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شرکت ملی گاز ایران

مدیریت پژوهش و فناوری

امور استانداردها

IGS

مشخصات فنی خرید

آند لوله ای تیتانیوم پوشش شده با ترکیب اکسید فلز

Mixed Metal Oxide (MMO) Coated Titanium Tubular Anode



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شرکت ملی گاز ایران



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باسلام،

به استحضار می‌رساند در جلسه ۲۱۰۰ مورخ ۱۴۰۳/۱۲/۲۶ هیأت مدیره، نامه شماره ۲۰۶۰۲۲ مورخ ۱۴۰۳/۱۲/۱۴ آن مدیریت درمورد تصویب نهایی مقررات فنی شرکت ملی گاز ایران مربوط به گروه های پوشش و حفاظت کاتدی و ابزار دقیق به شرح زیر مطرح و مورد تصویب قرار گرفت.

۱- مشخصات فنی خرید آند لوله ای تیتانیوم پوشش شده با ترکیب اکسید فلز

IGS-M-TP-022(1)

۲- دستور العمل بازرسی کنتورهای دیافراگمی

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این مصوبه در حکم مصوبه مجمع عمومی شرکت های تابعه محسوب و لازم الاجرا می باشد.

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Foreword

This standard specification is intended to be mainly used by N.I.G.C. and contractors, and has been prepared base on interpretation of recognized standards and technical documents, as well as knowledge, backgrounds and experiences in gas industries at national and international levels.

Iranian Gas Specification (IGS) are prepared, reviewed and amended by technical standard committees within NIGC standardization division of research and technology management and submitted to "the standards council of NIGC" for approval.

IGSs are subjected to revision, amendment or withdrawal, if required, and thus the latest edition of IGS shall be checked / inquired by NIGC'S users.

This standard must not be modified or altered by NIGC employees or its contractors. Any deviation or conflicts between this specification and other applicable standards, codes, procedure or well-known manufacturer's specifications must be resolved in writing by the user or its representative through Manager, Engineering Department or standardization division of NIGC.

The technical standard committee welcomes comments and feedbacks from concerned or interested corporate and individuals about this standard, and may revise this document accordingly based on the received feedbacks.

General Definitions

Throughout this standard the following definitions, where applicable, should be followed:

- 1- "STANDARDIZATION DIV." is organized to deal with all aspects of industry standards in NIGC. Therefore, all enquiries for clarification or amendments are requested to be directed to mentioned division.
- 2- "COMPANY": refers to National Iranian Gas Company (NIGC).
- 3- "SUPPLIER": refers to a firm who will supply the service, equipment or material to IGS specification whether as the prime producer or manufacturer or a trading firm.
- 4- "SHALL ": is used where a provision is mandatory.
- 5- "SHOULD": is used where a provision is advised only.
- 6- "MAY": is used where a provision is completely discretionary.

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IGS-M-TP-022(1) 2024 SUMMARY OF CHANGES

The most important changes include the following but are not limited to, and the complete reading of the standard text by the end user is mandatory:

Clause	Title
3	DEFINITIONS
4	REQUIREMENTS
5	DOCUMANTATION
6	PACKAGING
12	INSPECTION AND TESTING
13	HEALTH, SAFETY AND ENVIRONMENT
ANNEX B	Data Sheet for MMO Anode
ANNEX D	Backfill Material Properties

1. SCOPE

This standard specification covers the minimum requirements for manufacturing, procurement and inspection of mixed metal oxide (MMO) coated titanium tubular anodes to be used mainly in deep anode beds for pipelines and gas distribution networks in impressed current cathodic protection (ICCP) systems.

The anodes in both the dry-type deep and surface anode beds shall be backfilled with calcined petroleum coke according to Annex D.

2. REFERENCE

Throughout this standard the following dated and undated standards/codes are referred to. This referenced documents shall, to the extent specified herein, from a part of this standard. For dated references, the edition cited applies. For undated references, the latest edition of the referenced documents applies.

