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HELICOPTER VIBRATION FLIGHT TESTING - THE ROTORTUNER APPROACH

by

Noel Trigg, Managing Director, Helitune MCT Ltd

Fleet, England

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ABSTRACT

The paper describes how the ROTORTUNER is used to detect, record and minimise any vibration found in a helicopter. It states the philosophy behind the creation of the instrument as a tool for the maintenance engineer, whilst realising the ROTORTUNER's potential as a bridge between the helicopter and the operator.

The paper also describes the use of the line scan camera to observe main rotor blade height and inter-blade timing with very high accuracy, both on the ground and in flight. This leads to the ROTORTUNER's use for setting up blades on a rotor tower or on a static helicopter. As a research tool for in-flight rotor blade and damper behavioural studies, the ROTORTUNER's micros compare the digitised track, accelerometer and one per rev signals with the known limits or expected behaviour of the helicopter. The ROTORTUNER gives decisions on corrective adjustments. This leads to the tuning of each individual helicopter to its optimum smoothness in the minimum elapsed time.

The paper describes the built-in simulation mode of the ROTORTUNER for initial training, refresher training and for demonstration of its capabilities. The philosophy of the ROTORTUNER USERS GROUP data base is explained, and the use of the instrument for trend monitoring. The theme of co-operation between helicopter manufacturer, the operator and the ROTORTUNER designers is highlighted in order to realise the full potential of the instrument. The ROTORTUNER can be programmed to look for specific faults and to identify them, when found, to the operator. Manufacturers and fleet managers will be encouraged to use this facility to improve flight safety. Future developments are outlined and further applications proposed.

VIBRATION MANAGEMENT - THE WAY AHEAD

INTRODUCTION

1. Over the last three years Helitune MCT Ltd has designed and is now manufacturing the ROTORTUNER. This paper is a follow-on from my closing remarks in the previous paper which I presented to the Fifth European Rotorcraft And Powered Lift Forum in Amsterdam, when I said that "the technology exists. All we have to do is to package the product". Little did I know how difficult that course would be. However, I will now introduce the results of all those efforts.

AIM

2. The aim of this paper is to describe a cost effective and timely means of helicopter vibration management and research.

THE PROBLEM

3. Overview. The helicopter is inherently a vibrating machine. Not surprisingly, if its rotors are out of adjustment, the whole machine and its occupants are shaken continuously. If vibration is left uncorrected, the ensuing damage is cumulative and attacks the fabric of the fuselage and the components within it. In fact, vibration ranks as one of the principal reasons for keeping helicopters on the ground. Annex A shows the top ten such reasons for a modern military helicopter and dramatically illustrates this point. It also shows the very high manhour cost of finding a correction. Annex B is of special interest. It can be seen that it can take some 7 flying hours to cure a vibration problem. Moreover, this single feature pervades the whole serviceability, reliability and flight safety of the helicopter. Vibration is a major factor in the cost of ownership of a helicopter, having a direct effect on the life cycle costs as well as the more obvious and readily apparent effects on the direct operating costs. If we look at one example at Annex C, which is not untypical, it is reasonable to believe that the real cause of the problem may not yet have been identified. Yet how much has all the rectification cost? How much of it is nugatory? How many rejected components will be No Fault Found (NFF) when they eventually emerge from the repair pipeline?

4. The Present Approach. Although some operators monitor helicopter vibration on a routine basis, the pilot is still relied upon as the principal arbiter of serviceability. We rely on him to report unacceptable vibration levels between routine checks. The reason why so many potentially damaging vibration sources are allowed to pass undetected is that the human body is a very poor measuring instrument. We can detect low frequency vibration through our stomach and ears. High frequency vibration can only be felt by touch and even then it may only be detected as a tingle when in fact the 'g' levels, causing cumulative damage, are extremely high.

5. The Requirement. Helicopter operators and researchers require a system which will manage vibration. The essential elements of the system are:

```
Data Acquisition )
Interpretation   )
Decision making  ) ---- (DIDAT)
Action           )
Trend monitoring )
```

All of these elements should ideally reside in one equipment, be available on site, have high data integrity and should incur minimal overheads in data processing and decision making time. The latter requirement is paramount at coal face level, if the helicopter is to be corrected and returned to front line service in the minimum down time.

6. Existing Equipment.

a. Chadwick Helmuth. The Vibrex has done sterling work since its acceptance into service in 1975.

(1) Advantages. Its advantage was its small size, weight and simple technology. It was a major advance over the tracking flag. Those who ultimately made the decision to purchase the Vibrex were faced with a major cost differential between a flag and a sophisticated piece of electronics, by the standards of the day. After a hesitant beginning, the equipment quickly established its supremacy and the military were the world leaders in its adoption and in recognising its cost effectiveness. The author remembers the battles well, having introduced it into Royal Air Force Service.

(2) Disadvantages. The Vibrex however has several drawbacks. The principal one is the complexity of its knobs, dials and switches leading to confusion and misinterpretation in the hands of an untrained operator. It relies on a high level of gauge reading, plotting and interpretation of polar charts. Also, when the helicopter fails to respond in the predicted way, a further action of clock angle correction is necessary. This action is widely misunderstood and is only really grasped by a handful of trained operators. An orderly beginning usually degenerates into a very hit and miss affair which is very disquieting to test pilots. This usually results in subjective 'why not try this'. The result is tail chasing. The over-riding weakness is the crudity of blade track pattern acquisition, assessment, interpretation, recording and subsequent decision making. Also, there is no quantitative assessment of damper behaviour. Human errors abound at every phase. Moreover, there is little or no guidance given on the correct sequence of adjustment of the interacting variables of dampers, tabs, pitch links, mass balance and blade sweep. The training and re-training bill is extrememly high and retention of skill relies on regular use of the equipment.

b. Scientific Atlanta 2538. The specification of this instrument was written by the author in 1977.

