Temperature Service.
ASTM A403	Standard Specification for Wrought Austenitic Stainless Steel Piping Fittings.
ASTM A420	Standard Specification for Piping Fittings of Wrought Carbon Steel and Alloy Steel for Low-Temperature Service.
ASTM A453	Standard Specification for High-Temperature Bolting Materials, with Expansion Coefficients Comparable to Austenitic Stainless Steels.
ASTM A694	Standard Specification for Carbon and Alloy Steel Forgings for Pipe Flanges, Fittings, Valves, and Parts for High-Pressure Transmission Service.
ASTM A707	Standard Specification for Forged Carbon and Alloy Steel Flanges for Low-Temperature Service.
ASTM A789	Standard Specification for Seamless and Welded Ferritic/Austenitic Stainless Steel Tubing for General Service.
ASTM A790	Standard Specification for Seamless and Welded Ferritic/Austenitic Stainless Steel Pipe.



ASTM A815	Standard Specification for Wrought Ferritic, Ferritic/Austenitic, and Martensitic Stainless Steel Piping Fittings.
ASTM A860	Standard Specification for Wrought High-Strength Low-Alloy Steel Butt-Welding Fittings.
ASTM A928	Standard Specification for Ferritic/Austenitic (Duplex) Stainless Steel Pipe Electric Fusion Welded with Addition of Filler Metal.
ASTM A988	Standard Specification for Hot Isostatically-Pressed Stainless Steel Flanges, Fittings, Valves, and Parts for High-Temperature Service.
ASTM B366	Standard Specification for Factory-Made Wrought Nickel and Nickel Alloy Fittings.
ASTM B423	Standard Specification for Nickel-Iron-Chromium-Molybdenum-Copper Alloy (UNS N08825 and N08221) Seamless Pipe and Tube.
ASTM B444	Standard Specification for Nickel-Chromium-Molybdenum-Columbium Alloys (UNS N06625) Pipe and Tube.
ASTM B564	Standard Specification for Nickel Alloy Forgings.
ASTM B705	Standard Specification for Nickel Alloy (UNS N06625, N06219 and N08825) Welded Pipe.

Det Norske Veritas (DNV)

DNV RP F112	Design of duplex stainless steel subsea equipment exposed to cathodic protection (Draft April 2006).
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International Organisation for Standardisation (ISO)

ISO 3183	Petroleum and natural gas industries - Steel pipe for pipelines. Technical delivery conditions.
ISO 10423	Petroleum and natural gas industries - Drilling and production equipment - Wellhead and Christmas tree equipment.
ISO 13628-1	Petroleum and natural gas industries - Design and operation of subsea production systems - Part 1: General requirements and recommendations.
ISO 13628-4	Petroleum and natural gas industries - Design and operation of subsea production systems - Part 4: Subsea wellhead and tree equipment.
ISO 14723	Petroleum and natural gas industries - Pipeline transportation systems - Subsea pipeline valves.
ISO 15156	Petroleum and natural gas industries - Materials for use in H ₂ S-containing environments in oil and gas production. Same document as NACE MR0175.

NACE International

NACE MR0175	Petroleum and natural gas industries - Materials for use in H ₂ S-containing environments in oil and gas production. Same document as ISO 15156.
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3. Terms and definitions

For the purposes of this GP, the following terms and definitions apply:

BP Approval

Approval by the relevant BP Engineering or Technical Authority.



Cladding

Metallurgically bonded corrosion resistant layer (e.g. as applied by roll bonding or fusion welding).

Coating

External applied corrosion protection, e.g. painting system.

High pressure/high temperature (HP/HT)

Equipment rated at or above 1034 bar (15 ksi) and 121°C (250°F) per API RP 6HP.

Historically, BP considered pressures and temperatures above 10ksi and 180°F to be HP/HT but this has evolved to the above-referenced industry recommended practice definition.

IIW Carbon Equivalent (CE)

$$CE = C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15}$$

Lining

Non-metallurgically bonded corrosion resistant layer (e.g., as applied by cold hydraulic expansion).

Material chemistry parameter (Pcm)

$$Pcm = C + \frac{Si}{30} + \frac{Mn + Cu + Cr}{20} + \frac{Ni}{60} + \frac{Mo}{15} + \frac{V}{10} + 5B$$

PREw

Pitting resistance equivalent (w) = %Cr + 3.3 (%Mo + 0.5 %W) + 16 x %N.

4. Symbols and abbreviations

For the purpose of this GP, the following symbols and abbreviations apply:

CE	Carbon equivalent.
CP	Cathodic protection.
CRA	Corrosion resistant alloy.
EA	Engineering Authority.
ELI	Extra low interstitial.
ENP	Electroless nickel plating.
ERW/HFI	Electric resistance welded / high frequency induction
FFKM	ASTM designation for perfluoroelastomers.
FKM	Viton type fluoroelastomers.
FPM	ASTM designation for fluoroelastomers.
HAZ	Heat affected zone.



