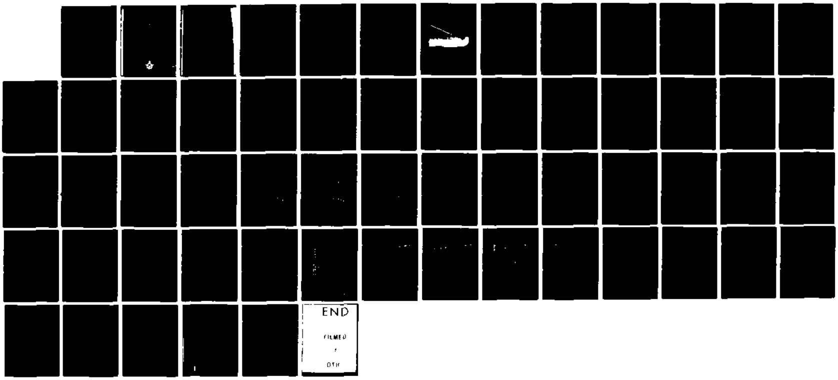
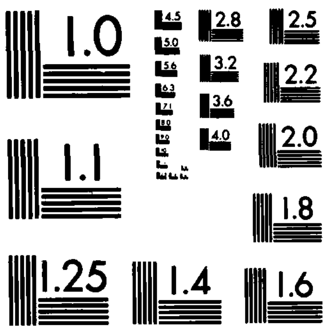
AD-A122 302 EVALUATION OF IROQUOIS UH-1B STABILITY AND CONTROL(U) 1/1
AIRCRAFT RESEARCH AND DEVELOPMENT UNIT EDINBURGH
(AUSTRALIA) L R WARD SEP 82 ARDU-TI-783

UNCLASSIFIED F/G 1/3 NL




1.0
4.5
5.0
5.6
6.3
2.8
3.2
3.6
4.0
2.5
2.2
2.0
1.1
1.8
1.25
1.4
1.6

ARDU-TI-783 AR-002-498



AUSTRALIA

DEPARTMENT OF DEFENCE

ROYAL AUSTRALIAN AIR FORCE

AIRCRAFT RESEARCH AND DEVELOPMENT UNIT

EDINBURGH, SOUTH AUSTRALIA

# TECHNICAL INVESTIGATION NO 783

# EVALUATION OF IROQUOIS UH-1B STABILITY AND CONTROL



PER ARDUA AD ASTRA



COPY NO 23

SEPTEMBER 1982

ACTION AUTHORITY

This report is for the communication of information and is not an authority. Any action required within the RAAF will be authorised by Headquarters Support Command.

Security classification of this page: UNCLAS

# DOCUMENT CONTROL DATA SHEET

| 1 DOCUMENT NUMBERS | | 2 SECURITY CLASSIFICATION | |
|---|---|---|---|
| AR Number: | AR-002-498 | a. Complete Document: | UNCLAS |
| Report Number: | ARDU-TI-783 | b. Title in Isolation: | UNCLAS |
| Other Numbers: | | c. Summary in Isolation: | UNCLAS |

**3 TITLE**

EVALUATION OF IROQUOIS UH-1B STABILITY AND CONTROL

**4 PERSONAL AUTHOR(S):**

FLTLT L.R. WARD

**5 RECLASSIFICATION AND CONTROL REVIEW AUTHORITY**

**6 DOCUMENT DATE:**

SEPTEMBER 1982

**7 CORPORATE AUTHOR(S):**

Aircraft Research and Development Unit

**8 REFERENCE NUMBERS:**

a. Task: TI 783

b. Sponsoring Agency: HQSC SENGSO

**9 COMPUTER PROGRAM(S): (Title(s) and language(s))**

**10. RELEASE LIMITATIONS:**

Approved for Public Release

Security classification of this page: UNCLAS

Security classification of this page | UNCLAS

11. ANNOUNCEMENT LIMITATIONS (of the information on these pages):

Unlimited

12. DESCRIPTORS:

Helicopter
Bell 204A
UH-1B
Flight Test
Stability
Control

13. COSATI CODES:

0102

14. SUMMARY OR ABSTRACT:

(if this is security classified, the announcement of this report will be similarly classified)

The purpose of this investigation was to evaluate the forward flight flying qualities of the Iroquois UH-1B helicopter for the Training and SAR missions as conducted by the Royal Australian Air Force.

Several unsatisfactory handling characteristics were identified. Highly undesirable features included the rapidly divergent longitudinal long term response in maximum power climbs; excessive vibration levels; coupling of sideslip to pitching moments; excessive trim changes when transitioning from climb to descent; and non-linearities in the collective fixed static longitudinal stability gradients in maximum power climbs. Undesirable features included the level flight gust response; longitudinal control response in level flight; lateral-directional oscillation; and adverse yaw.

Possible causes of the extremely divergent longitudinal long term response in high powered climbs and the sideslip-pitch coupling are discussed.

Security classification of this page | UNCLAS

# AIRCRAFT RESEARCH AND DEVELOPMENT UNIT

## EVALUATION OF IROQUOIS UH-1B STABILITY AND CONTROL


Project Officer:

(L.R. WARD)
Flight Lieutenant

Approved By:

(P.G. NICHOLSON)
Wing Commander
OIC Flight Test Squadron

(R.G. GREEN)
Group Captain
Commanding Officer


ARDU File Reference: 2535/2/783/Tech

HQSC File Reference: 3000/7/1-783

DEPARTMENT OF DEFENCE

ROYAL AUSTRALIAN AIR FORCE

AIRCRAFT RESEARCH AND DEVELOPMENT UNIT

TECHNICAL INVESTIGATION NO 783

# EVALUATION OF IROQUOIS UH-1B STABILITY AND CONTROL



## SUMMARY

The purpose of this investigation was to evaluate the forward flight flying qualities of the Iroquois UH-1B helicopter for the Training and SAR missions as conducted by the Royal Australian Air Force.

Several unsatisfactory handling characteristics were identified. Highly undesirable features included the rapidly divergent longitudinal long term response in maximum power climbs; excessive vibration levels; coupling of sideslip to pitching moments; excessive trim changes when transitioning from climb to descent; and non-linearities in the collective fixed static longitudinal stability gradients in maximum power climbs. Undesirable features included the level flight gust response; longitudinal control response in level flight; lateral-directional oscillation; and adverse yaw.

Possible causes of the extremely divergent longitudinal long term response in high powered climbs and the sideslip-pitch coupling are discussed.

LIST OF CONTENTS

## LIST OF TABLES



## LIST OF FIGURES



## ANNEXES

# EVALUATION OF IROQUOIS UH-1B STABILITY AND CONTROL

## 1. INTRODUCTION

### 1.1 Background

1.1.1 Reference A tasked Aircraft Research and Development Unit (ARDU) to conduct an analytic study, followed if necessary by flight tests, to determine the stability and control characteristics of Iroquois UH-1B and UH-1H aircraft. The task was initiated as part of the investigation into the accident involving UH-1B A2-1023 on 19 August 1981. On 13 August 1981, this aircraft was involved in an incident in which an uncommanded nose-down pitch occurred as level-off was initiated after a climb. During a subsequent test flight to determine the cause of the nose-down pitching incident the aircraft crashed. Investigations have concluded that the two occurrences were not directly related.

1.1.2 The study of all available reports showed that reasonable stability and control data was available for the 'H' model, but there was a dearth of information for the 'B' model, especially in the RAAF Search and Rescue (SAR) configuration. The 'H' models were released for flight (Reference B) on 17 September 1981 based on the results of the review of the available reports and determination that the cause of the accident was unrelated to that model. The 'B' models remained withdrawn from service pending modification to obviate the cause of the accident.

1.1.3 During discussions involving Department of Defence (Air Force Office), Headquarters Support Command (HQSC), and ARDU representatives, a proposal was made to conduct a limited evaluation of a suitably modified UH-1B. The series of flight tests, mainly qualitative in nature, was to provide a basis to clear the UH-1B fleet for flight throughout most of the flight envelope. Reference C authorized the proposed tests. This final report amplifies the interim ARDU report (Reference D) and completes the reporting requirements of Reference A.

1.2 Purpose. The purpose of this investigation was to evaluate the forward flight flying qualities of the Iroquois UH-1B helicopter for the Training and SAR missions as conducted by the RAAF.

## 2. CONDITIONS RELEVANT TO TESTS

2.1 Description of Test Aircraft. The Bell Helicopter Textron UH-1B Iroquois is an 8,500 lbf maximum Gross Weight (GW) utility helicopter configured with a two-bladed 44 ft diameter teetering-head main rotor and an 8.5 ft diameter tail rotor. The aircraft is powered by a single Lycoming T53-L-11 free turbine engine capable of developing 1,100 SHP at sea level, standard day conditions. The flight control system is a positive mechanical, irreversible (hydraulic boosted) type which incorporates a force trim system using magnetic brakes and force gradient springs for artificial control feel and centring. The tail boom supports a synchronous elevator and a vertical fin which are designed to aid, respectively, longitudinal and directional stability and control. The synchronous elevator incidence is programmed as a function of longitudinal tilt of the main rotor swash plate by means of a push-pull rod system which incorporates an over-centre bellcrank. A plot of the design variation of synchronous elevator incidence is shown in Annex A, Figure 1. The elevator lift curve ($C_L$ versus $\alpha$) as derived from wind-tunnel tests is shown in Annex A, Figure 2. For operational use, the aircraft is normally configured with an external load cargo hook and a rescue hoist. Externally-mounted 60 US-gallon auxiliary fuel tanks may be fitted to increase endurance for the SAR role. A detailed description of the helicopter, applicable operating limits and flight characteristics is given in Reference E, Sections 1, 5 and 6. The test helicopter, A2-1022, was a representative squadron UH-1B.

## 2.2 Scope of Tests

2.2.1 Test Configurations. The weight and balance of the UH-1B was computed for various representative mission configurations. In the interests of economy, and to provide data which could be related to the RAAF SAR and training missions, the four configurations detailed in Table 2.1, and referred to throughout this report, were evaluated. Evaluation of the SAR 3 configuration was limited to one flight to determine if empty external fuel tanks had any significant effect on aircraft flying qualities. The target average test GW and longitudinal centre of gravity (CG) were achieved by adjusting the engine start GW and CG with appropriate ballast to account for the expected variation due to fuel burn-off during each flight.

TABLE 2.1 - TEST CONFIGURATIONS

| Configuration | Target Average GW (lbf) | Target Average Longitudinal CG (in) | External Tanks |
|---|---|---|---|
| Training | 6,500 | 133.0 | Off |
| SAR 1 | 7,250 | 130.5 | Off |
| SAR 2 | 8,000 | 128.0 | On/Full |
| SAR 3 | 6,400' | 134.0 | On/Empty |

2.2.2 Tests Made. Iroquois UH-1B A2-1022 was evaluated in eleven flights totalling 15.7 hours under daylight visual meteorological conditions. Tests made and the relevant conditions are detailed in Annex B. Prior to the test flights, ground runs and hover/taxi tests totalling 2.3 flight hours were made to evaluate tail rotor pitch control cable vibration modes and the suitability of cable shrouds installed under Reference F.

2.2.3 Test Envelope. The tests were conducted within the limits contained in Reference E, Section 5 and the special test limits defined in Annex C.

## 2.3 Methods of Test

2.3 Methods of Test. Test methods were generally in accordance with those contained in Reference G. Where appropriate, more detailed descriptions of methods of test are included in the Results and Discussion section of this report. Handling Qualities Ratings (HQR) were assigned as defined in Reference H. A relevant extract from the document is included at Annex D.

2.4 Instrumentation and Special Test Equipment. Due to time constraints and other tasking, full instrumentation of the helicopter was not possible. This limited the amount of data gathered and many test results are, therefore, of a qualitative rather than quantitative nature. Units of control positions and inputs cited in the body of this report are those which were actually measured. For ease of reference, control position data have been converted to percentages for presentation in Annex A. The following rudimentary instrumentation and special test equipment were use :

a. Prepared data cards.

b. Voice tape recorder connected into the intercommunication system.

c. Mechanical control position indicators for longitudinal cyclic and

d. Control input jigs for cyclic, collective and pedals.

e. Stop-watch.

f. A Photosonics 1VN cine camera, set to 24 frames per second, mounted in the cockpit to record data from the pilot's cockpit instruments.

g. The under-surfaces of the synchronous elevators were tufted and two Photosonics 1VN cine cameras, set to 48 or 100 frames per second, were mounted under the tail boom to record the behaviour of airflow around the elevators under various flight conditions.

h. A qualified test pilot flew as chase pilot in either a CT-4A Airtrainer or Bell 206B-1 for all test flights.

## 3. RESULTS AND DISCUSSION

### 3.1 Trimmed Control Positions - Level Flight

3.1.1 Purpose and Method of Test. This test was conducted to determine the trim changes required to be made by the pilot for level flight at varying airspeeds. The effect of power on control margins, and the presence of any discontinuities, non-linearities or excessive control displacements were of particular interest. The minimum acceptable control margin was considered to be 10% control travel remaining to the mechanical limit. The helicopter was trimmed at various airspeeds in straight and level flight under the conditions given in Annex B, Serial 1. The collective lever was adjusted at each trim point to maintain level flight. When stabilized, the relevant parameters were recorded.

3.1.2 Results and Discussion. The variation of longitudinal cyclic and pedal control positions with airspeed is shown in Annex A, Figure 3. For all conditions tested, adequate longitudinal control margins were available, the minimums occurring at the maximum level flight airspeeds attained. The maximum airspeeds were limited by power available, vibration levels or placarded $V_{NE}$. No discontinuities or non-linearities were noted. The effects of gross weight, longitudinal CG and configuration are reflected by the vertical shift and gradient change (especially for the SAR 2 configuration) of the longitudinal cyclic position curves. Linear extrapolation of the curves to 120 KIAS also shows that adequate margins would remain, the minimum being 12.5% from full forward for the SAR 3 configuration. The margin at 120 KIAS may reduce to less than 10% if the helicopter is operated at CG aft of those tested (aft limit 136 inches for gross weight 6,000 lbf to 8,500 lbf), but operation of the helicopter in this regime is highly unlikely since the aircraft is normally crewed by at least two personnel and the addition of cargo in the cabin moves the CG forward. For the configurations tested, pedal position varied only $\pm 10\%$ (approximately) from the pedals level position (50%). In general, increased left pedal was required with increased airspeed. Although minor non-linearities were exhibited, these did not cause any significant trimming or control problems. Comparison of the pedal position data of Annex A, Figure 3 with the tail rotor blade pitch data of Annex A, Figure 4 shows that, although only minor variations from pedals level were required for trimmed level flight, significant tail rotor pitch was still required. The deduction is that tail rotor thrust is high in forward flight and, consequently, large right yawing moments could be expected if a malfunction caused loss of tail rotor thrust.

3.1.3 Conclusion. Under the conditions tested, the trimmed control positions in level flight were satisfactory.

## 3.2 Trimmed Control Positions - Climb and Descent

3.2.1 Purpose and Method of Test. This test was conducted to determine the trim changes required to be made by the pilot when airspeed is held constant and power is adjusted to develop rates of climb or descent. The test gives an indication of what will happen to the aircraft if the pilot is not alert to power-related trim changes due to preoccupation with some other mission requirement. The aircraft was trimmed at various airspeeds in climbs at approximately 1,000 ft/min and maximum power, and in descents at approximately 1,000 ft/min and autorotation. When stabilized at the conditions given in Annex B, Serial 2, the relevant parameters were recorded.

3.2.2 Results and Discussion. The variation of longitudinal cyclic and pedal control positions with airspeed and flight condition is shown in Annex A, Figure 5. As noted, data for maximum power climbs and autorotational descents are not shown since the longitudinal cyclic positions were generally within plus or minus one percent of the data presented. The variations of longitudinal cyclic position with airspeed were approximately linear. Longitudinal control margins were adequate, the minimum margin of 20% from full forward occurring when climbing at 100 KIAS in the Training configuration. A longitudinal cyclic retrim of approximately 10% aft was required when transitioning from climb to descent in each configuration. Although lateral cyclic position was not instrumented, a right lateral retrim of some 3-4 cm (at the hand grip) was also required when transitioning from climb to descent. The amount of retrimming required indicated that significant pitching and rolling moments accompanied power changes and added to pilot workload, especially in terrain flight, level-offs and instrument flight. The pedal position data show that retrims of 15-25% were required when transitioning from climb to descent, reflecting the large change in anti-torque requirements. These retrimming requirements further added to pilot workload although the aircraft remained completely controllable, with adequate control margins, in all conditions tested.

3.2.3 Conclusion. Although cyclic and pedal retrimming requirements when transitioning from climb to descent were excessive, and therefore unsatisfactory, the trimmed control positions in climb and descent were acceptable under the conditions tested.

## 3.3 Collective Fixed Static Longitudinal Stability - Level Flight

3.3.1 Purpose and Method of Test. This test was conducted to determine the character of the longitudinal restoring moment generated as a consequence of airspeed disturbances in level flight. The longitudinal control displacement from trim indicates the changes in the aerodynamic rotor moment and fuselage pitching moments generated as a direct result of the related speed change, assuming longitudinal control power remains essentially constant for the airspeed band around the test trim point. The helicopter was trimmed in level flight under the conditions given in Annex B, Serial 3. Airspeed was then increased and decreased by approximately 10 KIAS about the trim point by using only the longitudinal cyclic control. Power (collective) was held constant at the initial trim value of each test point. When stabilized at the desired airspeed, the relevant parameters were recorded.

3.3.2 Results and Discussion. The collective fixed static longitudinal stability data for level flight are shown in Annex A, Figure 6. Although minor non-linearities were present about some trim points, the helicopter exhibited positive static longitudinal stability for all airspeeds and configurations tested. The average gradients for the airspeed envelopes tested are given in Table 3.1. These gradients were sufficient for longitudinal control displacement to be used as a satisfactory cue of airspeed.

TABLE 3.1 - AVERAGE STATIC LONGITUDINAL STABILITY GRADIENTS (LEVEL FLIGHT)

| Configuration | Gradient (Percent Longitudinal Control Displacement Per Knot IAS) |
|---|---|
| Training | 0.18 |
| SAR 1 | 0.30 |
| SAR 2 | 0.33 |
| SAR 3 | 0.21 |

3.3.3 Conclusion. Under the conditions tested, the level flight collective fixed static longitudinal stability was satisfactory.

3.4 Collective Fixed Static Longitudinal Stability - Maximum Power Climbs

3.4.1 Purpose and Method of Test. This test was conducted to determine the effects of configuration, power and rate-of-climb on the static longitudinal stability of the helicopter. The helicopter was trimmed in maximum power climbs under the conditions given in Annex B, Serial 4. A droop in N2 (power turbine speed) from 6,600 rpm to 6,400 rpm, with maximum N2 governor 'beep' selected, was used to indicate that maximum power had been developed. Airspeed was increased and decreased by approximately 10 KIAS about each trim point by using only the longitudinal cyclic control. The collective control position was held constant at the initial trim value of each test point. When stabilized at the desired airspeed, the relevant parameters were recorded.

3.4.2 Results and Discussion. The collective fixed static longitudinal stability data for maximum power climbs are shown in Annex A, Figure 7. The gradients varied significantly as a function of trim airspeed and configuration. A summary of the static stability characteristics is given in Table 3.2. In addition to the average gradient variation, non-linearities existed at several trim points. These combined to greatly increase the pilot workload to hold desired airspeed during climbs and constant attention to attitude and airspeed was required. This extra workload detracts from the ability of the pilot to cope with other mission sub-tasks such as lookout, monitoring of other instruments, radio calls and navigation, and could be hazardous for single pilot instrument flight. This reinforces the intuitively-derived minimum crew requirements for actual instrument flight as stated in Reference E, Section 7.

TABLE 3.2 - STATIC LONGITUDINAL STABILITY SUMMARY
(MAXIMUM POWER CLIMBS)

| Configuration | Trim Airspeed (KIAS) | Average Gradient (% Longitudinal Control Displacement per knot IAS) | Linearity | Stability |
|---|---|---|---|---|
| Training | 40 | 0.43 | Almost Linear | Positive |
| | 70 | 0.33 | Non-Linear | Positive |
| | 100 | 0.00 | Linear | Neutral |
| SAR 1 | 45 | 0.40 | Non-Linear | Positive |
| | 60 | 0.33 | Non-Linear | Positive |
| | 80 | 0.23 | Non-Linear | Positive |
| | 100 | 0.18 | - | Positive |
| SAR 2 | 40 | 0.25 | Non-Linear | Positive |
| | 60 | 0.55 | Non-Linear | Positive |
| | 80 | 0.35 | Linear | Positive |

3.4.3 Conclusion. Under the conditions tested, the collective fixed static longitudinal stability in maximum power climbs was unsatisfactory but acceptable.

3.5 Collective Fixed Static Longitudinal Stability - Autorotative Flight

3.5.1 Purpose and Method of Test. This test was conducted to determine the effects of autorotative flight on the static longitudinal stability of the helicopter in various configurations. The helicopter was trimmed in autorotation under the conditions given in Annex B, Serial 5. Autorotation was established by reducing the throttle to flight idle and lowering the collective. The helicopter was considered to be in steady autorotation when rotor speed recovered to 324 rpm, zero torque was indicated and the rate of descent had stabilized. Airspeed was increased and decreased by approximately 10 KIAS about each trim point by using only the longitudinal cyclic control. The collective control was held at the initial autorotative trim position throughout each test. When stabilized at the various points, the relevant parameters were recorded.

