OPERATIONAL DETAILS OF GEOMAGNETIC FIELD VARIATION SENSORS WITH SPECIAL REFERENCE TO IZMIRAN MAKE UNITS

R.C. DEKA AND R.M. KULKARNI

Indian Institute of Geomagnetism Colaba, Bombay 400005

ABSTRACT

Various types of magnetometers, both absolute instruments and variometers, are used at geomagnetic observatories in the world. After briefly stating the differences, the district advantages of the quartz sensors are reported here.

INTRODUCTION

Many of the researchers in the field of space physics and those engaged in studies related to solid earth geomagnetism are using Observatory data extensively. As the number of permanent and semi-permanent Observatories are increasing, it is felt that proper documentation of the installation procedures and cautious approaches for accurate recording of the geomagnetic field changes is highly essential both for the scientific personnel working at the Observatory and the user community. An attempt towards this is made in this note.

A brief description of the Observatory role in the measurements is given in the beginning and the specifies of the widely used sensors in the geomagnetic observatory net work maintained by the Indian Institute of Geomagnetism (I.I.G.) in the country are described in detail later.

THE ROLE OF GEOMAGNETIC OBSERVATORY

A Geomagnetic Observatory is mandated with the registrations of the time changes of the geomagnetic field at that place on continuous basis uninterruptedly. For this, it is well known that three components either the Horizontal (H), Vertical (Z) and Declination (D) or the geographical North-South (X), Geographical East-West (Y) and Z will suffice to describe the change in all the parameters of the geomagnetic field. (Chapman and Bartles, 1940). Towards the end of 19th century, continuous monitoring of the geomagnetic field was carried out by the photographic registration, which, conveniently replaced the painstaking eye-reading procedure adopted earlier.

Nearly 90 percent of the existing geomagnetic observatories in the world (about 350 permanent stations) are recording H, Z and D components of the geomagnetic field.

The recording unit along with the sensors, a magnetograph, is the back bone of a Magnetic Observatory. In analogue mode of registration, which is still the practice in many of the developing countries, consists of a photographic recorder, field variation sensors, source lamps and time marking units. A sketch map of the scheme of working is given in Fig.1.

VARIOMETERS

In the year 1845 Charles Brook devised a self-recording magnetometer with a light source, a mirror for amplifying the magnetic movement and a drum wrapped with a photosensitive paper. In India it was introduced at Colaba, Bombay in the year 1871.

A complete set of variometers (H, D, Z) similar to those in use at the Kew Observatory and made by Cambridge Scientific Instruments Company were is use at Alibag (Geographic lat. 18 deg 38 min N and geographic long 72 deg 52 min E) since its inception i.e. from 1904. In August 1927 Watson Variometer system was installed at Alibag. From August 1946, another new set, known as La-cour and from 1977, state of the art, stable Quartz Sensors IZMIRAN (Institute of Terrestrial Magnetism, Ionosphere and Radio wave propagation Academy of Science erstwhile USSR, also known as Bobrov sensors) are in operation.

The main differences between the Izmiran and La-Cour variometers are stated below :

	Type of difference	La-Cour	Izmiran
1.	Suspension of the Sensors in H & D	Long Quartz fibres	Clamped from both ends of Quartz fibre
	Z/	Pivoted on a knife edge	--Do--
2.	Sensitivity control	Through choice of the suspension fibre	Auxiliary external magnets of zero temperature coefficient
3.	Damping	Takes considerable time (3 to 4 min)	Few seconds by provision of a metallic cover on sensing magnet.
4.	Temperature Compensation	Optically carried out. by the help of bimatallic strip	By choice material of sensing magnets with near zero temp. coefficient.
5.	Take over (when the field exceed the range of photopaper width) known as reserve specks	Through making the light path passing throuth multiple prisms positioning	Additional source illuminating lamp.

