PROBLEMS OF SUPPLY IN DI-FLUX INSTRUMENTS

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Abstract. For the most part, the D/I fluxgate magnetometer is the only absolute instrument used in observatories and in the field. At present no company produces a nonmagnetic theodolite and there are only a few organizations converting geodetic theodolites to nonmagnetic instruments. A classic theodolite has many parts which have a magnetic moment. These parts have to be replaced before the instrument can be used as an absolute instrument for magnetic measurements. The most problematic part of these theodolites is the main axis. The precision of this part determines the overall quality of the instrument. Most observatories require 1" resolution. This can be achieved by converting the Zeiss THEO 010 or the Russian 3TK2П theodolites. The Zeiss models have been out of production for more than ten years; the Russian theodolites exhibit various qualities. In the future it will be necessary to introduce new measuring techniques and new instrumentation.

Keywords: magnetic absolute measurement, observatory measurements, field measurements, nonmagnetic theodolites, DI-flux instruments, Overhauser dIdD magnetometer

1. Introduction

DI-flux instruments are basic instruments in geomagnetism. They are used in observatories and in the field to determine declination and inclination angles of the geomagnetic field vector, **F,** in reference to geographic north and to the horizontal plane. In the past other methods existed to determine these values, but because of the very time consuming observation procedure and sometimes low precision, these methods can be regarded as obsolete. Nowadays, the DI-flux is practically the only instrument having worldwide acceptance.

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J.L. Rasson and T. Delipetrov (eds.), Geomagnetics for Aeronautical Safety, 167–175.

This instrument is a steel-free classic theodolite with a single axis fluxgate magnetometer mounted on its telescope. The most commonly used instrument was produced by Carl Zeiss Jena for many years but after the reunification of Germany, the company was closed down, and since that time there is no company producing steel-free theodolites with the same characteristics.

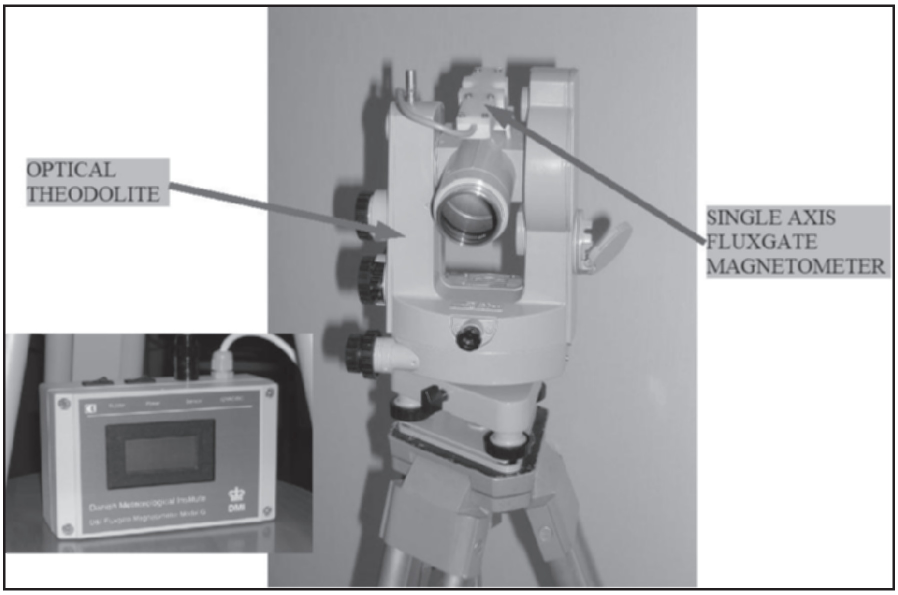

Figure 90. DI-flux magnetometer with theodolite Zeiss THEO 010A and magnetometer DMI model G.

