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Guidance on Practice for Cathodic Protection – Maintenance and Monitoring

GP 06-36

BP GROUP
ENGINEERING TECHNICAL PRACTICES

Foreword

This is the first issue of Engineering Technical Practice (ETP) BP GP 06-36. This Guidance on Practice (GP) is based on parts of 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-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-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-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.

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Introduction

Cathodic protection of facilities is a key component of integrity management. Cathodic protection is applied to buried or submerged metallic structures onshore and offshore. In limited circumstances it may also be applied to internal metallic surfaces of structures (e.g. tanks or caissons) in contact with aqueous electrolytes. This document provides guidance on monitoring, maintenance, and operating cathodic protection systems.

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*”.

The principal document relating to corrosion integrity is GP 06-10 Guidance on Practice for Corrosion Management, in which typical KPIs relating to cathodic protection are suggested including:

- Percent cathodic protection in compliance with target potentials.
- Number of overdue inspection/maintenance work orders for cathodic protection systems.

This document forms part of a series of guidance documents related to cathodic 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 & Equipment.
GP 06-34	Guidance on Practice for Cathodic Protection of Offshore Pipelines.
GP 06-35	Guidance on Practice for Cathodic Protection of Offshore Structures & 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

This GP provides guidance on maintenance and monitoring of cathodic protection systems within the larger context of the Integrity Management (IM) Standard.

The GP applies to cathodic protection systems used to provide corrosion protection of a wide variety of structures, production and process equipment offshore and onshore, including (but not limited to) the following:

- a. Offshore
 - 1. Fixed and floating production facilities.
 - 2. Drilling fluid storage tanks.
 - 3. Subsea systems, e.g. well-heads, risers, mooring systems, flowlines and pipelines.
 - 4. Firewater and sea water pump caissons.
 - 5. Coastal/marine terminals, e.g. wharfs, jetties, mooring and breasting dolphins.
- b. Onshore
 - 1. Above and below ground storage tanks and vessels.
 - 2. Buried process and utility piping.
 - 3. Buried pipelines.
 - 4. Well casings.
 - 5. Shell and tube heat exchangers using cooling water.
 - 6. Buried/immersed structures.

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

GP 06-10	Guidance on Practice for Corrosion Management.
GP 06-31	Guidance on Practice for Cathodic Protection.
	Integrity Management Group Standard, (IM Standard).

British Standards Institute (BSI)

BS 7430:1998	Code of Practice for Earthing. <i>[NOTE: CEN equivalent not yet developed]</i>
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3. Terms and definitions

For terms and definitions relating to cathodic protection refer to GP 06-31.



4. Symbols and abbreviations

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

Ag/AgCl	Silver/silver chloride
a.c.	Alternating current
CIPS	Close interval potential survey
Cu/CuSO ₄	Copper/copper sulphate
d.c.	Direct current
DCVG	Direct Current Voltage Gradient
EMF	Electro-Motive Force
GPS	Global Positioning System
ICCP	Impressed Current Cathodic Protection
IJ	Isolating joint
KPI	Key Performance Indicator
TR	Transformer rectifier
wrt	with respect to

5. Cathodic protection monitoring and maintenance philosophy

- a. Cathodic protection systems shall be regularly monitored and maintained to ensure the system is operating according to design specifications.
- b. Formalised risk-based corrosion control and maintenance systems shall be established to ensure installed systems provide required level of cathodic protection.
- c. Cathodic protection monitoring routines shall be auditable and managed by the technical authority responsible for field staffs that are trained to undertake the work.
- d. Routines shall take into account the potential for disturbances to cathodic protection systems by other maintenance and/or construction activities in the vicinity of the cathodically protected facilities.

6. Evaluation and validation

6.1. Risk assessment

- a. Risk assessment shall utilise design, maintenance, monitoring, and operational data to evaluate major risks and hazards associated with structures and equipment that are subject to cathodic protection.
- b. Based on associated, identified, health, safety, environment, commercial threats and consequences, appropriate risk-based facility, or pipeline or structural integrity management systems should be established. The system should identify monitoring, inspection, and maintenance routines that assess and maintain the condition and reliability of installed cathodic protection systems.



