CARLSBERG AUTOMATIC TRANSIT CIRCLE: FIRST TWO TEST CATALOGUES AND THE PROGRAMME FOR LA PALMA.

L V Morrison and P Gibbs
Royal Greenwich Observatory
UK

ABSTRACT

The first two catalogues produced from test observations made with the Carlsberg Automatic Transit Circle (CATC) at the Copenhagen University Observatory in the period 1981/83 have internal mean errors of 0".21 in right ascension and 0".22 in declination. In 1983 the CATC was moved to the international Observatorio del Roque de los Muchachos where it will begin a programme of differential and fundamental astrometry in 1984.

1. INTRODUCTION

Over the past few years the transit circle of the Copenhagen University Observatory has been fully automated. This instrument has been named the Carlsberg Automatic Transit Circle (CATC) and is operated jointly by Copenhagen University Observatory, Royal Greenwich Observatory and Instituto y Observatorio de Marina, San Fernando. In order to test the performance of the new instrumentation, two short test programmes of observation were carried out at Copenhagen University Observatory in the period 1981/83. The results of these programmes were published in two catalogues by Helmer et al. (1983, 1984). Following the completion of these test programmes, the telescope and control computers were moved in 1983 to the new international Observatorio del Roque de los Muchachos, La Palma, Las Islas Canarias. This paper gives a description of the test programmes and an outline of the first programme to be carried out at the new site on La Palma.

2. GENERAL DESCRIPTION OF THE CATC

The automatic control system of the telescope is described by Fogh Olsen and Helmer (1978) and also by Helmer et al. (1983). The transit circle is of traditional design and was built by Grubb Parsons in 1952. It has a clear aperture of 18 cm.

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The main parts of the automatic system are the V-slit photoelectric scanning micrometer mounted in the focal plane of the telescope, the six photoelectric scanning micrometers for reading the graduations of the glass circle, and the setting of the telescope using a combination of coarse and fine motion drives on a large gear wheel fitted to the casing of the spare declination circle. The control computer transmits the results of the circle reading and the photon counts from the photoelectric scanning micrometer to the second computer which then calculates the observed position of the star in the coordinate frame of the instrument.

3. METHOD OF OBSERVATION

The telescope is automatically set to the required declination (δ) with an accuracy of ±2". The plate containing the V-slits is driven at a constant speed of 38".75 per second forward and backward across the steadily moving image of the star. The V-slits are 4" wide and 32" long, and are inclined to the horizontal direction by 45^o. The separation between the middle of the slits is 39".

The velocity of the slits relative to the star is

$$\nu = 38.75 \pm 15 \cos\delta \ \text{"/s},$$

The plate is driven in the same direction as the star in the first scan. The scan distance (d) of the slit plate relative to the star is usually 71", but this can be increased to 142" or 213" if required. The output from the photomultiplier is passed into a binary counter which is read by the control computer every T seconds, where T is normally 32 ms. This produces a series of counts for N integration steps, where

$$N = nd/\nu T.$$

The number of scans is denoted by n. For eight scans the time taken is between 14.6 and 17.2 s, giving a range of 450 to 540 integration steps.

Fig. 1 shows the counts obtained for a 6.5 magnitude star at a zenith distance of 18^o. There are 16 peaks resulting from 8 scans with the V-slits. The mean position between each pair of peaks (calculated on-line by the second computer) gives the x-coordinates in the micrometer at which the star crossed the bisector of the V-slit. The right ascension is formed by combining the mean x-coordinate with the position and time at which the micrometer was started. Half of the difference between each pair of x-coordinates gives the vertical y-coordinate from the projected intersection of the slits. The mean y-coordinate combined with the circle reading gives the zenith distance, and hence the declination.