2.1 Normative References

ASTM B 338 (2014) "Standard Specification for Seamless and Welded Titanium Alloy Tubes for Condensers and Heat Exchangers"

ASTM B 539 (2020) "Standard Test Method for Measuring Resistance of Electrical Connections (Static Contacts)"

ASTM D 3032 (2016) "Standard Test Method for Hookup Wire Insulation"

ASTM D 3359 (2017) "Standard Test Method for Measuring Adhesion by Tape Test"

ASTM F 2391 (2022) "Standard Test Method for Measuring Package and Seal Integrity using Helium as Tracer Gas"

ISO 4624 (2023) " Paints and Varnishes–Pull-off Test for Adhesion "

IPS-M-TP-750 (2021) " Material and equipment standard for cathodic protection "

NACE TM0108 (2012) "Standard Test Method for Testing of Catalyzed Titanium Anodes for Use in Soils or Natural Waters"

NACE SP0572 (2007) "Standard Practice for Design, Installation, Operation, and Maintenance of Impressed Current Deep Anode Beds"

2.2 Informative References

EN 10204 (2004) "Metallic Products-Types of Inspection Documents"

3. DEFINITIONS

Anode Consumption Rate

The rate of anode coating mass consumption for a given current output over a given period, normally stated in milligram per ampere year.

Anode String

Several anodes fitted to a single lead wire to form a string of anodes for use in deep-well ground beds.

Backfill

Material placed in a hole to fill the space around the anodes, vent pipe, and buried components of a cathodic protection system.

Bore Hole

A hole drilled into the earth for the installation of a deep grounded system.

Centralizer

Centralizer is applied to ensure that the anode(s) remain central when installed in restricted vertical bore holes. Centralizer is fitted into the PVDF tube seals and do not restrict the active length of the anodes(s) element.

Standard sizes range between 150 mm (6") to 300 mm (12").

Coke

A carbonaceous solid produced from coal, petroleum, or other materials by thermal decomposition with passage through a plastic state.

Coke breeze

The fine screenings from crushed coke or from coke as taken from the ovens, of a size varied in local practice, but usually passing a 12.5 mm screen opening.

Current Density

The current to or from a unit area of an electrode surface.

Deep Grounded

One or more anodes installed vertically at a nominal depth of 30 m (100 ft.) or more below the earth's surface in a drilled hole for the purpose of supplying cathodic protection.

MMO Anode (Mixed Metal Oxide Anode)

MMO anode is a composite structure consisting of a titanium substrate covered by an electro catalytic film combination of iridium oxide (IrO_2) and tantalum oxide (Ta_2O_5).

4. REQUIREMENTS**4.1 Anode Substrate**

The titanium substrate shall be a seamless tube as per ASTM B 338 with chemical composition as indicated in Table 1.

Note: Each grade of 1 or 2 as indicated in Table 1 is acceptable.

Table1-Titanium Substrate Chemical Composition, %

Element	Grade 1	Grade 2
Nitrogen , max	0.03	0.03
Carbon , max	0.08	0.08
Hydrogen , max	0.015	0.015
Iron , max	0.20	0.30
Oxygen , max	0.18	0.25
Residuals or other elements singleness , max. each	0.1	0.1
Residuals or other elements , max. total	0.4	0.4
Titanium	Balance	Balance

4.2 Anode Catalyst

A coating of mixed metal oxide within the combination of iridium oxide and tantalum oxide (IrO_2 and Ta_2O_5) used as the catalyst of the anode suitable to work in an environment where the evolution of O_2 and Cl_2 or a combination of both would be presented at the anode surface. The exact composition may have varied.

4.3 Accessories

The MMO anodes shall be seamless tubular type with the anode lead attached at the center of the anode as per dimensions indicated in Table 2.

This standard specification covers both single and string types of the MMO anodes.

Note 1: The MMO anodes are diametrically per-reduced center to force into tube to ensure acceptable electrical contact between the MMO coated titanium anode and copper lead wire.

