Study on Instrument Performance Verification and Base Station Parameter Determination in Magnetic Method Testing

Abstract

To ensure that the quality of field observation data from magnetic method testing meets the accuracy requirements of the design document and relevant specifications, this study conducted systematic performance tests on four magnetometers (No. 1, No. 2, No. 3, and No. 5) used in production. These tests included noise level measurement, probe consistency measurement, and instrument system consistency measurement, and the determination of the base station T0 value (basic magnetic field value) was also completed. The test results showed that: the noise root mean square (RMS) values of the four magnetometers ranged from 0.34 nT to 1.33 nT, indicating a low noise level that meets the design accuracy; the arithmetic mean values of probe readings had minimal differences, and the variation trend of the host consistency curve was consistent with that of the diurnal variation curve and was smooth; the maximum single-instrument consistency of the instrument system was 2.32 nT, which was less than 2/3 of the designed mean square error (±3.3 nT), with no significant systematic errors; the determination of the base station T0 value identified the basic magnetic field value of the work area as 56962.52 nT (October 1, 2023) and that of Fire Area No. 1 as 56963.43 nT (October 2, 2023). All test indicators met the requirements, providing technical support for the reliability of subsequent magnetic method field observations.

Keywords

Magnetic Method Testing; Magnetometer; Instrument Performance Verification; Noise Level; Consistency Measurement; Base Station T0 Value

1 Introduction

As an important method in geophysical exploration, magnetic method measurement has its data accuracy directly determining the reliability of exploration results and the accuracy of interpretations. Before conducting formal field observations, it is necessary to perform comprehensive performance verification on the magnetometers used in production and determine the key parameters (T0 value) of the base station. This helps eliminate the impact of instrument errors and environmental interference on observation data, ensuring that the data meets the requirements of the design document and relevant standards such as the Specifications for Ground Magnetic Survey. This study focuses on the performance verification process of four magnetometers and the determination method of the base station T0 value, elaborating in detail the test design, data processing, and result analysis processes. It provides a reference for instrument verification and base station setup in similar magnetic method measurement projects.

2 Design and Implementation of Instrument Performance Tests

2.1 Overall Test Design

A test site with a stable magnetic field and no artificial interference was selected. The four magnetometers underwent sequential tests, including preliminary observation of the magnetic field T0 value, noise test, and multi-instrument consistency test (covering probe consistency and instrument system consistency). The core objectives of the tests were to verify the performance

stability of the instruments, quantify the observation accuracy, and confirm the data consistency among multiple instruments, ensuring that the instruments meet the accuracy requirements for field observations.

2.2 Noise Level Measurement

2.2.1 Test Method

An area near the work area with a stable magnetic field and no artificial interference (such as power lines, metal structures, etc.) was selected for simultaneous diurnal variation measurement using the four magnetometers. The test parameters were set as follows:

Time synchronization accuracy: Second-level (to ensure consistent observation time across multiple instruments);

Sampling interval: 20 seconds;

Probe spacing: ≥20 meters (to avoid magnetization interference between probes);

Observation data volume: Approximately 100 sets of valid observation values were collected for each instrument, and the noise RMS value (reflecting the instrument noise level) was calculated based on these observation values.

2.2.2 Test Results and Analysis

The noise level measurement results of the four magnetometers are shown in Table 1. It can be seen from Table 1 that Magnetometer No. 1 had the highest noise level (1.33 nT), while Magnetometer No. 5 had the lowest (0.34 nT). The noise RMS values of all four magnetometers fell within a low range, and the noise error was close to zero. This indicates that the impact of the instruments' own noise on the observation data is minimal, meeting the design accuracy requirements of the instruments and ensuring the signal-to-noise ratio of subsequent observation data.

Table 1 Statistical Table of Instrument Noise Level Measurement

Instrument No.	No. 1	No. 2	No. 3	No. 5	Test Date
Noise Level (nT)	1.33	0.41	0.58	0.34	20230930

The instrument commissioning noise test curve is shown in Figure 1. From the variation trend of the curve, it can be observed that the magnetic field values of each instrument fluctuated smoothly during the observation period, with no significant jumps or abnormal fluctuations. This further confirms that the instrument noise level is stable and meets the requirements.

