Mixed Metal Oxide (MMO) Anode

Quality Control (QC) Testing

INTRODUCTION

The excellent stability of mixed metal oxide (MMO) coated titanium anodes have been used in the cathodic protection industry for over 30 years. MMO coated titanium anodes are used in various environments, including:

- Seawater
- Brackish water
- Fresh water
- Carbon backfill
- Concrete
- Sand

However, many project owners and CP engineers simply specify MMO coated titanium anodes by size, life, current rate or manufacturer's name without understanding the characteristics, limitations and evaluation method of the MMO anodes. In many cases, the anode data sheets are exactly the same as those of other companies even though the MMO anodes' manufacturers are different. There is no same MMO coating in the market because each manufacturer has its own compositions.

The lack of knowledge on MMO anodes often results in the premature failure of the anodes. In many instances, CP design engineers are also misled by the information supplied by the anode suppliers. Since most anodes are used in cathodic protection for a long time (over 30 years), it is difficult to track their long term performance.

TECHNICAL BACKGROUND

MMO coatings for cathodic protection are mainly divided into two types, **Iridium Oxide (IrO_2-x)** and **Ruthenium Oxide (RuO_2-x)**. In some case, a mixture of these is used. In addition, titanium oxide (TiO_2-x) and tantalum oxide (Ta_2O_5) are also used as the bulk materials. MMO coating is applied on titanium substrate as a liquid form of metals salt and then is thermally decomposed to form an adherent layer of mixed oxides at temperatures typically ranging 400 to 600°C. The MMO coatings are applied in many layers and heat treated after each coat.

The life of MMO coated titanium anode is largely dependent on the following factors:

- MMO coating thickness
- Iridium or ruthenium based MMO
- Iridium or ruthenium content
- Coating uniformity
- Anode current density
- Type of electrolyte used

Iridium vs. Ruthenium MMO Coating

- Iridium MMO has longer life than ruthenium type when the same amount of current density discharges in a same electrolyte.
- Iridium MMO is much more expensive than that of ruthenium.
- Ruthenium MMO is typically used in seawater as the evolution of chlorine gas is no concern. In addition, the consumption rate of ruthenium is less in seawater than other electrolytes. However, when ruthenium based MMO is used in coke, freshwater, soil or sand, the consumption rates become much higher
- Iridium MMO is used in coke, freshwater, soil or sand because the consumption rates of Ruthenium MMO become much higher (shorter life).
- When chlorine gas evolution from the anode is a concern such as concrete, iridium based MMO coating is required. Chlorine gas turns to hypochlorite acid and dissolves the concrete.

Factors of MMO Anode Life

- **MMO coating thickness:** MMO coating thickness is adjusted by multiple coats, dipping or brushing. (Example: a manufacturer uses 6 coats for a sample for testing but only applies only 3 coats for a project to reduce the cost.)
- **Iridium content of MMO coating:** If iridium content is reduced, the anode life is reduced. (Example: a manufacturer makes MMO coating with 10% iridium for a sample for testing but may be 5% for the anodes or replace with ruthenium for a project.)
- **Ruthenium content of MMO coating:** MMO coating life is reduced when it is used in oxygen evolution condition, such as fresh water, brackish water, and carbon.
- **Uniformity of MMO coating:** When small amount of samples are made, they can apply the MMO coating uniformly. However, when large amount of anodes are produced, the MMO coating application may become sloppy, resulting in less uniformity of the MMO coating. This will cause local anode failure before it reaches the design life in thin coated areas.

The differences of these conditions indicated above cannot visually be distinguished. Therefore, the anodes which arrive your project site may not be the same as the data sheet or your specifications.

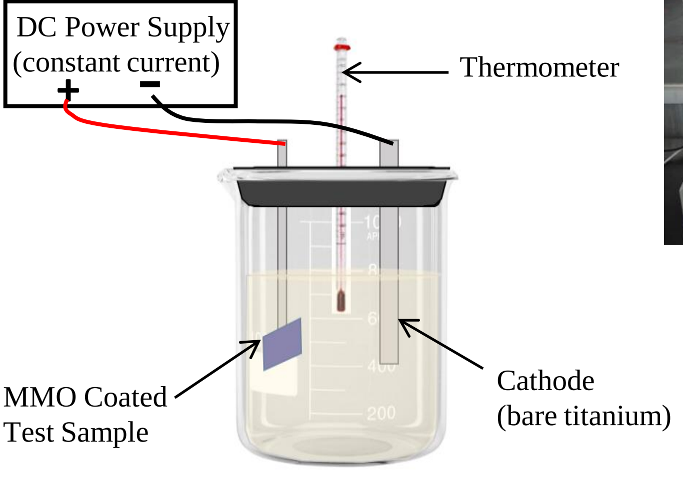
To make sure the anode life used for your structure meets the requirements, NACE TM0108 “Testing of Catalyzed Titanium Anodes for Use in Soils or Natural Waters” is recommended. It should be noted that this test is not applicable to Ruthenium based MMO anode. If you need to confirm if the anodes meet your design life regardless of the applications, Iridium based MMO must be specified for the life acceleration testing.

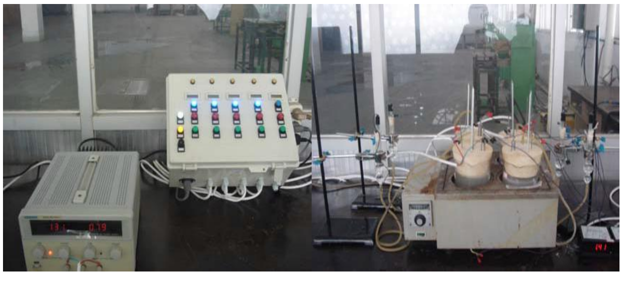
NACE TM0108-2012

Testing of Catalyzed Titanium Anodes for Use in Soils or Natural Waters

Life accelerated testing is intended to provide a measure of the anode's ability to perform satisfactorily for a specific design requirement in a relatively short period. Normally, the design requirements for an anode of a given surface area are expressed as a current rating (amperes) for a lifetime (years).

