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LANDING LOADS INVESTIGATION LABORATORY DROP TESTS

September 1962

Contract NOa(s) 59-6226-c

REPORT NO. ES 40641

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REPORT NO. ES 40641

LANDING LOADS INVESTIGATION LABORATORY DROP TESTS

CONTRACT NO. NOa(s) 59-6226c
MODEL A4D-2

DATE: SEPTEMBER, 1962

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DOUGLAS AIRCRAFT COMPANY, INC.
LONG BEACH, CALIFORNIA

FOREWORD

The work described in this report was accomplished by Douglas Aircraft Company, Aircraft Division, Long Beach, California, for the Bureau of Naval Weapons, Wasnington, D. C., under Contract NOa(s) 59-6226c. It represents one phase of a comprehensive program for the examination of loads experienced by Naval Aircraft during landings and the determination of the accuracy with which these loads may be duplicated by drop tests and analysis.

The project was performed under the general direction of Mr. C. T. Newby of the Bureau of Naval Weapons with Mr. D. C. Lindquist acting as cognizant technical project head. It was conducted by Douglas Aircraft Company with Mr. F. C. Allen providing the technical direction and Mr. L. B. Mosby acting as Chief Technical Investigator.

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SUMMARY

This report describes and presents the results of certain airplane drop tests which are part of an extensive program to compare the landing loads experienced by an A4D-2 airplane during flight tests and drop tests with those computed by analytical methods. Other phases of the program are reported in References (1), (2) and (3).

The instrumentation used in these tests was nearly identical to that used in the flight test program and was sufficient to determine the loads applied to the airplane at the ground, the position of the strut, the internal pressures in the gear and significant structural accelerations.

The results are presented in the form of curves of measured parameter versus time. Vertical and horizontal loads on the gear at the ground were computed from the strut instrumentation and are compared with data from the reaction platforms.

Discussion on the significance of the data is reserved for the Summary Report on this project (Reference (3)), however, two recommendations pertaining to the need for further work arise from this drop test program. The first is that a study of the dynamic characteristics of the reaction platforms be made in order that confidence in the strut instrumentation can be improved, and second, that a sliding coefficient of friction test be made of the tire on the reaction platform surface for the purpose of substantiating the high coefficients of friction registered by the left hand strut.

SYMBOLS

FA = Axial load in the strut at the axle, pounds. Positive up.

FN = Normal load in the strut at the axle, pounds. Positive aft.

FAA = Inertia force on the lower mass in the strut axial direction, pounds. Positive down.

= Acceleration of the lower mass in g's times its weight. (The lower mass weight, which includes the wheel, tire axle and instrumentation, is 120 pounds.)

FAN = Inertia force on the lower mass in a fore-aft direction normal to the strut, pounds. Positive forward.

FHG = Force on the gear at the ground parallel to the ground, pounds.

FVG = Force on the gear at the ground normal to the ground, pounds.

I = Intercept constant. (except as noted)

K = Calibration constant. (except as noted)

L = Total wing lift, pounds.

MUA = Average coefficient of frictions of the tire on the landing surface.

MUA_1 = Instantaneous coefficient of friction.

P = The value of any parameter. Subscript denotes the oscillograph channel from which the parameter was taken.

t = Time, seconds.

T = Time from instant of release to instant of ground contact, seconds.

SYMBOLS (Continued)

V_v = Airplane vertical velocity (sinking speed), at contact, feet per second.

W = Airplane weight, pounds.

δ = Displacement of any oscillograph trace from its zero position, inches.

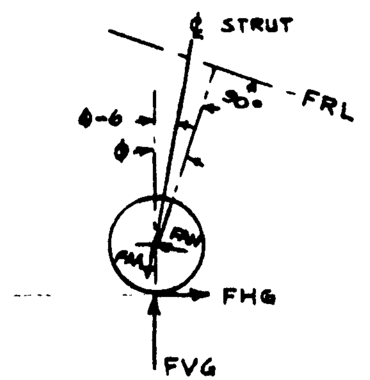
δ_i = Displacement of any oscillograph trace from the reference line, inches.

Δ = Displacement of any oscillograph trace from zero during the calibration run, inches.

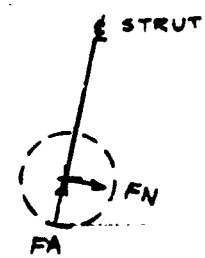
Δ_o = Distance between the zero position of any trace and the reference line, inches.

Δ_i = Displacement of any oscillograph trace from the reference line, inches.

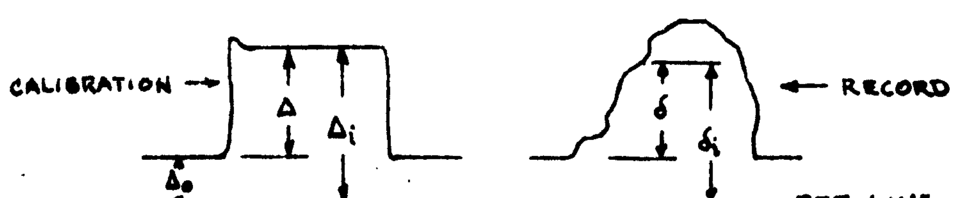
ϕ = Angle of the fuselage reference line with respect to the horizontal - degrees. Positive airplane nose up.



Positive Gear Forces



Positive Strut (Axle) Forces



Oscillograph Trace Terminology

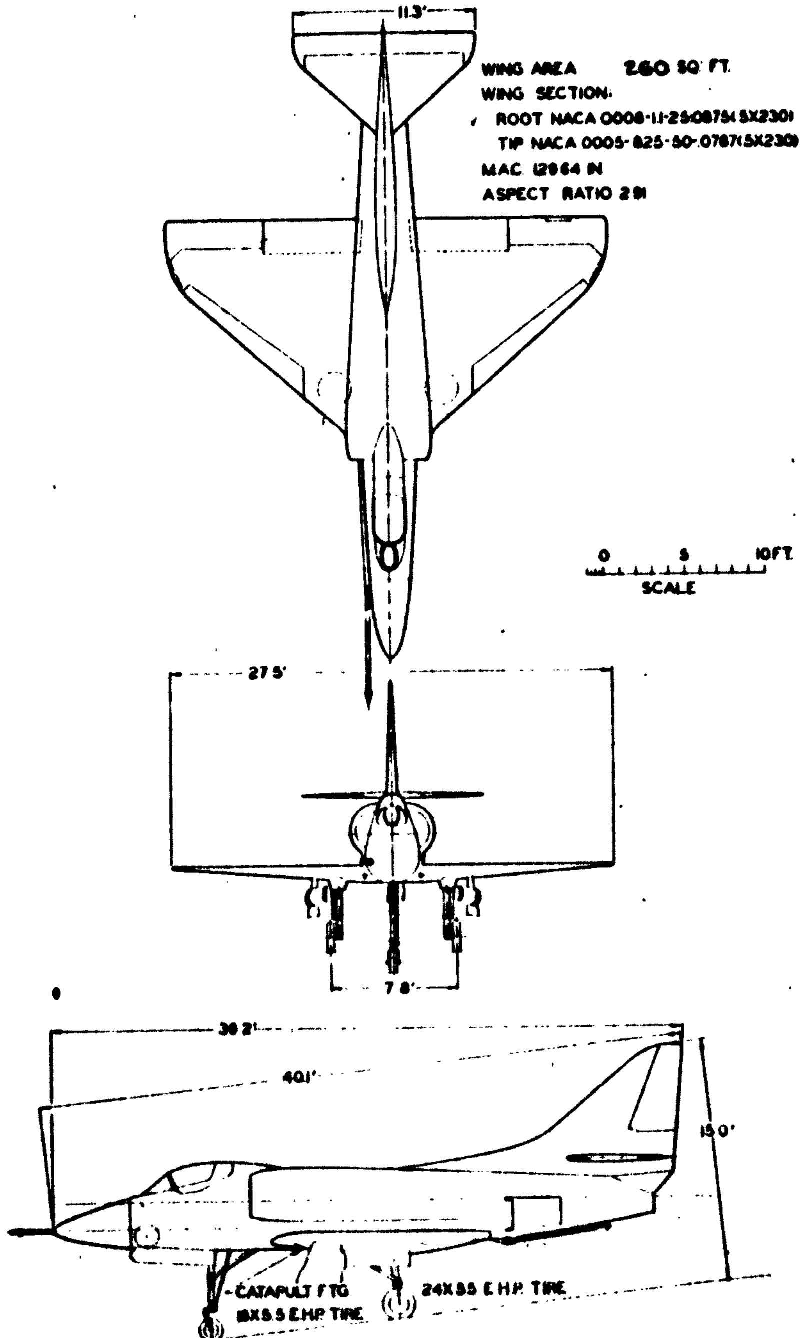
INTRODUCTION

The landing loads investigation, of which this report forms a part, provides for an experimental flight test program and an airplane drop test program with consistent instrumentation in conjunction with an analytical dynamic loads program. The purpose of the investigation is to determine the differences, if any, in the loads experienced in actual landings and the loads experienced in drop tests, and to determine the accuracy with which the landing loads can be duplicated by advanced analytical methods. This report describes the airplane drop tests and presents the results of the drop test phase of the investigation.

An additional objective of the program was to compare the loads resulting from actual landings with the loads measured on the moving drop test rig at the landing loads test facility of the National Aeronautics and Space Administration (NASA) at Langley Field, Virginia.

The airplane used was the Douglas A4D-2, general characteristics of which are shown in Figure 1. The NASA tests used a left hand A4D-2 gear which, together with similar instrumentation, was later used on the airplane during its flight tests and drop tests. In the flight and drop tests, a right hand gear with nearly identical instrumentation was also used.

The complete investigation is contained in three reports in addition to the present volume. A detailed description of the instrumentation and the calibration techniques is presented in Reference (1). A description of the flight tests and the results thereof are given in Reference (2) and the analytical investigation including the comparisons described above is presented in Reference (3). The NASA test results are contained in Reference (4).



DESCRIPTIVE ARRANGEMENT
MODEL A4D-2

Figure 1.

EQUIPMENT

Details of the airplane instrumentation used in this program are provided in Reference (1). A summary is provided in Table I for the reader's convenience.

Landing gear vertical and drag loads were measured by the landing gear instrumentation and by reaction platforms the configuration of which is shown in Figure 2. Variations in friction coefficient were obtained by varying the size of grooves in the surface of the platform. An average coefficient of friction of approximately 0.4 was sought by this procedure.

The airplane used in the drop tests was not the same as that used in flight test although the mass distribution and rigidities were identical in all important respects. Thus, all accelerometers in the body of the drop test article were mounted at the same location and with brackets that were identical to the flight test article. The landing gears were those used in flight test and the recording apparatus was the same.

In these flight tests, the recording apparatus was contained in a reworked 300 gallon external fuel tank mounted on the centerline of the airplane. This store was returned to the laboratory after flight testing for use in the drop test program. In the first 62 drops this store was mounted on the airplane in the same manner as in flight test. After Drop 62, the instrumented store was removed from the airplane and placed on the ground. Data was transmitted from the airplane to the store by a cable. This change reduced the maintenance required on the recording apparatus and eliminated some of the high frequency pulses on the oscillograph traces. A dummy store of equivalent mass and inertia was mounted on the airplane to relace the instrumentation package.

TABLE I

INSTRUMENTATION FOR DROP TESTS

Oscillograph 1

	Parameter Measured	Method of Measurement	Transducer Range	Transducer Type
1	L.H. Strut Vertical Load	Strain Gauge Installation on Axle	0-60K	18V 350 Ω
2	*L.H. Strut Drag Load	Strain Gauge Installation on Axle	± 20K	
3	*L.H. Strut Position	Slide Wire Device	0-16 in.	DAC
4	*L.H. Strut Velocity	Velocity Generator	± 30 FPS	Sanborn 10LV 17-n
5	*L.H. Air Chamber Press.	Pressure Transducer	0-5 KSI	DAC
6	*L.H. Metering Chamber Press.	Pressure Transducer	0-5 KSI	DAC
7	*L.H. Lower Mass Vert.Accel.	Miniature Accelerometer in Axle	± 90g's	**A6-100-350
8	*L.H. Lower Mass Long.Accel.	Miniature Accelerometer in Axle	±100g's	A6-100-350
9	*L.H. Lower Mass Side Accel.	Miniature Accelerometer in Axle	±100g's	A6-100-350
10	*L.H. Gear Upper Mass V.Accel.	Accelerometer	± 50g's	A5-50-350
11	*L.H. Gear Upper Mass V.Accel.	Accelerometer	± 50g's	A5-50-350
12	*L.H. Gear Upper Mass D.Accel.	Accelerometer	± 30g's	A5-50-350
13	*L.H. Drag Brace Axial Ld.	Strain Gauges	± 50K	18V 350 Ω
14	L.H. Gear Side Bending Mom.	Strain Gauge Installation		18V 350 Ω
15	*L.H. Wheel Angular Position	36 Magnets on Wheel - Pick-up on Strut	0-150KC	Electro 3010
16	Nose Gear Strut Position	Slide Wire Device	0-18 in.	DAC
17	Nose Gear Upper Mass V.Accel.	Accelerometer	± 30g's	A5-30-350
18	C.G. Normal Accel.	Accelerometer	± 1g	AJ26-1-350
19	C.G. Normal Accel.	Accelerometer	± 10g's	AJ43-10-350
20	C.G. Long. Accel.	Accelerometer	± 1g	D-06-350
21	Airplane Pitch Attitude	Vertical Gyro Installation	± 80°	P.R. Gyro
22	Airplane Roll Attitude	Vertical Gyro Installation	±160°	P.R. Gyro
23	L.H. Platform Vertical	Reaction Platform (Fig. 2)	0-60K	DAC
24	L.H. Platform Drag	Reaction Platform (Fig. 2)	± 15K	DAC

TABLE I (Cont.)

INSTRUMENTATION FOR DROP TESTS

Oscillograph 2

	Parameter Measured	Method of Measurement	Transducer Range	Transducer Type
1	*R.H. Strut Vertical Load	Strain Gauge Installation on Axle	0-60K	18V 350 Ω
2	*R.H. Strut Drag Load	Strain Gauge Installation on Axle	± 20K	18V 350 Ω
3	R.H. Strut Side Load	Strain Gauge Installation on Axle	± 8K	18V 350 Ω
4	*R.H. Strut Position	Slide Wire Device	0-16 in.	DAC
5	*R.H. Strut Velocity	Velocity Generator	± 30 FPS	Sanborn 10LV 17-n
6	*R.H. Air Chamber Pressure	Pressure Transducer	0-5 KSI	DAC
7	*R.H. Metering Chamber Press.	Pressure Transducer	0-5 KSI	DAC
8	*R.H. Lower Mass Vert. Accel.	Miniature Accelerometer in Axle	± 90g's	**A6-100-350
9	*R.H. Lower Mass Long. Accel.	Miniature Accelerometer in Axle	±100g's	A6-100-350
10	*R.H. Lower Mass Side Accel.	Miniature Accelerometer in Axle	±100g's	A6-100-350
11	*R.H. Gr.Upper Mass Vert.Accel.	Accelerometer	± 50g's	A5-50-350
12	*R.H. Gr.Upper Mass Drag Accel.	Accelerometer	± 3g's	A5-50-350
13	*R.H. Drag Brace Axial Load	Strain Gauges	± 50K	18V 350 Ω
14	*R.H. Wheel Angular Position	36 Magnets on Wheel - Pick-up on Strut	0-150KC	Electro 3010
15	L.H. Lift Damper Link	Strain Gauges	0-10K	18V 350 Ω
16	R.H. Lift Damper Link	Strain Gauges	0-10K	18V 350 Ω
17	L.H. Wing Tip Acceleration	Accelerometer	± 50g's	A6-50-35
18	R.H. Wing Tip Acceleration	Accelerometer	± 50g's	A6-50-35
19	*Time	Oscillograph Trace	20-20KC	205AG(H.P.)

* Items Identical on Both Gears

** All Accelerometers by Statham

PREPARED BY:

CHECKED BY:

TITLE:

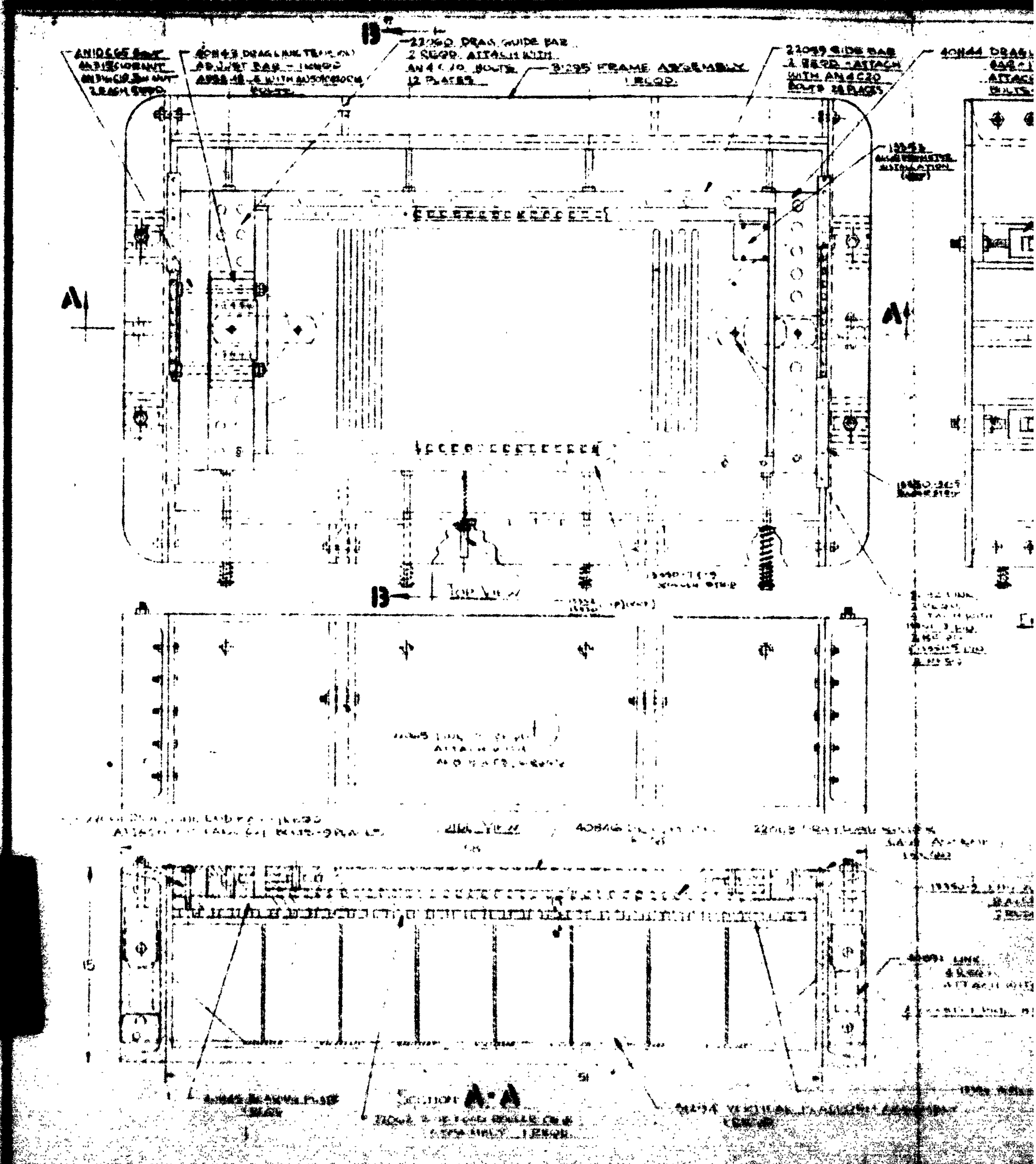
DOUGLAS AIRCRAFT COMPANY, INC.

LONG BEACH DIVISION

PAGE 6

MODEL:

REPORT NO.



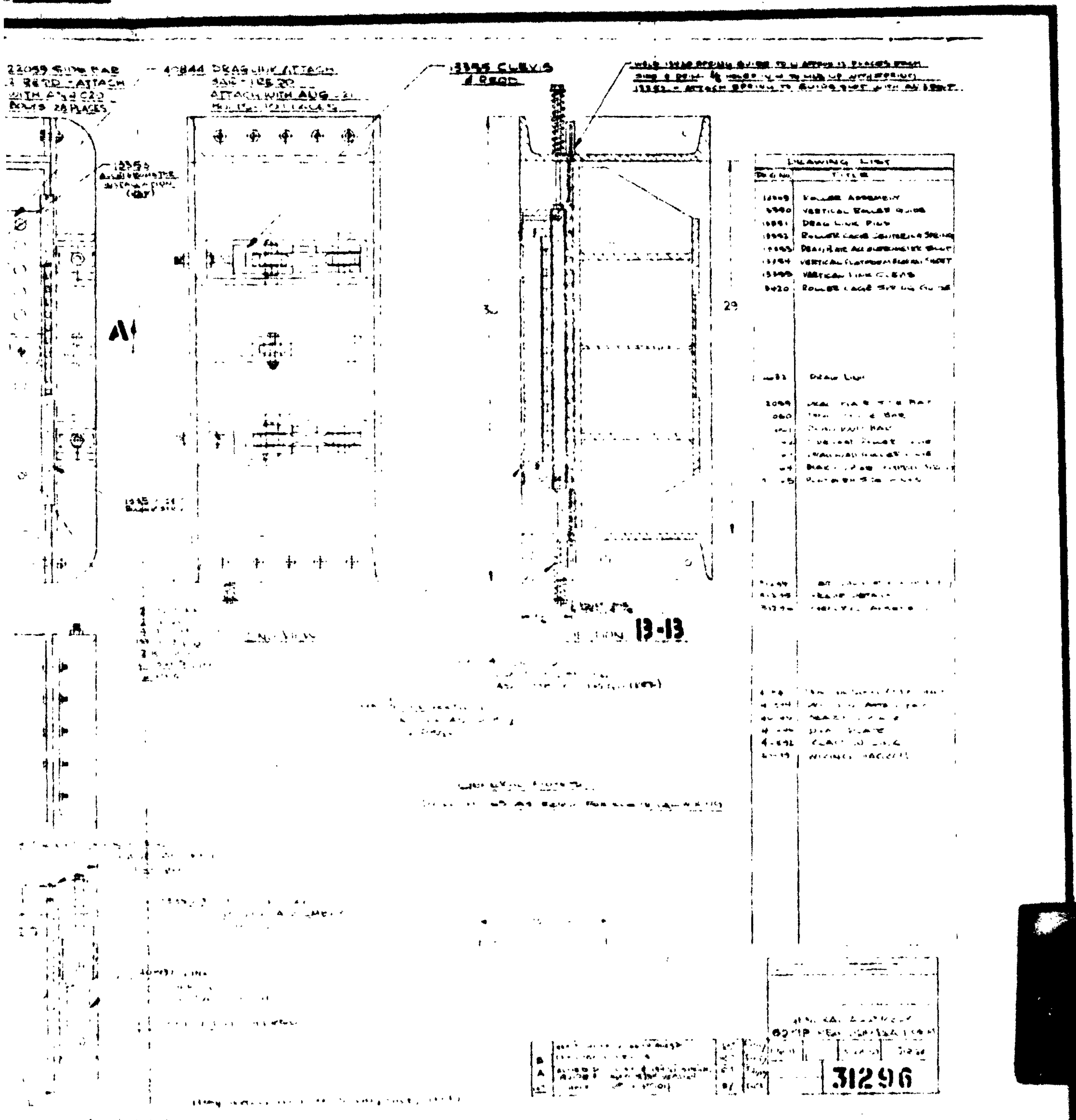


Figure 2. Rotation Platform

THE TEST SET-UP

Figure 3 shows the airplane in its pre-drop position and provides a picture of the test set-up. The apparatus and test procedures are, perhaps, typical of those used in the industry with the possible exceptions dicussed below.

Because of the special instrumentation located on the main landing gear axles, the wheel spin-up device shown in Figures 4 and 5 was designed. Angular velocity was imparted to the airplane wheels by bringing the tires in contact with two additional tires mounted on a jack shaft which was driven by two air motors. The jack shaft and its mounting was assembled on a carriage which was moved clear of the airplane immediately before it was dropped.

Wing lift was simulated by two 36 inch diameter pneumatic dampers (lift pots) shown in Figure 6. These were attached to the airplane at wing Stations 52.0 (right and left) as shown in Figure 7. The attachment mechanism was such that the load was applied shortly before the wheel contacted the ground. An essentially constant load was maintained throughout the stroke. Since this method of load application was one of the known significant differences between drop tests and flight tests, the attachment links of the dampers to the airplane were instrumented with strain gauges in order that the wing lift time-history could be determined. As indicated in Figure 7, additional lift dampers were provided to catch the airplane in the event of a structural failure. These lift pots applied no load to the airplane under normal circumstances.

Sinking speed was measured during the tests by a TRODI instrument set-up as shown in Figure 8. Sinking speed could not be obtained directly from the drop height without correcting for the forces introduced by the lift pots prior to wheel contact, hence TRODI was used as a rapid means of obtaining this parameter during test.

