AJ.

DEPARTMENT OF SUPPLY
AUSTRALIAN DEFENCE SCIENTIFIC SERVICE
AERONAUTICAL RESEARCH LABORATORIES

Instruments Technical Memorandum 44

VIBRATION TESTS ON MALKARA J-3 GYROSCOPE

by

K.F. Fraser

SUMMARY

Vibration tests were performed on a Malkara J-3 gyroscope to determine under what conditions either the wiper or the centre contact of the pitch potentiometer system would lift.

CONTENTS

1. INTRODUCTION

Following the failure of several Malkara J-3 rounds to respond faithfully to command signals under conditions of extreme manoeuvre, an investigation into possible causes of malfunction was started. One suggested cause was vibration of the missile in flight which it was thought might be sufficient to cause lift of the pitch potentiometer wiper or centre contact. It was felt that this lift (which would effectively open circuit the input to the gyro networks) could seriously affect the system behaviour. A request was made to A.R.L. for examination of the effects of vibration on a J-3 gyro.

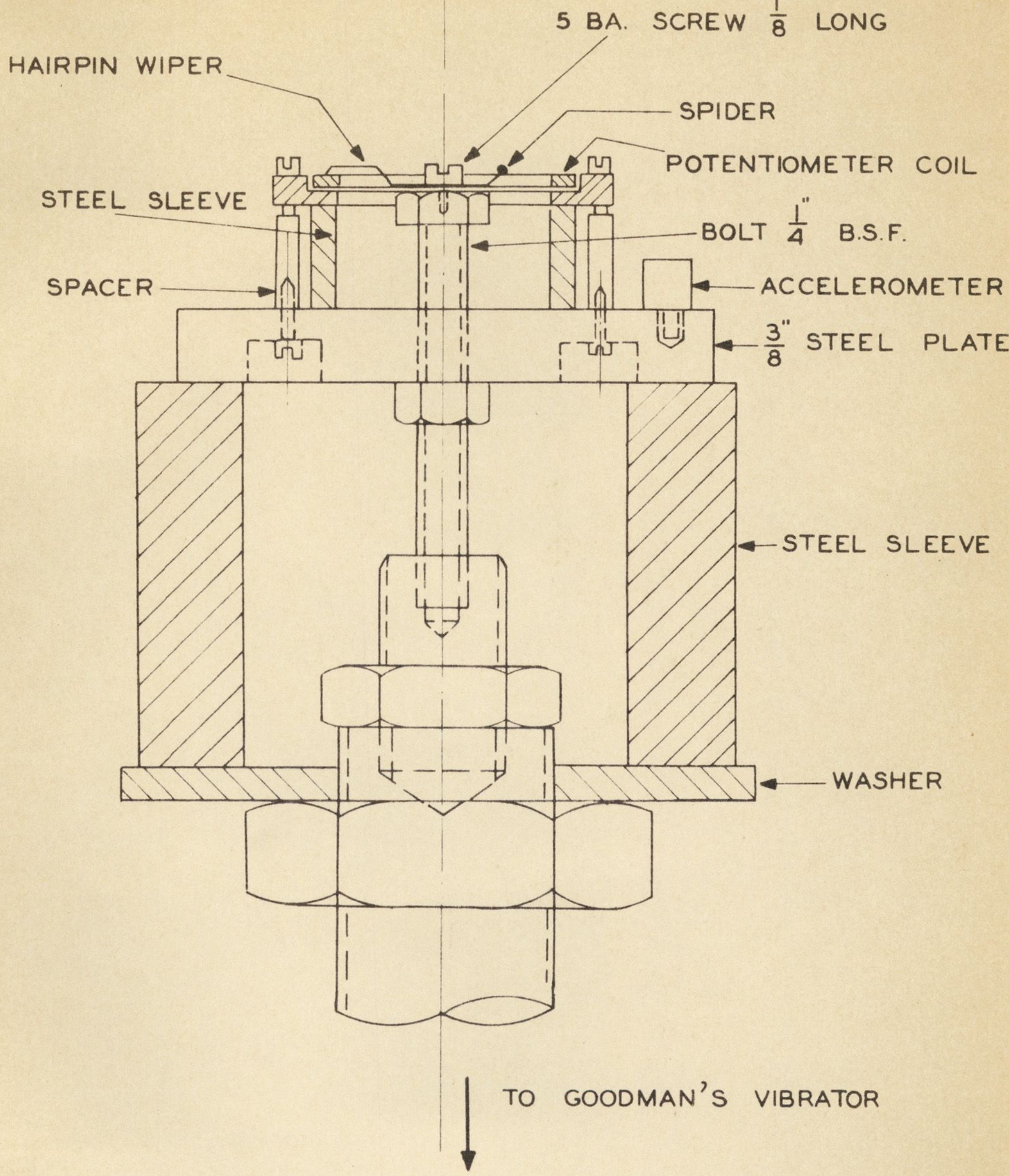
Details of tests carried out form the substance of this document. At the same time, a separate investigation was carried out on J-3 Malkara networks to determine the effect of intermittent gyroscope potentiometer contact. For details of the latter investigation refer to Instruments Technical Memorandum 42 "Response of J-3 Malkara Networks with Intermittent Gyroscope Potentiometer Contact" by J.A. Phillips and T.J. Struys.

