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TECHNICAL SPECIFICATION

HIGH PRESSURE (HP) TRANSMISSION SYSTEMS

CATHODIC PROTECTION COMMISSIONING AND START-UP

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1. INTRODUCTION

The installation of the Cathodic Protection System will be in compliance with this specification, the Study of the Cathodic Protection System, which shall be carried out by EPC Contractor during the detail engineering phase, the Standard drawings for Cathodic Protection System, as well as the applicable codes and standards referred to in paragraph 3.2 here in.

2. SCOPE AND OBJECTIVES

This specification covers general instructions for setting in operation and commissioning of an Impressed Current Cathodic Protection System for the natural gas transmission pipeline.

3. REFERENCES

3.1 Reference Documents

DSF-SPC-CPR-001: Cathodic Protection Anode Material.

DSF-SPC-CPR-002: Cathodic Protection Transformer Rectifier Cabinets at Anode Beds.

DSF-SPC-CPR-003: Cathodic Protection Polarization Probe, Reference Electrode and ER Coupon.

DSF-SPC-CPR-004: Electrical Resistance Welding "Pin Brazing".

DSF-SPC-CPR-005: Installation of Cathodic Protection System.

DSF-SPC-CPR-007: Marker and Measuring Posts.

DSF-SPC-CPR-008: Precautions Against Proximity Effects during the Construction Phase.

STD-00-78-01: Cathodic Protection for Pipelines - Transformer Rectifier Cabinet.

STD-3-78-02: Cathodic Protection for Pipelines - Installation of Transformer / Rectifier Cabinet.

STD-00-78-04: Cathodic Protection for Pipelines - Location of Reference Electrode.

STD-00-78-05: Cathodic Protection for Pipelines - Anode Bed Installation for Impressed Current Horizontal Anodes.

STD-00-78-06: Cathodic Protection for Pipelines - Anode Bed Installation for Impressed Current Vertical Anodes.

STD-00-78-07: Cathodic Protection for Pipelines - Anode Bed Installation for Sacrificial Anodes.

STD-00-78-15: Cathodic Protection for Pipelines - Measuring Posts K3S.

STD-00-78-16: Cathodic Protection for Pipelines - Measuring Posts K3J, K3G / A & B.

STD-00-78-18: Cathodic Protection for Pipelines - Measuring Posts K4J, K4G / A & B.

STD-00-78-29: Cathodic Protection for Pipelines - Cable Laying in Casing Pipe.

3.2 Reference Codes and Standards

EN 12068: Cathodic Protection, External organic coatings for the corrosion protection of buried or immersed steel pipelines used in conjunction with cathodic protection, tapes and shrinkable materials

EN 12954: General principles of cathodic protection of buried or immersed onshore metallic structures.

ISO 15589-1: Petroleum, petrochemical and natural gas industries — Cathodic protection of pipeline systems — Part 1: On-land pipelines.

ELOT EN 13509: Cathodic Protection Measurements Techniques.

EN ISO 18086: Corrosion of metals and alloys - Determination of AC corrosion - Protection criteria.

ELOT EN 50122: Railway applications - Fixed installations - Electrical safety, earthing and bonding.

ISO 21857: Petroleum, petrochemical and natural gas industries — Prevention of corrosion on pipeline systems influenced by stray currents.

EN 50443: Effects of electromagnetic interference on pipelines caused by high voltage A.C. electric traction systems and / or high voltage A.C. power supply systems.

AfK Recommendation No. 3: Measures for the installation and operation of pipelines in the vicinity of three-phase high voltage systems and single line traction systems.

ISO 15589-1: Petroleum & Natural Gas Industries - Cathodic Protection of Pipeline Transportation Systems - Part 1: On-land Pipelines.

IEC 60502-1: Power Cables with extruded insulation and their accessories – Cables for rated voltages of 1KV.

4. ACRONYMS

CP	Cathodic Protection.
EN	European Norms.
ELOT	Hellenic Organization for Standardization.
NG	Natural Gas
T/R	Transformer Rectifier

5. GENERAL

This specification covers measuring and inspection procedures, time schedule instructions for performance of measurements, measuring instrument specifications and instructions for compiling of reports.

In all phases of the commissioning, Contractor shall be aware, that dangerous induced voltages may occur on metallic equipment, electrically connected to the pipeline.

Contractor is responsible of using safe procedures to provide protection against induced voltages, including:

- Attaching all test leads first to the instrument and then to the structure to be tested. Leads shall be removed from structure first and from instrument last.
- Rubber boots or insulating gloves where direct contact with the structure is possible.