(1). Advantages. It is a small rugged and reliable pen plotter which gives a vibration signature from 0-100 Hz and 0-1500 Hz on pre-printed cards.

(2) Disadvantages. It has a very wide bandwidth of 2.5 Hz on the 0-100 Hz scale which prevents it from discriminating between adjacent frequencies common in most helicopters, notably, two of the most influencial forcing frequencies, NR and 1T. Also, its bandwidth of 15 Hz from 0-1500 Hz is inadequate for accurate fault diagnosis. Moreover, its outputs are unreliable below 3 Hz and thus it cannot be

relied upon to measure 1R and 1/2 x main rotor (typically less than 2 Hz) with any accuracy. Being analogue it requires pens and operator intervention to record details of the aircraft data, accelerometer location, axis and flight test on every single card. Also its results are a snapshot and do not take into account proper signal averaging. If further trend analysis is required, the results have to be read off the cards and entered into a data storage system.

THE ROTORTUNER

7. Background. Analysis of the growth of our Company's activities into diverse applications of the Helituning techniques and into world-wide military and civilian vibration training programmes, showed that, although the vehicles and situations differed, there was a common thread running through all the problems encountered. They all boiled down to the DIDAT process. We identified a clear requirement for an equipment which would embrace all of the elements and wrote the specification of the ROTORTUNER. Since no equipment existed, we decided 3 years ago to design and build it ourselves as a Private Venture. This we have now done.

8. Features. The main features of the system are:

a. Programs. The ROTORTUNER contains all the generic programs for helicopter vibration management in EPROM. These can be readily updated to incorporate the lesson learned from field use and software enhancements.

b. Tapes. Each helicopter has its own DATA tape specific to the particular model of helicopter. This is used to create TEST tapes specific to each helicopter's tail number from BLANK tapes.

c. Tape Contents. Each TEST tape contains:

(1) All that we know of the helicopter's personality.

(2) The instructions on how to wire up the ROTORTUNER to the aircraft.

(3) The list of vibration excitation frequencies.

(4) A pool of simulation data similar to the actual helicopter.

d. Main Rotor Track. The track is gathered and digitised using a hand-held line scan camera. The camera is pointed at the tip path plane of the rotor at the ahead position and detects the height and time for each blade to pass through the 'beam'. Blade heights are measured to the nearest 1/8" (3mm) and blade timings to the nearest 96 msecs.

e. Data Validation. Track, balance and all vibration Fast Fourier Transform data is validated during the gathering process and checked for consistency. Once accepted, it is analysed, dated and timed, and then automatically stored in compacted digital form onto the digital quality TEST tape.

f. Tape Directory. The TEST tape contains a directory of all tests, adjustment settings, vibration signatures, annotated with the time and date of recording. This provides a complete aircraft vibration history and a technical audit trail of the results, recommendations, actions taken and calibrations of the adjustment sensitivities to the particular tail number. Whenever a directory is requested, the ROTORTUNER reads the remainder of the unused tape and prints "Space available for ... flight tests". A typical directory is shown in Annex D fig 1.

g. Set-up Instructions. The operator may obtain a print of the set-up instructions on a key press, which will show him how to instal the ROTORTUNER. These are shown at fig 2.

h. Vibration Order Sheet. An example of a vibration order sheet is shown at fig 3.

i. Track and Damper Assessment. During the air test, the operator can see the track of the main rotor blades displayed on the screen to an accuracy of 1/8" (3mm) as shown in fig 4. Defective dampers are also identified on the same display.

j. Magnetic Pick-up Pulse. The magnetic pick-up pulse - being the heart of the camera, balance and FFT - is continuously monitored and checked for accuracy. If the quality is inadequate or the pulse is intermittent or fails, the screen is flashed with a warning. If uncorrected, all bets are off.

k. Balance Points. The operator may observe the balance points whilst on condition, to assess their stability as illustrated in fig 5.

l. Vibration Signatures. Up to 20 vibration signatures may be taken during each flight test from any of up to 12 accelerometers (depending upon the customers' requirements). Once an accelerometer is selected for measurement, the ROTORTUNER carries out a Fast Fourier Transform (FFT) on the output. Once this has been done, the display is auto-scaled, displayed and automatically recorded on tape for further analysis if required.

m. Rotor RPM Calibration. If the cursor is placed on the 1R peak of the 0 - 30R vibration signature, rotor frequency is indicated to 2 decimal places of accuracy in Hz, as shown in fig 6. Rotor rpm can be calculated for tacho calibration. Display of the rotor frequency in rpm will be available shortly.

n. Bandwidths and Ranges. The vibration signature bandwidths are 1/8R from 0 - 30R, 5 Hz from 0 - 1.2 kHz and 50 Hz from 0 - 12 kHz, there being 240 spectral lines along the frequency axis.

o. Auto Scaling. The amplitude scales of the balance and FFT displays are automatically scaled to max values of 0.25, 0.5, 1.0 and 5.0 ips. The operator may redisplay the FFTs against any of these scales.

p. Peak Identification/Limits. The FFT displays may be redrawn to reveal only the amplitudes of the known sources of vibration. In this case, the peaks are labelled at the cursor position with the identifying text drawn from the vibration order sheet as shown in fig 7. Coincidentally, the recommended GO/NOGO limits are displayed for each peak, if they are known.

q. Trends and Recommended Action. At the end of the flight test, the operator can call up trends of track and balance. From these, the ROTORTUNER recommends the relevant adjustments of ground track, tabs, balance weights, blade sweep and vertical balance pitch links. A set of examples of trend plots are shown at fig 8.

r. Adjustments. Once the adjustments have been made, the operator is prompted to input the actions that he has taken. These are entered and recorded on the tape and used as calibration moves.

