determine "g" (see for example references and details in (10)).

The accuracy achieved by a proper instrument is phenomenal. Changes of 20 millisecs of arc are normal for tidal effects and are relatively easily measured. A disturbance of 1-2 millisecs of arc would be noticeable. Our observation of 5 secs. of arc would represent so large a disturbance as to be quite impossible to overlook. Moreover apart from its direction the value of "g" is almost certainly unaffected by lunar obstruction. Again changes of "g" were looked for in the records of the observatories at Bidston (England) and Mundaring (Western Australia) at the times when our Talyvel showed its effect and no such changes were found.

At the time the measurements were made, and for a long time subsequently, the details of the Talyvel effect were a complete puzzle. It would have to be a most unlikely coincidence if perhaps the building housing the experiment or the gyroscope mount just tipped in a manner to simulate the effects observed by Saxl & Allen & Allais. Indeed a tip in the E/W direction corresponds to a rotation about the N/S direction to which the gyroscope is sensitive. The gyroscope therefore ought to show the angular change easily in its output reading and no such effect is present.

However, with the tentative explanation put forward in the next section it will be seen that the Talyvel effect and the lack of a gyroscope effect would both be expected.

3. A PROPOSED MODEL

The experiments listed in Section 2 give various pointers as to what must be looked for in a possible explanation.

Firstly the sun plays a central rôle as shown by the eclipse effects. Something must be in motion more or less radially and at speeds of $\sim$ 500 kms/sec or the rough eclipse time coincidence could not be maintained. Gradients of velocity seem to be important and appear to be altered behind an obstruction such as the moon.

Secondly considering the kind of basis put forward for Mach's principle one might be tempted to postulate something similar to a fluid aether in radial motion from the sun, the radial motion being caused by the solar rotation. However, it is difficult on this basis to see why the effects are so small. An aether flow of 500kms/sec would be expected to cause enormous mechanical changes. A fluid model based on liquid helium below the λ point and near to absolute zero might be more sensible. The ground state fluid may, as in the He case, be a superfluid without viscosity and largely non interactive with matter.

The small fraction of excited state or "normal" fluid may be similar to a normal gas with appreciable interaction with matter. If the fraction of the excited state is small enough - say 1 pt in 10^5 or 10^6 - the effects may be of this magnitude and high velocities may be not unreasonable when applicable to only such a small part of the medium.

Interaction with the dense hot matter in the solar core may create the excited state phonons and the solar rotation may be responsible for their radial motion.

Let us then adopt this latter idea and see how it may be applied in detail to the experimental material. We begin by attempting to be more specific about the interaction of the excited state phonons with matter. The term phonon is used for lack of a better, but it should be noted that the similarity with a solid state phonon may not be too close.

The Allais experiment of Section 2.1 is important here. The motion of the support caused by anisotropy is in phase with the pendulum swing. This causes a phase difference of $\pi/2$ between the main amplitude and the transverse amplitude and leads to elliptical motion of the bob.

The gradient of phonon velocity must interact with the mass of the bob to give an effect of similar phase. This means that the transverse force on the pendulum bob must be in phase with the amplitude of the main swing.

(To see this more clearly note that the longitudinal driving force is out of phase with the longitudinal displacement for a resonant system. Thus if the transverse and longitudinal displacements are to be out of phase so must be the driving forces. Thus the transverse force must be in phase with the longitudinal displacement.)

We must now make a choice as to what form the interaction takes between phonon velocity (or momentum) and matter in the form of the bob. With the phase restriction above only two possibilities are open and one is much more likely than the other, though much less easy to visualize. Consider for simplicity the effect at midday when the phonon motion has a N/S component. The first choice is to have the force parallel to the phonon momentum and caused by the absorption of the phonon. The pendulum would be swinging E/W for largest effect and the gradient of phonon momentum be in the E/W direction. Thus the force is proportional to the E/W displacement as required.

The second is to have the force perpendicular to the phonon momentum and therefore the pendulum motion would be along the N/S direction for maximum effect. Since now there will be no effect of translation or displacement along the phonon direction we must assume the force is proportional to the acceleration of the bob, this being in phase with the displacement. It will be possible eventually to differentiate between these alternatives using their different dependence on azimuth. However the experiments of Allais do not give a clear lead and one must make a choice more or less by intuition.

At the moment the second choice is the one adopted. The first, effectively depends on the direction of "g" and would lead to rather severe changes in the direction of "g" over distances of tens or hundreds of kilometres. The inclination of the pendulum or direction of "g" changes by about 1 micron/metre of pendulum length i.e. 1 part in 10^6 of angle for an E/W amplitude of ∿ 10cms to give the right value for the minor axis. This would give enormous changes in the direction of 'g' over an E/W translation of many kms and these could not fail to have been noticed.

The second choice has no obvious objections in principle or in magnitude though as mentioned above it is difficult to see why acceleration should be the relevant parameter. It would be much easier to suggest a mechanism for the velocity but this would give the wrong phase and lead to anomalous precession rather than elliptic motion of the bob.

The suggested hypothesis then is as follows:

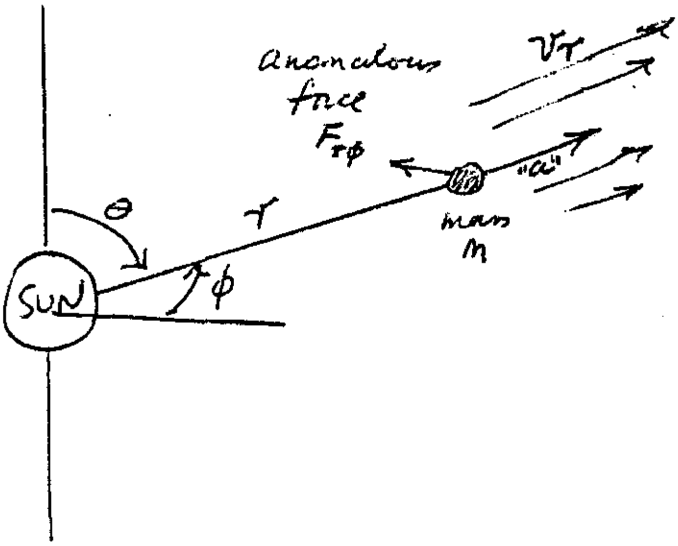


Fig.8

With $r\theta\phi$ coordinates centred on the sun and with the θ axis along its axis of rotation the velocity v_r will be a function of both $(r\theta)$ and $(r\phi)$.

Considering the gradient of velocity $\frac{\partial v_r}{\partial(r\phi)}$ in the plane of the solar equator (Fig.8) if a pendulum bob or other massive object of mass m is also moving in the r direction with acceleration "a" there is a force $F_{r\phi}$ in the $r\phi$ direction of amount proportional to:

$$\rho\ a\ m\ \frac{\partial v_r}{\partial(r\phi)}$$

Similarly considering the gradient $\frac{\partial v_r}{\partial(r\theta)}$ along the meridian there is a force in the $r\theta$ direction of amount proportional to:

$$\rho\ a\ m\ \frac{\partial v_r}{\partial(r\theta)}$$

In each case ρ is the density of the excited state.