2. DETAILS OF TESTS CARRIED OUT

2.1 Test on Wiper Alone

The pitch wiper together with the potentiometer and associated mountings was removed from a damaged gyroscope (Serial No. R & S 24) for the purpose of this test. The wiper was rigidly mounted with respect to the potentiometer on a stiff mounting which was further attached to a Goodman's Vibrator (Type 8/600A). For mounting details refer to Fig. 1. With this arrangement no structural resonances of the mounting parts occurred under about 1140 c/s. Using a beam balance the hairpin wiper was set to a pressure of 2.6 gm. Acceleration was monitored using a Bruel & Kjaer accelerometer.

The potentiometer was mounted with its axis vertical and the assembly was vibrated in the vertical direction. Lifting of the wiper did not occur in the frequency range 0c/s - 1000 c/s under a peak acceleration of 5g.



DETAILS OF PITCH POTENTIOMETER TEST MOUNTING

It was concluded from this test that wiper resonance in itself was not giving the trouble.

2.2 Test on Complete Gyroscope

A new gyroscope (Serial No. R & S 221, Part No. 6765B, Inspection Reference No. G39676) which had been fully tested and approved was obtained from G.A.F. for the purpose of this test.

Check on Wiper Pressure

According to manufacturer's specifications the wiper pressure for both potentiometers is set at 2.5 gm. at the factory. Using a beam balance the wiper pressure on the roll potentiometer was measured to be 4.95 gm., considerably different from that specified. The wiper pressure on the pitch potentiometer was not initially measured but was set here at 2.7 gm. in the first instance.

Vibration Test

(i) Pitch Wiper Set at 4.0 gm.

The gyroscope was bolted on a stiff 1" thick plate and attached to the Goodman's vibrator such that the axis of the outer gimbal coincided with the axis of vibration (horizontal). A Bruel & Kjaer accelerometer was mounted on the plate to enable the g loading to be monitored. The rotor was run up approximately to speed using a line from a nitrogen bottle. To monitor break of contact on the pitch potentiometer, voltage was applied to this potentiometer and the voltage at the wiper was observed on a D.C. C.R.O.

When the gyroscope was vibrated rattling of the outer gimbal bearings could be heard. On account of the spurious acceleration induced, when rattle commenced, it was extremely difficult to identify the g loading except with very low accuracy. Rattle of the bearings was quite significant over the frequency range 100 c/s - 500 c/s and seemed to be worst round about 300 c/s. At this frequency rattle commenced at a peak loading of about 1 g or less. Rotor speed did not seem to affect rattle in any observable way. Lifting of the pitch wiper did occur and it seemed to commence when rattle of the bearings became apparent.

The frequency of excitation at which bearing rattle and wiper lift were most pronounced was found to be 320 c/s. Lift of the pitch wiper was monitored on a Cossor oscilloscope using the arrangement depicted in Fig. 2.