3.5.2 Results and Discussion. The collective fixed static longitudinal stability data for autorotative flight are shown in Annex A, Figure 8. The gradients show the helicopter possessed positive static stability in all conditions tested. The gradient changed as a function of airspeed and configuration, and minor non-linearities were present. This information is summarized in Table 3.3. Although the gradients were not significantly different to those for level and climbing flight, the pilot noted that it was much easier to stabilize on desired airspeed in autorotation, and longitudinal cylic displacement from trim could be used as a good cue for airspeed changes. The helicopter could be stabilized at the off-trim speeds with very little or no pitch attitude and airspeed oscillations, and very few control inputs were required to maintain trim.

TABLE 3.3 - STATIC LONGITUDINAL STABILITY SUMMARY (AUTOROTATION)

| Configuration | Trim Airspeed (KIAS) | Average Gradient (% Longitudinal Control Displacement per knot IAS) | Linearity | Static Stability |
|---|---|---|---|---|
| Training | 40 | 0.30 | Almost Linear | Positive |
| | 70 | 0.25 | Almost Linear | Positive |
| | 100 | 0.10 | Slightly Non-Linear | Positive |
| SAR 1 | 42 | 0.35 | Almost Linear | Positive |
| | 60 | 0.25 | Almost Linear | Positive |
| | 80 | 0.30 | Almost Linear | Positive |
| | 98 | 0.28 | Slightly Non-Linear | Positive |
| SAR 2 | 40 | 0.35 | Almost Linear | Positive |
| | 60 | 0.45 | Linear | Positive |
| | 80 | 0.33 | Slightly Non-Linear | Positive |

3.5.3 Conclusion. Under the conditions tested, the collective fixed static longitudinal stability in autorotative flight was satisfactory.

3.6 Longitudinal Long Term Response - Level Flight

3.6.1 Purpose and Method of Test. This test was conducted to determine the nature of the 'open loop' dynamic response of the helicopter to an out-of-trim condition encountered in level flight. For this investigation, only the 'controls fixed' response was evaluated. The helicopter was stabilized at the various trim conditions given in Annex B, Serial 6, and the relevant parameters recorded. The airspeed was then increased or decreased using longitudinal cyclic only. When the desired increment of speed change had been achieved, the controls were returned to the original trim position and held fixed while the response of the aircraft was observed. Observed airspeed was recorded every five seconds so that a time history of the response could be reconstructed.

3.6.2 Results and Discussion. The longitudinal long term responses in level flight are shown in Annex A, Figures 9 to 15. Excluding the Training configuration responses at 100 KIAS trim, the results are summarized in Table 3.4. The Training configuration 100 KIAS trim responses are excluded due to the slight to moderate turbulence encountered during the tests. Under all other conditions, the helicopter demonstrated oscillatory (roughly sinusoidal) responses which ranged from slowly convergent to slowly divergent. Other parameters (pitch attitude, vertical speed and altitude) varied in a similar oscillatory manner to airspeed, but not in phase. For example, pitch attitude led airspeed by a phase angle of approximately 90 degrees; that is, maximum nose-up pitch for any one cycle occurred as airspeed was decreasing at the maximum rate, and so on. The period of the response reduced primarily as a function of gross weight rather than configuration, as shown by Annex A, Figure 16. The long term dynamic longitudinal stability in level flight can be summarized as 'basically neutral'. The response was fairly easily damped by the pilot (HQR=4) and the helicopter could be flown 'hands-off' for short periods of time in smooth air when accurately trimmed with the force trim system activated.

TABLE 3.4 - LEVEL FLIGHT LONGITUDINAL LONG TERM RESPONSE SUMMARY

| Configuration | Average Period (sec) | Dynamic Stability |
|---|---|---|
| Training | 34 | Neutral to Slightly Positive (Convergent) |
| SAR 1 | 30 | Essentially Neutral |
| SAR 2 | 23 | Essentially Neutral |
| SAR 3 | 30 | Slightly Negative (Divergent) |

3.6.3 Conclusion. Under the conditions tested, the longitudinal long term response in level flight was satisfactory.

3.7 Longitudinal Long Term Response - Maximum Power Climbs

3.7.1 Purpose and Method of Test. Except for flight condition, the purpose and method of this test were the same as outlined in Paragraph 3.6.1. A 200 rpm N2 droop from 6600 rpm to 6400 rpm, with maximum N2 governor 'beep' selected, was used to indicate development of maximum power. Test conditions are given in Annex B, Serial 7.

3.7.2 Results and Discussion. Representative longitudinal long term responses in maximum power climbs are shown in Annex A, Figures 17 to 19. The response at 100 KIAS trim (Figure 17) was different to all others observed in that the helicopter entered a steep dive (pitch attitude approximately 25 degrees nose-down) and the airspeed stabilized at 120 KIAS. No explanation of this response was readily apparent. All other responses were rapidly divergent, with a period of approximately 20 seconds and one to two cycles to double amplitude. For excitations of approximately 10 KIAS off trim speed, recovery was usually required within 15 seconds due to reaching pitch attitude limits ($\pm$ 30 degrees). The helicopter was tested over similar speed and configuration ranges as the level flight evaluation (Paragraph 3.6) but the rapid divergence made hand recording of cockpit data difficult. Most responses were therefore recorded on cine film of the cockpit instruments. Annex A, Figure 19 shows a long term response reconstructed from cine film. The aircraft was being flown in smooth air. The response was self-excited (no deliberate control inputs were made) and the controls were held fixed at the 45 KIAS initial trim point until recovery was required (as the airspeed reached zero) due to excessive nose-down pitch rate and reduced normal acceleration. Large longitudinal cyclic control inputs were required during climbing flight to maintain constant airspeed and pitch attitude. These inputs were assymmetrical about trim - often aft inputs of one to two centimetres were required to prevent the development of substantial nose-down pitch rates. Forward control inputs were required far less frequently than aft, and less forward displacement (usually one half centimetre maximum) was required to damp the nose-up pitch of the helicopter as it entered the divergent long term response. Pilot workload to maintain trim speed ± 5 KIAS was very high (HQR=6). During climbing flight, if the pilot is distracted and a gust or very small inadvertent control input excites the long term response, the aircraft will rapidly diverge. Constant attention to attitude and airspeed will, therefore, be required in climbing flight.

3.7.3 Conclusion. Under the conditions tested, the longitudinal long term response in climbing flight was unsatisfactory, but acceptable provided pilots are aware of the characteristics and devote considerable attention to pitch attitude and airspeed.

## 3.8 Longitudinal Long Term Response - Autorotative Flight

3.8.1 Purpose and Method of Test. Except for flight conditions, the purpose and method of this test were the same as outlined in Paragraph 3.6.1. The helicopter was established in autorotative flight under the conditions given in Annex B, Serial 8. Autorotation was established as outlined in Paragraph 3.5.1.

3.8.2 Results and Discussion. Representative longitudinal long term responses in autorotative flight are shown in Annex A, Figures 20 and 21. The response was well damped with a period of 20 to 25 seconds. The oscillation required approximately half a cycle to damp to half amplitude. During the SAR 2 configuration tests, moderate to severe low frequency vibrations (1:1 rotor-induced vertical vibrations and pylon rock) were present. These vibrations made the test difficult to perform and reduced the reliability of hand-recorded data. However, in all configurations tested, the response was well damped, requiring little pilot effort to control disturbances (HQR=2). When trimmed with the force trim selected ON, the aircraft could be flown 'hands off' and disturbances encountered were damped without pilot input. The helicopter was, therefore, considered to be very stable in autorotation. Although large cyclic and pedal trim changes would be required (as discussed in Paragraph 3.2) entry to autorotation, or at least reduction of collective, should help stabilize the aircraft if any longitudinal divergence is encountered.

3.8.3 Conclusion. Under the conditions tested, the longitudinal long term response in autorotative flight was satisfactory.

## 3.9 Level Flight Gust Response

3.9.1 Purpose and Method of Test. The purpose of this test was to examine helicopter response to longitudinal and vertical gusts in level flight. The helicopter was trimmed at the conditions given in Annex B, Serial 9. Once established at the desired condition, one-inch longitudinal control pulses of one second duration were used to simulate longitudinal gusts, and one-second, one-inch collective control pulses were used to simulate vertical gusts.

3.9.2 Results and Discussion. In all configurations tested, the response of the helicopter to simulated longitudinal gusts was an initial pitch up or down corresponding to the input direction. The helicopter then entered long-term longitudinal responses similar to those described in Paragraph 3.6. At airspeeds above 80 KIAS the amount of pitch-up/down was increased. Some lateral cross-coupling was noted during the initial phase of the responses. Aft cyclic pulses produced pitch-up and right roll while forward pulses produced pitch down and left roll. The responses were moderately easy to damp by the pilot (HQR=4) although constant small corrections to aircraft pitch attitude were required to maintain trimmed level flight in moderate turbulence (HQR=5) due to the relatively long period and undamped nature of the induced long term response. Simulated vertical gusts produced flat (no roll) yawing oscillations which damped quickly (three or four discernible reversals). The short period (2 to 3 seconds) and natural damping of these oscillations made them impractical to damp by pilot control inputs. As a result, during level flight in moderate turbulence, the yawing oscillations were continually excited and small heading excursions (± 3 degrees from desired) were constantly present, detracting from helicopter ride qualities. The one-inch upward collective pulses also produced upward heaves ($+\Delta N_z$) which increased from a pilot-judged value of +0.2g at 40 KIAS to +0.5g at 100 KIAS (all increments based on +1.0g normal load factor). The one-inch downward collective pulses produced a downward heave ($-\Delta N_z$) which appeared to remain constant at approximately -0.2g over the airspeed range tested. This was a desirable characteristic considering the implications (rotor instability causing possible mast bumping) if the downward heave had increased to -0.5g or more with airspeed.

3.9.3 Conclusions. The helicopter displayed some undesirable characteristics in response to gusts encountered in level flight. These characteristics caused the pilot to apply constant small corrections to pitch attitude to maintain level flight in moderate turbulence. Ride qualities in moderate turbulence were also degraded due to continuous short period, small amplitude yawing oscillations about the desired heading.

## 3.10 Level Flight Longitudinal Control Response

3.10.1 Purpose and Method of Test. The purpose of this test was to determine the short term (less than 3 seconds) longitudinal control response characteristics of the helicopter in level flight. These characteristics include control sensitivity, damping and control system and rotor lags. A full evaluation of these control response characteristics was not possible due to the lack of appropriate instrumentation. The helicopter was trimmed in level flight under the conditions given in Annex B, Table 1, Serial 10 and the relevant parameters recorded. Step longitudinal control inputs were then made with the aid of a hand-held control jig. The size of the inputs was increased in half-inch increments to a maximum step input of two inches from the trim point. Aircraft reaction to these inputs was observed and noted.

3.10.2 Results and Discussion. The longitudinal control response of the helicopter appeared to be rate-demand in the short term (less than three seconds) and similar for all configurations. After the control was displaced from trim, there was a short delay, estimated at 0.2 sec, before a pitch response was detected by the pilot. The aircraft then attained a steady state pitch rate in about one to two seconds. The pitch rate appeared to be proportional to the size of the control input (that is 'rate-demand'). For small inputs, the aircraft entered a long term response if the control was held fixed for a prolonged period (greater than five seconds) after the initial displacement. In most configurations tested, two-inch step inputs were possible without excessive rates developing. Some cross-coupling, producing pitch down and right roll for forward control step inputs, was noted in all configurations at 100 KIAS. The longitudinal control response was smooth and predictable, but the amount of control displacement required to develop a desired pitch rate was greater than expected, and therefore not harmonized with the response. Lateral control inputs will also have to be made to counter the cross-coupling at higher airspeeds.

3.10.3 Conclusion. Although displaying some undesirable characteristics, the longitudinal control response of the helicopter in level flight was satisfactory under the conditions tested

## 3.11 Static Lateral-Directional Stability

3.11.1 Conditions and Methods of Test The static lateral-directional stabevaluated by performing steady heading side-slips, pedal only turns and lateral cyclic only turns under the conditions given in Annex B, Serials 11 to 13. Since the lateral control position was not instrumented, displacements from trim were judged by the pilot. The inclinometer ball position was used as an indication of side-slip as a side-slip vane and indicator were not fitted. The results of the tests are shown in Annex A, Figures 22 to 25.

3.11.2 Directional Stability. In all configurations tested, the helicopter exhibited positive directional stability as reflected by the variation of pedal position versus side-slip (ball position). Left pedal was required for right side-slips and right pedal for left side-slips. The gradients were almost linear. During turns on the lateral control only, the helicopter rapidly settled on a small into turn side-slip (pilot judged) after an initial excursion during the roll to the desired bank angle. The rapid subsidence of the side-slip to the final value indicated reasonably strong directional stability. The positive directional stability characteristics of the helicopter will produce restoring yaw moments when side-slip excursions are encountered and aid the controllability of the helicopter in forward flight. Under the conditions tested, the directional stability characteristics of the helicopter were satisfactory.

3.11.3 Effective Dihedral. Steady heading side-slips in the various configurations showed that the helicopter possessed weak to neutral effective dihedral as little or no lateral cyclic displacement from the balanced flight position was needed to stabilize at the various side-slip angles (ball widths). Turns using pedal control only also showed that the helicopter possessed neutral to weakly negative effective dihedral. During right pedal only turns, the helicopter initially yawed slightly right, but then rolled away from the turn, indicating negative effective dihedral for left side-slips. Large aft cyclic displacements were also required to prevent the nose from pitching down. Left pedal only turns (producing right side-slips) caused the helicopter to yaw and roll left and then settle on a steady left bank angle and side-slip after an initial lateral-directional oscillation damped. Mild pitch-up had to be countered by the application of a small forward cyclic displacement from trim. Although the effective dihedral varied from weakly positive to weakly negative, this did not significantly degrade aircraft control in visual meteorological conditions. Stronger effective dihedral would be desirable for flight in instrument meteorological conditions; however, under the conditions tested, the effective dihedral characteristics were satisfactory.

3.11.4 Sideforce Characteristics. The variation of bank angle with sideslip (ball widths) during steady heading side-slip tests showed that reasonable sideforces were generated. Sideforce was, therefore, able to be used by the pilot as a cue that the helicopter was not in balanced flight. The sideforce characteristics were satisfactory for the Training and SAR missions.

### 3.12 Dynamic Lateral-Directional Stability

3.12.1 Conditions and Methods of Test. The dynamic lateral-directional stability characteristics of the helicopter were evaluated by performing releases from steady heading side-slips, lateral control doublets, pedal doublets, collective pulses, turns on lateral cyclic only and turns on pedal control only under the conditions given in Annex B, Serials 11 to 14.

3.12.2 Lateral-Directional Oscillations. This response was easily excited by collective pulses, releases from steady heading side-slips and pedal doublets. The pilot perceived the oscillation as moderately damped with one to 1½ cycles to half amplitude, a period of 2-3 seconds and a bank to side-slip ratio of almost zero (that is a yaw only oscillation). The damping appeared to be less in the SAR 2 configuration with 1½ to two cycles to half amplitude, but there was no discernible change in the period. As discussed in Paragraph 3.9.2, flight in

3.12.3 Spiral Stability. Positive spiral stability was indicated, during lateral control only turns in all configurations, by a requirement to hold lateral cyclic control into the direction of turn to maintain bank angle. When the pedals were returned to the straight and level trim point from pedal only turns, the spiral stability response was observed to be non-oscillatory convergent, with a time to half amplitude of seven to eight seconds. This pedal only turn test technique was not possible at 100 KIAS in the SAR 1 configuration or 90 KIAS in the SAR 2 configuration due to the neutral to negative effective dihedral under those conditions, although turns on the lateral control only had indicated positive spiral stability. The positive non-oscillatory spiral stability of the helicopter will automatically compensate for bank angle disturbances, reducing the lateral retrimming demands made on the pilot. Under the conditions tested, the spiral stability of the helicopter was satisfactory.

3.12.4 Adverse Yaw. The yaw due to roll characteristics of the helicopter were evaluated during turns on the lateral cyclic control only. Under all the conditions tested, the helicopter demonstrated mild adverse yaw. As the cyclic control was displaced laterally to initiate the turn, the turn needle momentarily indicated a yaw in the opposite direction. For normal control movement rates, the adverse yaw was only just perceived by the pilot, as the nose was observed initially to yaw slightly in the opposite direction to the lateral control input. In most circumstances, the adverse yaw will be unnoticed by the pilot, and no significant additional directional control inputs will have to be made to counter the characteristic. Under the conditions tested, although adverse yaw was present, the amount was insignificant and, therefore, satisfactory.

## 3.13 Side-slip-Pitch Coupling

3.13.1 Steady Heading Side-slips. Significant side-slip to pitch coupling was found during the steady heading side-slip flight tests. The steady heading side-slip data (Annex A, Figures 22 to 25) show the longitudinal control displacements from trim as a function of side-slip (ball position) to maintain the desired trim speed. The coupling was worse in the SAR 1, SAR 2 and SAR 3 configurations than the Training configuration, and asymmetrical about trim in that more aft cyclic was required to counter pitch-down for left side-slips than forward cyclic to counter pitch-up for right side-slips.

3.13.2 Pedal Only Turns. Turns on the pedal control only also demonstrated that significant pitching moments were developed with side-slip. Pedal inputs (producing side-slip) were made while holding the cyclic and collective controls fixed. The tests were repeated at various airspeeds (see Annex B, Serial 15) at rates varying from four seconds down to one second for a 10% pedal control displacement from trim. Right pedal inputs (left side-slip) caused the helicopter to yaw initially slightly right, roll away from the turn (negative effective dihedral) and pitch down substantially. Left pedal inputs (right side-slip) caused the aircraft to yaw and roll left and pitch slightly nose-up, then settle on a steady bank angle and side-slip after the initial lateral-directional oscillation damped. The pitch-up moments were far smaller than the pitch-down moments generated by right pedal inputs. In all cases, the pitching moment was reasonably easy to overcome by the application of aft or forward cyclic (as applicable) and return to balanced flight.

3.13.3 Possible Explanation for Side-slip-Pitch Coupling. Due to the complex nature of helicopter aerodynamics, a categorical explanation of the observed behaviour is difficult. However, Reference I, Chapter II contains the following:

> 'Pitch-Side-slip Coupling
> An effect noticed on helicopters with big horizontal stabilizers is a tendency to pitch up in a right side-slip and down in a left

side-slip. This phenomenon can be traced to the asymmetrical distribution of induced downwash in the main-rotor wake.

Wind-tunnel measurements of wake strength have shown that the induced velocity is higher behind the advancing side than behind the retreating side, where the reversed-flow region with its negative lift is decreasing the downwash. (Figure 3.1) shows how a side-slip to the right moves the stabilizer into a region of high downwash with a resulting increase in download and a corresponding nose-up pitching moment.'

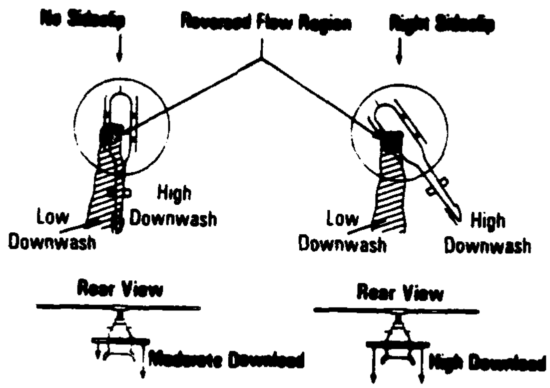



FIGURE 3.1 - SOURCE OF PITCH-SIDE-SLIP COUPLING

Cine film of tufts placed under the synchronous elevators showed that most of the elevator virtually stalled when left side-slip was introduced. This could have been a result of the elevator being initially enveloped in the low downwash, highly turbulent portion of the main rotor wake, causing the onset of nose-down pitching. The consequences of nose-down pitching on elevator airlow are discussed in Paragraph 3.15.

3.13.4 Conclusion. As reported in References D and J, the side-slip-pitch coupling was unsatisfactory, but controllable by the application of aft cyclic and return to balanced flight, and was therefore acceptable. A possible cause of the nose-down pitching with left side-slip is that most of the synchronous elevator stalls after being enveloped by the low downwash, highly turbulent portion of the main rotor wake.

3.14 Vibrations. Generally, aircraft vibrations increased as a factor of gross weight, airspeed and configuration. The maximum vibration level experienced was in the SAR 2 configuration. The amplitude of low frequency, rotor induced 1:1 vertical vibrations was substantially increased when compared to the clean, lighter weight configurations. The vibration became intolerable above 90 KIAS in straight and level flight. Addition of the external auxiliary fuel tanks seemed to excite a very low frequency vibration known as 'pylon rock'. This vibration mode was evident in all SAR 2 configuration tests, but was worse under the following conditions:

a. at about 50 KIAS during maximum power climbs,

b. in autorotative descent, and

c. during manoeuvres at greater than +1.0g.

The pylon rock made trimming difficult as it imparted a movement to the pilot's arms and legs, which in turn caused oscillatory control movements, exacerbating the vibrations. This almost led to a pilot-induced oscillation problem. If the controls were released (with the force trim system selected ON) the pylon rock reduced. 'Beating' was also evident in that the vibrations increased and decreased cyclically with time, with a period of approximately 5-10 seconds. Airframe vibrations became excessive with the addition of external fuel tanks and as gross weight, airspeed and normal acceleration were increased. The vibrations substantially reduced the tolerable flight envelope.