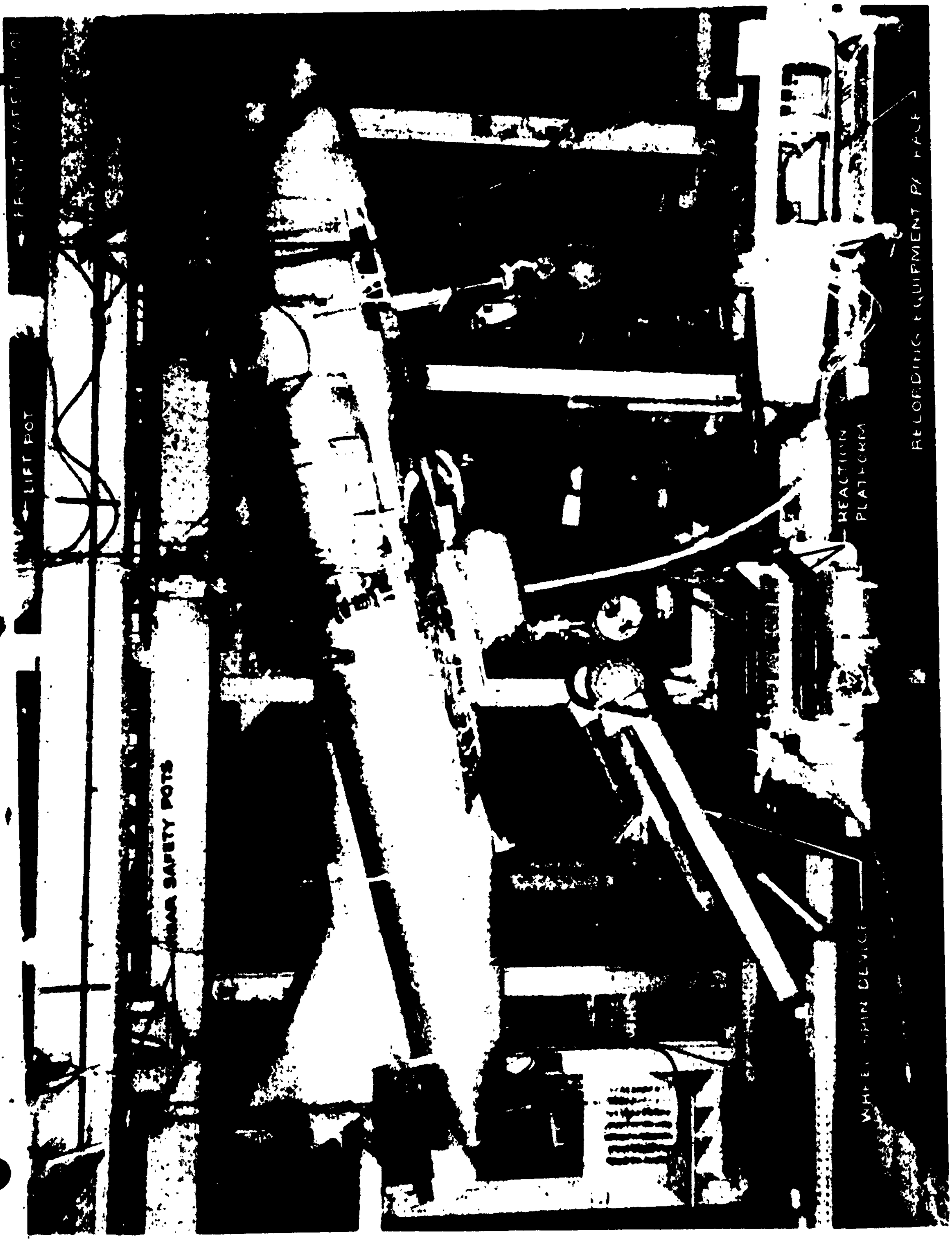


Figure 3. Drop Test Airplane in Pre-drop Position

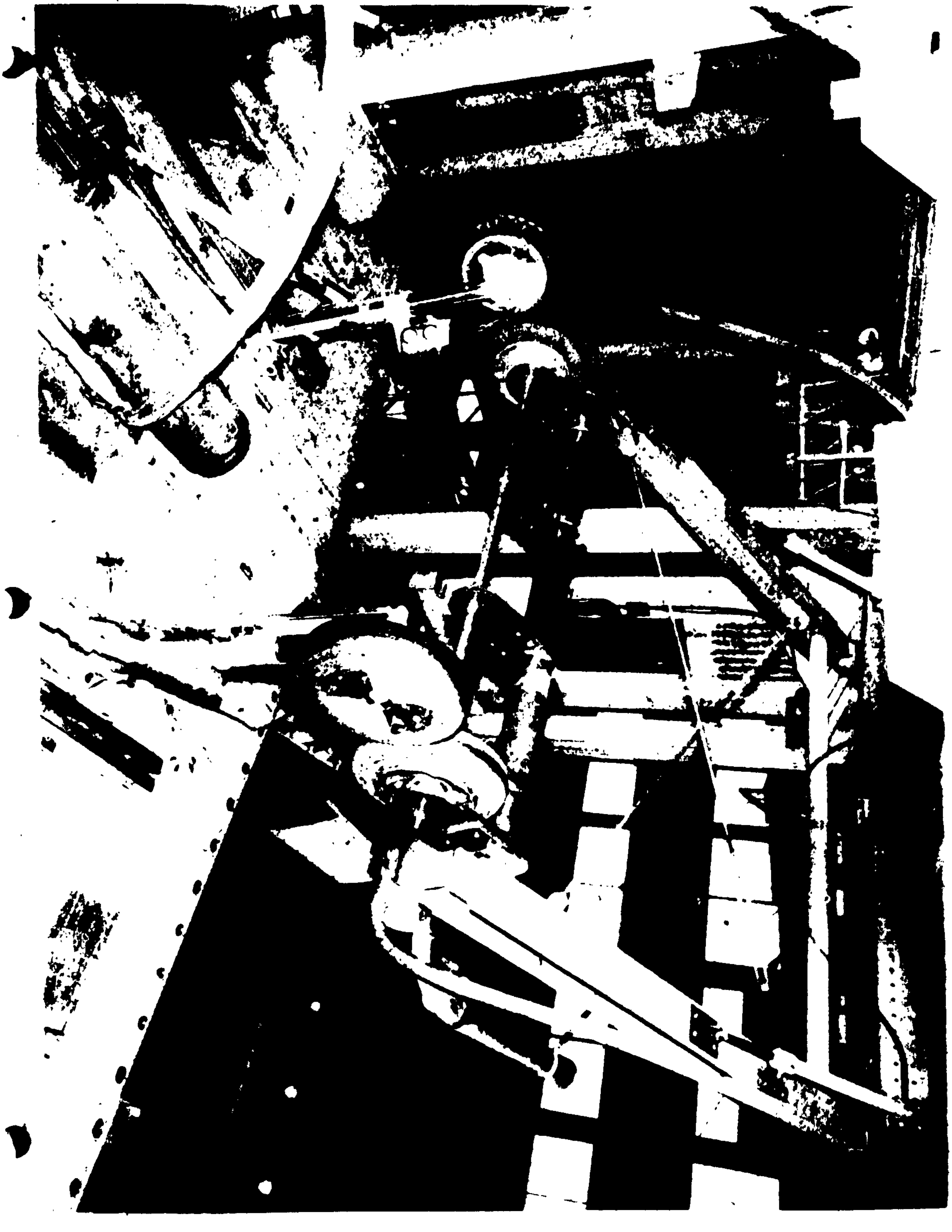
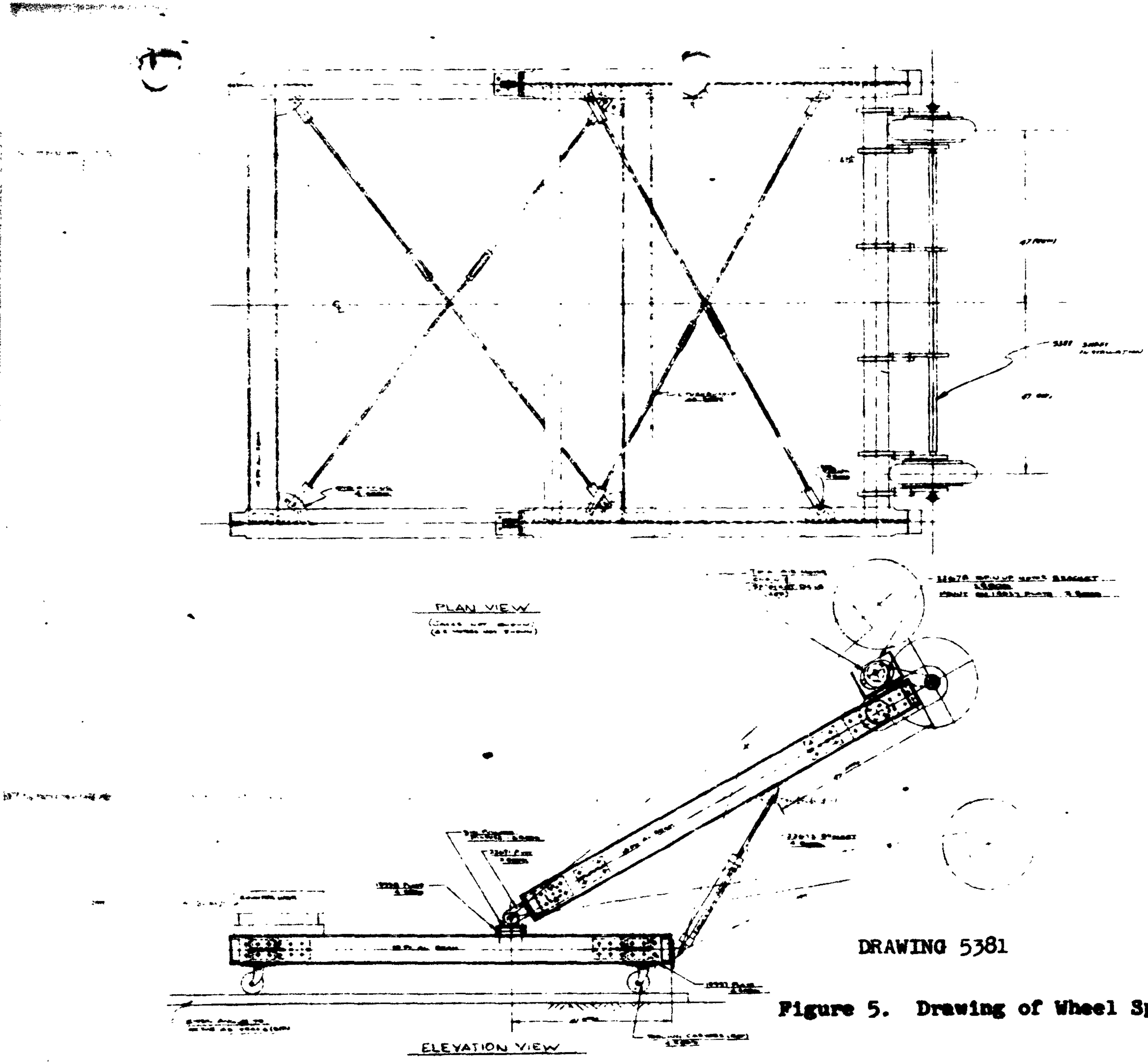


Figure 4. Wheel Spin-up Device



DRAWING 5381

Figure 5. Drawing of Wheel Spin-up Device

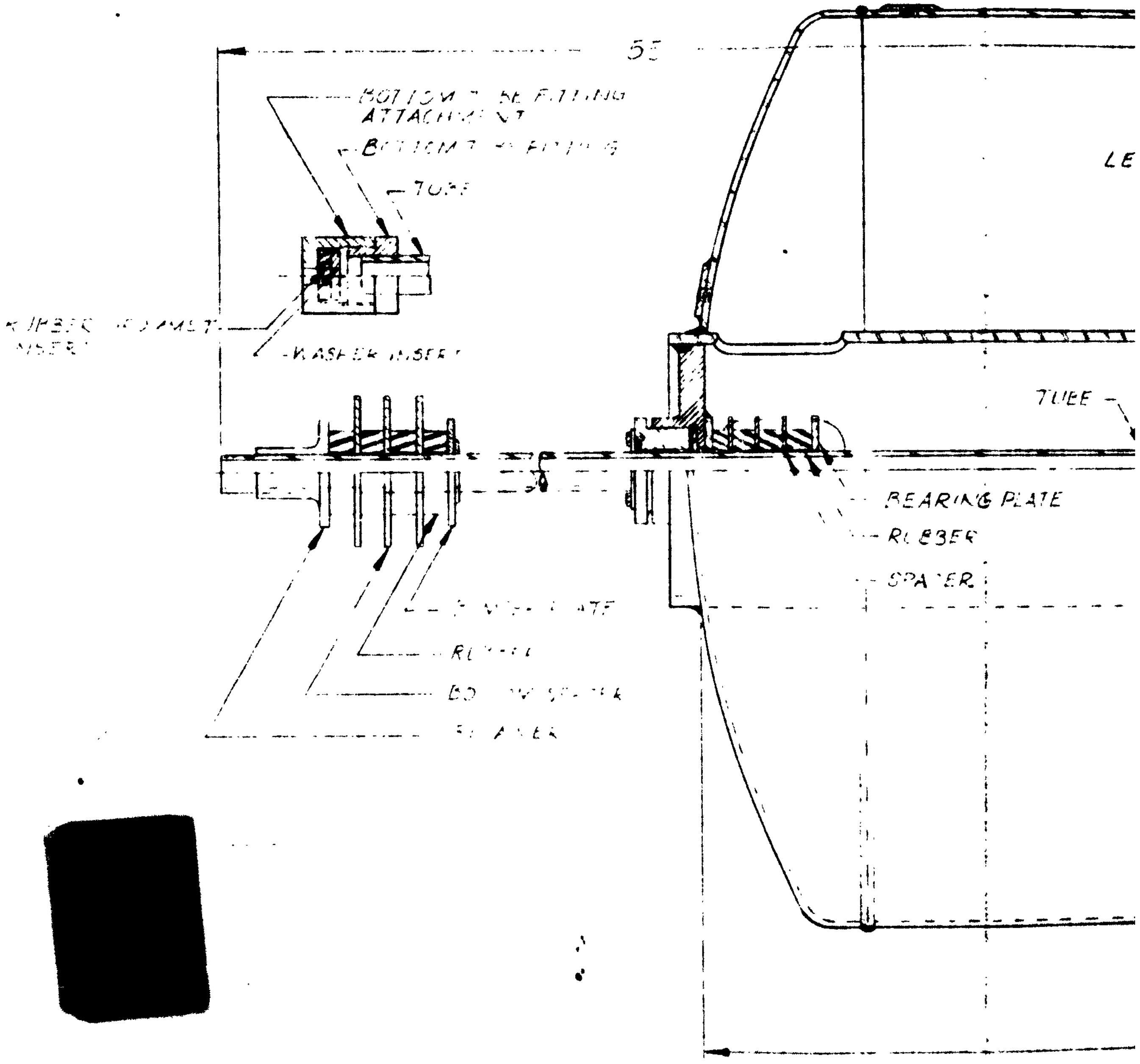


Figure 6. Wing Lift Damper

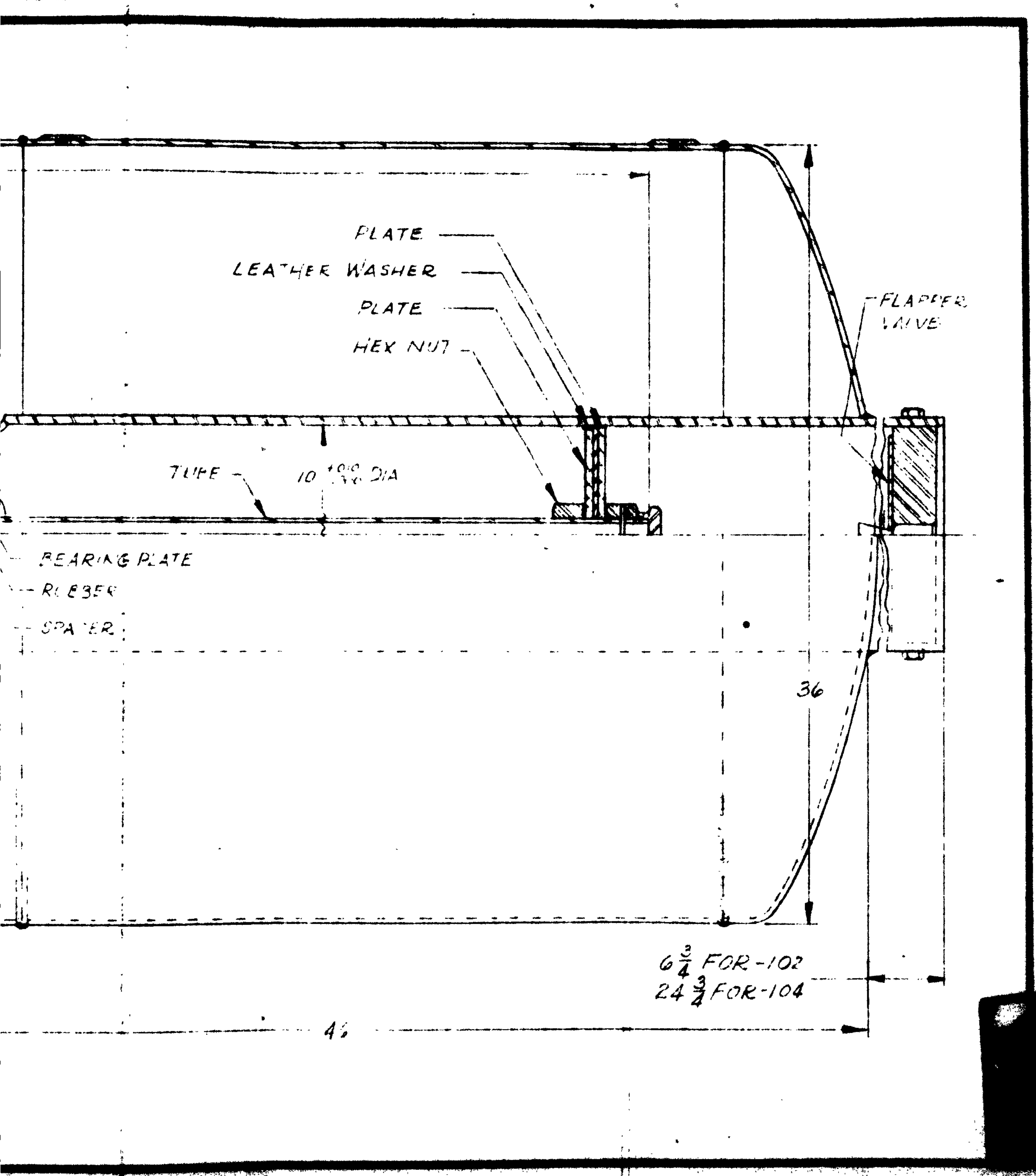


PLATE
LEATHER WASHER
PLATE
HEX NUT
BEARING PLATE
36
6 3/4 FOR -102
24 3/4 FOR -104

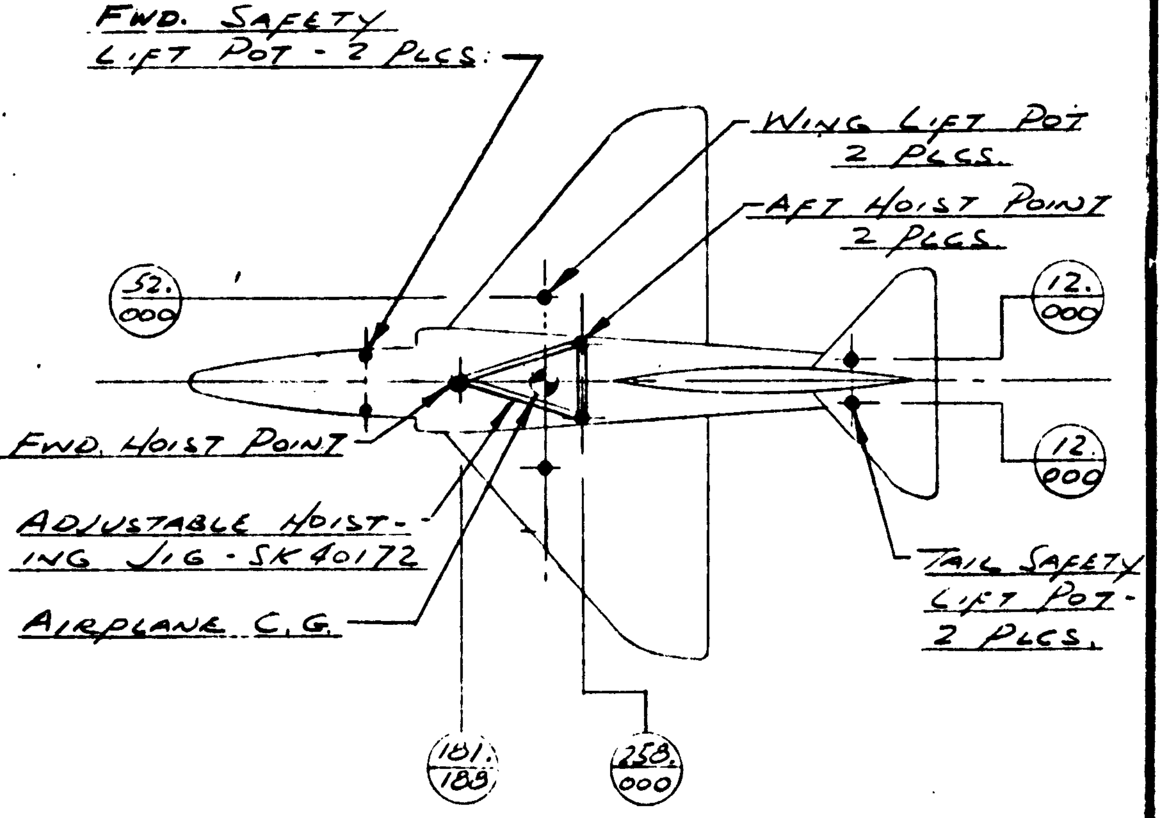
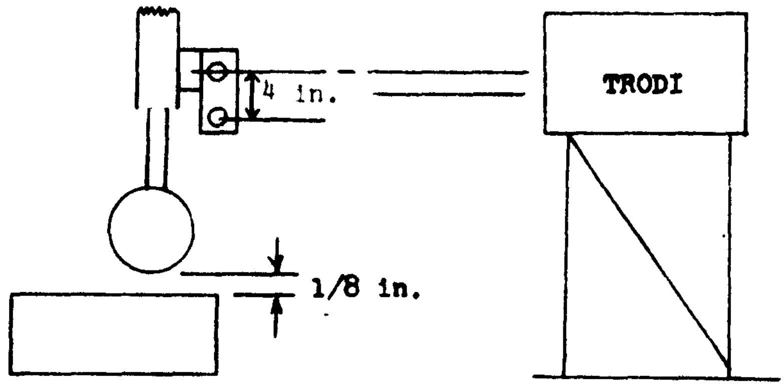


Figure 7. Test Set-up



Top beam cut 1/8 inch above platform.

Sink speed measured 2 1/8 inch above platform.

Figure 8. TRODI Installation

PROCEDURE

From a preliminary examination of the flight test data, several landings were chosen for duplication in drop tests. Numerous drops were made for the purpose of checking the instrumentation and to provide accurate duplication of the landings. A log of all drops is contained in Appendix A.

Table II provides a list of the initial conditions of all drops for which detailed data are presented herein and the initial conditions of those flight landings which will be compared with drop tests in the Summary Report (Reference 3). Not all drop tests were duplicated by landings because of the fact that after the drop tests were conducted, the data from some flight landings were found to be unacceptable.

The following paragraphs describe the methods of measuring the initial conditions and the estimated accuracy of the readings.

A. Weight and Weight Distribution.

Weight and C.G. position were determined by means of Cox and Stevens Electronic Weighing Units placed under the jacking points of the airplane. The accuracy of the weighing units is ±0.1% and their location was known within 0.2 inch. The maximum possible error on airplane weight is, therefore, ±13.5 lb. and on C.G. position 0.4 inch.

The moment of inertia of the airplane in pitch was determined by measuring the frequency of oscillation of the airplane when supported in the manner shown in Figure 10. The measurement was made for one distribution only, analytical corrections being made for other gross weights. Overall accuracy of ±2% is estimated for the moment of inertia.

TABLE II

INITIAL CONDITIONS

AIRPLANE DROPS AND CORRESPONDING FLIGHT TEST LANDINGS

Landing No.	Drop No.	Gross Weight lbs.	FRL Angle Degrees	Horiz. C.G. Position*	Wing Lift ÷ Weight	Sink Speed fps	Horizontal Speed Wheel RPM	Horizontal Speed Knots
121		12,876	13.0	232.9	1.10	13.2	1793	106.1
	84	12,876	13.4	232.9	1.055	13.9	1811(L) 1794(R)	
123		13,735	8.5	235.2	1.10	12.0	1930	113.9
	70	13,516	9.5	234.5	1.03	12.2	2097(L) 2089(R)	
125		13,446	9.5	234.3	1.07	15.0	1933	112.9
	68	13,446	8.8	234.3	1.07	15.0	1925(L) 1918(R)	
126		13,276	9.3	233.9	1.06	17.0	1933	110.6
	93	13,276	10.0	233.9	1.045	16.7	1936(L) 1912(R)	
128		12,775	10.5	232.7	1.00	14.7	1872	109.1
	82	12,876	6.0	232.9	1.05	16.2	2074(L) 2044(R)	
	75	13,226	5.4	233.7	1.015	17.0**	2062(L) 2048(R)	
	78	13,186	11.0	233.6	1.07	13.5**	1965(L) 1972(R)	
	88	12,776	21.1	232.7	1.04	12.3**	1801(L) 1784(R)	

* Refer to Figure 9 ** TRODI Readings (See Discussion p. 19)

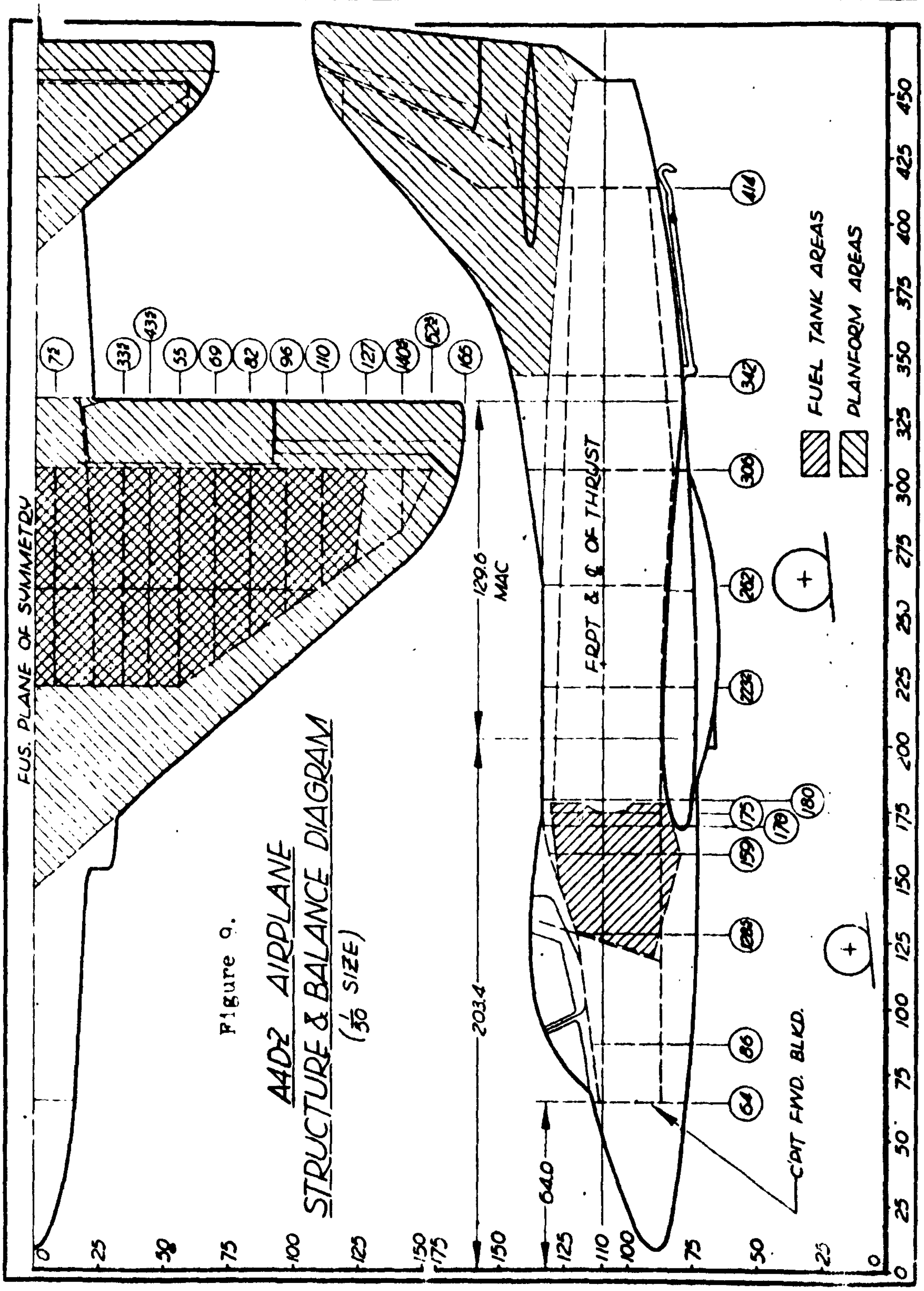


Figure 9.

A4D2 AIRPLANE
STRUCTURE & BALANCE DIAGRAM
(1/30 SIZE)

A4D-2 DROP TEST ARTICLE

MOMENT OF INERTIA

$$f = \frac{1}{2\pi}\sqrt{\frac{Ka^2 - Wc}{I + M(b^2 + c^2)}}$$

$$I = \frac{Ka^2 - Wc}{4\pi^2 f^2} - M(b^2 + c^2)$$

$K = 6400$ lbs/ft.

$a = (132.6/12)$ ft.

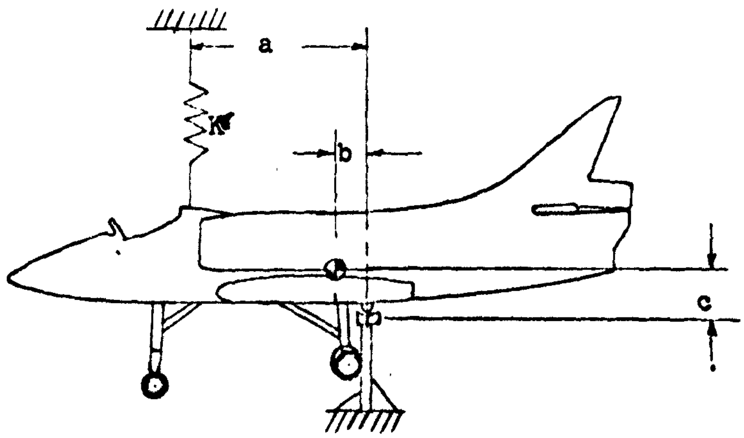
$W = 12770$ lbs. $= Mg$

$c = (17.3/12)$ ft.

$b = (28.1/12)$ ft.

$f = 0.88$ cps

$$I = 19328.2/f^2 - 2998.8 = 21960 \text{ slug ft}^2$$



Xcg = 0

Ycg = 232.5

Zcg = -16.0

Figure 10. Measurement of Moment of Inertia

B. Fuselage Reference Line Angle (♦)

The fuselage reference angle was measured prior to drop by a bubble protractor level. The pitch-roll gyro in the airplane (Item 20 Page 4) was set on this value, and the airplane attitude at the time of contact was determined from the oscillograph trace of this instrument. The angle listed in Table II is the angle at time of contact.

The protractor was placed on the airplane at the gun-sight level points which were manufactured parallel to the fuselage reference line within ±0.1 degree at the time the fuselage was in its tooling jig. Structural deflections caused by differences in method of support created a certain amount of change in the relative position of the level points and the fuselage reference line and, consequently, introduced an error in the value of ♦. Investigations of such deflections made for the purpose of calculating gun-sight errors lead to the conclusion that the error in this case is of the order of 0.1 degree. The combined error introduced by the protractor and gyro is also estimated at 0.1 degree, hence, the overall accuracy of the value of ♦ is estimated to be within ±0.2 degree.

Variation in pitch attitude was obtained by moving the hoist point fore and aft. Oscillations of the aircraft caused by wheel spin-up and airplane rotation after release caused lack of precise duplication of the landing attitude, however, analytical considerations indicated that accuracy greater than ±1.0 degree was unnecessary.

C. Wing Lift

Wing lift was determined from the instrumented links attaching the lift dampers to the airplane. Since fluctuations of the lift occurred during the stroke, the average values shown in Table II were computed from the oscillograph records. Lack of precise agreement between flight test and drop test values was caused by the fact that the average lift was approximated during drop tests and computed more accuratley later. The accuracy of the lift, as measured, was within ± 2%.

D. Sink Speed

Sink speed was measured during the tests by a TRODI instrument set-up as shown in Figure 8. Sinking speed was subsequently obtained for Drops 68, 70, 82, 84 and 93 by the following application of the classic equations of motion in which consideration was given to the effect of wing lift applied prior to the instant of ground contact:

$$V_v = g \cdot \bar{t} - \frac{g}{W} \int L \, dt$$

where $\bar{t}$ is the time from the instant of release to the instant of ground contact, L is the lift applied to the airplane through the lift pots and W is the gross weight of the airplane. A comparison of the TRODI readings with V_v obtained from solution of the above equation is of interest in the evaluation of the accuracy of the sinking speed measurement.

The variation of wing lift with time, as obtained from the oscillograph records, for the period before ground contact is shown in Figure 11. Integration of these curves provides the information for the second term of the right hand member of the above equation. The following table provides a comparison of sinking speeds obtained by the two methods.

Drop No.	$\bar{t}$	$g\bar{t}$	$\frac{g}{w}$ Ldt	V_v-fps (Computed)	V_v-fps (TRODI)
84	.460	14.8	.90	13.9	13.8
70	.419	13.5	1.34	12.2	12.0
68	.504	16.2	1.15	15.0	14.8
93	.551	17.7	.95	16.7	16.8
82	.540	17.4	1.20	16.2	15.8

TRODI readings agree with the calculated within ±0.2 fps with the exception of Drop 82. A notation on the log (Appendix A) for drops made on the same day as Drop 82 to the effect that the TRODI sensitivity was set too low leads to the conclusion that the computed value is more correct. In addition, the only experimental parameter in the computed value having a significant effect on the results if $\bar{t}$. A conservative estimate of the maximum error in $\bar{t}$ is ±.004 sec. which produces ±.13 fps error in sinking speed. In view of these factors, the computed sink speeds are used in preference to the TRODI readings for the drop tests which are to be compared with flight landings in subsequent investigations.