2. Production of DI-flux instruments

The easiest way to build a DI-flux instrument is to take a classic, geodetic theodolite and change all the steel parts to brass or other nonmagnetic materials. This is not a simple task and extreme care must be used. All parts of the disassembled instrument have to be magnetically checked as aluminum or plastic parts can have magnetic impurities or internal magnetic particles. The springs are made from steel and are magnetic.

In some cases, the magnetic parts can be replaced easily by copies made of brass or aluminum. This method however cannot be used in all cases. For instance, the main axis of the instrument is constructed with ball bearings. To reproduce the ball bearings with nonmagnetic materials would require costly technology and since very few instruments are required by users such cost would be prohibitive.

For theodolite conversion, a new plain bearing assembly for the axis was constructed. This part is satisfactory for DI-flux magnetometers since the frequency of use is low compared to geodetic instruments. But they must be manufactured with high precision and a careful selection of parts before assembly.

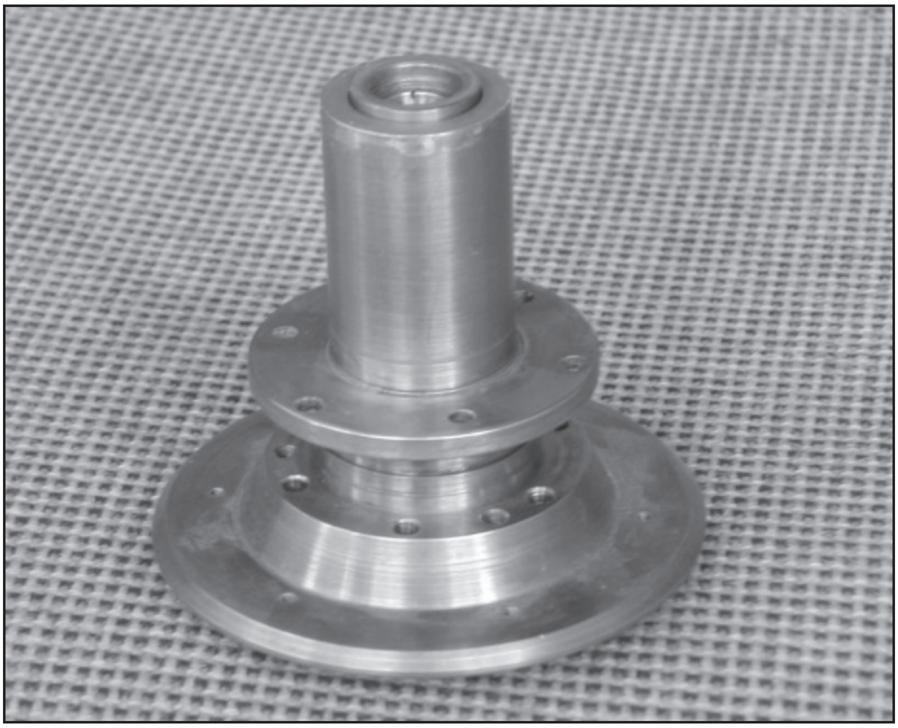

Figure 91. Nonmagnetic vertical axis for a Zeiss THEO 010 theodolite.

The most common instruments used for conversion are the Zeiss THEO 010, 015, and 020 and the Russian YOM 3TK2П. The conversion method for all instruments is nearly the same. There are 40 to 60 parts that must be changed.

There are very few new or second-hand Zeiss instruments on the market and at some time in the future, production of the classic theodolites will end since production costs of graduated glass circles is very high compared to modern angular encoders. Angular encoders also have a convenient direct digital output. Unfortunately, modern instruments are very magnetic and the encoders are encased in magnetic parts.