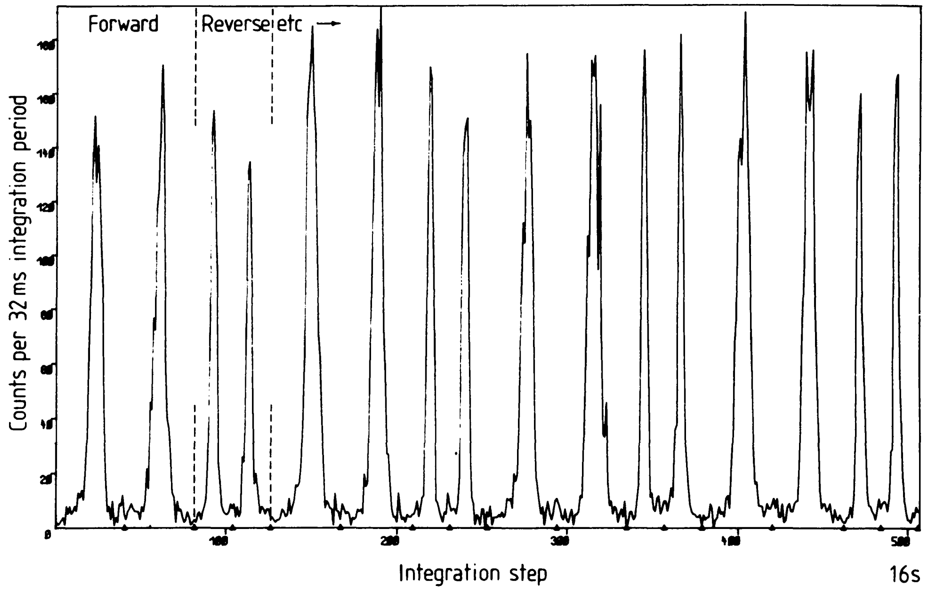

Fig. 1. Counts obtained from 8 scans with V-slit micrometer of a 6.5 magnitude star at a zenith distance of 18°.

4. TWO TEST CATALOGUES

The two test periods of observation were July 1981 to May 1982 and May 1982 to March 1983. The stars were mainly selected from the following sources: FK4, AGK3 zones 88° and 89°, northern PZT catalogues, and the GC zone around the North Galactic Pole. In the second catalogue, reference stars with $m_V \sim 12$ within 1° of benchmark radio sources were included to test the magnitude limit of the CATC.

The scatter of the x,y values in the micrometer obtained from individual scans was found to have an average standard deviation of 0".26. The mean from 8 scans (the usual number) has a standard error of 0".10. During part of the second test period the number of scans was increased to 32, giving a standard error of 0".05 for the mean. The standard deviation in declination due to the error in measuring the zenith angle on the graduated circle is 0".04 (see Fabricius et al., 1980).

The observations were fitted nightly to the FK4 system using all observed FK4 stars by performing a least-squares solution to determine the collimation correction, the Besselian constants m and n and their linear rates of change, the zenith point correction and its quadratic change with time, and the horizontal flexure and its linear change with

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time. Increasingly in the second test period, the variations with time of collimation, level and zenith point corrections were adopted from the instrumental determinations using collimators and a nadir mercury pool. Investigations showed these to be very reliable. Figures 2 (a), (b) show comparisons of the hourly instrumental determinations (made automatically) of level and zenith point with values calculated from the raw residuals of individual FK4 stars observed during a typical night. These figures show large changes at the start of observing which are associated with the rapid change in temperature inside the dome when it is first opened at night. From the behaviour of the data plotted in these figures, it appears that an interval of about 1 hour is adequate for the measurement of level etc. It also seems desirable to control the air temperature inside the building.

The internal mean errors for the two test catalogues are summarised in Table 1.

Table 1 Internal mean errors for test catalogues

Catalogue	No. of observations		8 scans (16 seconds)	8 scans* (16 seconds)	32 scans* (64 seconds)
1	9594	α	0".21	0".19	–
		δ	0.22	0.20	–
2	8283	α	0.21	0.19	0".17
		δ	0.22	0.20	0.17

*Restricted to stars brighter than m_V = 9.5 and within 30^o of the zenith

There is a dependence of the size of the errors on stellar magnitude. At m_V = 10, the mean error for 8 scans reaches 0".25 in right ascension and declination.

The faintest magnitude reached in the second test catalogue was m_V = 12.0. It should be possible to reach about one magnitude fainter than this on La Palma.

