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UNCLASSIFIED 206-194-134 USAAVSCOM-TR-77-14 NL

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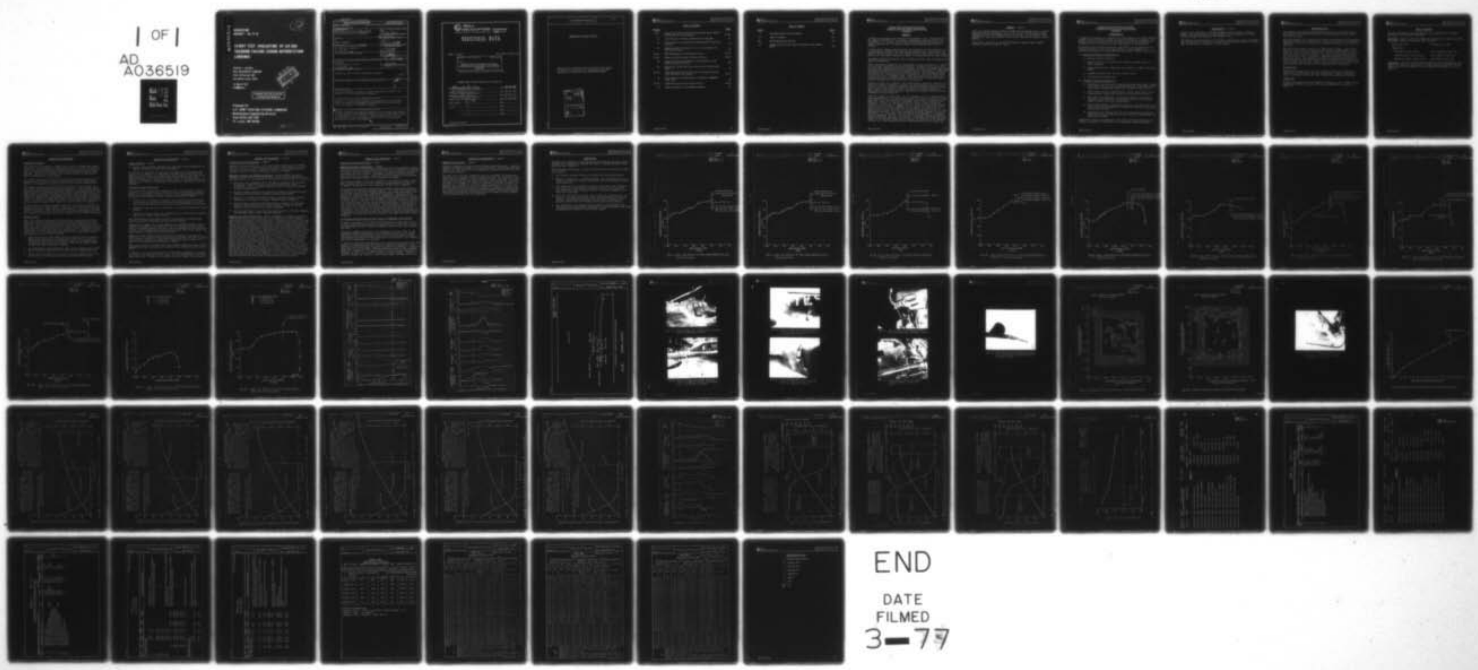

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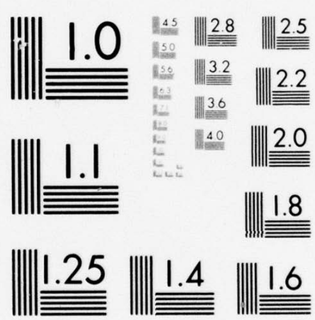

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USAAVSCOM
REPORT - TR 77-14

FLIGHT TEST EVALUATION OF OH-58A TAILBOOM FAILURE DURING AUTOROTATION LANDINGS

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Post Office Box 482
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14 March 1973
Final Report

APPROVED FOR PUBLIC RELEASE
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Prepared for
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Maintenance Engineering Division
Post Office Box 209
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REPORT DOCUMENTATION PAGE

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This report presents the results of Product Improvement Task 69-45. See USAAVSCOM TR 77-10 for additional information.

19. KEY WORDS (*Continue on reverse side if necessary and identify by block number*)

Flight test, Ground tiedown evaluation, Instrumentation, Test Helicopter, Ground run results, Flight Results, Tailboom Failure Evaluation, Reduced Collective Evaluation, (USAASTA) Test Results.

20. ABSTRACT (*Continue on reverse side if necessary and identify by block number*)

A flight program was initiated in September 1971 to investigate the causes of the model OH-58A tailboom failures occuring in service and to explore methods of eliminating this type of failure. From the results of this test it is concluded that the tailboom failures would not have occurred had proper autorotative techniques been observed.

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TECHNICAL DATA

MODEL OH-58A

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TITLE
FLIGHT TEST EVALUATION OF OH-58A TAILBOOM FAILURE DURING AUTOROTATION LANDINGS

PREPARED UNDER CONTRACT DAAJ01-70-C-0057(2E)

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FLIGHT TEST EVALUATION OF OH-58A TAILBOOM FAILURE DURING AUTOROTATION LANDINGS

SUMMARY

A flight test program was initiated in September 1971, under Contract No. DAAJ01-70-C-0057(2E) and Product Improvement Task No. 69-45, to investigate the cause(s) of the Model OH-58A tailboom failures occurring in service and to explore methods of eliminating this type of failure.

A three phase company investigation was initiated and consisted of (1) a mathematical analysis and associated computer runs, (2) a series of ground vibration tests, and (3) a ground tiedown and flight test. The results of the flight evaluation, phase 3, are presented in this report.

Two Model OH-58A Helicopters, S/N's 41080 and 41155, were utilized during the evaluation.

With a telemetry capability of monitoring critical parameters, a series of tests were conducted and data obtained. Analysis of the data that were recorded during autorotations showed that when touchdowns were made at abnormally high speeds and at abnormally low rotor rpm, aft fuselage wrinkling and failure of the tailboom occurred. This damage occurred when loads were introduced into the fuselage at the pylon spike stops via the main rotor flapping stops. This was demonstrated during the evaluation when a tailboom failure was duplicated to study the influential circumstances associated with the failure.

Results of this test indicate that autorotation touchdown airspeeds in excess of 30 knots should be avoided and upon ground contact the collective should be smoothly reduced as soon as touchdown conditions permit. Also, tests conducted with the collective range reduced by approximately 20 percent showed a substantial reduction in main rotor flapping and pylon behavior.

From the results of this test, it is concluded that the tailboom failures experienced by the Army (which caused initiation of this test program) would not have occurred had proper autorotative techniques been observed. That is to say that primarily cyclic control should be utilized to flare the helicopter so as to arrest forward airspeed and initial rate of descent. Application of collective thereafter should occur and only in close proximity to the ground to arrest rate of descent for the last few feet of altitude until ground contact is made. Upon ground contact, collective should be smoothly reduced as soon as practical; not increased. This technique is recognized by helicopter pilots throughout the world as the safe and proper method of making a full autorotative landing. Conversely, a technique of flying the helicopter to the ground, primarily by the use of collective, is improper in that (1) it is inherently unsafe (miscalculation by the pilot can

SUMMARY - (cont)

result in the helicopter being too high off the ground with no arresting capabilities remaining), and (2) it results in abnormally high touchdown speeds and abnormally low rotor rpm. Other types of rotor systems for other helicopters flown in this manner are equally unforgiving.

Tests were conducted at the Bell Helicopter Company (BHC) Flight Research Center, Arlington, Texas.

FLIGHT TEST EVALUATION OF OH-58A TAILBOOM FAILURE DURING AUTOROTATION LANDINGS

INTRODUCTION

A flight test program was initiated to investigate U. S. Army reported OH-58A tailboom failures during autorotation touchdown landings. The intent of the investigation was to explore methods or techniques of eliminating these failures and make appropriate recommendations.

A standard Model OH-58A Helicopter, S/N 41080, was instrumented and several hypotheses were to be investigated. Test emphasis was directed towards the following ground and possible flight evaluations.

A. Ground Run Tiedown Evaluation of

1. Baseline pylon stability.
2. Effect of first and second drive system torsional mode on pylon damping.
3. Blade chord natural frequency and feedback at high collective pitch.
4. Damping of pylon fore and aft, lateral mode.
5. Coriolis Force Excitation.

B. Possible Flight Evaluation of

1. Binding of the main rotor flapping bearings under high collective pitch and low rotor speed resulting in an unstable rigid rotor effect producing pylon whirl and pylon stop contact.
2. Rotor blade resonant amplification (chord and/or beam) which could produce large pylon motions and high control loads.
3. The effect of significant rotor out-of-balance resulting in excessive pylon response and possible contact of the pylon stops as pylon modes are transitioned.
4. Pylon whirl induced by pylon stop contact with high rotor coning, sustained and amplified by symmetric chordwise deflection of the rotor blades.
5. High main rotor one-per-rev hub forces produced by Coriolis accelerations resulting from cyclic inputs in the presence of high rotor coning.

Additional tests were conducted on the Model OH-58A Helicopter, S/N 41155, to evaluate a reduction in the available collective range.

INTRODUCTION - (cont)

Flights were performed at the BHC Flight Research Center, Arlington, Texas. The first ground run was conducted on 20 September 1971 and the last flight was completed 24 November 1971.

The dynamic characteristics of the rotor, pylon, drive train, fuselage, and skid gear were evaluated in detail by the Dynamic Group and results are on file but not presented in this report.

INSTRUMENTATION

The airborne data acquisition system installed in the Model OH-58A Helicopter, S/N 41080, consisted of an oscillograph recorder and a telemetry package.

The oscillograph was a standard 18 channel Consolidated Electrodynamics Corporation Model S-114-P3 recorder with galvanometers. A calibrate equivalent was used to correlate the initial calibration with the data obtained.

The telemetry package consisted of BHC designed signal conditioning modules, vector voltage controlled oscillators, Model TL407, and a conic "L" band telemetry transmitter. The telemetry link had a maximum capacity of 13 data channels. The signal conditioning modules are the passive type, and insert a calibration signal at the end of each data point. The incoming telemetry multiplex signal includes a system status and reference signal which is recorded on magnetic tape in the Ground Data Center. Brush charts are used for real time display allowing data parameters to be reproduced as they occur.

Calibrations

Standard procedures were used by the BHC Standards and Calibration Laboratory to instrument the test helicopters. Table I presents a list of calibrated items and their respective calibration numbers.

Flight Log

A log of all ground runs and flights, listing the date, flight and/or ground run numbers, duration time and configuration, is shown in Table II.

TEST HELICOPTER

The test helicopters used during this test program were the Model OH-58A Bell S/N's 41080 and 41155.

S/N 41080: Prior to the test flight the aircraft was leveled and the following rigging measurements were obtained.

Main Rotor Mast	5° forward, 1° left
Swashplate	
F/A Cyclic (full throw)	+17.5° forward, +8.0° aft
Lateral Cyclic (full throw)	+5.5° right, +8.0° left
Collective Pitch (full throw)	-0.5° down, +16.6° up

S/N 41155: Aircraft was received, inspected, and instrumented. The collective pitch was measured at the main rotor hub and the minimum blade angle was +0.4 degrees and the maximum blade angle was +17.7 degrees.

RESULTS AND DISCUSSION

Ground Run Results

The aircraft was placed on tiedown and a series of ground runs were conducted. Cyclic inputs at approximately 1.0, 2.5, and 5.0 cps were made to obtain baseline pylon stability information and to determine the effect of first and second drive system torsional mode on pylon damping. During the evaluation, main rotor thrust was varied from zero to approximately 2410 pounds.

At a main rotor speed of 200 rpm and with 91 percent collective, the maximum main rotor blade chord excitation was ±13,500 inch-pounds. Efforts to determine the blade natural frequency were unsuccessful.

The lateral pylon stops could be contacted with a cyclic input at a main rotor rpm of 180 and 91 percent collective. Mast bumping could be induced with 100 percent collective and at a main rotor rpm of 240. Pylon contact or mast bumping did not reflect any unusual loads in the main rotor or fuselage. A maximum tailboom stress of only 4000 psi, which is a nominal load, was generated with a cyclic input of approximately 5.0 cps with a main rotor rpm of 270 and collective at 86 percent. To evaluate the Coriolis effect, cyclic inputs were made during a main rotor rpm sweep with a blade root collective of 10 degrees.

Results obtained during the ground runs did not offer any insight or peculiarities that might suggest tendencies that could result in high tailboom stresses. Also, it was very difficult to determine fuselage natural frequencies while the aircraft was secured during ground run. As a result, the decision was made to proceed to the flight evaluation.

Flight Results

Since the tiedown results were inconclusive, investigation efforts were directed towards duplicating the tailboom failures reported by the Army. With a telemetry capability of monitoring critical parameters, a series of hovering throttle chops and touchdown autorotations were conducted. During a variety of autorotational landings, various techniques of cyclic and collective application at a disparity of main rotor rpm's were investigated. Many of the basic hypotheses became inconsequential due to the following.

1. Pylon stop contact with high main rotor coning did not indicate pylon whirl tendencies. Lateral pylon spike contact could be obtained without too much difficulty; however, no unusual loads or peculiar tendencies were evident. Fore and aft pylon spike contact was very difficult to obtain.

2. At conditions of high collective pitch and low rotor speed, there was no evidence of binding in the main rotor flapping bearing.

3. There was no evidence of rotor blade resonant amplification that could result in large pylon motions and high control loads.

RESULTS AND DISCUSSION - (cont)

Flight Results - (cont)

4. Cyclic inputs during conditions of high main rotor coning did not appear to influence main rotor hub forces.

A total of 36 touchdown autorotation landings and 10 throttle chops were flown to obtain data. Analysis of autorotation data began to suggest certain trends of maximum main rotor flapping with high touchdown airspeeds at low main rotor speeds of 200 rpm or less, see Figures 1 through 10. During the third flight, a tailboom failure was duplicated to study the influential circumstances associated with the failure.

Tailboom Failure Evaluation

A review of the recorded data suggested that several factors contributed to the tailboom failure and the absence or reduction of any one factor was sufficient to prevent failure. The characteristics associated with the tailboom failure can be summarized as follows:

1. Prior to or at aircraft touchdown, the collective must be raised to the full up mechanical stop and allowed to remain at the up stop until the main rotor rpm decays to approximately 200 or less.

2. Touchdown airspeed must be sufficient to provide considerable rotor inflow.

3. Main rotor blade coning and flapping must be sufficient to produce fore and aft pylon stop contact.

The combinations of the above results in sufficient rotor-fuselage inertia to produce damaging fuselage stress loading.

Comparison of Figure 11, a time history of a normal touchdown autorotation, and Figure 12, a time history of the touchdown autorotation when the tailboom failure occurred, tend to substantiate the influence of main rotor flapping with collective position, main rotor speed, and pylon behavior associated with the failure.

Figure 13 shows aircraft ground contact and subsequent ground roll, and Figures 14 through 20 are photographs depicting test vehicle damage that occurred during the evaluation. Figures 21 and 22 depict the extent of the pylon motion during the failure.

Main rotor control and blade loads were normal during the autorotation landings and only increased after onset of the tailboom failure condition.

A vertical and roll acceleration of considerable amplitude, in excess of two g's, was observed in the cabin. At the conclusion of the landing, there was no doubt by the flight crew that damage of one form or

Tailboom Failure Evaluation - (cont)

another had been sustained. It is the further opinion of the flight crew that a pilot of even minimal experience would recognize that the aircraft had experienced an abnormal situation and would conduct an exterior safety of flight inspection prior to a takeoff.

Options Available for Failure Reduction: After careful review of available data, the following items were evaluated and considered as possible methods of eliminating or reducing the possibility of a failure.

1. Determine the technique the U. S. Army is using in the training of new and transition pilots, and the rationale for their techniques. Also, recommend modifications of existing techniques if deemed appropriate.

2. Provide cockpit indicator to indicate warning of excessively hard landings and potentially damaging tailboom vibrations.

3. Reduce the available collective range to avoid excessive dynamic loading and yet maintain adequate height-velocity margins.

4. Consider basic structural modifications to stiffen the critical areas, reduce stress levels, and/or produce changes in dynamic response characteristics and system coupling.

5. Provide mechanical fixes, such as pylon viscous or friction dampers, and fuselage impact and/or friction dampers.

Reduced Collective Evaluation: After reviewing the options available, indications were the best solution to the problem was that improper autorotative techniques needed revising. However, in the event the ship were landed improperly it was judged that a reduction of the collective range would be beneficial. As a result, a Model OH-58A Helicopter, S/N 41155, was instrumented and a series of tests were begun to determine the feasibility of limiting the available collective pitch during autorotation landings (Option 3). This reduction was accomplished by attaching an adjustable cable on the copilot collective stick that physically limited the maximum up position of the collective, see Figure 23. Figure 24 shows the results of a hangar calibration of collective stick position versus main rotor blade angle. A series of hovering throttle chops, slide on landings, and autorotation touchdowns at various percent of collective reduction were evaluated to determine if a reduction in the available collective would prohibit maintaining adequate height-velocity margins. During the hovering throttle chops at a gross weight (GW) of 3000 pounds, there was a definite change in the character of main rotor blade stall when the available collective blade angle was reduced to 75 percent; however, time airborne, which is an indicator of rotor capability, was also reduced. At 80 percent available collective the time airborne after throttle chop was adequate, 3.6 seconds, and pylon motion and main rotor flapping were greatly reduced.

RESULTS AND DISCUSSION - (cont)

Tailboom Failure Evaluation - (cont)

Reduced Collective Evaluation - (cont)

Six autorotation landings were accomplished with the available collective pitch reduced by approximately 20 percent, and Figures 25 through 30 present the data obtained by using the Federal Aviation Administration (FAA) Runk Grid Camera. Touchdown calibrated airspeed varied from 24 knots to 41 knots. Table III presents important oscillograph parameters recorded during the autorotation landings.

Test results indicate that the probability of tailboom failure, with the available collective range reduced by approximately 20 percent, is greatly decreased due to a reduction in main rotor flapping.

A mathematical analysis and associated computer study were conducted to evaluate the tailboom failure problem. The study was concentrated in the area of main rotor flapping versus main rotor blade angle and main rotor inflow during autorotation touchdown. Synopsis of the evaluation concluded that main rotor flapping benefits derived by the reduction of the main rotor blade angle can be reduced by an increase in rotor inflow. However, the touchdown airspeeds required to produce the mandatory rotor inflow are considered excessive and unrealistic for normal autorotation touchdowns. An autorotative touchdown in excess of 40 kts coupled with improper landing techniques is judged to be outside the reasonable and mandatory operating envelope of the helicopter. As a result, it can be concluded that the probability of a tailboom failure would be greatly reduced by improving autorotation techniques to avoid high speed touchdowns with high main rotor blade angles.

U. S. Army Aviation Systems Test Activity (USAASTA) Test Results

A flight evaluation of the Model OH-58A Helicopter, S/N 41155, with a reduced collective blade angle was conducted by an Army test team at the BHC Flight Research Center, Arlington, Texas, on 23 and 24 November 1971.

During the USAASTA evaluation the helicopter was first flown in the standard OH-58A configuration. The adjustable cable on the copilot collective stick was installed prior to the second flight to limit the maximum up position of the collective to 80 percent (13.6 degrees main rotor blade angle at the hub).

A series of touchdown landings were made utilizing techniques that had produced tailboom failures in the past. Figure 31 presents a time history of an autorotation touchdown landing that produced a considerably high level of vertical tailboom excitation with a near damaging stress of 17,586 psi. The pilot reported the touchdown airspeed was probably in excess of 40 knots indicated airspeed (KIAS). Visible airframe damage was limited to minor pylon upper cowling contact and

USAASTA Test Results - (cont)

cracked fiberglass fairing at the tailboom connection area. Aircraft damage was considered minor and tests continued. This documented autorotation landing incident is an additional substantiation of the computer study results.

The Army test team also conducted tests to determine if the present height-velocity margins could be maintained when the available collective range was reduced to avoid excessive dynamic loading. Data were obtained by using the FAA Runk Grid Camera and results are presented in Figures 32 through 34. Table IV presents the height-velocity time history data. Figure 35 shows the runway gradient at the test site. Maximum available collective was limited to 85 percent. Results of the evaluation indicated that the maximum collective utilized during the autorotation was 70 percent and as a result, shows that adequate collective is available to maintain present height-velocity margins at the altitude the test was conducted.

CONCLUSIONS

A flight test program to investigate OH-58A tailboom failures during autorotation landings and explore methods of eliminating these failures has been completed.