3. Measurement characteristics

The main technical characteristics of converted theodolites have not changed. The angular resolution for a THEO 010 and a 3TK2П is one arc second (and for THEO 020 it is six seconds). The angular resolution and the resolution of the magnetometer determine the precision of the geomagnetic measurement. Using a G type fluxgate magnetometer from the Danish Meteorological Institute, which has 0.1 nT resolution observers can get a 5 to 9 arc second measurement error for declination and a 2 to 4 arc second error for inclination in observatory conditions. In the field, the measurement errors can be in the range of 15 to 25 arc seconds for declination and 6-12 arc seconds for inclination. These statistical values were recorded during the last repeat station campaign in Hungary. At different latitudes or under different external conditions, the errors could be different.

4. Increasing measurement precision

Measurement error can occur when the geomagnetic field changes during the measurement procedure. This error depends on the amount of field activity and is usually larger at high magnetic latitudes. If the observations are made faster, the errors are smaller.

Another source of error in field measurements is that the time correction made with observatory variation data can be slightly different at the field site even if the distance to the observatory is small.

To eliminate this problem an on-site recording variometer should be used. Recording variometers however can have high thermal sensitivity and outside temperatures can change significantly in field conditions. A solution to this problem is to use a temperature controller, but this requires more power. The best solution would be to design a magnetic recording system with low temperature sensitivity.

The precision of absolute measurements can be increased by performing the observations during a magnetically quiet period of the day. This is possible if we automatize the measurement procedure. To do so an automatic absolute instrument would have to be constructed using either the present manual method or some new method. Jean Rasson and Sebastien Van Loo from the Institute Royal Meteorologique in Belgium are developing an instrument which uses the present manual procedure. A new instrument, based on a modified version of the dIdD instrument using a different measurement method than the classic DI Flux, is presently being developed in Hungary.