s. Auto Clock Angle Correction. If the balance points do not behave as predicted, the operator can instruct the ROTORTUNER to calibrate itself against the previous flight and the actions which resulted from it. The ROTORTUNER will then calculate the change in the vector angle and length, and give the post-calibration adjustments and record the new adjustment coefficients.

t. Print Identification. Any and every display may be printed. Each print is identified with the aircraft type, the tail number, the DATA tape revision number, the time of recording and the date. If the print was taken during a subsequent REVIEW of the data, the date and time of printing is added to the subscript.

u. Trend Monitoring. The ROTORTUNER may be ordered with an output port for connection to a terminal, such as the IBM PC. We will provide programs to allow the terminal to be used to re-examine the TEST tape in order to display waterfall plots of FFT data. These may be in the form of frequency v amplitude on the Y and X axes, and the different flight conditions on the Z axis. Alternatively, the historical trends of the same flight condition on succeeding dates may also be displayed. Many applications spring to mind. The important point is that once the data has been recorded, it is available for deeper analysis with no overhead for transcription. Throughout the chain, the data is never touched by human hand, although the man is retained in the loop to bring his innate judgement to the solution of the problem. This has been a deliberate policy in the system architecture to ensure that the operator feels an affinity with the ROTORTUNER, enjoys using it and retains the mastery of driving it.

v. Built-In Simulator. The ROTORTUNER has an in-built SIMULATION. It is activated by a key press at the top of the menu structure. This simplifies the training process and provides a brush-up facility prior to a live Helitune. From then on, the ROTORTUNER behaves in the identical way in which the student will drive it in the air. Once the instructor or the operator is satisfied that the menu is understood, the simulation may be switched off and the same ROTORTUNER may be taken to the helicopter for a live test with confidence.

w. Power. The ROTORTUNER may be powered from its internal batteries, from aircraft 24-28 VDC, or from 110 or 240 VAC mains.

x. ROTORTUNER Users Group (RUG). The ROTORTUNER will copy any TEST tape and produce a RUG tape. We appreciate it when operators send a copy of their results back to Helitune to enable us to build up a data bank of user experience. Also, copies may be sent back from remote flights to a central location for fleet management purposes. Being digital data it could be transmitted by wire or satellite if necessary, with far less risk of corruption. We suggest that this is the proper use of data. The man at the sharp end needs the answers immediately to get his aircraft back into service. Later on and in relative calm, the data may be reviewed for underlying trends, as a supervisory or research function, without the need for any manual transcription. We have been very encouraged by the helicopter manufacturers who were amongst the first of our customers. Like us, they see the ROTORTUNER as a bridge between manufacturers and operators, principally because of the hitherto unattainable quality of the data.

9. Size and Price. We understand the comments on the size of the ROTORTUNER, but quite frankly, for its ability to understand and solve problems, it is as small as present technology will allow. Yet if one aggregates the size and weight of the equipments needed to do comparable work, with comparable effectiveness and which it makes redundant, then the ROTORTUNER is a remarkably compact and power efficient equipment. A similar truth emerges when aggregate prices are considered. The quantum leap between the tracking flag and the Vibrex is small compared with the totally different systems approach concept which the ROTORTUNER brings to the requirement of helicopter vibration management.

SUMMARY

10. Existing Equipment. The existing equipment is barely adequate for the task of data acquisition in order to identify the causes and sources of vibration in helicopters and engines, even in the hands of a skilled operator. The interpretation of the data is not fully understood and leads to an iterative process of errors. Decision making is not prompted, formalised, or documented in any orderly way and errors abound. The action which is taken often amounts to inspired guess work which is shown to be very expensive and does not lead to any formalised method of learning from mistakes. Trend analysis is left to a few numerate devotees who have to pay the overhead of labour intensive manual transcription. In short, the system is creaking at the seams and can only be maintained by a massive training and continual re-training bill.

11. The ROTORTUNER. We submit that the ROTORTUNER goes a long way to meet the requirements of the DIDAT process and is the most cost effective method of vibration management. It has great potential to reduce the diagnosis time and correction of faults and hence to reduce the cost of helicopter ownership. Its basic philosophy is to perfect the tuning of the rotors and to seek the minimum vibration levels for each tail number. We should therefore expect the time between vibration problems to increase. Furthermore, it has growth potential and, through different DATA tapes, may be applied to any rotating machinery such as gas turbines, propellers, by-pass jets, submarine diesels, gearboxes, shafts, airships, hovercraft, trains, high speed diesels, tanks, ships machinery, turbines and the whole host of industrial plant and machinery. If connected to microphones it will become a noise analyser; to strain gauges - a stress analyser; to engine temperatures, pressures, fuel flow and rpm indicators - an on-board engine test set. In short, a very versatile tool built by practicing engineers for maintenance engineers. It is at the very lift off point of its lifespan and usefulness. We are sure that it is the only equipment available now or for the foreseeable future, to meet the requirements for vibration management and research.

THE FUTURE

12. I hesitate to make predictions for fear of disappointing what we believe is an eager market. However it is clear that we should now concentrate on creating a higher level of intelligence in the system, shrink its size and work towards building the system into all new helicopters which should also be designed to have active control of adjustments capable of being used in flight.

HELITUNE MCT Ltd.,
9, Kings Road,
FLEET,
Hampshire,
England GU13 9AA

Tel: (02514)4798 Tx: 858893 FLETEL G

Annex:

A. Top Ten Defect Arising - Typical Helicopter
B. Example of Tracking, Balancing and Vibration Defect Arisings
C. Number of Arisings by Symptom
D. ROTORTUNER Display Prints

List of Figures:

ANNEX A1

TOP TEN DEFECT ARISINGS

HELICOPTER TYPE A

Ranking	Arising Rate per 1000 Flying Hours	Man Hour Rate per 1000 Flying Hours	System
a.	b.	c.	d.
1.	83.0	273.4	Communications
2.	78.2	892.3	Transmission/ Gearboxes
3.	59.2	253.9	Structures
4.	57.3	300.9	Main Rotor Head and Blades
5.	48.8	67.0	Lighting
6.	30.7	108.2	Doors
7.	29.8	109.6	Engine Indicating
8.	27.2	452.3	Power Plant
9.	27.2	146.2	Hydraulic Power
10.	25.7	103.3	Flight Navigation

Note:

1. Radios are particularly susceptible to vibration.
2. Out of balance shafts in transmissions cause case cracking and leaks which nearly always result in a gearbox rejection, hence the high manhour content.