- c. An assurance process shall be established to verify that established routines and frequencies are sufficient to ensure cathodic protection systems function in accordance with the design intent. Frequent checks, adjustments, and modifications shall be made by qualified personnel in order to manage the consequences of any disturbances to the system.
- d. When taking over old plant, a risk assessment as described above shall be carried out before the plant is incorporated into the appropriate risk-based facility, or pipeline, or structural integrity management systems.
- e. Data obtained from routine and non-routine monitoring shall be maintained and stored in appropriate risk-based facilities, or pipeline, or structural integrity management systems that can be easily appraised for trend analysis.
- f. Historical data shall be reviewed by a competent person.

As many production units do not employ a competent person on cathodic protection; specialist advice should be sought externally or from EPTG.

- g. Risk of changes to operating parameters should be considered in relation to the operating environment, e.g. where a pipeline is routed through aggressive soils or parallel to other cathodically protected pipelines, power lines, electrical transport systems, etc.

6.2. Protection criteria

- a. Cathodic protection systems shall be capable of polarizing the submerged or buried carbon steel of a structure to a potential that is more negative than -850 mV wrt Cu/CuSO₄ reference electrode (for buried carbon steel) or more negative than -800 mV wrt Ag/AgCl/Seawater reference electrode (in seawater).
- b. In anaerobic soil or mud, in which there is a risk of sulphate reducing bacteria (SRB), the system shall be capable of polarizing all of the carbon steel structure to a more negative potential than -950 mV wrt Cu/CuSO₄ or -900 mV wrt Ag/AgCl/Seawater.
- c. To prevent damage to coating and avoid problems associated with over-protection, instantaneous OFF potentials should be maintained less negative than $-1\ 100$ mV wrt Cu/CuSO₄ (or $-1\ 050$ mV wrt Ag/AgCl/Seawater).

Excessive current levels applied to a buried coated structure increase electrolyte pH at the metal surface, causing damage to the coating and cathodic disbondment. At excessive negative potential levels hydrogen can also be evolved, further damaging the coating and affecting integrity of the metal structure.

- d. For onshore applications, potential shift criteria can be used to assess effectiveness of cathodic protection, if approved by the local technical authority.
- e. Whilst it is not necessary for CRAs to be polarised to the same negative potentials as carbon steel, it is often, from a corrosion protection standpoint, impractical to electrically isolate them from metal/carbon steel structures, and therefore the same protection criteria will often apply.

The hazards of over-protection apply equally to high strength CRAs and carbon steels, i.e. hydrogen embrittlement. Martensitic stainless steels, duplex/ superduplex stainless steels, and precipitation hardened nickel alloys have all been associated with hydrogen embrittlement failures when polarised to potentials designed to protect adjacent carbon steel components. This is a complex phenomenon that is also affected by tensile stress levels. Guidance should be sought externally and/or from EPTG whenever CRAs are subjected to CP.

6.3. Current density

- a. Current density is not routinely used as a criterion for protection as it is difficult to measure accurately. The cathodic protection system shall be designed and operated to



ensure sufficient current is available to achieve protection for the full lifespan of the structure.

- b. On buried pipelines the current density and potential at a coating holiday can be estimated by using bare coupons of the same materials as the pipeline and of a known surface area connected to the structure via cables and a shunt.
 1. The coupon represents a simulated pipeline coating defect.
 2. The shunt enables the current flow to the coupon to be measured and the current density to be determined from the coupon surface area.
 3. The measured current density and potential can be compared with the design value.

6.4. Factors affecting protection

- a. The cathodic protection system should be capable of protecting a structure fully, according to the design intent.
 1. Operating system parameters shall be regularly verified to be maintaining the operating system parameters within the established operating limits for full protection.
 2. Inadequacies in the cathodic protection system shall be promptly identified to facilitate timely implementation of corrective actions.

Inadequate or infrequent checks of the cathodic protection system settings and protection status may result in the eventual complete loss of protection.

- b. Numerous environmental factors can reduce the effectiveness of cathodic protection, including:
 1. Sulphate reducing bacteria (causing pH changes).
 2. Coating damage to an extent which is greater than envisaged in the design (increasing the area to be protected) due to poor coating quality, third party damage, etc.
 3. Shielding by non-metallic foreign structures (e.g. adjacent new concrete constructions).
 4. Construction of adjacent foreign pipelines.
 5. Construction of adjacent electrical power transmission systems.
 6. Construction of adjacent electrical transport systems.
 7. Electrolyte factors (e.g. poor initial assessment of soil type, moisture levels, etc.).
 8. Presence of drilling mud and/or metallic debris on seabed adjacent to offshore structures.
 9. Pollution from adjacent effluent outfalls, etc.