Table 2-Performance Properties

Item	Environment	Length cm (inches)	Diameter cm (inches)	Maximum current output Amps
1	Special calcined petroleum coke breeze / fresh water seawater mud / brackish water	50 (19.7)	2.5 (1)	4 25 4
2	Special calcined petroleum coke breeze / fresh water seawater mud / brackish water	100 (39.4)	2.5 (1)	8 50 8

4.4 Anode Design Life

The coating mass shall be sufficient for loading characteristics according to Table 3 for the minimum 20 years of design life.

Table 3-Loading Characteristics

Electrolyte	Maximum current density , A/m ²
Carbonaceous backfill	50
Calcined petroleum coke	100
Freshwater	100
Brackish water	100 – 300
Sea water	600

4.5 Anode Lead Wire

Each anode and anode string shall be provided with an insulated lead wire. The size of lead wire shall be determined by anode's physical properties and electrical requirements but with a minimum of 16 mm² cross-section. Unless otherwise specified by the Purchaser, the lead wire length shall be 3 meters, chlorine resistant type in accordance with 4.6.

Note 2: In case of string type of anodes, the cross section of lead wires up to four anodes shall be 25 mm² and for four and more anodes 35 mm².

4.6 Anode Lead Wire Insulation

The lead wire insulation shall provide continuous and adequate dielectric properties. The lead wire shall be double insulated and to be protected from both mechanical forces and chemical attacks and shall be either standard or chlorine resistant type in accordance with following details:

– Standard Type: For surface anode beds installation which the electrolyte is not expected to contain chloride or other halogen ions, high-molecular weight polyethylene (HMWPE) as per NACE SP0572 clause 4.5.4.3 and/or cross-linked polyethylene (XLPE) shall be used.

– Chlorine Resistant Type: For deep anode beds installation, anode lead wire shall be sheathed with a chemical resistance insulation material to be resistant to halogen or other corrosive gases and ions.

Polyvinylidene fluoride (PVDF)*, radiation cross-linked polyvinylidene fluoride (XLPVDF)*, ethylene chlorotrifluoroethylene (ECTFE)*, and cross-linked ethylene chlorotrifluoroethylene (XLECTFE)* shall be used. In addition, the abrasion resistant materials such as high molecular weight polyethylene (HMWPE)* shall be used to jacket sheathed anode lead wires for mechanical protection.

- Anode lead wire insulation shall be tested in accordance with the procedure set forth in clause 4.10

4.7 Lead Wire to Anode Connection

The lead wire to anode connection shall be of low resistance (≤ 0.001 ohms), provide a positive moisture seal, and have a sufficient mechanical strength to support the anode weight. Anode lead wire connection shall be fabricated by manufacturer and shall be complied with the following details:

- Anode shall be center connected by means of internal impression of lead/suitable conductive material insert molded to the anode lead wire into the diametrically pre-reduced center of the anode tube . (Center connected anodes prevent lead wire to anode connection failure caused by end effect on MMO anodes according to NACE SP0572 clause 4.5.5).

- Center-connected anodes shall be sealed with 100% filling of a two component sealing material (sealant) inside the anode tube after internally connection of lead wire to anode. The moisture seal shall resist to degradation from oxidizing gases released at the anode. (The specification and data sheet of the sealant materials shall be specified by manufacturer for approval).

- Sufficient anode lead wire centering elements shall be furnished to each end of lead wire extending from the anode tube in order to prevent possible anode lead wire insulation defects during transportation, installation and service life. While minimum of 15 cm of the insulated lead wire extending along the centering elements plugged between the anode tube and lead wire shall be covered by polyolefin based heat shrinkable cap(s).

Heat shrink anode cap used for sealing the anode lead connection, as will be specified by the purchaser, shall be either standard or chlorine resistant type in accordance with following:

Standard Type:	Heat shrinkable polyethylene
Chlorine Resistant Type:	Heat shrinkable polyvinylidene fluoride

Note 3: End connection and/or externally center crimp connection is not acceptable due to anode end effects and the possible defects on MMO coating during external crimping process.