TOP TEN DEFECT ARISINGS

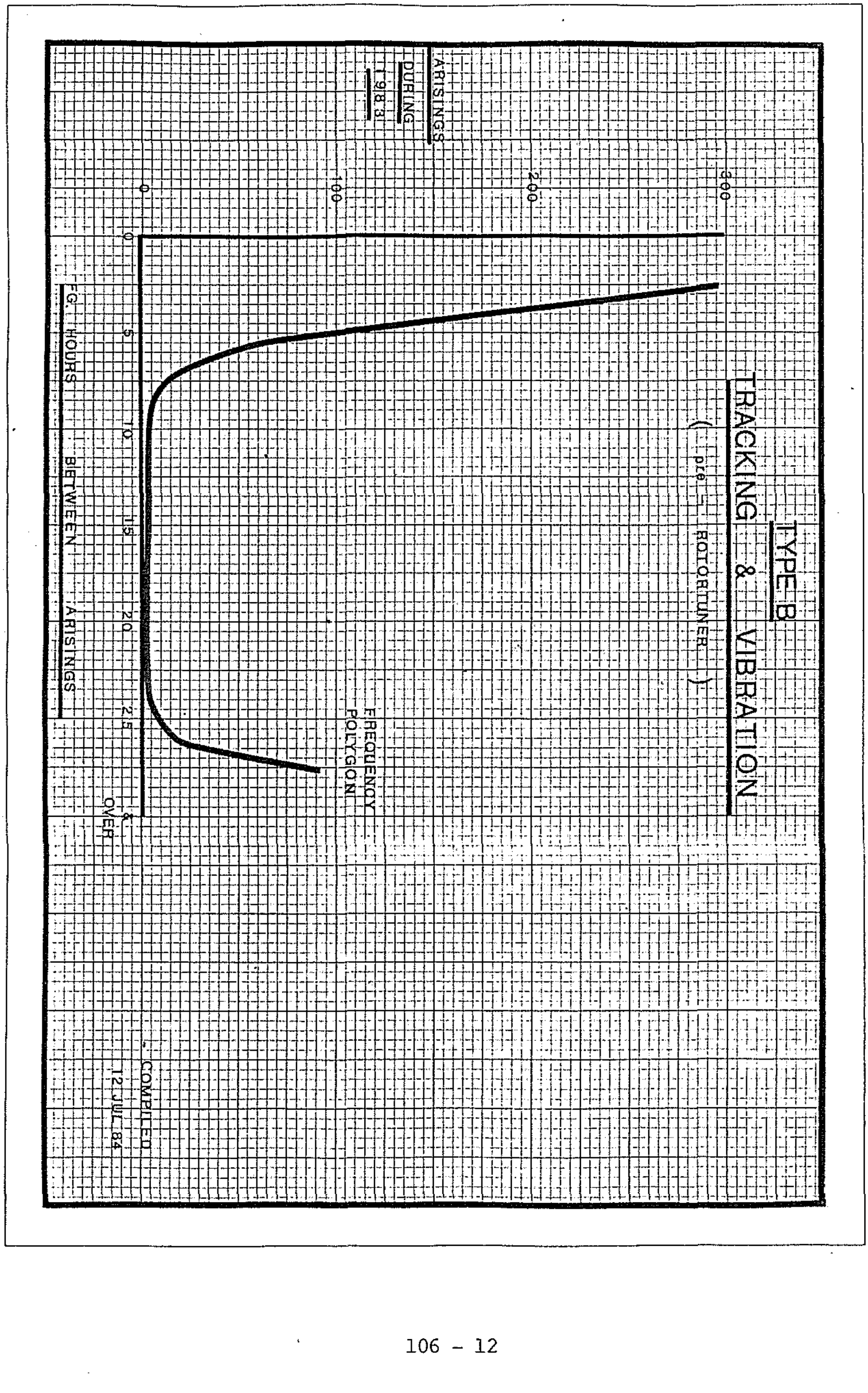
HELICOPTER TYPE B

Ranking a.	Arising Rate per 1000 Flying Hours b.	Man Hour Rate per 1000 Flying Hours c.	System d.
1.	178.5	1133.7	Fuselage
2.	83.4	378.0	Main Rotor Head and Blades
3.	81.7	365.8	Communications
4.	79.4	351.1	Power Plant
5.	71.1	383.9	Transmission
6.	63.9	170.8	Doors
7.	59.9	370.3	Flying Controls
8.	46.5	112.6	Furnishings
9.	40.6	175.4	Navigation
10.	35.3	171.2	Alighting Gear

Note: 1. This helicopter has a delicate structure. Cumulative vibration damage probably accounts for the bulk of the arisings.