5. FUNDAMENTAL WORK

Besides instrumental calibration using collimators and a nadir mercury pool, observations of the Sun and planets, and daytime observations of stars are required for fundamental work. Test observations of the outer planets have been made successfully and reduced using the methods given by Lindegren (1977). Test observations have also been made of the Sun using an aluminised mylar screen in front of the objective to reduce the heat and light from the Sun. Four slits 4" wide and 55" long at the ends of two diagonals of the solar disc in

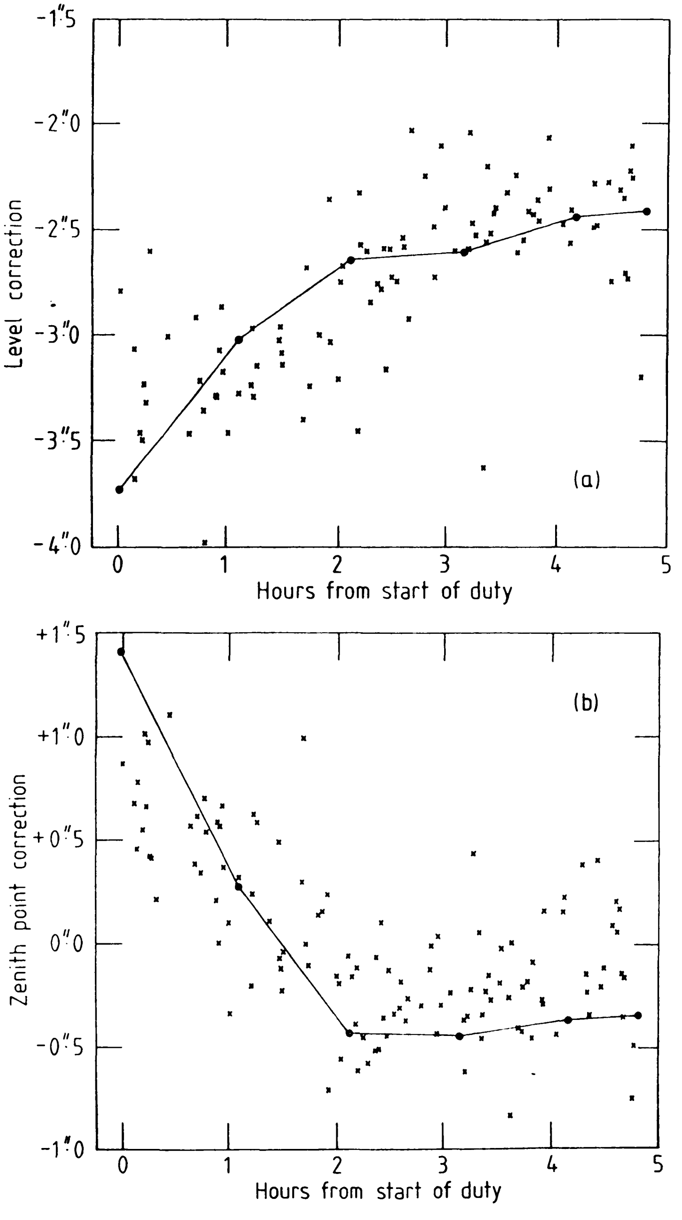

Fig. 2. Comparison of (a) level correction and (b) zenith point correction measured from the nadir mercury pool (lines joining hourly values) with estimates of these corrections derived from the residuals of individual FK4 stars. The vertical adjustment is arbitrary; however the agreement is not entirely satisfactory because of remaining quadratic changes in azimuth and flexure which affect the level and zenith point, respectively, derived from the FK4 stars.

the focal plane are used to scan the limbs. The output from four silicon diodes behind the slits are read every 20 ms. The response of the diodes combined with the two transmission filters produces a peak at 5400Å.

Daytime observations of stars were obtained by masking the lower half of the V-slits with the diaphragm in order to reduce the signal from the sky background. The daylight is further reduced by neutral density filters and a polaroid which give a peak transmission near 6000Å. The number of scans is increased to 32 and the 16 scans in the forward direction are folded, and the 16 scans in the reverse direction are folded. Fig. 3(a) shows the raw counts from 32 scans of a 3.9 magnitude star in the zenith about 1 hour before sunset. Fig. 3(b) shows the accumulated counts which results from folding the forward and reverse scans. The star signal can be clearly seen above the daylight signal. The faintest star observed during the day at Copenhagen University Observatory, which produced acceptably small residuals, was 4.2 magnitude, about 13^{o} from the zenith.

