



شرکت ملی گاز ایران

مدیریت پژوهش و فناوری

امور تدوین استانداردها

IGS

Iranian Gas Standards

مشخصات فنی خرید

مشخصات فنی آند MMO

Mixed Metal Oxide (MMO) Coated Titanium Anode



شرکت ملی گاز ایران

دفتر مدیرعامل

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باسلام،

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FOREWORD

This standard specification is intended to be mainly used by NIGC and contractors and has been prepared on interpretation recognized standards , technical documents , knowledge , backgrounds and experiences in gas industries at national and international levels .

Iranian gas standards (IGS) are prepared , reviewed and amended by technical standard committees within NIGC Standardization division and submitted to the NIGC's "STANDARDS COUNCIL" for approval .

IGS Standards are subject to revision , amendment or withdrawal , if required , thus the latest edition of IGS shall be checked/inquired by NIGC users .

This standard must not be modified or altered by the end users within NIGC and her contractors . Any deviation from normative references and / or well known manufacturers specifications must be reported to Standardization division .

Any comments from concerned parties on NIGC distributed IGS are welcome to technical standards committees and will receive serious attention and consideration should a revision to standards is recommended .

GENERAL DEFINITIONS :

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

1- "STANDARDIZATION DIV." has been organized to deal with all aspects of industrial standards in NIGC . Therefore , all queries for clarification or amendments are requested to be directed to mentioned div.

2- "COMPANY" : refers to national Iranian gas company .

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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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 .

Note : For surface anode beds , the anodes shall be used only in stable soils with low resistivity .

2. REFERENCES

Throughout this standard specification the following standards are referred to . The editions of these standards that are in effect at the time of issue of this standard specification (2010) shall , to the extent specified herein, form part of this standard specification . The applicability of changes in standards that occur after the date of this standard specification shall be mutually agreed upon by the purchaser and the supplier .

2.1 Normative References

ASTM B 338 (2001) "Standard Specification for Seamless and Welded Titanium Alloy Tubes for Condensers and Heat Exchangers"

ASTM B 539 (2002) "Standard Test Method for Measuring Resistance of Electrical Connections (Static Contacts)

ASTM D 3032 (2004) "Standard Test Method for Hookup Wire Insulation"

ASTM D 3359 (2002) "Standard Test Method for Measuring Adhesion by Tape Test"

ISO 334 (1992) "Solid Mineral Fuels – Determination of Total Sulfur – ESCHKA Method"

ISO 351 (1996) "Solid Mineral Fuels – Determination of Total Sulfur – High Temperature Combustion Method"

ISO 562 (1998) "Hard Coal and Coke – Determination of Volatile Matter"

ISO 567 (1995) "Coke – Determination of Bulk Density in a Small Container"

ISO 609 (1996) "Solid Mineral Fuels – Determination of Carbon and Hydrogen – High Temperature Combustion Method"

ISO 625 (1996) "Solid Mineral Fuels – Determination of Carbon and Hydrogen – LIEBIG Method"

ISO 687 (2004) "Solid Mineral Fuels – Determination of Moisture in the General Analysis Test Sample"

ISO 1013 (1995) "Coke – Determination of Bulk Density in a Large Container"

ISO 1171 (1997) "Solid Mineral Fuels – Determination of Ash Content"

ISO 2325 (1986) "Coke – Size Analysis (Nominal Top Size 20 mm or Less)"

NACE TM0108 (2008) "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"

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 groundbed 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") .

Current Density

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

Deep Groundbed

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 electrocatalytic film combination of iridium oxide (IrO_2) and tantalum oxide (Ta_2O_5) .

4. MATERIALS AND MANUFACTURE

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 .

Table 1 – 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) shall be 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 .

4.3 Anode Geometry

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; 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	calcined petroleum coke breeze / fresh water	50 (19.7)	2.5 (1)	4
	seawater			25
	mud / brackish water			4
2	calcined petroleum coke breeze / fresh water	100 (39.4)	2.5 (1)	8
	seawater			50
	mud / brackish water			8

4.4 Anode Design Life

The coating mass shall be sufficient for loading characteristics according to Table 3 for the minimum 25 years of design life .