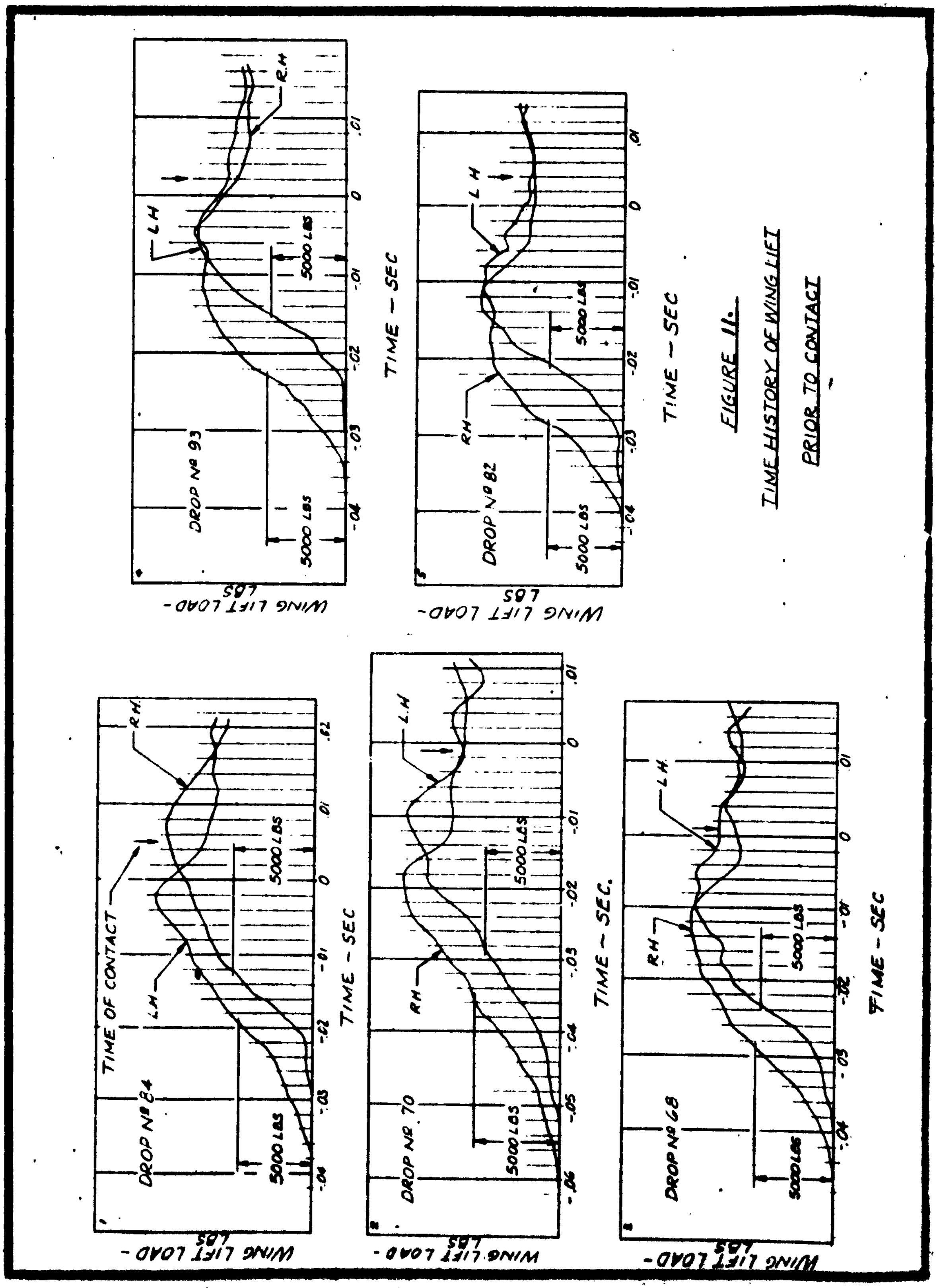


FIGURE 11.

TIME HISTORY OF WING LIFT PRIOR TO CONTACT

E. Horizontal Speed (Wheel Rotational Velocity)

The rotational velocity of the wheels of the drop test airplane and of the flight test airplane was measured by a magnetic pickup mounted on the brake assembly which was activated by steel studs fastened to the wheel at 10 degree intervals. As each stud passed the sensor, an electrical current was generated which was recorded on the oscillograph.

The relationship between wheel maximum rotational velocity and airplane forward velocity on the flight landings was a variable which depended upon the tire deflection at the time of spin-up. The procedure used in the drop tests was to match as closely as possible the maximum wheel RPM obtained in the flight landings. Since the relationship between RPM and airplane velocity is indefinite, no airplane speed is listed for the drop tests in Table II.

In drop tests the wheels were spun by the device described on Page 7 . After spin-up it was necessary for the spin-up apparatus to be moved and for the airplane to stop oscillating, during which time the wheel rotational velocity varied. It was necessary, therefore, to make allowance for this variation and, again, exact duplication of the flight condition was not possible.

The accuracy of the rotational speed measurement at these speeds was very good being limited only by the accuracy of the recording apparatus and the time signal. Without a detailed analysis it can be stated that the accuracy is well within ± 1 RPM. Accuracy of this device reduced as the speed reduced, hence, it was not possible to obtain a satisfactory reading as the rotational velocity approached zero or to determine accurately the time at which rotation stopped.

REDUCTION OF DATA

Figure 12 is a reproduction of the oscillograph records obtained during a typical drop test. In accordance with standard practice, each record was preceded by a calibration run in which zero's and the response of each channel to known voltages were obtained. Channel 22 on each oscillograph monitored the voltage of the power supply since this was not precisely constant throughout the run.

The oscillograph data, in terms of trace deflection from a reference line was read by a Benson-Lerhner "Oscar J" reader which provided punched cards for input to an IBM program for reduction of the data. The data were read at .001 sec. intervals.

The reduction equations were not identical for all channels. The channels and the equations used by the machine are identified in Table III and in the following paragraph:

When Flag 1 = 1 and Flag 3 = 0; $\frac{\delta}{\Delta} = \frac{\delta_1 - \Delta_o}{\Delta_1 - \Delta_o}$. (1)

When Flag 1 = 1 and Flag 3 = 1; $\frac{\delta}{\Delta} = \frac{\delta_1 - \delta_o}{\Delta_1 - \Delta_o}$. (2)

When Flag 1 = 0 and Flag 3 = 0; $\frac{\delta}{\Delta} = \frac{\delta_1 - \Delta_o}{\left(\frac{\delta}{\Delta}\right)_{22}(\Delta_1 - \Delta_o)}$ (3)

When Flag 1 = 0 and Flag 3 = 1 $\frac{\delta}{\Delta} = \frac{\delta_1 - \delta_o}{\left(\frac{\delta}{\Delta}\right)_{22}(\Delta_1 - \Delta_o)}$. (4)

Flags 2 and 4 control the equations to be used in converting δ/Δ to parameter value, "P".

When Flag 2 = 0,

$$P = \frac{\delta}{\Delta}\,(K+) \ . \qquad (5)$$

When Flag 2 = 1, $\frac{\delta}{\Delta}$ is minus, and the alternate constant is used:

$$P = \frac{\delta}{\Delta}(K-) \quad . \tag{6}$$

When Flag 4 = 1, an intercept constant is added. Then,

$$P = I + \frac{\delta}{\Delta}(K) \tag{7}$$

Table III provides the calibration constants, K, and the flag information pertaining to each channel. The intercept, I, applies to pressures only and is equal to the strut initial absolute pressure with strut extended (14.7 + 25.0 = 39.7 psi).

Additional operations were required on certain parameters to present information in a preferred form. Thus, the axle strain gauge readings, channels 10 and 14, were converted to strut axial and normal force, after which strut axial and normal force combined with the axle accelerations were converted to loads at the ground. Also, the instantaneous, coefficient of friction was computed as well as the average coefficient. The equations applicable to these operations are as follows:

A. Axle readings to strut load*

L.H. Gear (Osc 1)

$$FA = (43{,}574-142.1P_6)P_{10} + (-223.8-66.7P_6)P_{13} \tag{8}$$

$$FN = (983.3-99.1P_6)P_{10} + (4575.0-5.0P_6)P_{13} \tag{9}$$

R.H. Gear (Osc 2)

$$FA = (56{,}995+337.2P_6)P_{10} + (1200-101.1P_6)P_{13} \tag{10}$$

$$FN = (4800-145.3P_6)P_{10} + (8{,}455.8 + 30.8P_6)P_{13} \tag{11}$$

* The equations are derived in reference (1).

B. Strut loads to ground loads

$$FVG = (FA + FAA)\cos(\phi-6) - (FN + FAN)\sin(\phi-6) \qquad (12)$$

$$FHG = (FN + FAN)\cos(\phi-6) + (FA + FAA)\sin(\phi-6) \qquad (13)$$

C. Coefficient of friction

$$MUA_1 = \frac{FHG}{FVG} \qquad (14)$$

$$\text{Average } MUA = \sum \left[\frac{1}{2}(MUA_{1-1} + MUA_1)\right] \frac{\Delta\ TIME}{\sum \Delta\ TIME} \qquad (15)$$

The reduced data were printed numerically and plotted mechanically.

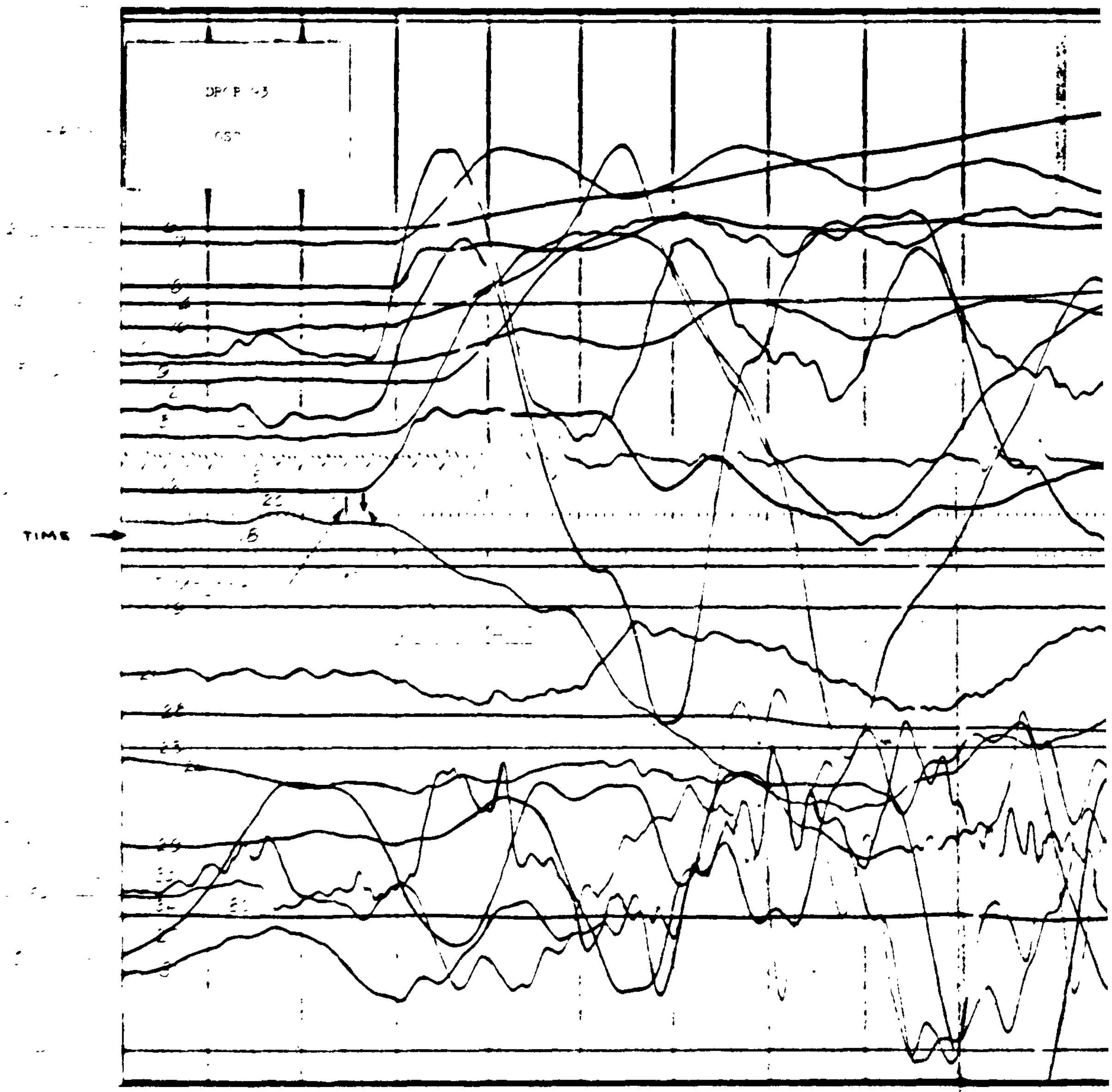
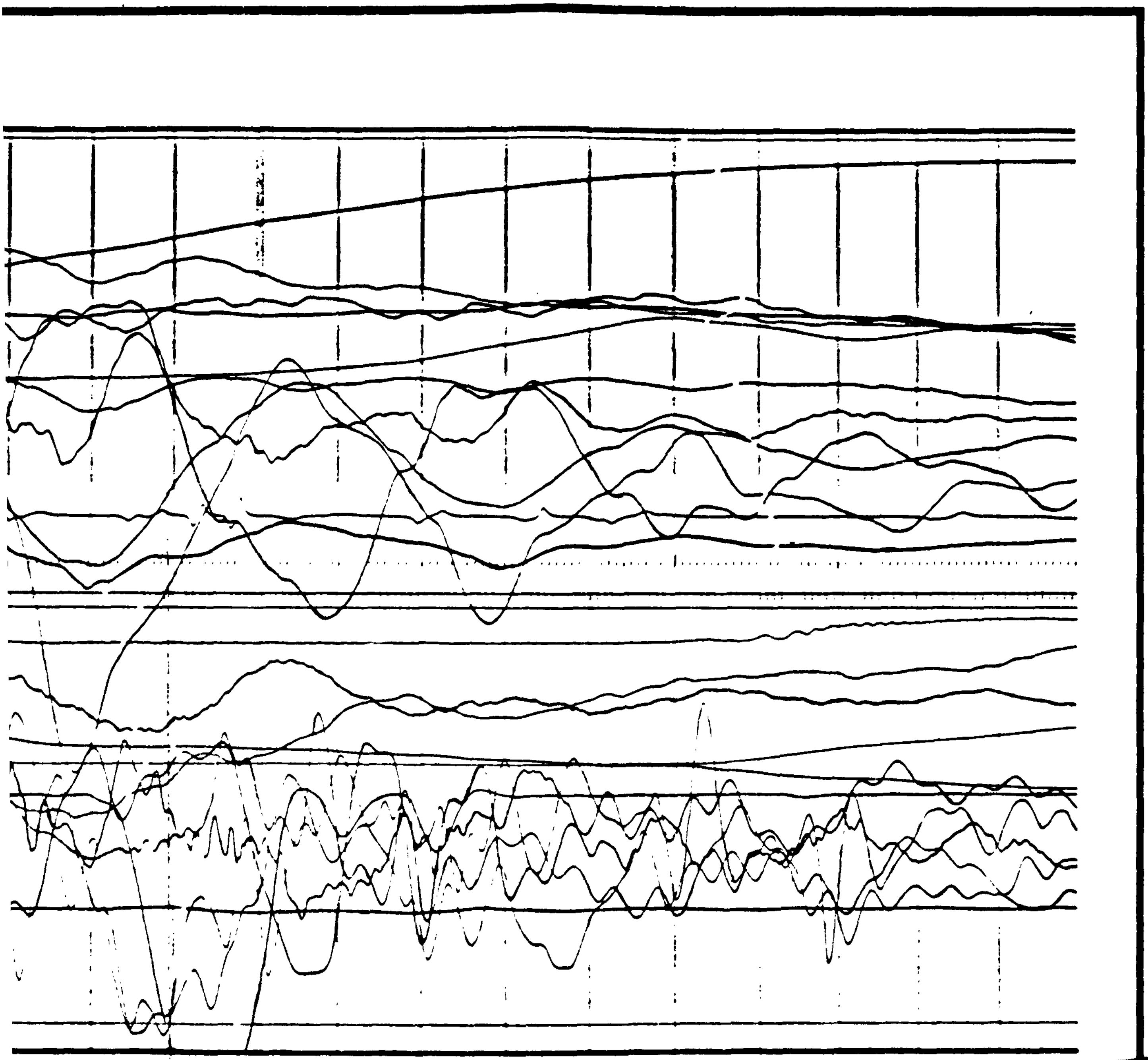


Figure 12. Reproduction of Typical Oscillograph Record

26

L: A4D-2

RT NO. ES 40641



rd

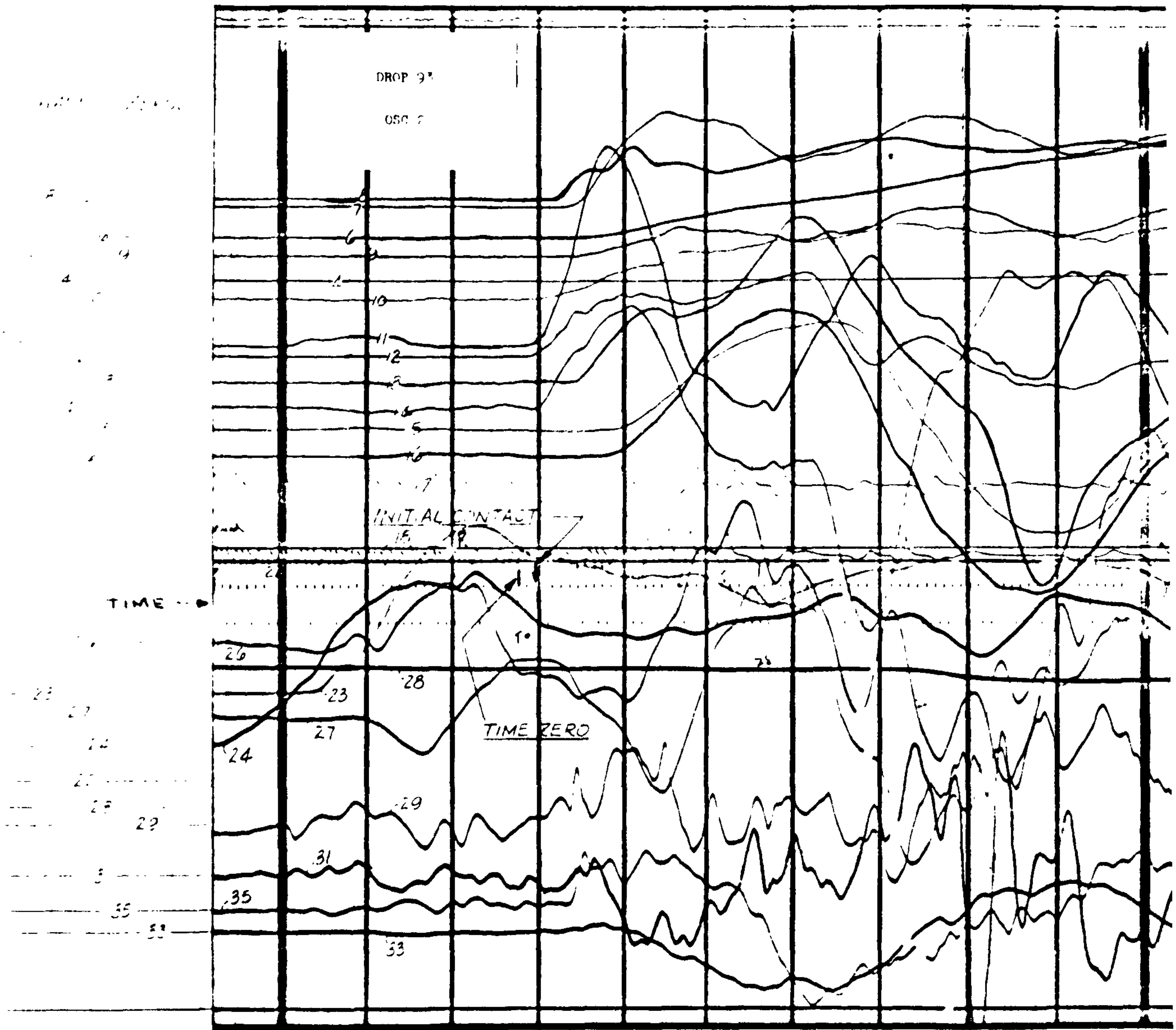


Figure 12. (Cont'd.)

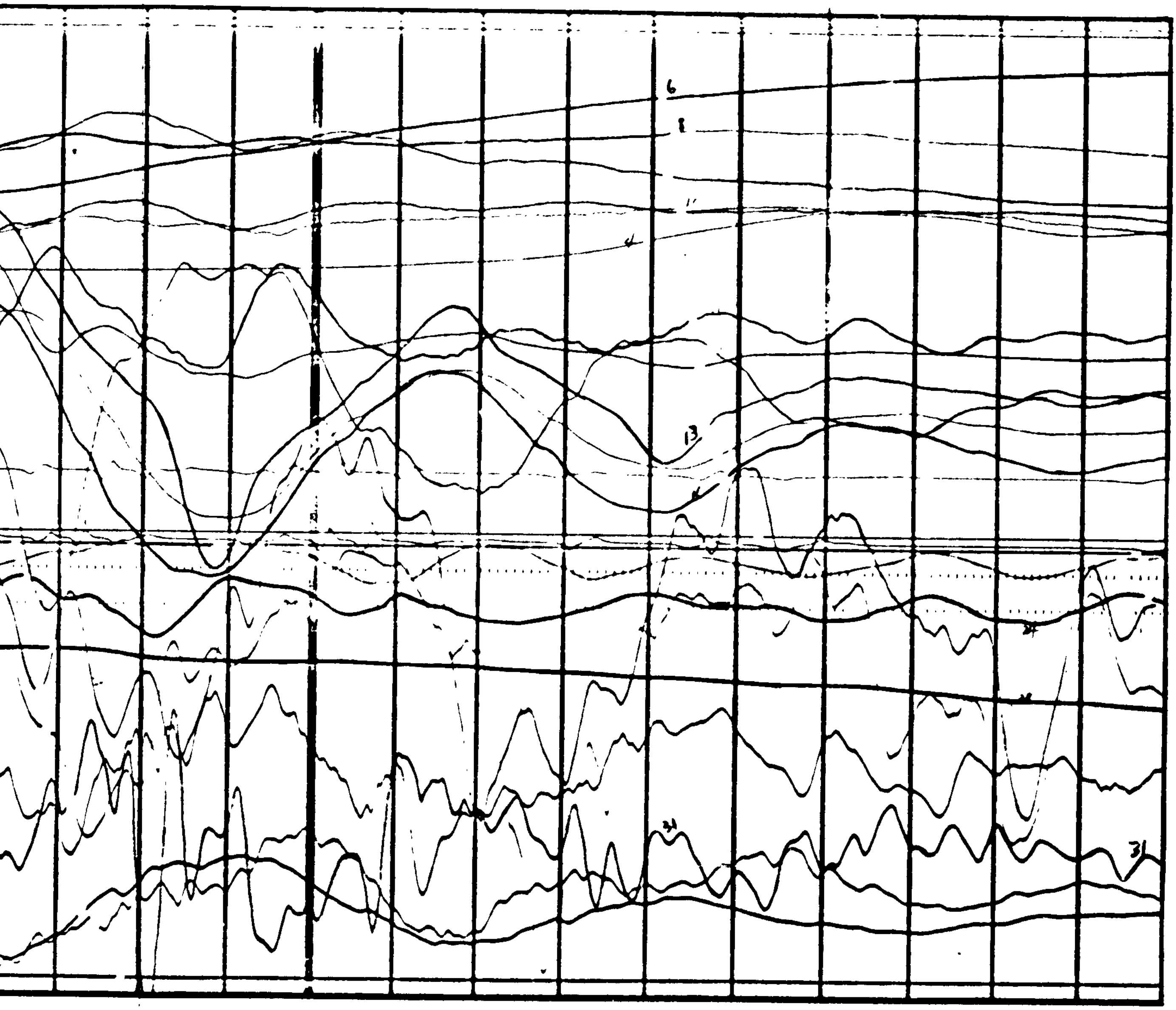

6
8
13
31
31

TABLE III. OSCILLOGRAPH TRACE IDENTIFICATION AND CALIBRATION CONSTANTS.

OSCILLOGRAPH NUMBER 1

CHANNEL NO.	TITLE	CONST. (K+)	CONST. (K-)	FLAG 1	FLAG 2	FLAG 3	FLAG 4
4.	L. H. STRUT AIR PRESSURE, P.S.I.	3942.0000	0.	0.	0.	1.	1.
6.	L.H.STRUT POSITION, INCHES	16.0040	0.	1.	0.	1.	0.
7.	L.H.STRUT VELOCITY, F.P.S.	21.7300	0.	1.	0.	1.	0.
8.	L.H.VERTICAL PLATFORM, LBS.	48450.0000	0.	1.	0.	1.	0.
9.	L.H.STRUT METERING PRESSURE, P.S.I.	4406.0000	0.	1.	0.	1.	1.
10.	L.H.AXLE STRAIN GAGE 1, VERTICAL	0.9947	0.	0.	0.	1.	0.
11.	L.H.AXLE VERTICAL ACCELERATION, G S	51.2398	0.	0.	0.	1.	0.
12.	L.H.DRAG BRACE, LBS.	56970.0000	56777.0000	0.	1.	1.	0.
13.	L.H.AXLE DRAG ACCELERATION, G S	52.3510	0.	0.	0.	1.	0.
14.	L.H.AXLE STRAIN GAGE 3, DRAG	1.0107	0.	0.	0.	1.	0.
16.	L.H.DRAG PLATFORM, LBS.	11644.0000	0.	1.	0.	1.	0.
19.	L.H.REBOUND CHAMBER PRESSURE	5640.0000	0.	1.	0.	1.	1.
21.	L.H.AXLE LATERAL ACCELERATION, G S	49.9610	0.	0.	0.	1.	0.
22.	VOLTAGE MONITOR	1.0000	0.	1.	0.	0.	0.
23.	NOSE GEAR STRUT POSITION, INCHES	16.0060	0.	1.	0.	1.	0.
24.	NOSE GEAR UPPER MASS VERT.ACC., G S	-11.4840	0.	0.	0.	1.	0.
20.	STRUT SIDE BENDING STRAIN GAGE	0.9980	0.	0.	0.	1.	0.
27.	C.G.NORMAL ACCELERATION 1, G S	0.6117	0.	0.	0.	1.	0.
28.	FRL PITCH ATTITUDE, DEGREES	3.5950	0.	0.	0.	0.	0.
29.	C.G.LONGITUDINAL ACCELERATION, G S	0.5488	0.	0.	0.	1.	0.
30.	A/C ROLL ATTITUDE, DEGREES	11.0950	0.	0.	0.	0.	0.
31.	C.G.NORMAL ACCELERATION 10, G S	7.8645	0.	0.	0.	1.	0.
33.	L.H.GEAR UPPER MASS VERT.ACC., G S	18.5320	0.	0.	0.	1.	0.
34.	L.H.GEAR UPPER MASS LONG.ACC., G S	11.8390	0.	0.	0.	1.	0.

OSCILLOGRAPH NUMBER 2

CHANNEL NO.	TITLE	CONST. (K+)	CONST. (K-)	FLAG 1	FLAG 2	FLAG 3	FLAG 4
4.	R.H.STRUT AIR PRESSURE, P.S.I.	3850.0000	0.	0.	0.	1.	1.
6.	R.H.STRUT POSITION, INCHES	16.0000	0.	1.	0.	1.	0.
7.	R.H.STRUT VELOCITY, F.P.S.	21.3400	0.	1.	0.	1.	0.
8.	R.H.VERTICAL PLATFORM, LBS.	47650.0000	0.	1.	0.	1.	0.
9.	R.H.STRUT METERING PRESSURE, P.S.I.	5290.0000	0.	1.	0.	1.	1.
10.	R.H.AXLE STRAIN GAGE 4 VERTICAL	1.0040	0.	0.	0.	1.	0.
11.	R.H.AXLE VERTICAL ACCELERATION, G S	53.6280	0.	0.	0.	1.	0.
12.	R.H.DRAG PLATFORM, LBS.	11411.7999	0.	1.	0.	1.	0.
13.	R.H.AXLE STRAIN GAGE 5 DRAG	1.0000	0.	0.	0.	1.	0.
14.	R.H.AXLE DRAG ACCELERATION, G S	67.2030	0.	0.	0.	1.	0.
15.	R.H. DRAG BRACE, LBS.	57626.0000	57638.0000	0.	1.	1.	0.
16.	L.H. DRAG BRACE, LBS.	57243.0000	56775.0000	0.	1.	1.	0.
22.	VOLTAGE MONITOR	1.0000	0.	1.	0.	0.	0.
23.	L.H.WING LIFT, LBS.	5044.0000	0.	0.	0.	1.	0.
24.	R.H.WING LIFT, LBS.	5123.0000	0.	0.	0.	1.	0.
26.	R.H.WING TIP ACCELEROMETER, G S	38.0670	0.	0.	0.	1.	0.
27.	L.H.WING TIP ACCELEROMETER, G S	37.4680	0.	0.	0.	1.	0.
28.	FRL PITCH ATTITUDE, DEGREES	3.5340	0.	0.	0.	0.	0.
29.	R.H.GEAR UPPER MASS VERT.ACC., G S	19.4330	0.	0.	0.	1.	0.
31.	R.H.GEAR UPPER MASS LONG.ACC., G S	12.0950	0.	0.	0.	1.	0.
33.	R.H.AXLE STRAIN GAGE 3 SIDE	1.0033	0.	0.	0.	1.	0.
35.	R.H.AXLE LATERAL ACCELERATION, G S	-39.7000	0.	0.	0.	1.	0.