The following conclusions are made on the basis of the subject flight test program.

1. The results obtained during the ground run were inconclusive.

2. Efforts to duplicate a tailboom failure were successful and as a result, many of the original hypotheses to be investigated became inconsequential.

3. The combination of maximum main rotor blade angle and flapping, low rotor rpm, rotor inflow, and pylon contact (fore and aft) has sufficient rotor-fuselage inertia to produce damaging fuselage stress loading.

4. With the available collective range reduced by approximately 20 percent, test results indicate that the probability of tailboom failure, resulting from improper autorotation techniques, is greatly reduced due to the reduction in main rotor flapping.

5. The probability of tailboom failure would be eliminated by observing proper autorotation techniques, thereby avoiding high speed touchdowns with high main rotor blade angles.

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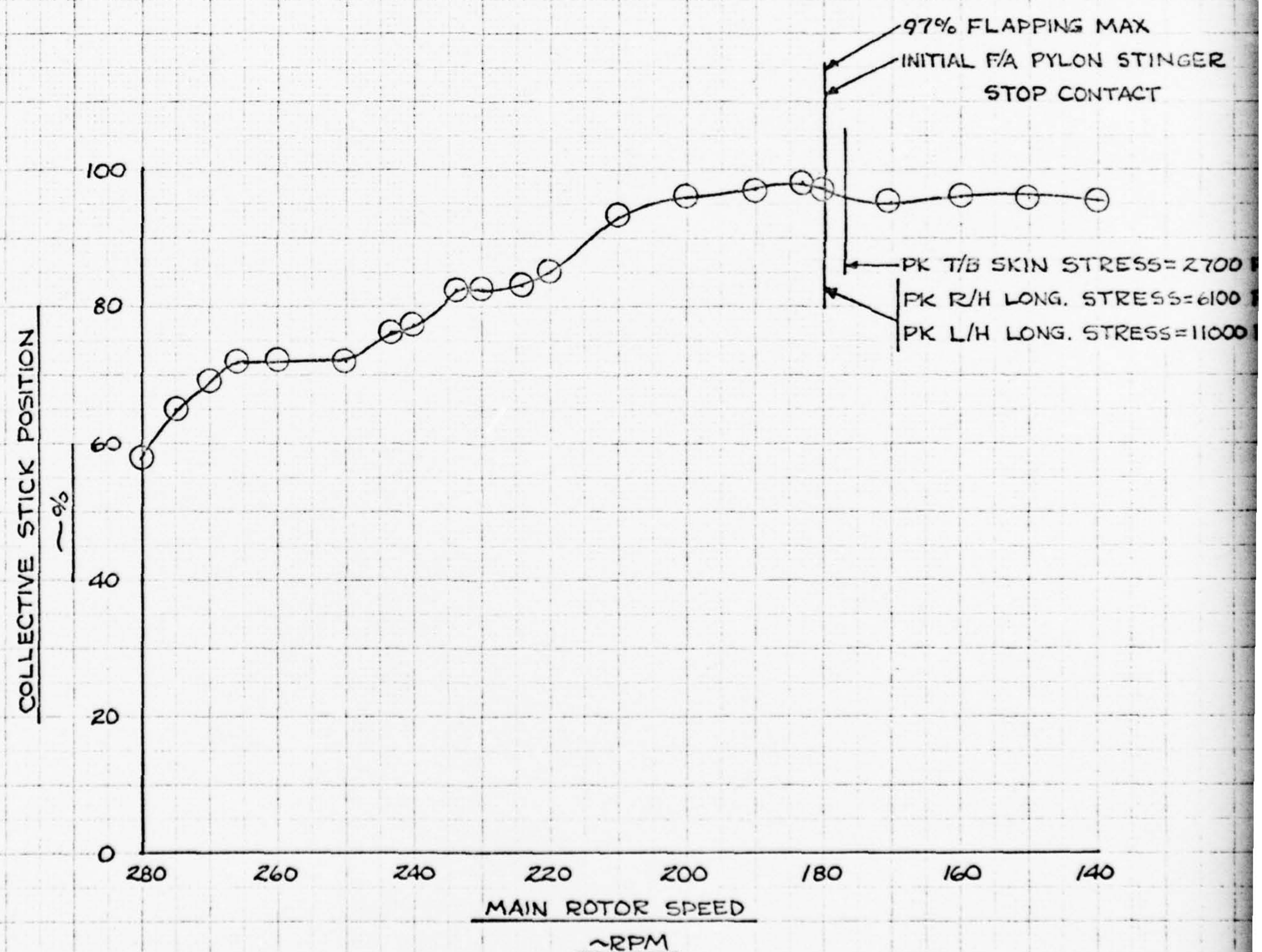

FIG. 1 COLL STK POSITION VS. M/R SPEED DURING RUN-ON AUTO LANDING.

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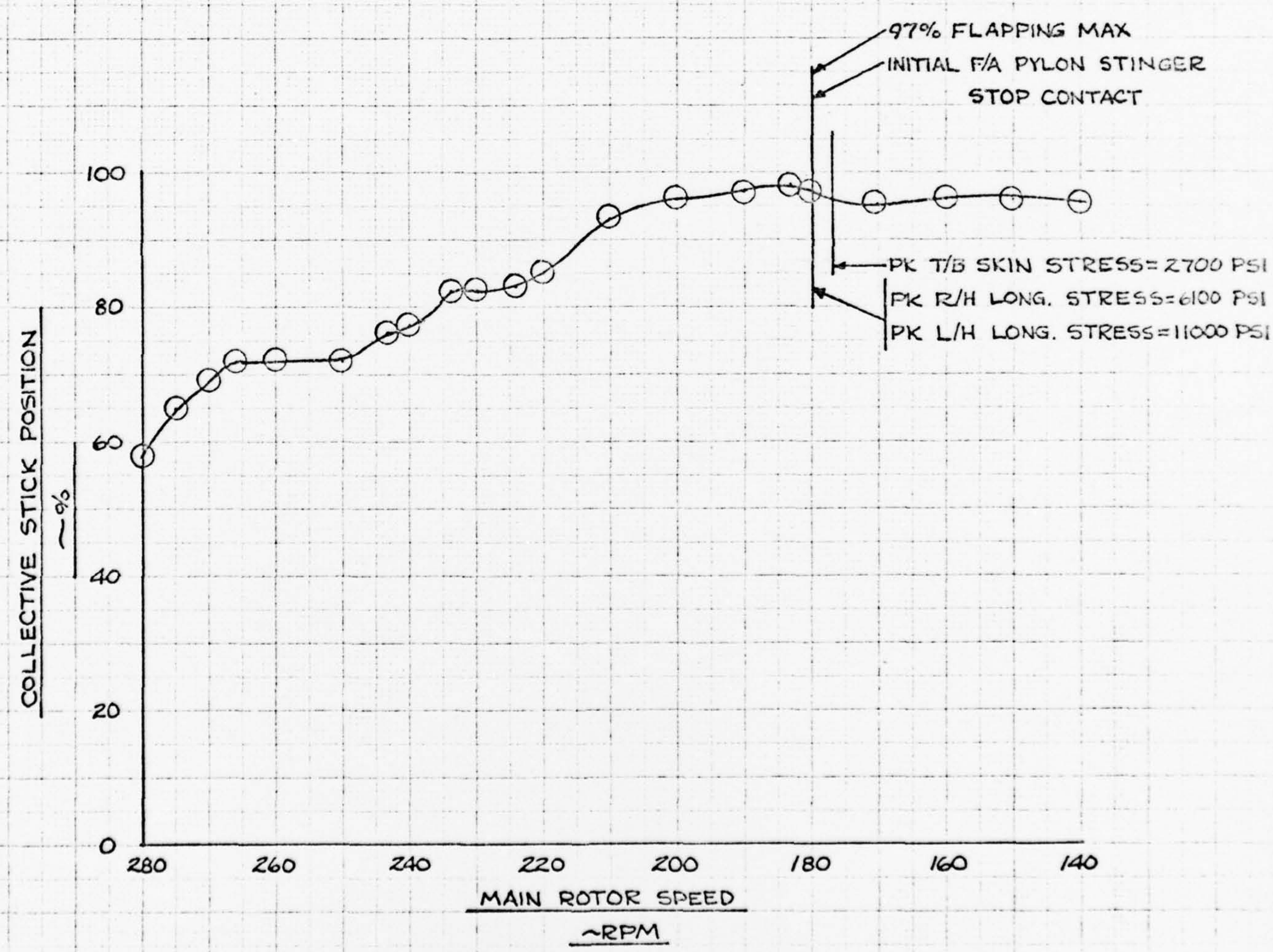

FIG. 1 COLL STK POSITION VS. M/R SPEED DURING RUN-ON AUTO LANDING.

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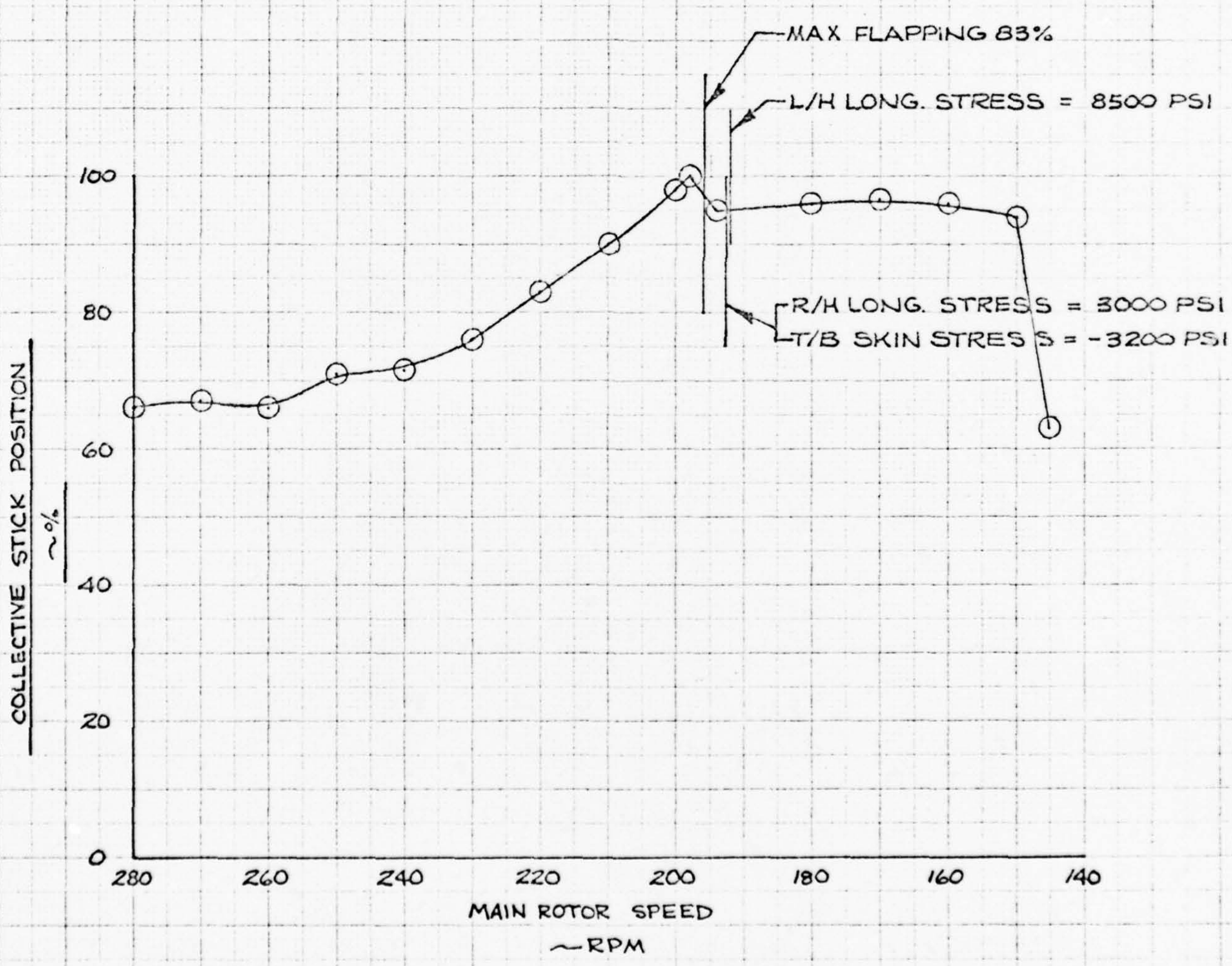

FIG. 2 COLL STK POSITION VS M/R SPEED DURING AUTO LANDING

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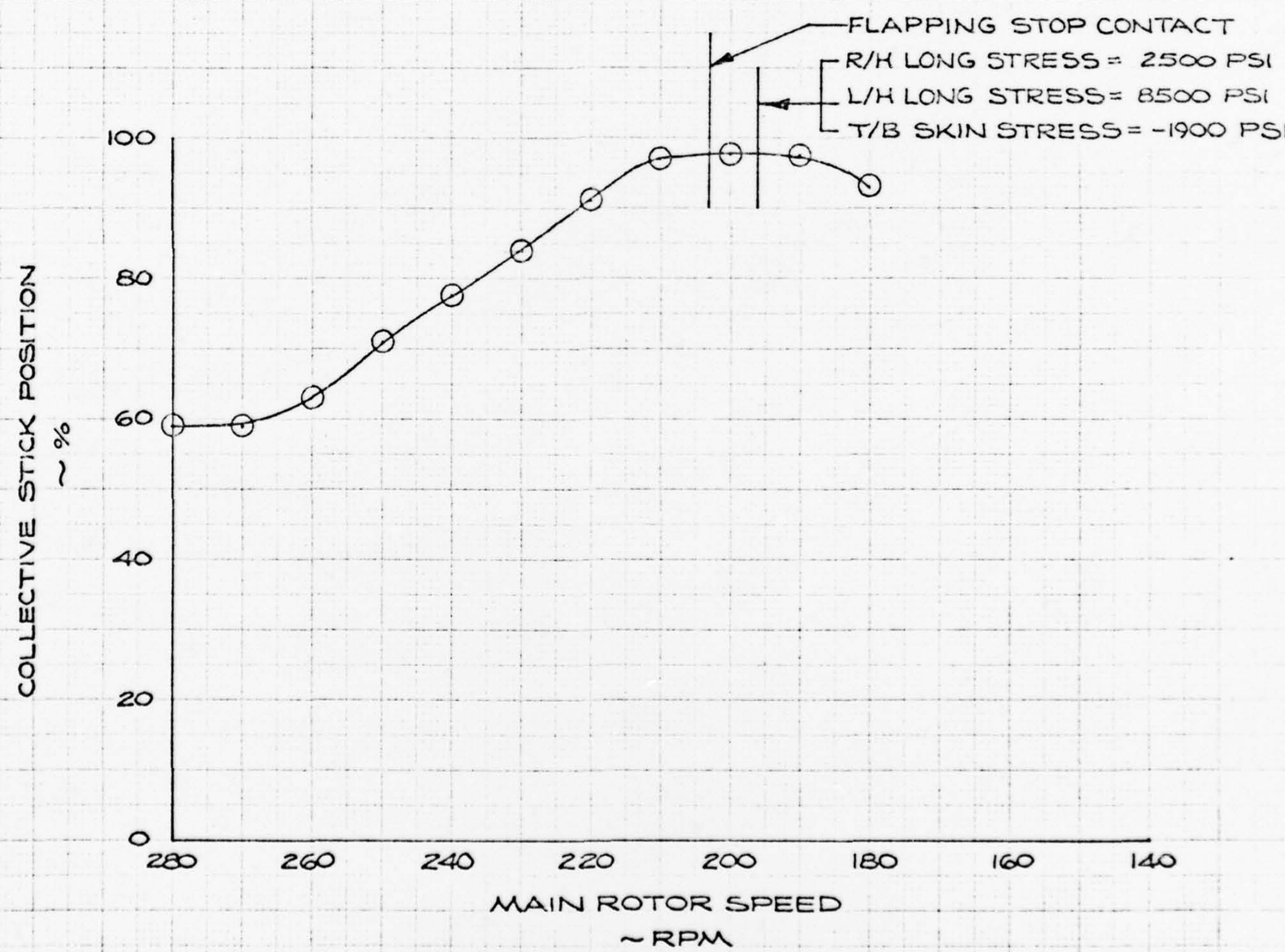