2. Note the similarity with the previous helicopter.

ANNEX B

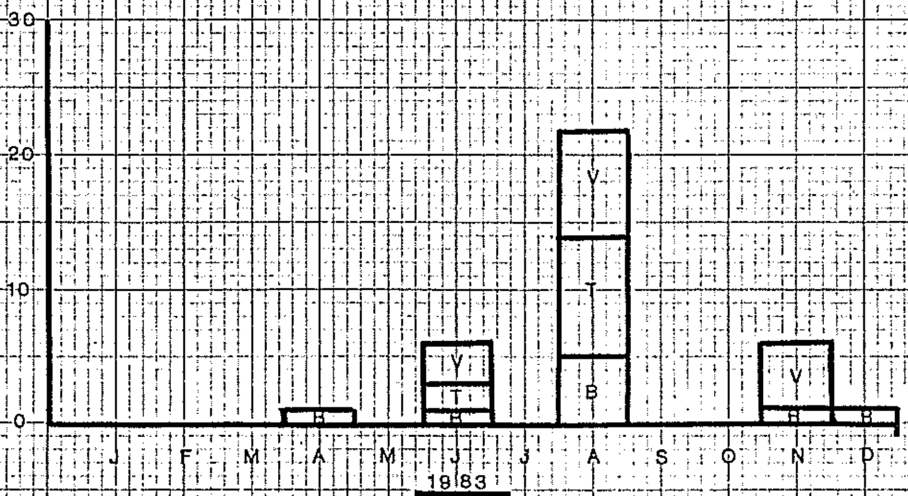


TYPE B
TRACKING & VIBRATION
(pre - ROTORTUNER)
ARISINGS
DURING
1983
300
200
100
0
0
5
10
15
20
25
& OVER
FG. HOURS BETWEEN ARISINGS
FREQUENCY POLYGON
COMPILED
12 JUL 84

NUMBER OF ARISINGS BY SYMPTOM

TYPE B, TAIL No XYZ

1983



V VIBRATION   T TRACKING   B BALANCE

RECTIFICATION

BLADE / HEAD ADJUSTMENT	27
BLADE REPLACEMENT	8
DAMPER ADJUSTMENT	1
DAMPER REPLACEMENT	7
OTHER	1

ANNEX D

FIG. 1

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Tape contents
-------------

Test 1
settings 1   11:6:40       25-Jun-84
flight   1   11:6:50       25-Jun-84
flight   2   11:33:26      25-Jun-84
flight   2 vibration signatures:
  REAR CABIN LATERAL
    at ground, 30R
    at 60 knts, 1kHz
    at 100 knts, 10kHz
  INST CONSOL VERTICAL
    at ground, 30R
    at 60 knts, 1kHz
    at 100 knts, 30R, 10kHz
flight   3   11:43:10      25-Jun-84
flight   4   17:29:8       26-Jun-84
flight   5   17:42:8       26-Jun-84
settings 5   17:39:40      26-Jun-84
flight   6   10:53:36      28-Jun-84
settings 6   10:14:1       28-Jun-84
flight   6 vibration signatures:
  REAR CABIN LATERAL
    at ground, 30R
    at hover, 30R
    at 60 knts, 30R
    at 80 knts, 30R
    at 100 knts, 30R, 1kHz, 10kHz
  INST CONSOL VERTICAL
    at ground, 30R
    at hover, 30R
    at 60 knts, 30R
    at 80 knts, 30R
    at 100 knts, 30R, 1kHz, 10kHz
flight   7   12:14:32      28-Jun-84
settings 7   12:14:9       28-Jun-84
flight   7 vibration signatures:
  REAR CABIN LATERAL
    at ground, 30R
    at hover, 30R
    at 60 knts, 30R
  INST CONSOL VERTICAL
    at ground, 30R
    at hover, 30R
flight   8   12:50:49      28-Jun-84
settings 8   12:54:44      28-Jun-84
flight   9   13:33:51      28-Jun-84
settings 9   13:33:23      28-Jun-84
flight   10  14:37:24      28-Jun-84
settings 10  13:42:53      28-Jun-84
flight   10 vibration signatures:
  REAR CABIN LATERAL
    at 100 knts, 30R, 1kHz, 10kHz
  INST CONSOL VERTICAL
    at 100 knts, 30R, 1kHz, 10kHz