RESULTS

The results of the drop tests are presented on pages 38 to 61 in the form of curves showing the variation of parameter versus time. Wherever right and left hand readings are available, the cruves are drawn so as to present a comparison of left and right parameters. The accuracy of the data is estimated in Reference (1). A summary of these estimates is included herein as Table IV for convenience. The response characteristics of each channel are described in Table V. Since the records were read at .001 second intervals and in most cases plotted at .002 second intervals, the accuracy of the plotted results with respect to frequency response will be limited in some instances by the number of points per cycle.

The comments which follow are made in the order that data appears on Pages 38 to 40.

1. C.G. Accelerations

   The normal acceleration (10 g's) trace is the most significant and useful. Both the normal accelerometer (1g) and the longitudinal accelerometer had maximum ranges of approximately ± 1.5g and higher accelerations were not recorded. The 1g normal accelerometer was used during flight tests to measure wing lift.

2. Nose and Main Gear Strut Position

   This is the reading from the slide-wire instrumentation. Left and right gear positions are consistent. These data are compared to the strut position determined from integrating the strut velocity under Item 14 and comment on the accuracy of this measurement is included therein.

3. Main Gear Side Bending Gauge

   No calibration was obtained for this portion of the instrumentation in terms of the basic ground loads, hence these data are not useful except as a qualitative indication of the variation of bending stress in the gear at the point of attachment of the gauges.

4. Main Gear Drag Gauge

This is the gauge on the axle responding primarily to fore and aft force at the ground. The readings presented here were used in conjunction with the vertical strain gauge reading to give the ground loads presented on Pages 69 to 84. Differences in magnitude of the trace displacement between right and left gears is compensated for by different calibration constants (see Table III). The first .08 second of this record is of greatest importance in this investigation since it includes the spin-up and spring back phenomena of interest to designers.

5. Pitch and Roll Attitude

The attitude readings were derived from the pitch-roll gyro. Pitch attitude at time zero provides the initial condition for Table II and the subsequent values were used as θ in the expressions for FVG and FHG in Equations (12) and (13) to determine the ground loads plotted on Pages 69 to 84. The roll attitude readings substantiate the fact that the drops were essentially symmetrical. Maximum readings of 1/2 degree were registered.

6. Main Gear Vertical Gauge

This gauge, mounted on the axle, responded primarily to vertical load and the reading was used in conjunction with the main gear drag gauge to obtain the ground loads plotted on Pages 69 to 84. The ground loads are one of the most important parameters in this investigation. Their accuracy and reliability are discussed in detail on Pages 63 to 68.

7. Wing Tip Acceleration

The consistency between right and left accelerations creates confidence in these readings. Certain differences can be expected, especially in the initial accelerations because of the slight time differential in the application of the wing lift loads (Figure 11).

8. Nose Gear Vertical Acceleration

With the exception of Drops 82 and 93, the nose gear vertical accelerations are those induced by main gear loads. In Drops 82 and 93 the nose gear touched down before the main gear load history was complete and additional accelerations were produced by the nose gear load.

9. Right and Left Upper Mass Accelerations

Certain of these records show inconsistencies between right and left gear both in the magnitude and phasing. Where such is the case, it is recommended that the results be used with caution, since no reason has been established for this lack of symmetry.

10. Right and Left Lower Mass Accelerations

The vertical and drag acceleration data are used in the determination of the ground loads and consequently are of primary interest. Detailed examination and extensive usage of these data has established a high confidence in their accuracy. The side accelerations have not been used as extensively, but because of the similarity of sensing and recording units, the reliability of these curves is also considered to be good.

11. Wing Lift

These curves show the extent to which a constant lift was maintained during the stroke. Variations of + 10% from the mean are noted with the larger variation occurring generally in the first part of the stroke. Inasmuch as the lift dampers may have individual characteristics and are not applied exactly simultaneously, consistency of phase relationship between right and left lift curves is not expected. Also, during the drop the wing will be vibrating because of the impulse introduced at the instant of release, and the lift damper will connect at difference times in the wing's deflection cycle. Hence, precise consistency between drops cannot be expected. The average values of lift determined from these data were used for comparison with the flight test landing lift (Table II). It is believed that these records present an accurate description of the loads applied to the airplane by the lift dampers, and the data can be used with confidence.

12. Drag Brace Axial Load

Good consistency between right and left drag braces is noted for all records except Drop 70. The differences noted in the Drop 70 record are consistent with a similar departure from symmetry between right and left axle drag acceleration (Item 10) and metering chamber pressure (Item 15). These phenomena may be associated with roll of the airplane since Drop 70 has the largest initial angle of roll.

13. Pressure Readings

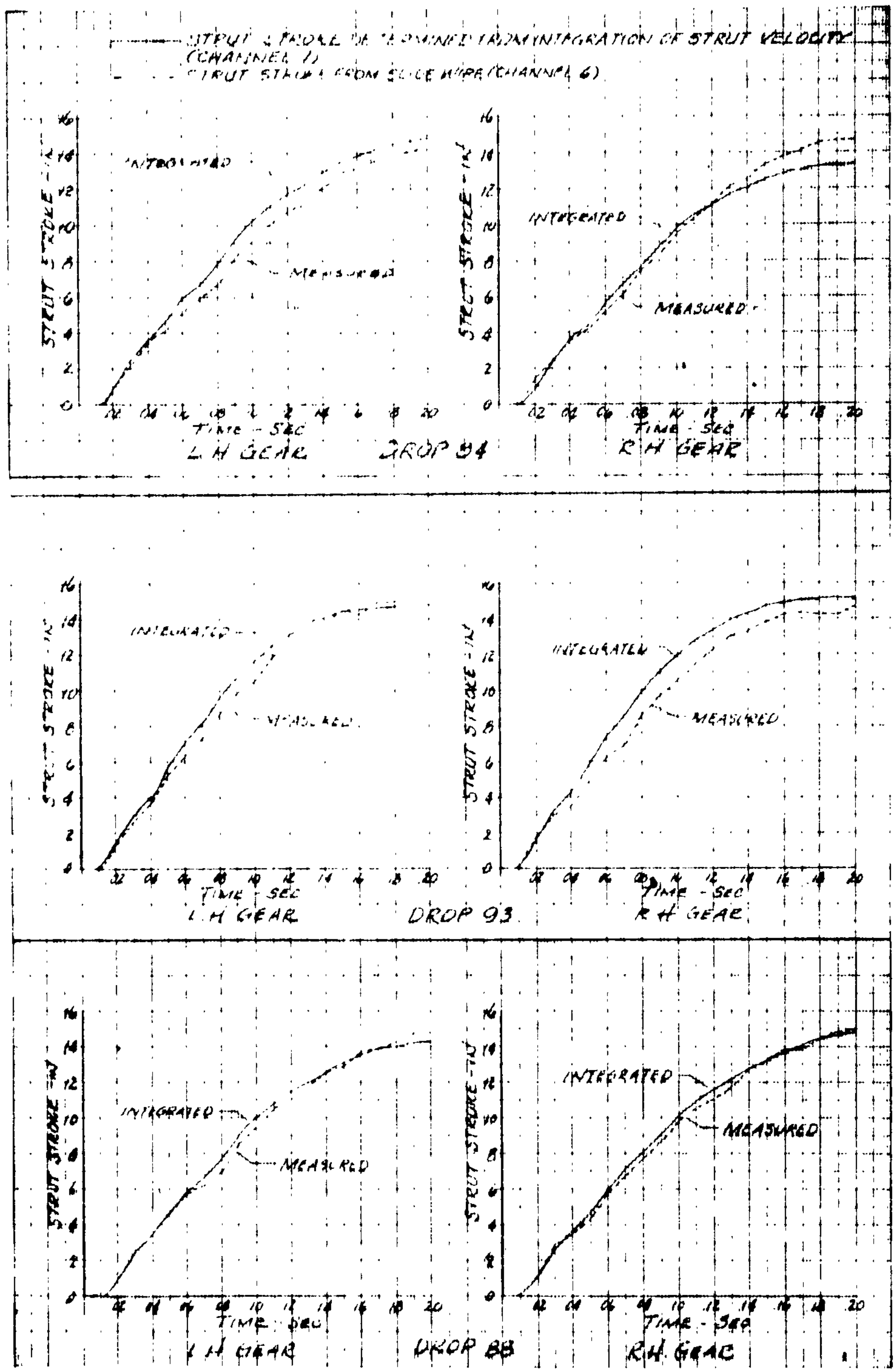
Good consistency is noted between right and left gear readings both as to magnitude and phasing again with the exception of Drop 70. Because of the fact that non-symmetry of data in Drop 70 is registered on several channels, it is considered a real phenomenon, and the reliability of the records is strengthened rather than reduced by the noted differences between right and left readings.

The rebound chamber pressure was measured only on the left gear and only in drop tests. This instrumentation was added as a result of the analytical study which showed that the rebound chamber pressure had a pronounced effect on the gear operation during the compression stroke.

14. Strut Velocity

As indicated in Table I, strut velocity was measured by a Sanborn velocity generator. The accuracy of this instrument has been estimated at ± 4% (Table IV). The resulting data appears consistent within itself and in comparison to the opposite side. A comparison was made for three cases of the integrated velocity and the stroke (Item 2 above) with the results shown in Figure 13. The agreement between slide-wire reading and integrated velocity reading is substantially less than the accuracy of each instrument since at certain times a difference of stroke of 1 1/2 inches is noted. In an effort to establish which of the readings is more reliable, a comparison was made with the analytical, or computed, stroke (see Figure 14). Slightly better correlation is noted for the integrated stroke. It is of interest to note that both the theory and the integrated stroke are high with respect to the slide wire reading in the middle time range.

There is insufficient evidence to establish which of the two measured values is more correct, however, the comparisons presented here cast some doubt on the accuracy of the slide wire. Further work needs to be done to clarify this point.


INTEGRATED
MEASURED
STRUT STROKE - IN
TIME - SEC
L.H GEAR
DROP 94
R.H GEAR
DROP 93
DROP 88

13.

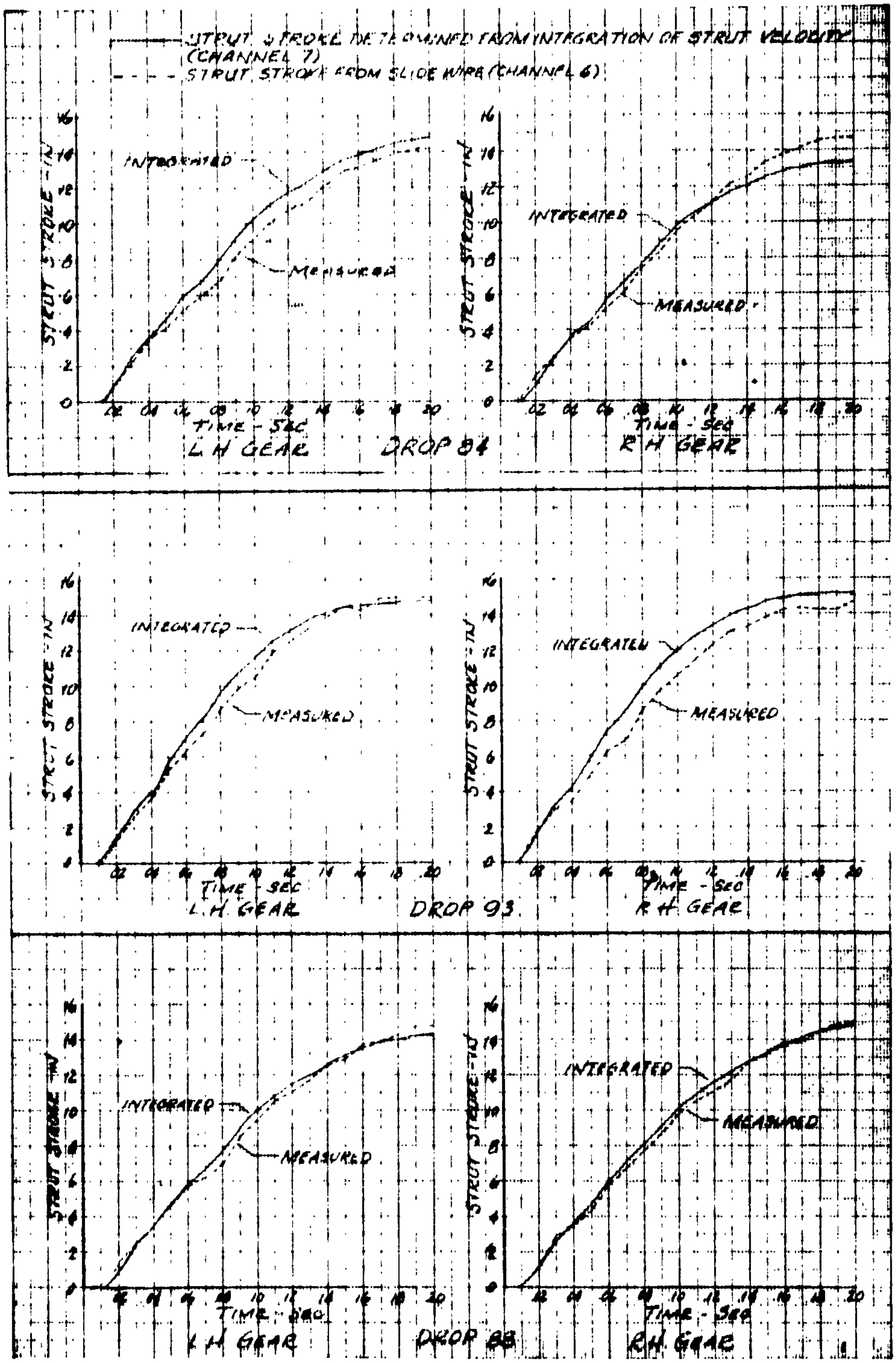


FIGURE 13. COMPARISON OF STRUT STROKE [illegible] VERSUS TIME AS DETERMINED FROM THE SLIDE WIRE AND THE VELOCITY GENERATOR.

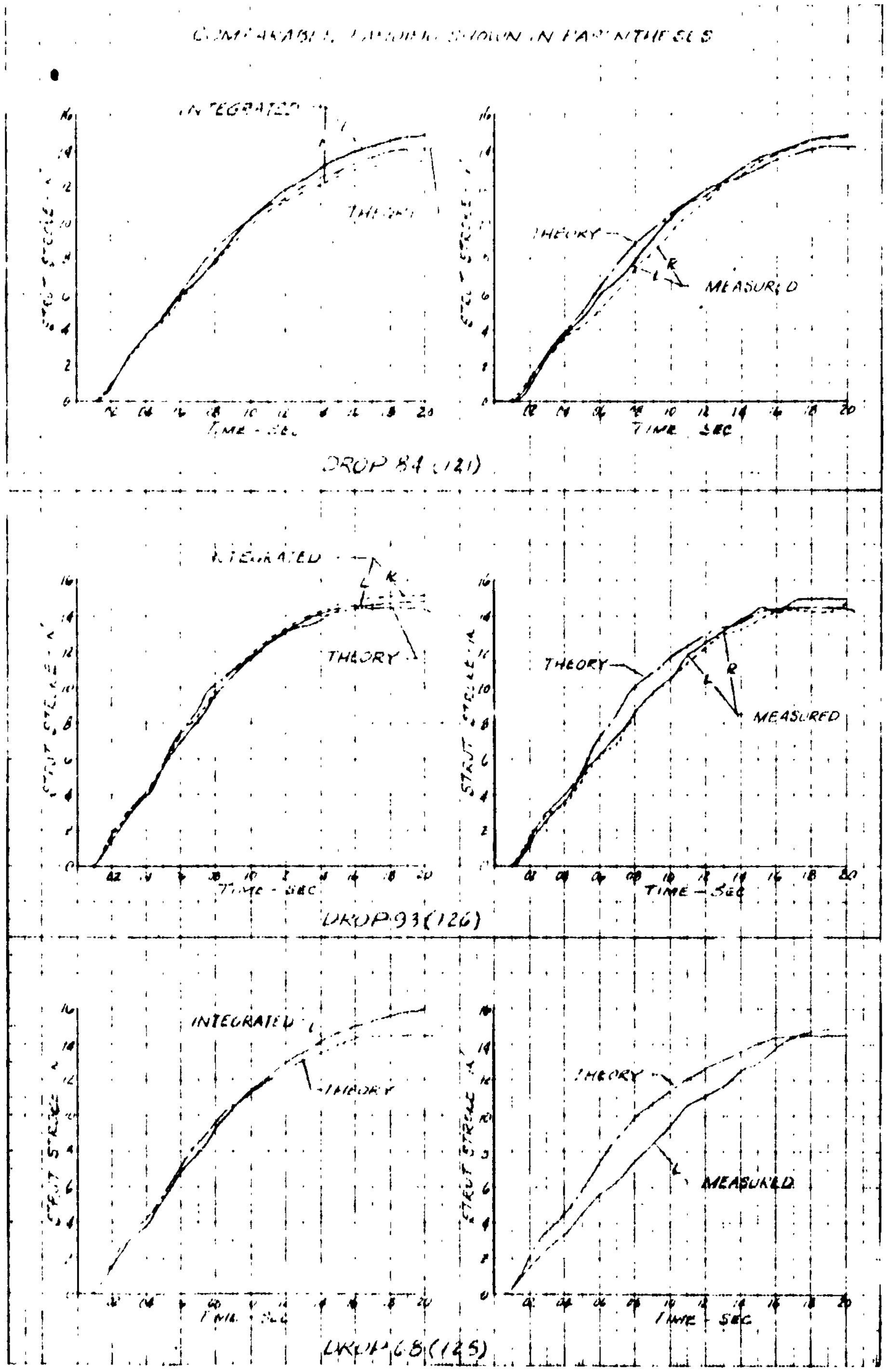


FIGURE 14. COMPARISON OF COMPUTED STROKE CURVES WITH THOSE OBTAINED FROM THE VELOCITY GENERATOR AND SLIDE WIRE

TABLE IV
ESTIMATED OVERALL RECORDED PARAMETER ACCURACY

PARAMETER	ACCURACY ± %
R.H. Gear Vertical Load	3
R.H. Gear Drag Load	3
L.H. Gear Vertical Load	3
L.H. Gear Drag Load	3
L.H. Gear Lower Mass Vertical Acceleration	2
L.H. Gear Lower Mass Drag Acceleration	2
L.H. Gear Lower Mass Lateral Acceleration	2
R.H. Gear Lower Mass Vertical Acceleration	2
R.H. Gear Lower Mass Drag Acceleration	2
R.H. Gear Lower Mass Lateral Acceleration	2
R.H. Gear Upper Mass Vertical Acceleration	2
R.H. Gear Upper Mass Longitudinal Acceleration	2
L.H. Gear Upper Mass Vertical Acceleration	2
L.H. Gear Upper Mass Longitudinal Acceleration	2
R.H. Gear Strut Position	3
L.H. Gear Strut Position	3
R.H. Gear Strut Velocity	4
L.H. Gear Strut Velocity	4
R.H. Gear Metering Chamber Pressure	3
L.H. Gear Metering Chamber Pressure	3
L.H. Gear Shock Strut Rebound Chamber Pressure	2
R.H. Gear Strut Air Pressure	3
L.H. Gear Strut Air Pressure	3
R.H. Gear Drag Brace Load	2
L.H. Gear Drag Brace Load	2
Nose Gear Strut Position	3
Nose Gear Upper Mass Vertical Acceleration	2
C.G. Normal Acceleration (Low Range)	2
C.G. Normal Acceleration (High Range)	2
C.G. Longitudinal Acceleration	2
Aircraft Pitch Attitude	3
Aircraft Roll Attitude	3
R.H. Wing Tip Vertical Acceleration	2
L.H. Wing Tip Vertical Acceleration	2
R.H. Gear Reaction Platform Vertical Load	2
R.H. Gear Reaction Platform Drag Load	8
L.H. Gear Reaction Platform Vertical Load	2
L.H. Gear Reaction Platform Drag Load	8
Nose Gear Reaction Platform Vertical Load	2
R.H. Wing Lift Link Load	2
L.H. Wing Lift Link Load	2
Timing Clock	0.1

TABLE V
FREQUENCY RESPONSE CHARACTERISTICS OF RECORDED PARAMETERS

PARAMETER	FLAT RESPONSE-CPS ±2%	±5%
R.H. Gear Vertical Load	115	135
R.H. Gear Drag Load	55	95
R.H. Gear Side Bending Moment	90	180
L.H. Gear Vertical Load	65	195
L.H. Gear Drag Load	50	100
L.H. Gear Side Bending Moment	65	190
L.H. Gear Lower Mass Vertical Acceleration	60	180
L.H. Gear Lower Mass Drag Acceleration	135	150
L.H. Gear Lower Mass Lateral Acceleration	155	175
R.H. Gear Lower Mass Vertical Acceleration	110	130
R.H. Gear Lower Mass Drag Acceleration	45	75
R.H. Gear Lower Mass Lateral Acceleration	40	60
R.H. Gear Upper Mass Vertical Acceleration	50	85
R.H. Gear Upper Mass Longitudinal Acceleration	105	130
L.H. Gear Upper Mass Vertical Acceleration	50	85
L.H. Gear Upper Mass Longitudinal Acceleration	60	90
R.H. Gear Strut Position	65	110
L.H. Gear Strut Position	55	90
R.H. Gear Strut Velocity	45	70
L.H. Gear Strut Velocity	50	90
R.H. Gear Metering Chamber Pressure	70	180
L.H. Gear Metering Chamber Pressure	60	185
L.H. Gear Strut Rebound Chamber Pressure	55	185
R.H. Gear Strut Air Pressure	15	40
L.H. Gear Strut Air Pressure	15	40
R.H. Gear Drag Brace Load	60	100
L.H. Gear Drag Brace Load	50	80
Nose Gear Strut Position	80	135
Nose Gear Upper Mass Vertical Acceleration	120	145
C.G. Normal Acceleration (Low Range)	25	40
C.G. Normal Acceleration (High Range)	40	55
C.G. Longitudinal Acceleration	20	35
Aircraft Pitch Attitude	30	35
Aircraft Roll Attitude	20	35
R.H. Wing Tip Vertical Acceleration	65	160
L.H. Wing Tip Vertical Acceleration	50	80
R.H. Wing Lift Link Load	55	170
L.H. Wing Lift Link Load	125	145

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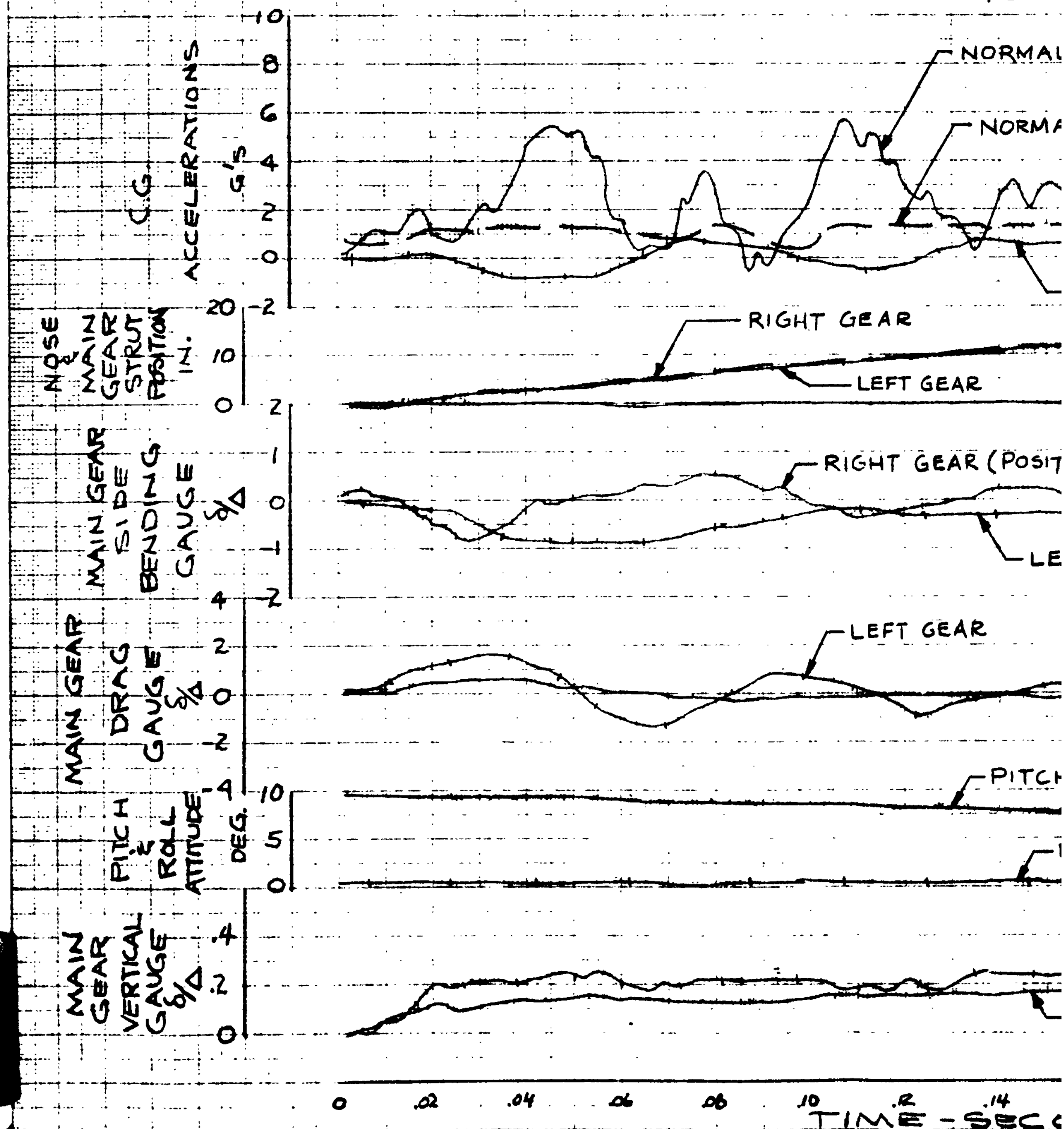
CHECKED BY:
DATE: August
TITLE: DROP T

FIGURE 15

LANDING LOA
AIRPLANE
70



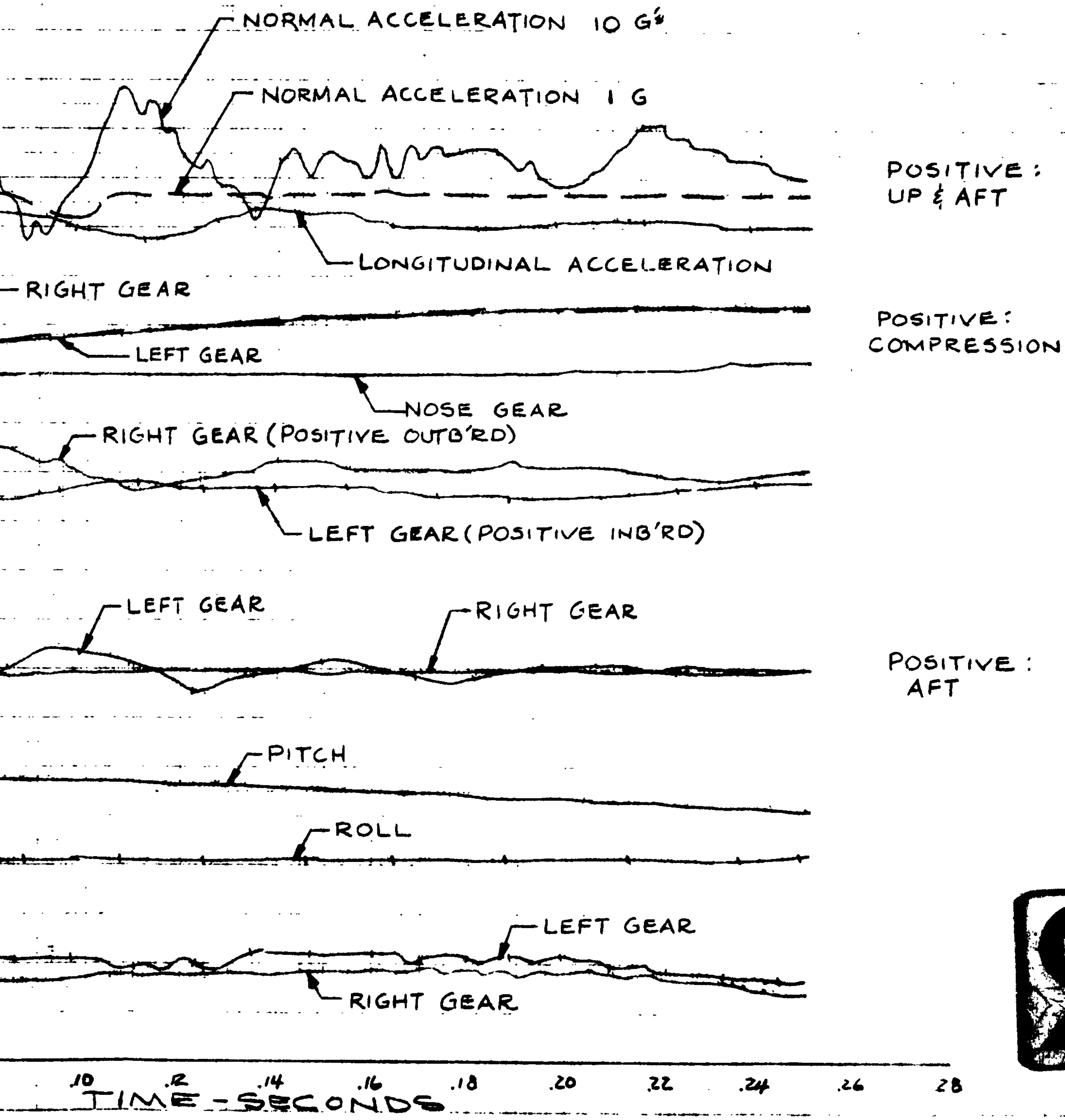
PREPARED BY: L. B. [illegible]
CHECKED BY: [illegible]
DATE: August 1952
TITLE: DROP TESTS FOR LANDING LOADS INVESTIGATION

DOUGLAS AIRCRAFT COMPANY, INC.