The accelerations normally present at a point on the surface of the earth due to its orbital motion round the sun, the lunar rotation and the angular velocity about the earth's axis are quite small compared to the pendulum bob acceleration.

Pendulum bob (amp 10cms, period 1.6 secs)"a"= 1.54 metres /s/s at the ends of each swing

Earths orbit - acceleration "a" = 5.93 mms/s/s

Lunar effect - acceleration "a" = .031 mms/s/s

Earth's rotation - acceleration "a" = .034 mms/s/s

The earth's orbital rotation has the largest acceleration but this is roughly two orders of magnitude down on the pendulum acceleration, and can be neglected.

4. HOW DOES THIS MODEL EXPLAIN THE EXPERIMENTS?

At the moment we are mainly restricted to a qualitative account, but on this level it will be seen that all the observed effects would be expected. Let us discuss the experiments in the order previously given.

4.1 The Allais Pendulum Experiment

Since the model has largely been suggested by this experiment it is not surprising, that there is reasonable qualitative agreement.

The direction of the mean azimuth is 150-170 grades measured clockwise from above with respect to the south direction so that the 24 hr curves should cross zero somewhat in advance of 6 hrs and 18 hrs, for which there is some evidence.

The 24 hr group of amplitudes in the periodogram of Fig.1 is just what would be expected if a daily effect due to the earth's rotation modifying the acceleration "a" along v_r is modulated by a monthly effect on $\frac{\partial v_r}{\partial (r\phi)}$ due to the solar rotation. One would also expect a smaller 12 hr group.

It is not at all obvious what causes the 140 hr and 10 hr.

40 min. peaks. Perhaps the longer one might be just a statistical fluctuation but the 10 hr.40 min.peak seems very large to be a statistical fluctuation. There are no known solar, earthly, or lunar oscillatory modes with anything like as long a period as this. Even the 2 hr.40 min. period found in some solar measurements is extremely difficult to reconcile with any expected solar periodicity (14)(15). We do however have a low density excited state fluid which is now proposed and which may have resonant frequencies of its own.

4.2 The Allais Eclipse Experiment

Again this requires no comment. We are presuming enough interaction with the mass of the moon to vary either the density or velocity and therefore cause the gradients which give the eclipse effect. The equilibrium azimuth of 175 grades has a N/S component which can interact appropriately with v_r for an eclipse time round mid-day. The centre time of the pendulum anomaly is roughly 30 mins. early on the visual eclipse centre. This, if one assumes a velocity of the excited state of roughly 500 kms/sec., requires the direction of flow to be a fraction of a degree in advance of radial. The angle of flow will be discussed in more detail in Section 4.7.

4.3 Variations in the Gyroscope Couple

The choice of acceleration as the relevant parameter to explain the Allais experiments has an interesting consequence for the gyroscope. The mass of the rotor has a rather high radial acceleration and therefore anomalous forces will be produced in an analogous way to those of the

Foucault pendulum. The direction of these will introduce a couple as can be seen from Figs. 9 and 10. Suppose the spin axis is vertical and we consider for example the situation about mid-day with a vertical velocity gradient $\frac{\partial v_r}{\partial(r_\theta)}$ (Fig.9). The accelerations will be in different directions at opposite ends of the rotor diameter (Fig.10) and the forces F will be as shown. A couple will be produced about the E/W axis which will show if the output axis is E/W.

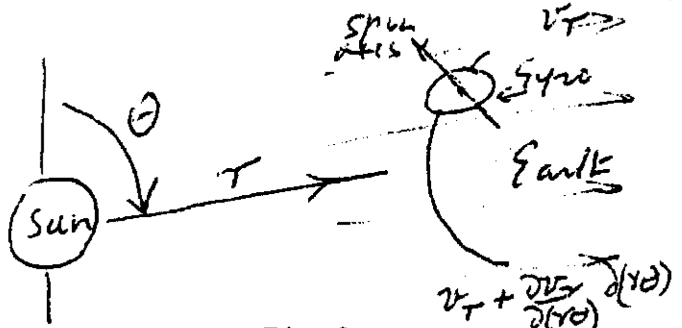


Fig.9

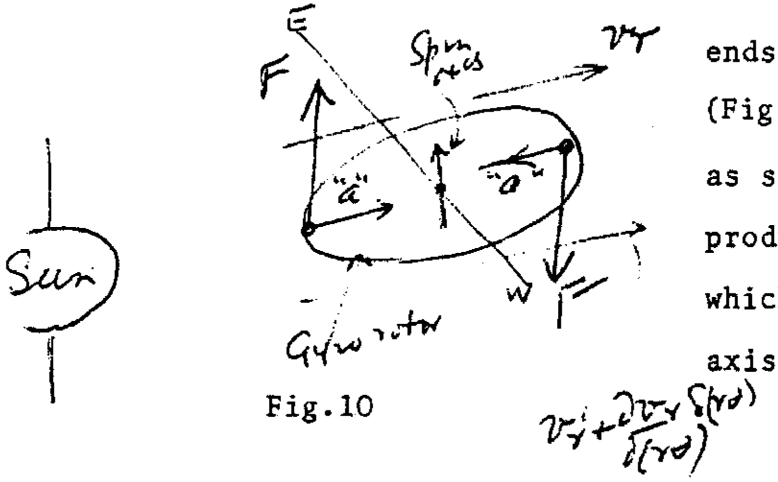


Fig.10

The couple - if it exists - will add to or subtract from the gyroscope couple. Since it is an external couple acting on the wheel it will not be cancelled out on changing the output axis by 180° from E/W to W/E. It will be a maximum or a minimum at mid-day (and midnight also if the attenuation of the phonon motion by the earth is small) and will be zero at ∿ 6 am and 6 pm. the quadrature positions, modified to some extent at different times of year by the inclination of the earth's axis. The gyroscope couple measurements were mainly done in a sequence from early to mid afternoon so the anomalous effect will be either rising or falling during the run dependent on the sign of $\frac{\partial v_r}{\partial(r\theta)}$. Evidence of this was obtained, as the output axis was changed from E/W to W/E and then to E/W again. The average of the two E/W readings was then compared to the W/E. Thus we had two E/W readings one at very roughly 2pm and the next at roughly 4pm. The difference Δ between these varied from zero up to $\sim$ 50 to 60 parts in 10^5 either up or down.

