Study on Testing Method of Non-polarized Electrode

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Abstract. The observation of geoelectric field in the field data acquisition of electrical prospecting is usually achieved by the use of non-polarized electrodes. The performance of non-polarized electrodes directly affects the quality of field data. The existing non polarized electrode is usually used to evaluate the initial range and the stability of the electrode. In order to make a further evaluation, an indoor and field test scheme is developed. In the laboratory, three parameters, such as the extreme stability, the source impedance and the background noise level, are tested. The field test is carried out from the following two aspects: the parallel consistency test and the MT test. The results show that the above parameters and the field test results show that the electrode can be used for field MT data acquisition. It provides a scientific and feasible test scheme for the full evaluation of the non-polarized electrode test.

Introduction

High precision observation of geoelectric field is a necessary condition for field data acquisition in electrical prospecting. The observation of geoelectric field is realized by embedding non polarized electrodes in the surface or underground space and observing the potential difference in different space. The performance of non-polarized electrodes directly affects the quality of field data. At present, the development and application of non-polarized electrodes have been carried out in many industries and units in China. The emphasis is focused on the indoor and field testing of the range stability, and the factors affecting the stability of the range difference are analyzed. The improvement direction and the optimization measures are put forward for the electrode fabrication process[1]. The existing testing methods also lack quantitative evaluation of electrode consistency, and the evaluation method is single. In this paper, the consistency of non-polarized electrodes is evaluated from the long-term stability, electrode impedance and background noise level. In order to fully evaluate the technical indexes of the non-polarized electrode, a method for measuring the long-term stability of multi-branch electrodes, the impedance of the electrode source, the level of the background noise of the electrode, and so on, is put forward. The indoor test of non-polarized electrodes provides technical guarantee for quality control of field data acquisition. The parallel consistency and MT data acquisition test under field conditions were carried out.

Electrode Principle

The working principle of the non-polarized electrode to be measured is based on the principle of electrochemistry, which is a Pb/PbCl\(_2\) non polarized electrode. Fig. 1 shows the structural schematic diagram of the non-polarized electrode, mainly including shell, mud, lead wire, Tung wood plate, sealing cover and lead out line. The internal mud is obtained by mixing hydrochloric acid, lead chloride, kaolin and purified water. The chloride ion in the mud of the electrode realizes the ionic potential balance with the chloride ion of the external mud, and transfers the potential to the external copper lead wire through the lead wire. The stability of range depends mainly on the pH value, ionic solubility and environmental temperature. The non-polarized electrode is mainly geomagnetic and long-range magnetotelluric observation field, and effective measures are taken in the extreme
stability. In order to improve the extreme stability of the non-polarized electrode, the pH value is set to 3-4, and the ion diffusion velocity is slowed down by with the help of the small channel at the bottom of the electrode\textsuperscript{[2,3]}.

![Figure 1](image1.png)

**Figure 1.** Left: non polarized electrode structure; Right: non polarized electrode.

**Indoor Testing**

The indoor test of the non polarized electrode mainly carries out parameter test such as extreme stability, electrode source impedance, background noise level and so on. The equipment involved in the test mainly includes multi-channel switch unit, dynamic signal analyzer and LCR meter. Table 1 gives the equipment type and main technical parameters.

As shown in Figure 2, all the measured electrodes are immersed in the saturated NaCl solution, with one non polarized electrode as the reference electrode, and the rest of the measured electrodes are connected to the input terminal of the switch unit, and the potential difference of the other electrode relative to the other electrode is recorded. The acquisition parameters are set to DC voltage, 10min sampling interval and range 100mV. In order to obtain temperature change data, the thermocouple is immersed in the solution during the testing process, and the environmental temperature changes are recorded at the same time. The above process is continuously observed for about 10 days.

![Figure 2](image2.png)

**Figure 2.** Schematic diagram of the stability test equipment.

Table 1. List of equipment required for testing.