FIG. 3 COLL STK POSITION VS M/R SPEED DURING RUN-ON AUTO LANDING

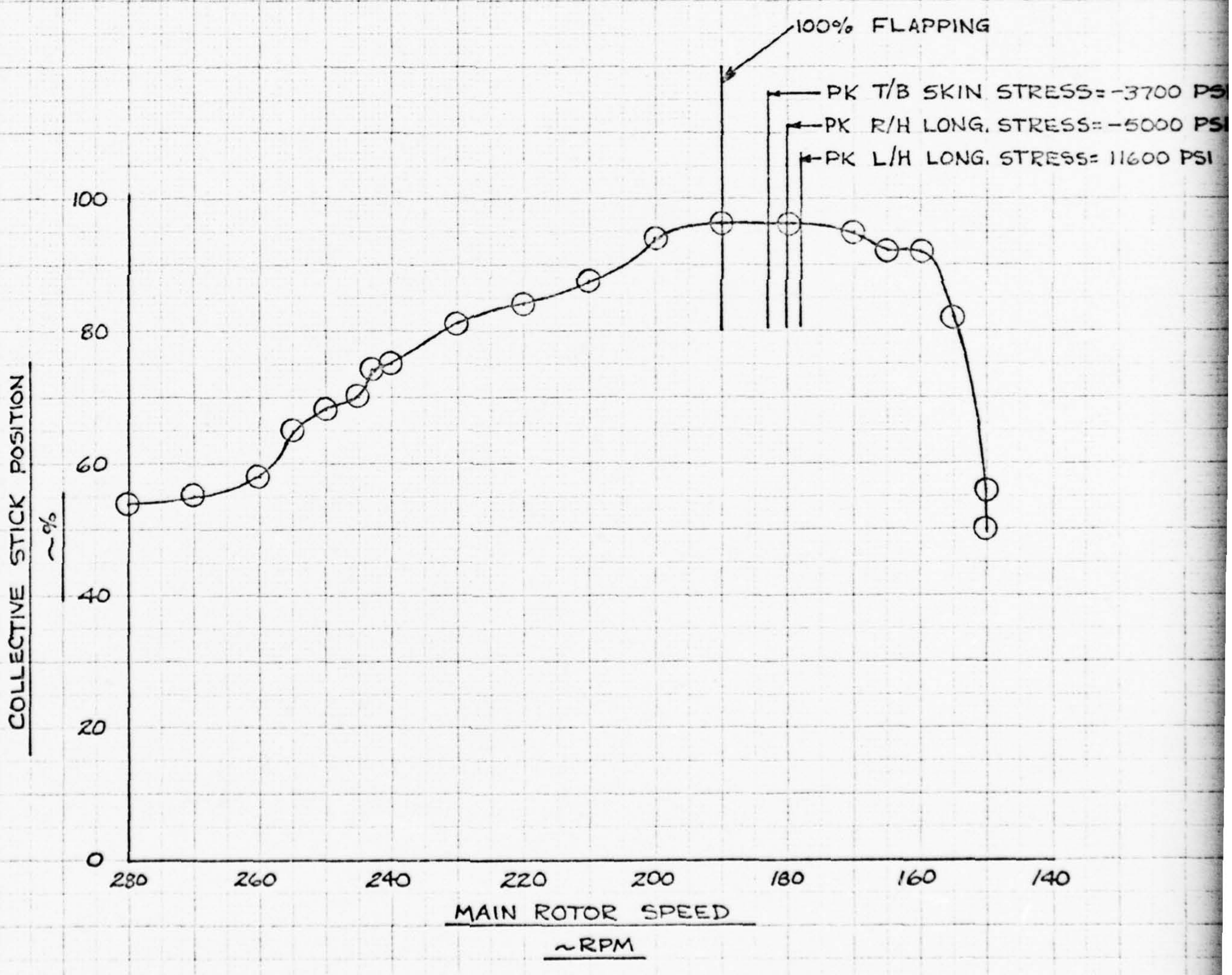

FIG. 4 COLL STK POSITION VS. M/R SPEED DURING RUN-ON AUTO LANDING

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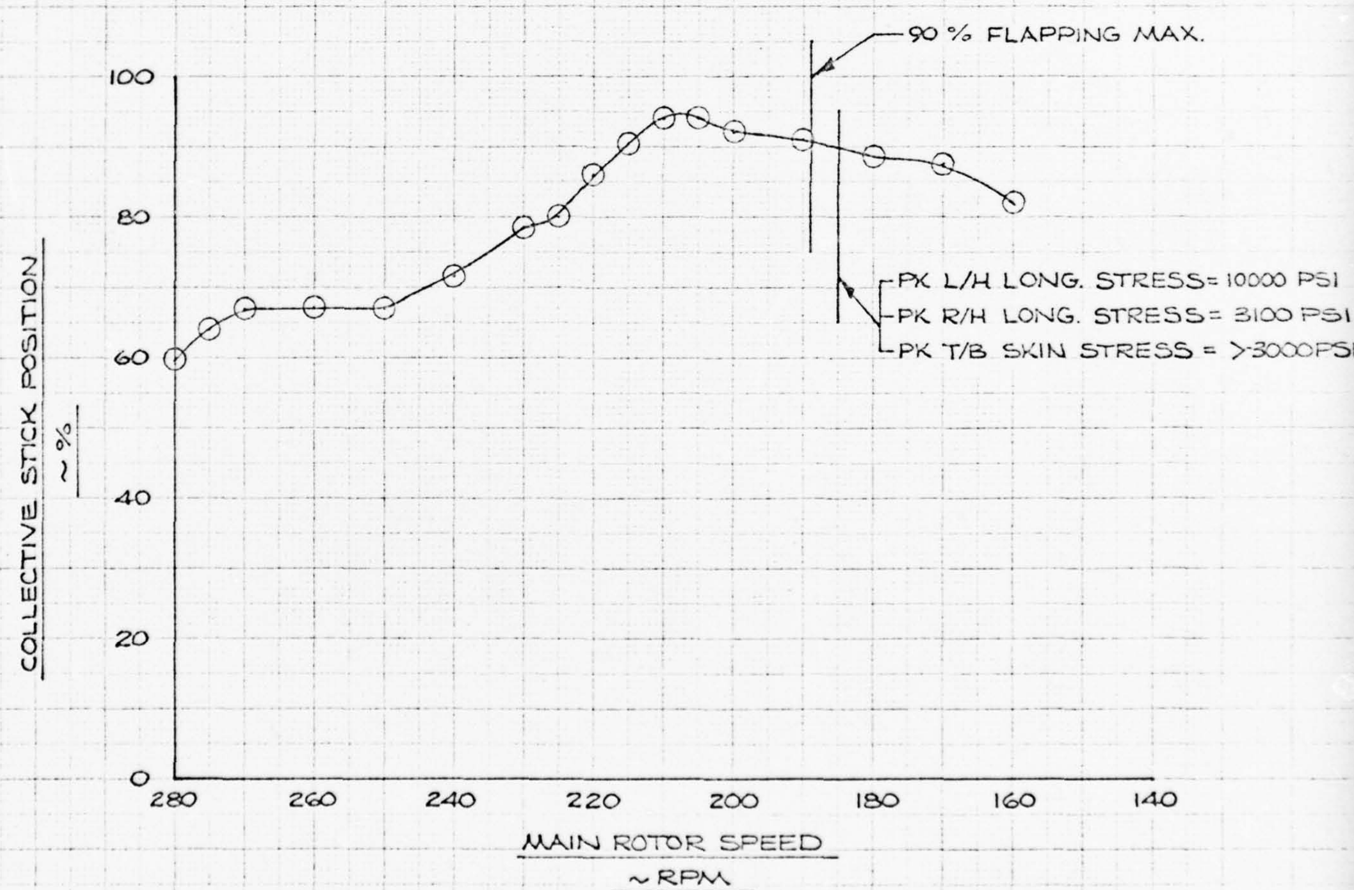

FIG. 5 COLL STK POSITION VS M/R SPEED DURING RUN-ON AUTO LANDING

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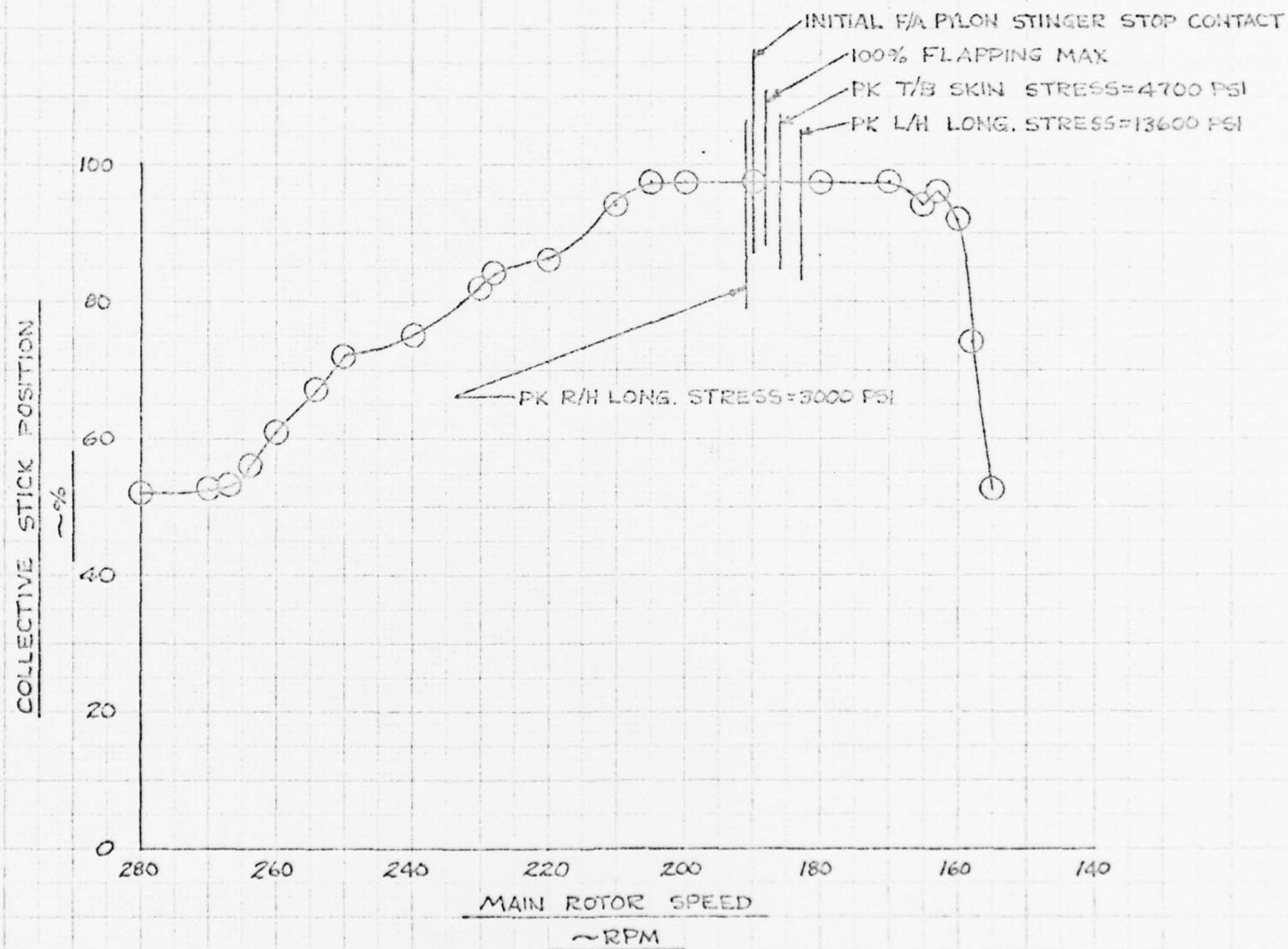

FIG. 6 COLL. STK. POSITION VS. M/R SPEED DURING RUN-ON AUTO LANDING

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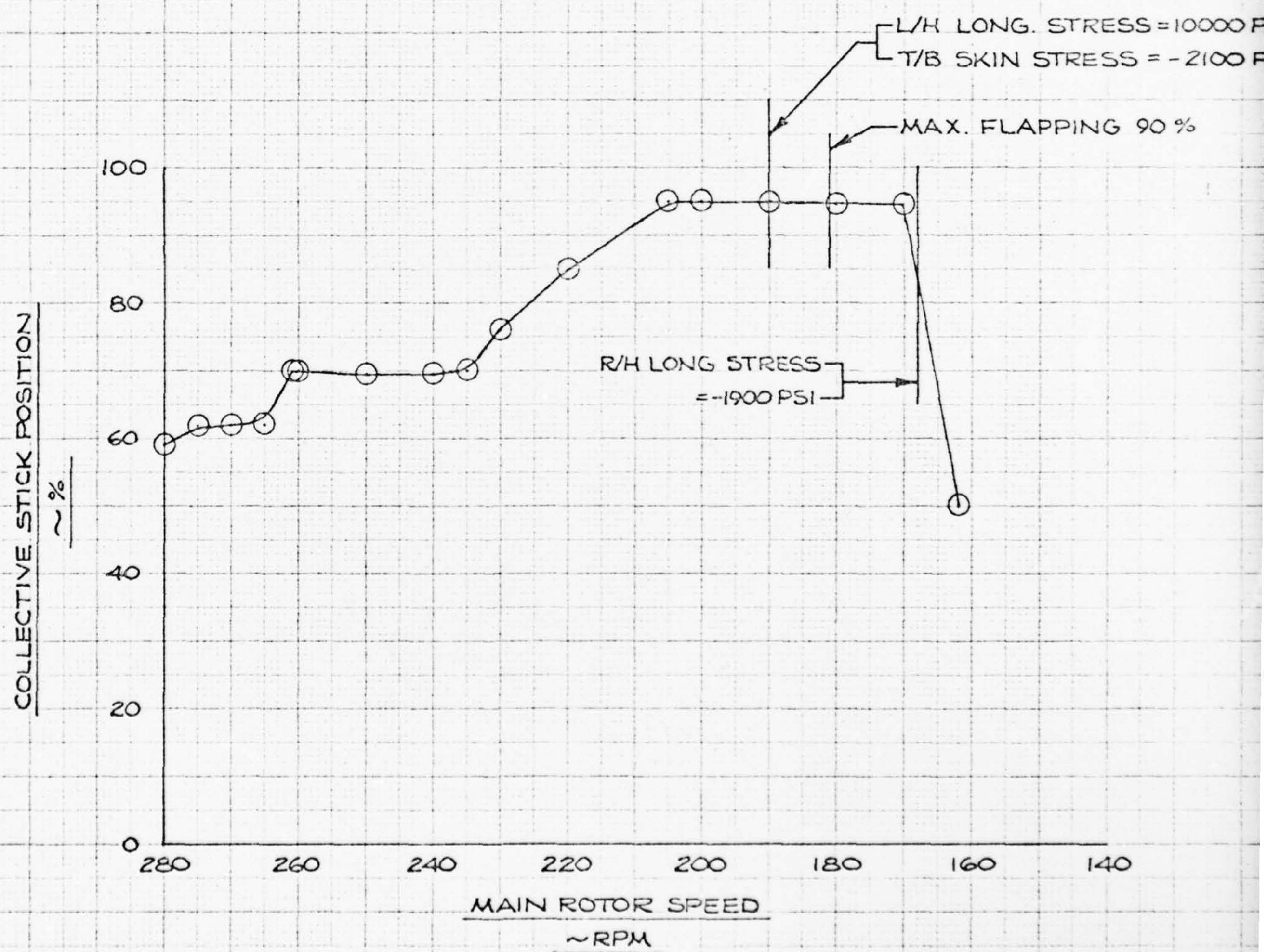

FIG. 7 COLL STK POSITION VS M/R SPEED DURING RUN-ON AUTO LANDING

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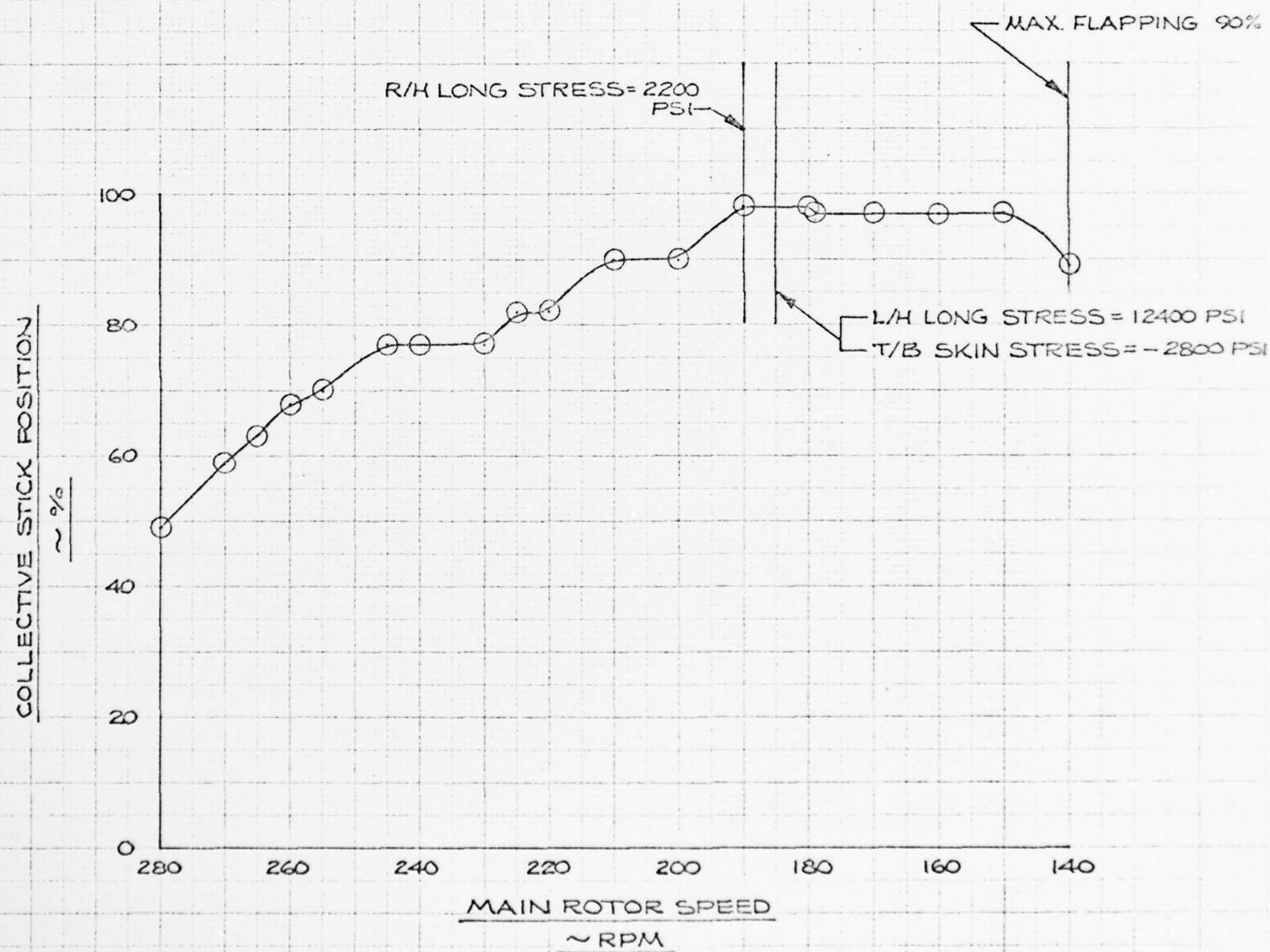

FIG. 8 COLL STK POSITION VS M/R SPEED DURING RUN-ON AUTO LANDING

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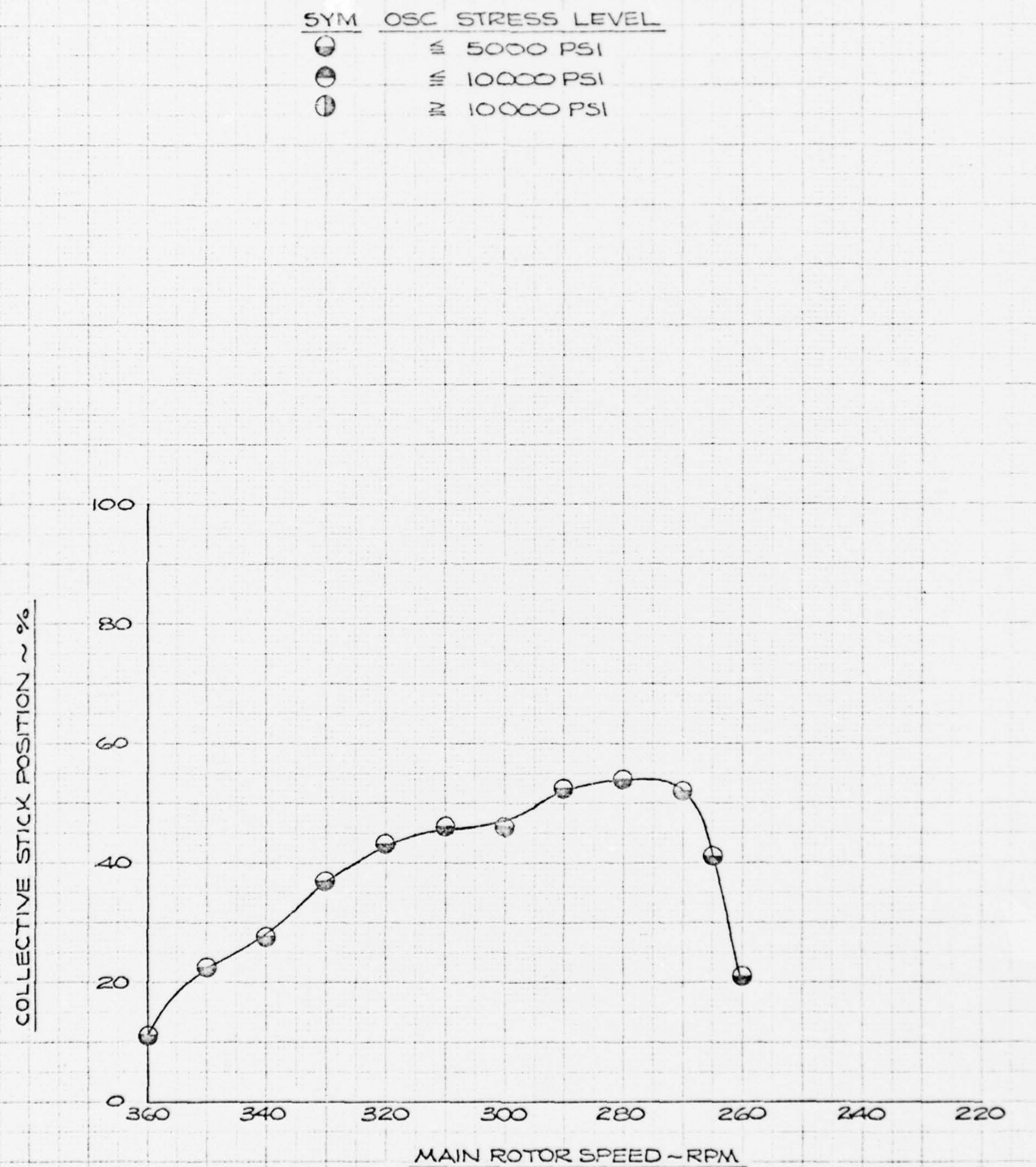