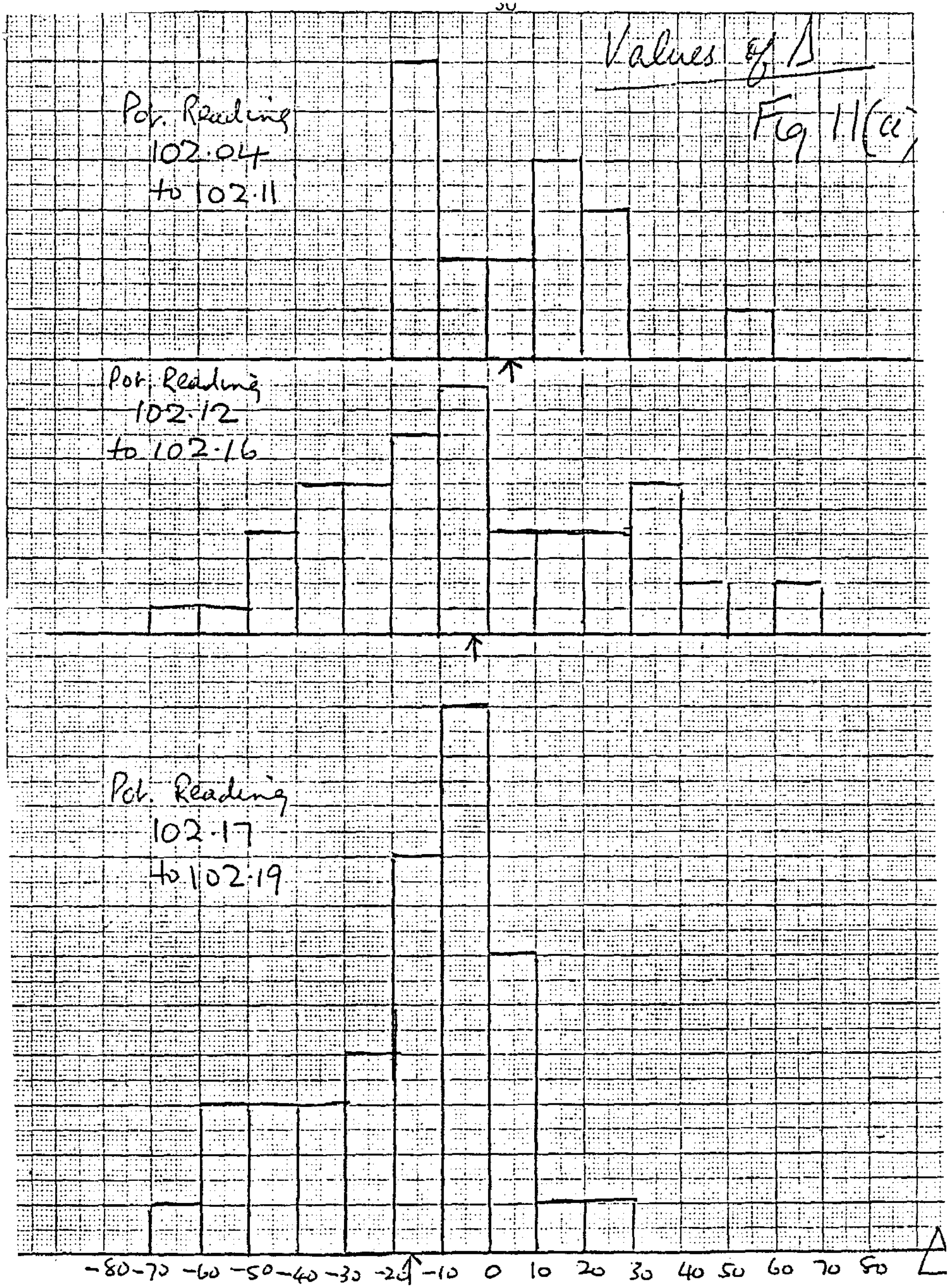
One would tend to expect an annual cycle in the main curve since the direction of v_r should be along the sun's equatorial plane and the 7° inclination of the sun's polar axis to the ecliptic will lead to v_r being above the earth for half the year and below for the other half altering the sign of $\frac{\partial v_r}{\partial (r\theta)}$. There is some evidence of this in Fig.4, though not a regular cycle.

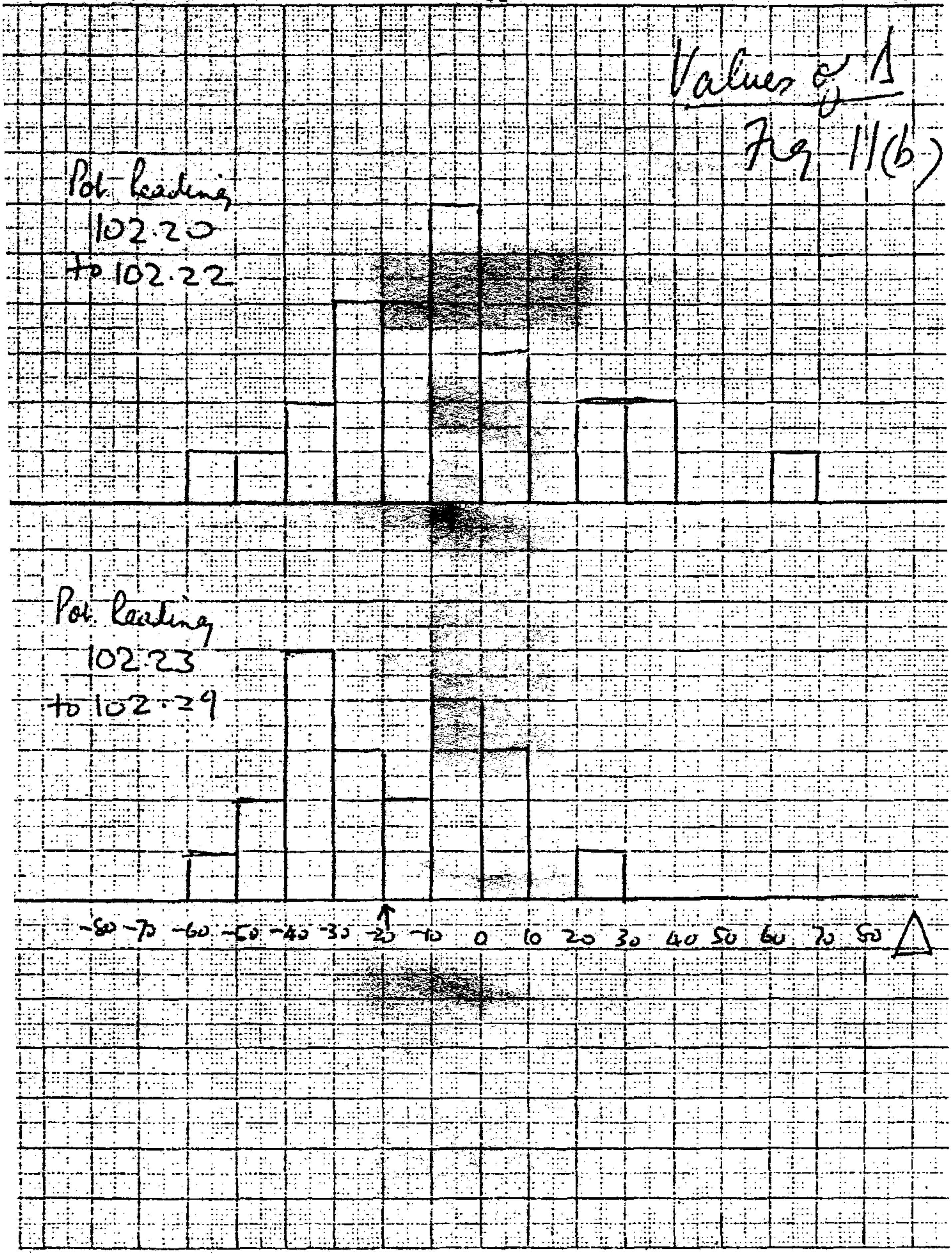
The gradient $\frac{\partial v_r}{\partial (r\phi)}$ which it was suggested caused the Allais anomaly has little effect on a gyroscope at mid day where the output axis is E/W though it will come in when the apparatus is at the quadrature position at 6 AM and 6PM and may well either contribute to the value of Δ mentioned above or indeed represent its whole magnitude.