<table>
<thead>
<tr>
<th>Equipment Name</th>
<th>Model</th>
<th>Main Specifications</th>
<th>Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Multiple switch unit</td>
<td>Agilent 34972A</td>
<td>Supports 40 voltage observations, self drift less than 10μV/day, 6-bit half-precision</td>
<td>Long term stability test of electrode range</td>
</tr>
<tr>
<td>Dynamic signal analyzer</td>
<td>HP 35670A</td>
<td>Bandwidth:51.2 kHz Line resolution:100, 200, 400, 800 and 1600 Instantaneous dynamic range:90 dB</td>
<td>Noise level test</td>
</tr>
<tr>
<td>LCR meter</td>
<td>U1733C</td>
<td>100Hz/1kHz/10kHz/100kHz Handheld LCR meter</td>
<td>Electrode source impedance test</td>
</tr>
</tbody>
</table>
Range Stability

Fig. 3 shows the results of all electrode drift tests, showing that the difference between the 8 electrodes to be measured relative to the reference electrode is distributed in the range of 0 V~400 V; The temperature ranges from 25 to 30 °C, showing 8 diurnal variations; There is a strong correlation between range variation and temperature change; The range drift is about 40 μV/day and the temperature coefficient is about 50μV/°C. The results show that the variation of electrode range is largely due to the change of environmental temperature, which should be paid attention to in field observation. The range variation caused by temperature variation is the source of interference for MT bathymetry. Therefore, it is necessary to bury the non-polarized electrode in order to reduce the range variation caused by temperature change[4].

Internal Resistance

The source impedance of the non-polarized electrode pair can be equivalent to series resistance and series inductance and parallel capacitance. Through the source impedance test, the internal resistance changes of the non-polarized electrodes at different frequency points can be obtained, providing an evaluation basis for the consistency of the electrodes[6]. The non-polarized electrode was immersed in saturated NaCl solution and the impedance of the electrode pair was measured by LCR meter. The specific test scheme is as follows: The source impedance of electrode pairs composed of other electrodes and reference electrodes is fixed with a reference electrode fixed. The test results contain the sum of the internal resistance of the electrode and the impedance of the conductive solution. Taking into account the high conductivity of the saturated NaCl solution, the impedance of the solution is temporarily ignored. The test process is carried out at 4 frequency points (10Hz, 100Hz, 1kHz, 10kHz). The test results are shown in Figure 4. In the range of 100Hz-100kHz frequency band, the impedance basically does not change with the frequency. It is located at the interval of 290Ω-360Ω, the change of impedance angle is located at the interval of 0~-1°, and the angle increases with the increase of frequency, but it is basically pure resistance.

Noise Level

Background noise level refers to the noise output of the electrode itself under relatively non-interference conditions. The excessive noise of electrodes will affect the signal-to-noise ratio of field data acquisition. The electrode noise source mainly comes from two aspects: thermal noise and range drift. It is an effective way to characterize electrode performance. The test scheme is as follows: the electrode is immersed in saturated NaCl solution, equivalent to electrode to input short. Because the background noise of the dynamic signal analyzer is about 10nV/rt (Hz) @1Hz, and the noise of the electrode is less than the background noise of the measuring instrument, the input of the dynamic signal analyzer is increased by the first order low noise amplifier, and the noise level of the amplifier is 1nV/rt (Hz). The power density of the electrodes is measured from the output to the low noise amplifier, the output of the LNA to the input end of the dynamic signal analyzer. The test results are shown in Figure 5. The black curve in the graph is the background noise of the dynamic signal analyzer and the amplifier, and the red curve is measured by the non-polarized electrode noise, and the self-noise of the electrode is about 7nV/rt (Hz) @1Hz. Noise increases at low frequency.
Field Comparison Test

Parallel Test

The principle of parallel testing is to connect the two pairs of electrodes arranged parallel to the two channels of the same instrument, calculate the power spectral density (PSD) of the obtained time series, and compare the differences of the different channels. The difference includes the background noise of the instrument channel itself and the noise of the electrode. Usually, the instrument thinks that the noise level of the instrument is low enough, and the difference is mainly reflected in the non-polarized electrode. The field parallel test cloth station map is shown in Figure 6, with the aid of the MTU5A magnetotelluric instrument produced by Phoenix, the two electric channels are connected to two pairs of electrodes, two pairs of electrodes are arranged in parallel, and the extreme distance is 100m. Set MTU-5A to work in AMT mode and collect time 30min. MT mode takes 10hr. The collected two channel time series is processed by NPI, and the result is shown in Figure 7.