HBN	Brinell hardness number.
HIC	Hydrogen induced cracking.
HIP	Hot isostatic pressed.
HNBR	Hydrogenated NBR (nitrile butadiene rubber).
HP/HT	High pressure/high temperature.
HRC	Rockwell hardness "C".
Hv	Vickers hardness number.
IIW	International Institute of Welding
LME	Liquid metal embrittlement.
MDT	Minimum design temperature.
NBR	Nitrile butadiene rubber.
NDE	Non-destructive examination.
Pcm	Material chemistry parameter.
PEEK	Polyether ether ketone.
PREw	Pitting resistance equivalent (w).
PSL	Product specification level.
PTFE	Polytetrafluoroethylene.
PWC	Preferential weld corrosion.
PWHT	Postweld heat treatment.
QA/QC	Quality assurance/quality control.
RTJ	Ring type joint.
SAW	Submerged arc welding.
SCC	Stress corrosion cracking.
SCR	Steel catenary riser.
SMYS	Specified minimum yield strength
SOHIC	Stress oriented HIC (hydrogen induced cracking).
SS	Stainless steel.
SSC	Sulphide stress cracking.
STP	Site Technical Practice.



SWC	Stepwise cracking.
TFEP	Tetrafluoroethylene/propylene.
UNS	Unified numbering system.

5. Materials selection philosophy and specifications

- a. Construction materials for subsea equipment shall be selected and specified to provide required levels of operational integrity, taking account of the following:
 1. Material availability in appropriate product forms.
 2. Weldability.
 3. Project cost and schedule requirements.
 4. Complexity and novelty of equipment manufacture and fabrication.
 5. Internal and external damage mechanisms during:
 - a) Storage.
 - b) Deployment.
 - c) Wet parking.
 - d) Hydrotesting.
 - e) Commissioning.
 - f) Operations (including shutdown and startup).
 - g) Decommissioning.
 6. Internal and external in-service damage mechanisms / failure modes, including:
 - a) Brittle fracture.
 - b) Plastic collapse/overload/buckling.
 - c) Fatigue.
 - d) Erosion.
 - e) Corrosion.
 - f) Environmentally assisted cracking.
 - g) Hydrogen embrittlement.
 7. Reservoir souring.
 8. Effect of contact with well treating and completion chemicals.
 9. Operational criticality.
 10. Required life.

High reliability is required in subsea systems due to difficulties and high cost associated with inspection and maintenance.
- b. Non-metallic materials shall be selected in accordance with principles described in GN 36-003.
- c. Projects shall produce a single materials selection philosophy that defines:
 1. The approach to materials selection.
 2. The application of national and international materials specifications.



3. Necessary requirements for materials and welding qualification testing.
The Project materials selection philosophy is normally developed and approved during select and/or define stages, applicable to entire subsea system.
- d. Materials for subsea application shall be:
 1. Covered by recognised a standard or written material specification, subject to BP approval.
 2. Manufactured to a qualified manufacturing procedure, subject to BP approval. For major pressure containing and structural components, the manufacturing procedure qualification shall be derived from sacrificial components of similar dimensions and include the specified range of mechanical tests. The use of a prolongation may be acceptable to BP provided that section thickness, degree of mechanical work and thermal history are the same as the critical regions in the actual component.
 3. Specified in accordance with relevant GIS documents.
- e. Standards and specifications for metallic materials shall include requirements for the following, as appropriate:
 1. Melting secondary refining and casting practice.
 2. Chemical composition (heat and product).
 3. Forging practice to produce a fully wrought microstructure.
 4. Quality heat treatment.
 5. Sampling for mechanical testing.
 6. Mechanical property requirements, including fracture toughness.
 7. Requirements for special testing (e.g. chemical resistance, metallography, corrosion testing).
 8. Welding and heat treatment.
 9. Non-destructive evaluation and defect acceptance criteria.
Equipment for high pressure/high temperature (HP/HT) designs may be beyond normal limits of typical API/ISO standards. Supplementary materials characterisation and non-destructive examination (NDE) requirements are likely to be needed. Reference should be made to API RP 6HP.
Relevant ETPs for welding and fabrication include GP 18-01, GP 18-02, GIS 18-011, GIS 42-101, and GIS 42-102.
- f. If the design temperature for material is above the range for which allowable stresses are listed in the applicable reference code, elevated temperature tensile testing (including welds) shall be performed.
- g. Components for subsea application shall be specified with high levels of traceability.
Refer to RD 78-002 for recommended approach for traceability methods.

6. Principles of materials selection

6.1. Materials selection for process side environment

6.1.1. General

The potential for exposure to raw or treated seawater (e.g. during installation, hydrotesting, and commissioning) shall be considered.



Principles of materials selection and specification for process side subsea environments are similar to those for surface (topsides) facilities, except that a more conservative approach is normally required to achieve higher reliability.

