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GP 36-15

Materials Selection for Surface (Topsides) Equipment in Oil and Gas Production Facilities

Group Practice

**BP GROUP
ENGINEERING TECHNICAL PRACTICES**

Foreword

This issue of Engineering Technical Practice (ETP) GP 36-15 includes the following significant changes:

- a. Greater detail on materials and coatings selection to resist the external environment.
- b. Clarification on the use of impact tested carbon steels for vessels and piping.
- c. Editorial cleanup throughout.

Because of the extent of changes, revisions have not been identified by a bar in the margin as is normal practice.

This Group Practice (GP) was created to supersede GP 36-10 and provide requirements for materials selection for construction of topsides equipment for oil and gas production facilities.

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1. Scope

- a. This Group Practice (GP) provides requirements for selection of materials for construction of surface (onshore and topsides) oil and gas production/injection equipment, including chemical and utility systems.

Equipment within the scope essentially comprises the topsides of offshore installations or within the battery limits of onshore sites.

- b. The scope of this GP does not include:
1. Drilling and completion equipment (see [GN 36-003](#) and [GN 36-013](#)).
 2. Wellhead and christmas tree equipment, including choke valves.
 3. Structural items and steel support fabrications.
 4. Fabrication and associated QA/QC requirements (see Category 18 series and Category 42 series ETPs).
 5. Subsea equipment (see GP 36-20).
 6. Flexible pipe (see GP 65-75).
 7. Pipelines, risers, pig traps (see Category 43 and Category 65 series ETPs).
 8. Bulk storage tanks.
 9. Protective coatings.
 10. Thermal insulation.
 11. Temporary equipment.
 12. Steam plant and boilers (see GP 56-10).

2. Normative references

The following normative documents may, to the extent specified in subsequent clauses and normative annexes, be required for full compliance with the GP.

- For dated references, only the edition cited applies.
- For undated references, the latest edition of the referenced document (including any amendments) applies.

BP

BPOUS RP 13-1-1	Crude Units.
EP-GP 26-10-1	Exploration and Production Heat Exchangers.
GIS 06-601	Painting of Metal Surfaces.
GIS 18-013	Integral Cladding, Weld Overlay, and Limited Loose Lining of Pressure Vessels and Components.
GIS 22-101	Fired Heaters (ISO 13705 or API 560).
GIS 22-201	Flare Details (API 537).
GIS 26-101	Shell and Tube Exchangers (ISO 16812 or API 660).
GIS 26-103	Air Cooled Heat Exchangers (ISO 13706 or API 661).
GIS 43-316	Manufacture of CRA Clad or Lined Steel Pipe.
GIS 46-010	New Pressure Vessels.
GN 06-001	Erosion Guidelines .



GN 06-005	Corrosion Protection of New and Existing Carbon and Low Alloy Steel Fasteners.
GN 06-010	Corrosion Prediction Modelling.
GN 18-003	Deposition of CRA weld overlay in small diameter tubulars and other components.
GN 36-003	Non-metallic materials selection.
GN 36-016	Piping Material Data Sheets.
GN 42-002	Piping Joints Handbook.
GP 06-14	Erosion Control.
GP 06-29	Corrosion Protection During Hydrotesting.
GP 06-60	Painting of Metal Surfaces.
GP 06-63	Internal Coatings.
GP 18-04	Manufacture of Duplex Stainless Steel Fittings and Components.
GP 22-20	API 537 Flare Details.
GP 24-23	Active Fire Protection - Offshore.
GP 30-25	Field Instruments - General.
GP 36-12	Amine Services.
GP 36-25	Materials for Sour Service in Exploration and Production Operations.
GP 42-10	Piping Systems (ASME B31.3).
GP 62-01	Valves.
GP 72-00	Design and Selection of Refractory Lining Systems.

American Petroleum Institute (API)

API RP 6HP	Design of High Pressure Equipment.
API Std 560	Fired Heaters for General Refinery Services.