FIG. 9 COLL STK POSITION VS M/R SPEED DURING RUN-ON AUTO LANDING

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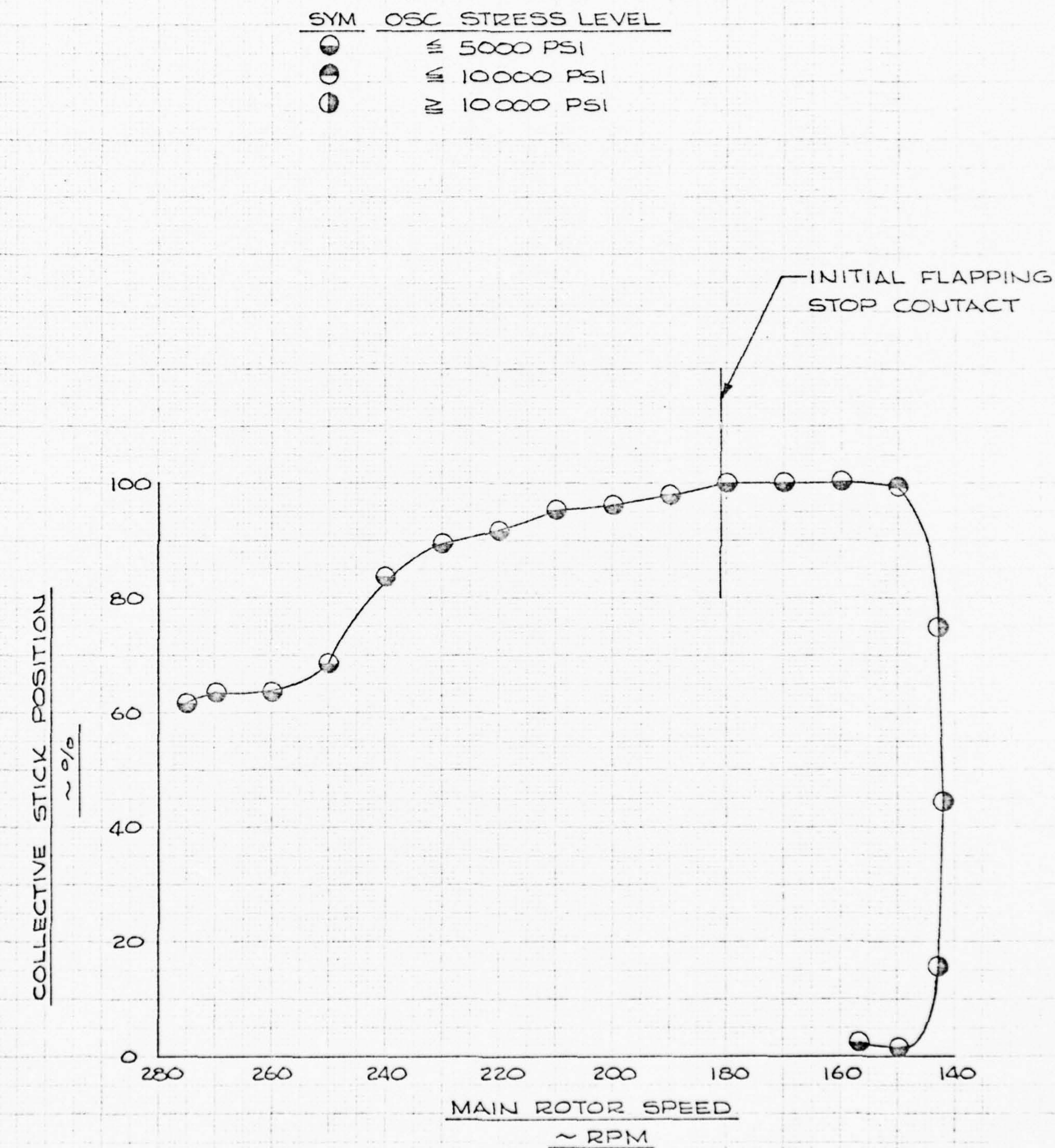

FIG. 10 COLL STK POSITION VS M/R SPEED DURING RUN-ON AUTO LANDING

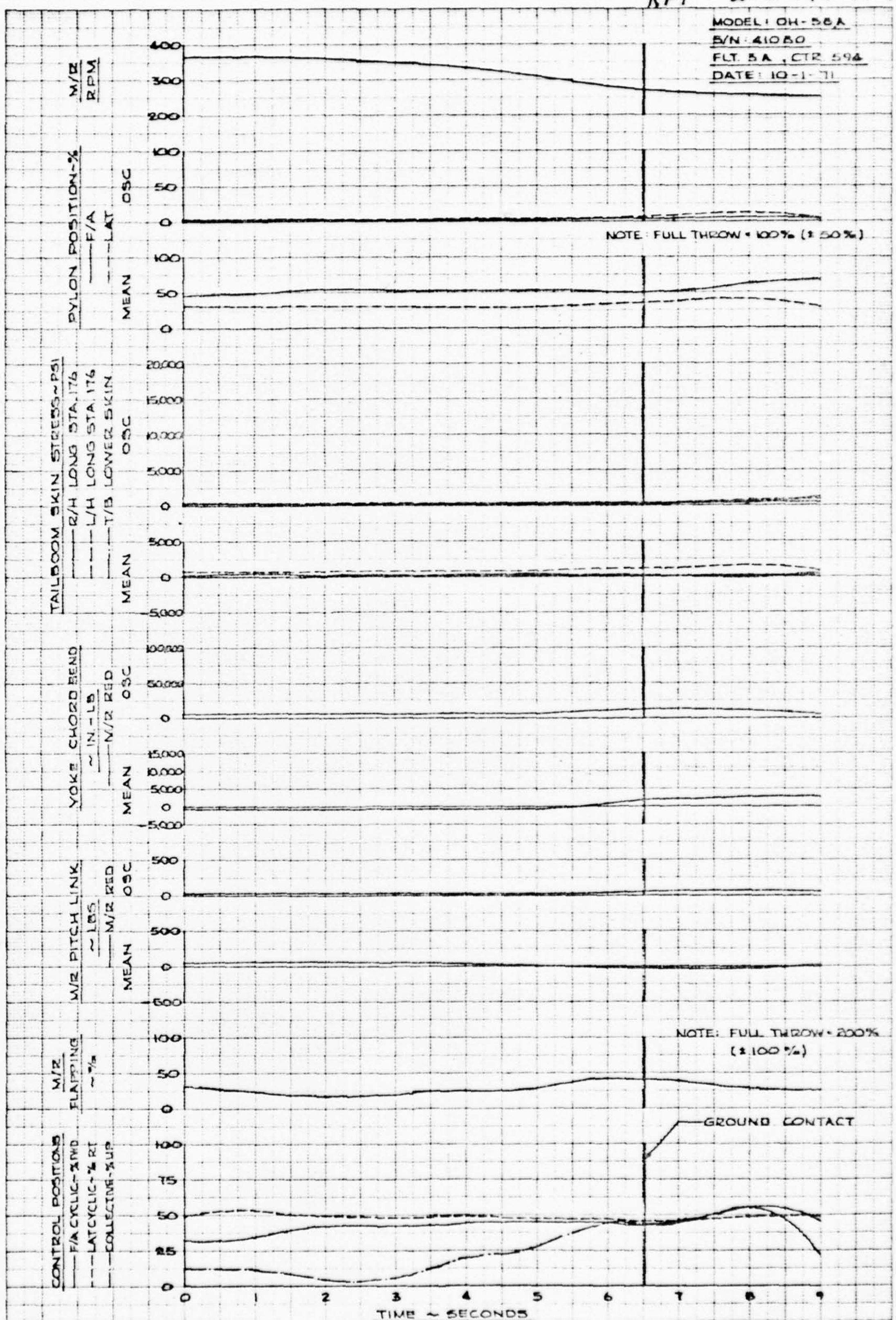

FIG. 11 TIME HISTORY OF AUTOROTATION LANDING (NORMAL AUTO)

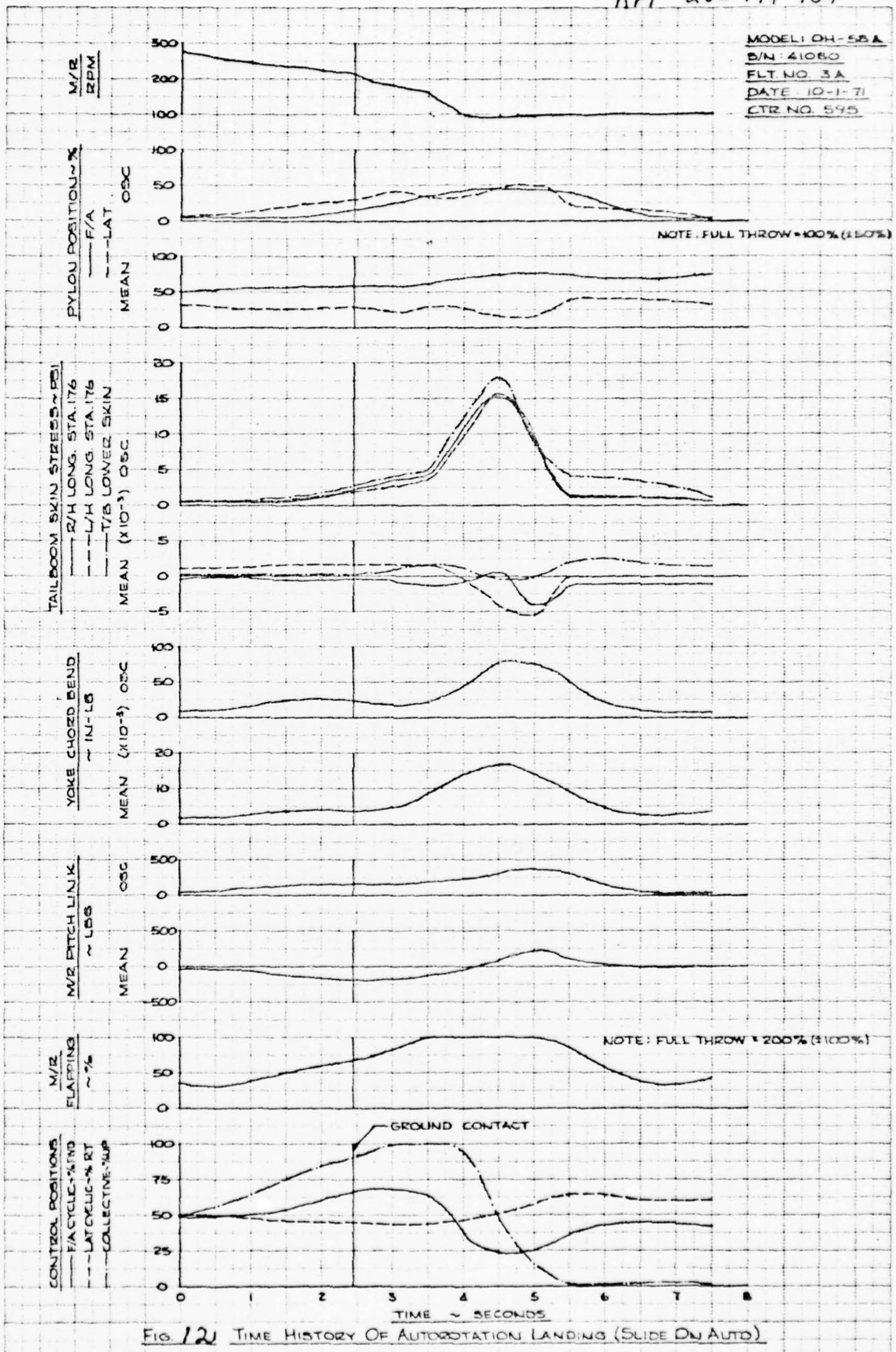

Fig. 12) Time History Of Autorotation Landing (Slide On Auto)

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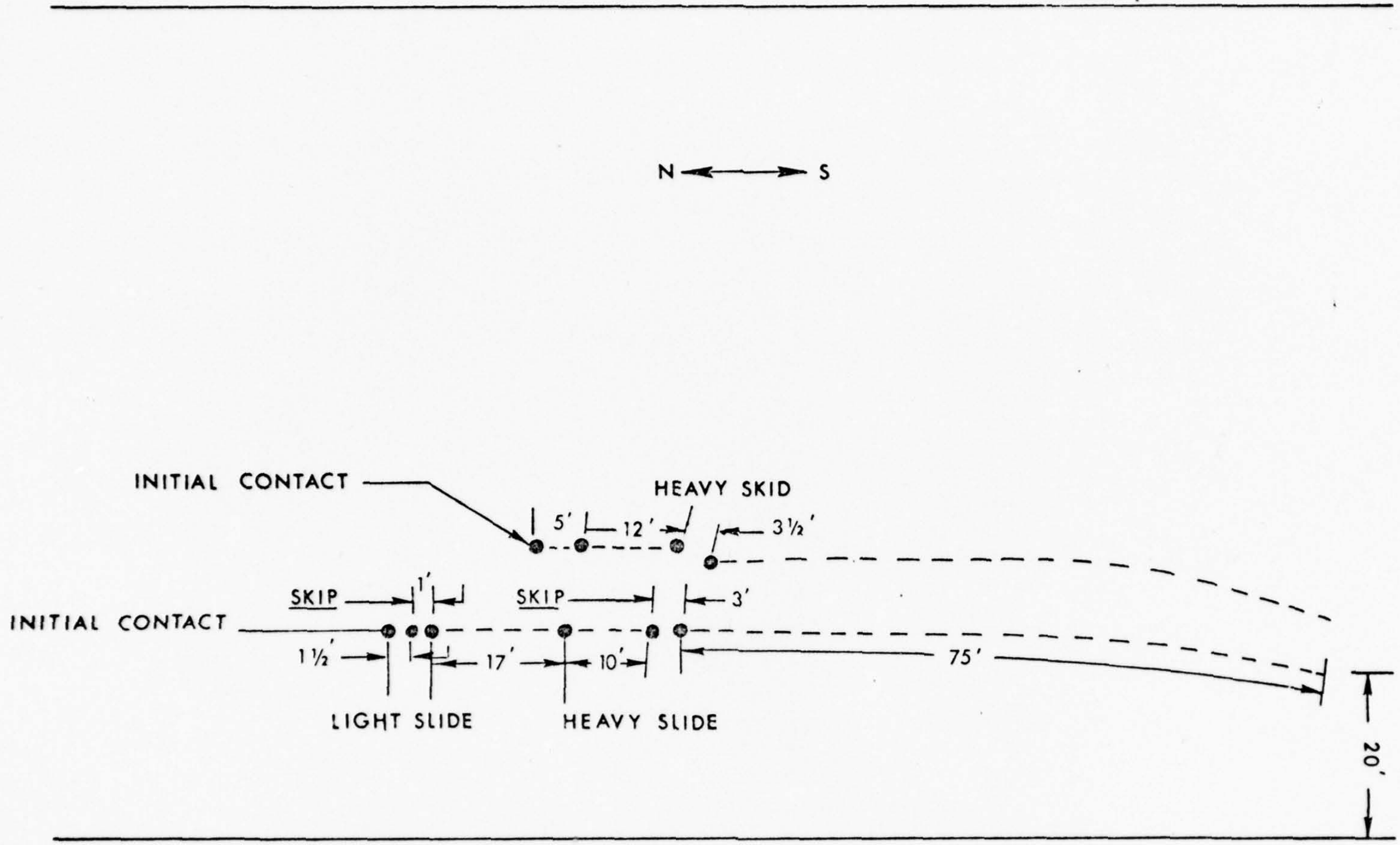

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FIG 13 RUNWAY CONTACT

Fig. 14 Model OH-58A, S/N 41080, After Tailboom Failure, BHC Photo 284188

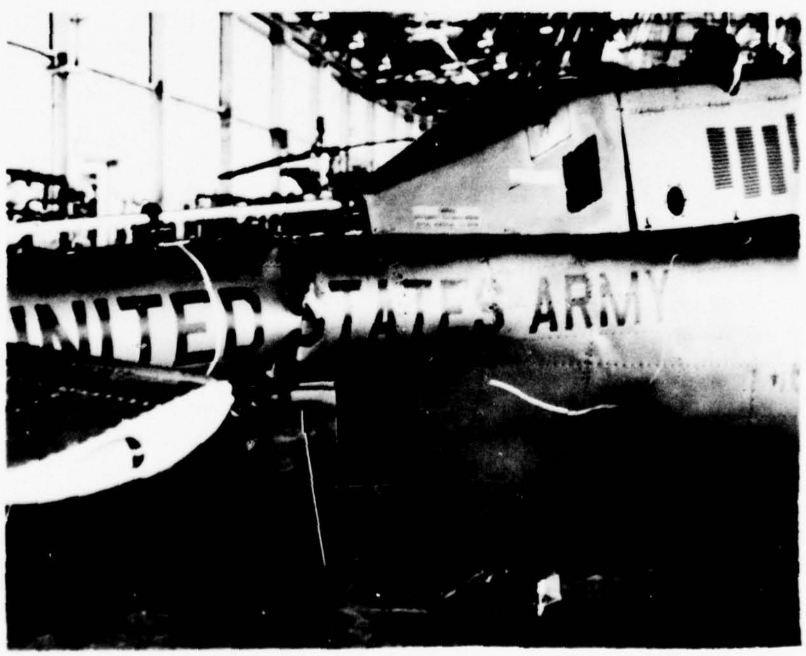

Fig. 15 Model OH-58A, S/N 41080, Right Aft View of Tailboom Failure at Fuselage Sta. 220, BHC Photo 284185

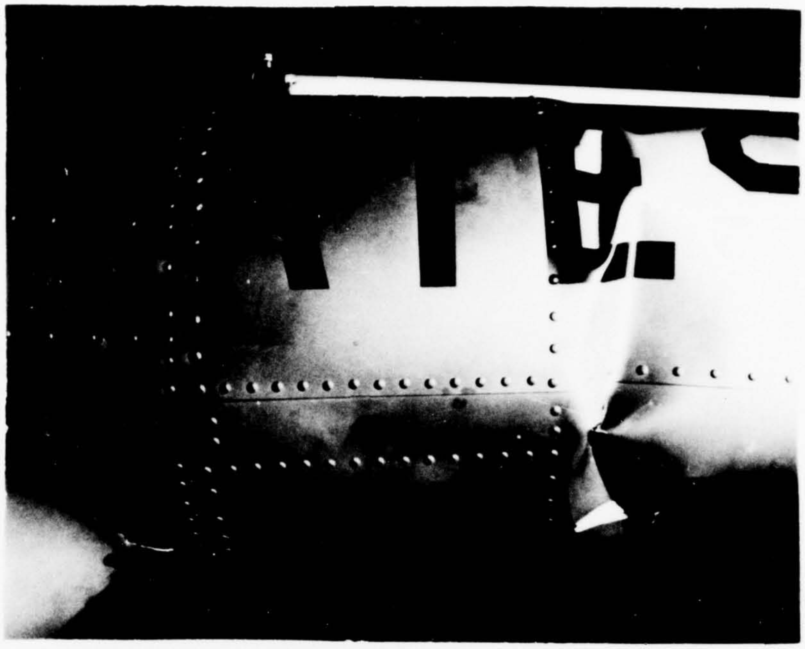

Fig. 16 Model OH-58A, S/N 41080, Tailboom Failure, Left Side, Fuselage Sta. 220, BHC Photo 284177

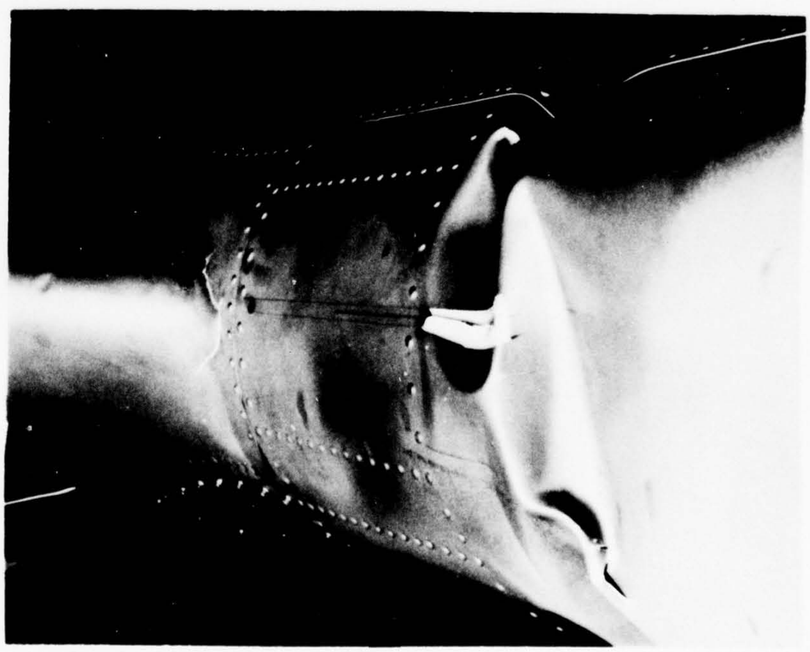

Fig. 17 Model OH-58A, S/N 41080, Tailboom Failure, Lower Surface, Fuselage Sta. 220, BHC Photo 284179