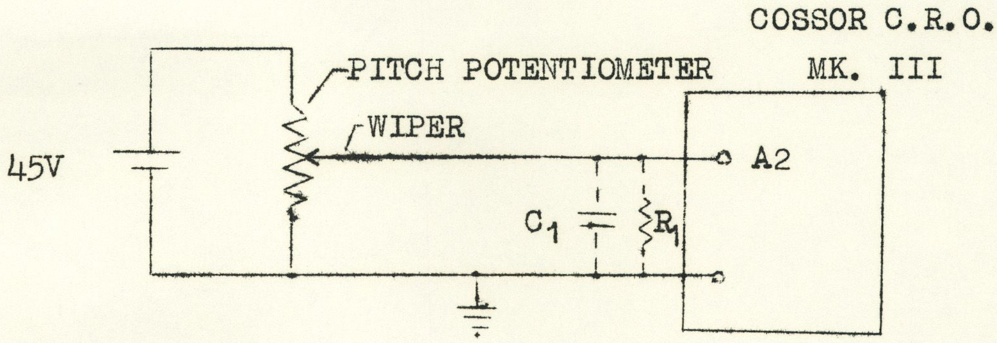


FIGURE 2

With the oscilloscope time base switched off films were taken of the movement of the spot using a Cossor camera for the conditions summarized below:

Film speed	=	25 in./sec.
Wiper pressure	=	4.0 gm.
Peak acceleration	=	5 g.
Excitation frequency	=	320 c/s.
Rotor speed	=	30,000 R.P.M. (approx.)

Samples of film taken (for the rotor respectively caged and uncaged) are shown in Figs. 3(a) and 3(b). It can be seen from these photographs that the "off" voltage level was not quite reached during lift of the wiper. The reason for this behaviour is that the input capacitance of the C.R.O., which was charged to a potential of about 22.5 V during the "on" period, had insufficient time to completely discharge during the very short time for which the wiper broke contact. It is apparent from the photographs that lift of the pitch wiper occurred more frequently for the rotor uncaged.

An estimate of the proportion of time for which the wiper was not making contact with the potentiometer coil under the above conditions and for the rotor uncaged, was made using the film of Fig. 3(b) and knowledge of the oscilloscope discharge time constant. The input capacitance C_1, of the oscilloscope (Refer to Fig. 2) is charged by the voltage obtained from the potentiometer wiper. When the wiper lifts, C_1 immediately begins to discharge through the oscilloscope input resistance R_1 as shown in Fig. 4.

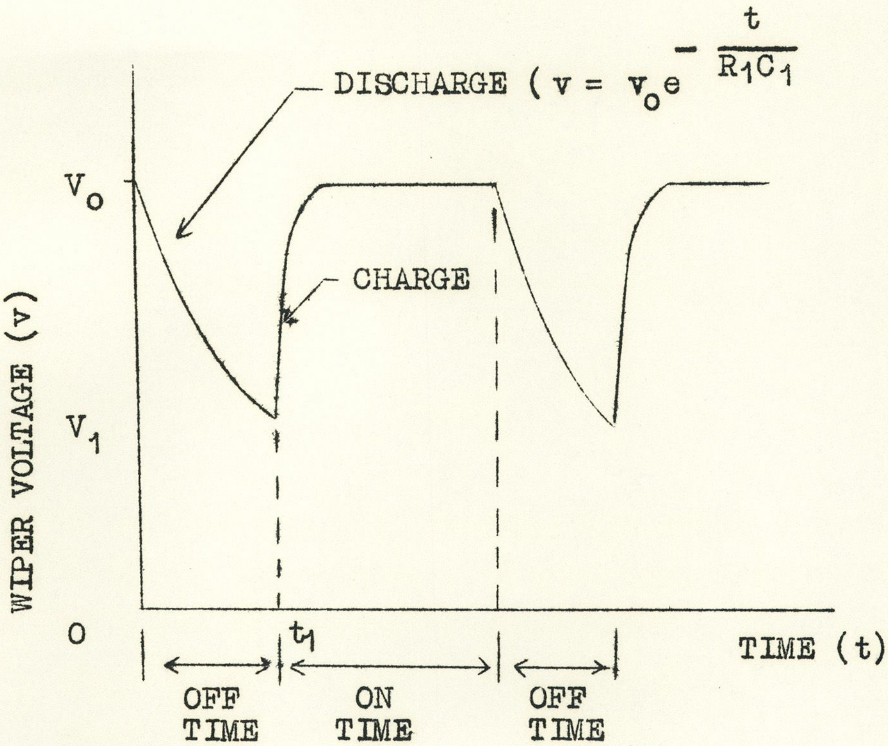


FIGURE 4

Referring to Fig. 4 we may write:

$$v_1 = v_o e^{-\frac{t_1}{R_1 C_1}}$$

$$t_1 = R_1 C_1 \ln \frac{v_o}{v_1}$$

The time constant of the oscilloscope R_1C_1 was measured and found to be about 108 μ sec. It can be seen from Fig. 3(b) that the voltage ratio $\frac{v_o}{v_1}$ is by no means constant, which indicates that the duration of the wiper lift is quite variable. An average value of $\frac{v_o}{v_1}$ is about 3,

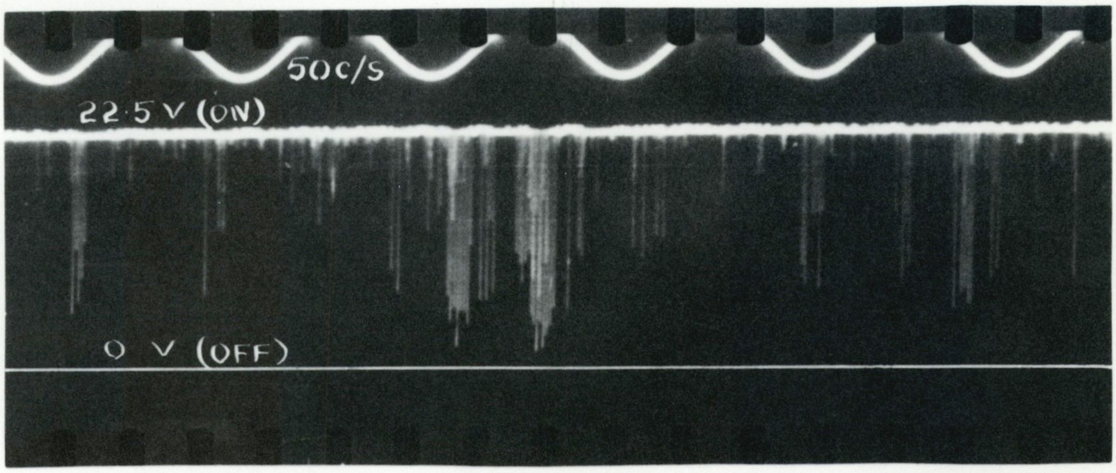


FIG. 3 [a] CAGED ROTOR

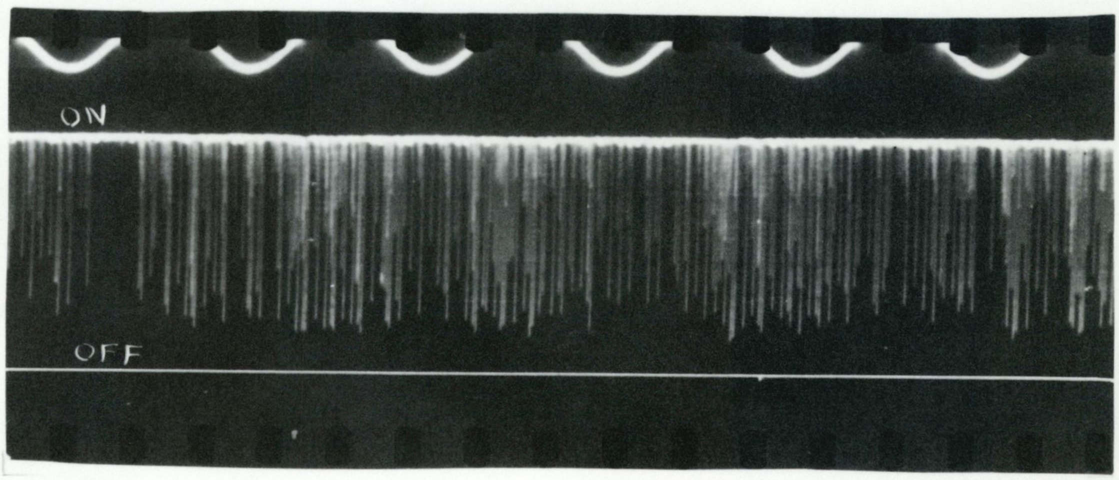


FIG. 3 [b] UNCAGED ROTOR

FILMS SHOWING LIFT OF PITCH POTENTIOMETER WIPER for which $t_1 \approx 110$ μsec. According to Fig. 3(b) the peak frequency of lift of the pitch wiper is about 2000 c/s. Hence the proportion of time for which the wiper does not make contact with the potentiometer is approximately 2000 x 110 x 10^{-6} or 0.22.