3.15 Pitch Damping. An analysis of cine film viewing the tufted synchronous elevators showed that the elevators stalled during the pitch-down phase of the longitudinal long term response in high power climbs at speeds between approximately 60 KIAS and 90 KIAS. The longitudinal long term response has been described in Paragraph 3.7. The cine film showed that the elevator was operating at high angles-of-attack under most climbing flight conditions. The effect of a nose-down pitch rate (+q) can be seen with reference to Figure 3.2.

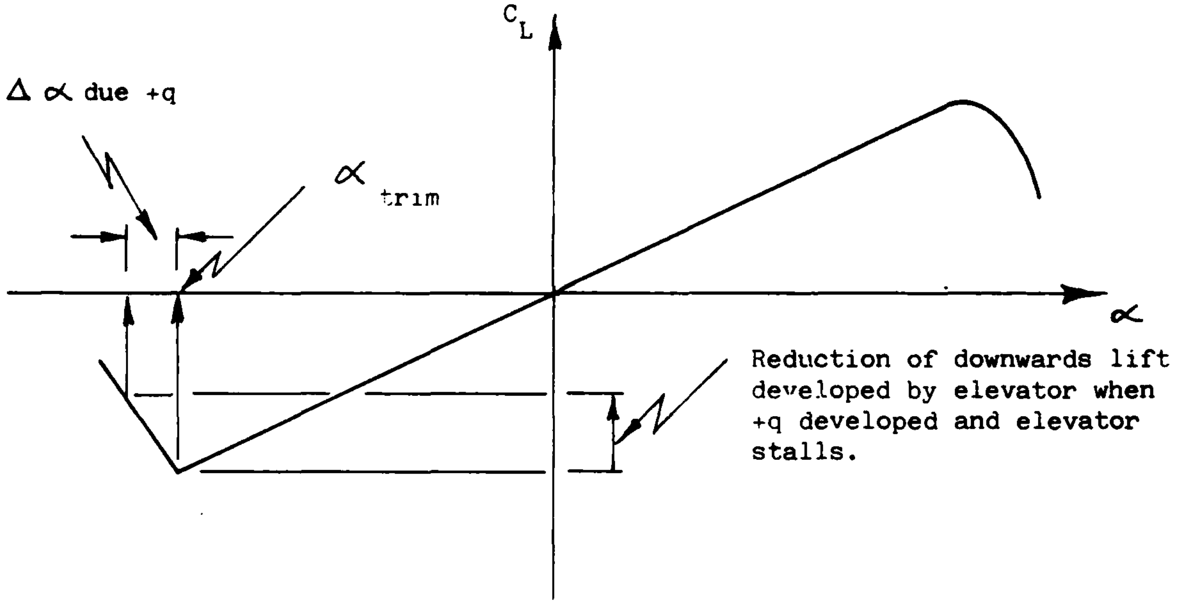



FIGURE 3.2. - EFFECT OF INCREASED ANGLE-OF-ATTACK ON ELEVATOR LIFT

A nose-down pitch causes an increase in the elevator angle-of-attack. If this increase is sufficient to stall the elevator, the download will be substantially reduced. The pitch damping ($M_q$) contribution from the elevator would in turn reduce, exacerbating the pitch down in the long term response. The elevator appeared to unstall just prior to the nose pitching up in the long term response. This could have been due to the substantial increase in airspeed which accompanied the nose down pitching. However, stalling of the elevator due to the onset of nose-down pitching is a likely cause of the extremely divergent nature of the long-term response in high powered climbs.

3.16 Flight Manual Amendments. Flight Manual amendments considered necessary as a result of this investigation have been reported in Reference J. Further data analysis has substantiated the information contained in Reference J except for the statement in Paragraph 4.a.(3) concerning the period of the longitudinal long term response in maximum power climbs. Data analysis indicates that the period is approximately 20 seconds, and not the pilot-judged value of 10 to 15 seconds reported in References D and J. The error of judgement probably arose due to the rapid divergence of the response and the limited observation times that were available before recovery was required. Consideration should be given to amending the erroneous Flight Manual entry arising from Reference J.

## 4. CONCLUSIONS

4.1 The trimmed control positions in level flight were satisfactory (Paragraph 3.1).

4.2 Although cyclic and pedal retrimming requirements when transitioning from climb to descent were excessive, and therefore unsatisfactory, the trimmed control positions in climb and descent were acceptable (Paragraph 3.2).

4.3 The level flight collective fixed static longitudinal stability was satisfactory (Paragraph 3.3).

4.4 The collective fixed static longitudinal stability in maximum power climbs was unsatisfactory, but acceptable (Paragraph 3.4).

4.5 The collective fixed static longitudinal stability in autorotative flight was satisfactory (Paragraph 3.5).

4.6 The longitudinal long term response in level flight was satisfactory (Paragraph 3.6).

4.7 The longitudinal long term response in climbing flight was unsatisfactory, but acceptable provided pilots are aware of the characteristics and devote considerable attention to pitch attitude and airspeed (Paragraph 3.7).

4.8 The longitudinal long term response in autorotative flight was satisfactory (Paragraph 3.8).

4.9 The helicopter displayed some undesirable characteristics in response to gusts encountered in level flight. These characteristics caused the pilot to apply constant small corrections to pitch attitude to maintain level flight in moderate turbulence. Ride qualities in moderate turbulence were also degraded due to continuous short period, small amplitude yawing oscillations about the desired heading (Paragraph 3.9).

4.10 Although displaying some undesirable characteristics, the longitudinal control response of the helicopter in level flight was satisfactory (Paragraph 3.10).

4.11 The static directional stability characteristics of the helicopter were satisfactory (Paragraph 3.11.2).

4.12 The effective dihedral characteristics were satisfactory (Paragraph 3.11.3).

4.13 The sideforce characteristics were satisfactory (Paragraph 3.11.4).

4.14 The lateral directional oscillations were continually excited in moderate turbulence. This was undesirable, but acceptable (Paragraph 3.12.2).

4.15 The spiral stability of the helicopter was satisfactory (Paragraph 3.12.3).

4.16 Although adverse yaw was present, the amount was insignificant and, therefore, satisfactory (Paragraph 3.12.4).

4.17 The side-slip-pitch coupling was unsatisfactory, but controllable by the application of aft cyclic and return to balanced flight and was, therefore, acceptable. A possible cause of the coupling is that most of the synchronous elevator stalls after being enveloped by the low downwash, highly turbulent portion of the main-rotor wake (Paragraph 3.13).

4.18 Airframe vibrations became excessive with the addition of external fuel tanks and as gross weight, airspeed and normal acceleration were increased. The vibrations substantially reduced the tolerable flight envelope (Paragraph 3.14).

4.19 Stalling of the synchronous elevator, due to the onset of nose-down pitching, is a likely cause of the extremely divergent nature of the longitudinal long term response in high powered climbs (Paragraph 3.15).

4.20 The period of the longitudinal oscillation in high powered climbs was approximately 20 seconds, and not 10 to 15 seconds as reported in References D and J (Paragraph 3.16).

## 5. RECOMMENDATION

5.1 The erroneous Flight Manual entry arising from Reference J should be amended (Paragraph 3.16).

## 6. REFERENCES

A. HQSCENG TN 042/SENGSO, 13 September 1981

B. HQOC A178/COFS, 17 September 1981

C. HQSCENG TN260/SOAIRENG, 12 November 1981

D. HQEDN TN030/COARDU, 9 December 1981

E. Defence Instruction (Air Force) AAP 7210.006-1, Flight Manual, Iroquois UH-1B, issued 31 October 1973, amended to AL 11 dated 18 September 1981

F. RAAF Special Technical Instruction - Iroquois/302, Incorporation of Iroquois Modification 7210-008-249, Installation of Tail Rotor Pitch Control Cable Shrouds on UH-1B Aircraft, 2 December 1981

G. United States Naval Test Pilot School Flight Test Manual No 101, Helicopter Stability and Control, issued 10 June 1968, amended February 1978

H. National Aeronautics and Space Administration Technical Note D-5153, 'The Use of Pilot Rating in the Evaluation of Aircraft Handling Qualities', April 1969

I. Prouty, R.W., 'Practical Helicopter Aerodynamics', PJS Publications Inc

J. ARDU 2535/2/783/Tech(70), 'UH-1B Iroquois Stability and Control - Flight Manual Amendments', 17 December 1981

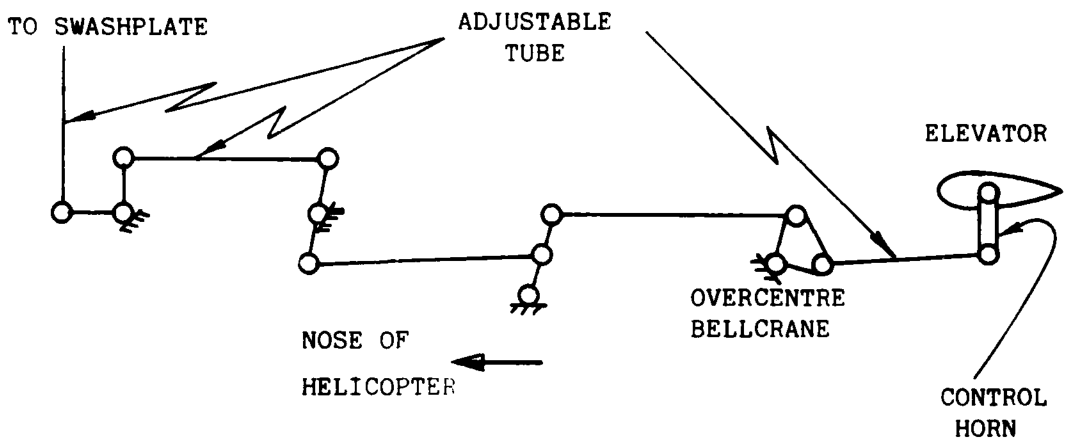
## 7. PROJECT PERSONNEL

7.1 Project Engineer: Flight Lieutenant M.J. Tobin, Dip MEng

7.2 Chase Pilot: Squadron Leader A.A. Vilcins

7.3 Computer Graphics: Mrs C. Johnson

## FIGURES



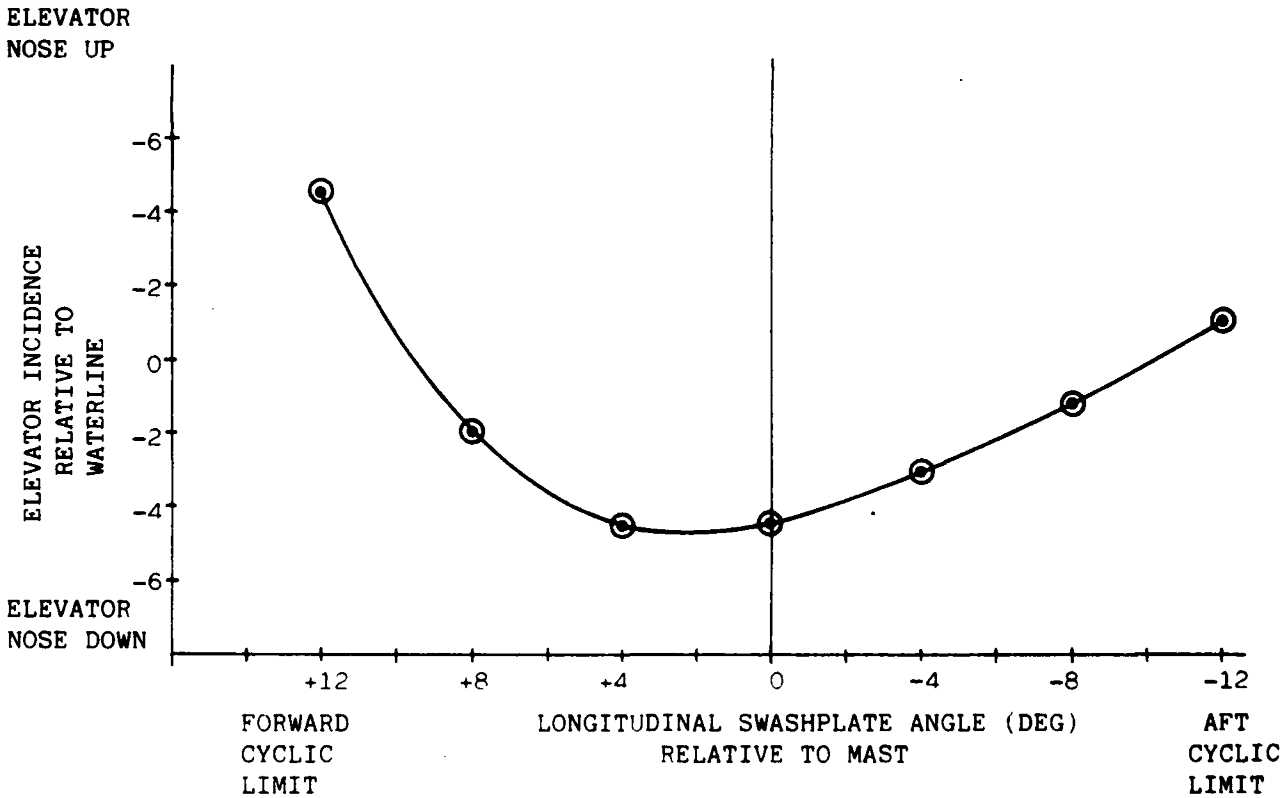
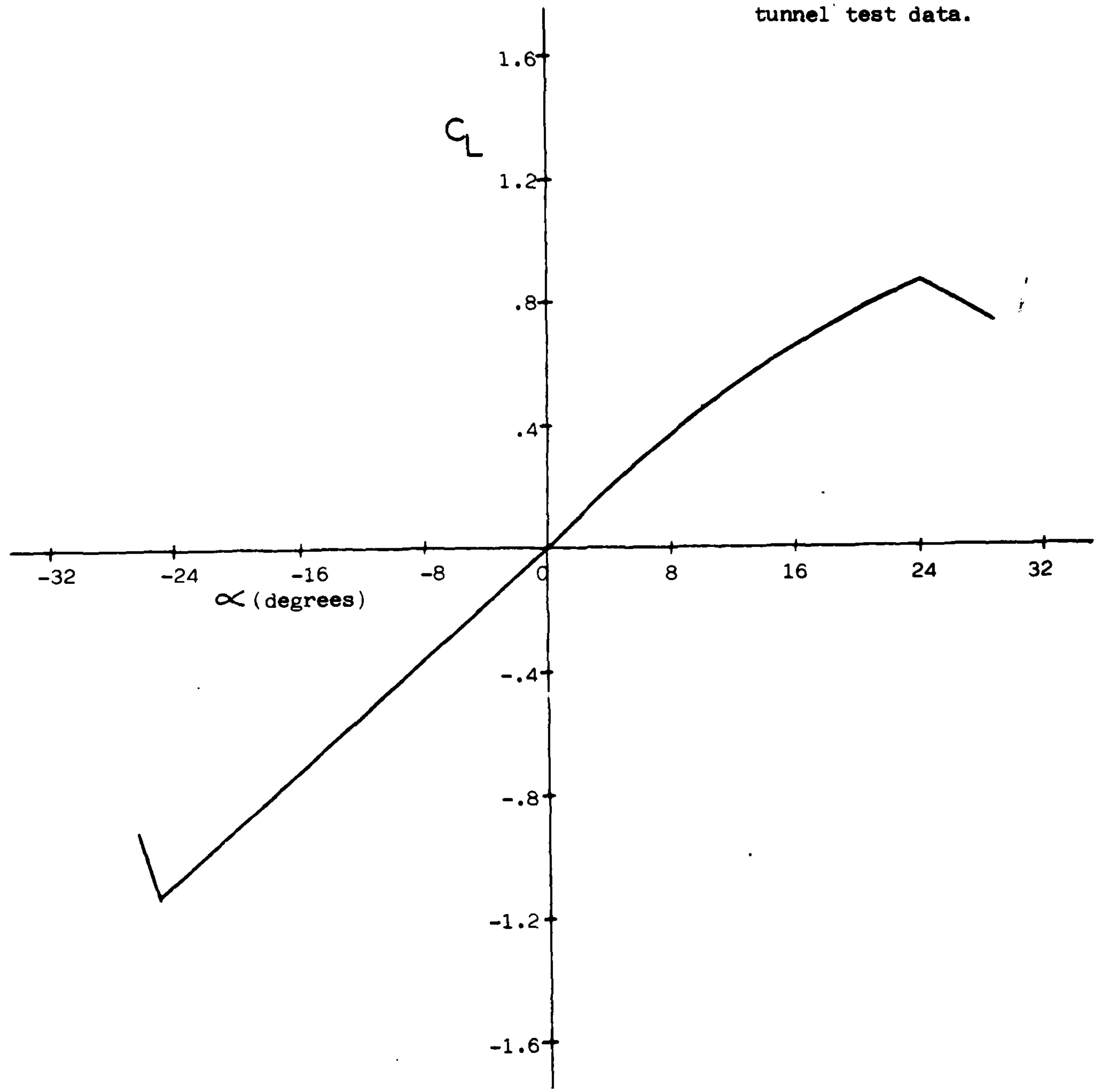



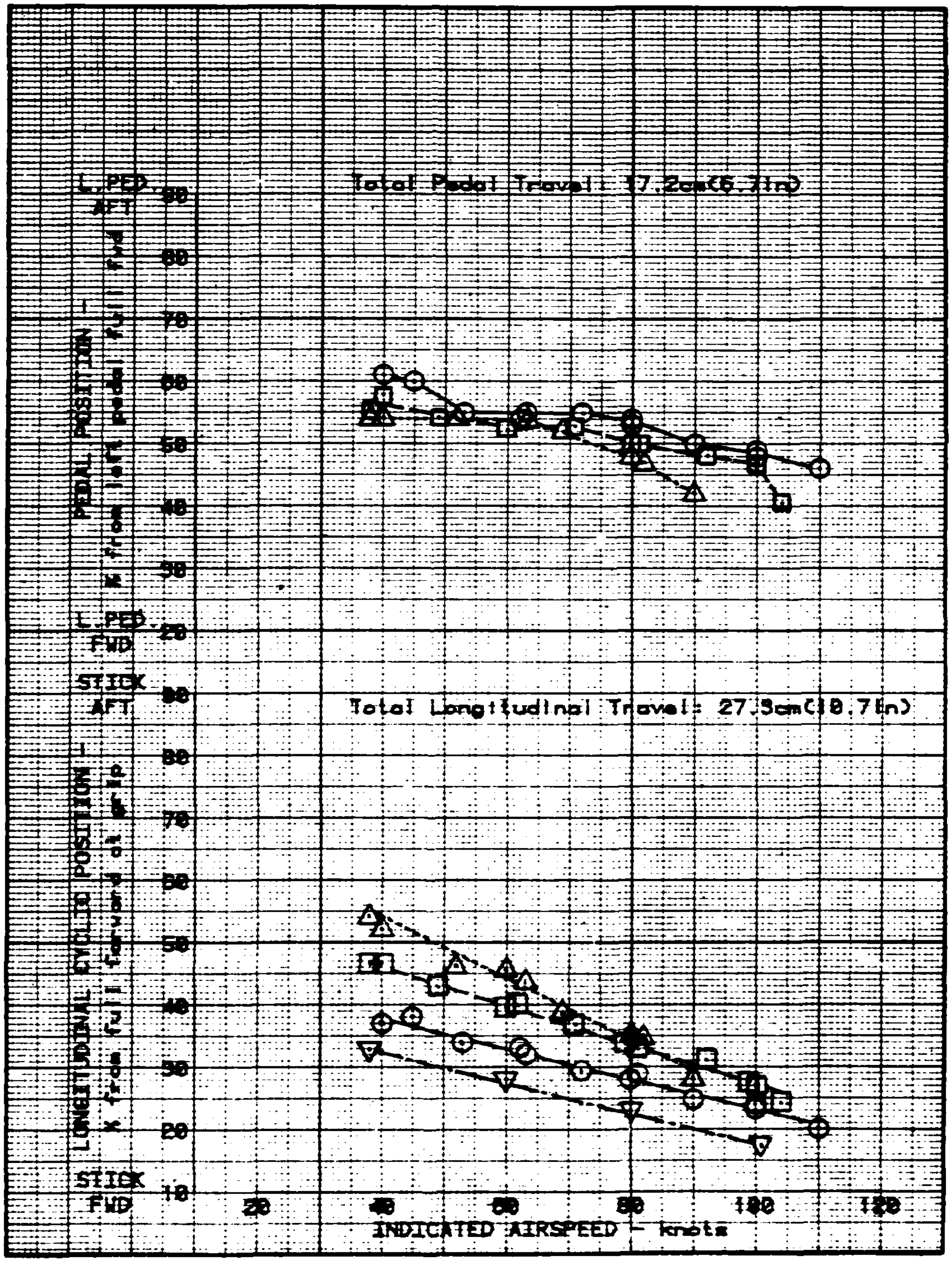

FIGURE 1 - UH-1B CYCLIC STICK TO HORIZONTAL
STABILIZER LINKAGE AND RIGGING CURVE

Note: Estimated - Based on 3 dimensional corrections to 2 dimensional wind tunnel test data.