Space available for 15 more flights


B212 RV3 SP212  Test 1  Flight 10
printed at  - 10:35:14    17-Jul-84
```

ROTORTUNER Set Up Instructions

MAGNETIC PICK-UP: SET GAP TO 0.060" +/-0.010". CONNECT CABLE TO MAG P/U INPUT 1 ON INTERFACE UNIT.

LATERAL ACCELEROMETER:ATTACH TO MAIN GEARBOX POINTING TO 3o'CLOCK. CONNECT CABLE TO ACCELEROMETER INPUT 1 ON INTERFACE UNIT.

VERTICAL ACCELEROMETER: ATTACH TO FORWARD INSTRUMENT CONSOL LOWER RIGHTHAND SIDE CONNECTOR POINTING DOWNWARDS.

BLADE IDENTITY:
ALIGN MAG P/U & INTERUPTER.
BLADE 1 = 12.00 o'clock
BLADE 2 = 3.00 o'clock
BLADE 3 = 6.00 o'clock
BLADE 4 = 9.00 o'clock

HELITUNE SEQUENCE:
CORRECT GROSS ERRORS 1st
1.MAKE GOOD GRD TRACK ON PITCH LINKS
2.TEST FLY,TAB CLIMB/DIVE BLADES
3.CHANGE ANY PERSISTANT U/S DAMPERS
4.SEE LATBAL TREND,CORRECT BY WGTS
5.SEE VERTBAL TREND,ADJ PITCH LINKS
6.CORRECT ANY RESIDUAL LATBAL
7.SET AUTO REVS

MINILYNX XZ379 Test 0 Flight 0
printed at - 10:8:41 12-Jul-84

ANNEX D

FIG. 3

ROTORTUNER Order Sheet

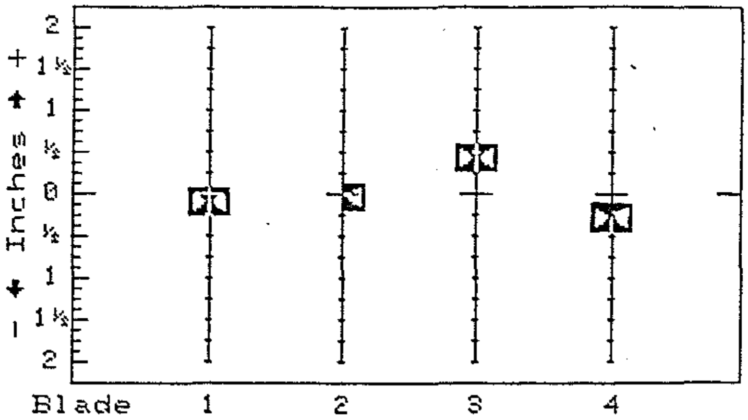
Description:	Frequency (*1R):	Frequency (*1Hz):
HALF R	0.50	2.50
1R	1.00	5.00
1* MAIN DRIVE WHEEL	1.00	5.00
2R	2.00	10.00
4R	4.00	20.00
1T	4.80	24.00
1S	4.80	24.00
6R	6.00	30.00
8R	8.00	40.00
2* TAIL DRIVE SHAFT	9.60	48.00
1* INPUT DRIVE	9.86	49.30
12R	12.00	60.00
16R	16.00	80.00
4T	19.20	96.00
2* INPUT DRIVE	19.73	98.65
20R	20.00	100.00
8T	38.40	192.00
M. TAIL OUTPUT BEVEL GEAR	75.00	375.00
M. MAIN GEAR	86.00	430.00
M. TAIL DRIVESHAFT GEAR	96.00	480.00
M. INPUT GEAR	98.66	493.30

MINILYNX XZ879 Test 1 Flight 1
printed at - 10:16:38 12-Jul-84

FIG. 4

Helitune MCT - ROTORTUNER