Surface treatment and cleanliness of the lead wire insulation shall be accomplished in accordance with the manufacturer's recommendations before the anode connection is made.

4.8 Workmanship, Finish and Appearance

4.8.1 Anode shall be free from defects which may impair the performance of the finished component. Anodes shall be free of flaws, cracks, blow holes and excessive porosity consistent with good commercial practice.

4.8.2 The lead wire insulation shall be continuous having a thickness as uniform as possible and shall be completely free of nicks, scratches or other discontinuities.

4.9 Accelerated Testing

The anodes shall be subjected to accelerated testing according to NACE TM0108 to demonstrate the anode's ability to perform satisfactory for a specific number of years.

4.10 Fluoropolymer Insulation Anode Lead Wire Test

The fluoropolymer insulation used on anode lead wire shall pass the impulse dielectric test performed in accordance with ASTM D 3032, section 12, at 60 volts (peak) per 0.025 mm or a maximum of 18 kilovolts (peak).

If an outer jacket of fluoropolymer or other material is applied, all finished wire shall pass the impulse dielectric test at a voltage equal to 600 volts (peak) per 0.025 mm of primary insulation plus 100 volts (peak) per 0.025 mm of the jacket thickness or a maximum of 18 kilovolts (peak).

4.11 NXRDF Spectrometry Test

Non-dispersive X-ray fluorescence (NXRDF) spectrometry test shall be performed. The uniformity shall be minimum 85% and the thickness of anode coating shall be minimum 5 μm .

4.12 Moisture Seal

The moisture seal shall be tested with helium at 2 atmosphere of pressure. Integrity is demonstrated using a helium detector with a sensitivity of 4 ppb. According to ASTM F2391 (1.3.2 Moderate leaks).

4.13 Mechanical Resistance Test

When a uniaxial force equivalent to 5 times the mass of the anode metal is applied to anode, it shall not result in damage to the cable or its connections.

4.14 Adhesion

The adhesion of electro catalytic coating to the titanium substrate shall be minimum rating 4A when tested in accordance with ASTM D 3359 – Test Method A (X-Cut Tape Test).

4.15 Electrical Resistance

The electrical resistance at the connection of a completely assembled anode shall be tested in accordance with ASTM B 539 and shall be ≤ 0.001 ohms.

Note 4: Connection resistance is defined as total resistance minus resistance of the anode cable.

Note 5: The specified requirements in 4.8 to 4.15 shall be carried out as working test procedure. The results and procedures shall be submitted by manufacturer for purchaser evaluation and approval.

Results of QC and certificates shall be signed and stamped by manufacturer/supplier according to Annex B.

Any deviation from this standard specification shall be clearly specified by manufacturer/supplier.

Table 4-Properties of Anode

Item	Element	Test Method	Requirements	Batch Certificate test	Qualification test
1	Workmanship , Finish and Appearance	-	4.8	yes	yes
2	Accelerated Testing	NACE TM0108	4.9	yes	yes
3	Fluoropolymer Insulation Anode Lead Wire Test	ASTM D 3032	4.10	yes	yes
4	NXRDF Spectrometry Test	-	4.11	yes	yes
5	Moisture Seal	ASTM F2391	4.12	yes	yes
6	Mechanical Resistance Test	-	4.13	yes	yes
7	Adhesion	ASTM D 3359	4.15	yes	yes
8	Electrical Resistance	ASTM B 539	4.16	yes	yes

5. DOCUMENTATION

The manufacturer/supplier shall provide sufficient information and submit to purchaser to identify the anode and shall supply the technical information, as a minimum requirement, the technical information of the coating components as follows:

Technical specification, manufacturing product data sheet and application procedure recommendation and guidelines (application instructions) for all of the items offered.