Aircraft: UH-1B S/N A2-1022 Engine: Lycoming T53-L11 S/N LE09004

| | | | | |
|---|---|---|---|---|
| Symbol: | ○ | □ | △ | ▽ |
| Density Altitude: ft. | 6,000 | 5,400 | 4,300 | 4,700 |
| Gross Weight (avg):lbf. | 6,740 | 7,560 | 8,340 | 6,610 |
| Centre of Gravity (avg.): in. | 132.9 | 130.2 | 128.1 | 134.0 |
| Rotor Speed: rpm | 324 | 324 | 324 | 324 |
| Configuration: | Clean, Doors Shut (Training) | Clean, Doors Shut (SAR 1) | Full Ext Tanks (SAR 2) | Empty Ext Tanks (SAR 3) |



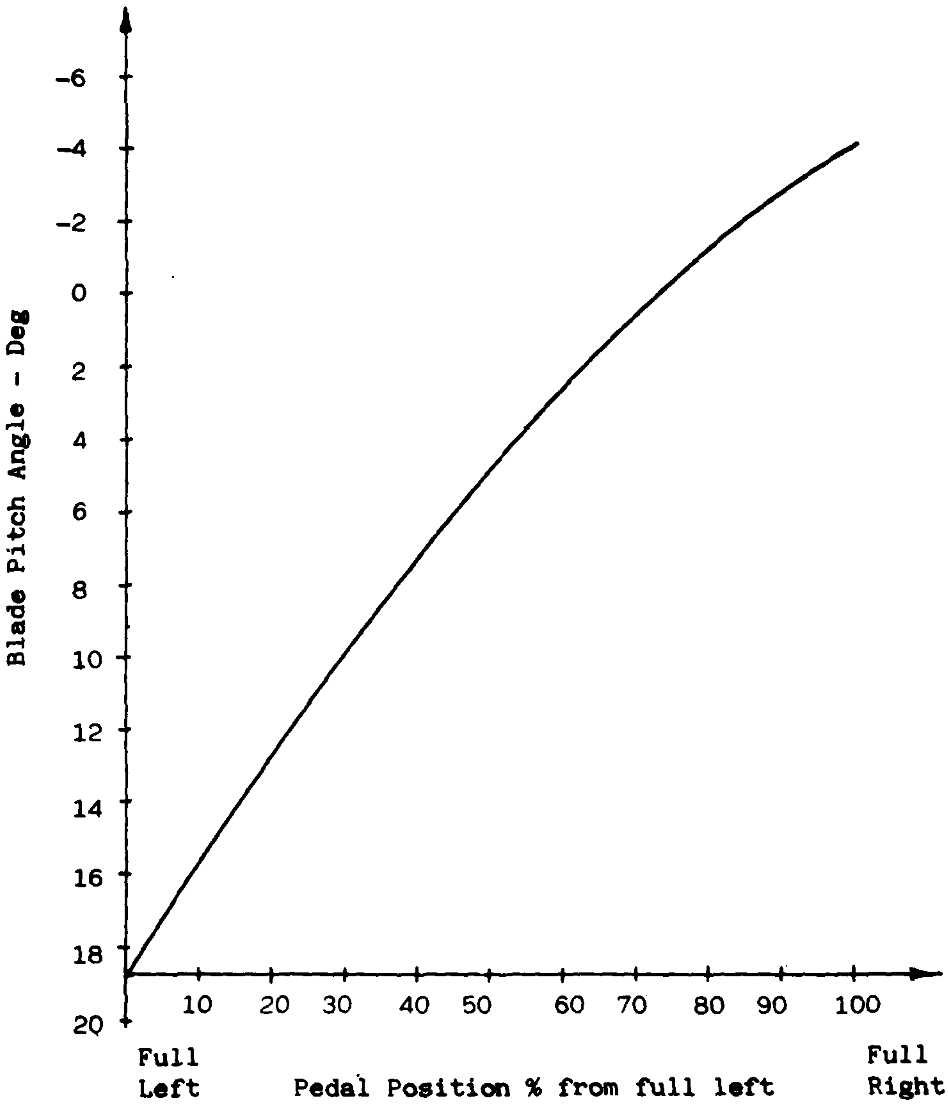
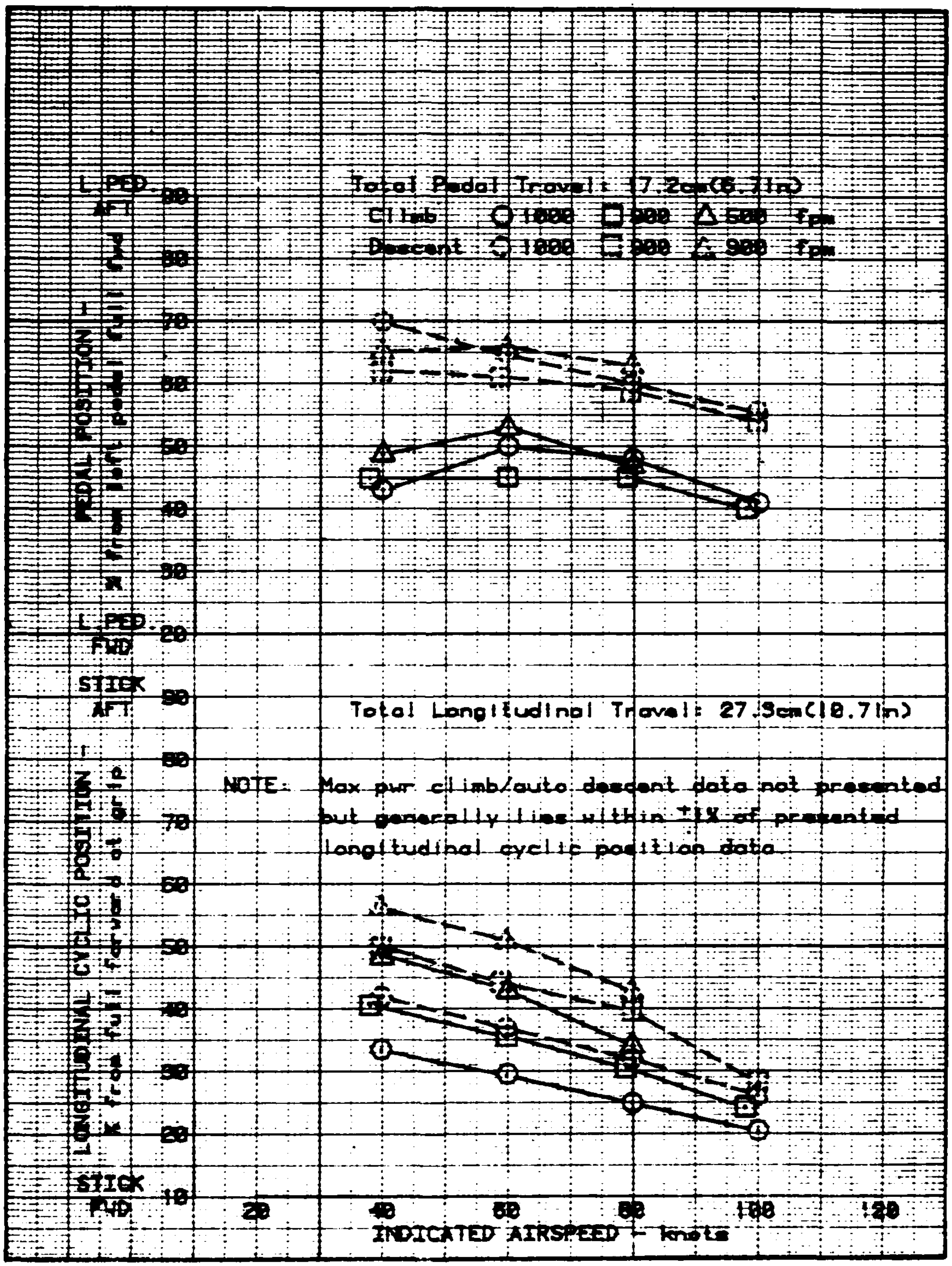



FIGURE 4 - TAIL ROTOR BLADE PITCH VS PEDAL POSITION

| | | | |
|---|---|---|---|
| Aircraft: UH-1B S/N A2-1022 | Engine: Lycoming T53-L11 S/N LE09004 | | |
| Symbol: | ○ | □ | △ |
| Density Altitude: ft. | 6,000 | 6,500 | 4,500 |
| Gross Weight (avg):lbf. | 6,500 | 7,370 | 8,140 |
| Centre of Gravity (avg.): in. | 132.8 | 130.0 | 127.9 |
| Rotor Speed: rpm | 324 | 324 | 324 |
| Configurations: | Clean, Doors Shut (Training) | Clean, Doors Shut (SAR 1) | Full Ext Tanks (SAR 2) |



| | | | | |
|---|---|---|---|---|
| Aircraft: UH-1B S/N A2-1022 | Engine: Lycoming T53-L11 S/N LE09004 | | | |
| Symbol: | ○ | □ | △ | ▽ |
| Density Altitude: ft. | 6,000 | 5,400 | 4,300 | 4,700 |
| Gross Weight (avg):lbf. | 6,630 | 7,480 | 8,230 | 6,610 |
| Centre of Gravity (avg.): in. | 132.9 | 130.1 | 128.0 | 134.0 |
| Rotor Speed: rpm | 324 | 324 | 324 | 324 |
| Configurations: | Clean, Doors Shut (Training) | Clean, Doors Shut (SAR 1) | Full Ext Tanks (SAR 2) | Empty Ext Tanks (SAR 3) |

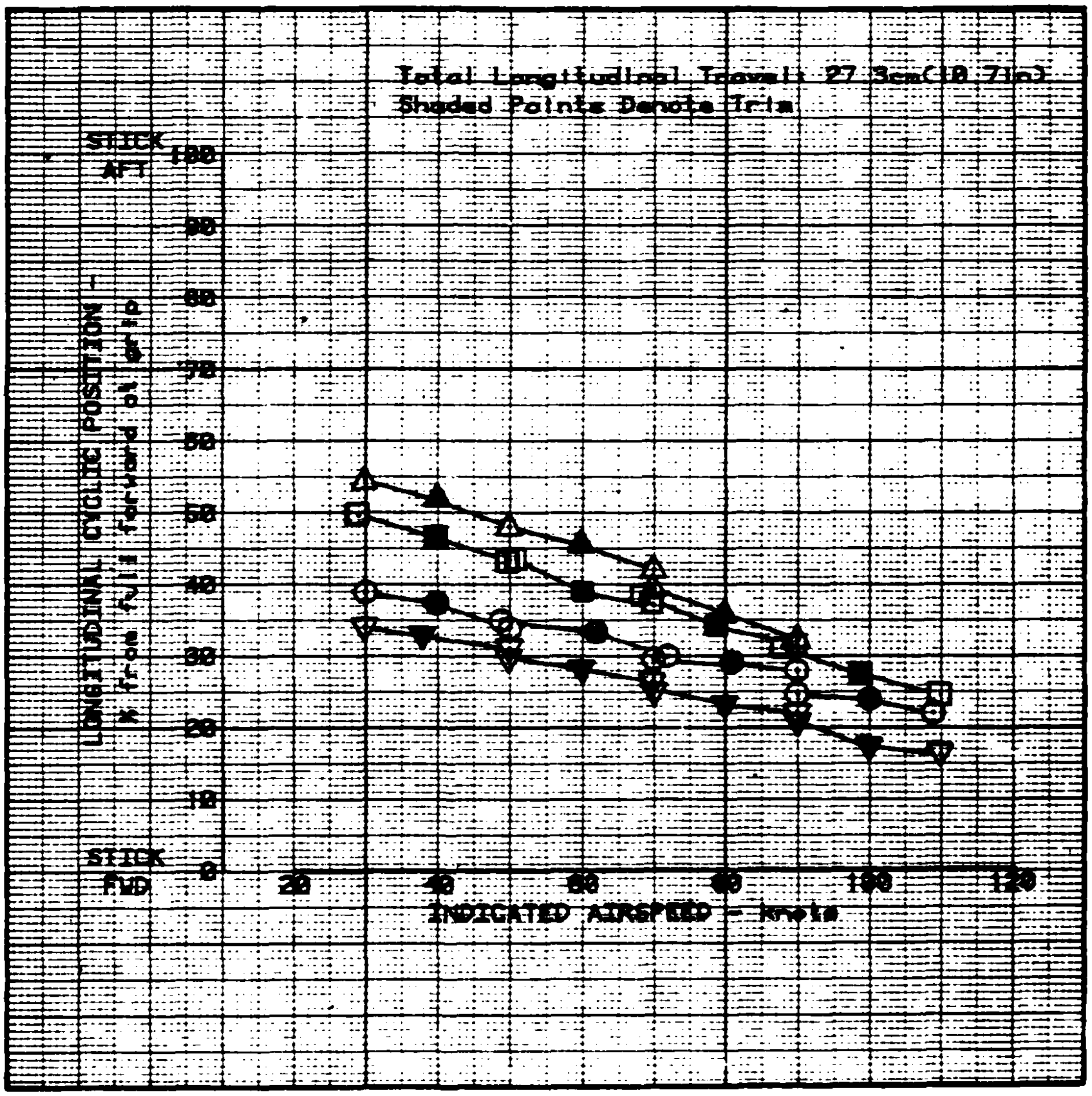



FIGURE 6 - COLLECTIVE FIXED STATIC LONGITUDINAL STABILITY IN LEVEL FLIGHT

| | | | |
|---|---|---|---|
| Aircraft: UH-1B S/N A2-1022 | | Engine: Lycoming T53-L11 S/N LE09004 | |
| Symbol: | ○ | □ | △ |
| Density Altitude: ft. | 4,800 | 5,000 | 4,700 |
| Gross Weight (avg):lbf. | 6,250 | 7,160 | 7,840 |
| Centre of Gravity (avg.): in. | 132.7 | 129.8 | 127.6 |
| Rotor Speed: rpm | 324 | 324 | 324 |
| Configuration: | Clean, Doors Shut (Training) | Clean, Doors Shut (SAR 1) | Full Ext Tanks (SAR 2) |

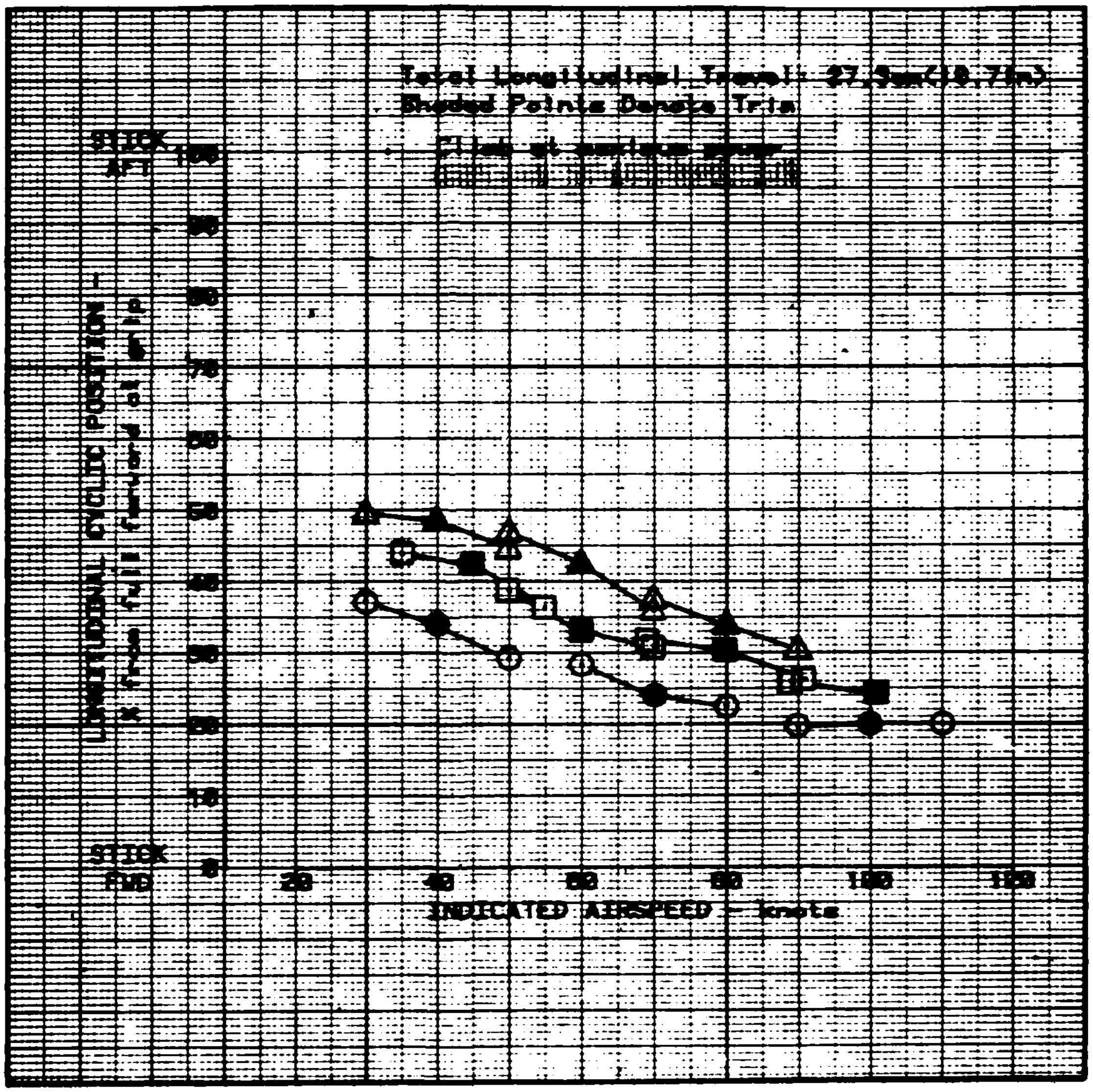



**FIGURE 7 - COLLECTIVE FIXED STATIC LONGITUDINAL STABILITY IN MAXIMUM POWER CLIMBS**

| | | | |
|---|---|---|---|
| Aircraft: UH-1B S/N A2-1022 | Engine: Lycoming T53-L11 S/N LE09004 | | |
| Symbol: | ○ | □ | △ |
| Density Altitude: ft. | 7,000 | 6,600 | 4,700 |
| Gross Weight (avg):lbf. | 6,250 | 7,160 | 7,840 |
| Centre of Gravity (avg.): in. | 132.7 | 129.8 | 127.6 |
| Rotor Speed: rpm | 324 | 324 | 324 |
| Configuration: | Clean, Doors Shut (Training) | Clean, Doors Shut (SAR 1) | Full Ext Tanks (SAR 2) |