American Society for Testing and Materials (ASTM)

ASTM A105/A105M	Carbon Steel Forgings for Piping Applications.
ASTM A182/A182M	Forged or Rolled Alloy and Stainless Steel Pipe Flanges, Forged Fittings, and Valves and Parts for High-Temperature Service.
ASTM A216/216M	Steel Castings, Carbon, Suitable for Fusion Welding, for High-Temperature Service.
ASTM A217/217M	Steel Castings, Martensitic Stainless and Alloy, for Pressure-Containing Parts, Suitable for High-Temperature Service.
ASTM A350/A350M	Carbon and Low-Alloy Steel Forgings, Requiring Notch Toughness Testing for Piping Components.
ASTM A351/A351M	Castings, Austenitic, for Pressure-Containing Parts.
ASTM A352/A352M	Steel Castings, Ferritic and Martensitic, for Pressure-Containing Parts, Suitable for Low-Temperature Service.
ASTM A395/A395M	Ferritic Ductile Iron Pressure-Retaining Castings for Use at Elevated Temperatures.
ASTM A494/A494M	Castings, Nickel and Nickel Alloy.
ASTM A744/A744M	Castings, Iron-Chromium-Nickel, Corrosion Resistant, for Severe Service.
ASTM A890/A890M	Castings, Iron-Chromium-Nickel-Molybdenum Corrosion-Resistant, Duplex (Austenitic/Ferritic) for General Application.
ASTM B164	Nickel-Copper Alloy Rod, Bar, and Wire.



ASTM B348 Titanium and Titanium Alloy Bars and Billets.

International Organization for Standardization (ISO)

ISO 13705 Petroleum, petrochemical and natural gas industries - Fired heaters for general refinery service.

ISO 15156 Petroleum and natural gas industries - Materials for use in H₂S-containing environments in oil and gas production.

NACE International (NACE)

NACE MR0175 Petroleum and natural gas industries - Materials for use in H₂S-containing environments in oil and gas production.

Norsk Sokkels Konkuranseposisjon (NORSOK)

NORSOK M-630 Material data sheets for piping.

3. Terms and definitions

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

Carbon steel

Weldable grades of carbon manganese steels suitable for pressure systems equipment.

Cladding

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

Coating

A material applied as a layer onto a substrate to provide corrosion protection.

High pressure/high temperature (HP/HT)

Equipment rated at or above 1 034 barg (15 ksig) and 121°C (250°F) in accordance with API RP 6HP.

Historically, BP considered pressures and temperatures above 690 barg (10 ksig) and 82°C (180°F) to be HP/HT, but this has evolved to the above referenced industry recommended practice definition.

International Institute of Welding (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.

Obturator

Part of the valve positioned in the flow stream to permit or block flow (i.e., gate or ball).

Pressure boundary equipment

Equipment that comprises the main pressure containing envelope (i.e., failure would result in an uncontrolled loss of containment to the atmosphere).

PRE_w

Pitting resistance equivalent number ($PRE_w = \%Cr + 3,3 (\%Mo + 0,5 \%W) + 16 \times \%N$).



Quality heat treatment

Collective sequence of heat treatments applied to forgings and forging qualification test coupons to achieve final properties.

Includes final austenitisation, quench from final austenitisation, tempering or ageing, and quenching (if applicable) from tempering or ageing.

4. Symbols and abbreviations

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

ABS	Acrylonitrile butadiene styrene.
CE	Carbon equivalent.
CA	Corrosion allowance.
CRA	Corrosion resistant alloy.
EG	Ethylene glycol.
GRP	Glass fibre reinforced plastic.
HIC	Hydrogen induced cracking.
HIPing	Hot isostatic pressing.
HP/HT	High pressure/high temperature.
Hv	Vickers hardness number.
KO	Knockout.
LME	Liquid metal embrittlement.
LP	Low pressure.
MEG	Monoethylene glycol.
PREw	Pitting resistance equivalent number.
PVDF	Polyvinylidene fluoride.
PWC	Preferential weld corrosion.
PWHT	Postweld heat treatment.
QA/QC	Quality assurance/quality control.
RCP	Resistor controlled cathodic protection.
SCC	Stress corrosion cracking.
SOHIC	Stress oriented HIC.
SSC	Sulphide stress cracking.