GENERAL DESCRIPTION OF IZMIRAN SENSING DEVICE

The magnet system and mirrors are housed in a airtight round chamber of 10cm diameter and 4cm thickness. Inside the chamber a quartz rod 7cm long and of 4cm diameter is fixed. The rod is fixed to the lid of the chamber. The sensing magnet which is attached with a mirror of about 4mm length and 2mm width is fixed from a quartz fibre. The quartz fibre, when fixed at two ends of the rod, the sensing magnet with the mirror is being hanged at the center of the rod. The magnet with the mirror is floating on the fibre when balanced by using an auxiliary magnet kept perpendicular with the axis of the sensing magnet at one end of the fibre. The auxiliary magnet is used to cancel the main part of the component of the earth's field at the place where the sensor is required to be installed. Using known amount of current through a helmholtz coil, an environment is created for using auxiliary magnet i.e. the area where the sensor is to be used for making the field intensity measurement. (for eg.at Alibag H field is about 38000nT, Z is 17000nT and D is nearly 0Deg). The auxiliary magnet is fixed permanently at one end of the quartz rod. For different latitudinal stations, the sensors are made exclusively and that is the reason why the same sensors cannot be used away from the latitude for which they are balanced. At the other end of the quartz rod another auxiliary magnet is fixed in parallel with the sensing magnet. It is meant to increase or decrease the sensitivity of the sensors. The sensing magnet is covered by a bracket to avoid any violent oscillations during installation time. From the quartz rod, a mirror of the same dimension as that of sensing magnet mirror is fixed just at the top of the bracket inside the case which is at the left side of sensing mirror. This is a fixed mirror for base line trace over which the variation of the field intensities are monitored.

Once things are taken care of and fixed properly, the lid is fixed round the chamber and made air tight. Just opposite to the sensing mirror, a round lense is fixed of about 2cm diameter. The focal length of this lens is chosen as per the requirement of the distance of the position of the recording unit from the magnetic sensors. The sensors are very handy, easy to carry and have very rare chances for any type of accident or slippage. Nowadays, all the observatories (In India 11 observatories at present are functioning under I.I.G.) are installed with this type of quartz sensors from **IZMIRAN**.

Special type of bulbs, single straight filament having uniform diameter throughout, are used as source lamps. Recording drum, having a circumfrence little more than 50 cms, is used so as to get 2cm/hour record. To get a sharp image of the source lamp filament reflected both from sensing and fixed mirrors, the recorder drum is placed at the focal length of the projection lens. (see sketch in Fig.2) Some times, the focal length of a projection lens has to be changed, depending upon the logistics at the installation site. Inexpensive lenses of reasonable quality are available in the shapes of spectacle glasses. For Izmiran sensor, about 2 cm diameter of lenses are required which can be grinded by any optician. The focal length of the system can be changed by mounting a convex or concave lens in the sensor, as required. Opticians grade lenses according to diopter, defined by

$d = 1/f$ where d = diopter, f = focal length of lens in meters.

If two lenses of diopter d1 and d2 are joined, the diopter of the resulting lens will be

$dx = d1 + d2$ and $fx = 1/dx$

The lenses of interest to a geomagnetician, among the optician's usual stock, are +_0.75, +_ 0.50, + 0.25 diopter. When investigating a batch of lenses, one will find appreciable departures of individual lenses from their nominal values, so that almost any focal length is available in the range of interest.

INSTALLATION DETAILS AND PRECAUTIONS

In this section the IZMIRAN variometer installation procedure is stated briefly.

i. Initially, draw a magnetic meridian line with the help of magnetic compass on the pillar where sensors will be insstalled and then draw perpendicular line to it, which is the E-W line where H variometer sensor will be placed. Keep H variometer sensor facing N-S direction on the mounting pillar depending in which direction the sensing magnet mirror is to be balanced. Preferably, sensor should always be in the north of the recording unit.

ii. On the opposite side of H sensor, north or south pillar about 1m apart (assuming 1m is the focal length of sensor lens) keep a single filament source lamp (lamp-1) exactly in the same line of H. Just behind the source lamp, keep recorder with cylindrical lens in front. Height of the source lamps may be so adjusted that it is just below the cylindrical lens of the recording drum. (See sketch in Fig.1). Focal length of the cylindrical lens may be checked and its point image may be made to fall exactly on the photo-graphic paper which is wrapped on the recorder drum.

iii. See the H base speck (reflection from the mirror attached to the bracket) properly focused and falls exactly at the center of the cylindrical lens. This speck can be adusted by varying the H variometer height/recorder height. Full filament of source lamp-1 may be made to fall on the recorder lens.