6. ACTIONS BEFORE SETTING IN OPERATION

After the pre-commissioning of the C.P. system and the verification of correct installation, Contractor must perform measurements and inspections.

The Contractor shall ensure that the test equipment used for obtaining each electrical measurement, is maintained in good operating condition, checked for accuracy, and is in compliance with the instrument specification given in this document.
During visible or audible thunderstorms Contractor must not perform any cathodic protection testing or work of similar nature, involving possible contact with the transmission pipe.

6.1 Check of Each Measuring Post

Contractor shall check the termination of the measuring cables in the terminal board at every measuring post for compliance with drawings and specifications.

Among other things the following shall be checked:

- Type of measuring post
- Mounting of cables
- Resistance of cables

The control of cable connections shall be performed with an ohmmeter. The resistance between the wires in the respective cables connected to the pipeline shall be measured and must practically not deviate from resistance of the wires (calculated or previous measured).

At measuring posts type K6, see Std Drawing No. STD-00-78-20, the resistance of insulating couplings (between terminals 3 and 4) shall be measured with an earth resistance meter, in order to determine the insulating effect of the couplings.

Electrical bondings between terminals that connect the two sections of the coupling must be removed. The resistance of the coupling must be greater than 10 Ohm.

At measuring post K4 and K5, see Std Drawing No. STD-00-78-17÷19, the resistance between pipeline and casing (between terminals 1 or 3 and 7 or 8 and between 2 and 4) or secondary structure shall be measured with an earth resistance meter in order to determine any direct galvanic contact between pipeline and the secondary steel structure.

Finally, at measuring posts K3S, see Std Drawing No. STD-00-78-15, the sacrificial anodes shall be disconnected from the pipeline.

6.2 Temporary Cathodic Protection

All temporary cathodic protection systems that were used to protect the pipe during the construction phase shall be disconnected, and the pipe shall be unprotected for few days for depolarization.

6.3 Natural Potential Measurements

All the pipeline potential measurements shall be performed by connecting the positive (+) terminal of a DC-voltmeter to the pipeline (terminals 1 or 3) and the negative (-) terminal to a Cu/CuSO4 reference electrode placed vertically over the pipeline.

To establish a good contact between the electrode and the electrolyte (soil), the reference electrode shall be pressed against the soil and, if necessary, the soil shall be watered.

If the top soil is frozen, Contractor shall assure that this layer is penetrated, in order to obtain a good contact between the reference electrode and the unfrozen soil.

Contractor shall assure that the reference electrode is completely filled with saturated copper sulfate and contains a sufficient amount of dissolved crystals.

In case of frosty weather, the reference electrode must be kept frost-proof to avoid measuring errors.

The accuracy of the potential measurements shall be better than + 2.5%.

By measurement of the natural pipe-to-soil potential Contractor shall assure that anode beds and any other connections between the pipeline and soil are disconnected. The pipeline section in question must have been backfilled, reinsulated, and the welding finalized.

The natural potential shall then be measured with a digital voltmeter, class 1.5; internal resistance > 10 Mohm; measuring range 0-2 V.

The natural potential measures shall be within a range of approximately -300 to -800 mV. If larger fluctuations are ascertained, the results must be rejected due to a possible stray current influence. The source of the stray currents shall be determined, e.g. telluric currents, welding

equipment, other CP-stations, induced high tension voltages, and the measurements repeated in the absence of the stray current influence.

6.4 Pipe resistance Measurements

The resistance measurements shall be performed with a DC-microvoltmeter, a DC-ammeter and a portable DC-current supply with an output current of approximately 1A.

The microvoltmeter is connected to the two inner line current measuring points (to be used for line current calculations, terminals 3, 4, blue cables). The mutual distance between the points is 50 m.

A connection in series is established between the current supply and the ammeter, connected to the two outer current measuring points in the measured section (terminals 1, 2, black cables, mutual distance 50, 2 m).

The resistance of the 50 m section can be calculated from the measured voltage drop for an output of the current supply of 1A. Future line current measurements can be performed as voltage measurements.

Instruments to be used:

- DC ammeter class 1.5, measuring ranges 1 mA to 1 A and 1 mA to 5 A.
- DC micro voltmeter class 1.5, with zero indication or automatic polarity indication.

6.5 Check and Measurements on C.P. Stations

Contractor shall perform checks also at C.P. stations concerning the installation of cables and the measurement of the resistance of cables following the methodology described, in paragraph 6.1.

Natural potential measurements shall take place using both a portable and the stationary reference electrode as in paragraph 6.3. Contractor shall perform all the previously described

checks and measurements (mounting of cables, resistance of cables, pipe resistance measurements etc.).