- Storage and handling procedures.

- Filled, signed and stamped data sheets in Annex A and Annex B.

The anodes shall be traceable to the manufacturing batch and all laboratory and shop testing shall be documented, filled, signed and stamped. Shipping, handling and storage procedures shall ensure that the MMO anode and lead wire are not damaged.

- Certificate of current output: Rated current output for various application as in Table 2

- Certificate of analysis according to ASTM B 338 for titanium as in Table 1.



- ISO 9001 "CERTIFICATION" for "Design, Manufacturing and Quality Control" of an offered coating system for "pipeline corrosion protection" issued by an internationally recognized body.

6. PACKAGING

Each anode purchased according to this standard specification shall be packaged in suitable containers that ensure acceptance and safe delivery to their destination. Each anode shall be packaged in a manner to prevent adherence to the packaging material or the container. For prevention of abrasive surfaces each anode shall be covered with a foam tube for mechanical protection (This covering must be removed just before the anode is installed in the ground bed).

The string type anodes shall be packaged in the crate/pallet with the bottom of the string placed at the top of the crate so that the string can pass directly from the crate to the ground bed.

Tubular anode shall be packaged in crates/pallets in a manner to prevent mechanical damage to the lead wire and anode.

Individual types and sizes shall be neatly bundled or boxed. Anodes shall be packaged in quantities not to exceed the weight limitation of the container specification.

Cables shall be carefully coiled and positioned inside the crates or on the pallets so that no cable damage can occur during loading and transportation. Under no circumstances must anodes lay on the cables.

7. MARKING

Each anode shall be plainly marked with the following information:

- Name and trademark
- Product designation
- IGS No.
- Order No.
- MESC No.
- Quantity (number of items in container)
- Anode dimension: Length mm / Diameter mm
- Batch No.
- Date of manufacture
- Manufacturer's name and address

8. STORAGE CONDITION

Each anode shall be stored in accordance with the Manufacturer's recommendations.

9. QUALITY ASSURANCE

Manufactures shall operate an effective, documented quality system based on the relevant part of the ISO 9001 and maintain records identifying the product, date of manufacturing, batch numbers and all results of inspection and testing.

11. INSPECTION AND TESTING

The manufacturer set up and maintain such quality and inspection system as to ensure the material supplied, comply with all aspect of the requirements of this standard specification.

The manufacturer shall furnish the purchaser or its nominated inspector an overall compliance certificate accompanied with all in-production quality control test results for review. These documents and test results shall be traceable with regard to the batch number of each item.

The purchaser or his nominated inspector may inspect a part or the whole of the goods at the manufacturer's works during manufacture and prior to packaging and may witness any inspections and tests as called for, by this standard specification.

Purchaser's inspector shall have free access to the manufacturer's works at any time during manufacturing.

The manufacturer shall provide all means necessary for carrying out all inspections and tests as required by this standard specification.

Random sampling proportional to the quantity of each item and frequency of inspections and tests shall be at the discretion of the inspector.

If a sample is rejected in any inspection or test, double sampling shall be carried out, in case of any rejection in new samples, all materials represented by such sampling shall be rejected.

Inspection or tests carried out by the purchaser's inspector, in no way relieves the manufacturer/supplier of his responsibilities and liabilities under the conditions, terms and specification of this standard specification.

11.1 Inspection for Qualification

Inspection shall be carried out as per Table 1 by the applicator. The results of inspection shall be recorded by the applicator and made available to the purchaser's inspector.

The purchaser's appointed inspector shall have free access to the workshops, storage yards and laboratory of the coating applicator. An inspector shall have the right and opportunity to witness any quality control tests and/or to perform such tests himself.



The applicator shall furnish the purchaser's inspector with all tools and equipment necessary for inspection at the application site.

Purchaser's inspector shall have free access at all times to all work related to the coating application process, with the right to inspect work and materials. All such work and materials shall be subject to approval by inspectors. Failure of inspector to identify or reject Defective work or materials shall not be construed as acceptance of such work or materials.