Main Rotor Track Display
Correction: Consult Track Trend



Speed = Ground (Avg)

MINILYNX XZ379 Test 1 Flight 2
printed at - 10:4:26 12-Jul-84

FIG. 5

Helitune MCT - ROTORTUNER

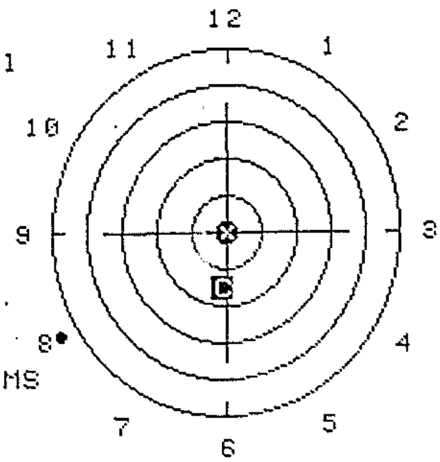
Main Rotor Balance Display

Axis = Lateral
Speed = Trend

Max Scale =
5.00 IPS

To Correct
Balance:

BLD3:+ 37.49 GRMS



MINILYNX XZ379 Test 1 Flight 2
printed at - 10:11:2 12-Jul-84

ANNEX D

FIG. 6

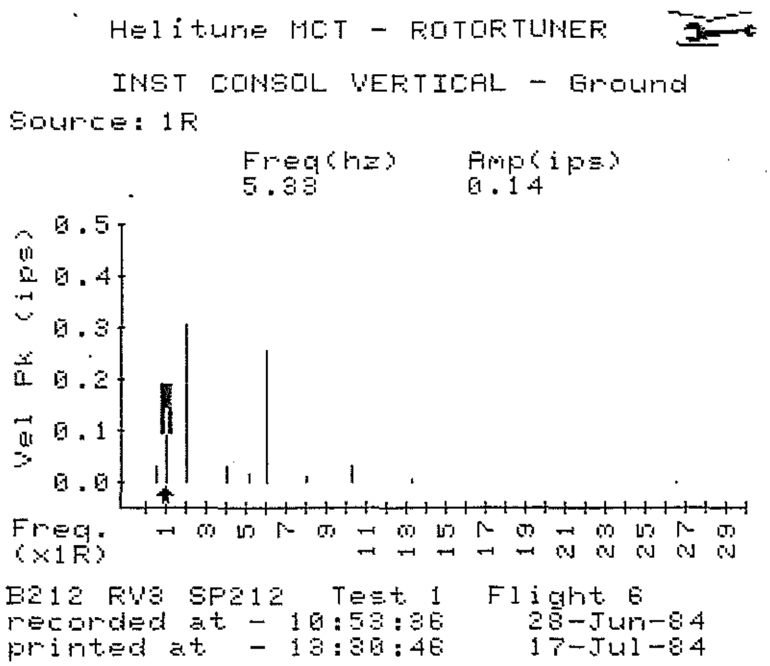
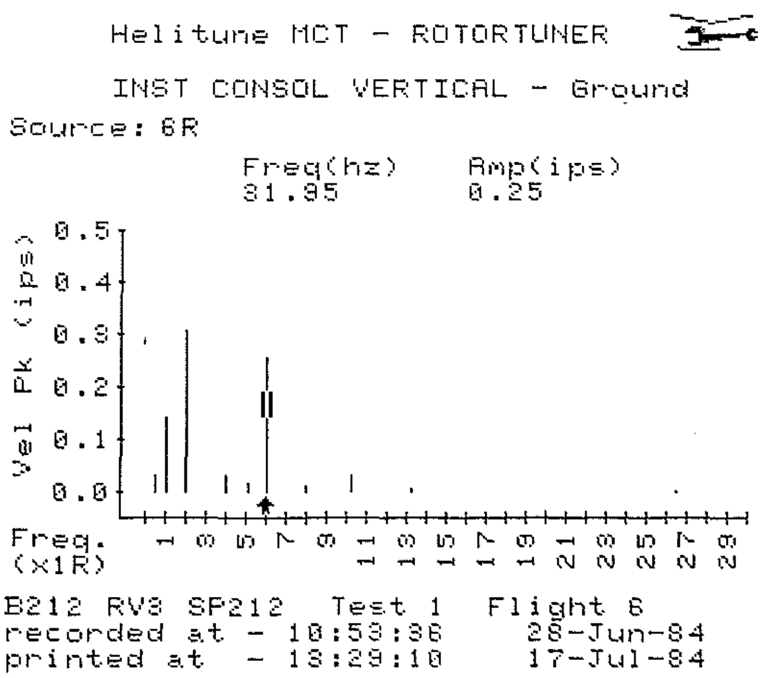
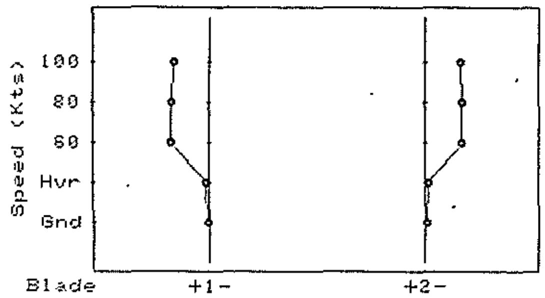


FIG. 7



Helitune MCT - ROTORTUNER

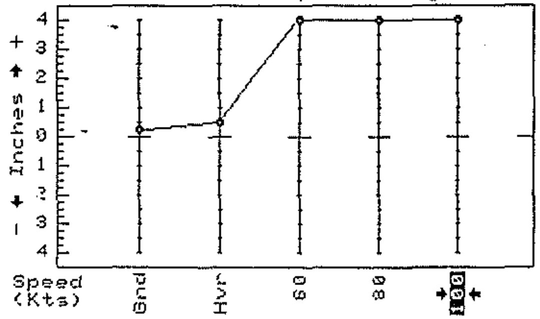
Main Rotor Trend Chart



B212 RV3 SP212 Test 1 Flight 6
recorded at - 10:53:36 28-Jun-84
printed at - 13:38:51 17-Jul-84

Helitune MCT - ROTORTUNER

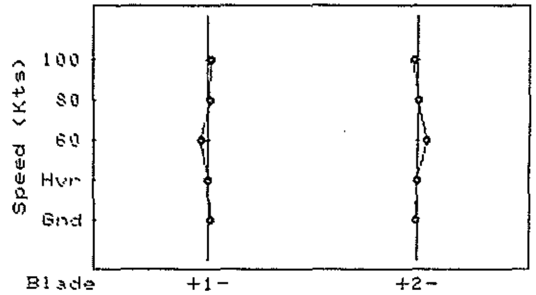
Main Rotor Blade 1 Trend Versus 2
Correction: Tab up 0.50 degrees



B212 RV3 SP212 Test 1 Flight 6
recorded at - 10:53:36 28-Jun-84
printed at - 13:40:22 17-Jul-84

Helitune MCT - ROTORTUNER

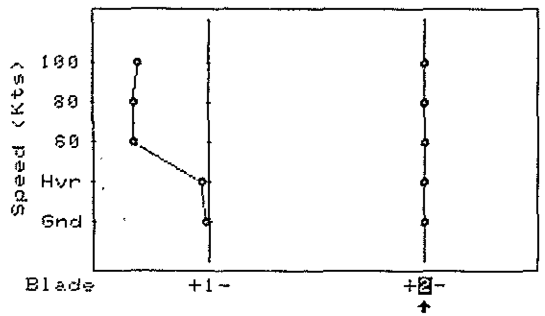
Main Rotor Trend Chart



B212 RV3 SP212 Test 1 Flight 10
recorded at - 14:37:24 28-Jun-84
printed at - 13:50:34 17-Jul-84

Helitune MCT - ROTORTUNER

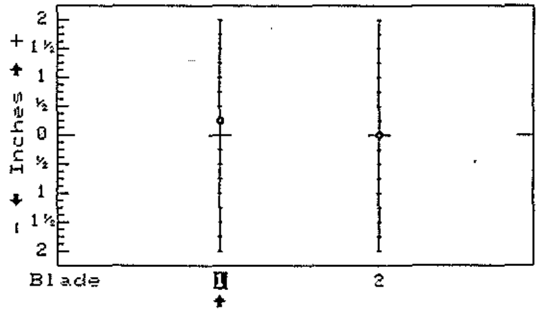
Main Rotor Trend Chart



B212 RV3 SP212 Test 1 Flight 6
recorded at - 10:53:36 28-Jun-84
printed at - 13:39:25 17-Jul-84

Helitune MCT - ROTORTUNER

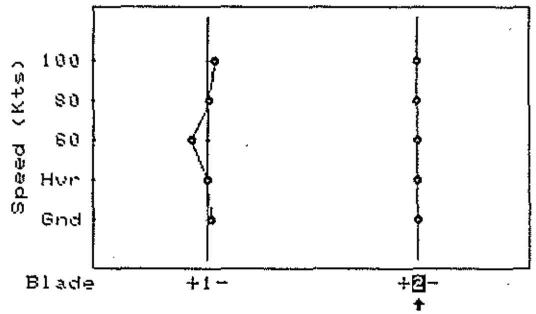
Main Rotor Ground Trend Versus 2
Correction: Pitch down 0.75 FLTS



B212 RV3 SP212 Test 1 Flight 6
recorded at - 10:53:36 28-Jun-84
printed at - 13:41:2 17-Jul-84

Helitune MCT - ROTORTUNER