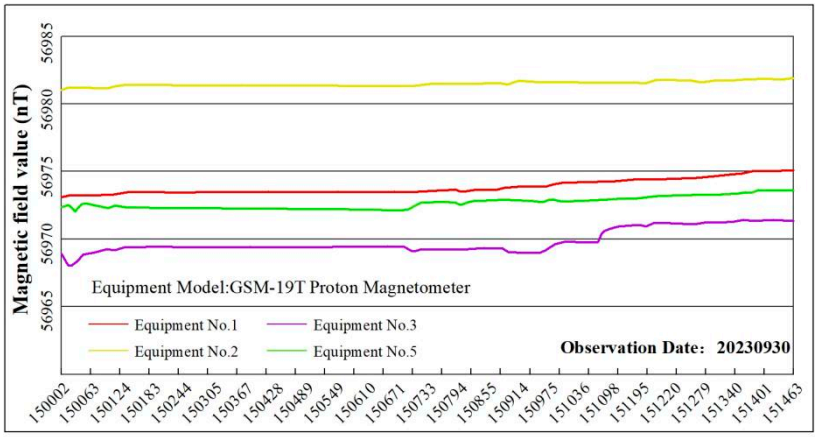


Figure 1 Noise Test Curves for Four GSM-19T Proton Precession Magnetometers

(Miaoergou Fire Zone, 2023-09-30): Demonstrating Low Noise Levels for High-Quality Magnetic Data

2.3 Probe Consistency Measurement

2.3.1 Test Method

To eliminate the impact of probe differences on observation data, the probes and hosts of the complete instrument sets were numbered and matched, and consistency verification was conducted. The specific steps were as follows:

Magnetometer No. 4 was selected as the reference for second-level synchronous diurnal variation observation, and the station-type instruments (No. 1, No. 2, No. 3, and No. 5) were fixed as the comparison references;

The host was kept unchanged, and the other two probes were connected in rotation. The instrument was not turned off during probe replacement, and the probe positions were fixed (to avoid errors caused by position deviations);

The tuning field value was uniformly set to 56900 nT, and more than 30 valid readings were collected for each probe;

The differences between the readings of each probe and the readings of the station-type instruments were calculated, and the arithmetic mean of the difference arrays was obtained. The probe consistency was verified by comparing these mean values.

2.3.2 Test Results and Analysis

The probe consistency measurement results are shown in Table 2. It can be seen from Table 2 that the arithmetic mean values of the readings of Probe No. 1, No. 2, and No. 3 were 155.55 nT, 155.52 nT, and 155.09 nT, respectively. With Magnetometer No. 5 as the diurnal variation station reference, the differences between the mean values of the probes were extremely small (the maximum difference was 0.46 nT). This indicates that the consistency among the probes is good, and systematic errors caused by probe differences can be avoided.

Table 2 Statistical Table of Instrument Probe Consistency Measurement

Probe No.	No. 1	No. 2	No. 3	No. 5 (Diurnal Variation Station)	Test Date
Mean Value (nT)	155.55	155.52	155.09	—	20230930

2.4 Instrument System Consistency Measurement

2.4.1 Test Method

The instrument system consistency includes host consistency and observation result consistency among multiple instruments. The test design was as follows:

Host consistency verification: With Magnetometer No. 5 as the diurnal variation station, Probe No. 1 was fixed, and Host No. 1, No. 2, and No. 3 were used in rotation for diurnal variation observation. More than 30 readings were collected for each host, and the observation curves were plotted and compared with the diurnal variation curve to verify the host consistency;

Observation result consistency verification among multiple instruments: A test profile was set up in the northwest of the work area. A calibrated handheld GPS was used to locate 51 observation points (with a point spacing of 10 meters). The profile covered both the anomalous field and the regional background field (the anomalous field intensity at some observation points was more than

5 times the mean square error). The three magnetometers conducted round-trip observations following the "calibration point - observation point - calibration point" mode. The observation mean square error (εi) and the total observation mean square error (ε) were calculated to verify the consistency among multiple instruments.