11.2 Inspection for Batch Certificate

To guarantee the quality of the products to be delivered, the inspection is carried out at the manufacturer's site prior to shipment.

Based on the results of material tests during the inspection and on the provided quality control data (process control, in-house and external tests), an inspection report shall be filled-out and signed by the inspector according to inspection type 3.1 of standard EN 10204.

This inspection and Testing Procedure regulates the steps that are taken during the inspection process.

The Inspector's work and duties consist of the following activities, but not limited to:

1. Checking of Documents

- a. Checking the raw material quality control test results and Certificates for all items and verifying the results versus the manufacturer's data sheets.
- b. Checking the manufacturer's daily production quality control test reports showing the amounts of produced material & results of the relevant tests and verifying the results versus the manufacturer's data sheets.
- c. Check the calibration certificates of the testing and inspection instruments.
- d. Check the test report for all items (long term and short term) of qualification properties according to related standard IGS, not exceeding two years from issuance date.

2. Visual Inspection of the Produced Goods:

- a. Visual inspection of the marking and packaging (number and weight of container, batch number of components, etc.) according to this standard and purchase order.
- b. Crosscheck purchase order quantities with stock

3. Selection of Samples for Material Tests

Selection of three rolls per each batch of all material to prepare samples from the coating system running for each item according to related test methods.

4. Batch Certificate Tests:

All tests shall be carried out according to table 2 of this standard.

5. Inspection Report:

Inspection report shall include the following items, but not limited to:
-List of inspection materials, quantities and batch numbers



- Report of document check (according to section 1)
- Report of visual inspection (according to section 2), plus photos of activities
- Description of sample selection and preparation of specimens, plus photos of activities
- Report of calibration certificates of the testing and inspection instruments
- Date of presence in factory, preparation of specimens and start of test
- Test reports include test results and graphs (if that is to exist)
- Third party inspection agency approves

Note 6: All in-house tests shall be performed under the witness of an inspector.

For Iranian manufacturers, the tests shall be carried out at a third-party laboratory that is approved by Technical & Industrial Research Laboratories of NIGC.

Details of all inspection and testing shall be fully documented by the manufacturer and certified by an inspector.

The results of all mentioned tests shall be checked and complied with criteria which are mentioned in related standards.

In the case of any failure to comply with any of the NIGC's requirements mentioned in the related standard IGS, new samples according to the above-mentioned table shall be selected by an inspector and all of the required tests shall be carried out accordingly. If any failure occurs again, it shall be the effect of rejection for each batch presented.

At least one photo of an inspector next to the goods is required. The photos of all parts (including of storage, batch number of drum, preparation of test specimens, test instruments etc.), plus the image of the inspector's photo attached to the certificate on the inspection report (via CD/DVD) are required.

A third party inspector shall issue a release note to the supplier and purchaser (two copies) after item acquisition.

A third party inspection agency shall issue an inspection certificate after a release note has been issued.

13. HEALTH, SAFETY AND ENVIRONMENT

The applicator shall comply with the requirements of the purchaser's HSE Management System, the product's MSDS and other requirements such as site regulations, safety rules, etc. The applicator shall ensure that updated MSDS are obtained from the manufacturer. The applicator shall provide all painters with approved protective clothing including safety glasses, safety shoes, hard hats, goggles, respirators, earplugs, fresh-air-fed hood and any other necessary safety equipment. All the safety equipment shall be maintained in a good working condition. The applicator shall be required to test work areas for flammable vapors, with an appropriate vapor tester, prior to and throughout abrasive blasting and coating operations. The applicator shall post appropriate warning signs and erect appropriate barriers in the work area. The waste produced during operation, repairing and maintenance shall be managed and disposed under waste management laws and related regulations (MOP-HSED-301 to 306).