[illegible] DIVISION

PAGE: [illegible]
MODEL: [illegible]
REPORT NO.: [illegible]

LANDING LOADS PROGRAM
AIRPLANE DROP
70



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DATE: Augu
TITLE: DROP

LANDING LO
AIRPLANE
70

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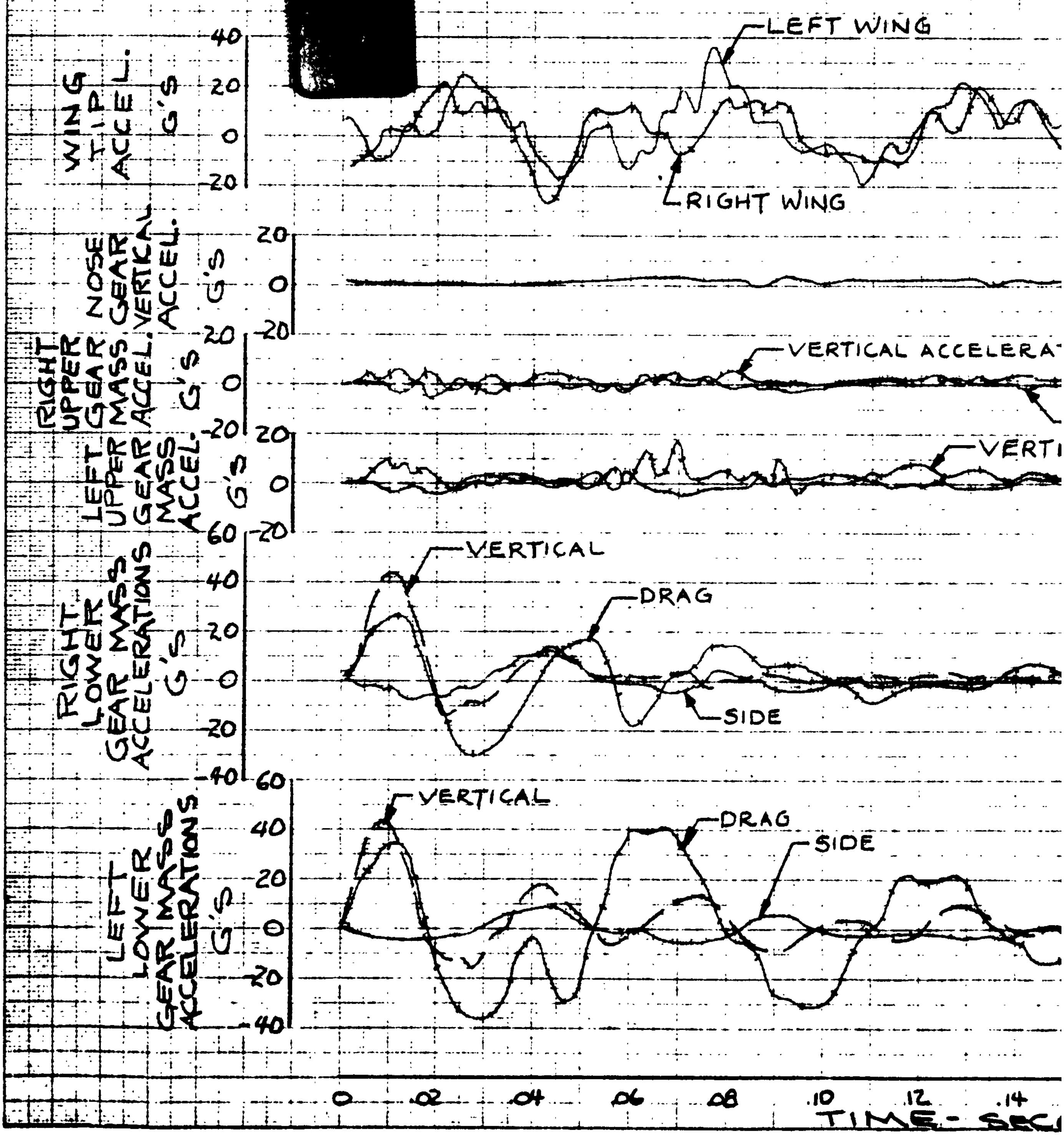
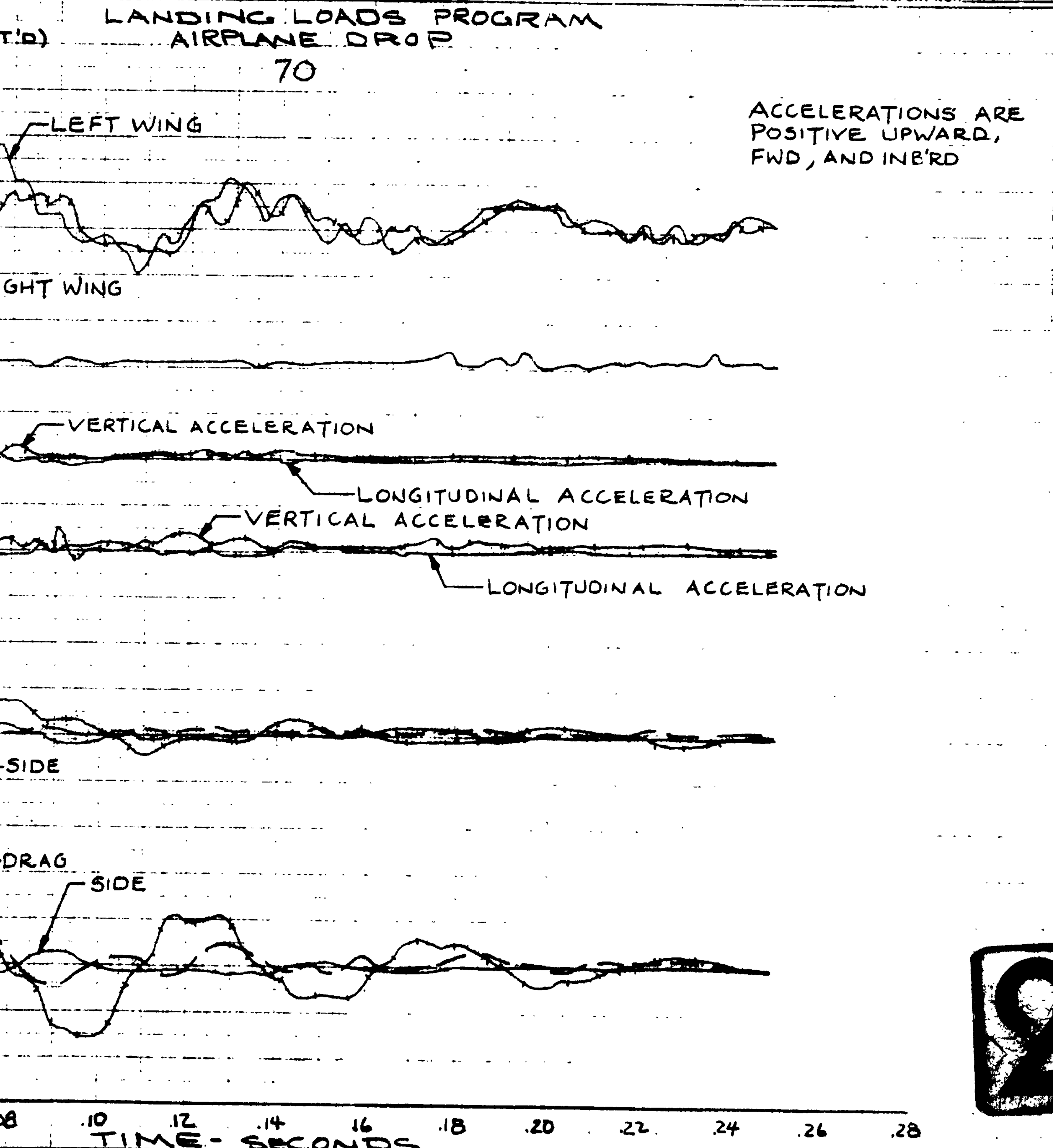
FIGURE 15 (CONT'D)



LANDING LOADS PROGRAM
AIRPLANE DROP
70



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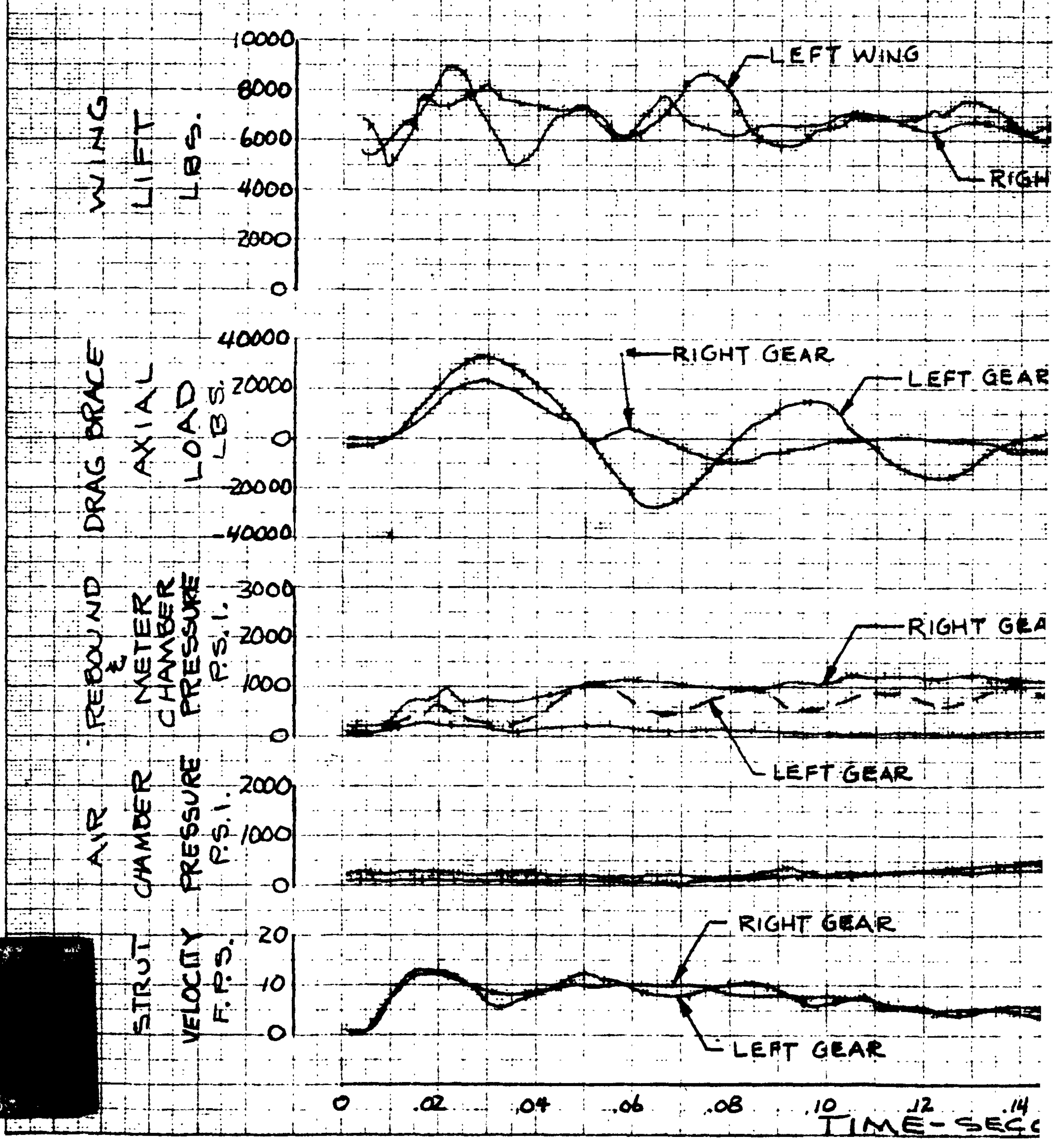
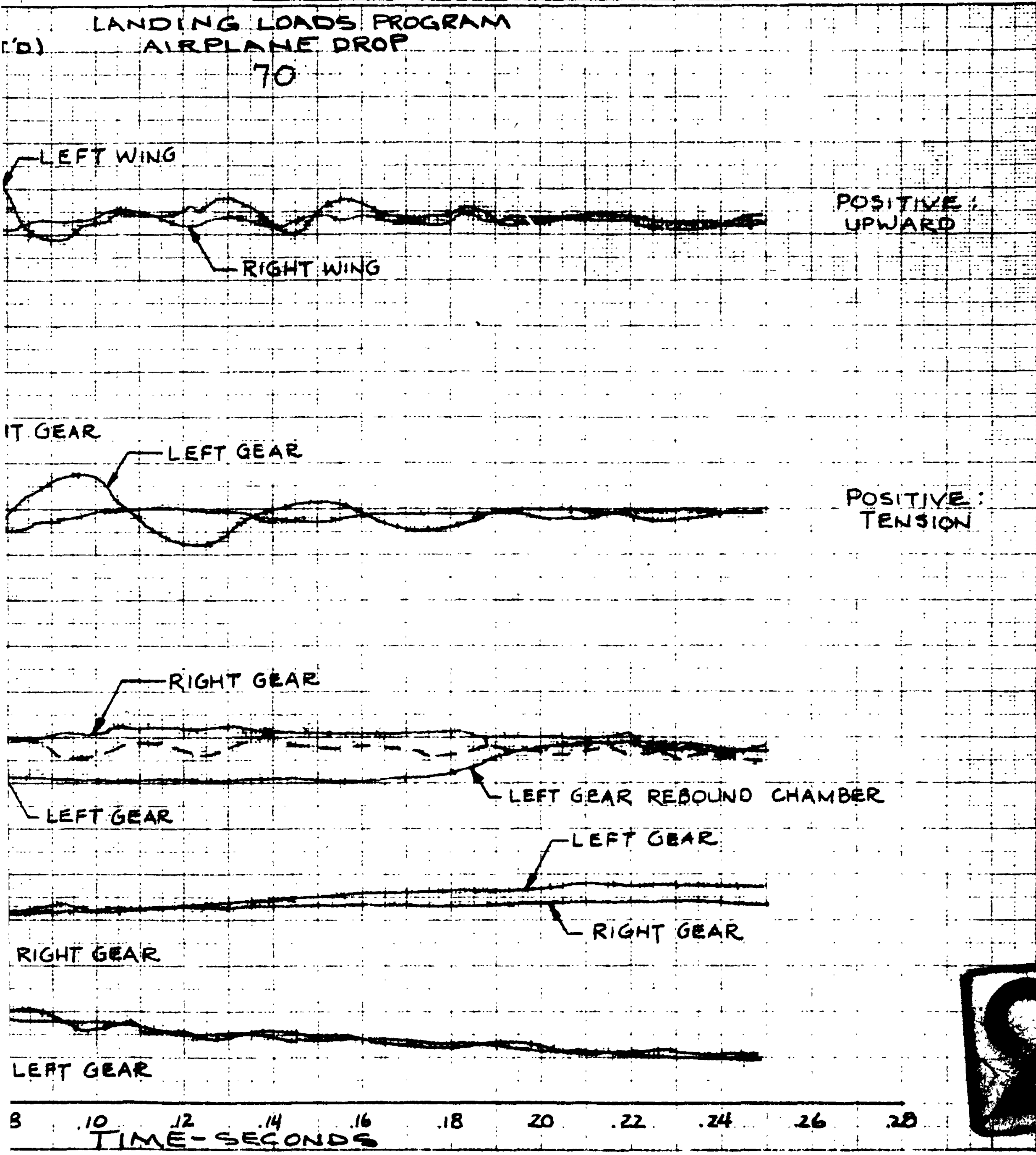
TITLE: DROP

FIGURE 15 (CONT'D)

LANDING LO
AIRPLAN
70

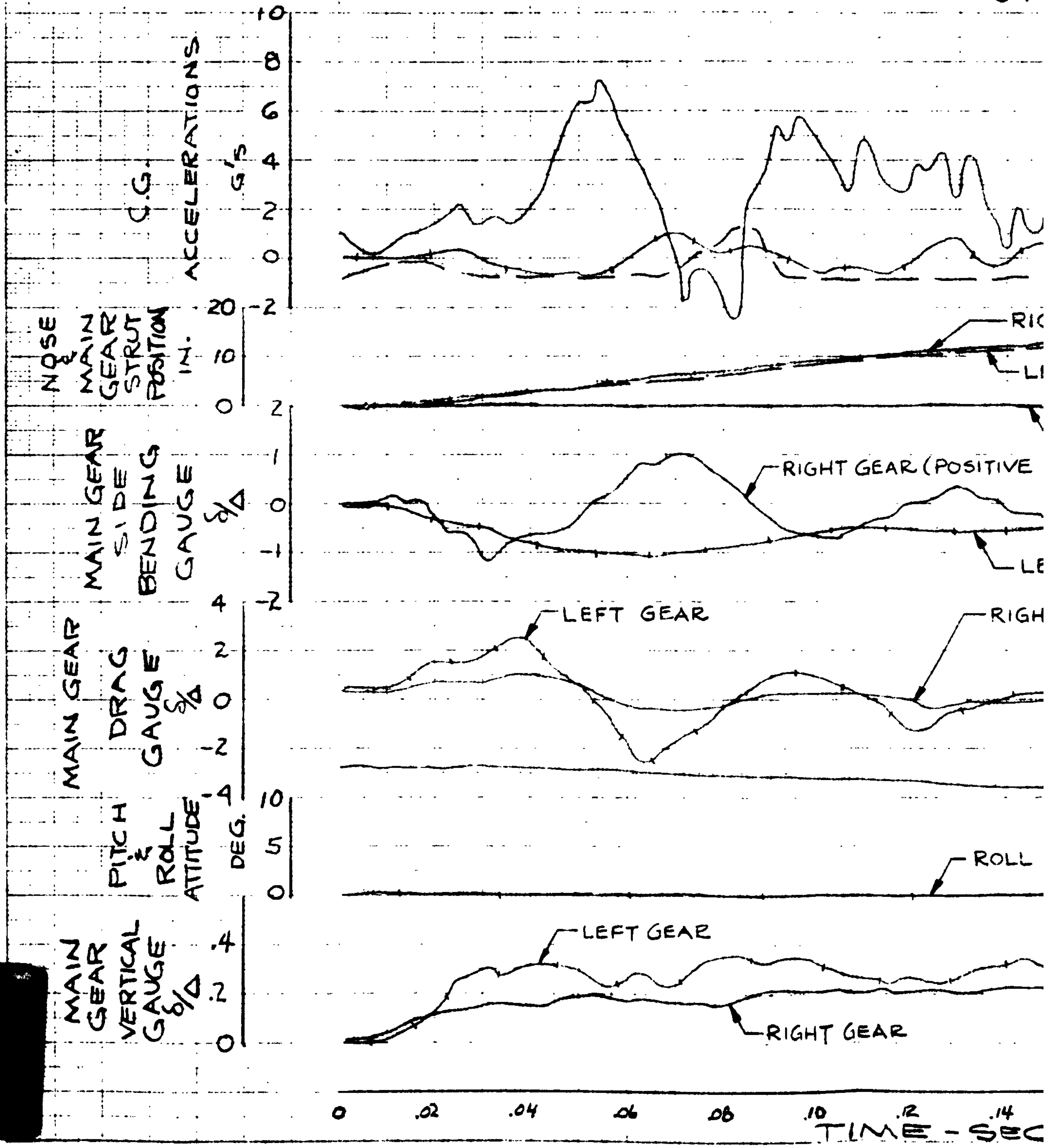



LANDING LOADS PROGRAM
AIRPLANE DROP
70
LEFT WING
RIGHT WING
POSITIVE: UPWARD
IT GEAR
LEFT GEAR
POSITIVE: TENSION
RIGHT GEAR
LEFT GEAR REBOUND CHAMBER
LEFT GEAR
LEFT GEAR
RIGHT GEAR
RIGHT GEAR
LEFT GEAR
8 .10 .12 .14 .16 .18 .20 .22 .24 .26 .28
TIME-SECONDS

PREPARED BY:
CHECKED BY:
DATE: Aug
TITLE: DRO

FIGURE 16

LANDING LO
AIRPLA
84



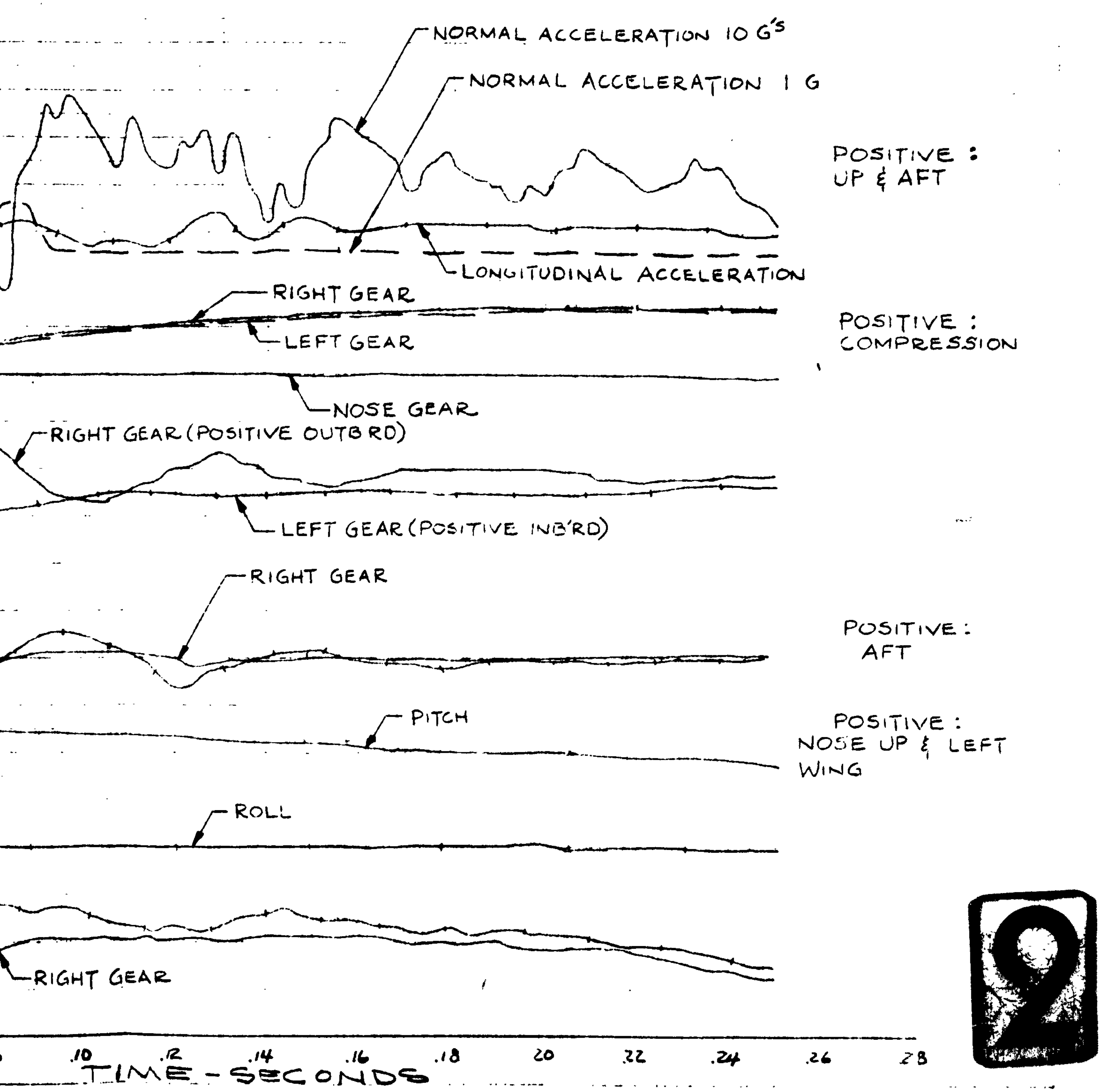
PREPARED BY: J. B. Mosby
CHECKED BY: F. C. R.
DATE: August 1962
TITLE: DROP TESTS FOR LANDING LOADS INVESTIGATION

DOUGLAS AIRCRAFT COMPANY, INC.

AIRCRAFT DIVISION

MODEL: A4D-2
REPORT NO.: ES-40541

LANDING LOADS PROGRAM
AIRPLANE DROP
84



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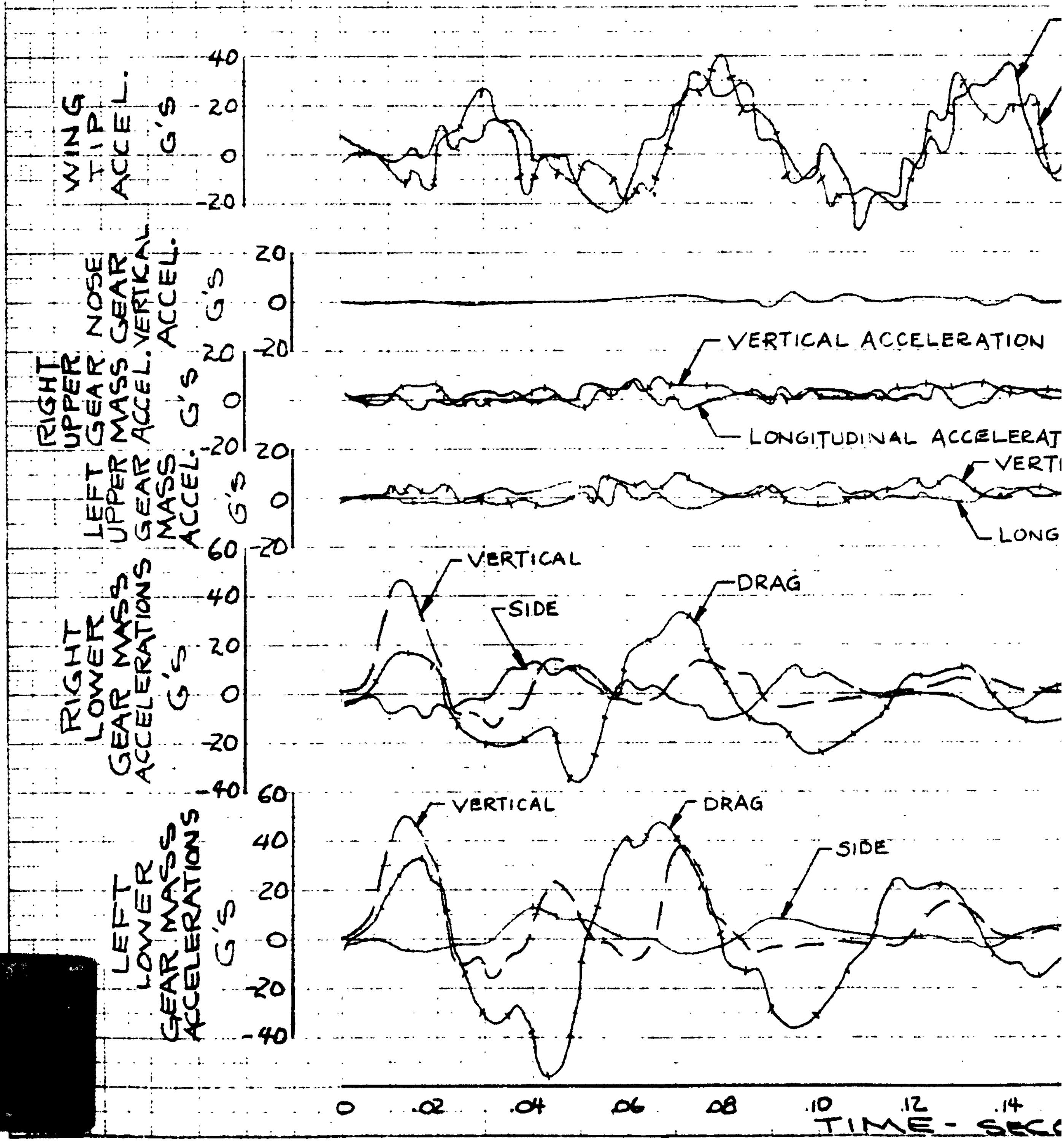
DATE:
TITLE:

LANDING LO
AIRPLANE
8

FIGURE 16 (CONT'D)