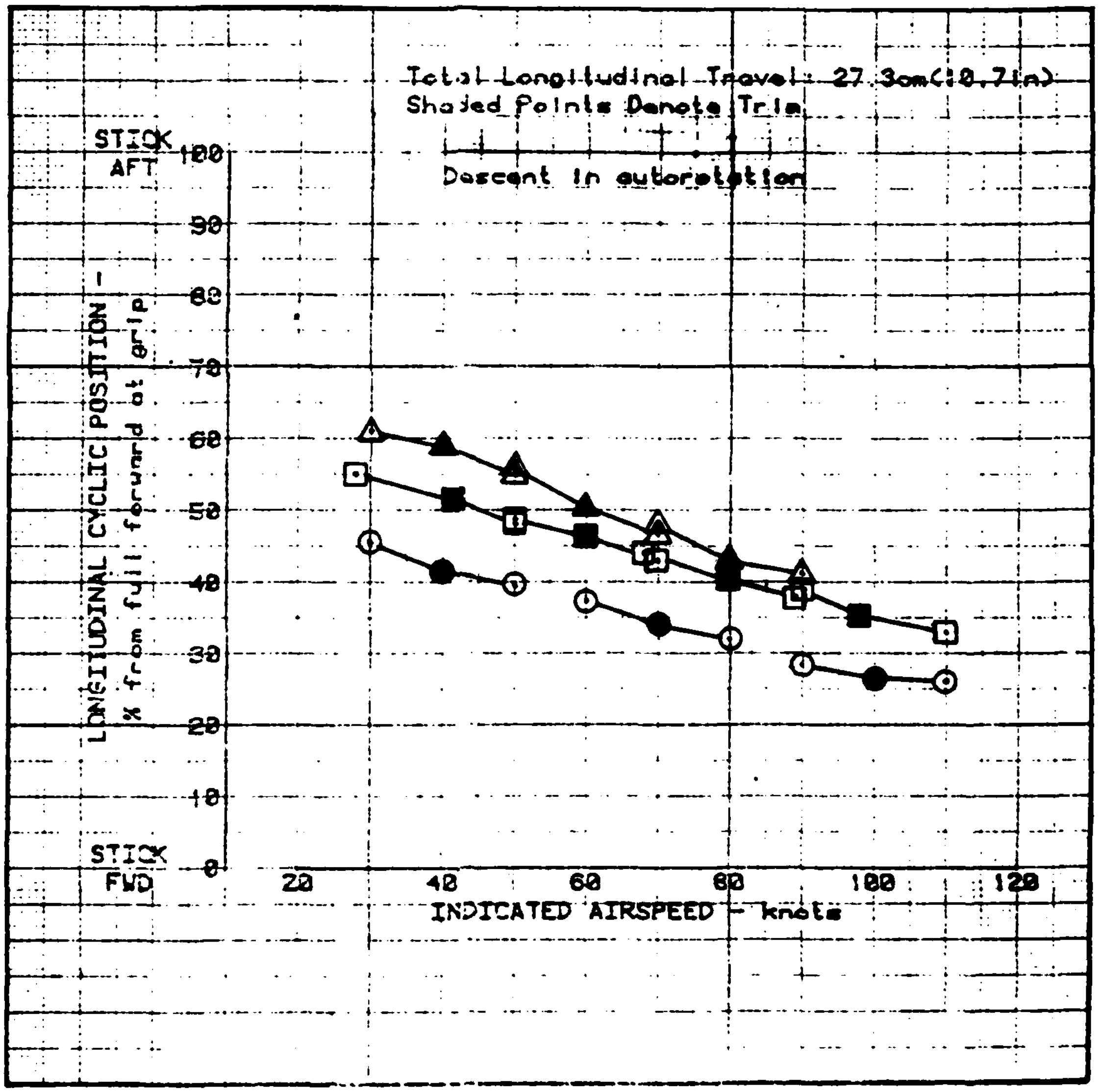
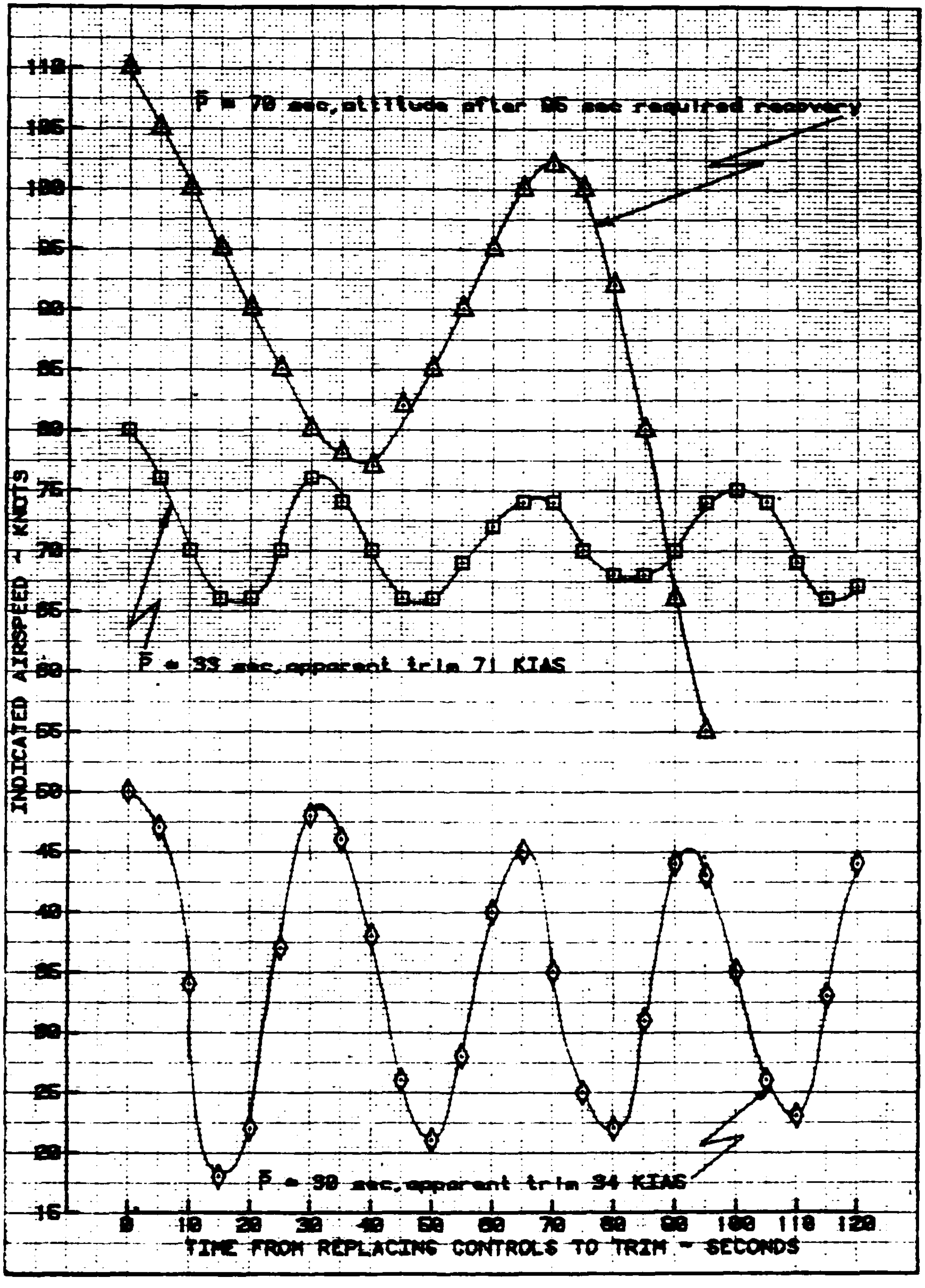



FIGURE 8 - COLLECTIVE FIXED STATIC LONGITUDINAL STABILITY IN AUTOROTATION

Aircraft: UH-1B S/N A2-1022
Density Altitude: 5,300 ft
Configuration: Clean, Doors Closed (Training)

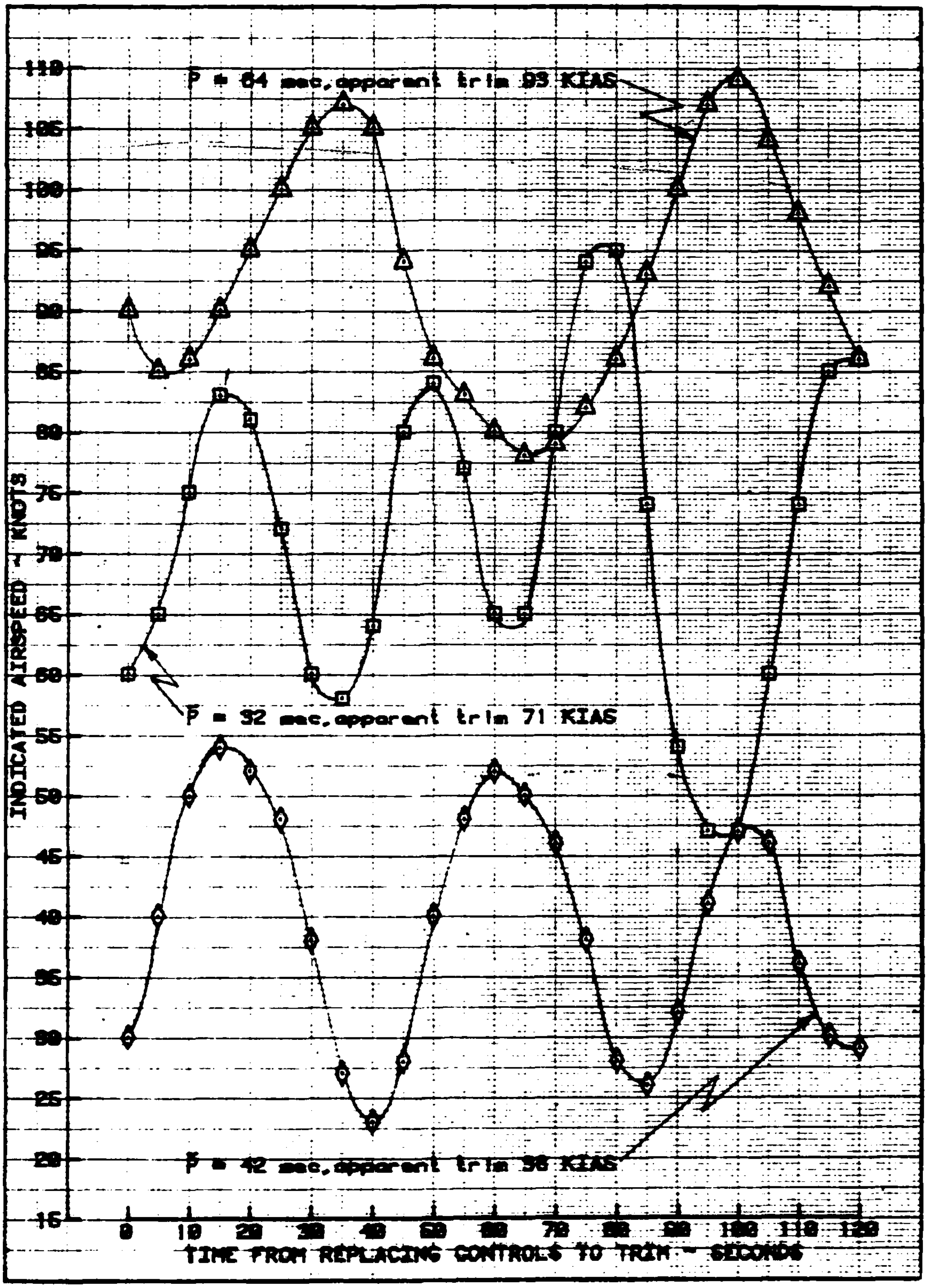
Engine: Lycoming T53-L11 S/N LE09004
Gross Weight (avg): 6,490 lbf.
Centre of Gravity (avg): 432.8 in. aft

Initial Trim Airspeed: ◇ 40, □ 70, △100 KIAS (fast starts).



Aircraft: UH-1B S/N A2-1022
Density Altitude: 5,300 ft
Configuration: Clean, Doors Closed (Training)
Engine: Lycoming T53-L11 S/N LE09004
Gross Weight (avg): 6,490 lbf.
Centre of Gravity (avg): 132.8 in. aft

Initial Trim Airspeed: ◊40, □70, △100 KIAS (slow starts).



Aircraft: UH-1B S/N A2-1022
Density Altitude: 5,300 ft
Configuration: Clean, Doors Closed (SAR 1)

Engine: Lycoming T53-L11 S/N LE09004
Gross Weight (avg): 7,270 lbf.
Centre of Gravity (avg): 129.9 in. aft

Initial Trim Airspeed: ◇40, □70, △100 KIAS (fast starts)

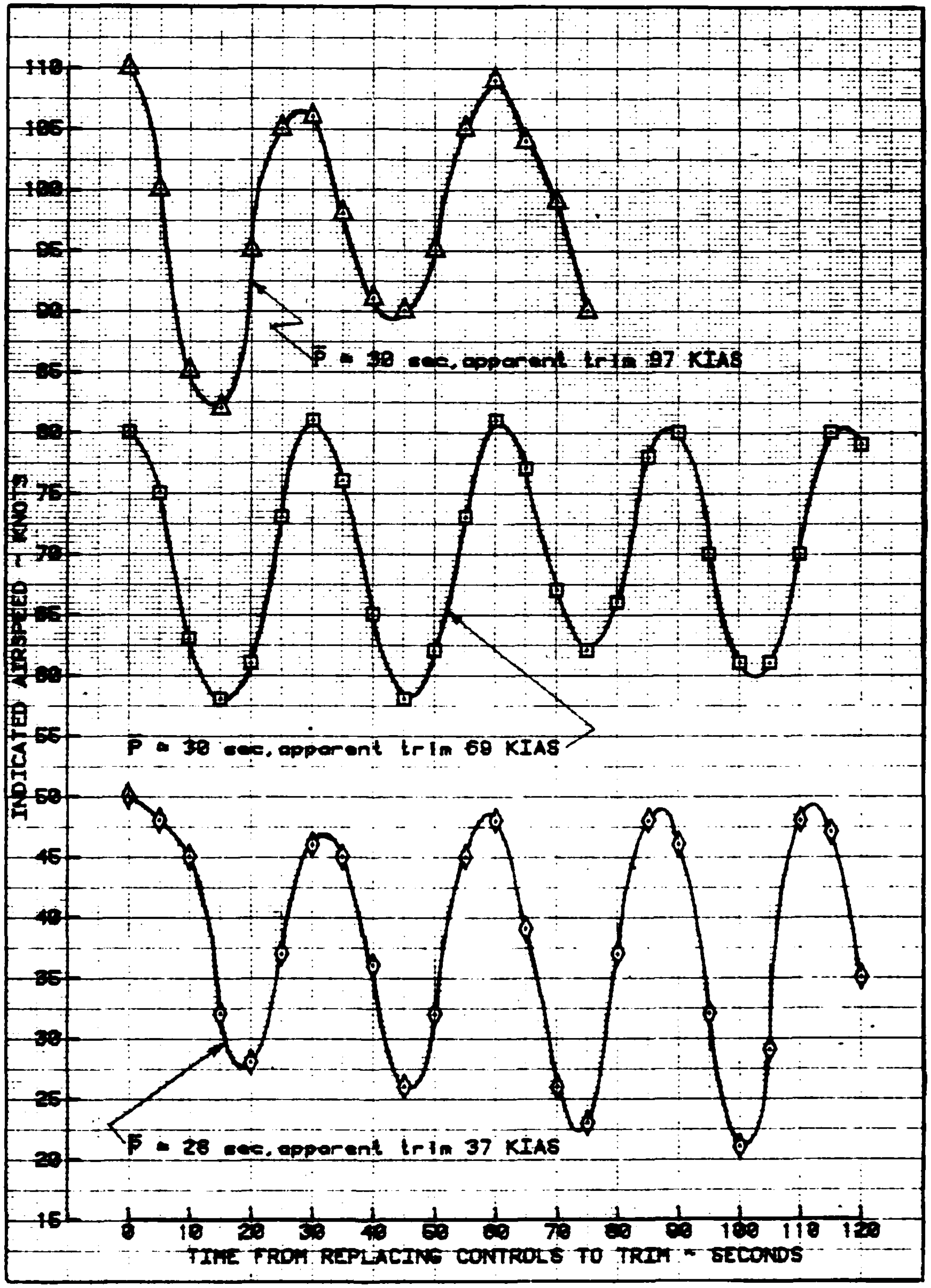
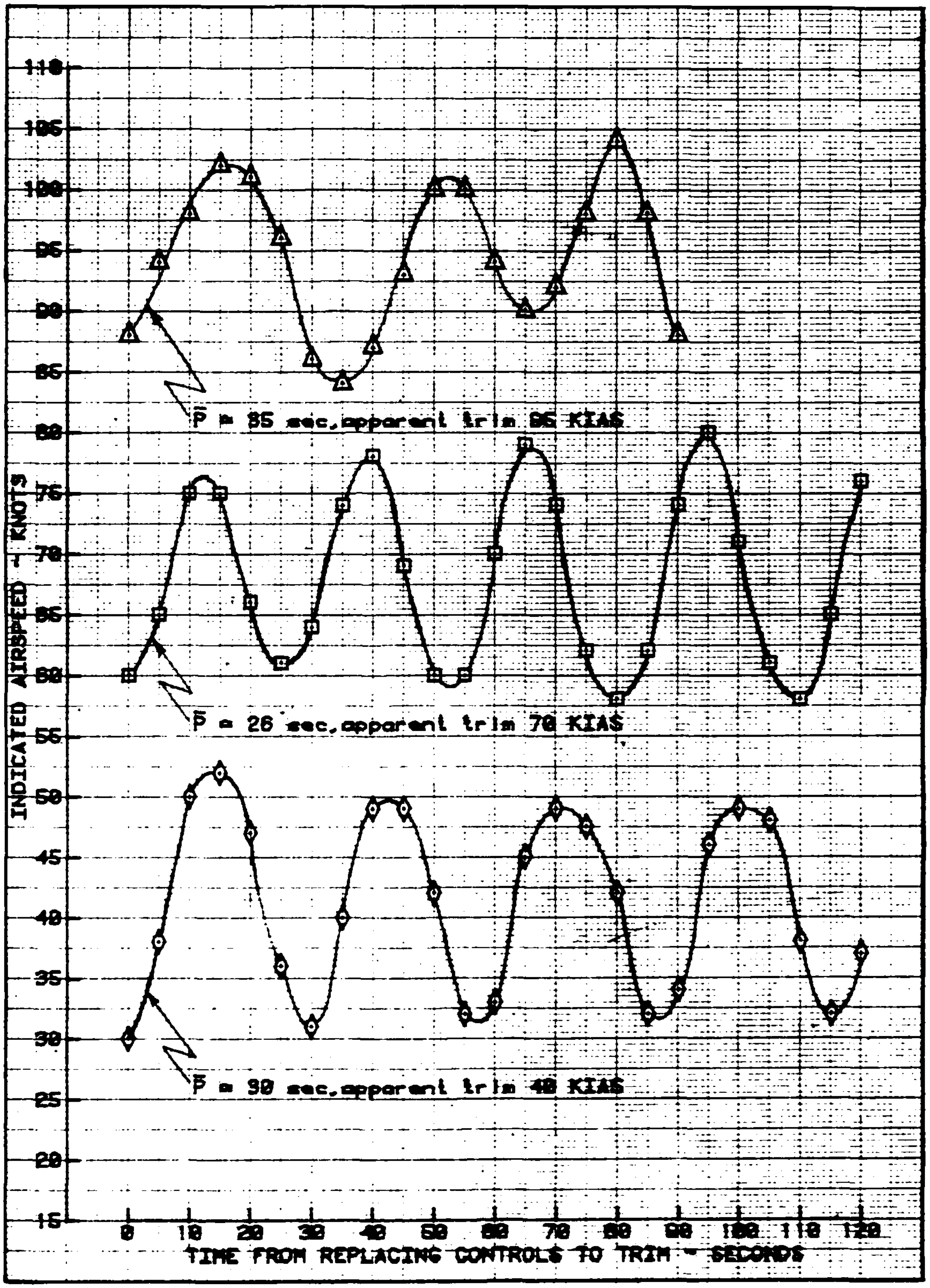



FIGURE 11 - LONG TERM RESPONSE IN LEVEL FLIGHT

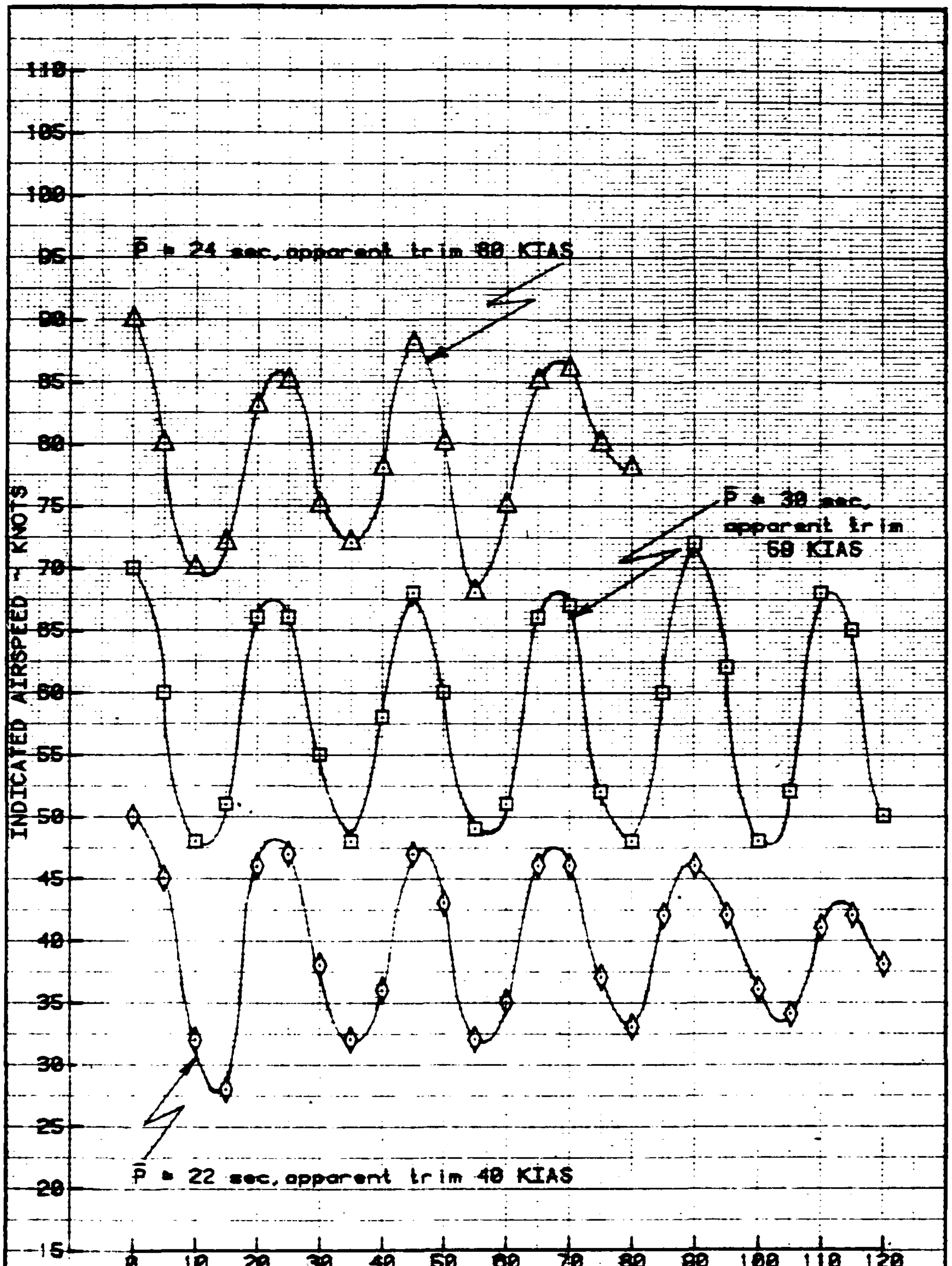
Aircraft: UH-1B S/N A2-1022
Density Altitude: 5,500 ft
Configuration: Clean, Doors Closed (SAR 1)
Engine: Lycoming T53-L11 S/N LE09004
Gross Weight (avg): 7,270 lbf.
Centre of Gravity (avg): 129.9 in. aft