Fig. 18 Model OH-58A, Lower Transmission Case After Failure, BHC Photo 284118

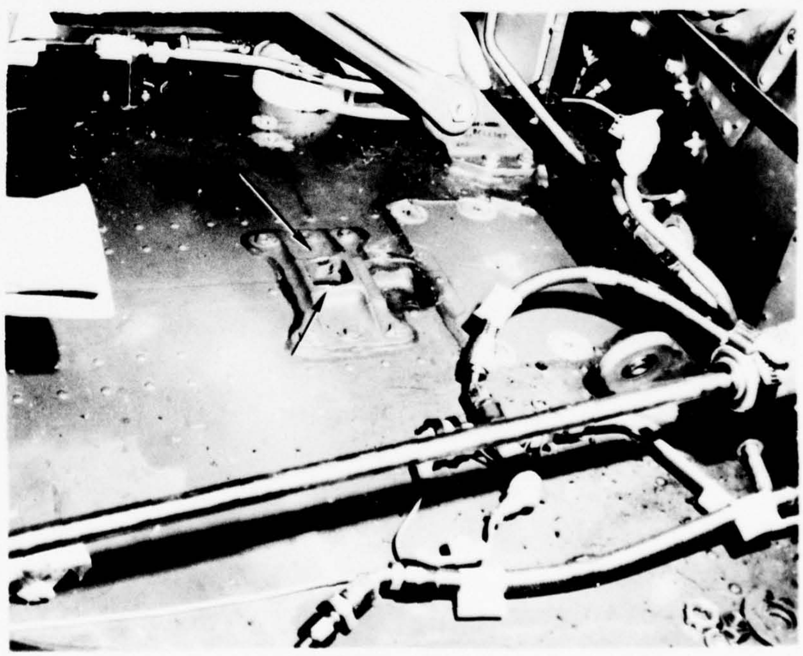

Fig. 19 Model OH-58A, Pylon Area After Tailboom Failure, BHC Photo 284120

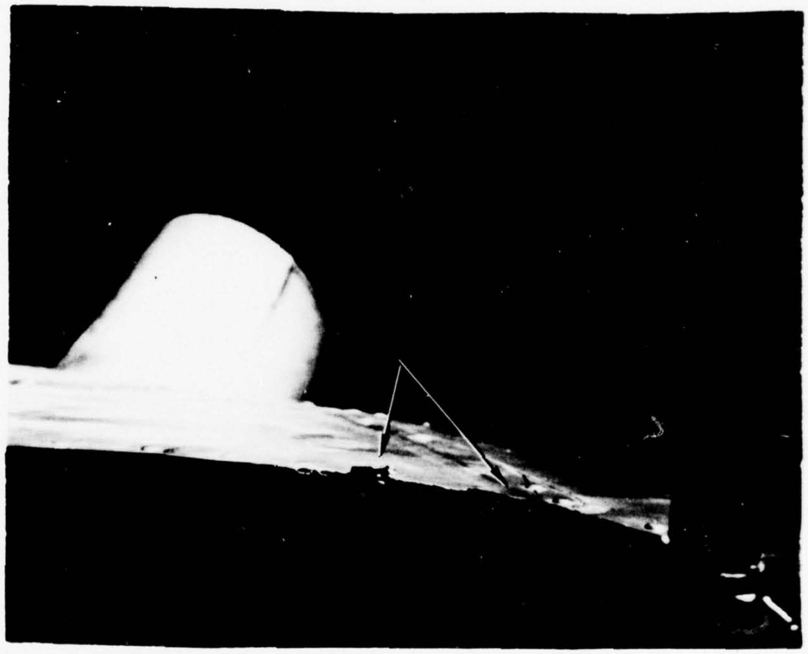

Fig. 20 Model OH-58A, Transmission Cowling, Left Side, After Tailboom Failure, BHC Photo 284183

BY ______ CHECKED ______

BELL HELICOPTER COMPANY

MODEL OH-58A PAGE 28
MSN 41080 RPT 206-194-1
FLT. 3
CTR. 595

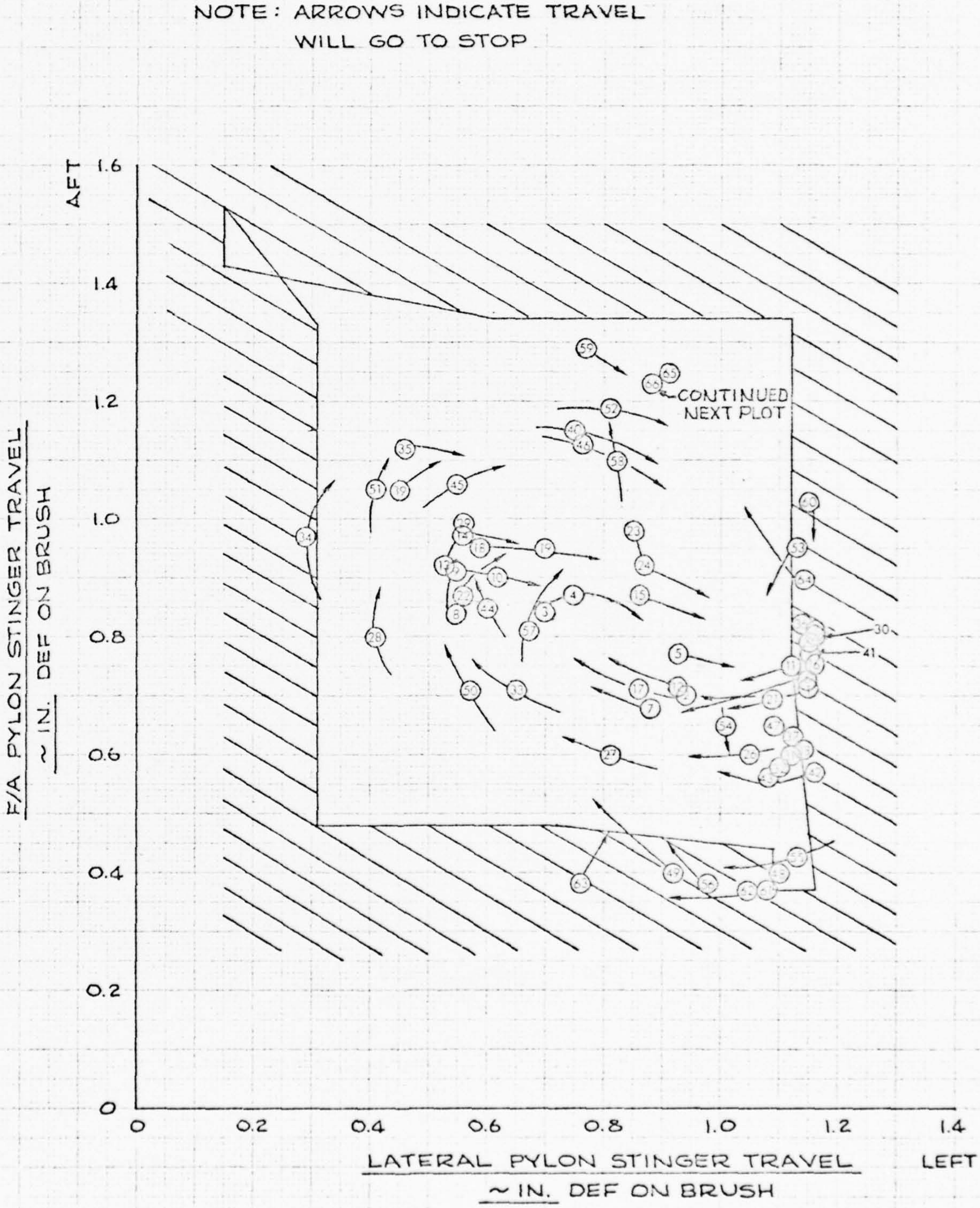

FIG. 21 PYLON POSITION DURING TAILBOOM FAILURE

FLT. 3
CTR. 595

NOTE: ARROWS INDICATE TRAVEL WILL GO TO STOP

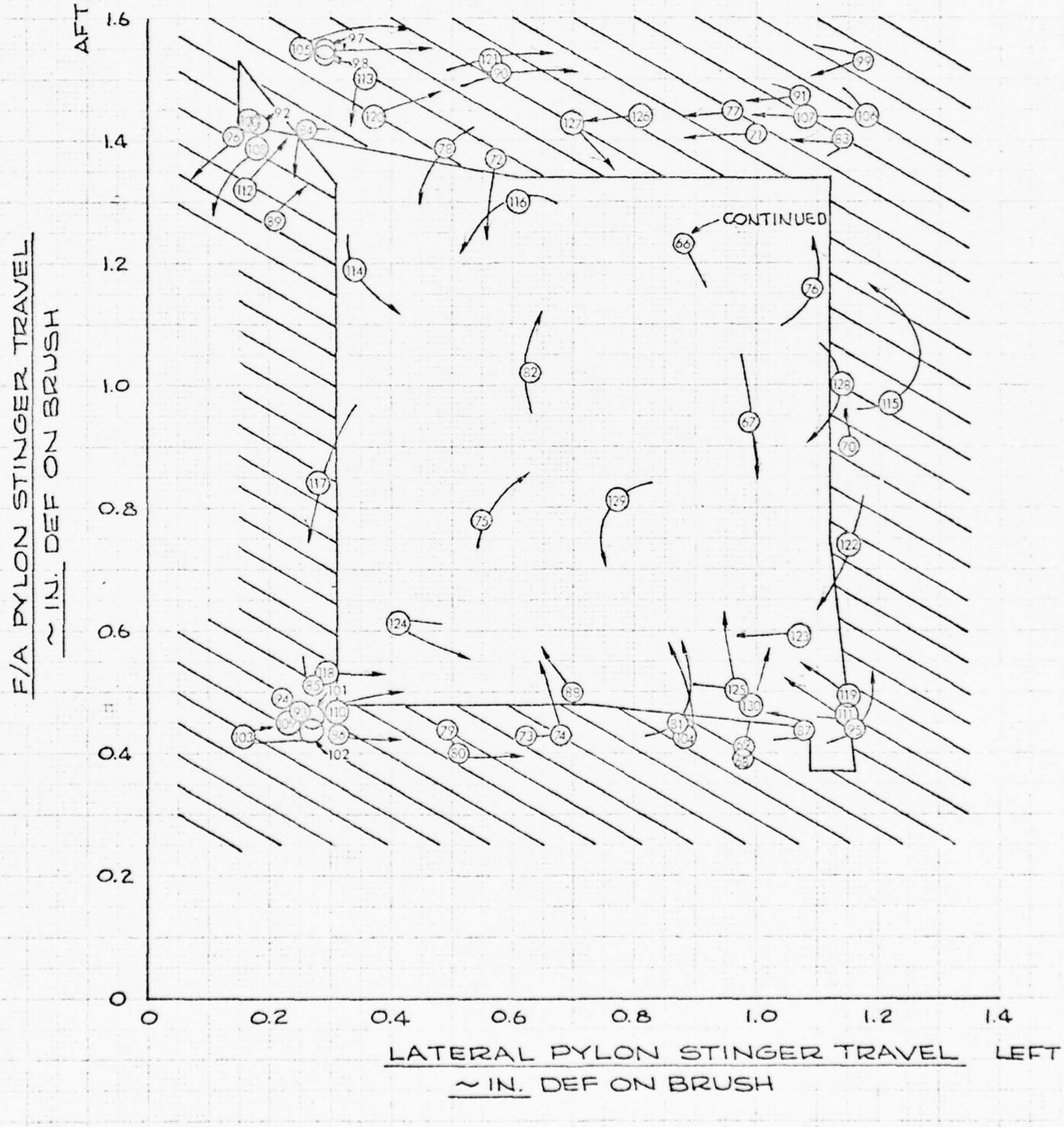

FIG: 22 PYLON POSITION DURING TAILBOOM FAILURE

HAB 2-14-73

Fig. 23 Collective Cable Restraint as Installed on the Model OH-58A, S/N 41155

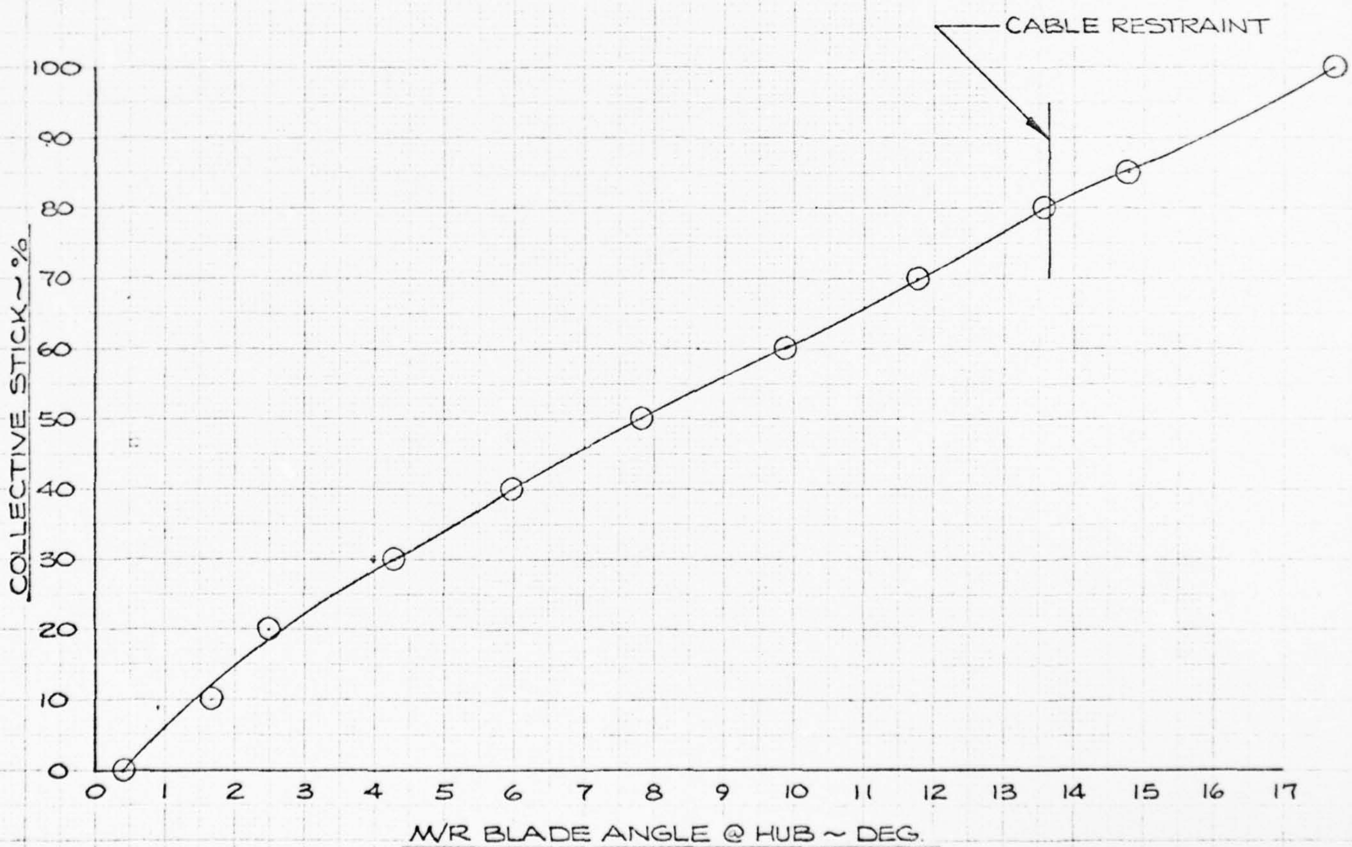

FIG 24 COLLECTIVE STICK POSITION VS M/R BLADE ANGLE

HW 11-30-71

OH-58A 32
206-194-134

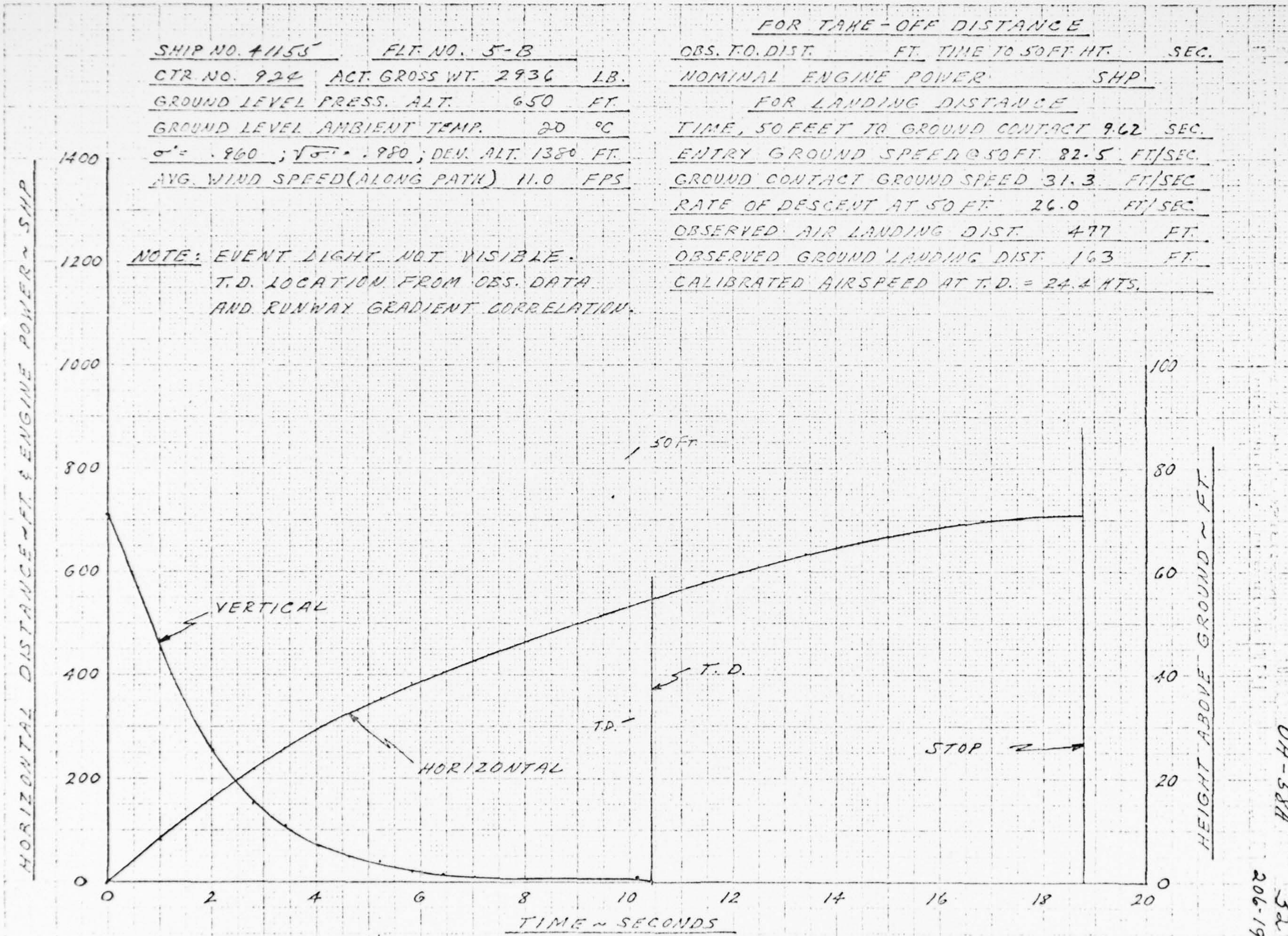

FIG. 25 TIME HISTORY OF LANDING RUN NO. 10 ~ FLT. NO. 5B

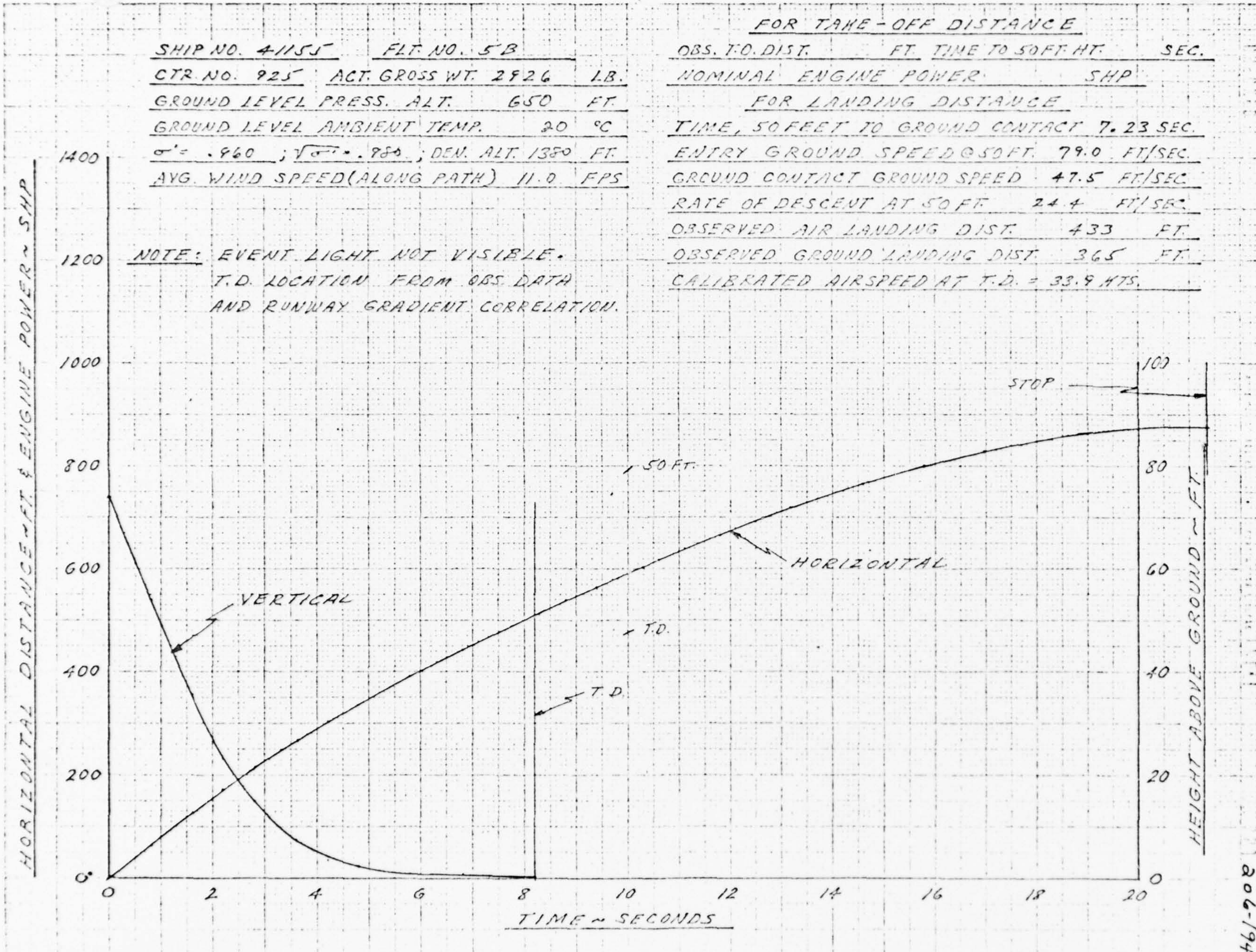

FIG 26 TIME HISTORY OF LANDING RUN No. 11 ~ FLT. No. 5B

J.G. 10-27-71

FOR TAKE-OFF DISTANCE

SHIP NO. 41155 FLT. NO. 5-B
CTR. NO. 921 ACT. GROSS WT. 2921 LB.
GROUND LEVEL PRESS. ALT. 650 FT.
GROUND LEVEL AMBIENT TEMP. 20 °C
σ' = .960 ; √σ' = .980 ; DEN. ALT. 1380 FT.
AVG. WIND SPEED (ALONG PATH) 11.8 FPS