2.4.2 Test Results and Analysis

Host consistency: The host consistency curve is shown in Figure 2 (to facilitate comparison, the magnetic field values of the three hosts were uniformly subtracted by a fixed value of 150 nT). It can be seen from the curve that the variation trend of the observation curves of the three hosts was completely consistent with that of the diurnal variation curve, with no disconnection and a smooth curve. This indicates that the host consistency is good, with no significant inherent errors.

Observation result consistency among multiple instruments: The instrument system consistency measurement results are shown in Table 3. It can be seen from Table 3 that the single-instrument consistency of Instrument No. 1, No. 2, and No. 3 was ±1.70 nT, ±2.29 nT, and ±2.32 nT, respectively, and the total observation mean square error was less than 2.32 nT, which did not exceed 2/3 of the designed mean square error (±3.3 nT). This indicates that the performance of each single instrument is stable, and there are no significant systematic errors in the observation results among multiple instruments, allowing them to be used simultaneously for field observations in the work area.

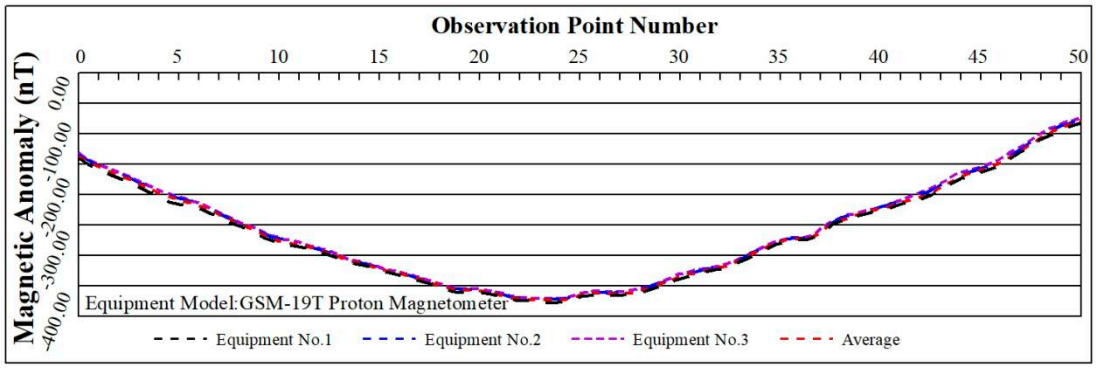


Figure 2 Consistency Curves of Multiple GSM 19T Devices

Table 3 Statistical Table of Instrument System Consistency Measurement

Instrument No.	No. 1	No. 2	No. 3	No. 5 (Diurnal Variation Station)	Test Date
Single-Instrument Consistency (±nT)	1.7	2.29	2.32	—	20230930

3 Determination of Base Station T0 Value

3.1 Base Station Site Selection and Setup Principles

The site selection for the base station (total base point) must meet the following conditions:

It should be located in a normal magnetic field area near the work area, with flat and open terrain;

Stable magnetic field gradient: Within a radius of 2 meters and a height difference of 0.5 meters, the magnetic field variation is less than 2 nT (not exceeding 1/2 of the designed total mean

square error, i.e., ±2.5 nT);

No magnetic interference: There should be no magnetic interference sources such as metal structures and power lines near the base station, especially mobile magnetic interference sources should be excluded;

Diurnal variation station control range: The distance from the farthest observation point in the work area to the diurnal variation station is less than 5 kilometers, meeting the design requirement of the diurnal variation station control range (≤30 kilometers).

In this study, a magnetic survey total base point was established in the background field in the central part of the work area. The positions of the total base point and calibration points were determined using the cross-section method. The diurnal variation station was set up and calibrated against the base point daily. After data transmission and organization, a diurnal variation curve album was formed.

3.2 T0 Value Determination Method and Results

The T0 value is the basic magnetic field value of the work area, which must be determined during the period when the magnetic field is stable (when the diurnal variation curve tends to be horizontally linear). The specific process was as follows:

Diurnal variation observation in Fire Area No. 1: The observation interval was set to 10 seconds, and the observation duration was longer than 9 hours, which meets the construction requirements in autumn and winter, to ensure coverage of the stable magnetic field period;

Identification of the stable period and calculation of the T0 value: The stable period of the magnetic field was identified based on the diurnal variation curve (Figure 3), and the average value of the magnetic field during the stable period was calculated as the T0 value.