Initial Trim Airspeed: ◇40, □70, △100 KIAS (slow starts)



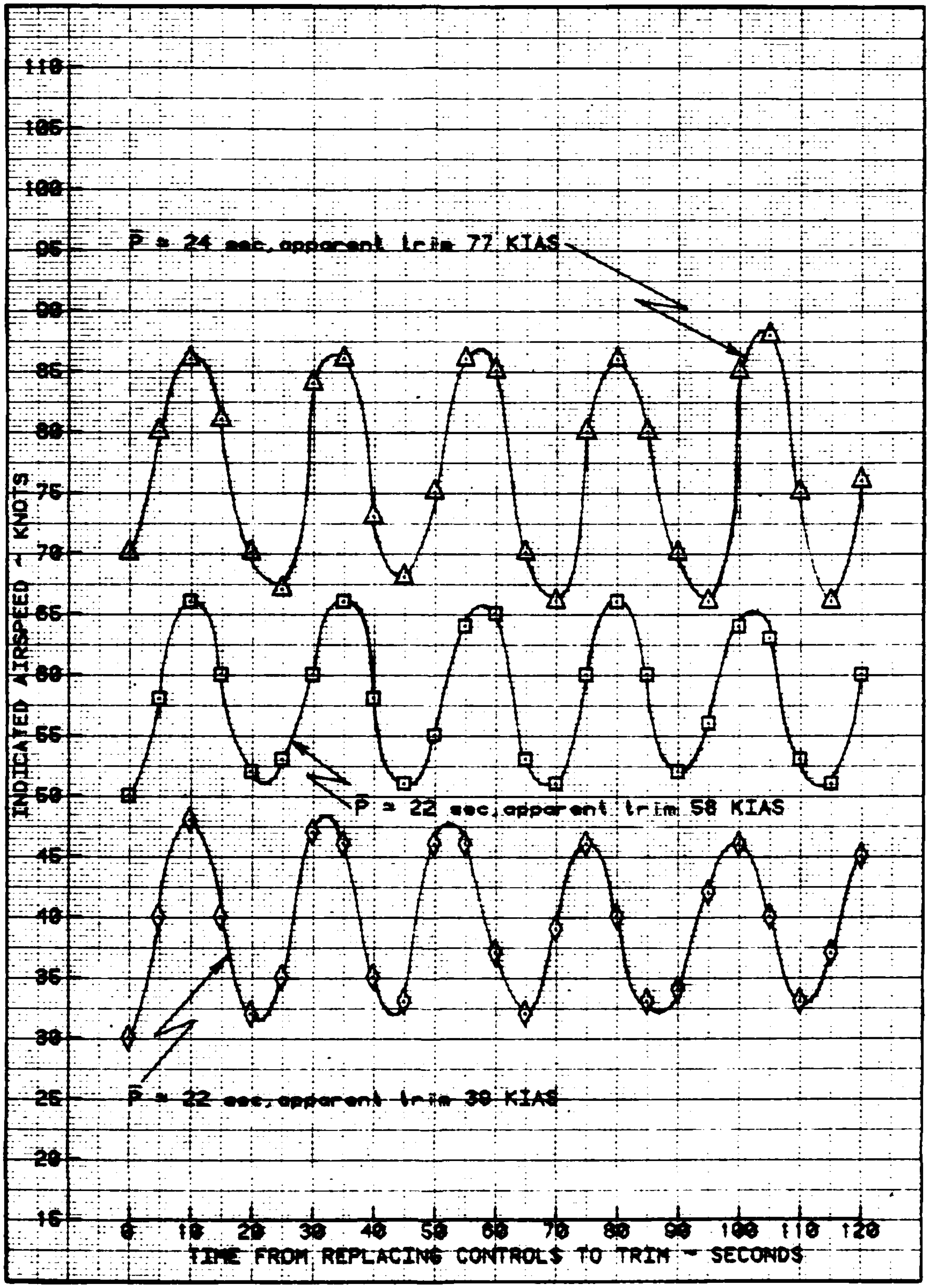
Aircraft: UH-1B S/N A2-1022
Density Altitude: 5,800 ft
Configuration: Full Ext Tanks (SAR 2)
Engine: Lycoming T53-L11 S/N LE09004
Gross Weight (avg): 8,130 lbf.
Centre of Gravity (avg): 127.9 in. aft

Initial Trim Airspeed: ◇40, □60, △80 KIAS (fast starts)



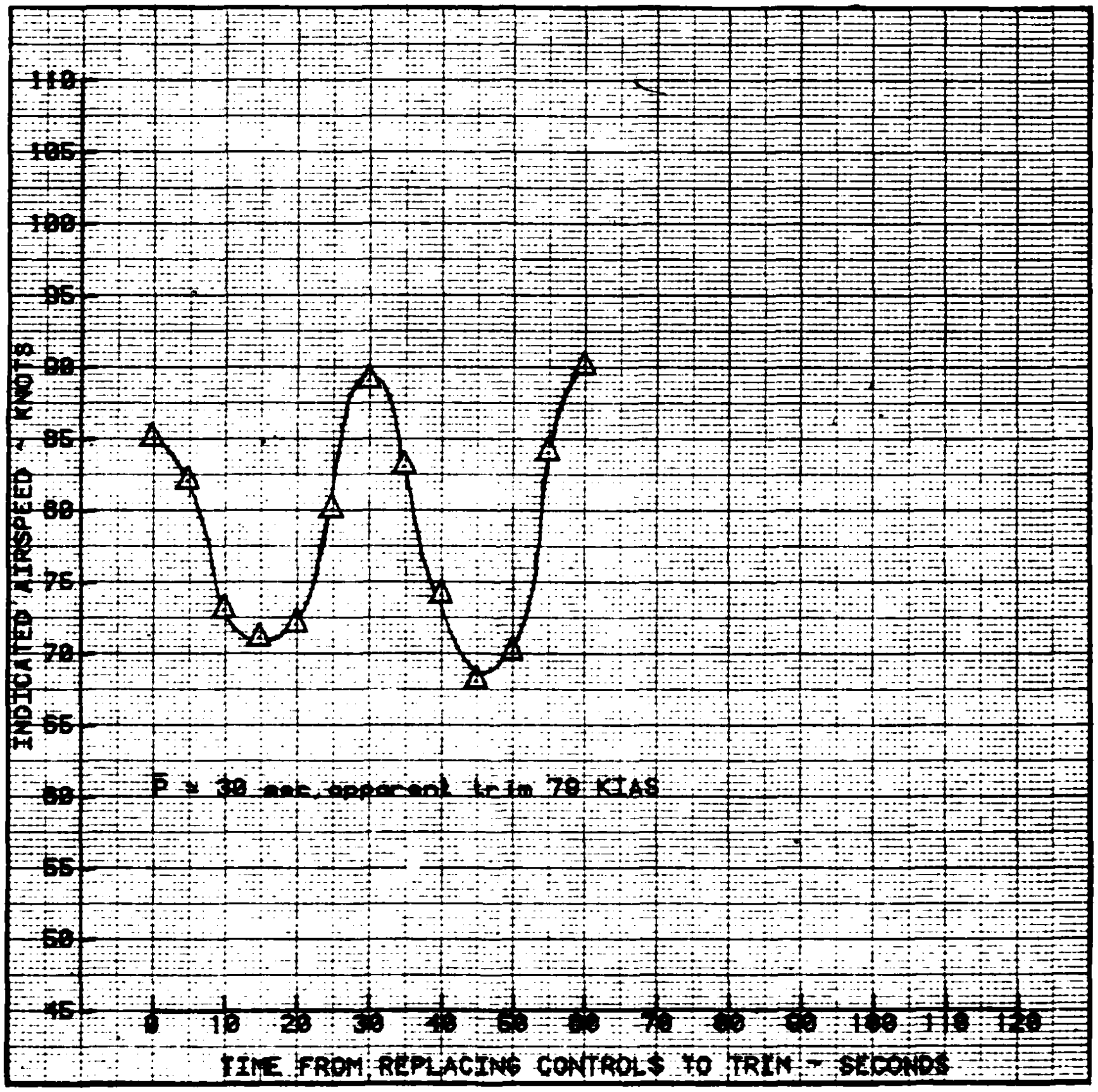
Aircraft: UH-1B S/N A2-1022
Density Altitude: 5,800 ft
Configuration: Full Ext Tanks (SAR 2)
Engine: Lycoming T53-L11 S/N LE09004
Gross Weight (avg): 8,130 lbf
Centre of Gravity (avg): 127.9 in. aft

Initial Trim Airspeed: ◇40, □60, △80 KIAS (slow starts)



Aircraft: UH-1B S/N A2-1022
Density Altitude: 5,000 ft
Configuration: Empty Ext Tanks
(SAR 3)
Initial Trim Airspeed: 75 KIAS (fast start)

Engine: Lycoming T53-L11 S/N LE09004
Gross Weight (avg): 6,490 lbf.
Centre of Gravity (avg): 134.0 in. aft



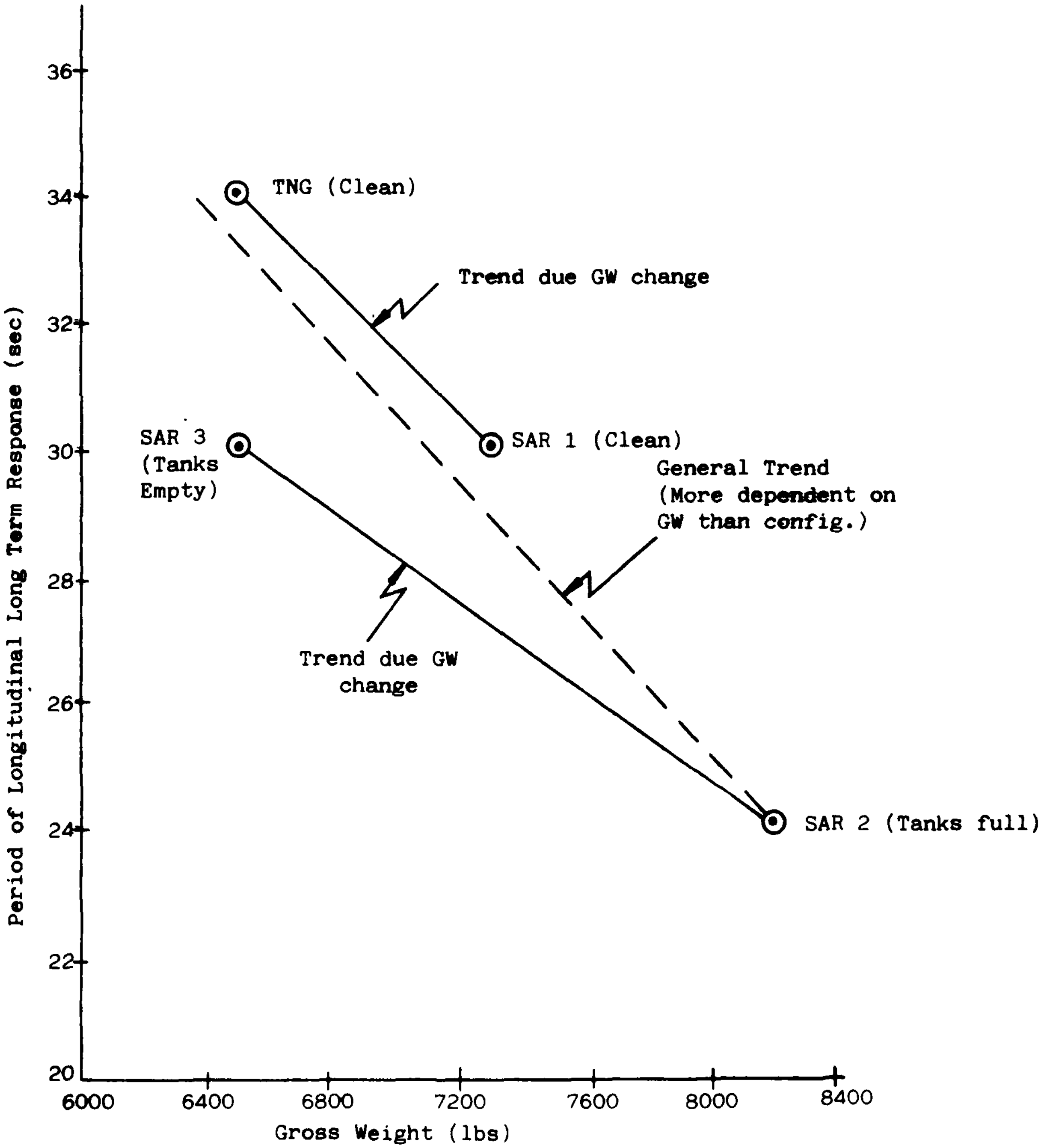
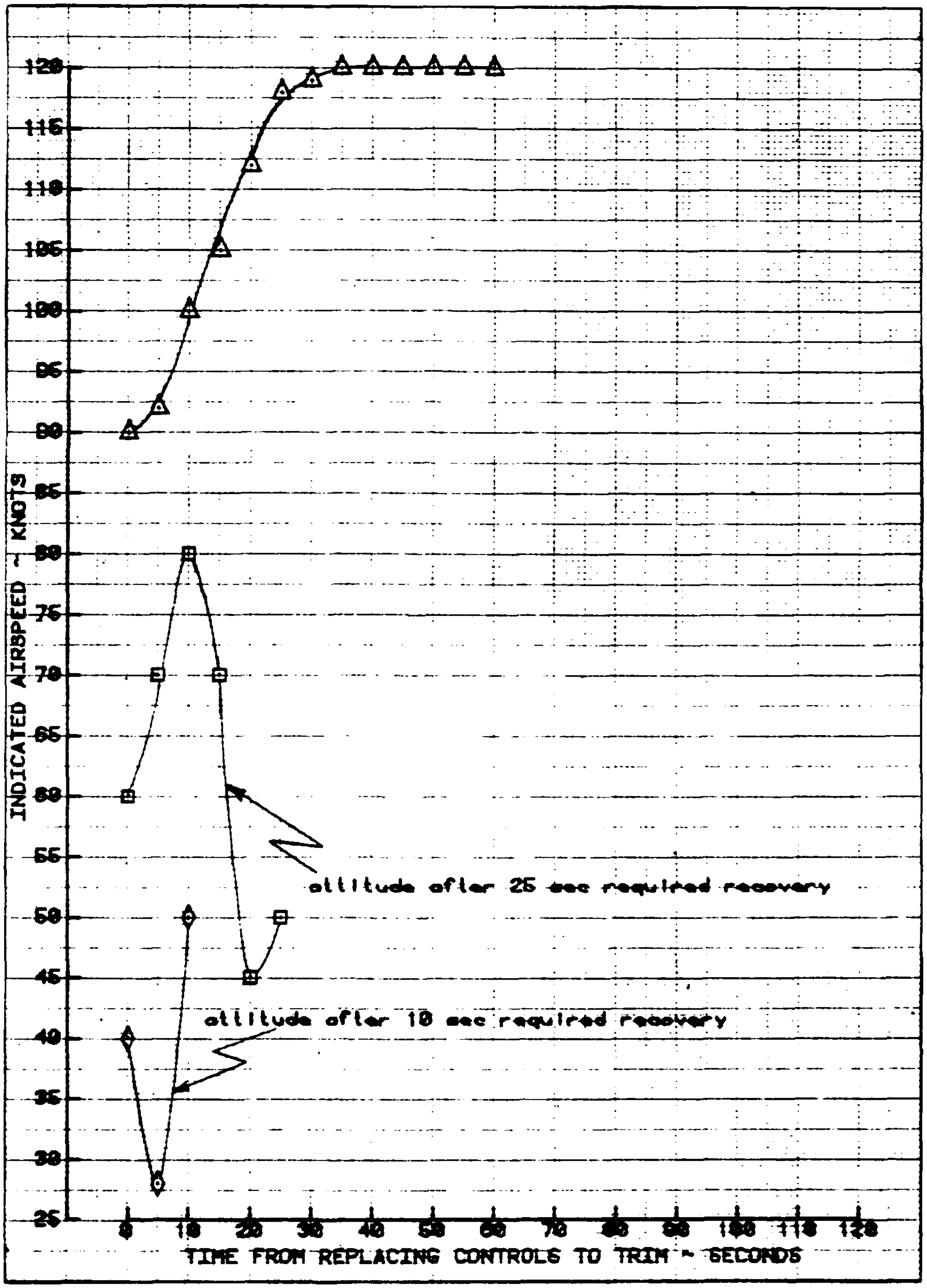



FIGURE 16 - EFFECT OF GROSS WEIGHT AND CONFIGURATION ON PERIOD OF LEVEL FLIGHT LONG TERM RESPONSE

Aircraft: UH-1B S/N A2-1022
Density Altitude: 5,200 ft
Configuration: Clean, Doors Closed (Training)

Engine: Lycoming T53-L11 S/N LE09004
Gross Weight (avg): 6,250 lbf.
Centre of Gravity (avg): 132.7 in. aft

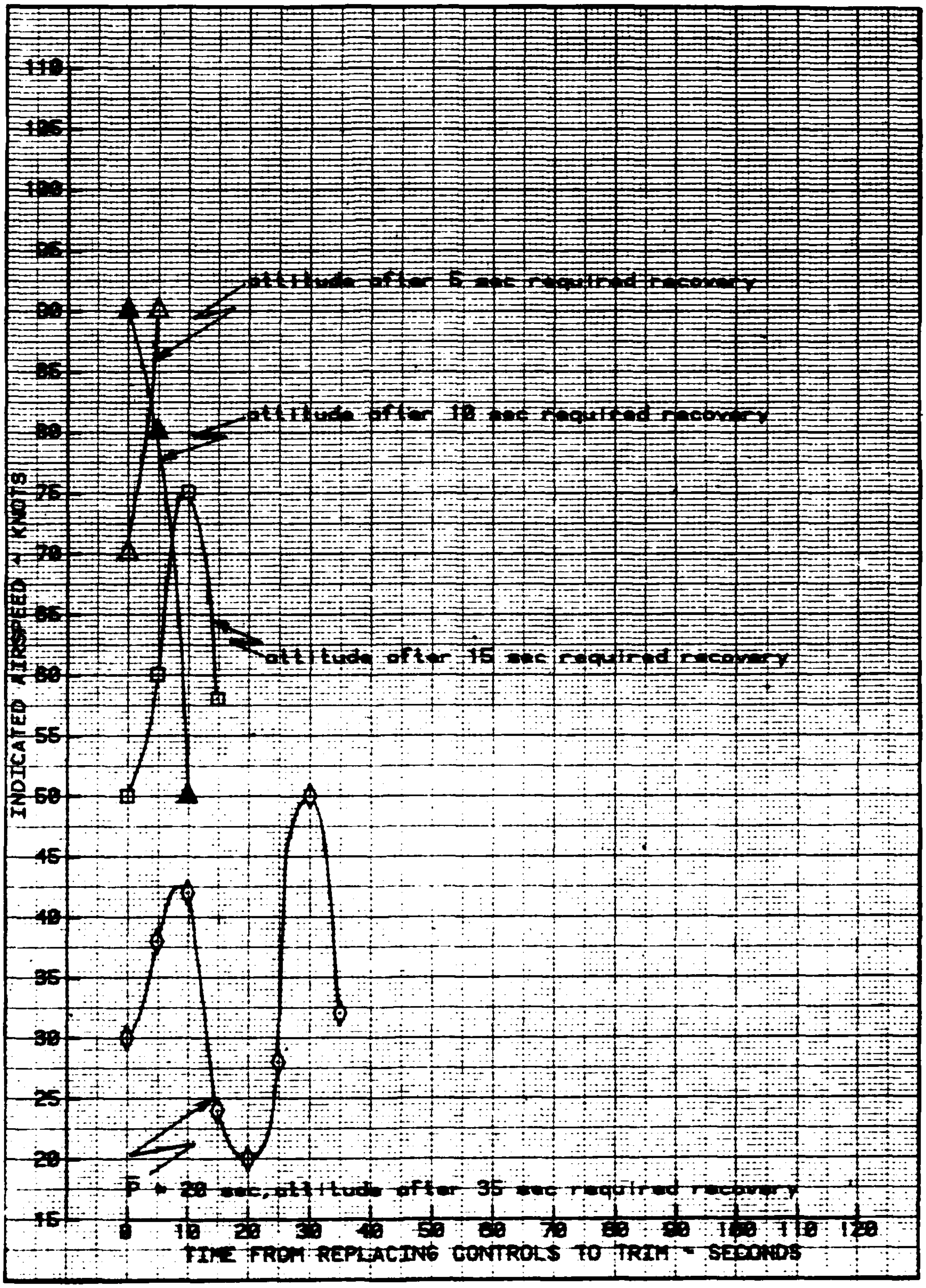
Initial Trim Airspeed: ◇ 45, □ 70, △ 100 KIAS (slow starts)



Aircraft: UH-1B S/N A2-1022
Density Altitude: 5,100 ft
Configuration: Full Ext Tanks (SAR 2)

Engine: Lycoming T53-L11 S/N LE09004
Gross Weight (avg): 7,960 lbf.
Centre of Gravity (avg): 127.7 in. aft

Initial Trim Airspeed: ◇ 40, □ 60, △ 80 (slow starts)
▲ 80 (fast start)