6. OBSERVING ON LA PALMA

The CATC was moved to the Observatorio del Roque de los Muchachos, La Palma, in 1983. The provisional geodetic coordinates of the CATC are:

28^{o} 45′ 31″ N
17^{o} 52′ 50″ W
2327m.

The new, compact building to house the telescope and control computers is designed to minimise thermal gradients in and around the telescope. The height at the apex of the roof is 4 m. The building comprises three areas: the telescope enclosure (10.5 x 6.4 m), the control room (6.7 x 4.5 m) and plant room (3.5 x 4.5 m). The walls and roof are made of lightweight plywood panels with a load-bearing sandwich filling of highly insulating glasswool, 295 mm thick. The floor around the telescope piers and the collimator supports is also made of this insulating material. With this high level of insulation, the daytime temperature of the telescope enclosure can be kept close to the prevailing night temperature, and there will be negligible amounts of residual heat radiated from the building at night. The control room is air-conditioned. Besides the two minicomputers it contains a 120 Mbyte disc, 2 magnetic tape decks, 2 graphics VDUs, 1 terminal printer, 1 printer.

The opening shutter comprises the western half of the roof and the south and north walls, which are mounted on rails and driven off to the west by hydraulic rams under computer control. The widest opening is 2 m. The shutter is framed with a steel channel which gives rigidity to the structure.

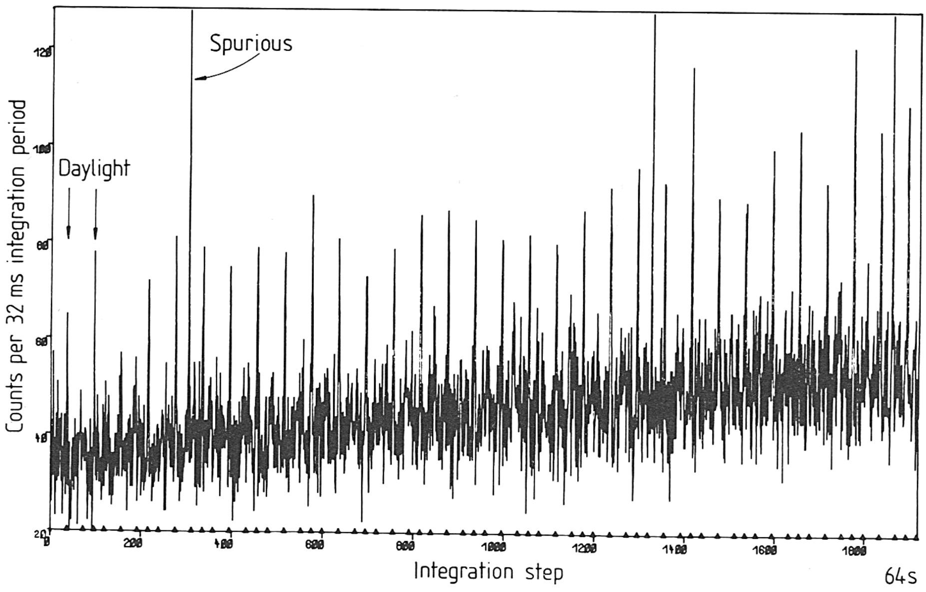

Fig. 3(a)Counts obtained from 32 scans with V-slit micrometer of a 3.9 magnitude star observed in the zenith 1 hour before sunset. The equidistant, pronounced peaks are caused by the daylight simultaneously entering both slits which are uncovered for a short while in the middle of each scan. The three counts of 128 were produced by noise in the binary counter system which has since been rectified.