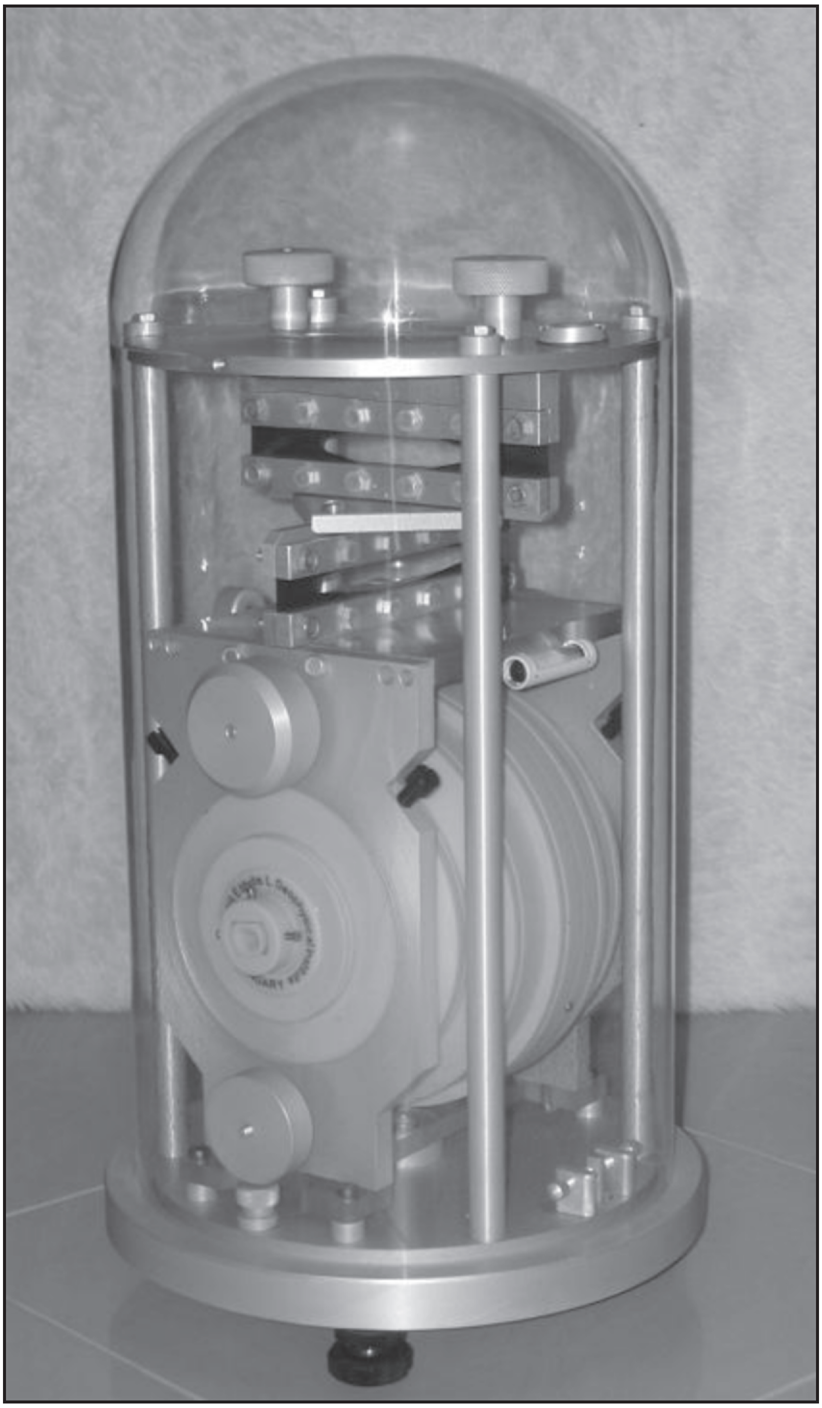

Figure 92. Suspended Overhauser dIdD magnetometer.

5. Basic principle of dIdD measurement

The Hungarian dIdD instrument is based on the Overhauser proton precession magnetometer. It measures the absolute value of the geomagnetic field vector, **F,** together with the declination angle, **D,** and the inclination angle, **I,** with reference to the position of the coil system. The instrument is an absolute instrument in its own coordinate system. If position control is employed for the coils absolute values are obtained for **D** and **I** without additional magnetic measurements.

The basic equations of the dIdD method are:

$$\Delta I = \frac{F_{Ip}^2 - F_{Im}^2}{4 A_D F \cos I}$$

$$A_I = \frac{1}{\sqrt{2}} \sqrt{F_{Ip}^2 + F_{Im}^2 - 2F^2}$$

Where:

ΔI is the difference between measured I and initial I

A_I is the deflection from the I coil

F_{Ip} and F_{Im} are Overhauser magnetometer readings due to opposite deflection currents in the I coil

F is the undeflected Overhauser magnetometer reading

$$\Delta D = \frac{F_{Dp}^2 - F_{Dm}^2}{4 A_D F \cos I}$$

$$A_D = \frac{1}{\sqrt{2}} \sqrt{F_{Dp}^2 + F_{Dm}^2 - 2F^2}$$

Where

ΔD is the difference between measured D and initial D

A_D is the deflection from the D coil

F_{Dp} and F_{Dm} are Overhauser magnetometer readings due to opposite deflection currents in the D coil

F is the undeflected Overhauser magnetometer reading

I is the mean inclination angle

The individual readings are obtained from the Overhauser magnetometer, and the expressions do not contain scale factors or constants which need calibration. The amplitude of the deflection field (if it is within a reasonable range) has no effect on the measurement if it is equal in both directions during one measurement period (e.g. 1-2 seconds).

If the direction of the axis of the coils can be determined with precision, the dIdD is an absolute instrument for determination of the geomagnetic field. The instrument can also work as a recording instrument and can make one complete series of D, I, and F measurements in one second.

A variometer version of the instrument is being tested. To make a complete instrument, devices must be added to measure the direction of one axis in reference to the horizontal line in the vertical plane and the other axis in reference to the geographic north in the horizontal plane. This is possible using angular encoders available today.