Aircraft: UH-1B S/N A2-1022
Density Altitude: 5,600 ft
Configuration: Clean, Doors Shut
(SAR 1)

Engine: Lycoming T53-L11 S/N LE09004
Gross Weight (avg): 7,100 lbf.
Centre of Gravity: 129.8 in. aft

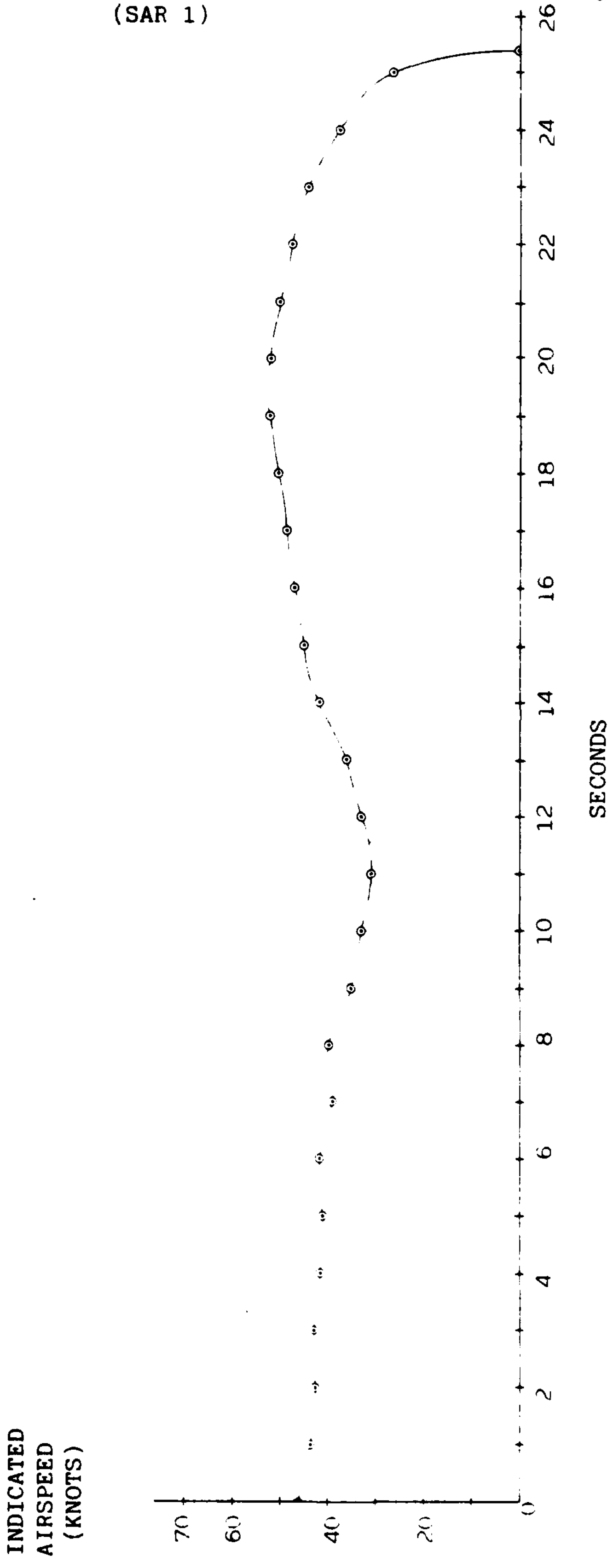
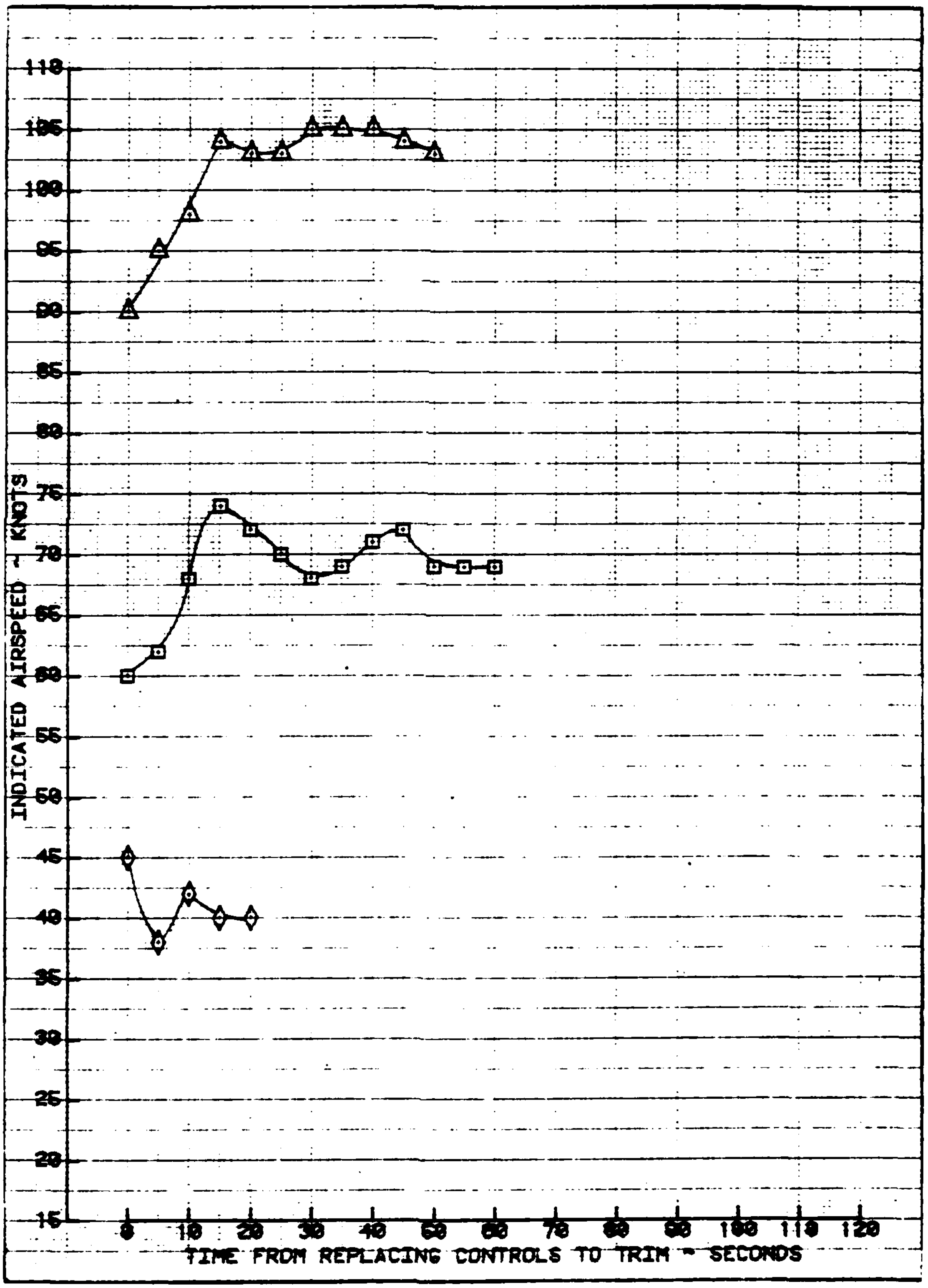



FIGURE 19 - TIME HISTORY OF SELF-EXCITED
LONG TERM RESPONSE IN CLIMB

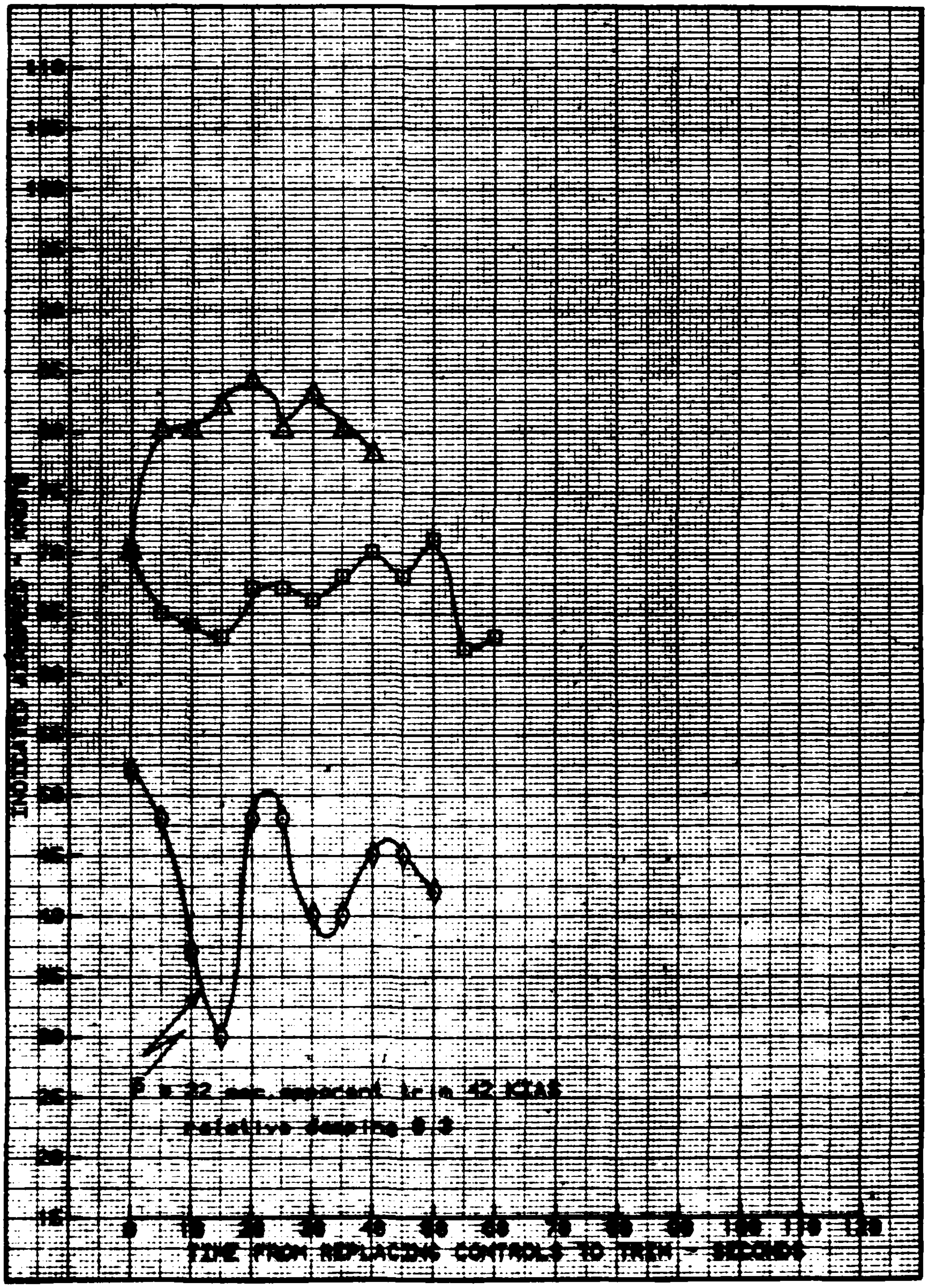
Aircraft: UH-1B S/N A2-1022
Density Altitude: 8,000 ft
Configuration: Clean, Doors Closed (Training)

Engine: Lycoming T53-L11 S/N LE09004
Gross Weight (avg): 6,250 lbf.
Centre of Gravity (avg): 132.7 in. aft

Initial Trim Airspeed: ◇ 40 (fast start), □ 70, △ 100 KIAS (slow starts)

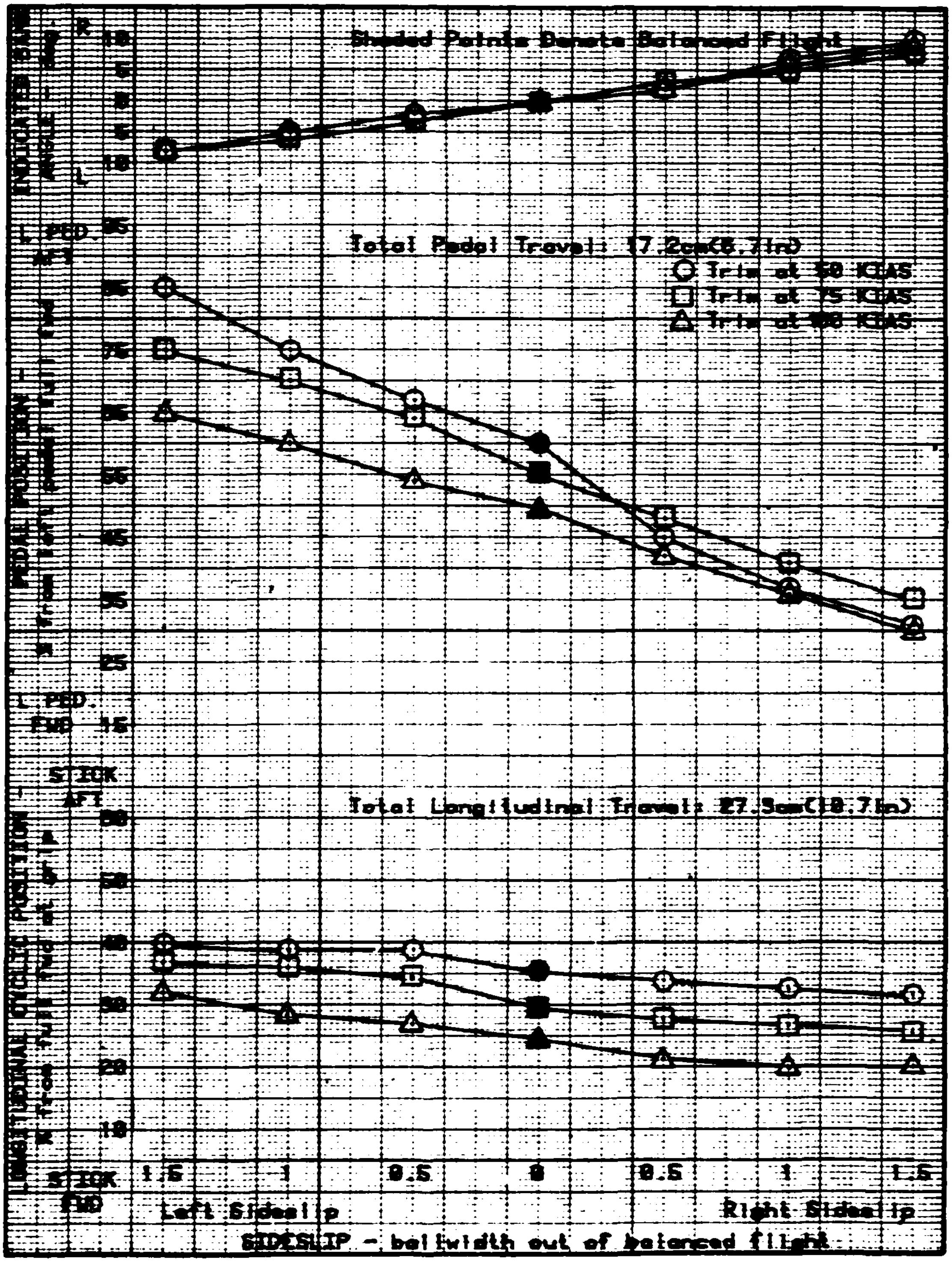


**Aircraft:** UH-1B S/N A2-1022
**Density Altitude:** 5,100 ft
**Configuration:** Full Ext Tanks (SAR 2)
**Engine:** Lycoming T53-L11 S/N LE09004
**Gross Weight (avg):** 7,960 lbf.
**Centre of Gravity (avg):** 127.7 in. aft
**Initial Trim Airspeed:** ◇40, □60 (fast starts), △80 KIAS (slow start)



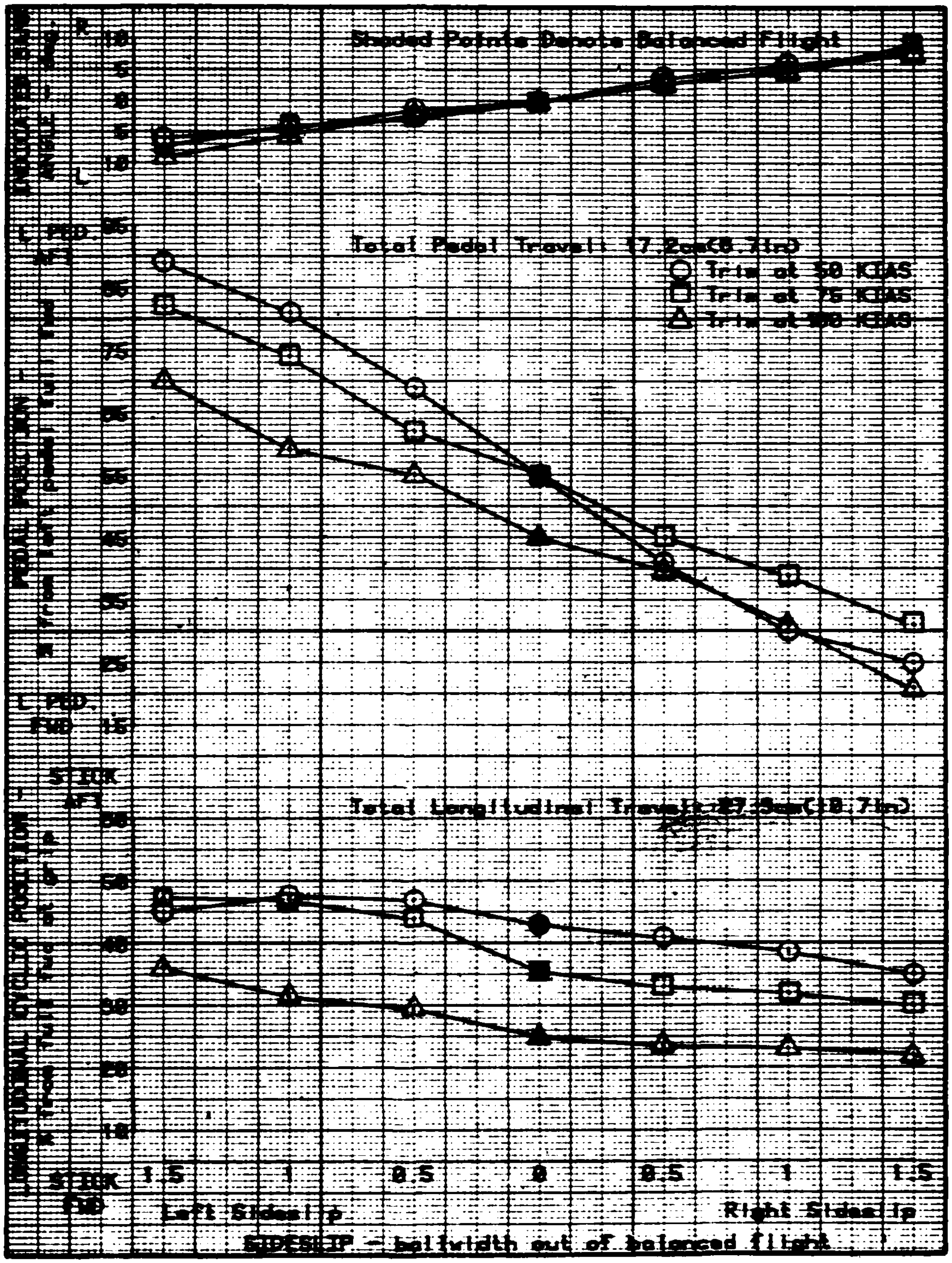
Aircraft: UH-1B S/N A2-1022
Density Altitude: 5,200 ft
Configuration: Clean, Doors Closed (Training)

Engine: Lycoming T53-L11 S/N LE09004
Gross Weight (avg): 6,720 lbf.
Centre of Gravity (avg): 133.0 in. aft