iv. Make H variometer base plates firm. (firm contact with the pillar) Since the sense of the diurnal variation at almost all the Indian stations are in the same direction, it can be checked for all the sensors b-y bringing a north pole of some small external magnet near to the sensors individually. For Z, when a north pole of an external magnet is moved is moved down towards the Z sensor, the Z trace should go away from the Z base (from the fixed mirror reflection). For H - the same point when bringing from south to north H trace should move away from the H base and for D, D trace has to come nearer to D base.

v. Remove the H variometer and draw magnetic meridian line to the East of variometer if H variometer was on north pillar or to the West of variometer if H variometer was on south pillar. Bring D variometer without shaft and auxiliary magnets near H variometer base plates.

vi. Make sure or check up that the D sensor and the prism are parallel. This can be made by adjusting the screws.

vii. Keeping north leg of D variometer sensor on the magnetic meridian line fixed, go on turning the sensor till the sensor mirror and the fixed mirror are in one plane. Fix all three legs firmly.

viii. Adjust D sensor prism screws in such a way that that base line speck (reflection from fixed mirror) and variation speck falls on the cylindrical lens.

ix. Having satisfied that both the D specks on the recorder drum are in proper position, bring the H variometer on to its original base plates.

x. Fix the shaft on H variometer and put two auxiliary magnet-holder.

xi. On the H shaft, an auxiliary magnet in the direction of N-S is now put for trace movement (position changing of recording).

xii. Adjust N-S magnet to bring H variation speck to desired level of recording.

xiii. Having brought H variometer near D variometer , D variometer speck gets disturbed, which can be brought back to its original position using an auxiliary magnet in the E-W direction on the shaft of D. If it is required to move both the specks of D (or Z) simultaneously, it can be made by adjusting prism screws (up and down screws for up and down movement of the specks and center screw for lateral movement of specks).

xiv. Bring the Z Variometer having shaft with i) vertical magnet for trace control ii) E-W for sensitivity control. Check Z variation magnet mirror balanced properly otherwise balance it by using vertical magnet on the shaft. Fix Z base speck (reflection from fixed mirror) below H base speck. Usually the order will be Z base (ZB), Z trace (ZT), HB, HT, DB and DT. Like D sensor, prism should be in parallel position to Z sensor by tightening all three screws.

xv. It is important to know properly the Z trace showing the expected sense of diurnal variation-bring a north pole of an external magnet, as stated earlier, straight down towards the Z sensor, the Z trace should move away from its base speck. Otherwise, turn the sensor 180 degree, then adjust the prism accordingly.

xvi. Preference should be made to face the prism of D towards H sensor. Having brought Z variometer near the D & H sensors their traces will get disturbed. Adjust D,H and Z traces suitably by auxiliary magnet which are fixed perpendicular to each sensor's sensing magnet.

xvii. The height of the Source lamp should be adjusted such that it is just below the cylindrical lens of the recorder drum to give minimum angle of reflection (Refer sketch in Fig.1). Care should be taken that the stand of the source lamp should not obstruct the reflected light.

xviii. The filament of the source lamp should be exactly vertical. The cylindrical lens of the drum should be exactly parallel with drum. Intensity of the source should always be constant.

xix. All the sensors are wounded by a calib-ration coil (Helmholtz coil) which has only one turn. The well known formula for field generation at the center of the coil is

$B = (\mu_0 I / 2a)$ T where $\mu_0 = 4\pi 10^{-7}$ H/M in S.I.Unit

T = tesla

I = current in amperes

a = radius in meter

xx. Calibration of sensors may be carried out by passing known amount of current in the sensor coil. Adjust their sensitivities using all parallel magnets on the shaft as per requirement. For low and mid latitudes, keep sensitivity 15-20 nT per cm for D and about 20-25 nT per cm for H & Z.

xxi. Source lamp-1 (in front of H) - gives main speck of H and reserve for D & Z. Source Lamp-2 (in front of Z) - gives main speck of Z & D and reserve for H element. Lamp-1 and Lamp-2 are so separated that they should not exceed the width of the photo-paper i.e. 20 cm. Arrangement may be made to have a time marking lamp. This lamp will glow exactly at every hour to record the time mark on the photo-paper for 1 or 2 seconds. Hourly time marks are very important to know the particular phenomena on the magnetogram with respect to that time. During great or rapid magnetic disturbance, loss of photographic trace may occur for two reasons. The spot of light may move so fast that no trace, or only a confused fragmentary trace, is left; or the spot may go beyond the limits of the photographic paper. To provide against the later additional light-spots will appear on the photographic paper from the lamp-2. This lamp-2, however, does not obliate the loss of trace caused by rapid motion of the light-spots. This additional light-spots recorded on the magnetogram is known as reserve speck. (See Fig.3)

xxii. Keep time marking lamp behind the sensors suitably and its full horizontal filament light should fall on the cylindrical lens of the recorder.