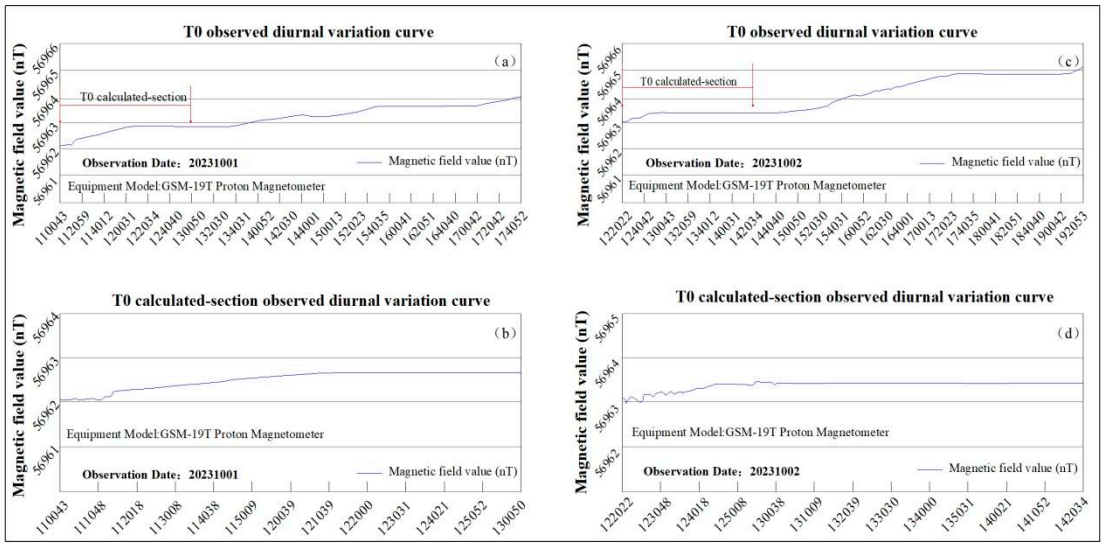


Figure 3 The daily variation curve of the base station T0 observation and T0 calculation time period observation

The determination results are as follows:

October 1, 2023: After 11:00 a.m., the diurnal variation curve tended to be horizontally linear. During the period from 11:00 a.m. to 1:00 p.m., the variation in the average magnetic field value was less than ±2 nT. The calculated average value was 56962.52 nT, which was used as the basic magnetic field value T0 of the work area;

October 2, 2023: After 12:20 p.m., the natural magnetic field in the area tended to be

horizontally linear. During the period from 12:20 p.m. to 2:20 p.m., the variation in the average magnetic field value was less than ±2 nT. The calculated average value was 56963.43 nT, which was used as the basic magnetic field value T0 of Fire Area No. 1.

4 Conclusions

The noise level measurement showed that the noise RMS values of the four magnetometers ranged from 0.34 nT to 1.33 nT, the noise error was close to zero, the instrument noise level was low, and it met the design accuracy requirements;

The probe consistency measurement indicated that the differences between the arithmetic mean values of the probe readings were extremely small (the maximum difference was 0.46 nT), showing good consistency among the probes; the variation trend of the host consistency curve was consistent with that of the diurnal variation curve and was smooth, indicating stable host performance;

The instrument system consistency measurement results revealed that the maximum single-instrument consistency was ±2.32 nT, the total observation mean square error was less than 2/3 of the designed mean square error, and there were no significant systematic errors among multiple instruments, allowing simultaneous field observations;

The determination of the base station T0 value identified the basic magnetic field values of the work area and Fire Area No. 1, providing a benchmark for the correction of subsequent field observation data and ensuring data accuracy.

In conclusion, the performance of the four tested magnetometers meets the requirements of the design document and specifications, and the base station setup is reasonable. They can be used for subsequent magnetic method field observation work.