Since the potentiometer resistance is much smaller than the input resistance of the oscilloscope the charging time of the input capacitance of the oscilloscope is much smaller than the discharge time.

Further vibration tests similar to those above were carried out in order to ascertain whether the centre contact on the pitch wiper was breaking contact. The centre contact was in the form of a small ball contacting the surface of the pitch wiper assembly which in turn carried the hairpin wiper contacting the potentiometer coil. Electrical connection, as regards the internal wiring of the gyroscope, is made by this centre contact. The arrangement of Fig. 5 was used to monitor, simultaneously, on a dual beam oscilloscope, lift of both wiper and centre contact.

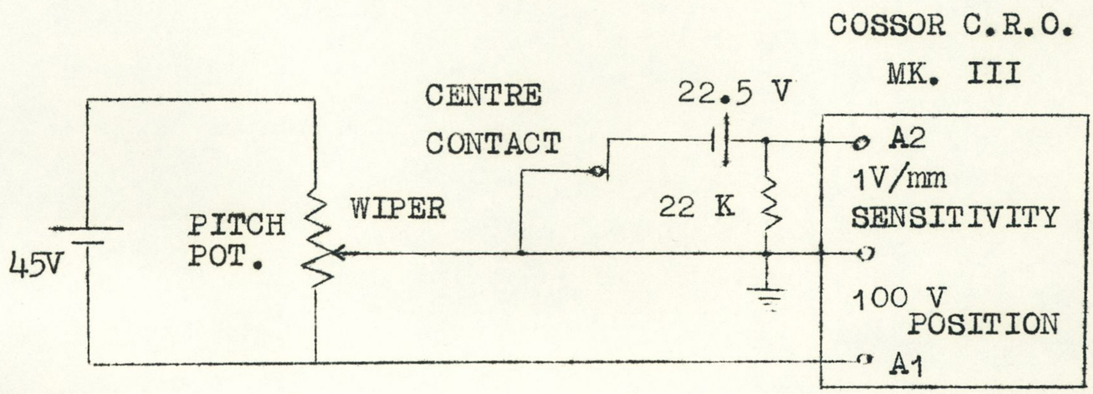


FIGURE 5

To conserve film and labour, some stationary photographs were taken of the two oscilloscope traces (for the rotor respectively caged and uncaged) under various g loads. The following parameters were held constant throughout the test:

Wiper pressure	=	4.0 gm.
Centre contact pressure	=	10.2 gm.

Frequency of excitation = 290 c/s.

C.R.O. time base = 50 msec.

Samples of these photographs are given in Figs. 6 and 7. In each case, the top trace monitors lift of the wiper and the bottom trace lift of the centre contact. For both traces a downward movement represents a break of contact.

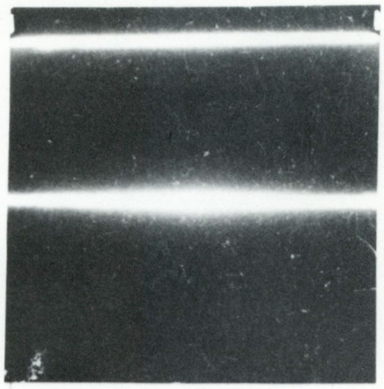
The photographs of Fig. 6 show that lift of the wiper for the rotor caged condition, was greater at 2 g and 3 g than at higher g's, a fact that could not be explained. For the rotor uncaged, lift of the wiper was clearly evident at loads of 2 g and above (Refer to Fig. 7). For both caged and uncaged rotor conditions, centre contact lift only became evident at the higher g loads. In general the photographs of Figs. 6 and 7 revealed that lift of both the wiper and centre contact was much more pronounced for the uncaged rotor case, and that centre contact lift was much less than wiper lift.