Table 3 – Loading Characteristics

Electrolyte	Maximum current density , A/m^2
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 .

Note : In case of string type of anodes , the cross section of lead wire up to four anodes shall be 25 mm² and for four to nine 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 on thin-wall insulations subject to abrasion or notch propagation .
- Anode lead wire insulation shall be tested in accordance with the procedure set forth in clause 5.3 .

.....
*As a reference the following trade names or any equivalent materials from any manufacturers are accepted :

Halar is a Register Trademark of Allied Chemical .

Kynar is a Register Trademark of Elf Atochem .

Wedglock is a Register Trademark of Corrpro Companies , Inc .

LIDA is a Register Trademark of Oronzio De Nora SA licensed exclusively to the De Nora Eletroddi Network .

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 : 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 .

5. REQUIREMENTS

The finished product shall meet the following requirements :

5.1 Workmanship , Finish and Appearance

5.1.1 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 .

5.1.2 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 .

5.2 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 .

5.3 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) .

5.4 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 7 μm .

5.5 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 .

5.6 Mechanical Resistance Test

When an 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 .

5.7 Bend and Peel off Test

The anodes shall not peel off when bend at a radius of 20 cm and an angle of 180° .

5.8 Adhesion

The adhesion of electrocatalytic 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) .

5.9 Acid Test

The acid test shall be performed by immersing the anode in H₂SO₄ 15% for 10 hours and no corrosion shall be observed .

5.10 Electrical Resistance

The electrical resistance of each anode shall be tested in accordance with ASTM B 539 and shall be ≤0.001 ohms .

Note : The specified requirements in clause 5 shall be carried out as per working test procedure . The relevant 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 .

6. DOCUMENTATION

The manufacturer/supplier shall provide sufficient information to identify the anode and shall supply the technical information as a minimum requirements as follows :

A : ISO 9001: 2008 certification for design , manufacturing and quality control of the MMO anode to be used for impressed current cathodic protection installation , issued by an internationally recognized body .

B : Original technical catalogue and data sheet , manufacturing procedure specification , quality control plan , application procedure recommendation and guidelines (installation instructions) .

C : Filled , signed and stamped data sheets as shown in Annexes A and B .

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

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

E : Certificate of analysis according to ASTM B 338 for titanium as in Annex A .

7. QUALITY ASSURANCE

Manufacturer shall operate an effective , documented quality system based on the relevant part of the BS EN ISO 9001 : 2008 and maintain records identifying the product , date of manufacturing , batch numbers and all results of inspections and testing .

8. 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 .

9. 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 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 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 .

10. MARKING

Each container 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

" ANNEX A "
Data Sheet for Titanium

Manufacturer's name and address	
Product designation	

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

Note :

This data sheet shall be filled , signed , and stamped by manufacturer/supplier .

AUTHORIZED SIGNATURE ;

COMPANY'S STAMP :

" ANNEX B "
Data Sheet for MMO Anode

Manufacturer's name and address	
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	Bend and Peel off Test				
8	Adhesion				
9	Acid Test				
10	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 .

DEVIATION(S)

AUTHORIZED SIGNATURE ;

COMPANY'S STAMP :

" ANNEX C "
Data Sheet for MMO Coated Titanium Anodes
(to be submitted by the purchaser)

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 : <input type="checkbox"/> Single type <input type="checkbox"/> String type
8	Anode dimensions :
9	Anode cap type(s) : <input type="checkbox"/> Standard <input type="checkbox"/> Chlorine resistant
10	Lead wire insulation type : - Standard type : <input type="checkbox"/> Double jacket – HMWPE/ HMWPE <input type="checkbox"/> Double jacket – XLPE/ HMWPE - Chlorine resistant type: <input type="checkbox"/> Single jacket – PVDF <input type="checkbox"/> 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	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 .