We have noticed when all the values of Δ are assembled that it tends to be negative for high values of the couple and to be positive for low values. The statistics are poor but the effect, shown in Figs.11(a),11(b) and 12 appears to be significant. This would be expected if the anomaly is due to $\frac{\partial v_r}{\partial (r\theta)}$ and the anomaly is decreasing or increasing from mid-day to 6PM while the experiment is being done.

Values of Δ

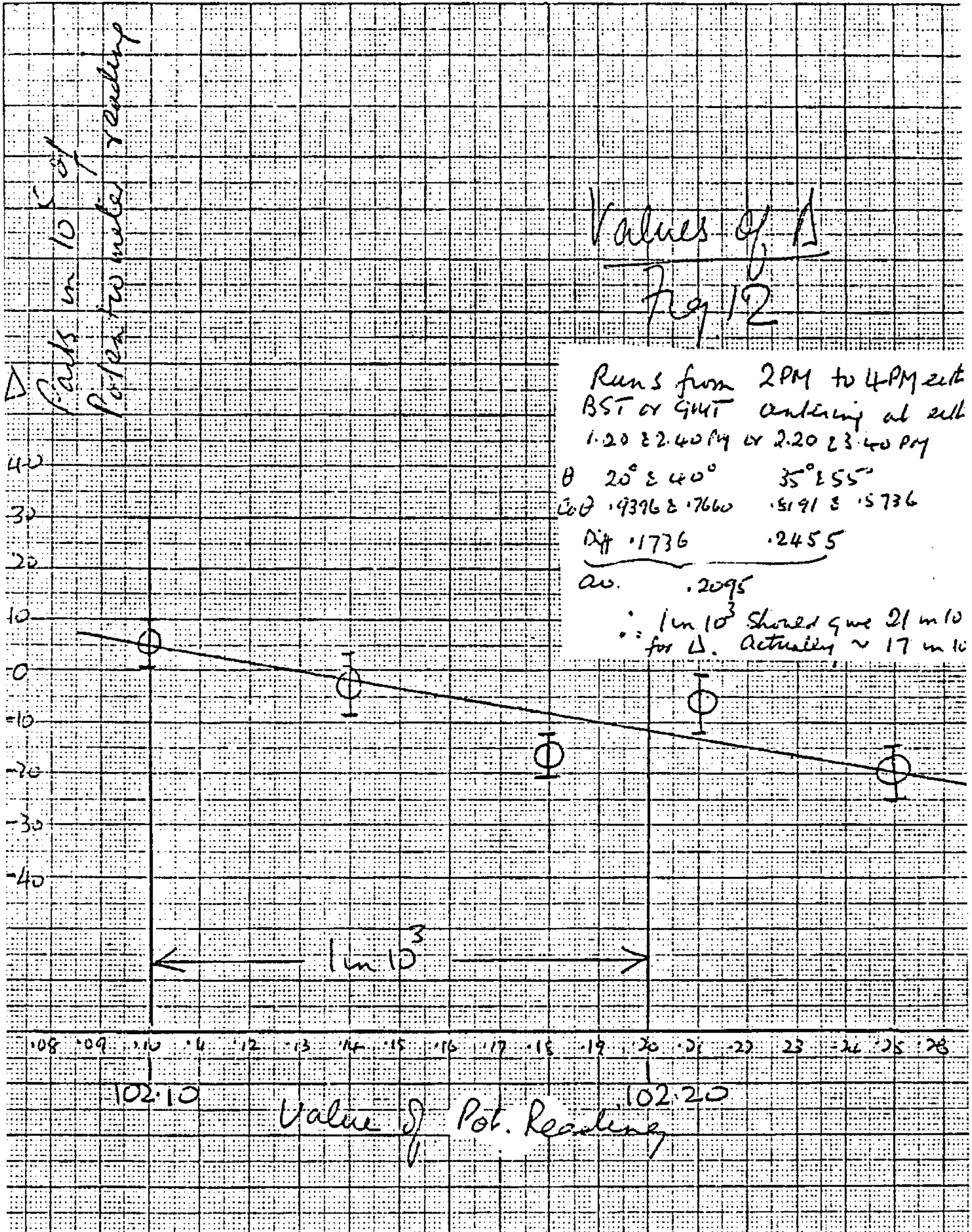
Fig 11(a)





Values of Δ

Fig 11(b)



Values of Δ
Fig 12

Runs from 2PM to 4PM each
BST or GMT centering at each
1.20 & 2.40 PM or 2.20 & 3.40 PM

θ 20° & 40° 35° & 55°
Cos θ ·9396 & ·7660 ·5191 & ·5736
Diff ·1736 ·2455
av. ·2095

∴ 1 in 10^3 should give 21 in 10
for Δ. Actually ~ 17 in 1

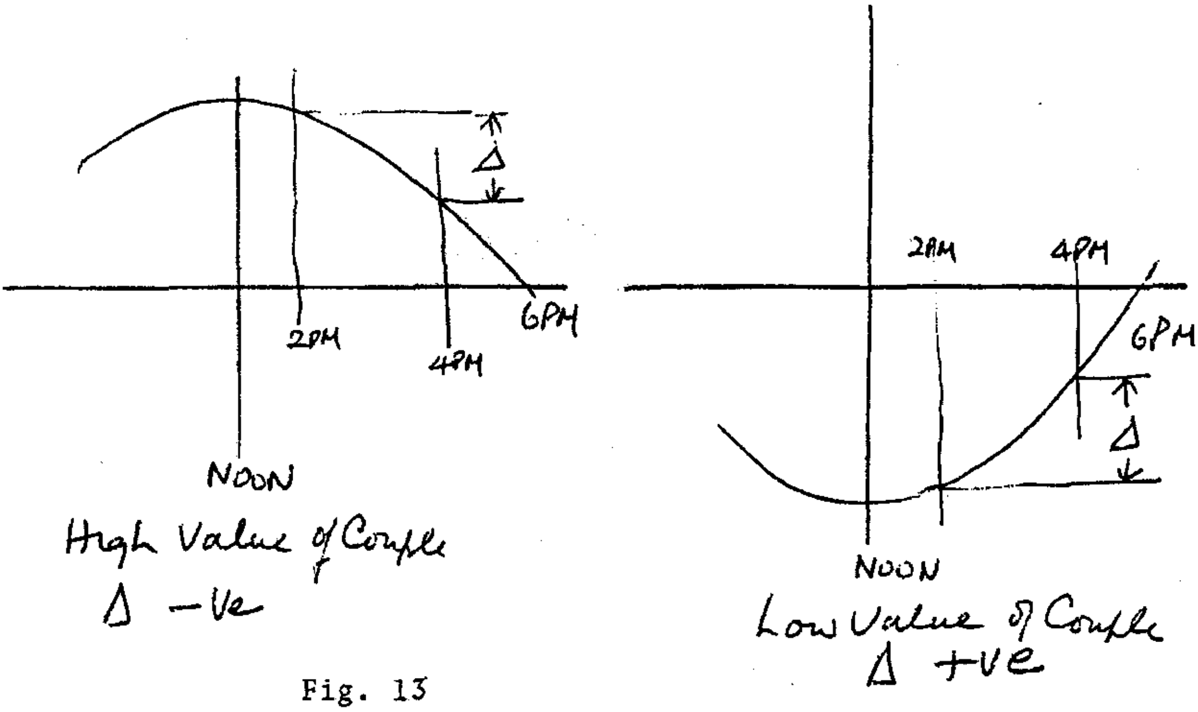


Fig. 13

Fig.13 demonstrates this. The effect requires the average of a good number of measurements before it shows up presumably because of "noise" introduced by $\frac{\partial v_r}{\partial (r\phi)}$ effects being superimposed.