(ii) Pitch Wiper Set at Other Pressures

To determine the effect of wiper contact pressure on lift of the wiper, further short tests were carried out at wiper pressures of 2.0 gm. and 5.5. gm. (the latter being the highest pressure we were able to obtain). It appeared that lift of the pitch wiper under the same conditions, as those above, (except for wiper pressure) was somewhat less for both of these pressures, than for the 4 gm. case. No suitable explanation was apparent for this seemingly anomalous behaviour. At this stage, due to absence of any malfunctioning of J-3 rounds in later flight trials, tests were discontinued. More exhaustive tests along the above lines would be necessary before any true assessment of the situation could be made.

Effect of Wiper Lift & Friction on Pitch Potentiometer Coil

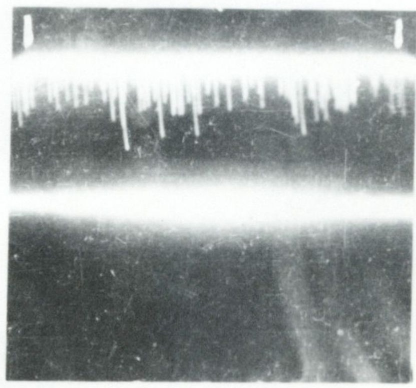
Earlier in the tests, after a period of approximately 15 minutes nett running time under vibration, the pitch potentiometer was examined and photographed under a microscope at 100 times magnification.



NO EVIDENGE OF WIPER LIFT

NO EVIDENCE OF CENTRE CONTACT LIFT

FIG. 6[a] ACCEL. = 1g



WIPER LIFT CLEARLY EVIDENT

FIG. 6 [b] ACCEL. = 2g

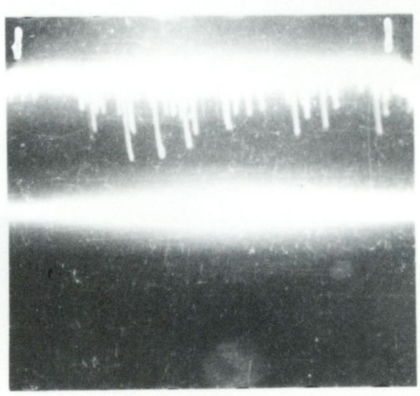


FIG. 6 [c] ACCEL. = 3 g

WIPER AND CENTRE CONTACT LIFT FOR ROTOR CAGED

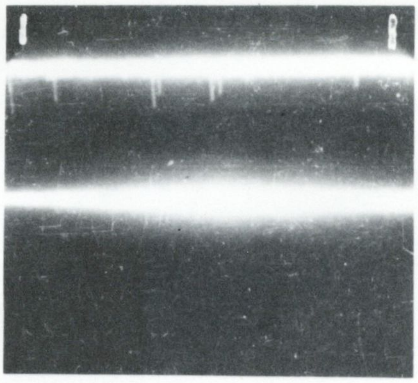
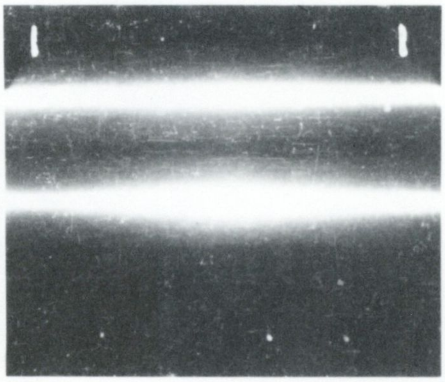
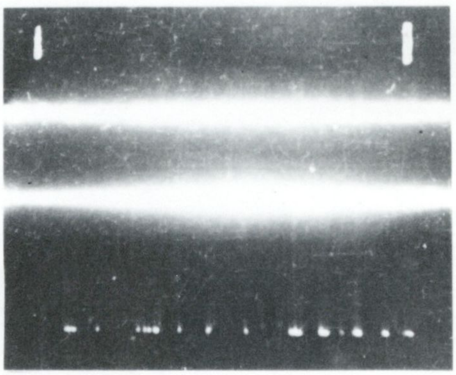