Resistance between anode bed, stationary reference electrode, and pipeline shall be measured with an earth resistance meter.

Resistances to remote earth of anode bed and auxiliary earth shall be measured with an earth resistance meter by the "three electrode alternating current method" according to IEC 61936 and prEN 50522. The probe distance for the auxiliary probe shall be more than 40 m.

The following resistance criteria must be followed:

- Resistance, auxiliary earth / remote earth < 100 Ohm
- Resistance, anode bed / remote earth < 10 Ohm
- Resistance, anode bed / pipeline < 10 Ohm
- Resistance, of the Cathode cables < 2 Ohm
- Resistance, stationary reference electrode / pipeline < 10 Ohm

6.6 Reports

The measured results shall be recorded on forms which shall be submitted to Supervision. Also, a diagram for each section showing the longitudinal change of natural potential and pipe resistance from post to post shall be drawn in order to show the change of the values along the pipeline.

7. START-UP OF THE C.P. SYSTEM - PHASE 1

Before setting in operation the system Contractor shall assure that all the above measurements prove the satisfactory installation of the system.

Upon completion of these measurements, a preliminary setting in operation of the C.P. system shall be performed by manually adjustment of the rectifier, so that the "ON"- potential at the drain point is between -1.3 V and -1.5 V and "ON"-potential is reached at the edges of the pipeline section more negative than -1.0 V.

After an adequate period of polarization (normally 24 hours), "ON-OFF" potential measurements shall be performed at "critical" points of the route (see paragraph 7.3.), such as locations where larger deviations in the natural pipe-to- soil potential occur, at bored crossings and at the end of the range of the protection system.

The rectifiers shall be re-adjusted if necessary until the pipe - to - soil potential, required for complete cathodic protection, is obtained in accordance with the following criteria.

Protection Potential Criteria:

- "ON" - potentials - 1000 to - 1600 mV
- "OFF"- potentials (<50°C) < - 850 mV
- "OFF"-potentials (>50°C) - 850 to - 1150mV

On pipelines with elevated temperatures (>50°C) "OFF" potential more negative -1150 mV may cause stress corrosion.

7.1 “On” and “On-Off” Potential Measurements

7.1.1 "ON" Potential Measurements

Measurement of the "ON" - potential shall be performed as in paragraph 6.3, but with the protective current applied constantly.

7.1.2 "ON-OFF" Potential Measurements

In order to obtain the true protective potential called the "OFF" - potential a time relay shall be installed in the cathode cable at the C.P. station on the protected section, interrupting the current for 3 to 5 sec., within a period of 60 sec.

The "ON-OFF" - potentials shall be determined by an analog DC voltmeter recorder with a periodic damping class 1.5 internal resistance >10 Mohm, measuring range 0-2 V, response time < 1 second.

The "OFF"-potential shall be determined within the first second of the "OFF" - period, and the "ON" - potential at the end of the "ON"- period.

7.2 Measurements on the C.P. Station

At the C.P. station the following measurements must be carried out and reported.

Output Voltage D.C.

"ON-OFF" - potential, stationary reference electrode/ pipeline

"ON-OFF" - potential, portable reference electrode/ pipeline

Protective current via the Ammeter readings.

Calculated protective current (from the 50m calculated resistance method see paragraph 6.4.).

Direct interference measurements at all secondary structures which are less than 100 m from the anode bed, if any, according to paragraph 7.2.1.

7.2.1 Direct Interference Measurements

Direct interference measurements on secondary structures less than 100 m from the anode bed shall be performed as a potential measurement in accordance with paragraph 7.1.2.

7.3 Measurements to be Carried out at the Measuring Posts

Measurements at all K1, K4, K5, K6, K8, K9 and at a random 25% of K3 measuring posts shall be carried out in accordance with the following:

- "ON" - potential measurements (see paragraph 7.1.1.)
- "ON-OFF" - potential measurements (see paragraph 7.1.2.)
- 50 m pipe resistance and calculated current with voltage and compensation method as in paragraph 7.3.1.
- Resistance pipeline/casing.

7.3.1 Resistance 50 M – Current Measurements

7.3.1.1 Voltage Method

By the voltage method, the voltage drops over the two inner measuring points (terminals 3, 4 blue cables), shall be measured in the "ON" - state.

From the pipe resistance and the voltage drop the line current shall be calculated.

7.3.1.2 Compensation Method

By the compensation method a compensation current opposing the line current is adjusted in the "ON"-state in such a way that the voltage drop over the two inner measuring points is 0 micro volts. The line current equals the compensation current.