An important consequence of the model suggested is that the couple is not affected by the direction of rotation of the wheel. This makes it <u>not</u> basically a gyroscope error but intrinsically a different phenomenon althogether. It should be cancelled out if an average is taken between couples for spin positive and spin negative the couple being taken without regard to sign. If the anomalous couple should increase the spin positive value regardless of sign it should decrease the spin negative couple.

Unfortunately, we did not do many reverse spin measurements and these do not correctly give a constant value of couple when averaged with normal spin measurements taken roughly at the same time. However there are two complications to bear in mind.

1) the spin axis may be slightly different for reverse and forward spins which could systemmatically alter the couple.
2) there is one magnetic error which has the same properties as the above anomaly. This is caused by magnetisation of the rotor along the spin axis. Such magnetisation interacting with the N/S horizontal component of the earth's field will introduce a couple about the E/W output axis. This couple is not averaged when the E/W axis is inverted, i.e. turned to W/E, and, like the anomalous couple, is not eliminated by our experimental technique.

The early values with SN_0 131 at a value of couple of $(122.11)^2$ arbitrary units give little change on reversal Fig.14. Later values at a couple of $(122.22)^2$ Fig.15, are much lower $(\sim 112.17)^2$ but not the corresponding amount -ve below $(122.11)^2$.

A measurement on S/No.217 Fig.16 shows a noticable difference between spin directions. This is all the reverse spin information available. One can only say that reversal of spin direction does change the apparent gyroscope couple but there would have to be other spin dependent errors if the model is correct.

It is a pity in retrospect that equal numbers of measurements were not made with opposing directions of the spin vector. However it was thought that the anomaly was a gyroscope anomaly and the few reverse spin measurements above tended to confirm this though not very accurately.

It is now rather important to check this carefully, but the apparatus has been dismantled long ago and the instruments may well no longer exist as they were obsolescent even in 1969. It would have to be done with different apparatus altogether.

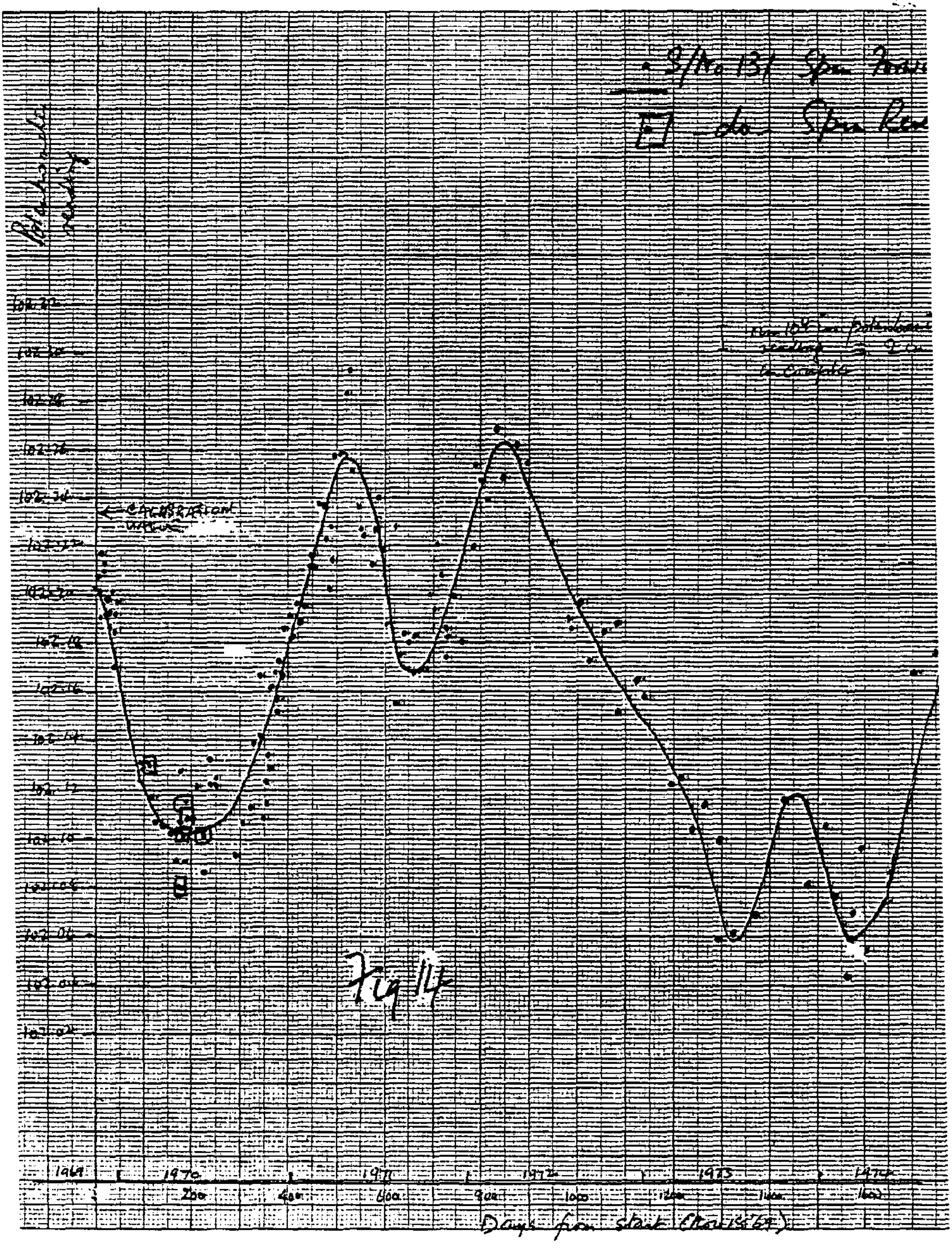

• S/No 131 Spur Mount
□ -do- Spur Rev
Potentiometer reading
1 in 10⁸ in potentiometer reading ≡ 2 ...
in ...
← CALIBRATION VALUE
102.32
102.30
102.28
102.26
102.24
102.22
102.20
102.18
102.16
102.14
102.12
102.10
102.08
102.06
102.04
102.02
1969
1970
1971
1972
1973
1974
200
400
600
800
1000
1200
1400
1600
Days from start (Nov 15 '69)