FIG. 6[d] ACCEL. = 4g



← CENTRE CONTACT LIFT JUST EVIDENT

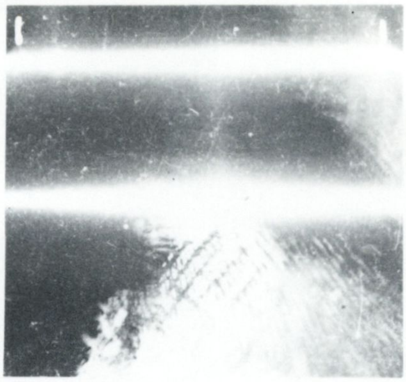
FIG. 6[e] ACCEL. = 5g



← CENTRE CONTACT LIFT CLEARLY EVIDENT

FIG. 6[f] ACCEL. = 6g

WIPER AND CENTRE CONTACT LIFT FOR ROTOR CAGED



← NO EVIDENCE OF WIPER LIFT

← NO EVIDENCE OF CENTRE CONTACT LIFT
(NEGATIVE DAMAGED)

FIG. 7[a] ACCEL. = 1g

← WIPER LIFT CLEARLY EVIDENT

FIG. 7[b] ACCEL. = 2g

FIG. 7[c] ACCEL. = 3g

WIPER AND CENTRE CONTACT LIFT FOR ROTOR UNCAGED

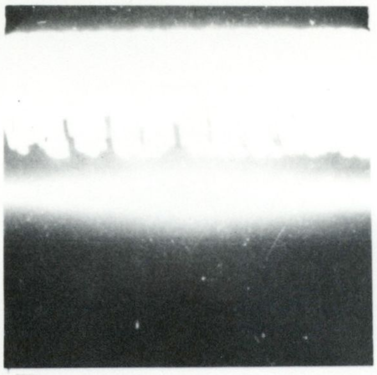


FIG 7[d] ACCEL. = 4g

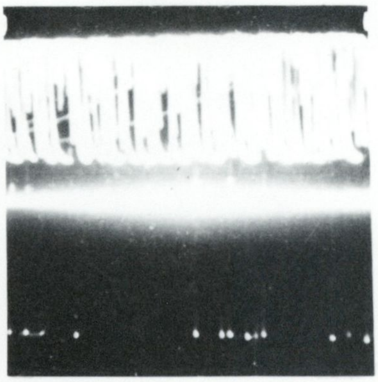


FIG. 7[e] ACCEL. = 5g

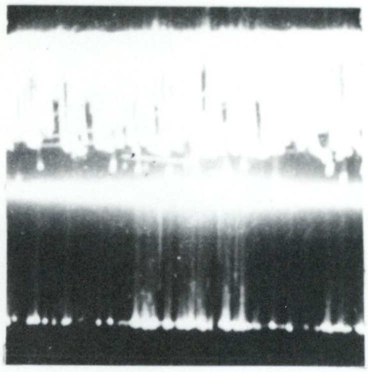


FIG. 7.[f] ACCEL.= 6g

WIPER AND CENTRE CONTACT LIFT FOR ROTOR UNCAGED

For comparison, two photographs (Figs. 8(a) and 8(b)) were taken, one in the 0° (pitch) position and the other at about a 45° position. The former clearly indicated that a considerable spreading of the wire had occurred and also that at various points consecutive turns were shorting together, whereas only slight deformation was evident in the latter. Since uncaging of the rotor takes place in the 0° position, most deformation due to both sliding and bouncing of the wiper, would be expected to occur in that region.

3. SUMMARY OF OBSERVATIONS

Resonance of the pitch wiper did not occur in the frequency range 0c/s - 1000 c/s. When the pitch wiper, set at 2.6 gm. pressure, was rigidly mounted with respect to the potentiometer, no lifting occurred at accelerations up to 5 g in the above frequency range.

When the complete gyroscope was shaken with the pitch wiper pressure set at 4 gm., lift of the wiper did occur. The wiper lift was closely associated with rattle of the outer gimbal bearings. The worst condition appeared to be at about 300 c/s at which frequency rattle became apparent at about 1 g. Under 5 g acceleration at this frequency of excitation lifting of the wiper occurred at a peak rate of 2000 c/s approximately. It was estimated that under the worst condition realised in this test the wiper would be off for about 0.2 of the time. Lift of the centre contact was also detected but this was negligible in comparison with that of the wiper.