7.4 Sacrificial Anodes

After the completion of the adjustment of the C.P. system, the Engineer shall decide which of the sacrificial anodes shall be connected to the pipeline by bonding the terminals 9 and 11 with 10 and 12 at measuring post type K3S, see Std Drawing No. STD-00-78-15.

7.5 Reports

For all the above measurements reports and diagrams shall be performed as in paragraph 6.6. A diagram shall also be provided showing the measured protective current at each post.

8. CONTROL MEASUREMENTS - PHASE 2

The complete control measurement in phase 2 (4 to 6 months after phase 1) comprises.

a) Same measurements as in paragraph 7.3 at phase 1 followed by eventual readjustment of the rectifiers.

b) Measurements at C.P. stations in accordance with paragraph 7.2.

c) Measurements at every measuring post according to the required measurements for each type of measuring posts (see Techical Specification DSF-SPC-CPR-005).

d) Two-reference cell interference measurements with normal current output at every measuring post, secondary pipeline and major power and telephone cable crossing, in accordance with paragraph 8.1.

e) Two - reference cell interference measurements in the vicinity of the anode beds in accordance with paragraph 8.1.

f) Direct interference measurements at all secondary structures which are less than 100 m from the anode bed, if any, according to paragraph 7.2.1.

8.1 Two – reference Cell Interference Measurements

Two-Reference cell, interference Measurements shall be performed as followed:

A reference cell connected to the negative analogue voltmeter recorder (class 1.5 internal resistance > 10 MOhm, measuring range 0-2 V) terminal shall be placed vertically above the transmission line. Two reference cells, placed at a distance of 10 m perpendicular to the transmission line to both sides, shall alternately be connected to the positive voltmeter terminal.

The difference between the potential values read in "ON" - state and the "OFF" - state gives the change in the voltage gradient and thus the interference level.

8.2 Reports

For all the above measurements reports and diagrams shall be performed as in paragraph 7.1.3.

9. COMPLETE CONTROL FINAL ADJUSTMENTS - PHASE 3

Except for the interference measurements, phase 3 (8 to 12 months after phase 2) is a repetition of phase 2. Line currents shall be measured by the voltage method only.

10. COATING DEFECTS - SECONDARY STRUCTURES INTERFERENCES

In all three phases the longitudinal diagrams and curves of "ON" and "OFF" potential, protective current e.t.c. may indicate coating defects or interferences from metallic secondary structures. Contractor is responsible to investigate for the specific point with the damaged coating (by using holiday detectors), and make all the required repairs to the coating.

Interferences of a metallic structure can be determined by the following criteria:

- Direct interference measurements:

  a) Current discharge points

  Steel structures: Potential change > 20 mV inthe positive direction of the structure - to - soil potential.

  b) Current entry points

  Lead structures: Structure – to - soil potential < - 2.5V.

  Aluminum structures: Structure – to - soil potential < - 1.2V

The potential change does not include the IR-drop so the guideline is a potential difference > 100 mV including the IR - drop.

- Two reference cell measurements:

  a) Current discharge points

  All structures: Potential change > 20 mV in the positive direction of the structure - to - soil potential.

11. CHECK AND MEASUREMENTS OF GROUNDING INSTALLATION - MEASUREMENTS OF PERMANENT INDUCED VOLTAGES

The measurement shall be carried out in conjunction with the commissioning phase 1 and phase 3.

Instruments to be used on pipelines influenced by high voltage transmission lines shall have sufficient alternating current rejection (>90 dB for 50 Hz signals) to provide accurate direct current data.

11.1 Phase 1

The following measurements shall be carried out in order to prove the efficient function of the installed permanent earthing system.

a. Measurements for all cable connections. As per paragraph 6.1.

b. Measurements for each discharge voltage arrester.

c. Measurements of the leakage resistance of each earthing installation to remote earth. Measurements by the "three - electrode alternating current method" with an earth resistance meter in accordance with IEC 61936 and prEN 50522.

d. Measurements of the voltage difference between pipeline and earth at every measuring post in proximity area (Measuring posts type K1G, K3G and K4G as per Std Drawings No. STD-00-78-13, 16 and 18 terminals 5 and 6).

11.2 Phases 2 and 3

A repetition of phase 1 items b and d.

11.3 Results - Reports

The results of the above inspection shall be recorded in the forms of the measuring posts.

12. REPORTS – SUPPLEMENTARY ACTIONS

In all phases Contractor shall handover to Supervision the above requested reports and diagrams, for information, review and comments on the C.P. system.

Any supplementary action (if any) to fulfill the Cathodic Protection Criteria, shall be approved by Supervision after full information by Contractor (including measurements and reports).