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Guidance on Practice for Cathodic Protection

GP 06-31

BP GROUP
ENGINEERING TECHNICAL PRACTICES

Foreword

This is the first issue of Engineering Technical Practice (ETP) BP GP 06-31. This Guidance on Practice (GP) replaces heritage documents from the merged BP companies as follows:

BP

PTA CP-CP-UGP-C	Corrosion Protection—Cathodic Protection—Electrical Bonding of Underground Pipe—Construction Specification.
PTA CP-CP-00-C	Corrosion Protection—Cathodic Protection—Steel Structures—Construction Specification.
PTA CP-CP-00-E	Corrosion Protection—Cathodic Protection—Engineering Specification.
PTA CP-CP-BRZ-R	Corrosion Protection—Cathodic Protection—Thermite Brazing—Recommended Practice.
PTA CP-CP-TST-R	Corrosion Protection—Cathodic Protection—Insulating Flanges and Unions Testing—Recommended Practice.
PTA CP-CP-00-G	Corrosion Protection—Cathodic Protection—Guide.

Amoco

A CP-CP-GAOP-E	Corrosion Protection—Cathodic Protection—Design of Galvanic Anodes for Offshore Platforms—Engineering Specification.
A CP-CP-00-C	Corrosion Protection—Cathodic Protection—Steel Structures—Construction Specification.
A CP-CP-00-E	Corrosion Protection—Cathodic Protection—Engineering Specification.
A CP-CP-00-G	Corrosion Protection—Cathodic Protection—Guide.
A CP-CP-BRZ-R	Corrosion Protection—Cathodic Protection—Thermite Brazing—Recommended Practice.
A CP-CP-TST-R	Corrosion Protection—Cathodic Protection—Insulating Flanges and Unions Testing—Recommended Practice.
A CP-CP-UGP-C	Corrosion Protection—Cathodic Protection—Electrical Bonding of Underground Pipe—Construction Specification.

ARCO

Engineering Standard 400	Electrical - General.
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Introduction

Cathodic protection of facilities is a key component of integrity management. Corrosion protection of onshore and offshore buried and submerged metallic structures shall be supplemented with cathodic protection. This document explains the importance of cathodic protection and gives guidance on how it should be applied.

Cathodic protection is mandated by “Getting Health Safety and Environment Right” and by the Group “Integrity Management Standard,” as follows: *“All BP Operations shall ensure processes are in place to confirm that facilities, and equipment used in that operation, are fit for service with the goals of avoiding loss of containment and maintaining structural integrity throughout the full lifecycle of the facility and equipment in question. For this purpose, the SPA IM shall ensure that integrity management and process safety issues are identified and managed.”*

This document falls within the corrosion series of technical practices and is the base guidance document related to cathodic protection. The following documents provide more detailed guidance on design and good practices:

Corrosion Protection

GP 06-31	Guidance on Practice for Cathodic Protection.
GP 06-32	Guidance on Practice for Cathodic Protection of Onshore Pipelines.
GP 06-33	Guidance on Practice for Cathodic Protection of Onshore Structures and Equipment.
GP 06-36	Guidance on Practice for Cathodic Protection - Maintenance and Monitoring.
GIS 06-311	Guidance on Industry Standard for Cathodic Protection – Procurement.



1. Scope

- a. This document provides guidance on the use of cathodic protection to mitigate (i.e. control and minimise) external and internal corrosion of metallic structures, buried or immersed in an electrolyte, i.e. an aqueous or soil environment.
- b. This GP provides guidance for the management, implementation, and continuous improvement of a cathodic protection system for pipelines, equipment, and structures, with emphasis on those that are considered to be health, safety, and environmentally critical.
- c. This GP defines the elements required to develop and implement cathodic protection within the larger context of the Integrity Management (IM) Standard.
- d. Cathodic protection should be applied to a wide variety of production and process equipment, offshore and onshore, including (but not limited to) the following:
 1. Offshore:
 - a) Fixed and floating production facilities.
 - b) Drilling fluid storage tanks.
 - c) Subsea systems, e.g. well-heads, risers, mooring systems, flowlines and pipelines.
 - d) Firewater and sea water pump caissons.
 - e) Coastal/marine terminals, e.g. wharfs, jetties, mooring and breasting dolphins.
 2. Onshore:
 - a) Above and below ground storage tanks and vessels.
 - b) Buried process and utility pipelines.
 - c) Well casings.
 - d) Shell & tube heat exchangers using cooling water.
 - e) Buried/immersed structures.