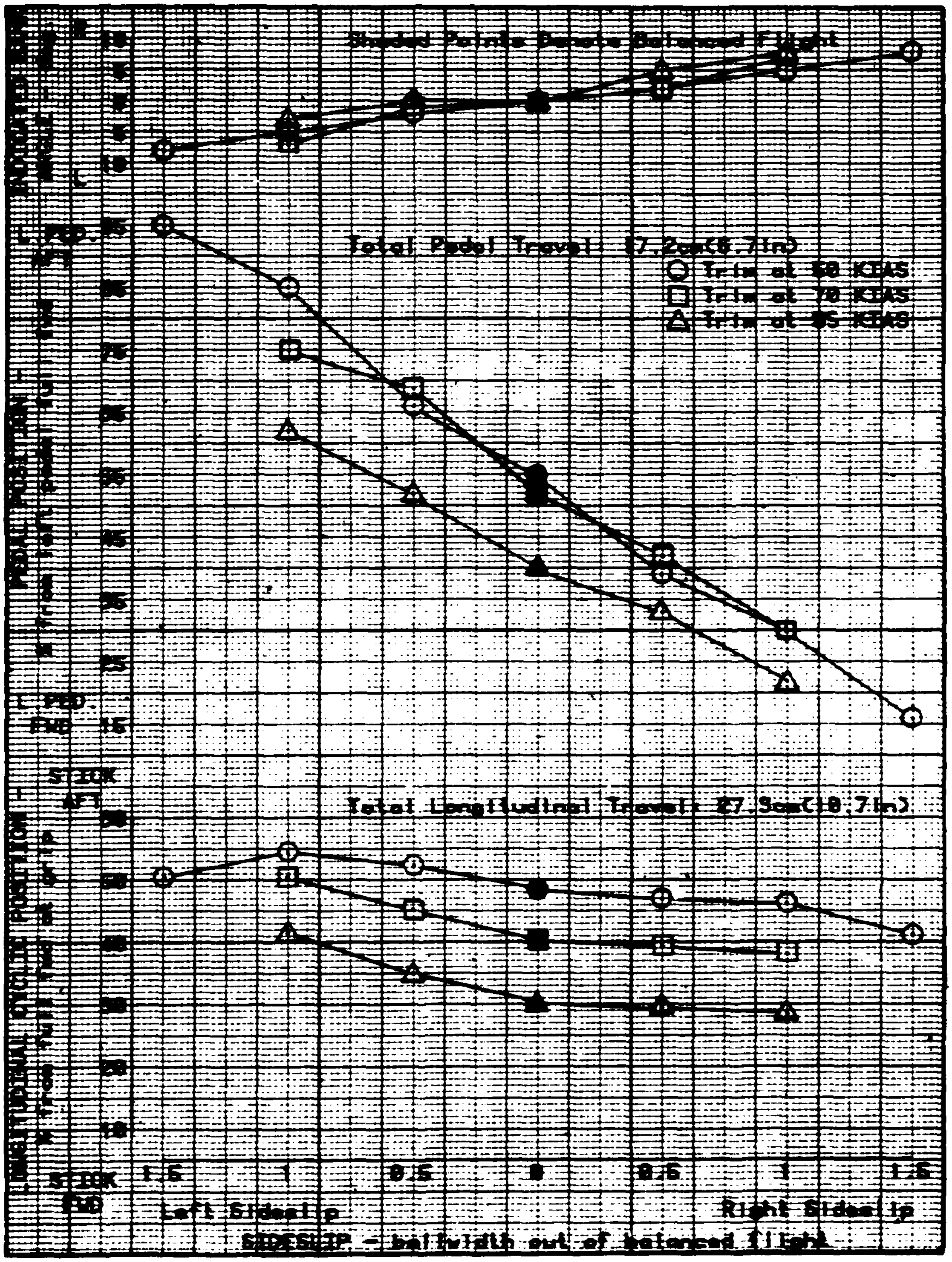
**Aircraft**: UH-1B S/N A2-1022
**Density Altitude**: 5,900 ft
**Configuration**: Clean, Doors Closed (SAR 1)

Engine: Lycoming T53-L11 S/N LE09004
Gross Weight (avg): 7,470 lbf.
Centre of Gravity (avg): 130.1 in. aft



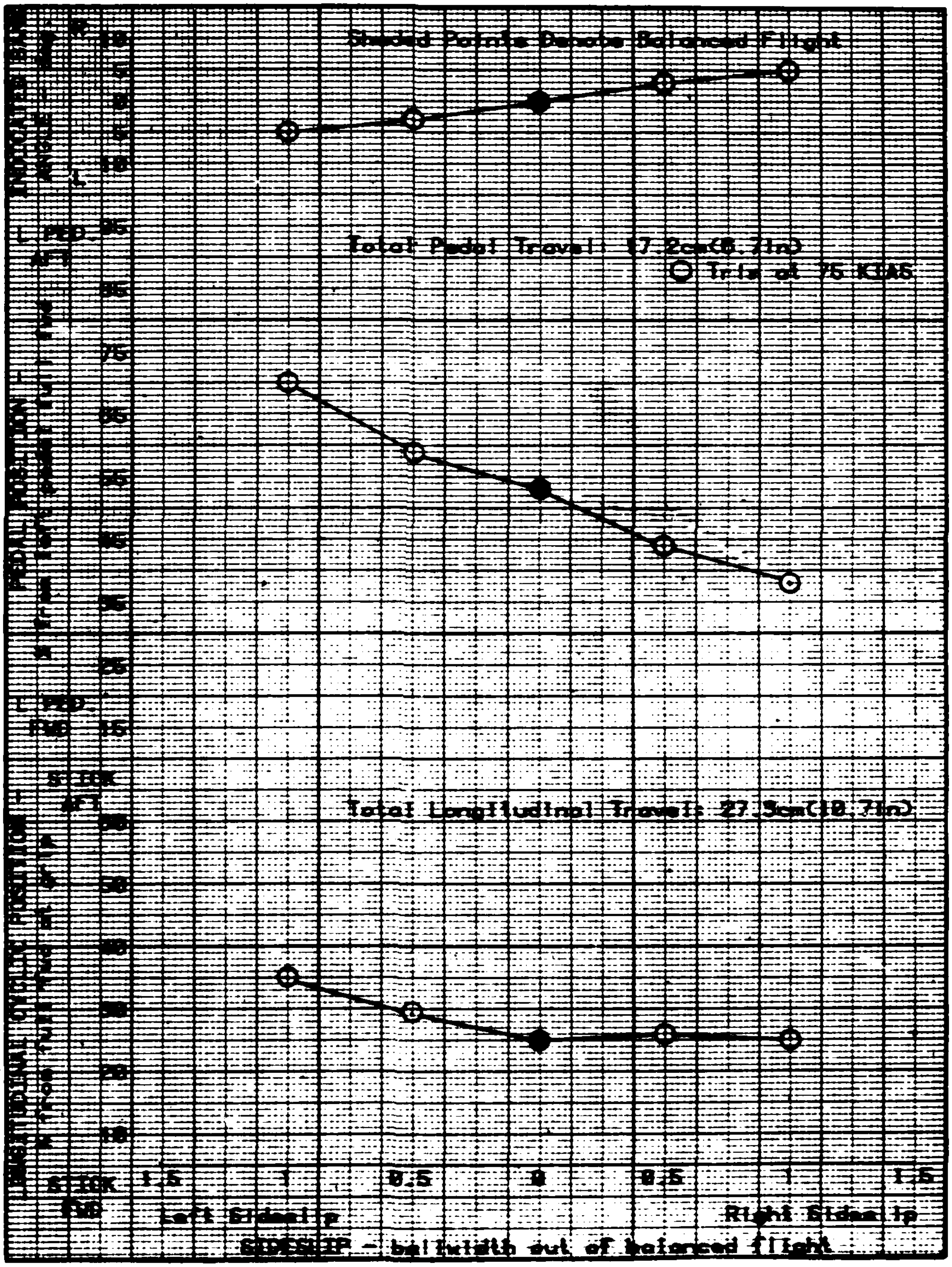
**Aircraft:** UH-1B S/N A2-1022
**Density Altitude:** 6,000 ft
**Configuration:** Full Ext Tanks (SAR 2)

**Engine:** Lycoming T53-L11 S/N LE09004
**Gross Weight (avg):** 8,290 lbf.
**Centre of Gravity (avg):** 128.0 in. aft



**Aircraft:** UH-1B S/N A2-1022
**Density Altitude:** 4,700 ft
**Configuration:** Empty Ext Tanks (SAR 3)

Engine: Lycoming T53-L11 S/N LE09004
Gross Weight (avg): 6,290 lbf.
Centre of Gravity (avg): 133.9 in. aft



## TEST CONDITIONS

| Serial | Type of Test | Configuration (see Notes) | Average Gross Wt. (lbf) | Average Long. C.G. (in) | Average Press. Alt. (ft) | Average Air Temp. (°C) | Trim Airspeeds (KIAS) |
|---|---|---|---|---|---|---|---|
| 1 | Level Flight Trimmed Control Positions | Training | 6,740 | 132.9 | 4,000 | 24 | 40, 45, 53, 62, 63, 72, 80, 81, 100, 110, |
| | | SAR 1 | 7,560 | 130.2 | 4,000 | 20 | 38, 40, 49, 60, 62, 71, 79, 81, 99, 100, 104 |
| | | SAR 2 | 8,340 | 128.1 | 4,000 | 10 | 38, 40, 52, 60, 63, 69, 80, 82, 90 |
| | | SAR 3 | 6,610 | 134.0 | 5,000 | 3 | 38, 60, 80, 101 |
| 2 | Climb and Descent Trimmed Control Positions | Training | 6,500 | 132.8 | 4,000 | 24 | 40, 60, 80, 100 |
| | | SAR 1 | 7,370 | 130.0 | 5,000 | 18 | 39, 60, 80, 99 |
| | | SAR 2 | 8,140 | 127.9 | 4,000 | 12 | 40, 60, 80 |
| 3 | Level Flight Collective Fixed Static Longitudinal Stability | Training | 6,630 | 132.9 | 4,000 | 24 | 40, 62, 81, 100 |
| | | SAR 1 | 7,480 | 130.1 | 4,000 | 20 | 40, 60, 79, 99 |
| | | SAR 2 | 8,230 | 128.0 | 4,000 | 10 | 40, 60, 80 |
| | | SAR 3 | 6,610 | 134.0 | 5,000 | 3 | 38, 60, 80, 100 |
| 4 | Climb Collective Fixed Static Longitudinal Stability | Training | 6,250 | 132.7 | 3,000 | 25 | 40, 70, 100 |
| | | SAR 1 | 7,160 | 129.8 | 3,500 | 20 | 45, 60, 80, 101 |
| | | SAR 2 | 7,840 | 127.6 | 4,000 | 13 | 40, 60, 80 |

| Serial | Type of Test | Configuration (see Notes) | Average Gross Wt. (lbf) | Average Long. C.G. (in) | Average Press. Alt. (ft) | Average Air Temp. ($^{o}C$) | Trim Airspeeds (KIAS) |
|---|---|---|---|---|---|---|---|
| 5 | Descent Collective Fixed Static Longitudinal Stability | Training | 6,250 | 132.7 | 5,500 | 22 | 40, 70, 100 |
| | | SAR 1 | 7,160 | 129.8 | 5,000 | 17 | 42, 60, 80, 98 |
| | | SAR 2 | 7,840 | 127.6 | 4,000 | 13 | 40, 60, 80 |
| 6 | Level Flight Longitudinal Long Term Response | Training | 6,490 | 132.8 | 4,000 | 19 | 40, 70, 100 |
| | | SAR 1 | 7,270 | 129.9 | 4,100 | 19 | 40, 70, 100 |
| | | SAR 2 | 8,130 | 127.9 | 4,800 | 13 | 40, 60, 80 |
| | | SAR 3 | 6,490 | 134.0 | 5,000 | 3 | 75 |
| 7 | Max Power Climb Longitudinal Long Term Response | Training | 6,250 | 132.7 | 4,000 | 18 | 45, 70, 100 |
| | | SAR 1 | 7,100 | 129.8 | 4,100 | 19 | 40, 70, 100 |
| | | SAR 2 | 7,960 | 127.7 | 4,200 | 14 | 40, 60, 80 |
| 8 | Autorotation Longitudinal Long Term Response | Training | 6,250 | 132.7 | 4,000 | 18 | 40, 70, 100 |
| | | SAR 1 | 7,100 | 129.8 | 4,100 | 19 | 40, 70, 100 |
| | | SAR 2 | 7,960 | 127.7 | 4,200 | 14 | 40, 60, 80 |
| 9 | Level Flight Gust Response | Training | 6,750 | 132.9 | 4,050 | 17 | 40, 60, 80, 98 |
| | | SAR 1 | 7,550 | 130.2 | 3,900 | 20 | 50, 75, 100 |
| | | SAR 2 | 8,400 | 128.2 | 4,000 | 12 | 50, 70, 90 |

| Serial | Type of Test | Config-uration (see Notes) | Average Gross Wt. (lbf) | Average Long. C.G. (in) | Average Press. Alt. (ft) | Average Air Temp. ($^oC$) | Trim Airspeeds (KIAS) |
|---|---|---|---|---|---|---|---|
| 10 | Level Flight Longitudinal Control Response | Training | 6,600 | 132.9 | 4,000 | 17 | 40, 70, 100 |
| | | SAR 1 | 7,420 | 130.1 | 4,000 | 20 | 50, 75, 100 |
| | | SAR 2 | 8,270 | 128.0 | 4,900 | 12 | 50, 70, 90 |
| 11 | Steady Heading Side-slips | Training | 6,720 | 133.0 | 4,000 | 18 | 50, 75, 100 |
| | | SAR 1 | 7,470 | 130.1 | 4,200 | 21 | 50, 75, 100 |
| | | SAR 2 | 8,290 | 128.0 | 5,500 | 6 | 50, 75, 85 |
| | | SAR 3 | 6,290 | 133.9 | 5,000 | 3 | 75 |
| 12 | Pedal Only Turns | Training | 6,550 | 132.8 | 4,100 | 16 | 50, 75, 100 |
| | | SAR 1 | 7,230 | 129.9 | 4,100 | 21 | 50, 75, 102 |
| | | SAR 2 | 8,110 | 127.8 | 5,500 | 6 | 50, 70, 90 |
| 13 | Cyclic Only Turns | Training | 6,550 | 132.8 | 4,100 | 16 | 50, 75, 100 |
| | | SAR 1 | 7,230 | 129.9 | 4,100 | 21 | 50, 75, 102 |
| | | SAR 2 | 8,110 | 127.8 | 5,500 | 6 | 50, 70, 90 |

| Serial | Type of Test | Configuration (see Notes) | Average Gross Wt. (lbf) | Average Long. C.G. (in) | Average Press. Alt. (ft) | Average Air Temp. (°C) | Trim Airspeeds (KIAS) |
|---|---|---|---|---|---|---|---|
| 14 | Spiral Stability (pedal only turns) | Training | 6,550 | 132.8 | 4,100 | 16 | 50, 75, 100 |
| | | SAR 1 | 7,230 | 129.9 | 4,100 | 21 | 50, 75, 102 |
| | | SAR 2 | 8,110 | 127.8 | 5,500 | 6 | 50, 70, 90 |
| | (release from steady heading side-slip) | Training | 6,380 | 133.3 | 3,000 | 18 | 50, 100 |
| | | SAR 1 | 7,090 | 129.8 | 4,150 | 21 | 50, 75 |
| | | SAR 2 | 7,940 | 127.7 | 5,750 | 5 | 50, 70, 90 |
| 15 | Dynamic Side-slip Effects | Training | 6,600 | 132.9 | 4,000 | 16 | 50, 75, 100 |

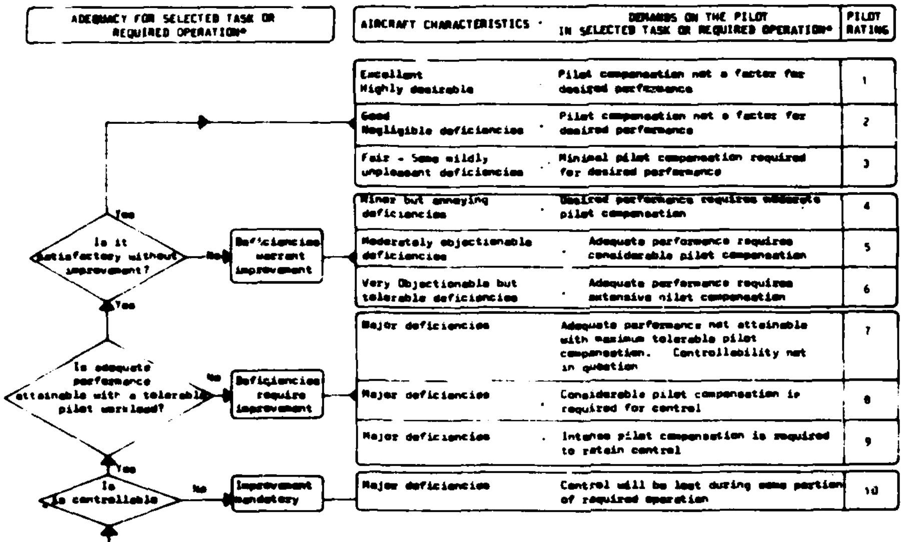
<u>Notes</u>:

1. Training configuration refers to pilot training with the two pilot seats occupied and a crewperson in the rear compartment.
2. SAR 1 configuration refers to the carriage of six persons plus SAR gear without external tanks.
3. SAR 2 configuration refers to the carriage of six persons plus SAR gear with full external tanks.
4. SAR 3 configuration refers to the carriage of two pilots only with empty external tanks.
5. Where 'average' is used this refers to the average condition experienced during each particular test sequence.

# SPECIAL TEST LIMITS

| Parameter | Limit |
|---|---|
| Airspeeds - Sideward | 30 KTAS |
| - Rearward | 30 KTAS |
| - Forward | $V_{NE}$ as placarded |
| Altitudes - General | Ground level to 10,000 feet AMSL |
| - Minimum for dynamic tests | 2,000 ft AGL |
| - Minimum for auto entry | 3,000 ft AGL |
| - Minimum for auto recovery | 2,000 ft AGL |
| Attitudes - Pitch | $\pm$ 30 degrees or excessive rate |
| - Roll | $\pm$ 60 degrees or excessive rate |
| Maximum step input to controls | |
| - Cyclic | 2 inches |
| - Collective | 2 inches |
| - Pedals | 2 inches |
| Normal Acceleration ($n_z$) | + 0.5 g minimum |
| Control system feedback/ blade stall | Onset |
| Side-slip | $\pm$ two skid-ball widths from balanced flight. |

## EXTRACT FROM NASA TN-D-5153




* Definition of required operation involves designation of flight phase and/or subphases with accompanying conditions.

### DEFINITIONS FROM TN-D-5153

**COMPENSATION**

The measure of additional pilot effort and attention required to maintain a given level of performance in the face of deficient vehicle characteristics.

**HANDLING QUALITIES**

Those qualities or characteristics of an aircraft that govern the ease and precision with which a pilot is able to perform the tasks required in support of an aircraft role.

**MISSION**

The composite of pilot-vehicle functions that must be performed to fulfill operational requirements. May be specified for a role, complete flight, flight phase, or flight subphase.

**PERFORMANCE**

The precision of control with respect to aircraft movement that a pilot is able to achieve in performing a task. (Pilot-vehicle performance is a measure of handling performance. Pilot performance is a measure of the manner or efficiency with which a pilot moves the principal controls in performing a task.)

**ROLE**

The function or purpose that defines the primary use of an aircraft.

**TASK**

The actual work assigned a pilot to be performed in completion of or as representative of a designated flight segment.

**WORKLOAD**

The integrated physical and mental effort required to perform a specified piloting task

AIRCRAFT RESEARCH AND DEVELOPMENT UNIT

TECHNICAL INVESTIGATION NO 783

EVALUATION OF IROQUOIS UH-1B STABILITY AND CONTROL

DISTRIBUTION EXTERNAL

| | | Copy No |
|---|---|---|
| **Department of Defence** | | |
| Air Force Office: | TP4-AF | 1 |
| | DAFS | 2 |
| | DRR-AF | 3 |
| | DGAIRENG-AF | 4 |
| | DGOR-AF | 5 |
| Navy Office: | DNAE | 6 |
| | AMFTU RAN NOWRA | 7 |
| | RANTAU | 8 |
| | Superintendent, Aircraft Maintenance & Repair, C/- RAN Dockyard, GARDEN ISLAND | 9 |
| | HC 723 Squadron RAN NOWRA | 10 |
| Army Office: | DAVN | 11-12 |
| | HQ AAVN OAKEY | 13-14 |
| Defence Science and Technology Organization: | DISB | 15-32 |
| **Overseas** | | |
| Air Attache WASHINGTON | | 33 |
| **Operational Command** | | |
| Headquarters Operational Command | | 34 |
| Headquarters RAAF AMBERLEY | | 35 |
| No 9 Squadron RAAF AMBERLEY | | 36-39 |
| No 12 Squadron RAAF AMBERLEY | | 40-41 |
| Headquarters RAAF EDINBURGH | | 42 |
| Headquarters RAAF FAIRBAIRN | | 43 |
| No 5 Squadron RAAF FAIRBAIRN | | 44-49 |
| Headquarters RAAF TOWNSVILLE | | 50 |
| No 35 Squadron RAAF TOWNSVILLE | | 51-53 |
| Headquarters RAAF WILLIAMTOWN | | 54-56 |
| **Support Command** | | |
| Headquarters Support Command (AIRENG3) | | 57-59 |
| Headquarters RAAF PEARCE | | 60-61 |
| No 2 Flying Training School RAAF PEARCE | | 62 |
| Headquarters RAAF POINT COOK | | 63 |
| Academy RAAF POINT COOK | | 64 |
| Aviation Medicine RAAF POINT COOK | | 65 |
| No 1 Flying Training School RAAF POINT COOK | | 66 |
| No 3 Aircraft Depot RAAF AMBERLEY | | 67 |

Civil Establishments

| | |
|---|---|
| Aeronautical Research Laboratories MELBOURNE | 68 |
| Defence Research Centre SALISBURY (Library) | 69 |

DISTRIBUTION INTERNAL

| | |
|---|---|
| Commanding Officer | 70 |
| Project Officer | 71-73 |
| Senior Research Scientist | 74 |
| Library | 75 |
| Report Production Flight (Master) | 76 |
| Spares | 77-85 |

Civil Establishments

| | |
|---|---|
| Aeronautical Research Laboratories MELBOURNE | 68 |
| Defence Research Centre SALISBURY (Library) | 69 |

DISTRIBUTION INTERNAL

| | |
|---|---|
| Commanding Officer | 70 |
| Project Officer | 71-73 |
| Senior Research Scientist | 74 |
| Library | 75 |
| Report Production Flight (Master) | 76 |
| Spares | 77-85 |

END

FILMED

1-83

DTIC