Fig 14

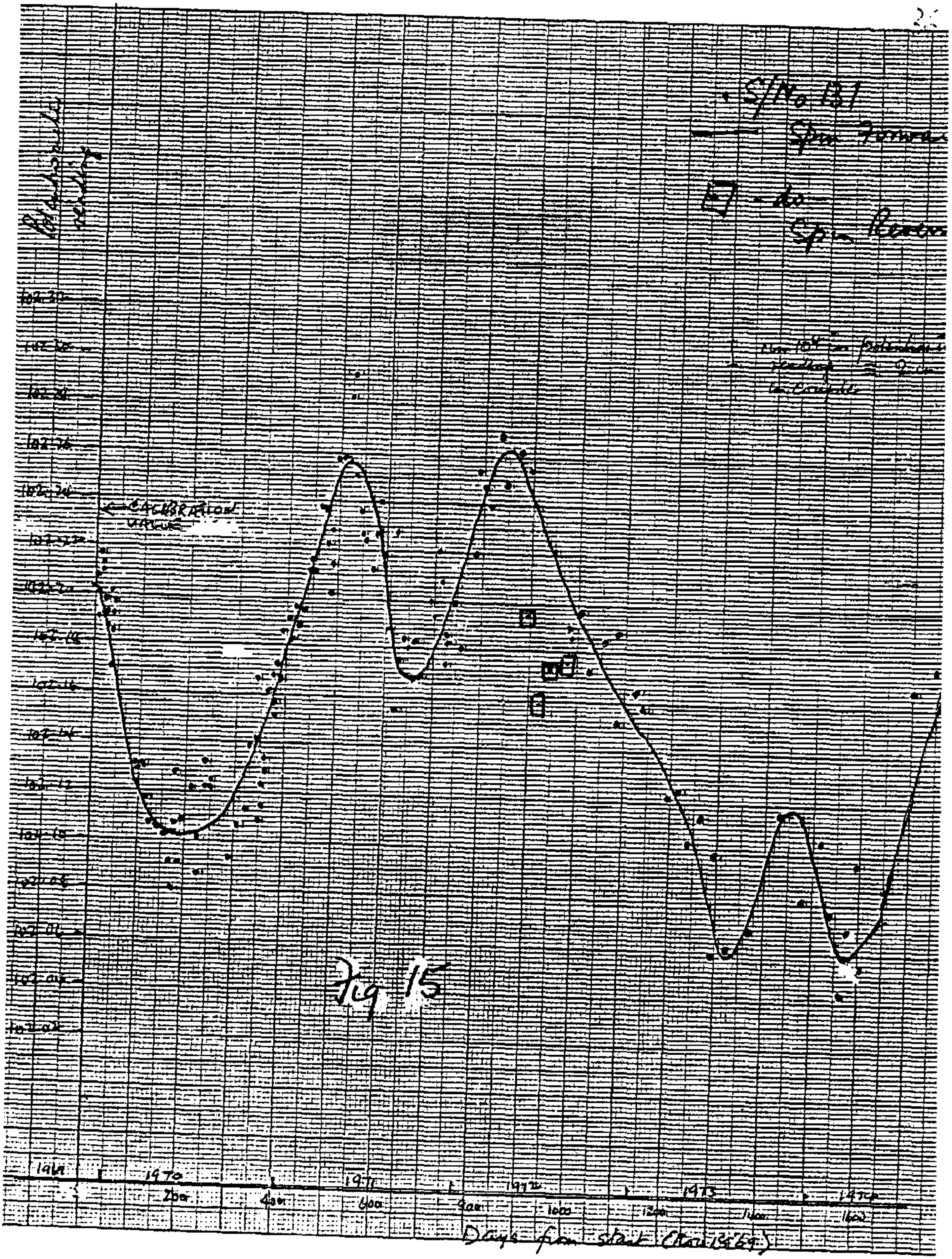

S/No 131
Spin Forward
□ - do -
Spin Reverse
102.30
102.30
102.28
102.26
102.24
102.22
102.20
102.18
102.16
102.14
102.12
102.10
102.08
102.06
102.04
102.02
← CALIBRATION VALUE
1969
1970
1971
1972
1973
1974
200
400
600
800
1000
1200
1400
1600
Days from start (Mar 1969)

Fig 15

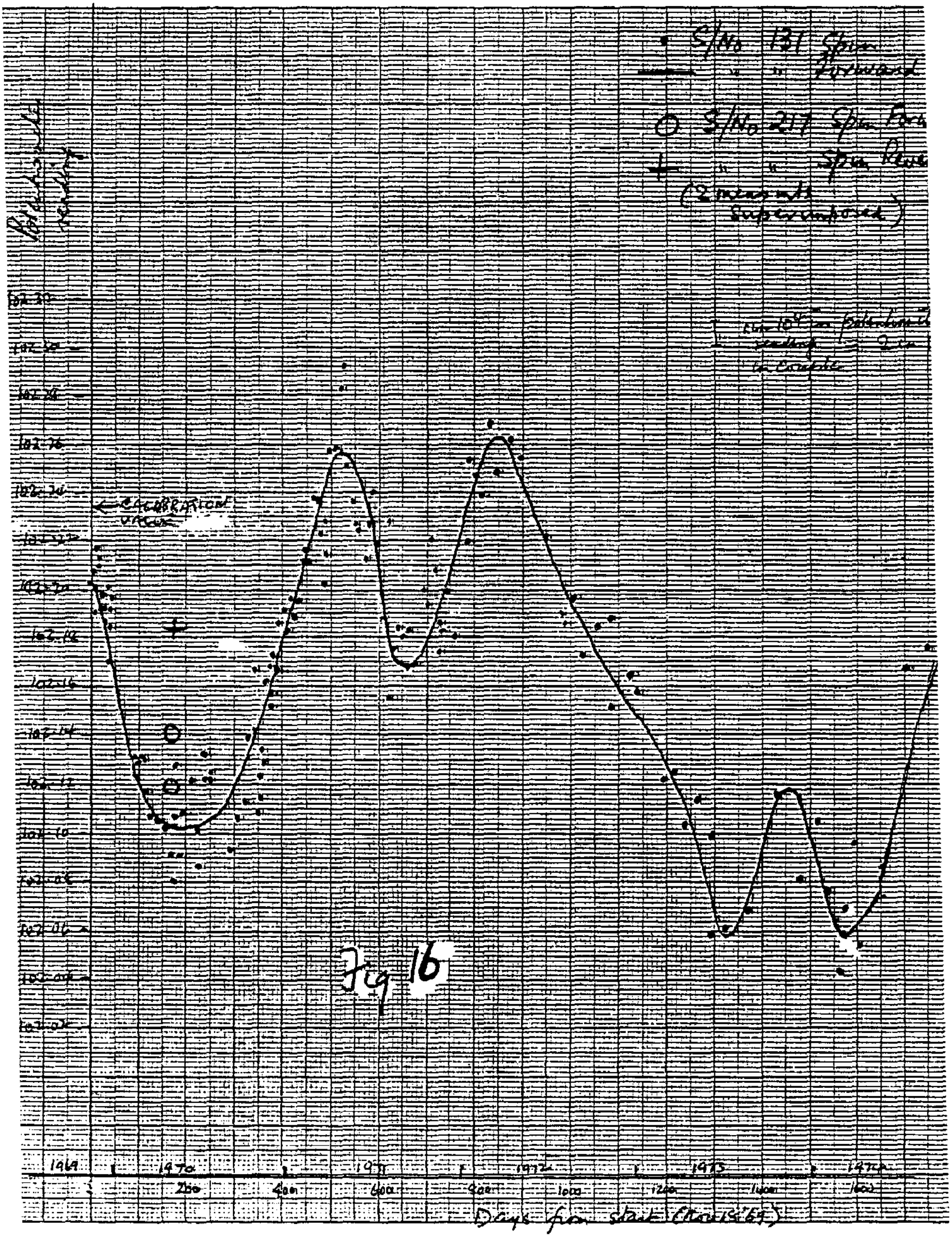

• S/No 131 Spin
— " " Forward
O S/No 217 Spin Forw
+ " " Spin Reve
(2 measmts superimposed)
Potentiometer reading
102.32
102.30
102.28
102.26
102.24
102.22
102.20
102.18
102.16
102.14
102.12
102.10
102.08
102.06
102.04
102.02
← CALIBRATION VALUE
1969
1970
1971
1972
1973
1974
200
400
600
800
1000
1200
1400
1600
Days from start (Nov 15 '69)