xxiii. A bit of record may be obtained on photo-paper for checking the ghost on traces, their sensitivity, time marking line, thickness of traces, senses of diurnal variation etc.

xxiv. Some times recorded traces becomes thick due to bad quality of mirrors. In such cases sensors may be covered by a suitabe small piece of paper for reducing the amount of light falling on mirrors.

xxv. For desired sensitivity, some times high value auxiliary magnets may be required. To achieve this, a magnet may be fixed with clay on the sensor body parallel to the particular sensing magnet.

xxvi. Make doubly sure that the room is free from any external magnetic elements and also free from electro-magnetic noise (man made or otherwise).

In the above note, the details on the variograph (field variation recordings) only are stated. To give a meaning for the fixed mirror trace called " BASE LINE ", it is necessary to calibrate with another set of absolute measurements. These aspects are not dealt in here and the details will be published elsewhere subsequently.

ACKNOWLEDGEMENT

The authors are indebted to Dr. D R K Rao for his valuable suggestions and encouragements and also wish to thank all the staff members of Magnetic Observatory, Alibag, for their kind help.

REFERENCES

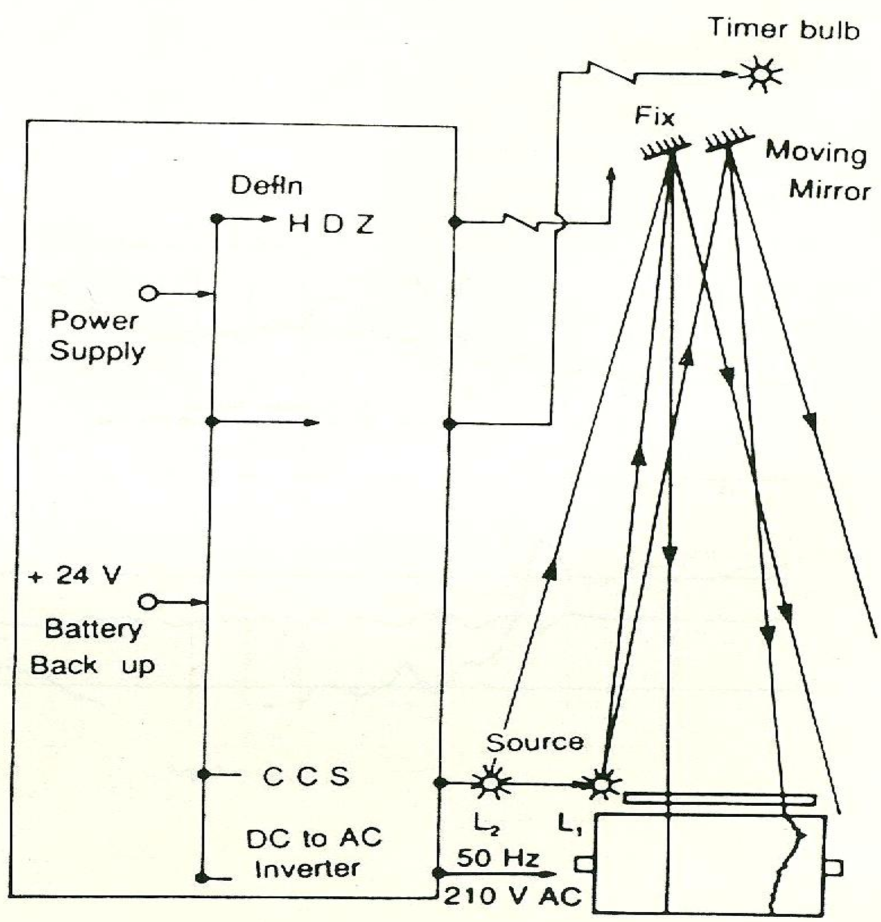
Bobrov, V.N. (1965 a) Three component magnetic variation instrument IZMIRAN 2 Geomagn. Aeron v.5, pp 153-156.