SWC	Stepwise cracking.
TEG	Triethylene glycol.
UNS	Unified numbering system.

5. Materials selection philosophy

- a. Projects shall produce a single materials selection philosophy from the Basis of Design document for the Project, which considers the following:

1. Design and operating conditions.
2. An evaluation of corrosivity, which shall include:
 - a) CO₂ content.
 - b) H₂S content.
 - c) Hg content.
 - d) Content of oxygen and other oxidising agents.
 - e) Design and operating temperature and pressure.
 - f) pH, including effects of organic acids.
 - g) Chloride/halide ion concentration.
 - h) Velocity and flow regime.
 - i) Sand or other solids production.
 - j) Microbiological activity.
 - k) Transient conditions (e.g., shutdown and startup).
 - l) Condensing conditions.

A gas is normally considered “dry” (i.e., no risk of free water) if the water dewpoint at the actual pressure is at least 10°C (18°F) lower than the actual operation temperature for the system. Materials for stagnant gas containment need particular attention.

3. Approach to materials selection.
4. Application of national and international materials specifications.
5. Compliance with regulations.
6. Requirements for materials and welding qualification testing.
7. Application of relevant GIS documents.

Project materials selection philosophy is normally developed during select and/or define stages.

- b. Construction materials for surface equipment shall be selected and specified to provide required levels of operational integrity, taking into account:

1. Material availability in appropriate product forms.
2. Operations and maintenance strategy.
3. Weldability.
4. Inspectability.
5. Project cost and schedule requirements.



6. Complexity and novelty of equipment manufacture and fabrication.
7. Internal and external in-service damage mechanisms for normal and transient conditions, including:
 - a) Corrosion (general and localised).
 - b) Environmentally assisted cracking.
 - c) Brittle fracture.
 - d) Erosion.
 - e) Fatigue and corrosion fatigue.
 - f) Hydrogen embrittlement.
8. Predicted changes in reservoir conditions over design life (e.g., souring).
9. Effect of contact with well treating and completion chemicals.
10. Operational criticality.
11. Required life.
12. Weight (for offshore).
- c. Application of carbon steels shall be maximised for pressure boundary equipment, consistent with requirements of relevant design codes to achieve:
 1. Economic wall thickness for design pressure.
 2. Adequate fracture toughness at the minimum design temperature.
- d. If required by the design case or for design minimum temperatures below 0°C (32°F), impact tested carbon steels shall be specified. Even if not required to meet the minimum design temperature requirements, impact tested carbon steels are still the preferred option and should be specified.

Project experience has shown that when purchasing bulk carbon steel materials, it is economic to select only impact tested carbon steels rather than purchasing mixed grades. Exclusively specifying impact tested carbon steels simplifies QA/QC issues during fabrication, which is an important consideration. The accidental substitution of non impact tested and impact tested grades of carbon steel has caused significant QA/QC issues for projects.

- e. If the predicted internal corrosion on carbon steels exceeds 8 mm (0,3 in) for the design life, with or without inhibitors, one of the following options, which shall be subject to BP approval, shall be specified:
 1. Carbon steel with internal CRA cladding.
 2. Solid CRA or non-metallic construction.
 3. Carbon steel with internal coating in accordance with GP 06-63 may be used in particular cases.

An internal corrosion allowance limit of 3 mm (0,12 in) may be more desirable as a weight saving requirement for offshore topsides equipment.

- f. Surface facility process plant equipment items, other than production flowlines and manifolds, shall not be designed to rely on upstream corrosion inhibition. Inhibition may be proposed for BP approval if the required inhibitor performance and availability can be ensured by taking into account geometry and layout and if whole life costing indicates this is cost effective.

Corrosion inhibition is best suited to long, larger diameter piping runs of minimal complexity. Effective inhibition in branched fittings, dead legs, and at locations of



turbulence may be difficult to achieve. The application of inhibitors mandates the need for effective corrosion monitoring and inspection, the costs of which also need to be taken into account.