ANNEX A
Data Sheet for Titanium

Manufacturer's name and address	
Product	
Product designation	

Element	Value	Remark
Nitrogen		
Carbon		
Hydrogen		
Iron		
Oxygen		
Residuals or other elements singleness each		
Residuals or other elements total		
Titanium		

NOTES:

1. This data sheet shall be filled, signed, and stamped by manufacturer/supplier.
2. Any deviation from this standard specification shall clearly be specified by manufacturer/supplier.

ANNEX B**Data Sheet for MMO Anode**

Manufacturer's name and address					
Product					
Product designation					
Item	Element	Actual and Reproducible Result	Unit	Test Method	Remark
1	Workmanship , Finish and Appearance				
2	Accelerated Testing				
3	Fluoropolymer Insulation Anode Lead Wire Test				
4	NXRDF Spectrometry Test				
5	Moisture Seal				
6	Mechanical Resistance Test				
7	Adhesion				
8	Electrical Resistance				

NOTES:

1. This data sheet shall be filled, signed, and stamped by manufacturer/supplier.
2. Any deviation from this standard specification shall clearly be specified by manufacturer/supplier.

The anodes shall be in accordance with the latest edition of above Iranian Gas Standard with following specific requirements:

1	Project title :
2	Indent No. :
3	MESC No. :
4	Quantity :
5	Date :
6	Purchaser :
7	Type of anode : ☐Single type ☐String type
8	Anode dimensions :
9	Anode cap type(s) : ☐Standard ☐Chlorine resistant
10	Lead wire insulation type : - Standard type : ☐Double jacket – HMWPE/ HMWPE ☐Double jacket – XLPE/ HMWPE - Chlorine resistant type: ☐Single jacket – PVDF ☐Double jacket – XLPVDF/HMWPE – ECTFE/HMWPE – XLECTFE/HMWPE
11	Lead wire length : Single anode: String type anode :
12	Lead wire insulation color :

" ANNEX D "

Backfill Material Properties

The Backfill shall be petroleum coke calcined (heat treated) to remove all other petroleum products, other than carbon, specially formulated to facilitate pumping, settling and compaction of carbon lubricants. The product shall contain 0.1% wetting agent to enhance setting of the granular particles and water absorption of the backfill. It shall have round, uncrushable shapes.

The proposed material shall have the following properties:

D.1 The composition shall be in accordance with Table D.1.

Table D.1 – Composition of Backfill Material (Special Petroleum Coke Breeze)

Property	Unit	Requirement	Test Method
Carbon content, min	wt.%	95(dry)	ISO 609 or ISO 625
Moisture content, max	wt.%	1	ISO 687
Ash content, max	wt.%	3	ISO 1171
Total Sulphur content, max	wt.%	1	ISO 351 or ISO 334
Volatile matter content , max	wt.%	1	ISO 562

D.2 The bulk density of backfill materials on dry packed basis shall be 1050 to 1200 kg/m³ when tested in accordance with ISO 1013 or ISO 567.

D.3 The resistivity of the tamped dry backfill shall not exceed 0.1-ohm cm.

D.4 The particle size of backfill materials shall conform to the following size distribution:

Less than 1.0 mm	100%
Less than 0.6 mm	80%
Greater than 0.4 mm.....	90%
Greater than 0.15mm	99%

The test method shall be in accordance with ISO 2325.

D.5 The material purchased shall be packaged in suitable containers to ensure acceptance and safe delivery to their destination.

The backfill shall be supplied in 25 kg bags, in 1 tone containers or other suitable containers as specified by the purchaser.

The method of shipment, as will be specified by the purchaser, may be either double bagged or bulk in accordance with following:

- Double bagged-packaging shall be double packing in bags, the inner bag being woven polypropylene, the outer bag can be hessian but not polyethylene which is subject to U.V deterioration and temperature distortion.
- Bulk-method of shipping shall be agreed upon by the purchaser and supplier.

D.6 For surface anode beds, the anodes shall be used only in stable soils with low resistivity (less than 500 ohm-cm) (API 651 table 1)