It was estimated that the frequency band in which pitch wiper lift was significant was approximately 100 c/s to 500 c/s with 300 c/s being approximately the frequency at which most trouble occurred. These results would be the basis for the design of new mountings to isolate this vibration, if required.

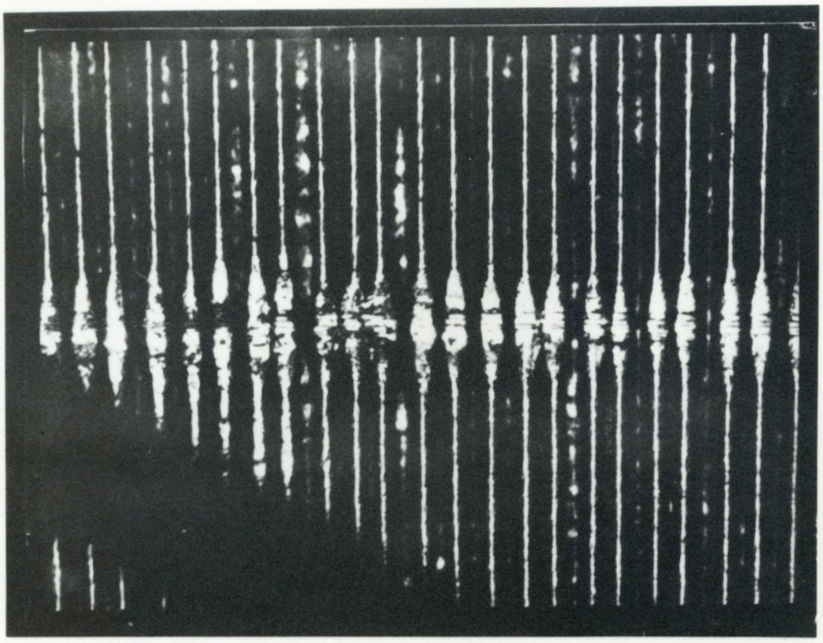


FIG. 8[a] 0°– CAGED POSITION

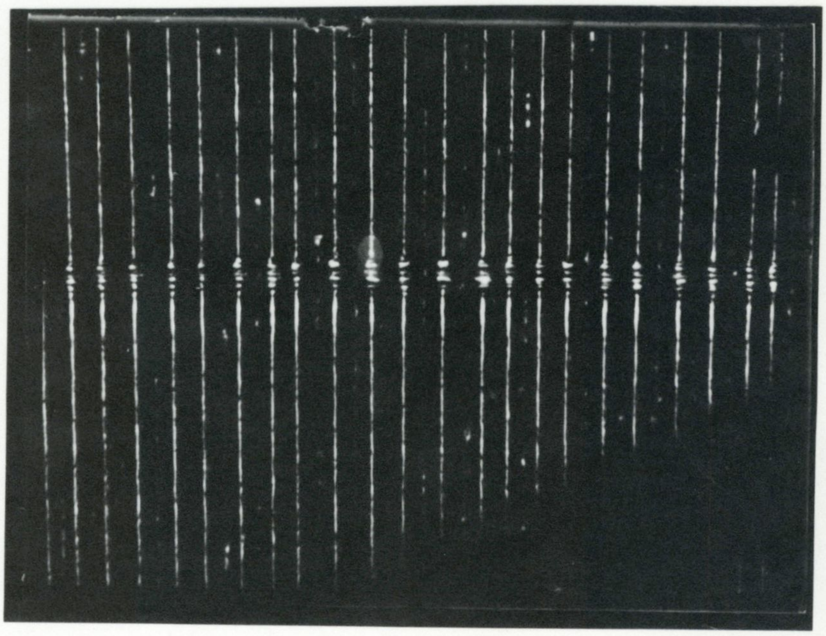


FIG. 8[b] 45° FROM CAGED POSITION

PHOTOGRAPHS OF PITCH POTENTIOMETER COIL AFTER DAMAGE BY WIPER LIFT