Fig 16

4.4 The Eclipse Effect and possible Short Term Variations in the Torsion Pendulum Period.

The anomalous couple caused by both $\frac{\partial v_r}{\partial(r\phi)}$ and $\frac{\partial v_r}{\partial(r\theta)}$ will act on the radial acceleration components of the motion of the torsional pendulum during its swing. The two gradients should each affect the period, though in different ways.

The gradient $\frac{\partial v_r}{\partial(r\phi)}$ would be expected to produce a couple about the vertical rotation axis and since the couple is independent of the sign of the rotation it should act like a change of zero, maximising at the centre of the swing and being identical for both forward and returning ½ cycles. Thus the period should be altered.

The gradient $\frac{\partial v_r}{\partial(r\theta)}$ on the other hand gives a couple similar to that for the gyrocope with spin axis vertical and will displace the vertical axis. For an eclipse at midday the pendulum bob should move either to the north or south. Again the movement is the same for each direction of rotation, and the effects should therefore not cancel. A change of period would occur if the optical lever run from light to pendulum mirror and to photocell lies in an E/W direction when a N/S deviation will affect the angle at which the photocell is energised. A similar effect at the other zero transit will add to give a effective change of period. It was this effect which we had in mind in taking the Talyvel level to Perth, however the actual expected movement had not been worked out.

Which of the two gradients is responsible for the change of period at the eclipse time is not known at present It should be noticed that the observed eclipse was in March at which time the solar latitude of the radius vector to the earth is almost the full 7^o from the solar equator. There is thus likely to be an appreciable $\frac{\partial v_r}{\partial(r\theta)}$ at the eclipse time. The erratic hourly variations in period mentioned by Saxl & Allen and shown in Fig.5, one would expect however, to be due to the $\frac{\partial v_r}{\partial(r\phi)}$ gradient, in line with the similar Foucault pendulum variations of Allais.

4.5 The Gyroscope Eclipse Experiment -

Latham & Last (10)

We are now in a position with our model and qualitative ideas on the anomalous forces to see in retrospect what the consequences are of the nil result of the Perth experiment.

The gradient $\frac{\partial v_r}{\partial(r\phi)}$ which one would expect to be the largest gradient should not produce couple about the E/W output axis at or around midday when the eclipse took place. What should occur is a couple tending to increase or decrease the angular speed of the wheel. This is synchronously linked to the 3 phase supply and no observable effect would be expected. The actual time of near totality was about 1 PM local time and the central time of the Talyvel movement was about 11.20 AM. Thus the conditions are such as to render a change in the apparent gyroscope couple very small.

The time of year (June 20th) is almost precisely when the radius vector to the earth from the solar centre lies on the solar equator. It is thus rather unlikely that any $\frac{\partial v_r}{\partial(r\theta)}$ component of gradient should exist at the earth. If it did, however, the arrangement of spin vertical and output axis E/W should allow the anomalous couple to be detected.

One must therefore conclude that the gyroscope experiment had the direction of spin and output axes very badly chosen for the time of day and of year at which the eclipse occurred, and that a negative result is not surprising.

4.6 The Talyvel Level Eclipse Results

Latham & Last (10)

If one accepts the fact that the direction of "g" does not change but that anomalies occur as a result of accelerated or rotational motion then the Talyvel effect must be due to electron spin consequent on the magnetic detection system. The Talyvel has a hanging pendulum P Fig.17 whose position is sensed by two inductors I_1, and I_2 on either side of a Permalloy armature A attached to the pendulum. Movements of the pendulum in the directions shown ⟷ alter the relative inductance of I_1 and I_2 which are parts of a bridge circuit. The bridge is powered by a 4kc/s oscillator and its off balance signal is amplified and recorded by a phase sensitive detector system which drives a meter. The set up is usually one in which the fields in A due to I_1 and I_2 are additive and not negligible in magnitude.

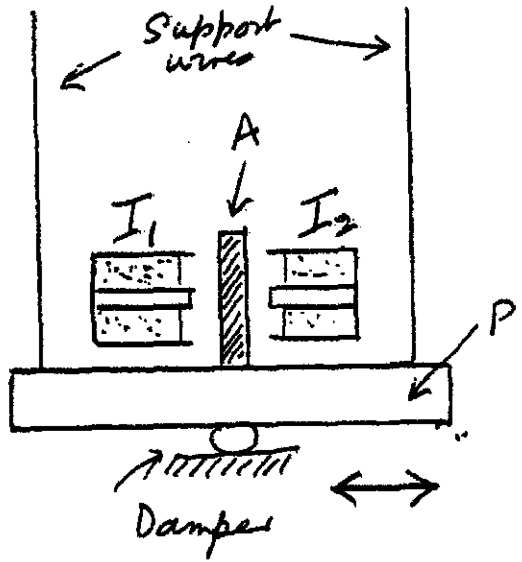


Fig. 17

The Talyvel was set up with the directions shown ⟷ lying along an E/W direction with the sun lying south. Thus viewed along I_2 say one would have magnetic fields as shown in Fig.18. in the armature.

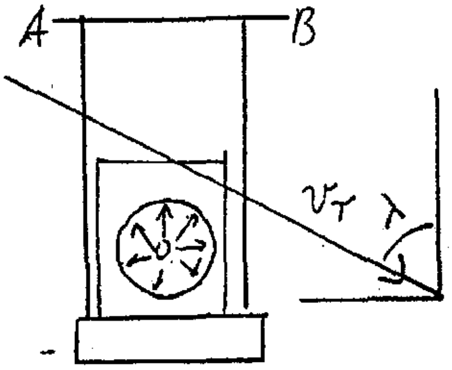


Fig.18

Electron spin in the ferromagnetic material would be similarly directed. v_r would also be as shown with the latitude λ of Perth and for a gradient $\frac{\partial v_r}{\partial(r\phi)}$ this would be into or out of the paper. None of the electron spins in this case would have a moment about the axis AB.

If we now consider the vertical component of v_r ($v_r \cos\lambda$) and the parts of the magnetic circuit where the lines are into or out of the paper as in Fig.19, then a couple is produced along the NS horizontal axis AB which will deflect the pendulum so that the bob moves either to the east or west, into or out of the paper. As the effect is independent of the sense of the spin vector all spins add in their effects and also during the rf cycle all parts of the cycle add similarly. Thus the pendulum deflects in an E/W direction which is the direction it was set to measure.

