

## THE RELATIONSHIP OF CARBON BACKFILL AND METAL CORROSION RATE IN SUBMARINE ELECTRODE ARRAY SYSTEM

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**Abstract:** Carbon backfill is an effective way to reduce corrossions rate by converting the ionic conduction of metal material into the electron conduction. This paper will demonstrate the precise effects of the carbon backfill towards the material's corrosion rate obtained during field trials. Moreover, the relationship between the amount of backfill material used and electrode corrosion rated is also calculated and presented in this paper according to trial results. Based on the outcome, the minimum amount of carbon backfill can be selected to simplify the installation process and reduce any associated engineering cost.

### 1. Introduction

In submarine telecommunication system, the copper conductor within the submarine cable carries a line current. The DC line current flows from the positive PFE to the correspondent negative PFE, and through the actual ground flows back to its source. The grounding electrode array is used to provide the system current with a reliable and low resistance path to the system ground. Due to the effects of electrochemical corrosion caused by the continuous system current, the corrosion rates of the electrode material is a key factor not only for the electrode system but also for the earth resistance. To reduce the electrochemistry corrosion rate, carbon backfill is an effective and economic method adapted in the industry. The principle is that carbon backfill can transfer the ionic conduction between earth electrode metal and the adjacent soil into the electron conduction. This paper studies whether the amount of carbon backfill used has any influence on the electrode corrosion rate, and we are confidence the results of this paper will simplify future site construction procedure.

### 2. Test setup

We have conduct field trial to determine the amount carbon backfill required and the electrochemical corrosion rate in the Chinese State electrical ultra-high voltage grid experiment base. In the experiment, six high-silicon chromium iron samples were chosen. High-silicon chromium iron is widely used in ground array system in both the submarine industry and electric power industry because of its excellent performance in anti-corrosion application. The samples used are high-silicon chromium iron cylinder with 20mm in diameter and 20cm long.

The spec. of the metal material and carbon backfill is shown below:

| Main Chemical Composition%(Excluding Fe) |             |       |       |       |         |
|--|-------------|-------|-------|-------|---------|
| C  | Si          | Mn    | Cu    | Mo    | Cr      |
| 0.7~1.4                                  | 14.24~15.25 | <=1.0 | <=0.5 | <=0.2 | 3.5~4.5 |

Table 1 The Spec. of High-silicon Chromium Iron

| Item                       | Technical Parameters          |            |
|----------------------------|-------------------------------|------------|
| Density                    | $\geq 1.9 \text{ g/cm}^3$     |            |
| Volume Weight              | $0.9 \sim 1.1 \text{ g/cm}^3$ |            |
| Solid Carbon Content       | $\geq 96\%$                   |            |
| Volatile Matter            | $\leq 0.5\%$                  |            |
| Particle Size Range (mesh) | Particle Size < 35            | $\leq 5\%$ |
|                            | 35 ~ 100                      | 55% ~ 65%  |
|                            | 100 ~ 200                     | 20% ~ 30%  |
|                            | Particle Size > 200           | Margin     |

Table 2 The Spec of Carbon Backfill

The experiment was performed in during field trials on the Chinese State ultra high voltage grid. Six electrodes were buried to a 1.5m depth, in a 3x3 meter pitch and backfilled with varying thicknesses of carbon. Over duration of 30-days, tests of the earth resistance for each sample changed marginally, primarily attributed to changes in weather conditions, soil conditions etc., with each sample connected to a slide rheostat. A current sensor was used to test the line current of each sample at various times and by adjusting the slide rheostat we were able to maintain a stable current of each of the sample electrodes. It was noted that the current flowing through the electrode to the actual ground, heat dissipation will occur due to the earth resistance. If the soil moisture is heated into water vapor, the corrosion mechanism will change along with the rapid increase of the earth resistance, which is not acceptable in an electrode systems. In order to prevent the evaporation of soil's moisture, five temperature probes are installed in samples #1 through #5 in order to monitor the circumstance temperature around each sample and the temperature of each sample should be limited to below 90 degC according to electricity industrial standard [1].

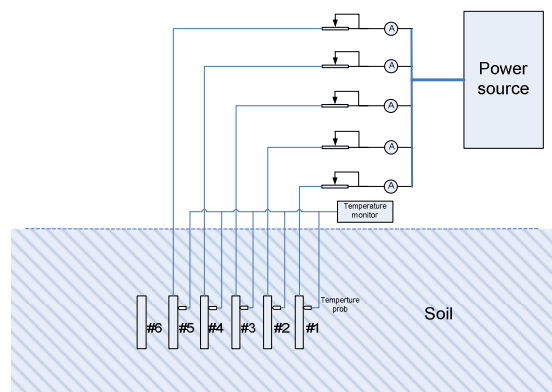


Figure 1 Test setup

With six samples in a parallel connection, the anode to the DC power source. Sample #2~#5 were buried in each four corners of a pit, surrounded by 40cm long backfill carbon, and the thickness of the carbon backfill was 10cm\*10cm, 20cm\*20cm, 30cm\*30cm, and 50cm\*50cm respectively, and samples #1 and #6 positioned in the middle of the pit had no carbon backfill.