OBS. T.O. DIST. FT. TIME TO 50 FT. HT. SEC.
NOMINAL ENGINE POWER SHP

FOR LANDING DISTANCE

TIME, 50 FEET TO GROUND CONTACT SEC.
ENTRY GROUND SPEED @ 50 FT. 80.0 FT/SEC.
GROUND CONTACT GROUND SPEED 43.0 FT/SEC.
RATE OF DESCENT AT 50 FT. 21.9 FT/SEC.
OBSERVED AIR LANDING DIST. 624 FT.
OBSERVED GROUND LANDING DIST. 237 FT.
CALIBRATED AIRSPEED AT T.D. = 31.9 KTS.

NOTE: EVENT LIGHT NOT VISIBLE.
T.D. LOCATION FROM OBS. DATA
AND RUNWAY GRADIENT CORRELATION

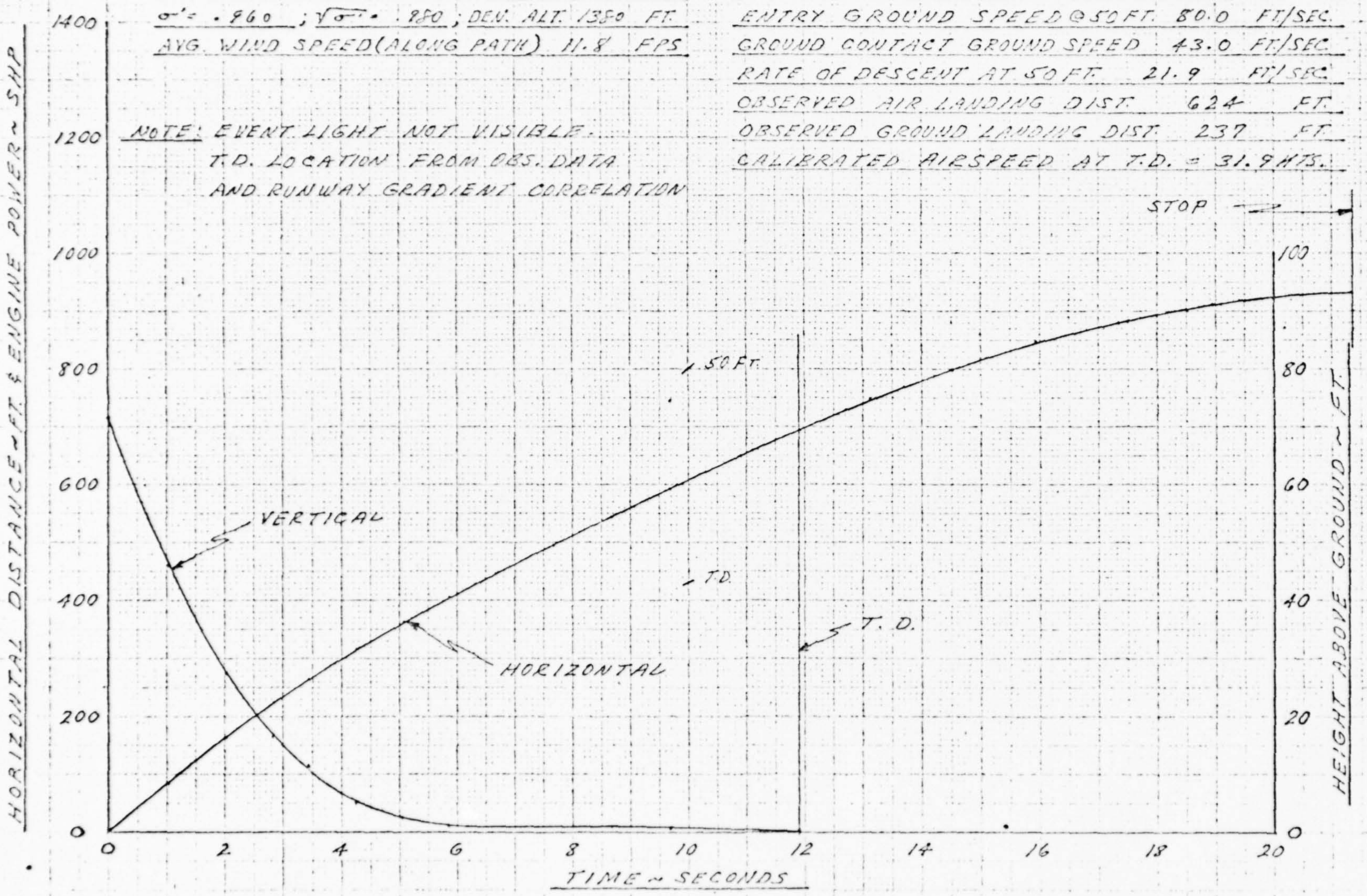

FIG. 27 TIME HISTORY OF LANDING RUN NO. 12 ~ FLT. NO. 5 B

J.G. 10-27-71

SHIP NO. 41155 FLT. NO. 5B
CTR. NO. 927 ACT. GROSS WT. 2911 LB.
GROUND LEVEL PRESS. ALT. 650 FT.
GROUND LEVEL AMBIENT TEMP. 20 °C
σ = .960 ; $\sqrt{\sigma}$ = .980 ; DEN. ALT. 1380 FT.
AVG. WIND SPEED (ALONG PATH) 16.0 FPS

NOTE: EVENT LIGHT NOT VISIBLE.
T.D. LOCATION FROM OBS. DATA
AND RUNWAY GRADIENT CORRELATION.

FOR TAKE-OFF DISTANCE
OBS. T.O. DIST. FT. TIME TO 50 FT. HT. SEC.
NOMINAL ENGINE POWER SHP

FOR LANDING DISTANCE
TIME, 50 FEET TO GROUND CONTACT 10.67 SEC.
ENTRY GROUND SPEED @ 50 FT. 81.5 FT/SEC.
GROUND CONTACT GROUND SPEED 49.5 FT/SEC.
RATE OF DESCENT AT 50 FT. 20.0 FT/SEC.
OBSERVED AIR LANDING DIST. 639 FT.
OBSERVED GROUND LANDING DIST. 332 FT.
CALIBRATED AIRSPEED AT T.D. = 38.1 KTS.

NOTE: TIME AT STOP = 23.29 SECONDS
HORIZ. DIST AT STOP = 1061 FT

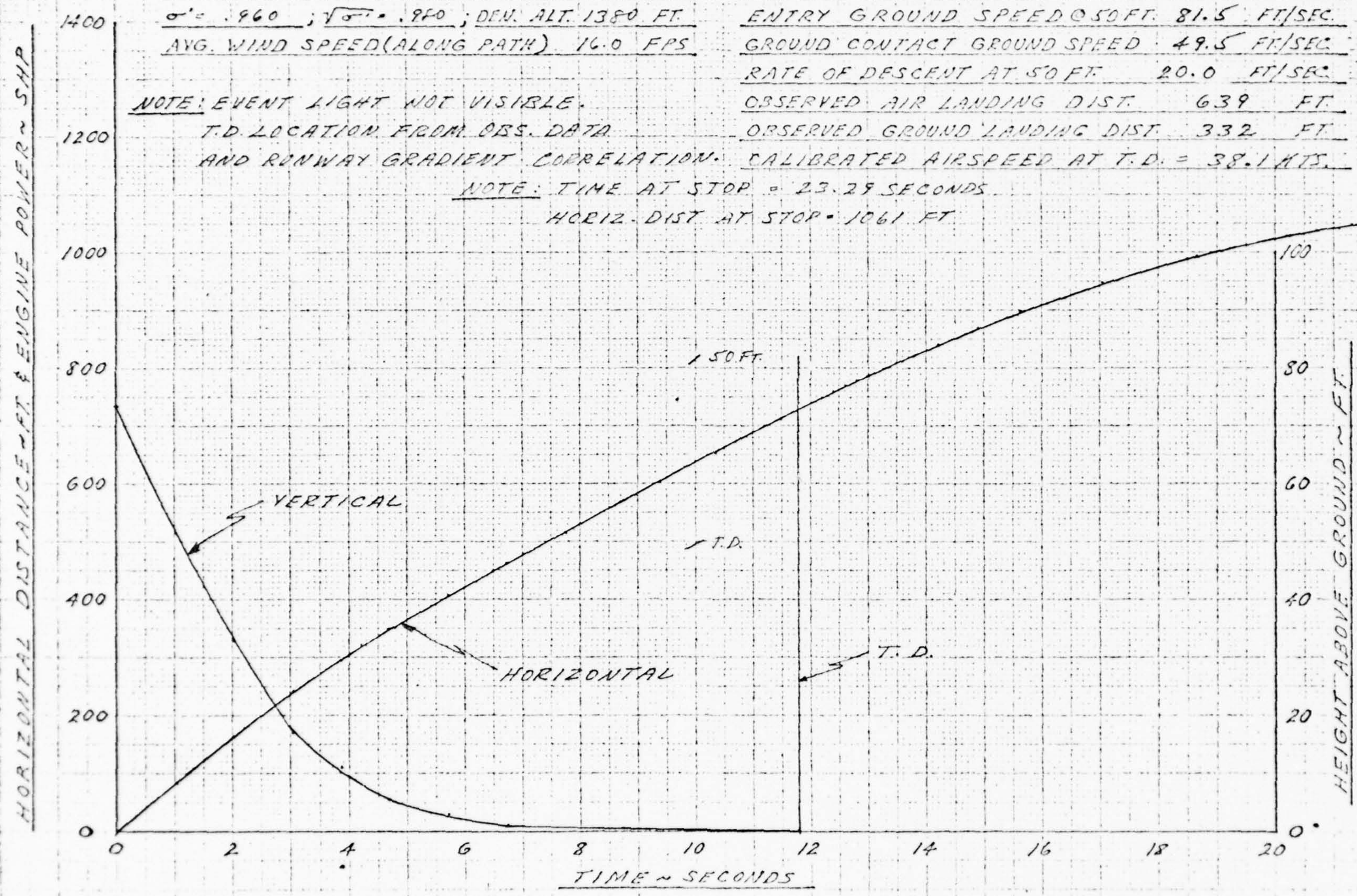

FIG. 28 TIME HISTORY OF LANDING RUN NO. 13 ~ FLT. NO. 5B

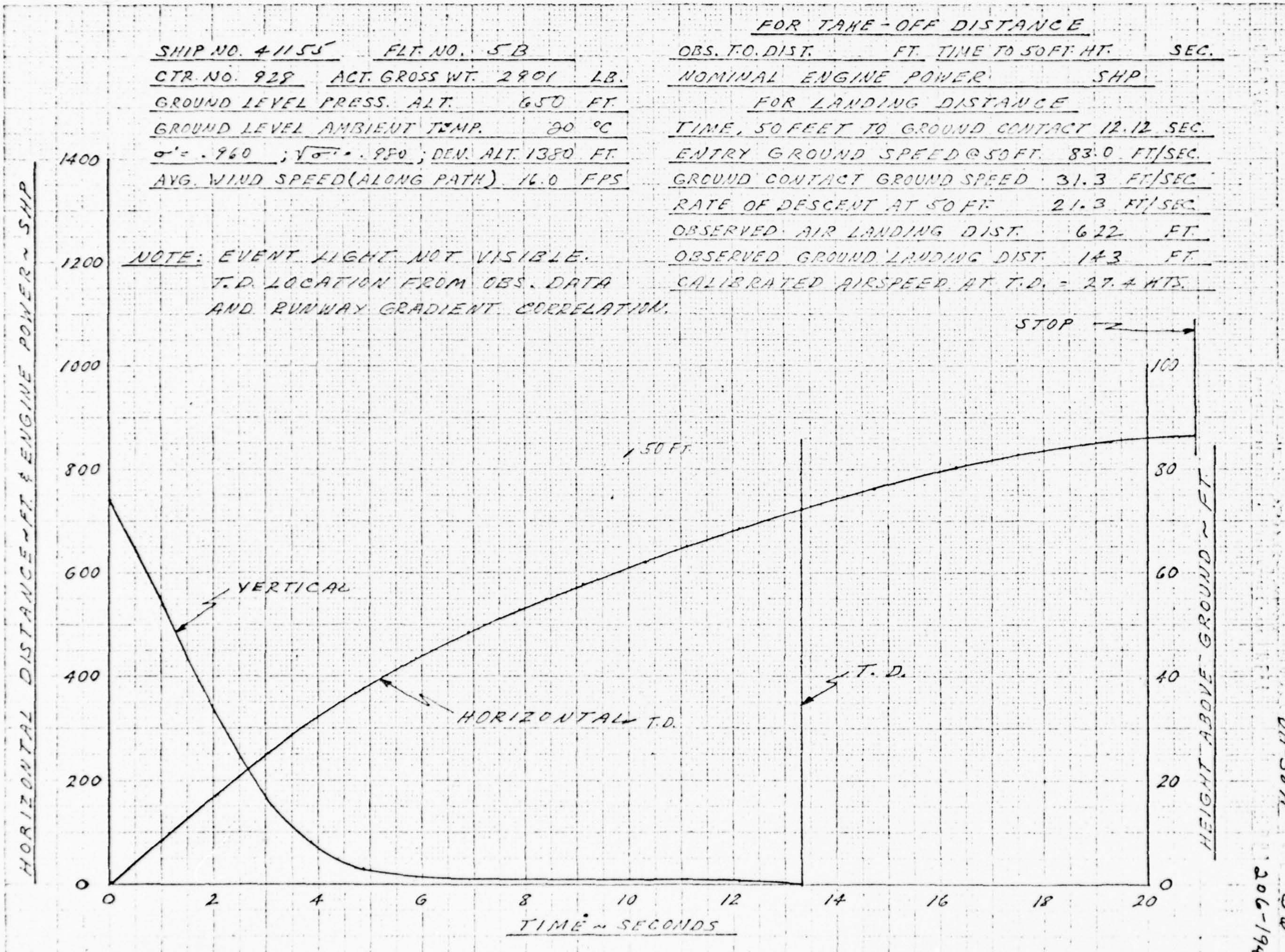

FIG. 29 TIME HISTORY OF LANDING RUN NO. 14 ~ FLT. NO. 5B

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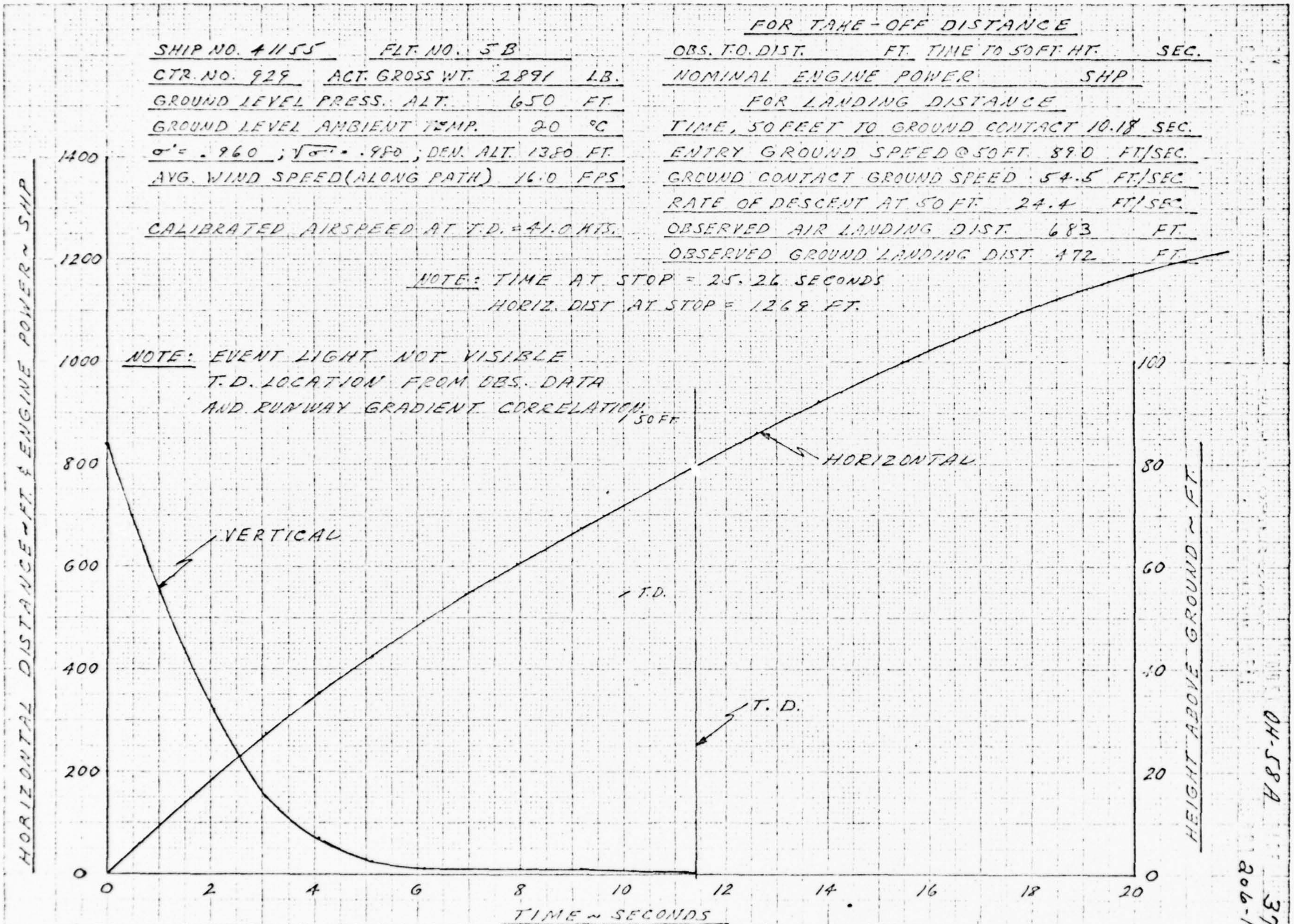