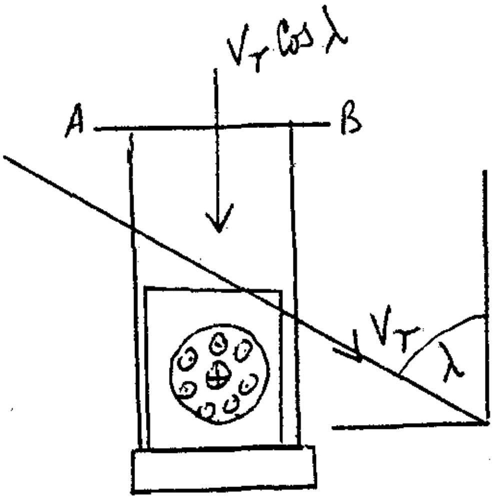


Fig. 19

The gradient in the $\frac{\partial v_r}{\partial(r\theta)}$ direction would only give a couple about the N/S axis for the component of v_r along the axis of the sensing solenoids for some of the directions in the upper figure. Since there is very little v_r component in this direction, at times close to noon the pendulum should not respond.

4.7 The Shape and Timing of the Eclipse Effect

It is interesting to compare shapes and relative times before eclipse centre for the three eclipse observations.

There are both drifts and errors to attempt to take into account and what follows is not very certain but as good as the data so far will allow.

The Allais curve (Fig.20) is really an integral since the anomalous effect is summed over succesive 14 minute cycles. The bold line is taken as a smoothed average of the data and this is roughly differentiated to give curve B on Fig.23. after inverting.

The Saxl and Allen curve Fig.21 has had a linear drift curve subtracted and the bold line again represents the smoothed data. The difference between data and drift line is plotted as Curve A on Fig.23.

Our own Talyvel data has also been subtracted from the drift curve included in Fig.22, and the difference is shown as Curve C on Fig.23. also after inverting.

There is fair similarity between curves A and B. Their total width is obviously to be compared with the time of onset and finish of the lunar obstruction - roughly 2 hours.

The similarity with our Talyvel curve is not so good, though it should be remembered that we were not situated in the region of totality. The lunar obstruction reached 95% at max, and we were roughly 200 miles from the centre line. One would not however expect this to have a very serious effect.

All three have the centre of the mechanical disturbance early with respect to the centre of the visual eclipse.

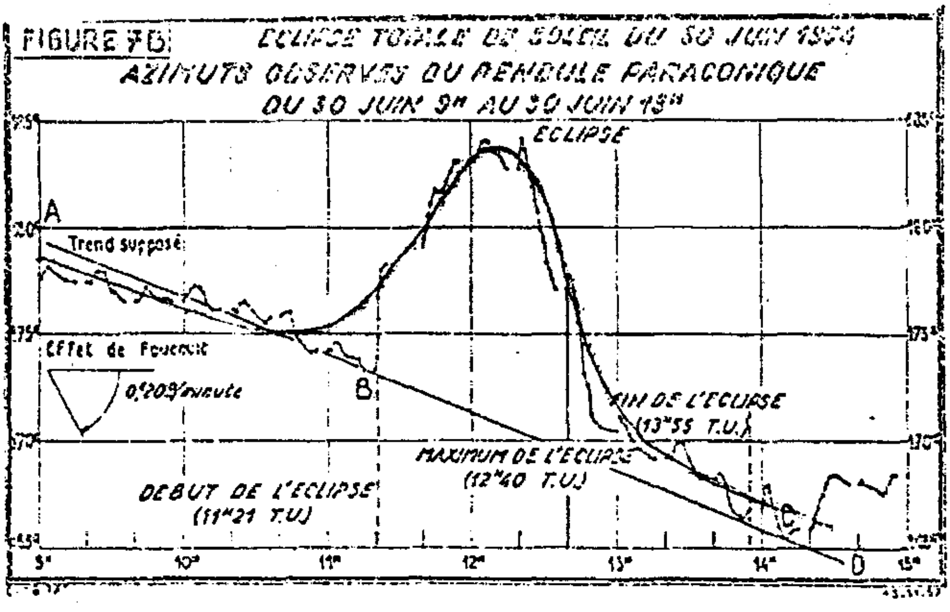


Fig. 7b Total solar eclipse, June 30, 1954. Azimuths of the para-conical pendulum observed from June 30, 9:00 a.m., to June 30, 3:00 p.m.

Fig 20

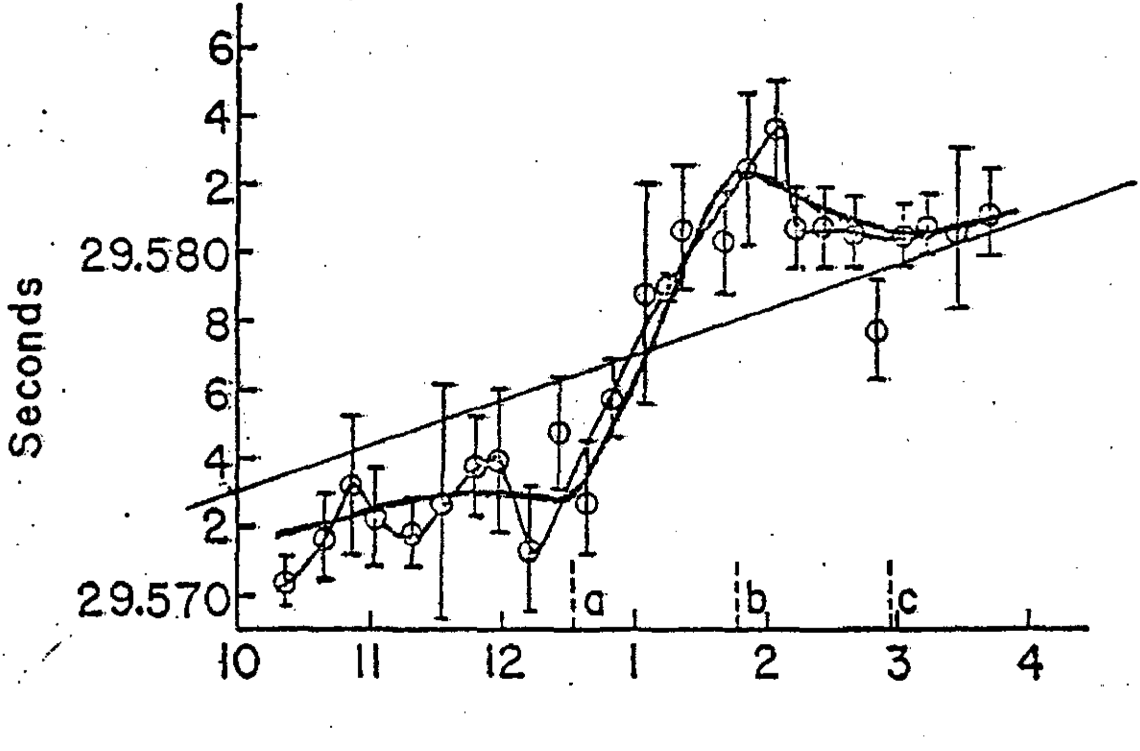


Fig 21