Chapman S. and Julius Bartels, continuous magnetic registration Geomagnetism Vol. I, pp. 48-56. Year 1940.

Rangarajan G.K. Magnetometry for Geomagnetic Observations, Geomagnetic studies at low latitudes 1992. pp 175-193.

Wienert K.A., Recording of time variations, Notes on Geomagnetic Observatory and Survey Practice, pp 149-169 Year 1970.

Fig 1



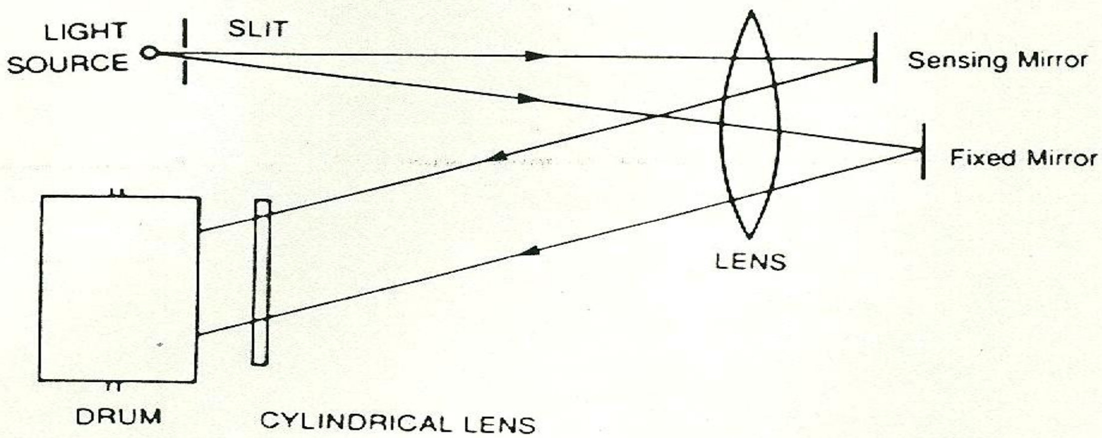


fig. 2 Schematic plan of a photographic recorder

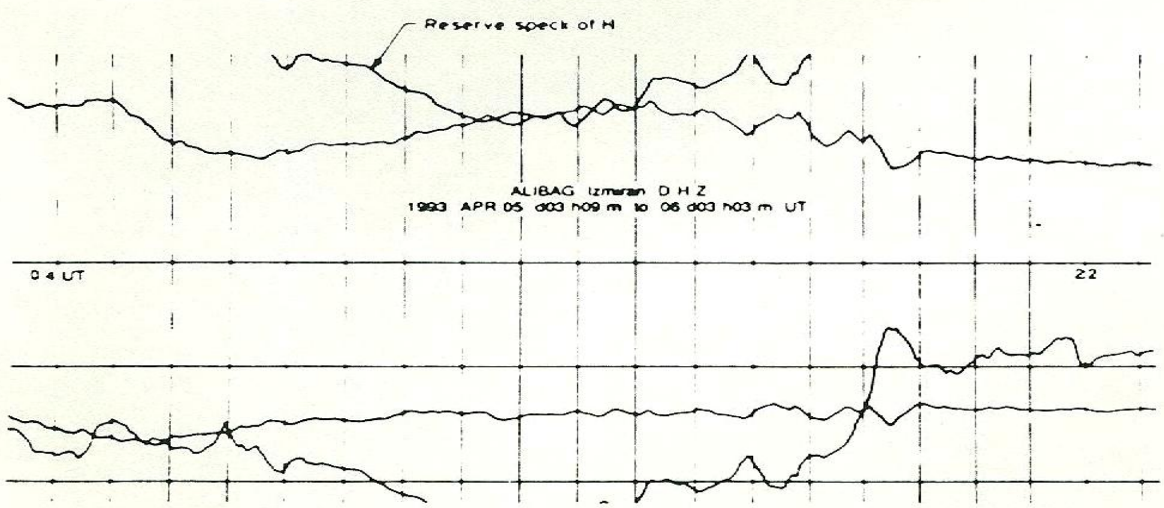


fig. 3