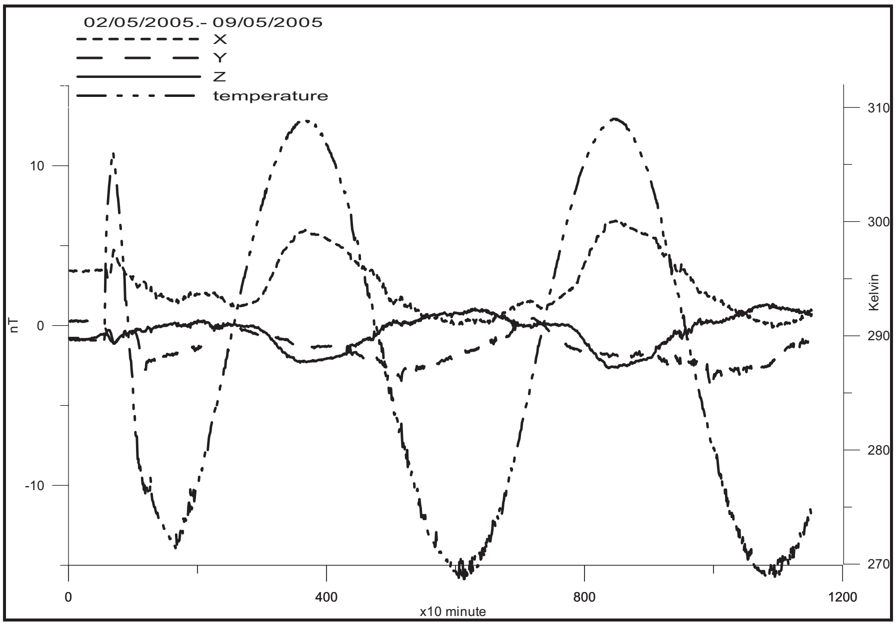

Figure 93. Thermal behavior of the suspended Overhauser dIdD magnetometer.

6. Thermal behavior of Overhauser dIdD instrument

External temperature changes have nearly no effect on the Overhauser magnetometer. The baseline change of a suspended dIdD instrument comes from mechanical instabilities. The amplitude of a dIdD's baseline drift is about one third of the best triaxial fluxgate instruments available today. All sources of thermal instability are not yet determined. A wide range of programmed temperature changes have been applied in the test chamber at the Tihany observatory. So far, some of the sources of thermal instability have been detected. There is hope for further improvements in the near future. The present stability of the dIdD makes the instrument suitable for use in the field. It can be used as a recording instrument to obtain variation data for time correction as well.

7. Conclusions

Only theodolites with graduated glass circles are suitable for conversion to magnetic absolute instruments, but in the near future there will be no more theodolites available for conversion. In addition there is a demand to increase the precision of absolute measurements. To overcome these challenges it may be advisable to change the measurement method used by most observatories and field survey parties.

We believe that the Overhauser dIdD instrument is stable enough to use in observatories and in the field. One possible application for use in the field is as a local reference instrument to reduce errors caused by the difference in the geomagnetic variation between observatories and field stations. By producing a modified version of this instrument, a recording absolute vector magnetometer can be obtained.

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DISCUSSION

Comment (Jean Rasson): Your device, even with encoders to measure the I and D angles, will not be absolute as long as you don't measure the collimation errors (difference between magnetic axis and optical axis).

We can speak about the absolute D, I measurement when you are able to fully orient magnetic vector with respect to geographic north and vertical.

Question (Angelo de Santis): First, I would like to make several comments and then just 1 question.

The comment is that all the geomagnetic community thanks and appreciates the work you and other people, as Valery Korepanov, do as designers of very good magnetometers. Without your work operators and modelers of the geomagnetic field could not make their own work.

The question is related to the errors you mention for your instrument in Observatory or field conditions. Are they associated to a single measurement or to a series of measurements?

Answer (Laszlo Hegymegi): Those are the minimum and maximum of calculated errors for series of measurements taken in the observatory and field stations but experienced with the same instrument. The difference comes from the influence of external effects which changes from place to place and time to time.