PREPARED BY: L.F. Mosby	**DOUGLAS AIRCRAFT COMPANY, INC.**	PAGE	42
CHECKED BY: W.C.J.	AIRCRAFT DIVISION	MODEL:	A4D-2
DATE: August 1962			
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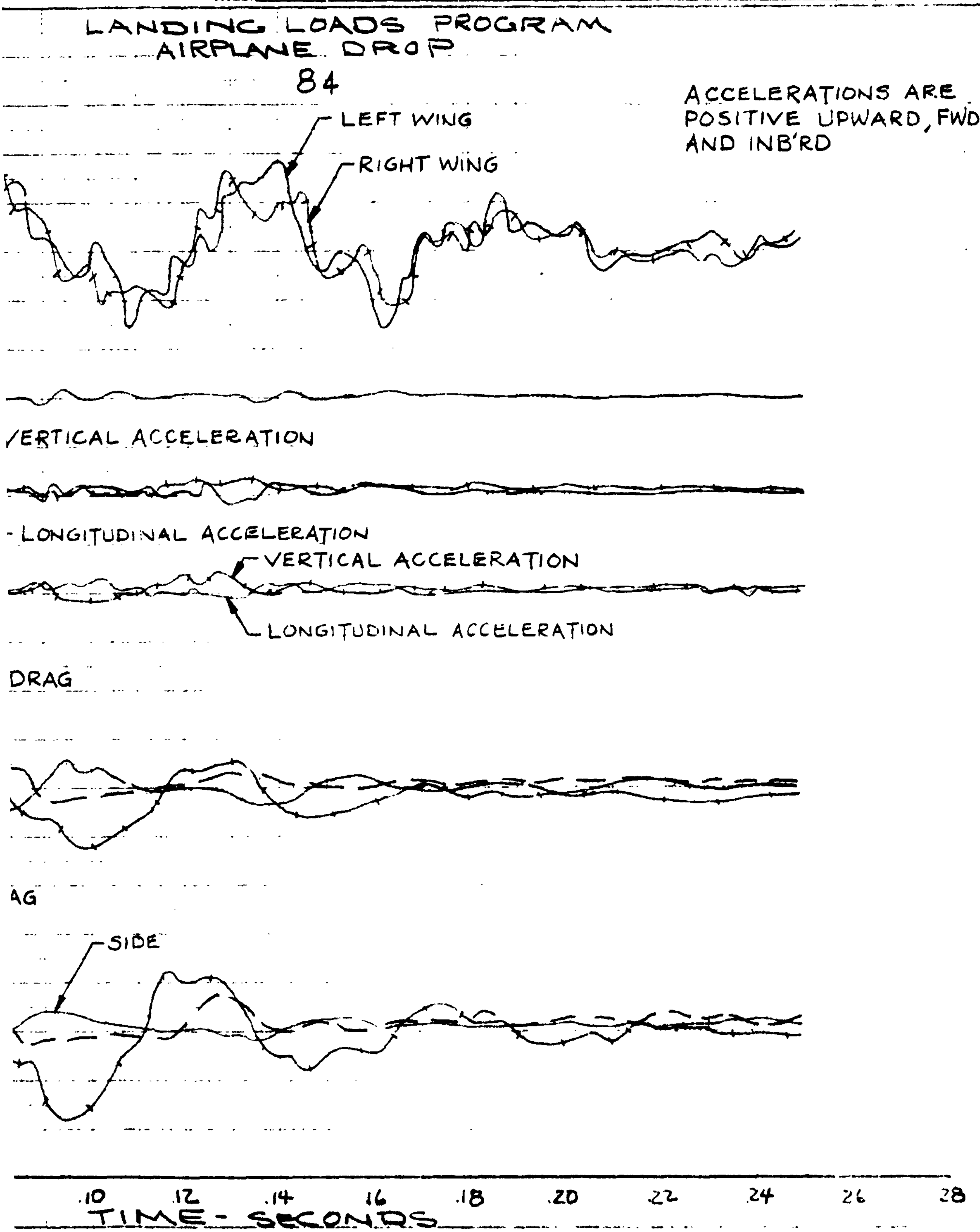

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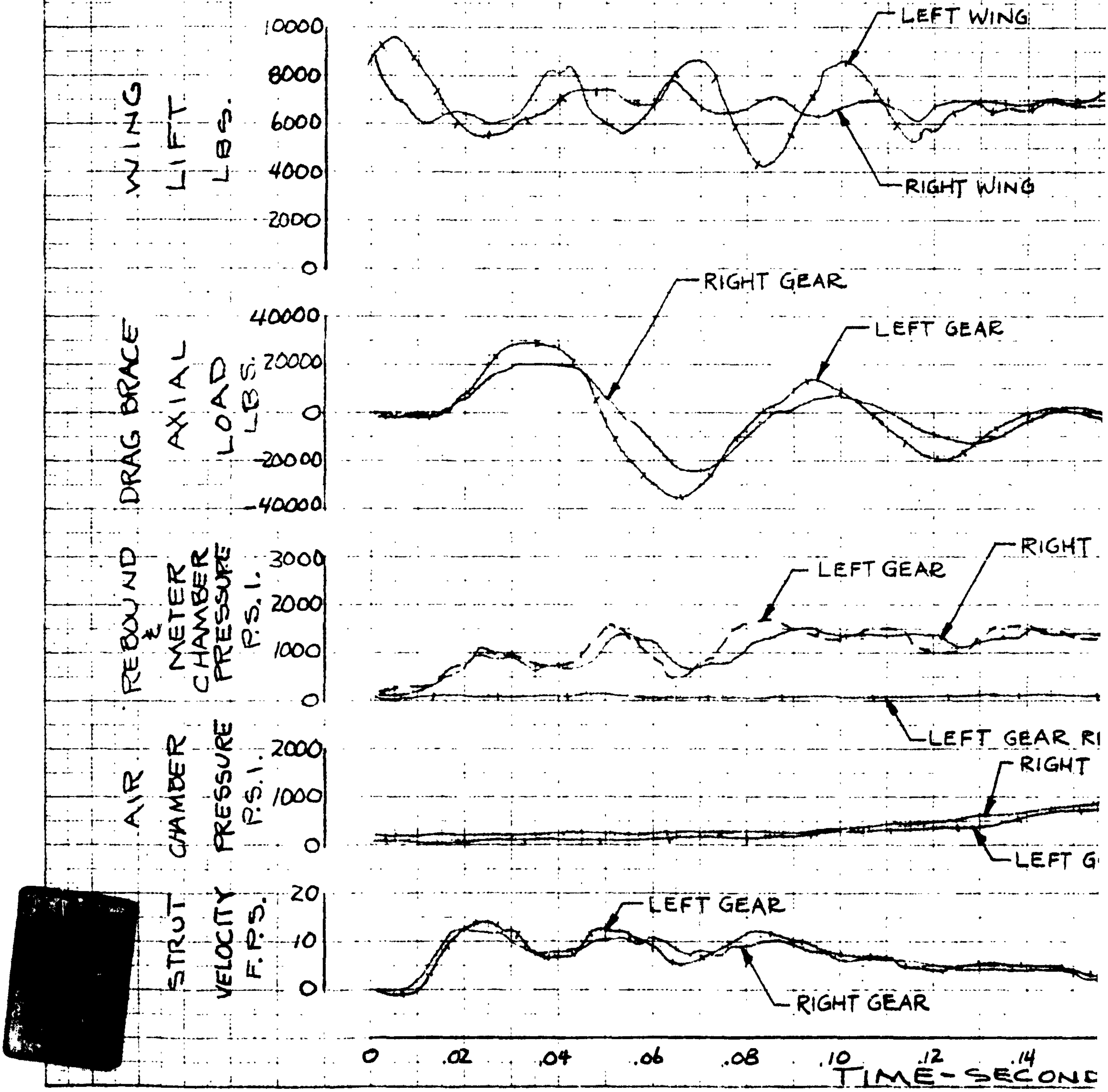
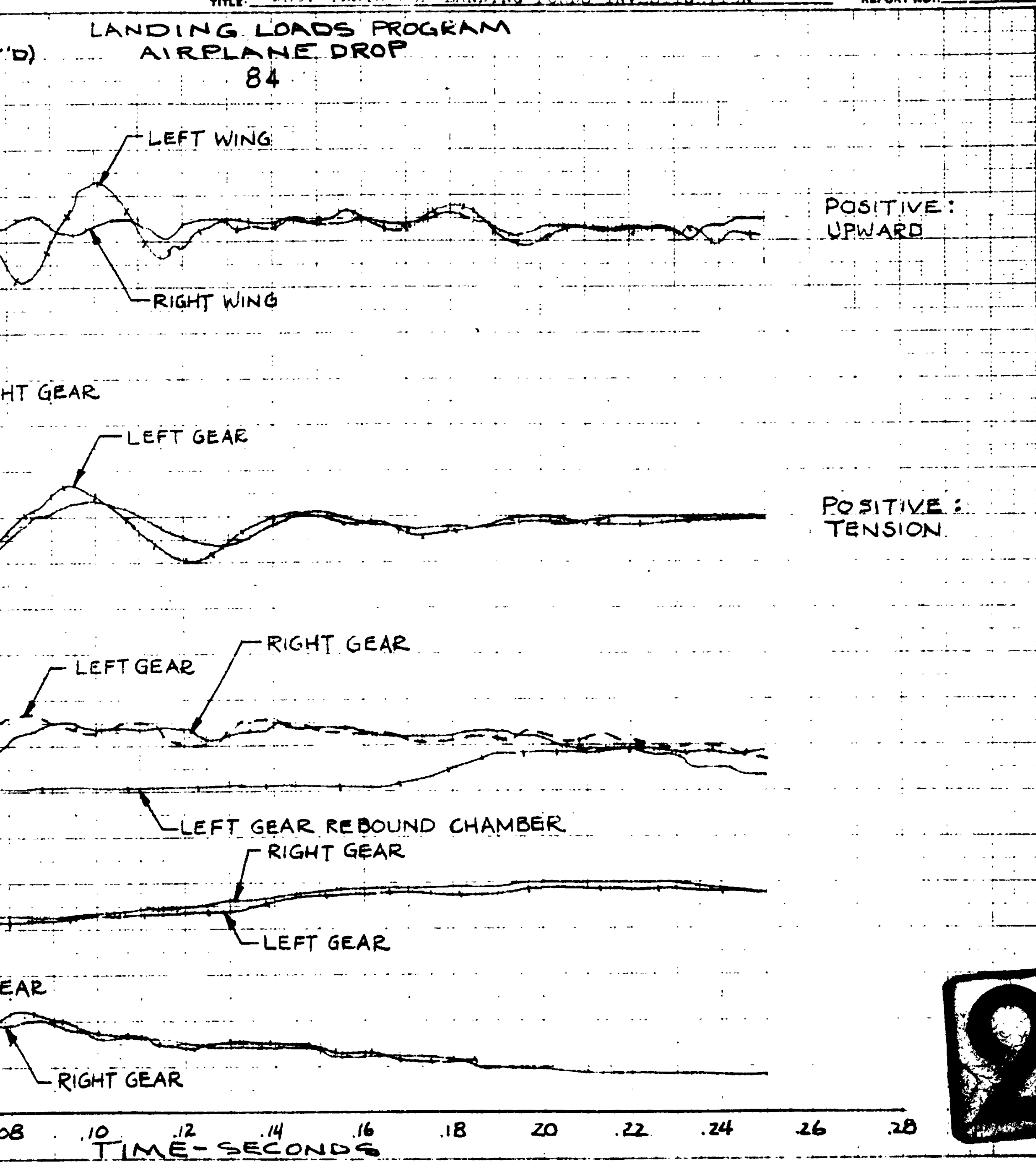
TITLE: DROP T

LANDING LOADS
AIRPLANE D
84

FIGURE 16 (CONT'D)




'D)
LANDING LOADS PROGRAM
AIRPLANE DROP
84
LEFT WING
RIGHT WING
POSITIVE: UPWARD
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LEFT GEAR
POSITIVE: TENSION
LEFT GEAR
RIGHT GEAR
LEFT GEAR REBOUND CHAMBER
RIGHT GEAR
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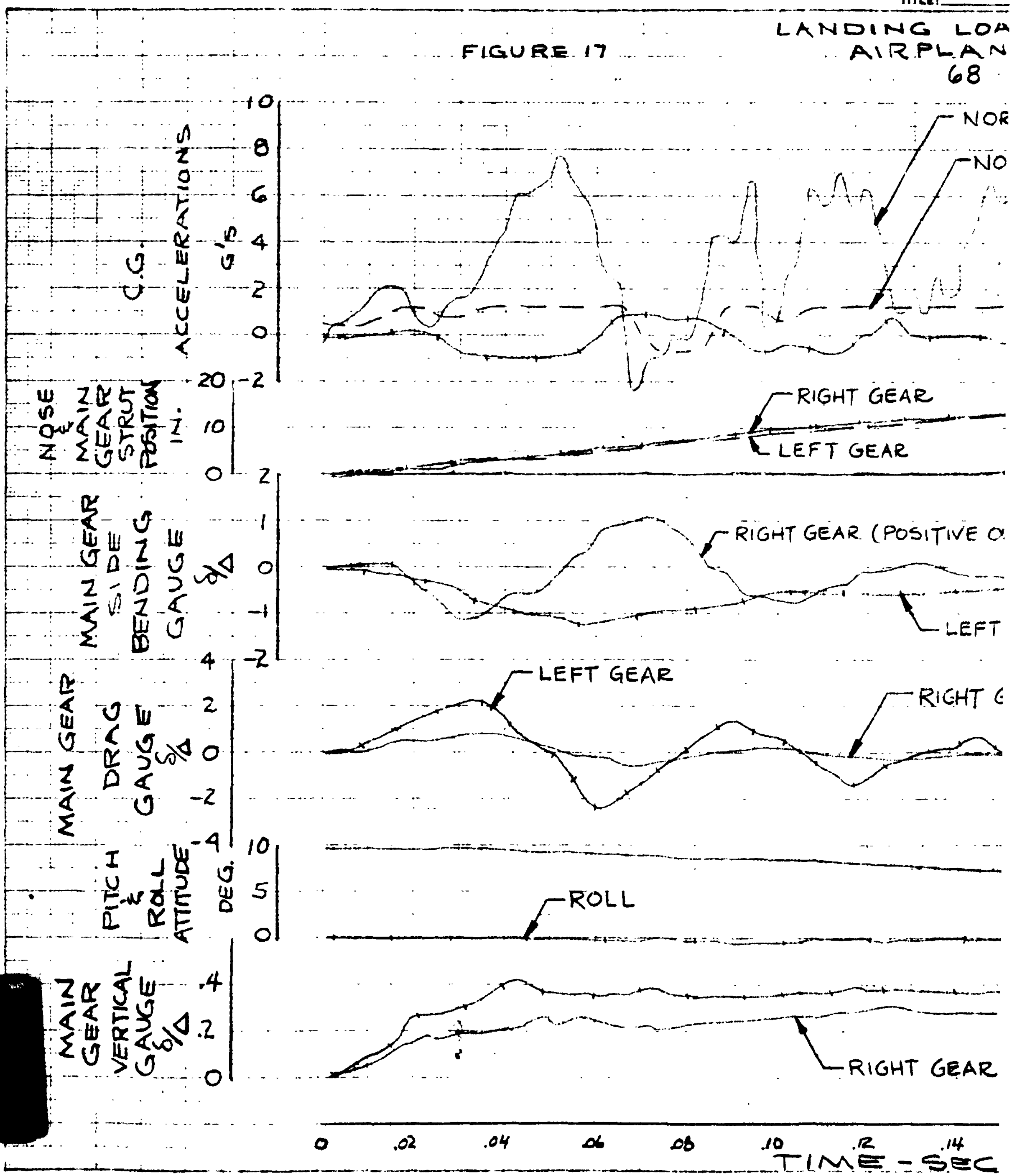
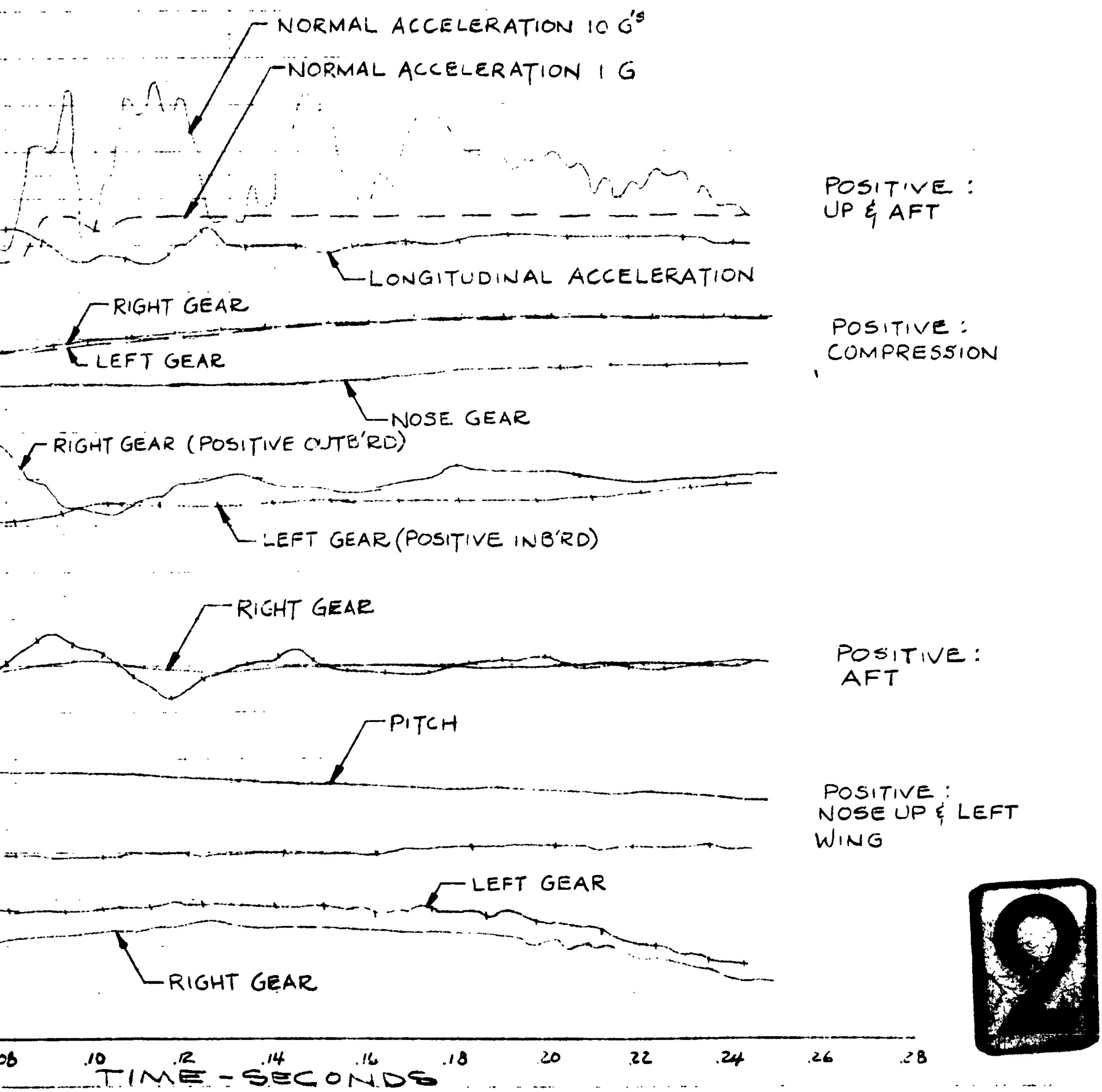
TIME-SECONDS

PREPARED BY:
CHECKED BY:
DATE: Augus
TITLE: DFOP



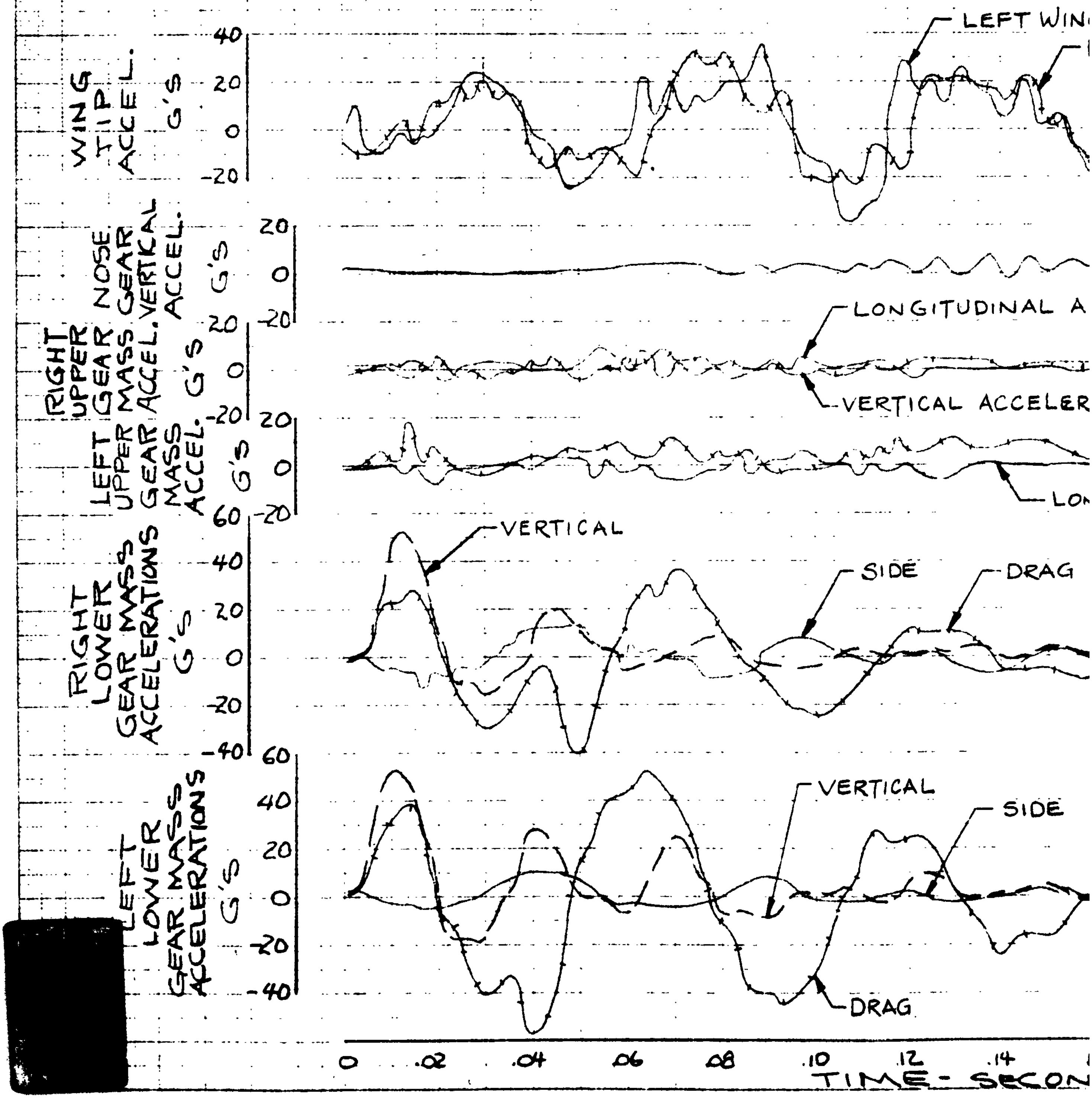
LANDING LOADS PROGRAM
AIRPLANE DROP
68



PREPARED BY: I.B.
CHECKED BY: F.S.
DATE: August 1
TITLE: [illegible]

LANDING LOAD
AIRPLANE D
68

FIGURE 17 (CONT'D)



PREPARED BY: L.B. Mosby
CHECKED BY: F.J.A.
DATE: August 1952
TITLE: [illegible] TESTS [illegible] LANDING LOADS INVESTIGATION

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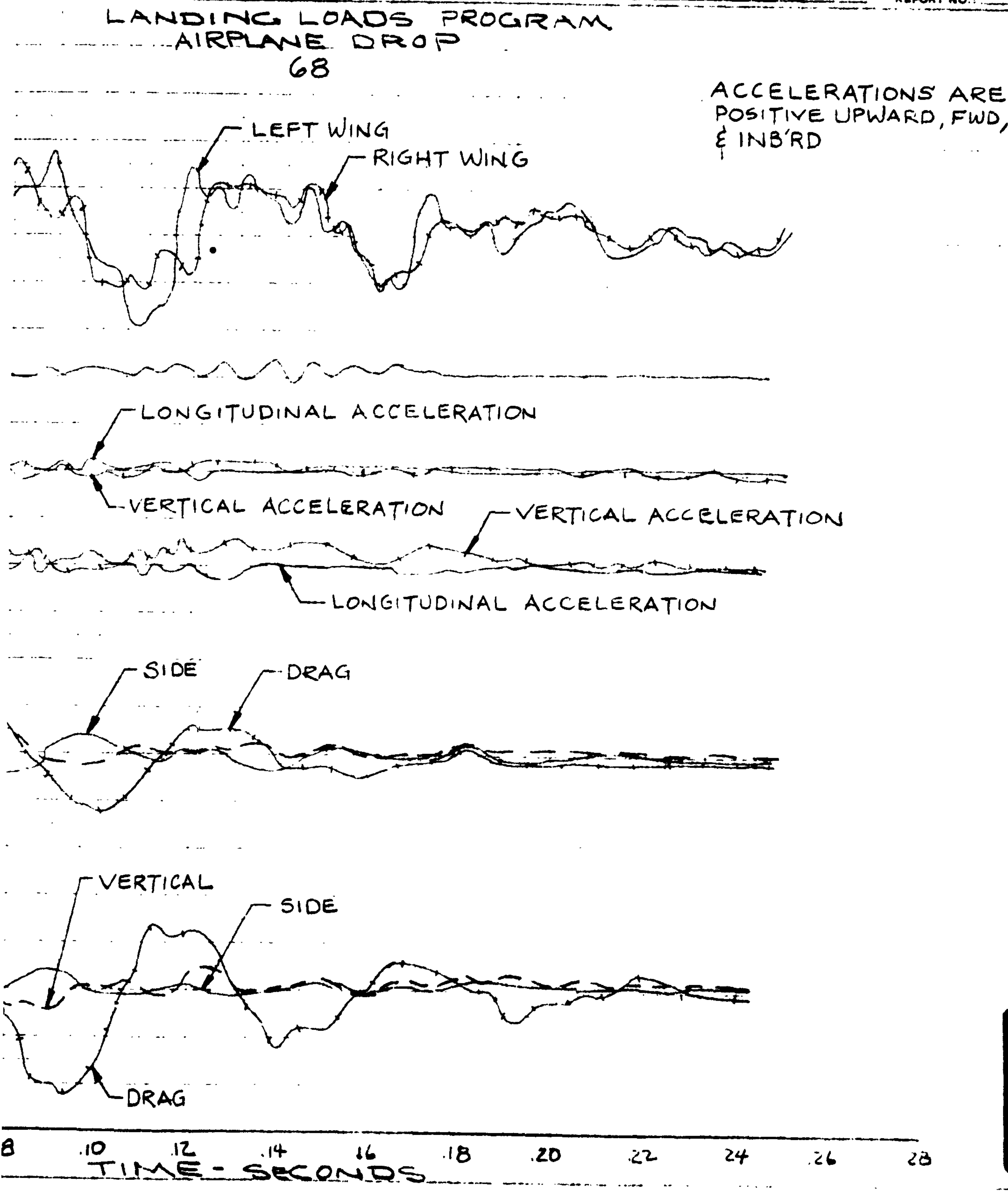
AIRCRAFT DIVISION

PAGE: 4[illegible]
MODEL: [illegible]
REPORT NO.: ES-40641



PREPARED BY: L.
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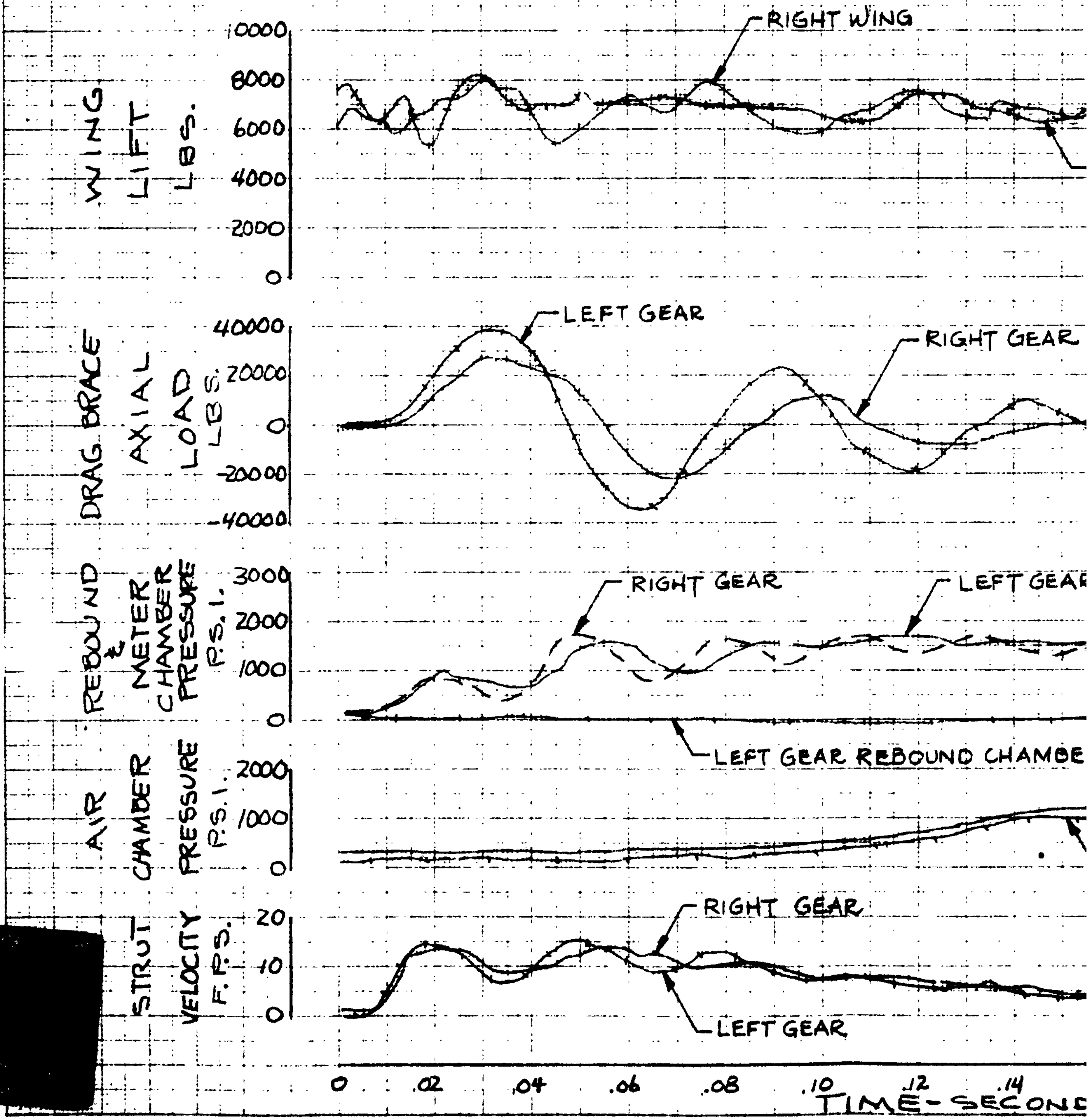
DATE: August
TITLE: DROP T