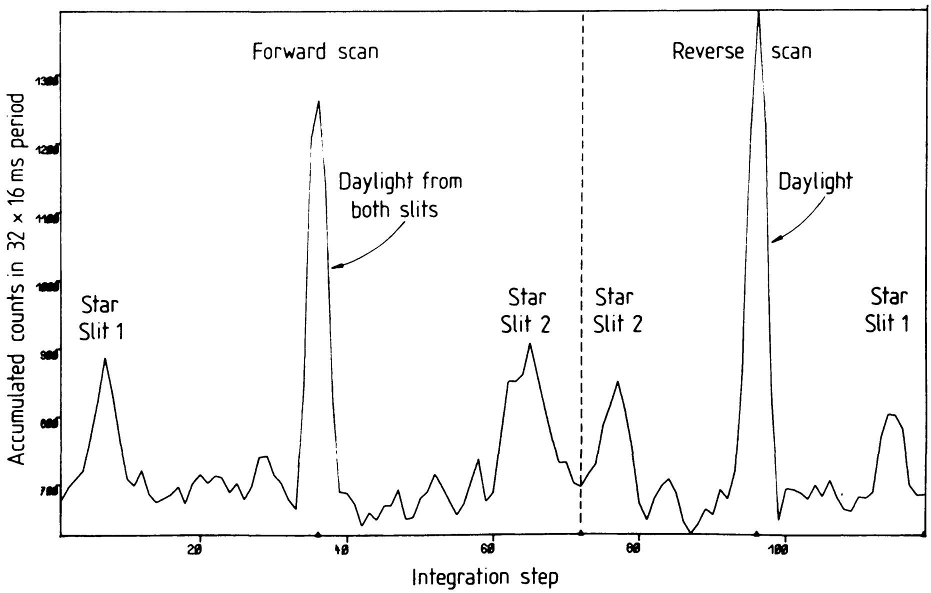

Fig. 3(b)As in (a), but with the forward and reverse scans folded on top of the first two scans.

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Regular observing is expected to begin in the summer of 1984. Stars will be selected by computer from a basic working catalogue of 350,000 stars which has been compiled from the AGK, SAO south to -60^o, PZT stars and ~10,000 stars with m_v ~12 in the fields of 340 benchmark radio sources. The first programme will comprise the following observations:

Differential; AGK3R, SRS (to -50^o), PZT, benchmark radio fields and selected Hipparcos stars.

Fundamental; FK5, Sun, planets, minor planets, daytime stars, hourly measurement of collimation, horizontal flexure, level and zenith point.

7. CONCLUSION

The successful testing of the CATC during 1981/83 at the Copenhagen University Observatory demonstrates that the instrument is capable of making about 100,000 observations per year under good conditions. Programmes of fundamental and differential observations will be started in 1984 at the new site in the Observatorio del Roque de los Muchachos, La Palma. Given the efficiency of the instrument and its capability of reaching m_v ~12, the CATC will make important contributions to extending the fundamental system to fainter magnitudes and to linking the fundamental reference frame to the extragalactic reference frame.

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Discussion:

CURRIE: Do you intend to measure the local variation of the temperature as the wind interacts with the ridge behind the observatory?

MORRISON: During site-testing, measurements of air flow across the site were made which showed that while there is turbulence at the edge of the caldera, the air flow is laminar by the time it reaches the telescope sites.

CORBIN: Will you observe all of the FK5 list in your fundamental program or just the current FK4 stars?
MORRISON: All of the FK5 stars.
REQUIEME: Your micrometer has a right ascension carriage. What about variation of the scale factor with temperature and about the backlash in ?
MORRISON: I'll let Dr.Helmer answer this.
HELMER: Backlash can be determined by observing an artificial star in the micrometer, but it cancels out in the mean of two scanning directions. The screw errors have been investigated by E. Høg and are small. They will be redetermined and eventually applied.
MORRISON: The variation of scale factor with temperature has not yet been investigated. With regard to possible slipping of the plate in the y-direction at different pointing angles, this would produce errors in declination as a function of declination. Judging by the test catalogues, the slipping must be small.
SMITH: At El Leoncity in 1968 we had no meridian marks, but we wished we had when we reduced the observations. I cannot over-emphasize the importance of meridian marks for fundamental work.
MORRISION: We intend to install azimuth marks soon.

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