2. Normative references

The following normative documents contain requirements that, through reference in this text, constitute requirements of this technical practice. The latest edition of the normative document referred to applies.

American Petroleum Institute (API)

API RP 580 Risk Based Inspection & Integrity Management.

BP

Group Integrity Management (IM) Standard

GP 06-36 Guidance on Practice for Cathodic Protection - Maintenance and Monitoring.

GIS 06-311 Guidance on Industry Standard for Cathodic Protection – Procurement.

GIS 06-601 Guidance on Industry Standard for Coating of Metal Surfaces and Equipment.

GP 32-30 Guidance on Practice for Inspection and Testing of Equipment In Service – Management Principles.



GP 32-40 Guidance on Practice for Technical Guidance and Implementation of Management Principles.

European Standard (EN)

EN 12473 General Principles of Cathodic Protection in Sea Water.
EN 12954 Cathodic Protection of Buried or Immersed Metallic Structures - General Principles and Applications for Pipelines.

Det Norske Veritas (DNV)

DNV RP-B401 Recommended Practice Cathodic Protection Design.
DNV RP-F103 Recommended Practice Cathodic Protection of Submarine Pipelines by Galvanic Anodes.

International Organization for Standardization (ISO)

ISO 15589-1 Petroleum and Natural Gas Industries - Cathodic Protection of Transportation Systems - Part 1: On-Land Pipelines.
ISO 15582-2 Petroleum and Natural gas Industries - Cathodic Protection of Transportation Systems - Part 2: Offshore Pipelines.

NACE International (NACE)

NACE RP0169 Control of External Corrosion on Underground or Submerged Metallic Piping Systems.
NACE RP0186 Application of Cathodic Protection for Well Casings.
NACE RP0193 External Cathodic Protection of On-Grade Carbon Steel Storage Tank Bottoms.
NACE RP0196 Galvanic Anode Cathodic Protection of Internal Submerged Surfaces of Steel Water Storage Tanks.
NACE RP0285 Corrosion Control of Underground Storage Tank Systems by Cathodic Protection.
NACE RP0286 Electrical Isolation of Cathodically Protected Pipelines.
NACE RP0388 Impressed Current Cathodic Protection of Internal Submerged Surfaces of Carbon Steel Water Tanks.
NACE RP0572 Design, Installation, Operation and Maintenance of Impressed Current Deep Groundbeds.
NACE RP0575 Internal Cathodic Protection Systems in Oil-Treating Vessels.
NACE RP0387 Metallurgical and Inspection Requirements for Cast Sacrificial Anodes for Offshore Applications.
NACE TM0190 Impressed Current Test Method for Lab. Testing of Aluminium Anodes.

NORSOK

NORSOK Std M-503 Cathodic Protection.

3. Terms and definitions

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

Anaerobic

Absence of un-reacted or free oxygen in the electrolyte.



Anode

The electrode at which oxidation or corrosion of some component occurs.

Anode backfill

Material with a low resistivity, which may be moisture-retaining, immediately surrounding a buried anode for the purpose of decreasing the effective resistance of the anode to the electrolyte.

Bond

Metal conductor, usually of copper, connecting two points on the same or on different structures usually with the intention of making the points equipotential.

Buried structure

Any metal construction built or laid beneath ground level or built on ground level and then covered with earth.

Calcareous deposit

A layer consisting of a mixture of calcium carbonate and magnesium hydroxide deposited on surfaces being cathodically protected because of the increased pH adjacent to the protected surface.

Cathode

The electrode of an electrolytic cell at which reduction is the principal reaction.