This test method is for anodes comprised of a titanium substrate to which a mixed metal oxide (MMO) catalytic coating has been applied. This test method accelerates the time-to-failure by operating the anode at a higher current than the application's design requirements using the acid solution.





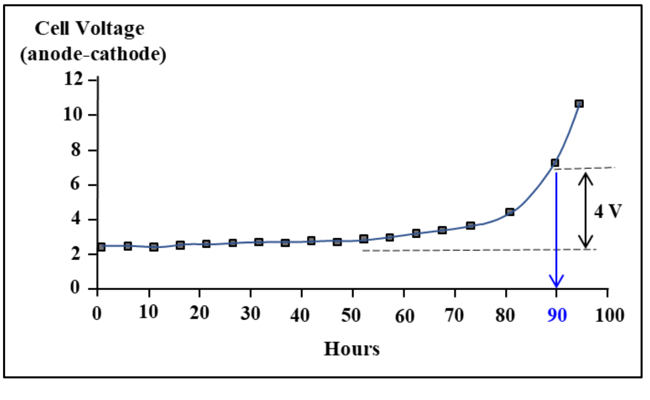
Suitable electrolytes are:

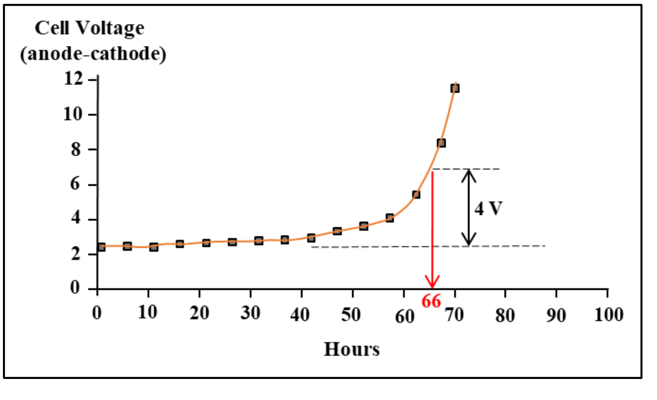
- 1 M sulfuric acid (H_2SO_4)
- 1 M sodium sulfate (Na_2SO_4)
- 180 g/L sodium sulfate with 0.1 N sulfuric acid to maintain pH at 1.

Example:

When MMO anode is designed to last 30 years at 3.3 amp/m^2 on anode surface, the DC power supply is set at 3.3 amp/m^2 base on the sample anode surface area. This is equivalent to 10,000 amp/m^2 . To meet the design life, the test sample should not be failed a minimum of 87 hours.

The mode of the anode failure is determined when the cell voltage starts increasing significantly from the initial voltage. The time of the failure is typically monitored until the cell voltage increased by 4 volts.





Sample Passed (Failure Time 90 hrs. > 87 hrs.) **Sample Failed (failure time 66 hrs. < 87 hrs.)**

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MMO

Air Tightness Tests for Cable Connection

The void insulation space of anode-cable connection is pressurized with helium gas. If any air void exists inside the anode, the helium gas passes through them and reaches the anode ends. That can be detected using a mass spectrometer for helium gas.

Procedure of Helium Gas Leak Test

1. Connect the fitting on the end of anode cable tail with helium hose and a pressure gauge.
2. Slowly pressurize the CP cable to 2 bar (g) with gas helium injection.
3. Stop the helium gas injection when testing pressure has been achieved.
4. Switch on the helium mass spectrometer and ensure sniffer is in good condition.
5. Helium leak test technician to check all the anode-to-cable connection points of each MMO tubular anode with sniffing mode.
6. The spectrometer will generate an alarm and light signal on the display panel when helium is detected, indicating a potential leak location.
7. The leak criteria for helium leak test is set at 1 x 10^{-5} mbar-liter/sec.
8. The technician to reconfirm again on the presence of the leak by studying the leak signals.
9. After a leak location has been confirmed, the leak is to be recorded in a report.
10. After confirmation that no leaks exist, vent off all pressure from the pressurized anode cable tail.

Helium gas pressure gauge

Helium leak test

RECOMMENDED SPECIFICATIONS FOR ANODE LIFE

1. The Contractor shall provide one additional anode for the project.
2. The Contractor shall deliver the anodes to the project site by considering the test duration period not to delay the project.
3. Following the delivery of the anodes and prior to anode installation, the owner's engineer will randomly select a test sample from them for quality control testing.
4. An independent laboratory that is approved by the owner shall test the sample.
5. The laboratory shall provide a formal report including the step-by-step photo-documents. If photo-documents are not included in the report, the report shall be rejected.
6. A copy of the test report shall also be included in the commissioning report or O&M manual.
7. The cost of the testing shall be borne by the Contractor.

<u>Example for 30 years design life anode</u>

9. The sample of MMO anodes shall be cut and tested using a current density of 10,000 or 15,000 amp/m^2 until the total amount of discharge current (amp-hour) equivalent to 30 years period provided by the anode supplier.
10. The time of the failure shall be monitored until the cell voltage increased by 4 volts.
11. Failure of the anode to achieve this charge shall be grounds for rejection of all remaining anodes and replaced by the Contractor. The Contractor shall provide new anodes and repeat the same test.
12. When the time of the project is limited for replacement of all anodes, the Contractor shall provide additional anode(s) to compensate the anode capacity based on the new design based on the lab test results.