LANDING LOAD
AIRPLANE
68

FIGURE 17 (CONT'D)



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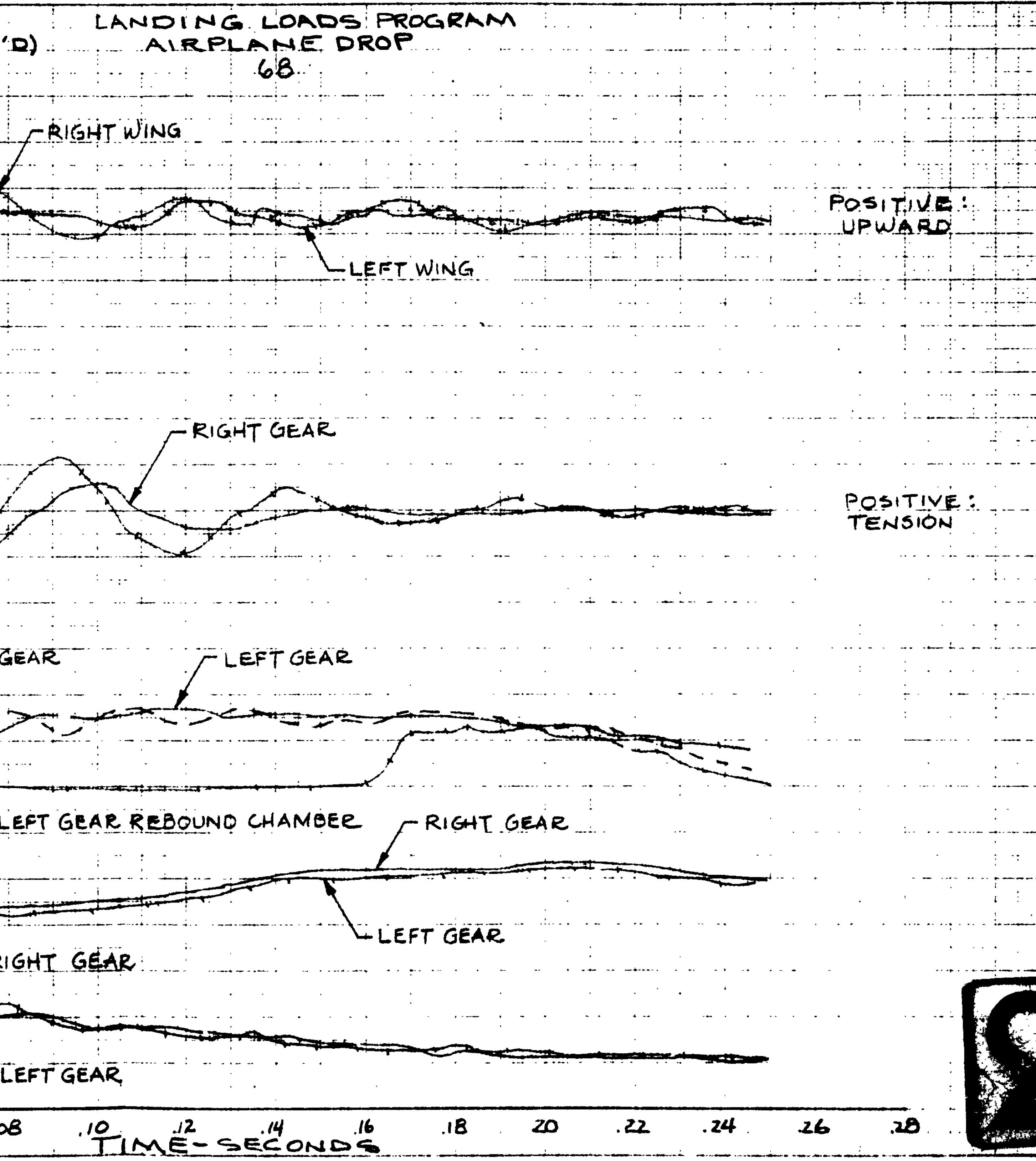
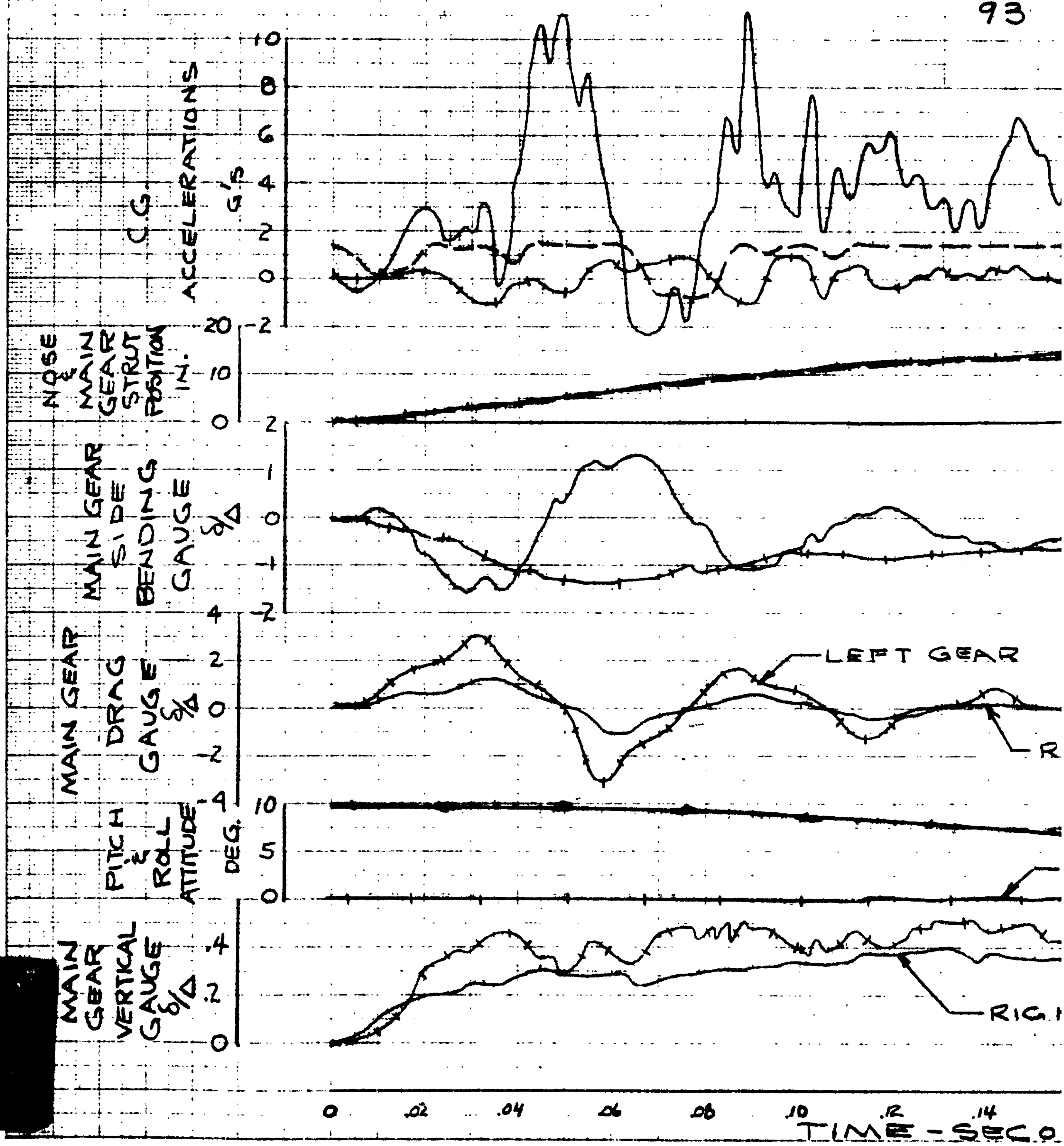


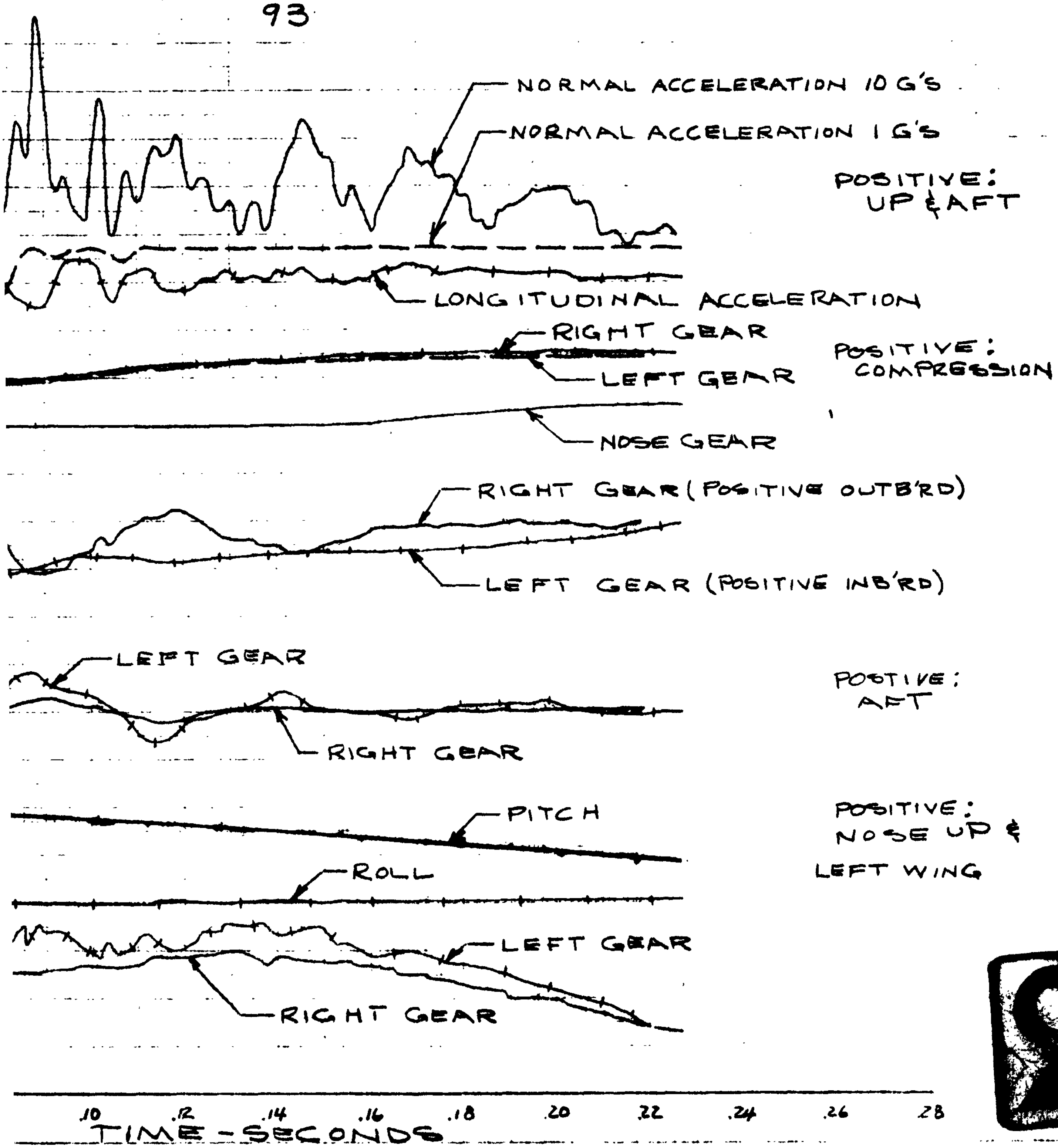
PREPARED BY: I.B
CHECKED BY: F.C
DATE: August
TITLE: DTCP T

FIGURE 18

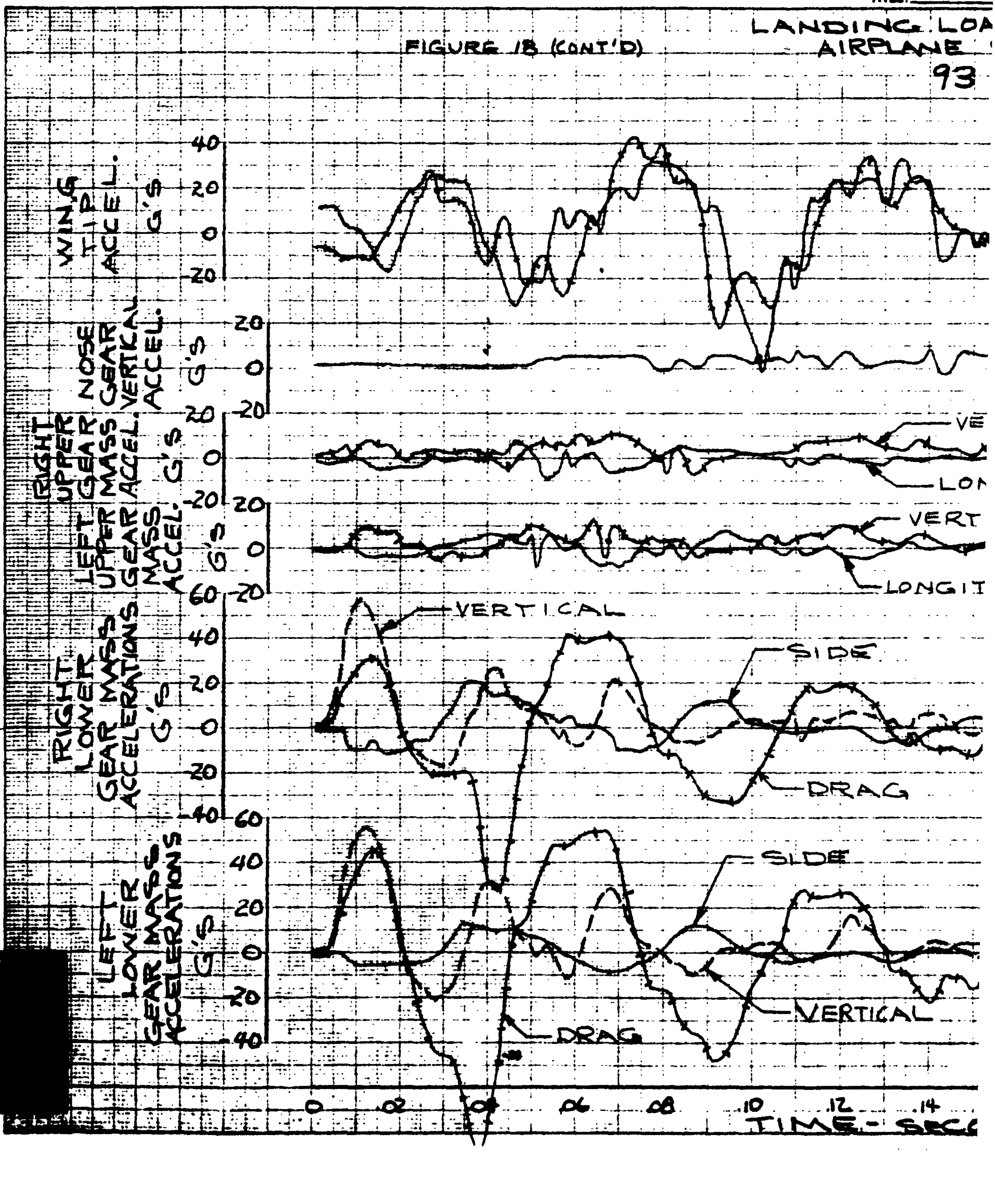
LANDING LOAD
AIRPLANE
93



LANDING LOADS PROGRAM
AIRPLANE DROP
93



PREPARED BY: L.
CHECKED BY: F.
DATE: August
TITLE: DROP T



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AIRCRAFT DIVISION

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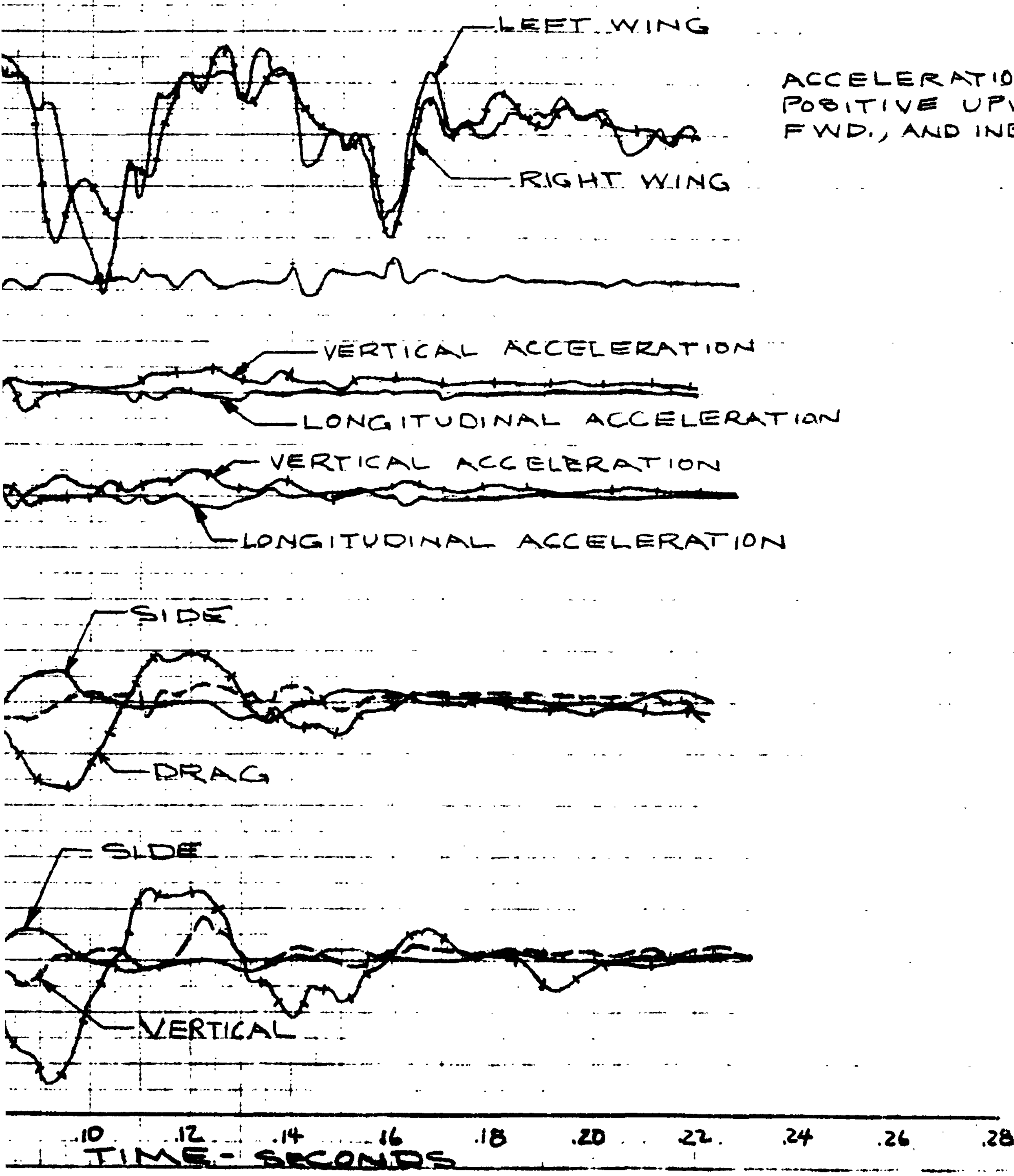
LANDING LOADS PROGRAM
AIRPLANE DROP
93

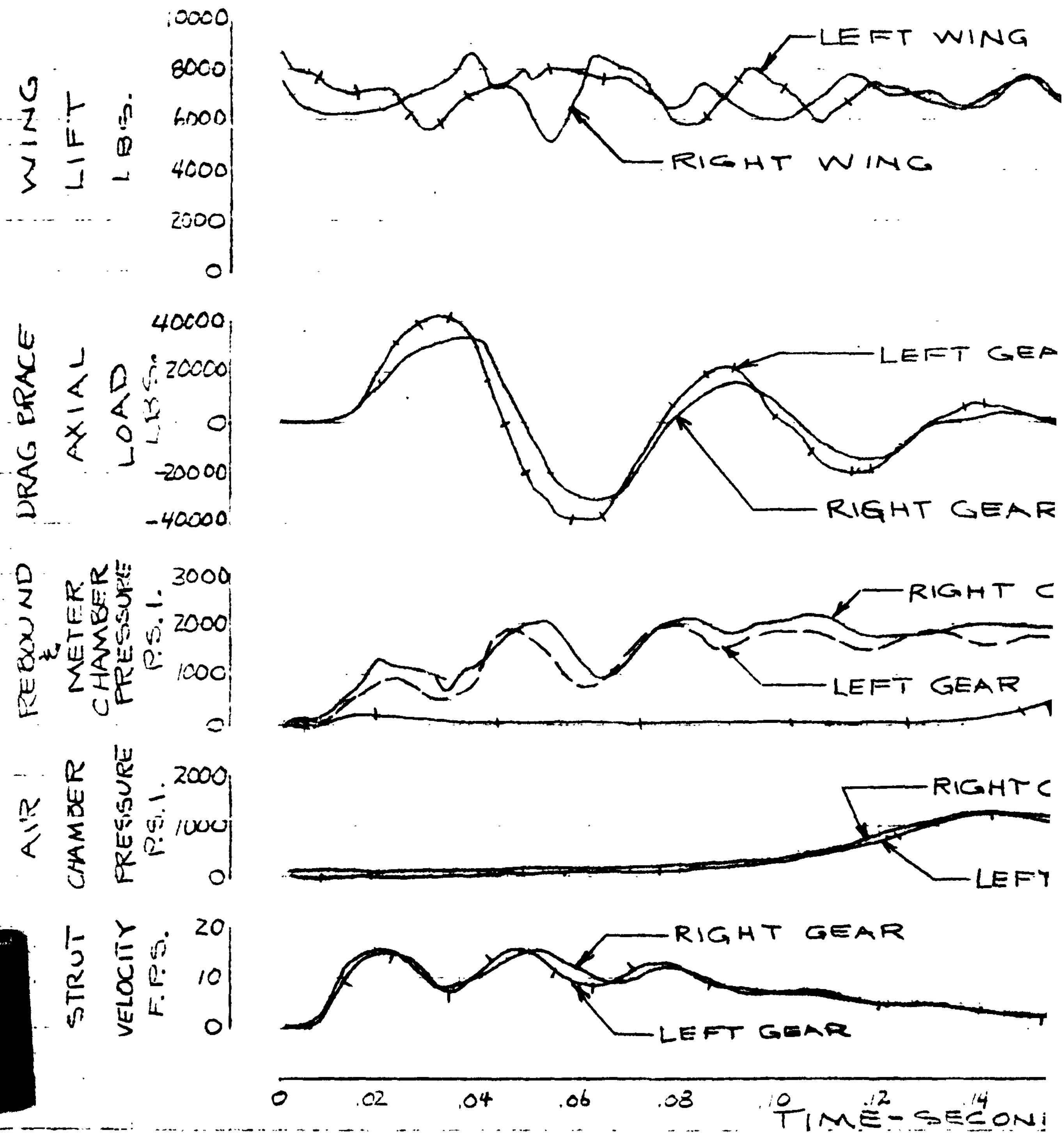
ACCELERATIONS ARE POSITIVE UPWARD, FWD., AND INB'RD

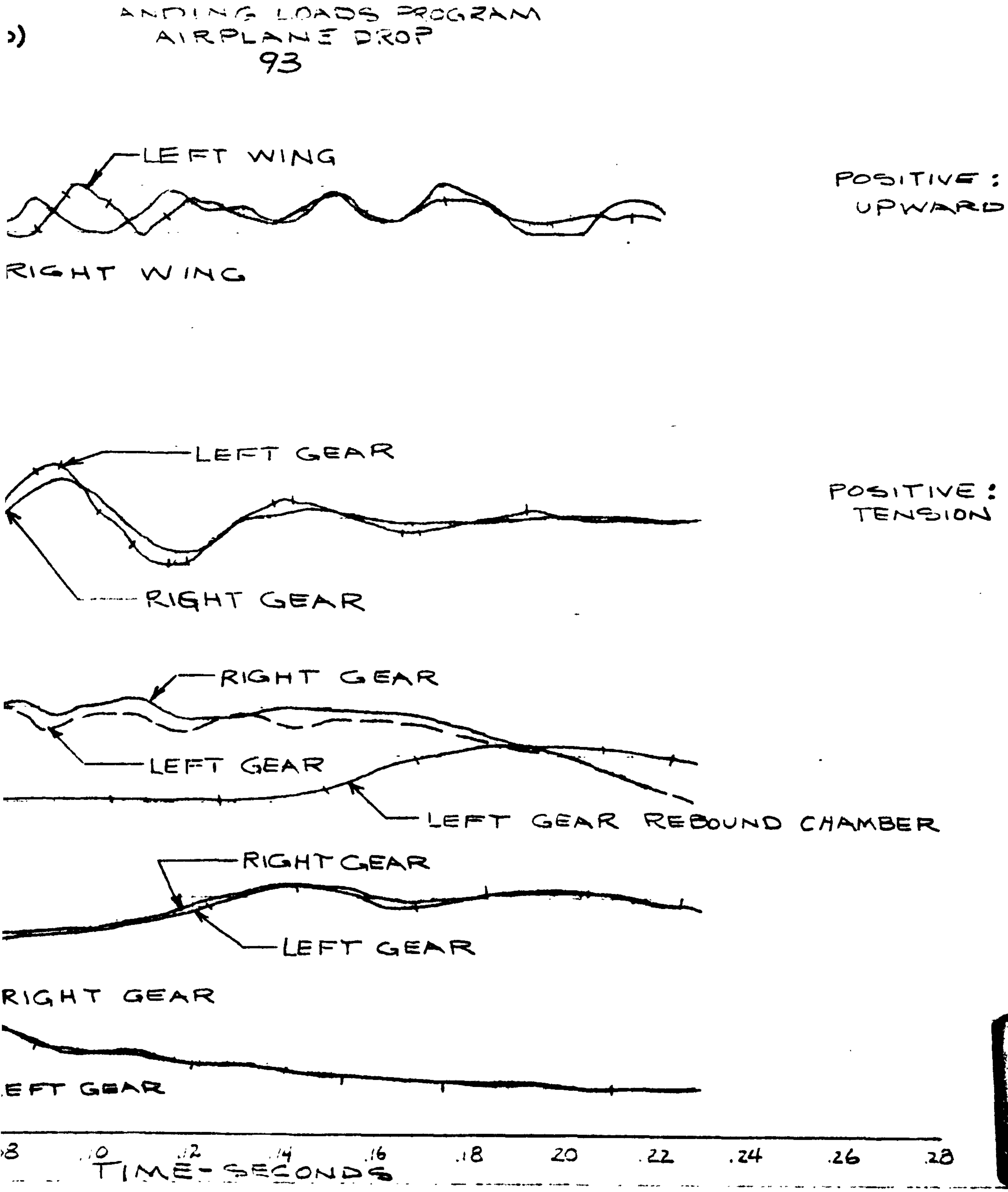


PREPARED BY L.B.
CHECKED BY: F.C.
DATE August
TITLE DROP TE

ANDING LOADS
AIRPLANE D
93

FIGURE 18 (CONT'D)





ANDING LOADS PROGRAM
AIRPLANE DROP
93
LEFT WING
RIGHT WING
POSITIVE: UPWARD
LEFT GEAR
RIGHT GEAR
POSITIVE: TENSION
RIGHT GEAR
LEFT GEAR
LEFT GEAR REBOUND CHAMBER
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RIGHT GEAR
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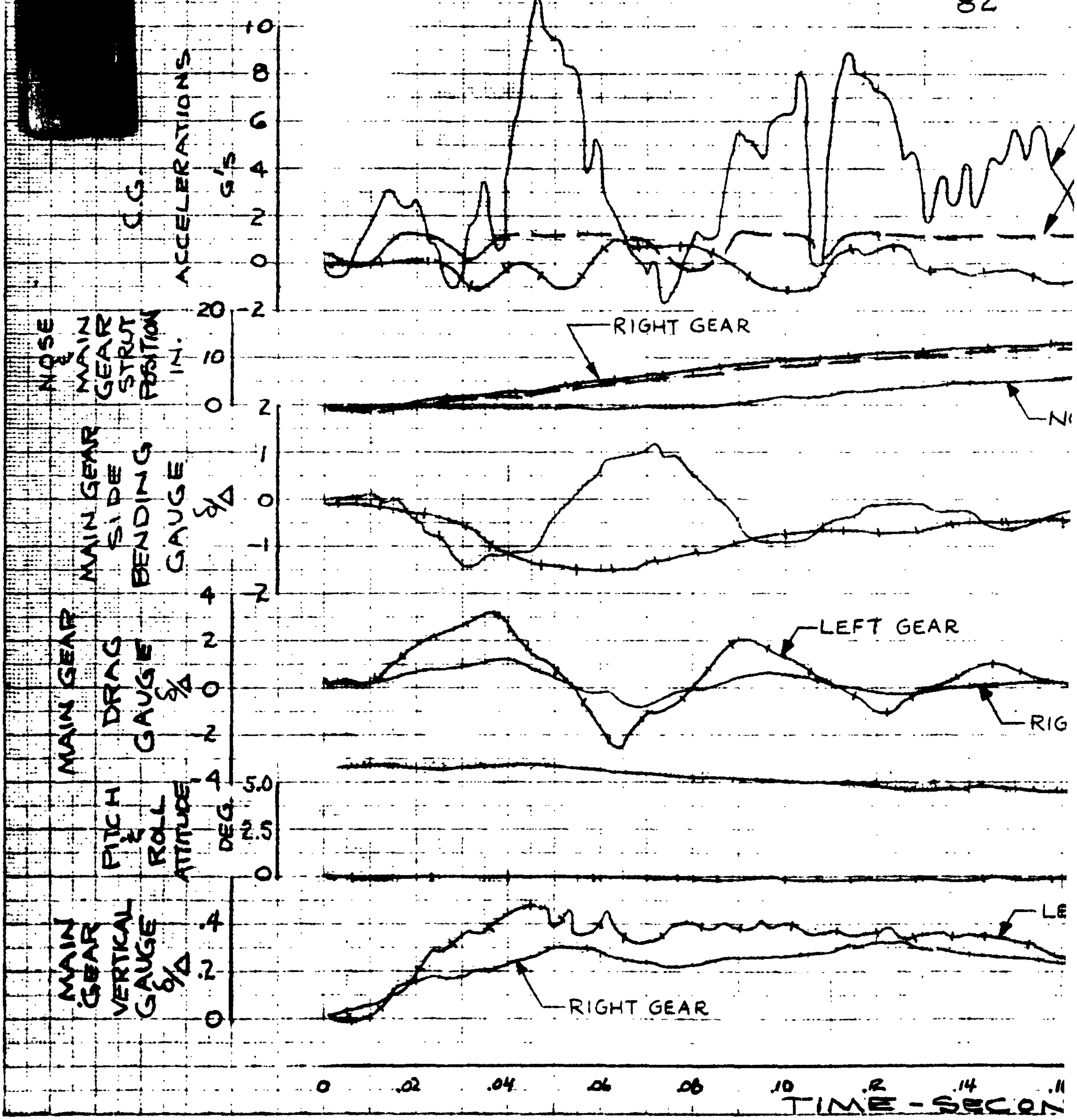
TIME-SECONDS