- g. Suitably qualified metallurgical, materials, welding, and corrosion specialists shall be involved in materials selection in projects. Complexity of some issues involved is such that this GP or derived site technical practices (STPs) cannot always provide definitive recommendations.
- h. Non-metallic materials should be selected in accordance with [GN 36-003](#).
- i. Materials for surface (topsides) application shall be:
 - 1. Covered by recognised standard or written material specification, subject to BP approval.
 - 2. Manufactured in accordance with qualified manufacturing procedures, subject to BP approval.
- j. 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 fully wrought microstructure.
 - 4. Quality heat treatment as related to forgings.
 - 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 post weld heat treatment.
 - 9. Non-destructive evaluation and defect acceptance criteria.

Relevant ETPs for welding and fabrication include GP 18-01, GIS 18-011, GIS 18-012, GIS 42-101, and GIS 42-102.

GN 36-016 contains data sheets for CRAs, which provide guidance for meeting most of the above requirements.
- k. If design temperature for material is above range for which allowable stresses are listed in applicable reference code, elevated temperature tensile testing (including welds) shall be performed and an allowable stress determined.
- l. Corrosion protection for carbon and low alloy steel bolting should be specified in accordance with [GN 06-005](#).
- m. The number of different materials should be minimised to reduce complexity.

6. Principles of materials selection

6.1. Materials selection for process side environment

6.1.1. H₂S containing environments

- a. Materials for H₂S containing environments shall comply with NACE MR0175/ISO 15156 and GP 36-25, including vessels with internal coatings/linings.



- b. “H₂S resistant” grades of carbon or low alloy steels should be considered for environments containing even low H₂S levels (i.e., below thresholds for SSC).
- c. Materials selection process should consider any predicted souring over the design life of the reservoir.

Cost of using “H₂S resistant” grades of carbon or low alloy steels is usually minimal, and they are recommended for environments containing even low H₂S levels.

- d. If erosion studies performed in accordance with GP 06-14 demonstrate that CRA internal cladding will remain intact for design life (i.e., predicted remaining cladding thickness at end of design life is at least 1 mm [0,04 in]), carbon and low alloy steels that are fully internally clad with CRA are not required to comply with hardness restrictions in NACE MR0175/ISO 15156 for non-clad constructions.
- e. The maximum individual hardness of fully internally clad carbon steel components measured at any location shall be 325 Hv 10.
 - Advantages of allowing increased hardness levels pertain to elimination or optimisation of PWHT parameters that:*
 - *Facilitate retention of tensile properties in high strength carbon steels and low alloyed steels.*
 - *Minimise formation of undesirable microstructures at bimetallic interfaces.*
- f. H₂S partial pressure limits for avoidance of SSC in welded CRAs are not well defined. Application specific qualification corrosion testing may be required including the effects of welding.
- g. If conditions are considered marginal between different classes or grades of steels/alloys:
 - 1. Conservative approach to materials selection shall be adopted, especially for high criticality equipment and for offshore applications.
 - 2. Alternates (e.g., carbon steel clad or lined with an austenitic CRA) should be considered.

The ease of in-service inspection is an important factor in selecting materials and the design of equipment.

- h. Steels for HIC, SWC, and SOHIC resistance shall comply with applicable requirements in GP 36-25.
- i. Resistance to H₂S shall also be considered in the selection of non-metallic materials.
- j. Elemental sulphur

Elemental sulphur deposits increase the susceptibility of carbon and low alloy steels to SCC, pitting corrosion, and general corrosion. However, corrosion can be controlled by the use of solvents to prevent sulphur deposition or selecting sulphur resistant CRAs. NACE MR0175/ISO 15156 provides requirements on environmental limits and selection of alloys resistant to elemental sulphur.

6.1.2. CO₂ containing environments

- a. CO₂ corrosion rates on carbon and low alloy steel shall be predicted in accordance with [GN 06-010](#). Predictions shall be developed using the latest version of BP CO₂ corrosion model for assessment of viability for use on surface equipment.
- b. Effects of organic acids shall be taken into account in corrosion prediction modelling and testing for corrosion inhibitor selection.