FIG. 30 TIME HISTORY OF LANDING RUN NO. 15 ~ FLT. NO. 5B

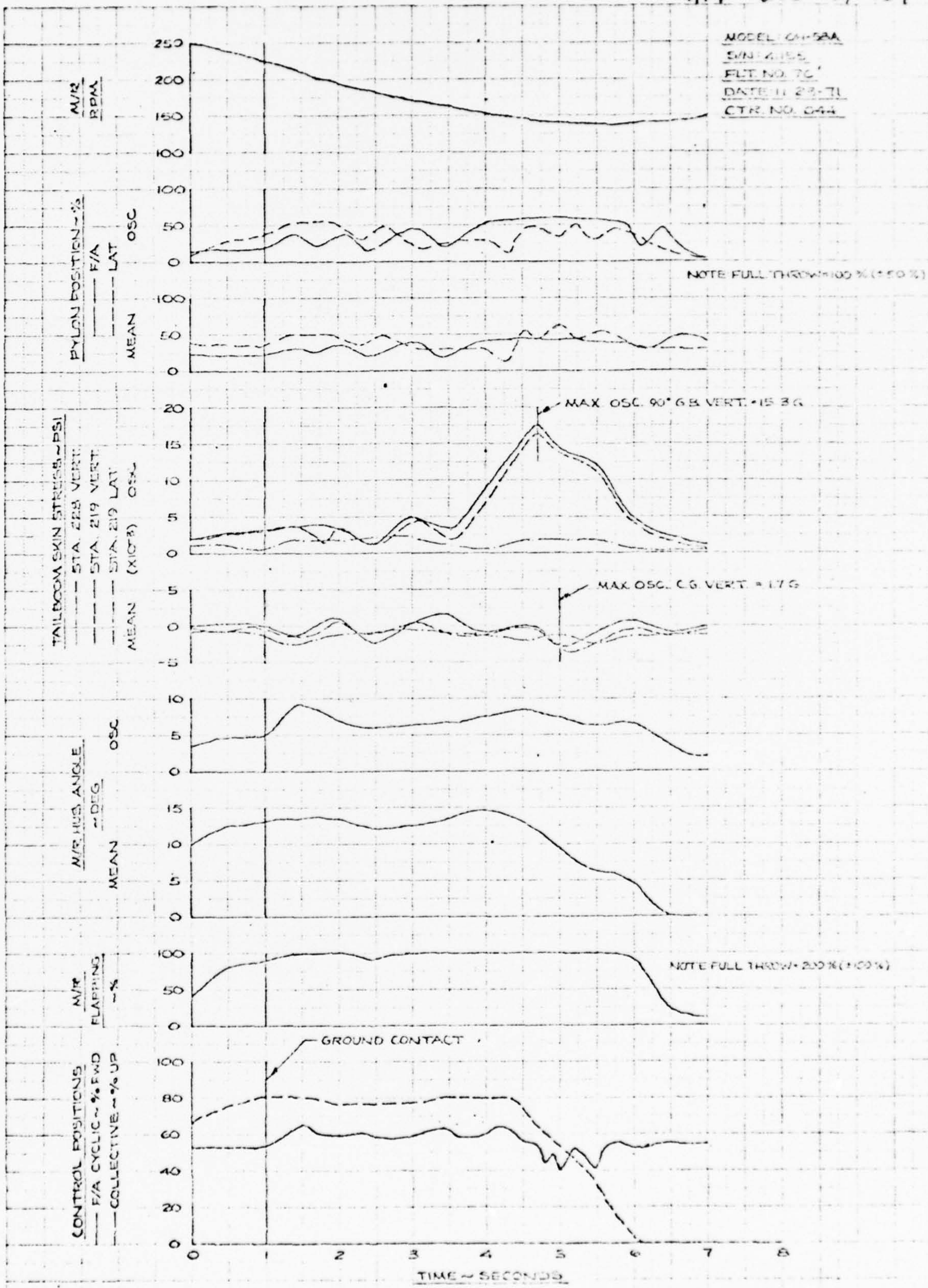

FIG 31 TIME HISTORY OF AUTOROTATION LANDING

SHIP NO. 41155 DATE: 11-24-71
GROSS WEIGHT 2939 LBS.
PRESSURE ALTITUDE 200 FT.
AMBIENT TEMPERATURE 20°C
DENSITY RATIO: σ = 1.021 $\sqrt{\sigma}$ = 1.010
DENSITY ALTITUDE -700 FT.

ENTRY HEIGHT (AT T.C.) 96.0 FT.
ENTRY SPEED (AT T.C.)
$\frac{ds}{dt}$ = 73.7 FPS = 43.7 KTS. VGS.
Vw.c. = 4.6 KTS.
$\sqrt{\sigma}$ (VGS. + Vw.c) = 48.8 KTS. VCAL
GRND. CONTACT = 22.0 FPS = 13.0 KTS. VGS.
ARMY PILOT, JOE WATTS

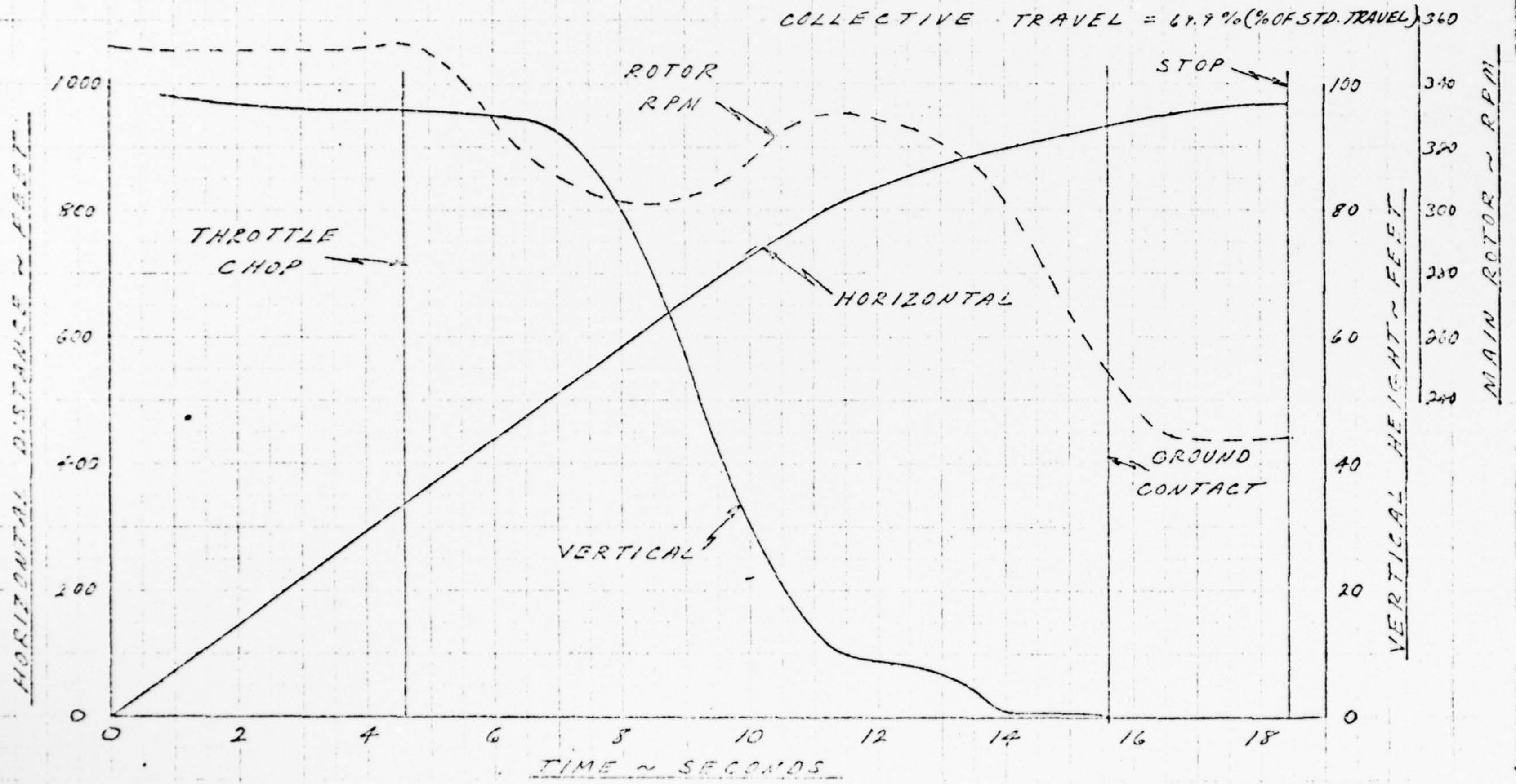

FIG. 32 TIME HISTORY OF HORIZONTAL DISTANCE, HEIGHT ABOVE GROUND AND MAIN ROTOR RPM ~ HEIGHT-VELOCITY RUN NO. 6

SHIP NO. 4155 DATE: 11-24-71
GROSS WEIGHT 2959 LBS.
PRESSURE ALTITUDE 200 FT.
AMBIENT TEMPERATURE 7.0 °C
DENSITY RATIO: σ = 1.021 $\sqrt{\sigma}$ = 1.010
DENSITY ALTITUDE -700 FT.

ENTRY HEIGHT (AT T.C.) 88.0 FT.
ENTRY SPEED (AT T.C.)
$\frac{ds}{dt}$ = 65.0 FPS = 40.3 KTS. $V_{G.S.}$
$V_{W.C.}$ = 4.2 KTS.
$\sqrt{\sigma}$ = ($V_{G.S.}$ + $V_{W.C.}$) = 44.9 KTS. V_{CAL}
GRND. CONTACT = 16.5 FPS = 9.8 KTS. $V_{G.S.}$
ARMY PILOT, JOE WATTS

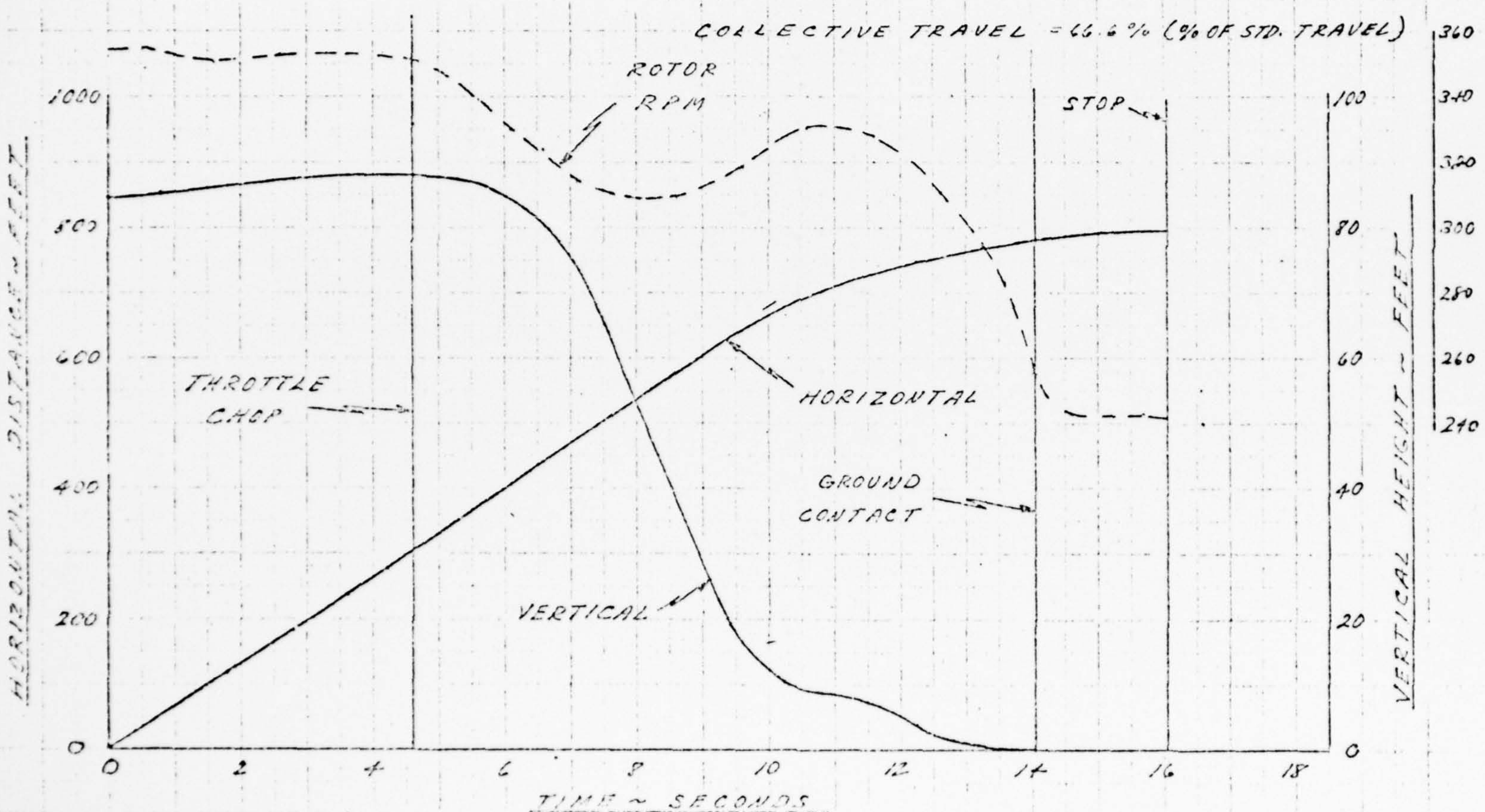

FIG. 33 TIME HISTORY OF HORIZONTAL DISTANCE, HEIGHT ABOVE GROUND AND MAIN ROTOR RPM ~ HEIGHT - VELOCITY RUN NO. 7

SHIP NO 41155 DATE: 11-24-71
GROSS WEIGHT 2954 LBS.
PRESSURE ALTITUDE 200 FT.
AMBIENT TEMPERATURE 7°C
DENSITY RATIO: σ = 1.021 $\sqrt{\sigma}$ = 1.010
DENSITY ALTITUDE -100 FT.

ENTRY HEIGHT (AT T.C.) 85.5 FT.
ENTRY SPEED (AT T.C.)
$\frac{\Delta s}{\Delta t}$ = 62.0 FPS = 36.7 KTS $V_{G.S.}$
$V_{W.C.}$ = 4.2 KTS.
$\sqrt{\sigma}\cdot(V_{G.S.}+V_{W.C.})$ = 41.3 KTS. V_{CAL}
GRND. CONTACT = 21.3 FPS = 12.6 KTS. $V_{G.S.}$
ARMY PILOT, JOE WATTS

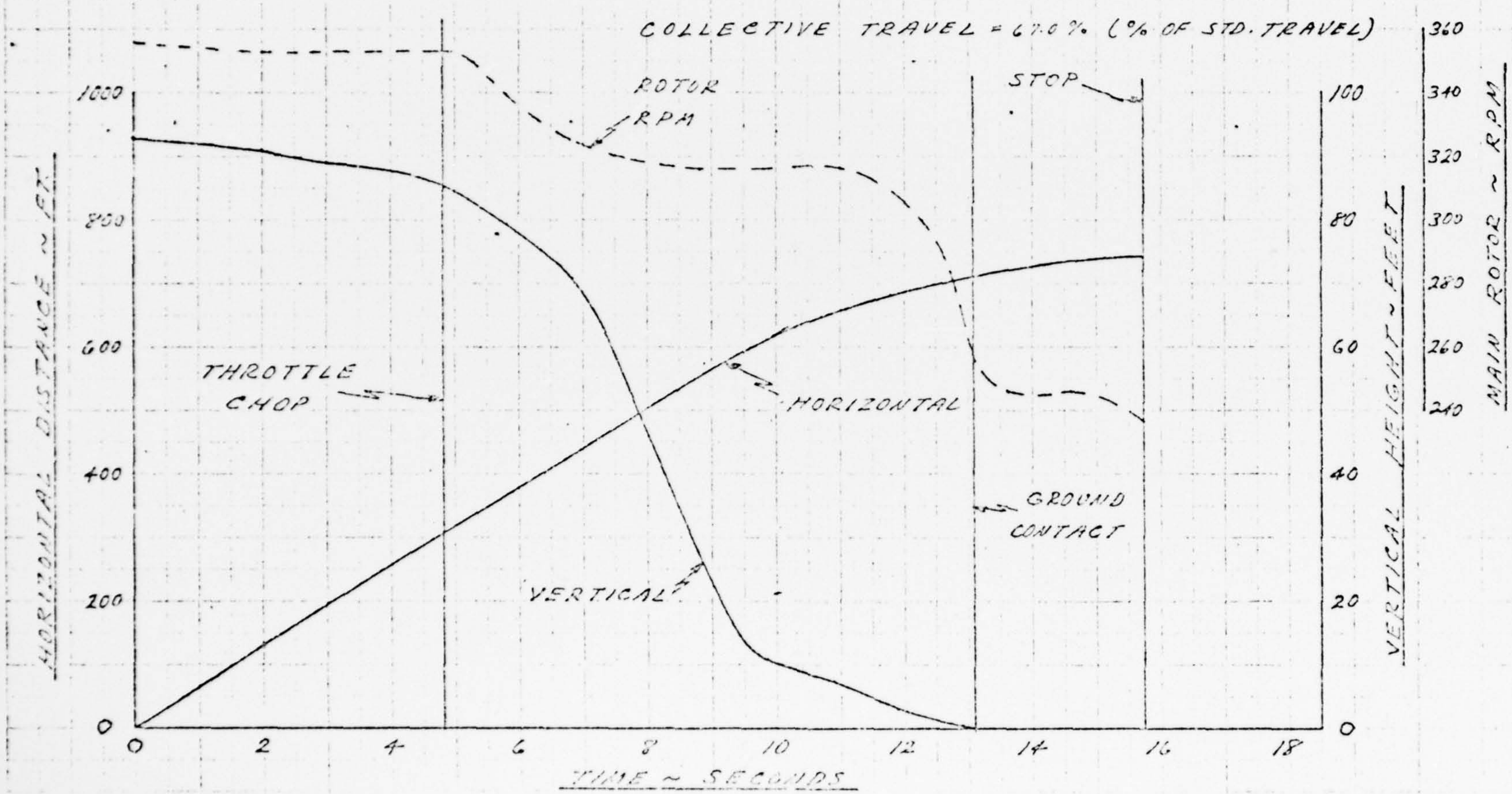

FIG. 34 TIME HISTORY OF HORIZONTAL DISTANCE, HEIGHT ABOVE GROUND AND MAIN ROTOR RPM ~ HEIGHT - VELOCITY RUN NO. 8

NOTE: CURVE OBTAINED FROM TABLE OBSERVED READING OF BELL TRUCK AT VARIOUS RUNWAY LOCATIONS USING THE FAA GRID CAMERA

BELL NO. 41155
FLT. NO. ARMY
DATE: 11-24-71
GRID RUN NO. 9

* AS READ FROM THE FAA GRID CAMERA

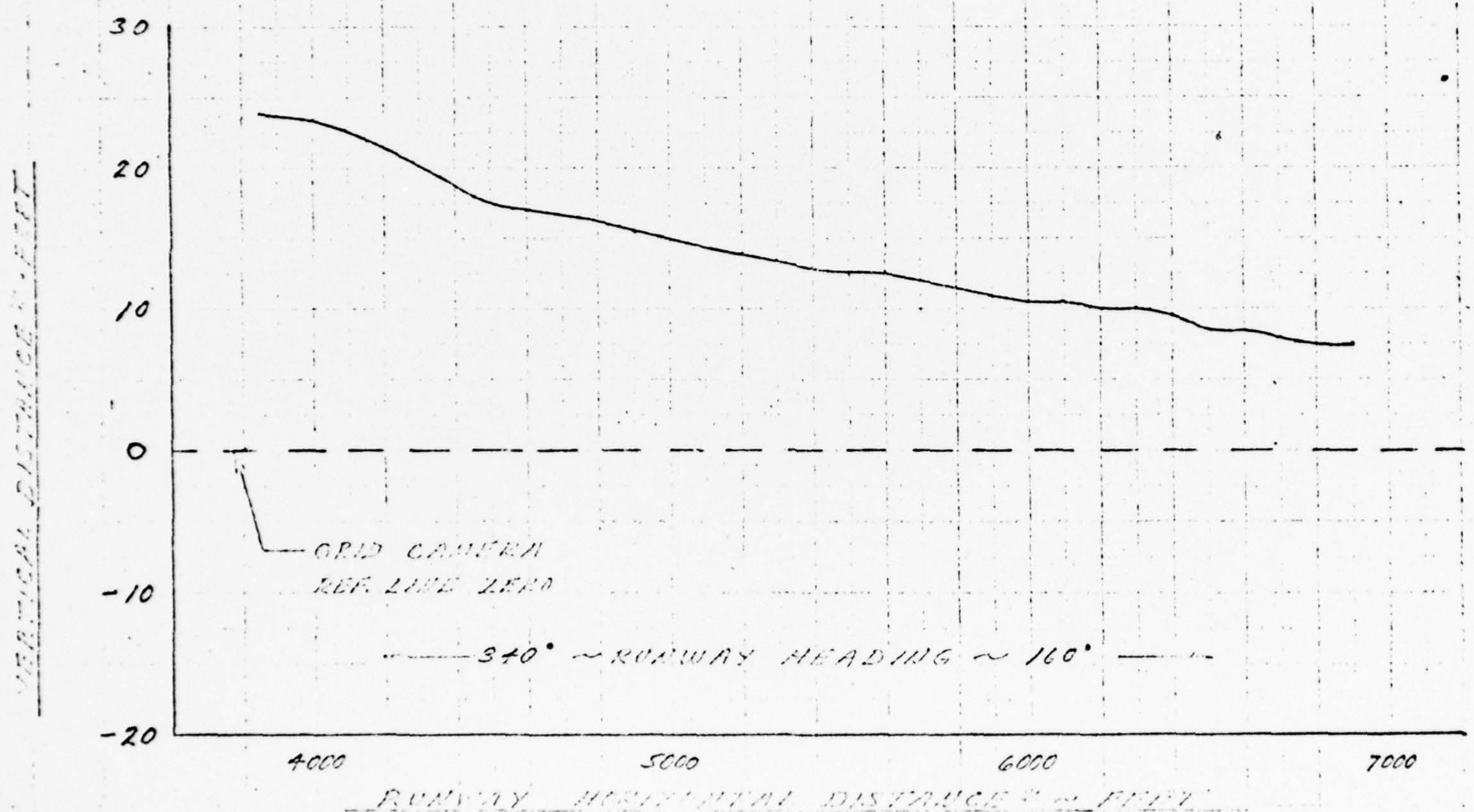

Fig 35 Runway 16-34 Gradient @ Arlington Municipal Airport, Texas

J.G. 11-29-71

PROG. NO. F0132 MODEL OH-58A S/N 41080 DATE 9-30-71 1ST REC 0539
PROGRAM T/B FAILURE INVESTIGATION CHANGE LETTER B 1ST FLT 2