Main Rotor Trend Chart



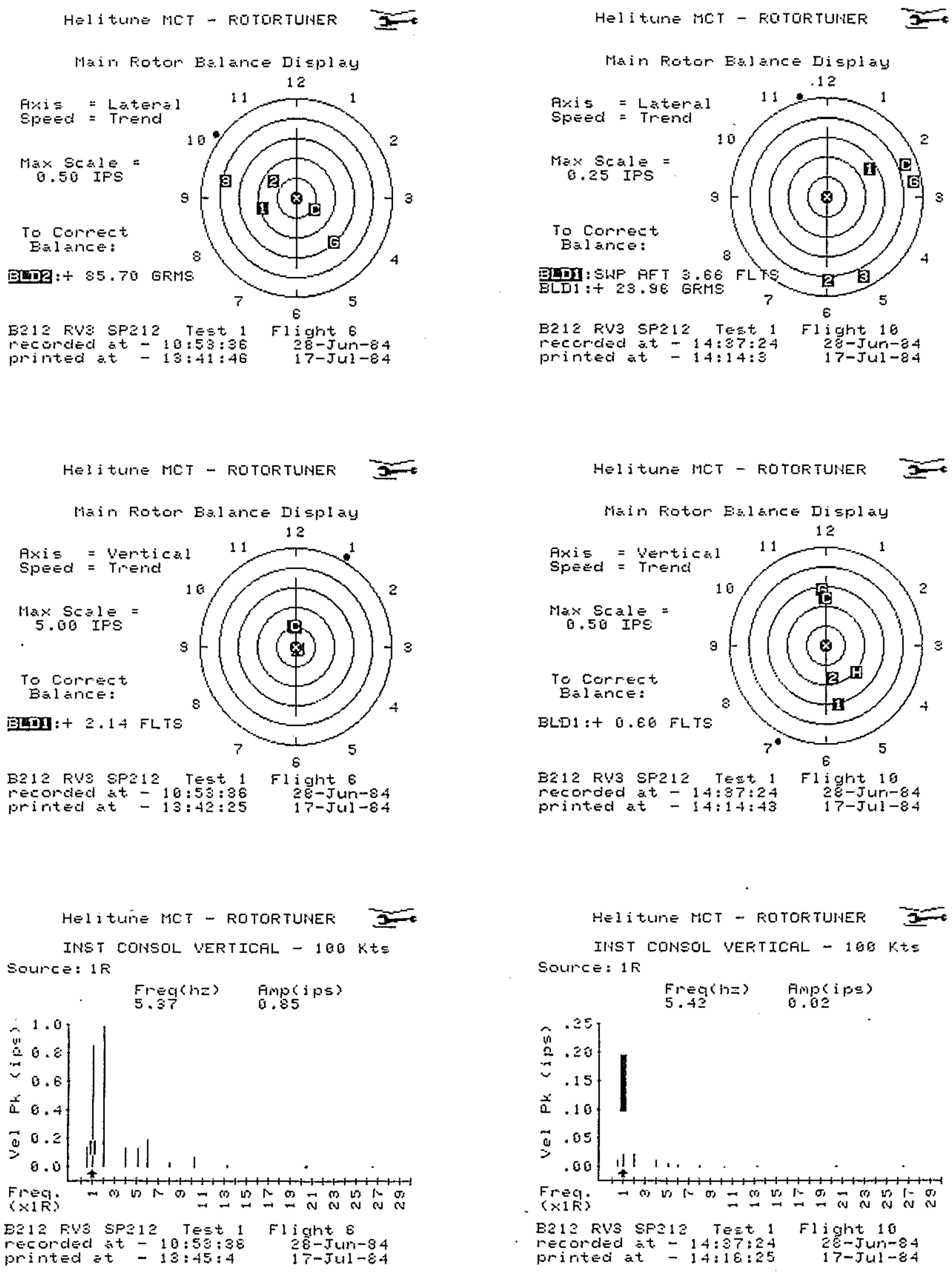
B212 RV3 SP212 Test 1 Flight 10
recorded at - 14:37:24 28-Jun-84
printed at - 13:51:13 17-Jul-84

BEFORE CORRECTIONS AFTER

ANNEX D
FIG. 8

ANNEX D

FIG. 8


Helitune MCT - ROTORTUNER
Main Rotor Balance Display
Axis = Lateral
Speed = Trend
Max Scale = 0.50 IPS
To Correct Balance:
BLD2:+ 85.70 GRMS
B212 RV3 SP212 Test 1 Flight 6
recorded at - 10:53:36 28-Jun-84
printed at - 13:41:46 17-Jul-84
Helitune MCT - ROTORTUNER
Main Rotor Balance Display
Axis = Lateral
Speed = Trend
Max Scale = 0.25 IPS
To Correct Balance:
BLD1:SWP AFT 3.66 FLTS
BLD1:+ 23.96 GRMS
B212 RV3 SP212 Test 1 Flight 10
recorded at - 14:37:24 28-Jun-84
printed at - 14:14:3 17-Jul-84
Helitune MCT - ROTORTUNER
Main Rotor Balance Display
Axis = Vertical
Speed = Trend
Max Scale = 5.00 IPS
To Correct Balance:
BLD1:+ 2.14 FLTS
B212 RV3 SP212 Test 1 Flight 6
recorded at - 10:53:36 28-Jun-84
printed at - 13:42:25 17-Jul-84
Helitune MCT - ROTORTUNER
Main Rotor Balance Display
Axis = Vertical
Speed = Trend
Max Scale = 0.50 IPS
To Correct Balance:
BLD1:+ 0.60 FLTS
B212 RV3 SP212 Test 1 Flight 10
recorded at - 14:37:24 28-Jun-84
printed at - 14:14:43 17-Jul-84
Helitune MCT - ROTORTUNER
INST CONSOL VERTICAL - 100 Kts
Source: 1R
Freq(hz) 5.37
Amp(ips) 0.85
Vel Pk (ips)
Freq. (x1R)
B212 RV3 SP212 Test 1 Flight 6
recorded at - 10:53:36 28-Jun-84
printed at - 13:45:4 17-Jul-84
Helitune MCT - ROTORTUNER
INST CONSOL VERTICAL - 100 Kts
Source: 1R
Freq(hz) 5.42
Amp(ips) 0.02
Vel Pk (ips)
Freq. (x1R)
B212 RV3 SP212 Test 1 Flight 10
recorded at - 14:37:24 28-Jun-84
printed at - 14:16:25 17-Jul-84