6.1.2. H₂S containing environments

- a. Materials for H₂S containing environments shall comply with NACE MR0175/ISO 15156 and GP 06-20.

The cost of using “H₂S resistant” grades for carbon or low alloy steels is usually minimal, hence they should be considered for environments containing even low H₂S levels (i.e. below thresholds for sulphide stress cracking [SSC]). This is to cater for possible increases in H₂S levels during life of field, e.g. when additional tie-ins from other sources or unexpected souring behaviour occur, that should be considered in the risk and business case.

- b. Carbon and low alloy steels that are fully internally clad with CRA and that comply with specifications other than ISO 13628-4 (API Spec 17D) are not required to comply with hardness restrictions in NACE MR0175/ISO 15156 for non clad constructions, provided that:

1. Erosion studies performed in accordance with **Error! Reference source not found.** demonstrate that the cladding will remain intact for the design life (i.e. the predicted remaining cladding thickness at the end of design life is at least 50% of the initial specified minimum thickness).
2. Local regulations do not mandate otherwise

Equipment manufactured to ISO 13628-4 generally will not include through-thickness butt welds and therefore concerns with PWHT of weld buttering of joint faces will not arise.

- c. The maximum individual hardness of internally clad components for fabricated equipment downstream of production wellheads and designed to pipeline codes, such as ASME B31.8, measured at any location shall be 325 Hv10.

Advantages of permitting increased hardness levels pertain to optimisation of postweld heat treatment (PWHT) parameters that facilitate retention of tensile properties in high strength carbon steels and minimise formation of undesirable microstructures at bimetallic interfaces.

- d. The Substrate material for CRA lined constructions shall comply with NACE MR0175/ISO 15156.

- e. H₂S partial pressure limits for avoidance of SSC in welded CRAs are not well defined such that application-specific corrosion testing shall be specified, unless agreed upon otherwise by BP.

For CRAs with only limited “H₂S resistance”, e.g. weldable 13% Cr steels and duplex/super duplex stainless steels, the need to use a different alloy composition for H₂S service is likely to have a significant cost effect. “H₂S service” limits for weldable 13% Cr and duplex/super duplex stainless steels are somewhat complex. Such materials would probably fail H₂S service testing in “standard” conditions as defined in NACE TM0177 and associated documents. Susceptibility to SSC is a function of temperature, H₂S level, pH and chloride content of the transported water. Limits that have been applied in BP include the following:



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Material	Partial pressure (H ₂ S)		pH
	bara	psia	
13% Cr steel (weldable) (1)	0,008	0.12	at least 3.5

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knowledge of this phenomenon can be found at UK Health and Safety Executive website: <http://www.hse.gov.uk/research/rrpdf/rr129.pdf>. These conditions are unlikely to be experienced subsea, but should nevertheless be checked in HP/HT developments if duplex stainless steel is proposed for flowlines or manifold piping.

6.1.5. Erosion

Erosion rates in subsea equipment and implications for materials selection shall be evaluated in accordance with GP 06-14 and GN 06-001.

6.1.6. Chemical treatment and deployment

- a. The subsea system design shall consider the range of expected chemical treatments, including understanding how required chemicals will interact with materials they contact (metals and elastomers) and how they will behave with one another if mixed.
- b. Compatibility between treatment chemicals shall be established before final selection and use, since potential incompatibility may result in neutralisation of one or more of product active ingredients or in precipitation and blockage (i.e. “gunking”).

For non-metallic materials, requirements for testing of compatibility of elastomers and plastics with production chemicals are described in GN 36-007.

Reference GP 78-11 for design guidelines for subsea chemical injection.

Chemical treatments are frequently adopted for flow assurance and/or control of corrosion or scaling in subsea producing systems, such as:

- *Corrosion inhibition/pH modifiers.*
- *Scale inhibition.*
- *Hydrate inhibition.*
- *Wax control.*
- *Asphaltene control.*
- *Flow improvers.*

6.1.7. Mercury and liquid metal embrittlement (LME)

- a. Effects of mercury in produced fluids on materials of construction shall be considered.
- b. Mercury bearing streams shall not use copper and aluminium base alloys.
- c. Titanium alloys containing aluminium and/or copper for duty in systems that may contain mercury shall be qualified by testing.

Mercury and associated mercury compounds can be detrimental to certain materials. Mercury can occur naturally as a contaminant in well production fluids. The potential of mercury presence should be recognised at the earliest possible stage of design to avoid potentially susceptible materials being specified.

It is generally accepted that mercury needs to be present in liquid form for damage to occur. Attack can be by amalgamation or by LME.

Lead, antimony and tin compounds, which may be found in some thread dopes, have been found to lead to LME problems.

6.1.8. Preferential weld corrosion (PWC)

- a. Propensity for PWC shall be assessed.
- b. PWC shall not be mitigated by additional design corrosion allowances.

PWC is a particular concern with carbon and low alloy steels in wet hydrocarbon service that have been welded with consumables depositing approximately 1% Ni