Cathodic protection

(1) Reduction of corrosion rate by shifting the corrosion potential of the electrode toward a less oxidizing potential by applying an external electromotive force. (2) Partial or complete protection of a metal from corrosion by making it a cathode, using either a galvanic or an impressed current.

Cell

Electrochemical system consisting of an anode and a cathode immersed in an electrolyte. The anode and cathode may be separate metals or dissimilar areas on the same metal. The cell includes the external circuit, which permits the flow of electrons from the anode toward the cathode.

Coating defect

Deficiency in protective coating (e.g. flaws, holidays, porosity).

Copper/saturated copper sulphate reference electrode (Cu/CuSO₄)

Reference electrode consisting of copper in saturated solution of copper sulphate.

Coupon

Representative metal sample used to quantify the extent of corrosion or the effectiveness of applied cathodic protection.

CRA

Corrosion resistant alloy.

Drain point

Location of negative cable connection to protected structure through which protection current returns to its source.

Driving voltage

Anode close circuit potential, minus polarized cathode (steel) potential, expressed in volts.



Earthing (Grounding)

Earthing (Grounding) may be described as a system of electrical connections to the general mass of earth. The characteristic primarily determining the effectiveness of an earth (ground) electrode is the resistance, which it provides between the earthing (grounding) system and the general mass of earth.

Electrical isolation

The condition of being electrically separated from other metallic structures or the environment

Electrolyte

Liquid, or the liquid component in a medium such as soil, in which electric current flows by the movement of ions.

Electrolyte resistivity

Electric resistance of the electrolyte assuming the electrolyte is homogeneous, expressed in Ohm-m.

Electro motive force (e.m.f.)

Naturally occurring open circuit electrical potential difference between the anode and the cathode.

Galvanic anode

Electrode providing current for cathodic protection by means of galvanic action.

Groundbed

System of buried or immersed galvanic or impressed current anodes.

Impressed current anode

Electrode that supplies current for cathodic protection by an impressed current source.

Ion

Atom or group of atoms, carrying a negative or positive charge.

Interference

Any change of the structure to electrolyte potential which is caused by foreign electrical sources.

IR drop

Voltage due to any current, developed in an electrolyte, such as soil, between reference electrode and metal of structure, in accordance with Ohm's law ($U(\text{voltage}) = I(\text{current}) \times R(\text{resistance})$).

Isolating joint

Electrically discontinuous connection between two lengths of pipe, inserted to provide electrical discontinuity between them, e.g. monolithic isolating joint, isolated flange.

Natural potential

Structure to electrolyte potential measured with no cathodic protection applied.

OFF potential

Structure to electrolyte potential measured immediately after synchronous interruption of all sources of applied cathodic protection current.

ON potential

Structure to electrolyte potential measured with cathodic protection current flowing.



Permanent reference electrode

Permanently buried or immersed reference electrode designed for long life and installed close to the structure.

pH

Measure of the activity of hydrogen ions (H^+) in a electrolyte/solution and, therefore, its acidity or alkalinity; acidic (0-7), neutral (7) or alkaline (7-14).

Polarization

A shift in the potential of an electrode (structure) from the equilibrium value as a result of current flow through its surface.

Protected structure

Structure to which cathodic protection is effectively applied.

Protection current

Current made to flow into a metallic structure from its electrolytic environment in order to effect cathodic protection of the structure.

Protection potential

The structure to electrolyte potential for which the metal corrosion rate is acceptable.

Sacrificial anode

See galvanic anode.

Silver/silver chloride reference electrode (Ag/AgCl)

Reference electrode consisting of silver, coated with silver chloride, in an electrolyte containing a fixed concentration of chloride ions.

Structure-to-electrolyte potential

The measured potential of a structure/electrode in the soil/electrolyte relative to the potential of a reference electrode, at a point sufficiently close to, but not actually touching, the structure.

Stray current corrosion

Corrosion resulting from direct current flow through paths other than circuit intended.

Sulphate reducing bacteria (SRB)

Organisms found in most soils and natural waters which reduce sulphate to sulphide in the absence of oxygen. When sulphide is liberated, it reacts with iron in typically tubed culture medium to form iron sulphide, thus accelerating corrosion.