1000s to 1kHz frequency range test results show that in the range of 1Hz to 0.1Hz and 600s to 1000s frequency range, the consistency of two channel PSD is slightly worse than that of other frequency bands, and the coherence coefficient is also low to 0.95, which is related to the humanities interference and the short acquisition time. From 1kHz to 1000s, the other bands had better consistency, and PSD difference was basically better than 1%.

Figure 6. NPI parallel test station.
MT Test

A number of electrodes to be selected were put into field real MT method to test the working conditions of non-polarized electrode under field conditions. With the help of Phoenix MTU5A magnetotelluric instrument and LEMI417 long period magnetotelluric instrument of Ukraine LVIV, the field data collection of AMT, MT and LMT methods is realized. The three methods were 30min, 10hr and 7day respectively. The cannon apparent resistivity curve is obtained from the original realization sequence. Figure 8 shows the results of three methods. The high quality data in the 10kHz-10000s band range are obtained, which proves that the non-polarized electrode to be tested can meet the actual MT data acquisition in the field.

Conclusion

To sum up, in order to evaluate the performance of the non-polarized electrode, the parameters such as the extreme stability, the internal resistance and the background noise level were tested under the indoor conditions, and the parallel consistency test and the MT/AMT test were carried out under the field conditions. The list of main parameters is shown in Table 2.
Table 2. List of main parameters of electrode.

<table>
<thead>
<tr>
<th>Parameter Name</th>
<th>Parameter</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Range of extreme difference</td>
<td>±500μV</td>
<td></td>
</tr>
<tr>
<td>(μV)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Extreme stability</td>
<td>20μV/day</td>
<td>The temperature is distributed at 25 to 30°C</td>
</tr>
<tr>
<td>Internal resistance</td>
<td>300Ω</td>
<td>One pair of electrodes</td>
</tr>
<tr>
<td>Background noise level</td>
<td>About 7nV/rt(Hz)@1Hz</td>
<td></td>
</tr>
<tr>
<td>Size (D×H)</td>
<td>90mm×85mm</td>
<td></td>
</tr>
<tr>
<td>Weight (g)</td>
<td>640g</td>
<td></td>
</tr>
</tbody>
</table>

The conclusions are as follows:
1. The polarization stability of the non-polarized electrode is about ±500μV, which meets the specification requirements.
2. The internal resistance is about 300Ω range, which is basically resistive.
3. The noise level is about 7nV/rt (Hz) @1Hz.
4. Field parallel test results show that in the range of 1Hz to 10kHz, the coherence coefficient is located in 0.99~1 interval, and the ratio is in 0.95~1 interval. In the range of 1000s to 32Hz, except for a small number of SNR, the ratio and the ratio of the miss to the 0.95~1Hz are located.
5. Field AMT/MT conformance test showed that the test curve was consistent with the PbCl2 electrode, and the mean square deviation of the 6 pairs of electrodes was in the 1%~5% range.
6. Indoor and field test results show that the non-polarized electrode can be used in field electromagnetic exploration tasks, and the data quality is high, and has good stability and reliability.

The existing “magnetotelluric sounding regulations” only regulate the range of non-polarized electrode, and the evaluation method for electrodes is single. According to the working principle of the non-polarized electrode, the non-polarized electrode is standardized from three aspects of the extreme stability, the internal resistance and the background noise level. The specific testing method is given, which has strong maneuverability. It provides theoretical support and practical guidance for improving the quality of field data acquisition.

Acknowledgement
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References