Figure 2 Carbon backfill for sample#3

Sample #1~#5 was then powered by approximately 4A continuous DC current, for 722 hour period to test the corrosion rate of the different carbon thickness (and in the case of samples 1 and 6, with no carbon backfill). Sample #6 was not powered, as it was utilized to observe the natural corrosion levels of an electrode. After the carbon backfill, we filled the pit

with soil and implemented the following procedures to observe the corrosive states of each electrode:.

### 3. Test Procedure

- 1) Measure the weight of each sample electrode before they are buried by using a balance, the measuring accuracy is 0.01g, mark the measuring result as  $m_1$ .
- 2) Power the samples, using slide rheostat to balance the current in each sample.
- 3) During the testing phase, daily measurements of the current were recorded from each sample. If the current changes, adjustments to the slide rheostat were made in order to maintain a steady current to the sample's original values.
- 4) A continuous power was applied to each sample for period of 30-days
- 5) After the 30-days, powered down and dug out the samples.
- 6) Clean the samples, following the next steps: [2]
  - a Clean the surface of the samples using tap water, then dry the samples with absorbent paper.
  - b Using mixed solution (Hydrochloric acid : distilled water : Hexamethylenetetramine = 50ml:50ml:2g ) clean the surface of the samples until all the impurities are removed. The clean time take no longer than 25 minutes.
  - c Clean the samples again with tap water and drop the sample in a 6% sodium hydroxide mixture for less one minute.
  - d Clean the samples again with distilled water and then dry the samples with absorbent paper
  - e Drop the samples in absolute ethyl alcohol for 5 minutes.

f Dry the samples with absorbent paper before put the samples into a drying apparatus for 24 hours.

- 7) Mark the weight of the samples after cleaning as  $m_{loss}$ . In order to exclude the influence of the cleaning procedure, repeat step 1~7 with an unused sample, and mark the weight loss before and after the clean process as  $m_0$ . Then mark the weight  $m_2 = m_{loss} + m_0$  as the weight after corrosion.

The total weight loss of the sample due to the corrosion test is  $m_1 - m_2$  and the corrosion rate of the samples can be calculated by following formula:

$$G = (m_1 - m_2) / (A \times T) \times 8760$$

Where

$A$  is the test current

$T$  is the test hours

$m_1$  and  $m_2$  is as described above.

Constant 8760 equals to the hours per year



Figure 3 Sample after the test (Sample #3)

### 4. Test result

| Sample No.        | m1<br>Sample weight<br>before test(g) | m2<br>Sample weight<br>after test(g) | A<br>Sample<br>current(A) | T<br>Poweing<br>hours(h) | G<br>Corrosion<br>rate/(kg/A.y) |
|-------------------|---------------------------------------|--------------------------------------|---------------------------|--------------------------|---------------------------------|
| 1#                | 444.28                                | 159.21                               | 4.1                       | 722.5                    | 0.843                           |
| 2#<br>(10cm*10cm) | 443.92                                | 442.98                               | 4.2                       | 722.5                    | 0.0027                          |
| 3#<br>(20cm*20cm) | 437.02                                | 435.57                               | 4.08                      | 722.5                    | 0.0043                          |
| 4#<br>(30cm*30cm) | 447.39                                | 446.17                               | 4.24                      | 722.5                    | 0.0035                          |
| 5#<br>(50cm*50cm) | 441.34                                | 440.37                               | 4.2                       | 722.5                    | 0.0028                          |
| 6#                | 445.37                                | 445.3                                | /                         | /                        | /                               |

Table 3 Test result

The results showed that Sample #1's corrosion rate of high-silicon chromium iron was  $0.843\text{kg/A} \cdot \text{Y}$ ; which is in accordance with the corrosion rate provided by the supplier of the electrode (In the vendor specifications this value should be below  $1\text{kg/A} \cdot \text{Y}$ ). For those samples with differing carbon backfill thickness, the corrosion rate reduced dramatically by two orders of magnitude. Also, it was observed from the tests that the amount of the carbon backfill utilized had almost no influence on the corrosion rate. In the industry, two kinds of electrode are provided. First one is separated electrode, the vendor sells electrodes only and customers have to purchase carbon backfill independently. Another kind is so called pre-fabricated electrode. The pre-fabricated electrodes contain high-silicon chromium iron and together with the carbon backfill, the metal and carbon portions are loaded into a metal container. From anti-corrosion point of view, those two kinds electrode have the same ability, but pre-fabricated electrodes are more convenient for transportation, storage and installation.

### 5. Conclusion

From the field test, we can draw the conclusion that although carbon backfill can reduce the corrosion rate by two orders of magnitude, the amount of carbon backfill used has an insignificant influence on the metal corrosion rate. In the submarine industry, the electrode installation faces many difficulties, such as inadequate installation equipment, complex topography, limited availability of carbon material etc. The conclusion of this paper can ease the installation process by giving the field installation engineer the flexibility to choose minimum amount carbon backfill material according to actual

conditions at each respective site. Meanwhile, the costs benefits of using less carbon has designate advantages. Furthermore, this paper has therefore proved that pre-fabricated electrode product do not require additional carbon backfill during onsite construction.

### 6. REFERENCES

- [1] DL/T 253-2012 *Measurement Method for Earth Resistance, Ground Potential Distribution Step Voltage and Current Dividing on Earth Electrodes*
- [2] GB/T 25147-2010 *Test method of metal corrosion amount and corrosion rate of chemical cleaning for industrial equipment—Gravimetric method*