7. Structural integrity

7.1. Existing structures

- a. When the integrity status of an existing structure is assessed, historic operating data relating to cathodic protection shall be considered, including design and commissioning data.
- b. The appropriate documents and data shall be used to establish, evaluate, and maintain the integrity of the system.
- c. Depending on the level and accuracy of the applicable data, the integrity status of the cathodic protection system shall be regularly confirmed by the following:



1. Full audit survey, which for pipelines include CIPS and DCVG surveys.
 2. Soil resistivity measurements (see Annex A).
 3. Trial excavations of buried structures to assess coating condition at suspect areas.
 4. ROV or diver inspection of offshore structures (visual inspection, voltage gradient surveys, electrical potential surveys).
- d. Data obtained shall be maintained in appropriate risk-based facility, or pipeline, or structural integrity management systems.

7.2. New structures

7.2.1. Responsibilities

- a. For new structures, the cathodic protection is usually the responsibility of a specialised subcontractor working for the main installation contractor.
 1. Subcontractor work should be integrated with overall project activities.
 2. The work scope should include design, supply, installation, or supervision of main contract labour and commissioning.
- b. The cathodic protection system shall be handed over in a fully operational state with complete documentation provided, including the design package and commissioning results.
- c. Handover should be to a competent person who shall review the system operating parameters to confirm the system is functioning in accordance with the design and providing full protection.

If cathodic protection systems have been extended or upgraded to provide protection to structures that have been modified or extended, the same procedures shall apply, and shall include consideration of the historic operating data, following review by a competent person knowledgeable in cathodic protection.

7.2.2. Testing during cathodic protection installation and pre-commissioning

- a. During cathodic protection installation works, when test facilities are being installed, structure-to-electrolyte potentials shall be recorded to confirm cable continuities and cable-to-structure connections. Cable continuity measurements should always be made independent of potential measurements.
- b. At ICCP groundbeds, the installed resistance to earth (ground) of each anode shall be recorded using a 'Megger' type earth (ground) tester and 3-pin method in accordance with BS 7430.

NOTE: ISO/CEN equivalent not yet developed.

This test confirms the information used in the original design and identifies any problems with individual anodes, such as mechanical damage, loss of electrical continuity, etc.

- c. On completion of the groundbed, the overall groundbed electrical resistance to remote earth (ground) shall be measured and compared to the intended design electrical resistance.
- d. No specific pre-commissioning activities are required for sacrificial anode type cathodic protection systems on offshore structures.
 1. The electrical continuity of the anode connections should be checked.



2. However, inspection shall be carried out at all stages to identify that the anodes are correctly installed, without any damage and that the strength of the welded connections have been tested appropriately onshore.

7.2.3. Isolation testing

- a. For a cathodic protection system to function correctly the structure protected shall be electrically isolated from other non-cathodically protected structures and electrical earthing (grounding) systems.
- b. Integrity of an installed IJ or insulating flange should be determined using the 'potential swing test'.

The potential swing test is carried out by impressing a direct current onto the pipe on one side of the IJ to achieve a negative swing, that should cause the potential on the opposite side of the IJ to 'swing' in the positive direction (or not change).

7.2.4. Commissioning

After installation of cathodic protection system, commissioning tests shall be performed in accordance with the following programmes:

- a. ICCP systems
 1. Record 'as found' (natural) structure-to-electrolyte potentials at all test facilities.
 2. Power source should be energised and output set to achieve the required level of protection at all test facilities. This may require several adjustments following monitoring at test facilities.
 3. Confirm no interference is occurring on other buried or immersed plant as result of cathodic protection system (see clause 7.2.5)
 4. Allow system to achieve full polarization and stable operation.
 5. Final adjustments should be made and all operating parameters recorded.
- b. Sacrificial systems
 1. Record 'as found' (natural) structure to electrolyte potentials at all test facilities, (only valid for onshore buried structures).
 2. Connect the anode(s) to the structure and record anode current outputs, (valid only for onshore buried structures).
 3. Record structure-to-electrolyte potentials at all test facilities and/or designated test points to confirm protection is achieved.
 4. Allow system to achieve full polarisation and stable operation.

Note: For structures in seawater, it may take several months to achieve full polarization.

5. Operating parameters should be recorded.

7.2.5. Interaction testing

- a. Cathodic protection interaction or interference is caused by stray currents from a cathodic protection system flowing onto another (foreign) structure, then leaving the structure at different location causing accelerated corrosion at this point.
- b. A typical example of interaction between a protected and non-protected pipeline is shown in Figure 1.