TRACK 1

TABLE I Sheet 1 of 4

SET UP	ITEM	DESCRIPTION	DELTA CAL	REF VALUE	UNITS
01-01-0483	F101	M/R RED PITCH LINK	1284.21	0.00	LBS
01-02-0539	B103	M/R RED YOKE CHD BEND	107589.33	0.00	IN-LB
01-03-0539	B102	GROUND CONTACT INDICATOR	0.00000	0.00000	
01-04-0483	D104	M/R FLAPPING	184.48963	100.00001	%
01-05-0483	D021	F/A CYCLIC STK POSITION	99.90400	50.00000	%
01-06-0483	D022	LAT CYCLIC STK POSITION	75.79881	50.00000	%
01-07-0483	D023	COLL STK POSITION	105.86958	0.00000	%
01-08-0483	D051	F/A PYLON MOUNT MOTION	91.88653	60.55000	%
01-09-0483	D052	LAT PYLON MOUNT MOTION	116.88656	28.30000	%
01-10-0483	S251	R/H LONGERON STRESS STA 176	24354.79	0.00	PSI
01-11-0483	S252	T/B LOWER SKIN STRESS STA 219	24350.70	0.00	PSI
01-12-0483	S253	L/H LONGERON STRESS STA 176	48810.96	0.00	PSI
01-13-0483	R018	M/R AZIMUTH	0.00000	0.00000	

TABLE I Sheet 2 of 4

Instrumentation Set-Up Sheet, S/N 5610

Purpose: Tailboom Evaluation Flight: 1 Date: 9-29-71

Chan. No.	Measured and Location	Sta.	Lab No.	100 K Ω C.E.	Units	Ref. Value
1	Engine Torque Pressure		8761	27.2	psi	0
2	Hydraulic Pressure		8785	252.7	psi	0
3	Center of Gravity Vertical Acceleration		14649	1.09	g	1.0
4	C.L. Hub F/A Acceleration		2041	1.365	g	0
5	C.L. Hub Lateral Acceleration		2040	1.29	g	0
6	R/H Cyclic Boost Tube		5903C	731	lb	0
7	L/H Cyclic Boost Tube		5904C	751	lb	0
8	Collective Boost Tube		7557A	918	lb	0
9	M/R Feathering		7894	14.65	deg	-
13	M/R rpm (Linear)		-	C.C. 54.0	rpm/in.	-
17	Skid Gear Ground Contact		-	-	-	-
18	M/R Azimuth		-	-	-	

PROG. NO. F0132 MODEL OH-58A S/N 41155 DATE 10-9-71 1ST REC 0617

PROGRAM TAILBOOM INVESTIGATION CHANGE LETTER C 1ST FLT 1

TABLE I Sheet 3 of 4

SET UP	ITEM	DESCRIPTION	DELTA CAL	REF VALUE	UNITS
01-01-0617	B102	GROUND CONTACT INDICATOR	0.00000	0.00000	
01-02-0617	D104	M/R FLAPPING	145.79598	100.00001	%
01-03-0617	D023	COLLECTIVE STK POSITION	105.15599	0.00000	%
01-04-0617	D021	F/A CYCLIC STK POSITION	96.85609	50.00000	%
01-05-0617	D022	LAT CYCLIC STK POSITION	138.17599	50.00000	%
01-06-0617	D051	F/A PYLON POSITION	153.65130	39.41000	%
01-07-0617	D052	LAT PYLON POSITION	204.35375	71.70001	%
01-08-0617	B106	M/R MAST PARA BEND STA 18	42786.73	0.00	IN-LB
01-09-0617	B103	M/R RED YOKE CHORD BEND	110712.18	0.00	IN-LB
01-10-0617	B105	M/R RED BLADE BEAM BEND	20842.76	-3039.00	IN-LB
01-11-0617	S253	L/H LONGERON STRESS	49639.97	0.00	PSI
01-12-0617	S252	T/B LOWER SKIN STRESS STA 219	49783.66	0.00	PSI
01-13-0483	R018	M/R AZIMUTH	0.00000	0.00000	

TRACK 1

7862 57976

TABLE I Sheet 4 of 4

Instrumentation Set-Up Sheet, S/N 5632

Purpose: Tailboom Failure Investigation Flight: Date: 10-9-71

Chan. No.	Measured and Location	Sta.	Lab No.	100 K Ω C.E.	Units	Ref. Value
1	M/R Blade Angle		7894	14.65	deg	-
2	M/R Pitch Link, Red		5875B	876	lb	0
3	M/R Mast Parallel Bending	35.87	5865D-06	10,830	in.lb	0
4	M/R Mast Perpendicular Bending	18	5865D-03	7082	in.lb	0
5	Center of Gravity Vertical Accel.		14699	1.09	g	1.0
6	90° Gear Box Vertical Acceleration		16950	4.748	g	1.0
7	90° Gear Box Lateral Acceleration		5566	4.783	g	0
8	Tailboom Skin Vertical Stress	228	7916A	16,768	psi	-
9	Tailboom Skin Lateral Stress		7916A	16,768	psi	-
10	R/H Longeron Stress		7915	16,768	psi	-
11	Ground Contact Indicator		-	-	-	-
17	Throttle Chop Event		-	-	-	-
18	M/R Azimuth		-	-	-	-

TABLE II

LOG OF FLIGHTS

G. R. No.	Flt No.	1971 Date	Time (hr)	G. W. (lb)	C. G. Sta.	Configuration/Purpose
OH-58A S/N 41080						
1		9-20	0.3			Shakedown after build-up.
2A		9-21	0.3			To record data of rotor, pylon and airframe loads during rpm and collective sweeps.
2B		9-21	0.5			"
2C		9-21	0.5			"
3A		9-24	0.7			"
3B		9-24	0.4			"
4A		9-27	0.4			To obtain data of airframe and rotor vibrations during ground run.
4B		9-27	0.3			
	1A	9-29	0.2	2710	109.9	Accumulate a number of autorotation landings using various landing techniques.
	1B	9-29	0.6	2710	109.9	"
	1C	9-29	0.4	2710	109.9	"
	1D	9-29	0.7	2710	109.9	"
	2A	9-30	0.2	2710	109.9	"
	2B	9-30	0.3	2710	109.9	"
	3A	10-1	0.3	2710	109.9	Tailboom failure occurred.
OH-58A S/N 41155						
1		10-14				Shakedown after instrumentation changes.
	1	10-15	0.5	3000	109.1	Record rotor rpm decay rate at limited collective.
	2	10-19	1.4	2986	109.6	"

Sheet 2 of 2

TABLE II

LOG OF FLIGHTS

G. R. No.	Flt No.	Date	Time (hr)	G. W. (lb)	C. G. Sta.	Configuration/Purpose
OH-58A S/N 41155 - (cont)						
	3A	10-20	0.5	2986	109.6	Record and evaluate a series of autorotation landings with collective up stop restricted to 85% or 14.7° main rotor blade angle.
	4	10-21	0.4	2712	108.6	Continue autorotation landings with reduced available collective.
	5A	10-25	0.5	2984	109.6	Autorotation landing with collective stop reduced to 80%.
	5B	10-25	0.9	2984	109.6	"
	5C	10-25	0.1	2984	109.6	"
	6	11-19	0.3	2700	108.5	Shakedown for USAASTA Evaluation. Standard collective bellcrank.
	7A	11-23	0.1	2700	108.6	Shakedown.
	7B	11-23	0.4	2700	108.6	USAASTA Evaluation.
	7C	11-23	0.4	2700	108.6	USAASTA Evaluation with 80% collective available.
	8A	11-24	0.1	3000	109.6	USAASTA height-velocity evaluation.
	8B	11-24	0.8	3000	109.6	"

TABLE III

OSCILLOGRAPH PARAMETERS

S/N: 41155 MODEL: OH-58A FLIGHT: 5B DATE: 22 OCT. 71

RUN NO.	CTR. NO.	GROUND CONTACT GROUND SPEED ~ KTS	COLLECTIVE POSITION @ CONTACT ~ %	F/A CYCLIC POSITION @ CONTACT ~ %	N_R @ CONTACT ~ RPM	N_R @ LOWERED COLLECTIVE ~ RPM	% OF FLAPPING @ CONTACT ~ %	% OF FLAPPING @ LOWERED COLLECTIVE ~ %
10	924	18.53	57.7	37.9	258	144	± 32.0	± 16.2
11	925	28.10	57.7	41.3	264	138	± 32.0	± 17.6
12	926	25.46	80.4	52.8	228	186	± 64.8	± 13.5
13	927	29.30	70.1	54.5	228	198	± 62.2	± 18.9
14	928	18.53	80.4	44.6	225	132	± 62.2	± 21.6
15	929	32.26	78.3	53.7	240	132	± 62.1	± 32.4

OTHER INFORMATION:
GROSS WEIGHT 2936 TO 2891 LBS. DURING RUNS 10-15
GROUND LEVEL H_D 1380 FT.
GROUND LEVEL AMBIENT TEMP. 20°C

BY ______ CHECKED ______	BELL HELICOPTER COMPANY POST OFFICE BOX 482 • FORT WORTH, TEXAS	MODEL OH-58A PAGE 50 RPT 206-194-134

TABLE IV (SHEET 1 OF 3)

FAA GRID CAMERA DATA

☐ TAKE OFF DISTANCE ☐ LANDING DISTANCE ☒ HEIGHT VELOCITY

BELL S/N 41155 LOCATION: ARLINGTON, TEXAS

		①	②	③	④	⑤	⑥	⑦	
FLT. NO.	RUN NO.	OBS. TIME SEC.	OBS. DISTANCE VERT. FT.	OBS. DISTANCE HORIZ. FT.	VERTICAL READING & GRADIENT CORR. (NOTE: 1) FT.	CORR. TIME ① @ NOTE: 2 SEC.	CORR. DISTANCE VERT. ②+④ FT.	CORR. DISTANCE HORIZ. ③ @ (NOTE: 2) FT.	REMARKS
ARMY	6	10.04	121	6583	21.5	0	99.5	0	
		10.84	120	6526		0.80	98.5	57	
		11.64	119	6468		1.60	97.5	115	
		12.44	118	6408		2.40	96.5	175	
		13.44	117.5	6334		3.40	96	249	
		14.24	117.5	6276		4.20	96	307	
		14.64	117.5	6247		4.60	96	336	LIGHT ON
		15.44	117	6188		5.40	95.5	395	
		16.24	116.5	6130		6.60	95	453	
		17.24	112.5	6057		7.20	91	526	
		18.24	98	5984		8.20	76.5	599	
		19.24	72	5911		9.20	50.5	672	
		20.24	48	5842		10.20	26.5	741	
		21.24	33	5781		11.80	11.5	802	
		22.24	30	5738		12.80	8.5	845	
		23.24	27.5	5705		13.20	6.0	878	
		24.24	22	5679		14.20	0.5	904	
		25.25	22	5656		15.21	0.5	927	
		25.65	21.5	5647	21.5	15.61	0	936	LIGHT OUT
		26.65	21.5	5628		16.61	0	955	
		27.86	21.5	5614		17.82	0	969	
	6	28.47	21.5	5613		18.43	0	970	STOP
	7	15.88	106	6401	21.5	0	84.5	0	
		16.68	107	6348		0.80	85.5	53	
		17.68	108	6283		1.80	86.5	118	
		18.69	109	6218		2.81	87.5	183	
		19.49	109.5	6164		3.61	88	237	
		20.10	109.5	6124		4.22	88	277	
		20.49	109.5	6097		4.61	88	304	LIGHT ON
		21.10	109	6055		5.22	87.5	346	
		22.10	105	5987		6.22	83.5	414	
		23.10	93.5	5919		7.22	72	482	
		24.10	69	5849		8.22	47.5	552	
		25.11	44	5780		9.23	22.5	621	
ARMY	7	26.11	32	5722	21.5	10.23	10.5	679	

NOTE: (1) CORRECTION OF READING (MAST) TO GROUND (SKID-GEAR): - 9.5 FT. PLUS RUNWAY GRADIENT CORRECTION (FIG. ____) USING THE TOUCHDOWN POINT FOR HEIGHT VELOCITY AND LANDING AND THE HOVER POINT FOR TAKE-OFF.

(2) CORRECTED TIME ZERO AND HORIZONTAL DISTANCE ZERO TO BE START OF TAKE-OFF RUN, APPROX. 1 SEC. PRIOR TO THROTTLE CHOP FOR HT. VELOCITY, AND ANY TIME PRIOR TO 50 FT. HEIGHT FOR LANDING.

J. G. 11-29-71

BY ____________ CHECKED ____________	BELL HELICOPTER COMPANY POST OFFICE BOX 482 • FORT WORTH 1 TEXAS	MODEL OH-58A PAGE 51 RPT 206-194-134

TABLE IV (SHEET 2 OF 3)

FAA GRID CAMERA DATA

☐ TAKE OFF DISTANCE ☐ LANDING DISTANCE ☒ HEIGHT VELOCITY

BELL S/N 41155 LOCATION: ARLINGTON, TEXAS

FLT. NO.	RUN NO.	① OBS. TIME SEC.	② OBS. DISTANCE VERT. FT.	③ OBS. DISTANCE HORIZ. FT.	④ VERTICAL READING & GRADIENT CORR. (NOTE: 1) FT.	⑤ CORR. TIME ① @ NOTE: 2 SEC.	⑥ CORR. DISTANCE VERT. ②+④ FT.	⑦ CORR. DISTANCE HORIZ. ③ @ (NOTE: 2) FT.	REMARKS
ARMY	7	27.12	29.5	5681	21.5	11.24	8	730	
		28.12	25.5	5652		12.24	4	749	
		29.12	22.0	5632		13.24	0.5	769	
		29.92	21.5	5619	21.5	14.04	0	782	LIGHT OUT
		30.92	21.5	5608		15.04		793	
	7	31.92	21	5604		16.04		797	STOP
	8	10.60	115	6246	22	0	93	0	
		11.60	114	6178		1.00	92	68	
		12.60	113	6112		2.00	91	134	
		13.61	111	6049		3.01	89	197	
		14.61	109.5	5987		4.01	87.5	259	
		15.42	107.5	5937		4.82	85.5	309	LIGHT ON
		16.43	101.5	5877		5.83	79.5	369	
		17.44	93	5815		6.84	71	431	
		18.45	72	5751		7.85	50	495	
		19.45	48	5689		8.85	26	557	
		20.46	33	5633		9.86	11	613	
		21.47	29.5	5592		10.87	7.5	654	
		22.48	25	5560		11.88	3	686	
		23.49	22.5	5538		12.89	0.5	708	
		23.69	22	5533	22	13.09	0	713	LIGHT OUT
		24.71	22	5516		14.11		730	
		25.72	22	5505		15.12		741	
ARMY	8	26.33	22	5503		15.73		743	STOP

NOTE: (1) CORRECTION OF READING (MAST) TO GROUND (SKID-GEAR): -9.5 FT. PLUS RUNWAY GRADIENT CORRECTION (FIG. ____) USING THE TOUCHDOWN POINT FOR HEIGHT VELOCITY AND LANDING AND THE HOVER POINT FOR TAKE-OFF.

(2) CORRECTED TIME ZERO AND HORIZONTAL DISTANCE ZERO TO BE START OF TAKE-OFF RUN, APPROX. 1 SEC. PRIOR TO THROTTLE CHOP FOR HT. VELOCITY, AND ANY TIME PRIOR TO 50 FT. HEIGHT FOR LANDING.

J.G. 11-29-71

TABLE IV (SHEET 3 OF 3)

FAA GRID CAMERA DATA — RUNWAY GRADIENT

☐ TAKE OFF DISTANCE ☐ LANDING DISTANCE ☒ HEIGHT VELOCITY

BELL S/N 41155 LOCATION: ARLINGTON, TEXAS

FLT. NO.	RUN NO.	① OBS. TIME SEC.	② OBS. DISTANCE VERT. FT.	③ OBS. DISTANCE HORIZ. FT.	④ VERTICAL READING & GRADIENT CORR. (NOTE: 1) FT.	⑤ CORR. TIME ① @ NOTE: 2 SEC.	⑥ CORR. DISTANCE VERT. ②+④ FT.	⑦ CORR. DISTANCE HORIZ. ③ @ (NOTE: 2) FT.	REMARKS
ARMY	9		30	3850	6		24	3850	
			29.5	4000			23.5	4000	RUNWAY GRADIENT
			28	4150			22	4150	
			26	4300			20	4300	
			24	4450			18	4450	
			23	4600			17	4600	
			22.5	4750			16.5	4750	
			21.5	4900			15.5	4900	
			21	5000			15	5000	
			20.5	5100			14.5	5100	
			20	5200			14	5200	
			19.5	5300			13.5	5300	
			19	5400			13	5400	
			18.5	5500			12.5	5500	
			18.5	5600			12.5	5600	
			18	5700			12	5700	
			17.5	5800			11.5	5800	
			17	5900			11	5900	
			16.5	6000			10.5	6000	
			16.5	6100			10.5	6100	
			16	6200			10	6200	
			16	6300			10	6300	
			15.5	6400			9.5	6400	
			14.5	6500			8.5	6500	
			14.5	6600			8.5	6600	
			14	6700			8	6700	
			13.5	6800			7.5	6800	
ARMY	9		13.5	6800	6		7.5	6900	

NOTE: (1) CORRECTION OF READING (MAST) TO GROUND (SKID-GEAR): ______ FT. PLUS RUNWAY GRADIENT CORRECTION (FIG. ____) USING THE TOUCHDOWN POINT FOR HEIGHT VELOCITY AND LANDING AND THE HOVER POINT FOR TAKE-OFF.

(2) CORRECTED TIME ZERO AND HORIZONTAL DISTANCE ZERO TO BE START OF TAKE-OFF RUN. APPROX. 1 SEC. PRIOR TO THROTTLE CHOP FOR HT. VELOCITY, AND ANY TIME PRIOR TO 50 FT. HEIGHT FOR LANDING.

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