Transformer rectifier

A device which converts alternating current (a.c.) to direct current (d.c.). The d.c. voltage derived in this way is used as a power source for impressed current cathodic protection systems.

4. Symbols and abbreviations

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

AgCl	Silver chloride
a.c.	Alternating current



CuSO ₄	Copper sulphate
d.c.	Direct current
e.m.f.	Electro motive force
EPTG	Exploration Production Technology Group
IM	Integrity Management
SRB	Sulphate Reducing Bacteria
SPA IM	BP Operation Single Point of Accountability for Integrity Management
wrt	with respect to

5. The importance of cathodic protection

5.1. Corrosion threats

Corrosion related to lack of or insufficient cathodic protection (CP) can have catastrophic consequences on hydrocarbon production and treatment facilities. Corrosion damage causing loss of containment may seriously harm the environment, personal health and safety, production, revenue, as well as BP's reputation both locally and globally.

5.2. Hazards identification and mitigation

- a. Corrosion hazards related to lack of or ineffective cathodic protection shall be systematically identified for BP operated facilities according to the requirements of the IM standard.
- b. In-service inspection of equipment should be done in accordance with GP 32-30 and GP 32-40.
- c. Any required modifications to the CP systems shall be implemented as soon as reasonably practicable.

6. Competent person

- a. Design, installation, and testing of a cathodic protection shall be carried out under the direction of a 'Competent Person' in this field. The competent person shall be of Chartered status, with relevant qualifications from a recognised body such as the National Association of Corrosion Engineers (NACE), the Institute of Corrosion (ICorr), or equivalent.
- b. Standard practice should be to utilize a specialist contractor, experienced in cathodic protection applications. If this is not possible or if the cathodic protection system forms part of a larger contract, the 'Competent Person' shall be involved by supervising, approving, or consulting continually during the contract.



7. Cathodic protection principles

7.1. Corrosion control

- a. For effective corrosion control, engineering principles and procedures should be used to minimise corrosion to an acceptable level by the most economical method in a lifetime perspective.

It is rarely practical or economical to eliminate corrosion completely.

- b. Corrosion should be prevented by removing one or more of the conditions which allow corrosion to occur (see Annex A).
- c. The corrosion control principles described in clauses 7.2-7.10 shall be adhered to when designing and installing cathodic protection systems.

7.2. Coatings

The primary corrosion control principle for the use of coatings is to provide an isolating barrier between the metal and its surrounding electrolyte and to reduce the flow of corrosion currents (including stray currents). However, coatings unfortunately always contain defects and, in service, further flaws develop over a period of time.

- a. A combination of applying both a coating and cathodic protection results in the most practical and economical overall corrosion protection system and shall be the primary principle for corrosion protection of immersed and/or buried structures operated by BP.
- b. Most of the corrosion protection is provided by the coating while cathodic protection provides protection to deficiencies in the coating and ensures the integrity of the associated structure. As the coating degrades with time, the activity of the cathodic protection system develops to ensure continued efficient protection of the defects in the coating.

The provision of a protective/insulating coating to the structure greatly reduces the current demand for cathodic protection of the metallic surface and the use of a well-applied and suitable coating increases the effective spread of cathodic protection current.

- c. The coatings that shall be used are those that have a high electrical resistance, shall be continuous, and shall adhere strongly to the surface to be protected. Furthermore, coating characteristics shall include: stability in the environment, abrasion resistance, and compatibility with the alkaline environment created by cathodic protection.
- d. GIS 06-601 shall be referred to for details of surface preparation before applying any coating system.

Correct surface preparation is vital for coating systems and often governs service life of the coating system.

The following documents provide details of coating systems that can be deployed on cathodically protected steel structures.

- GP 06-40 Pipeline Coating Guide and Selection.
- GP 06-63 Internal Coatings.

7.3. Cathodic protection

7.3.1. General

The principle of cathodic protection is in connecting an external anode to the metal to be protected and the passing of an electrical d.c. current so that all areas of the metal surface become cathodic and, therefore, do not corrode. The external anode