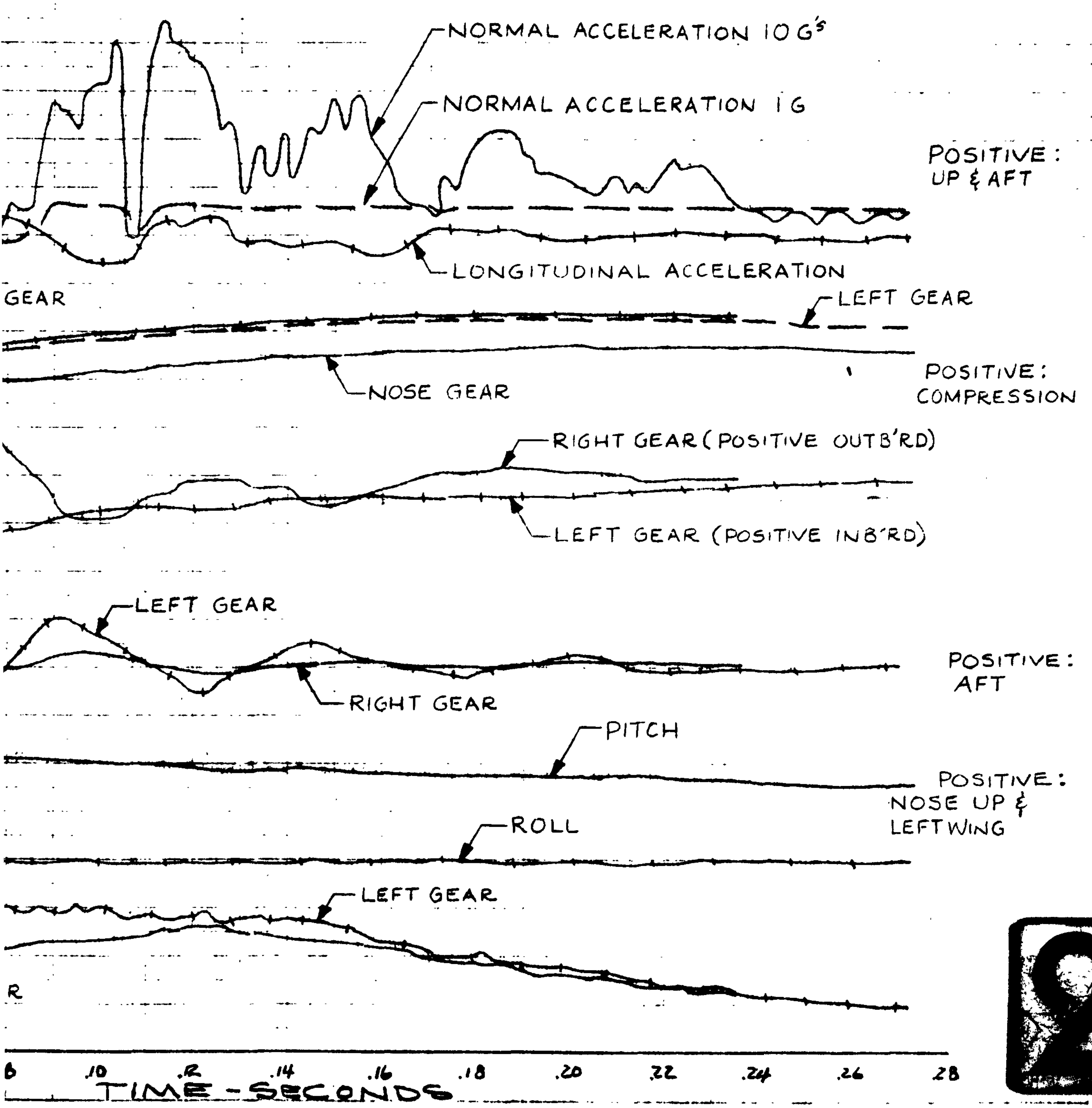
PREPARED BY: 1.B. I
CHECKED BY: F.?.A
DATE: August 19
TITLE: DROP TESTS

FIGURE 19

LANDING LOADS
AIRPLANE D
82



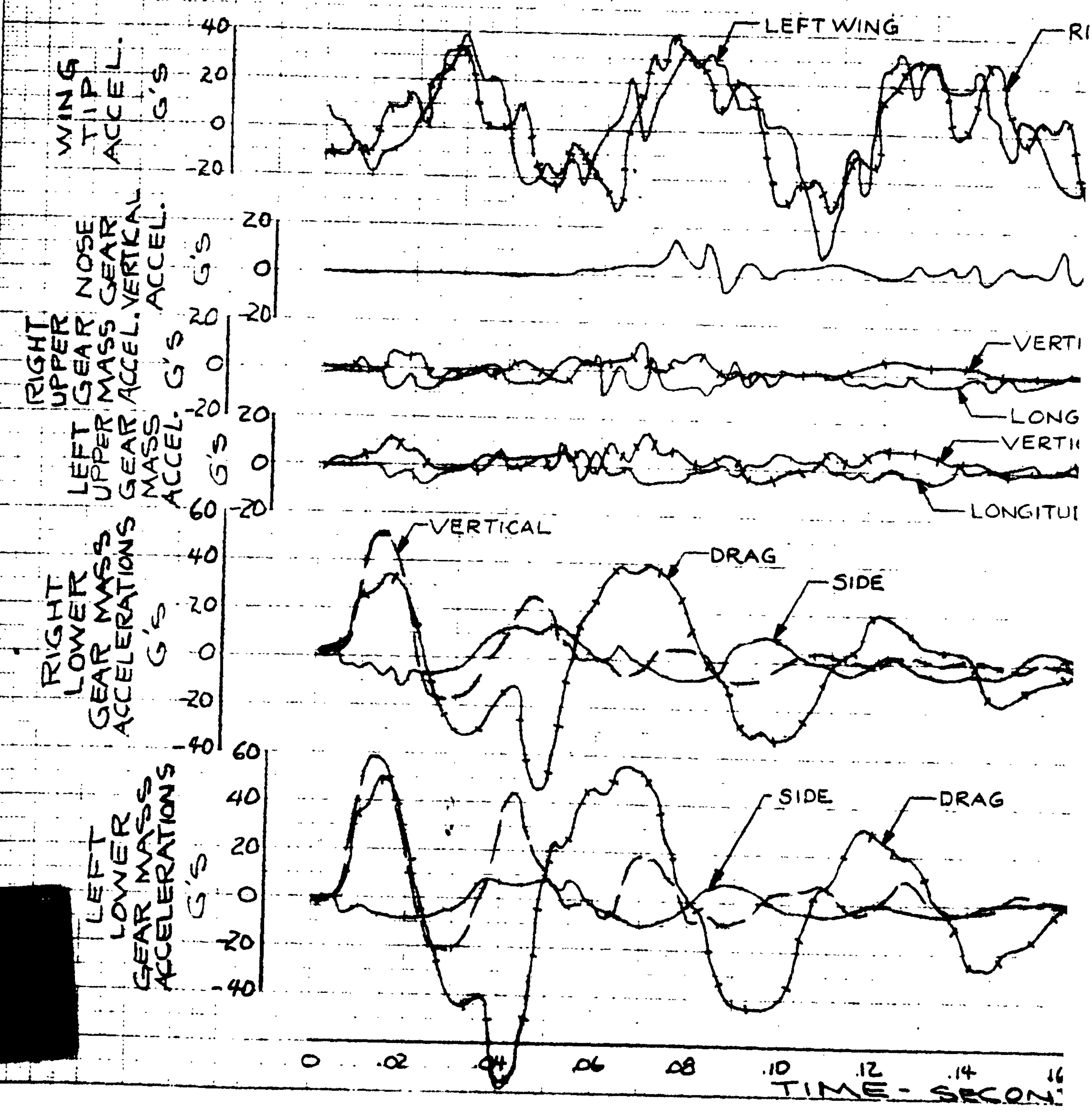
LANDING LOADS PROGRAM
AIRPLANE DROP
82

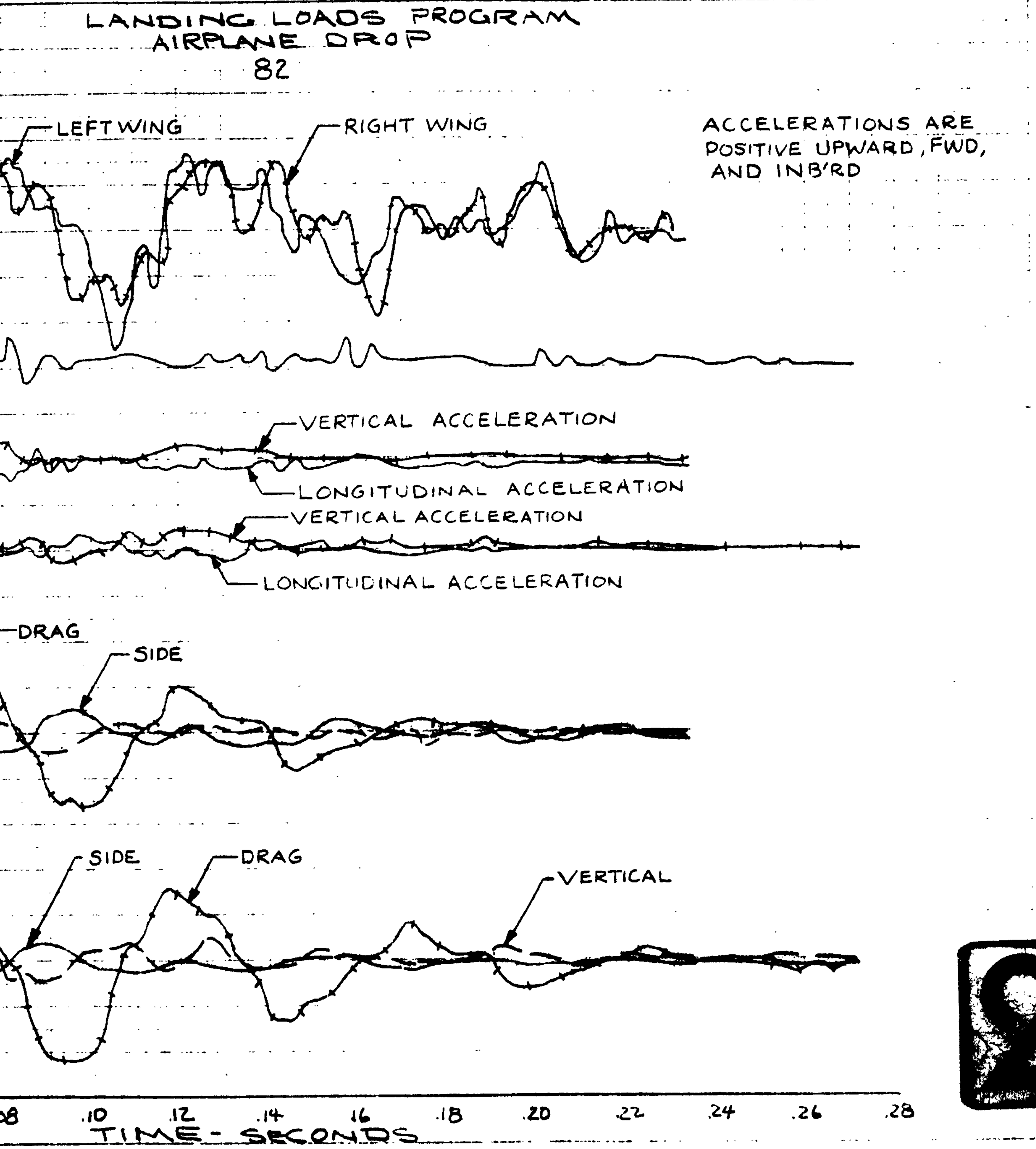


PREPARED BY: I.B. M
CHECKED BY: F.C.A.
DATE: August 1
TITLE: DROP TEST

FIGURE 19 (CONT'D)

LANDING LOAD
AIRPLANE DE
82




LANDING LOADS PROGRAM
AIRPLANE DROP
82
LEFT WING
RIGHT WING
ACCELERATIONS ARE POSITIVE UPWARD, FWD, AND INB'RD
VERTICAL ACCELERATION
LONGITUDINAL ACCELERATION
VERTICAL ACCELERATION
LONGITUDINAL ACCELERATION
DRAG
SIDE
SIDE
DRAG
VERTICAL
.08
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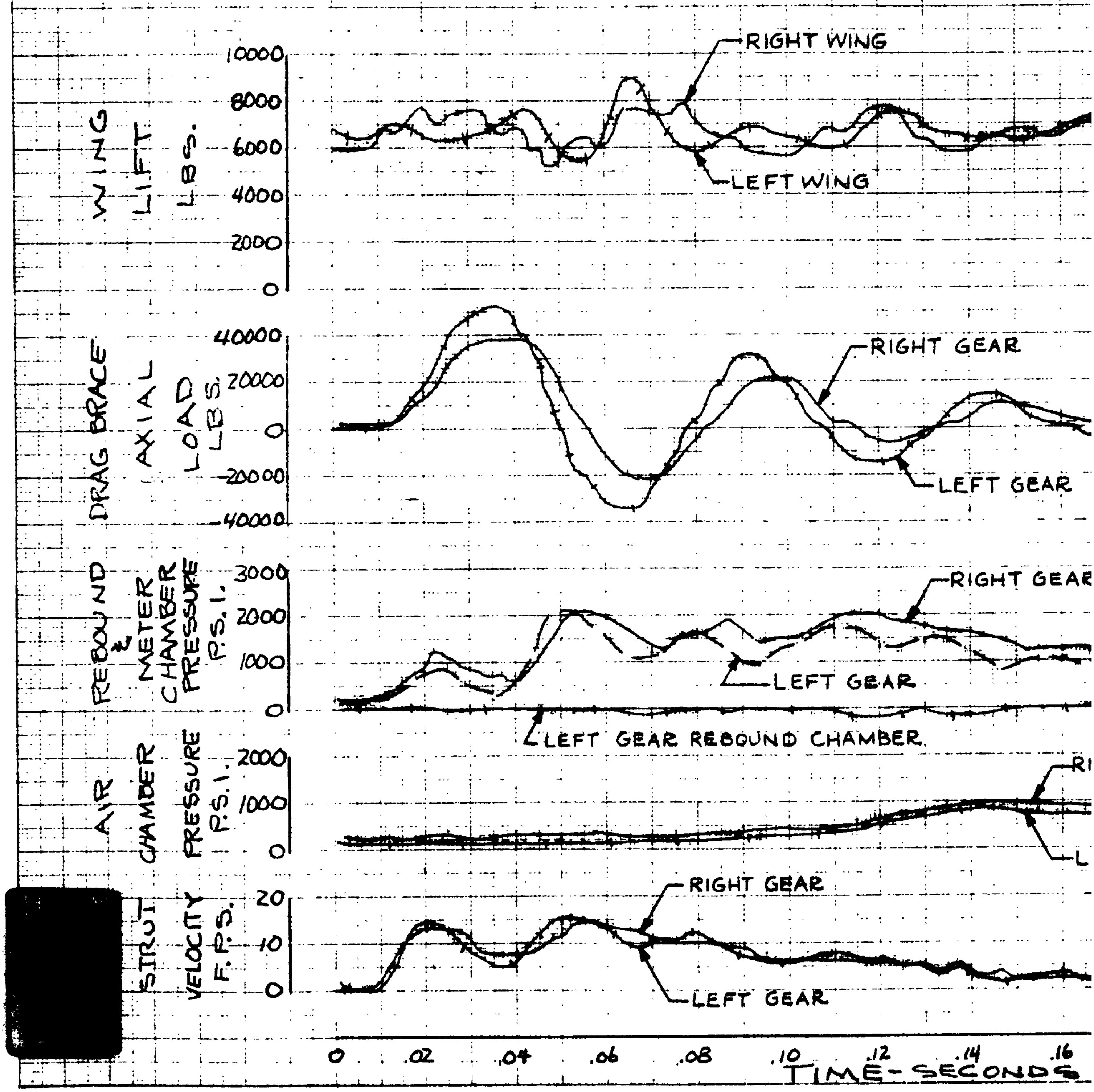
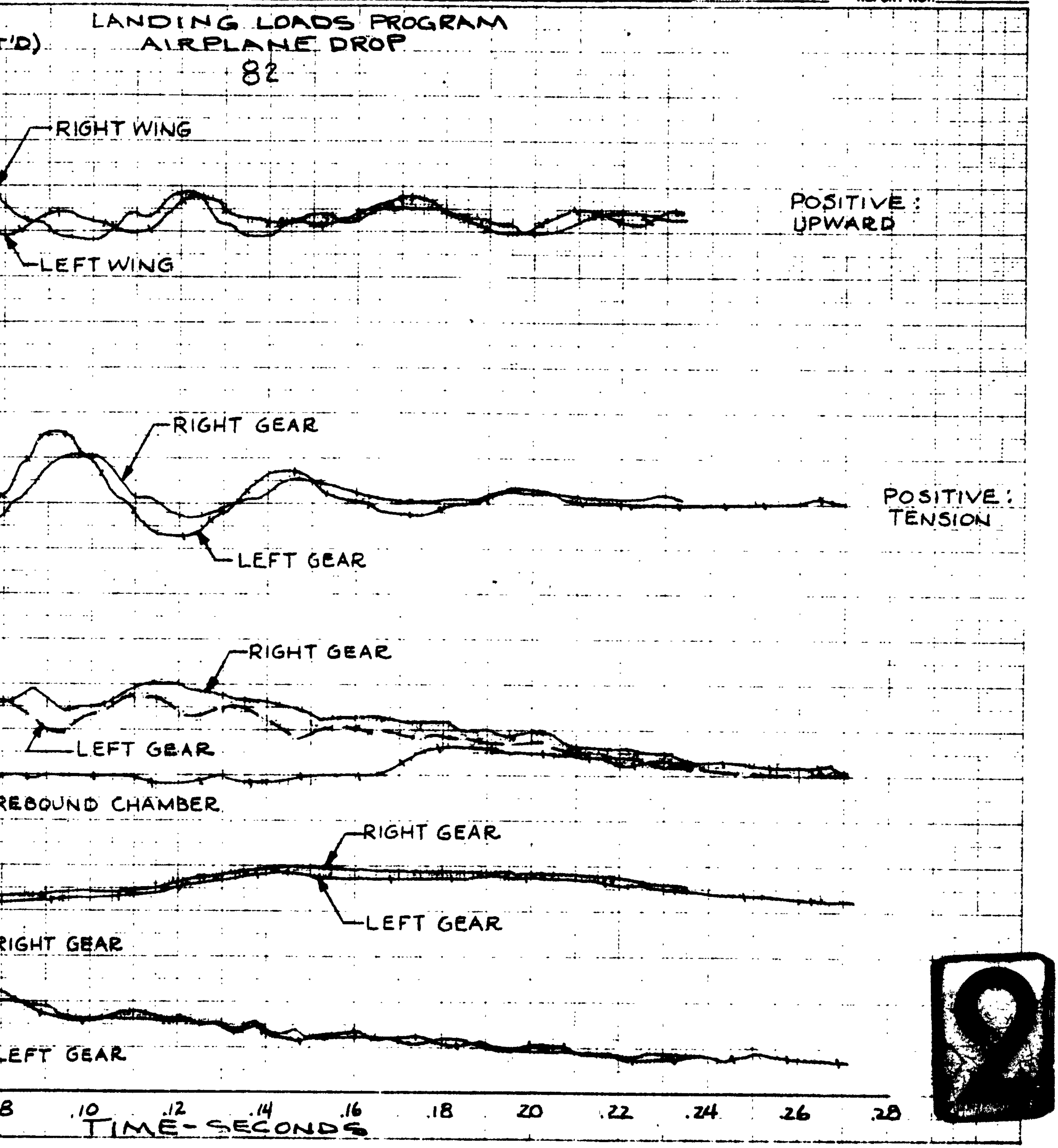
.28
TIME - SECONDS

PREPARED BY: I.B. Mos
CHECKED BY: F.C.A.
DATE: August 1962
TITLE: DROP TESTS

LANDING LOADS P
AIRPLANE DRO

FIGURE 19 (CONT'D)




LANDING LOADS PROGRAM
AIRPLANE DROP
82
T'D)
RIGHT WING
LEFT WING
POSITIVE: UPWARD
RIGHT GEAR
LEFT GEAR
POSITIVE: TENSION
RIGHT GEAR
LEFT GEAR
REBOUND CHAMBER
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RIGHT GEAR
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TIME-SECONDS

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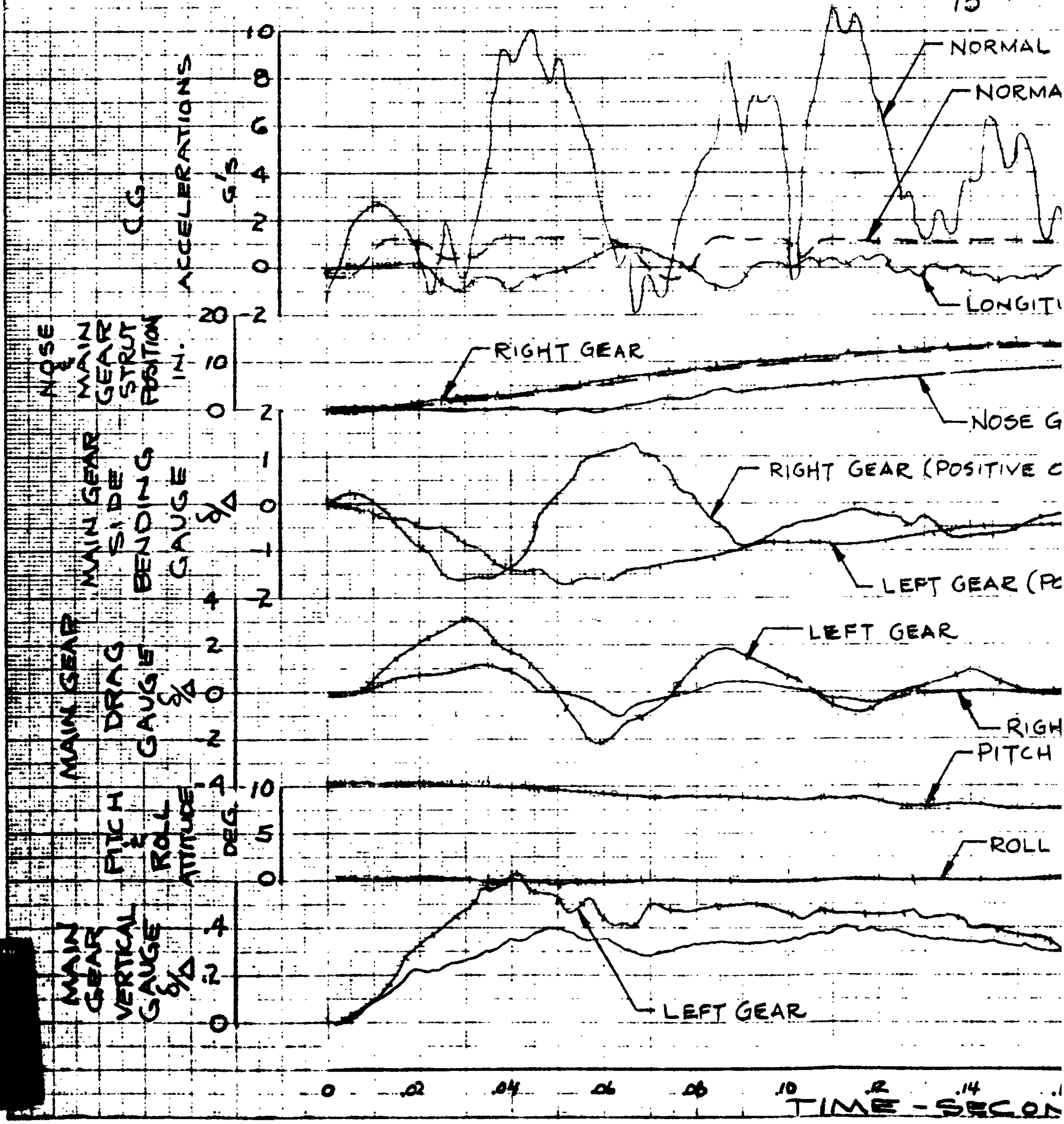
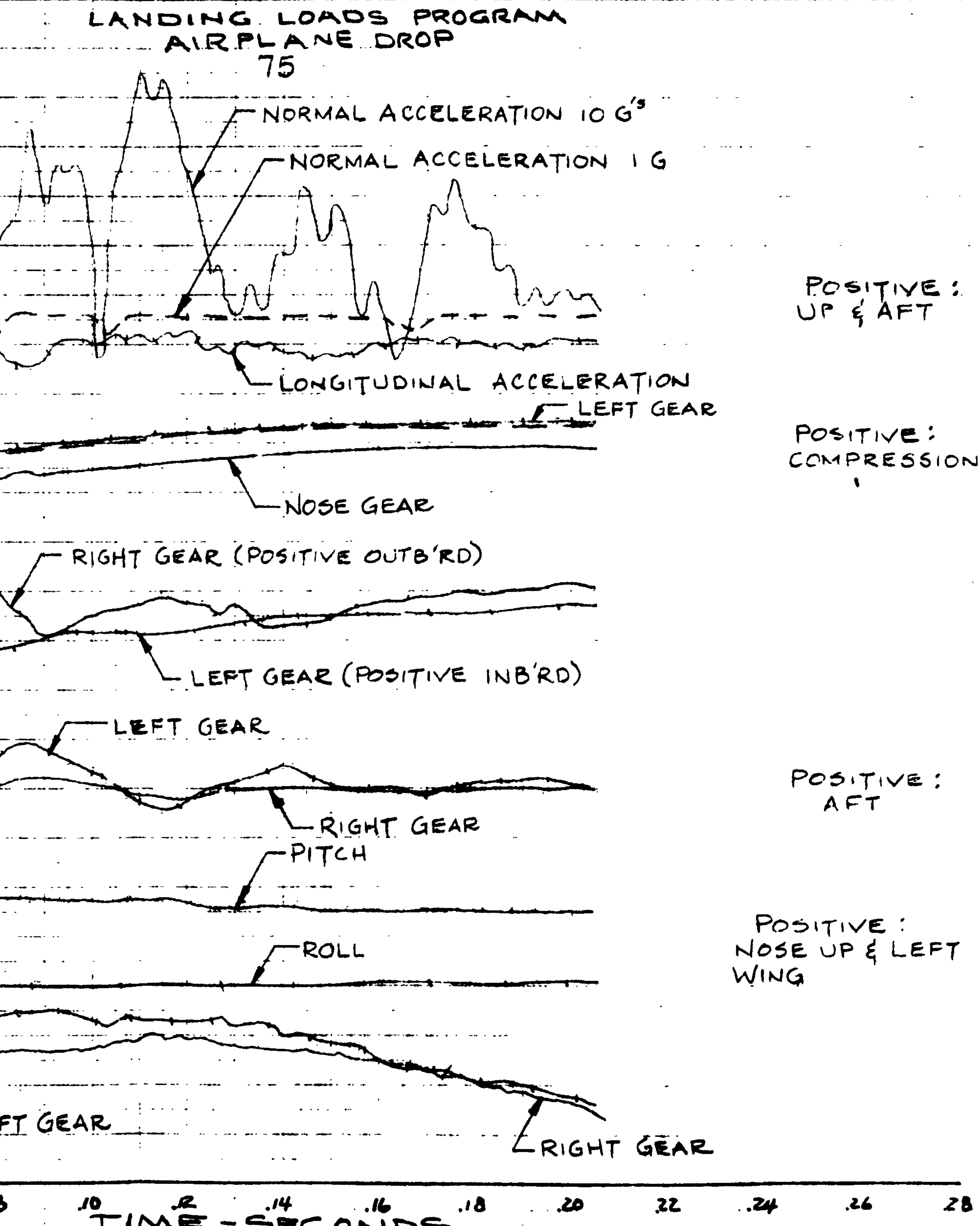
CHECKED BY: F.C.
DATE: August
TITLE: DROP TE

LANDING LOADS
AIRPLANE

FIGURE 20





LANDING LOADS PROGRAM
AIRPLANE DROP
75
NORMAL ACCELERATION 10 G's
NORMAL ACCELERATION 1 G
POSITIVE: UP & AFT
LONGITUDINAL ACCELERATION
LEFT GEAR
NOSE GEAR
POSITIVE: COMPRESSION
RIGHT GEAR (POSITIVE OUTB'RD)
LEFT GEAR (POSITIVE INB'RD)
LEFT GEAR
RIGHT GEAR
POSITIVE: AFT
PITCH
ROLL
POSITIVE: NOSE UP & LEFT WING
FT GEAR
RIGHT GEAR
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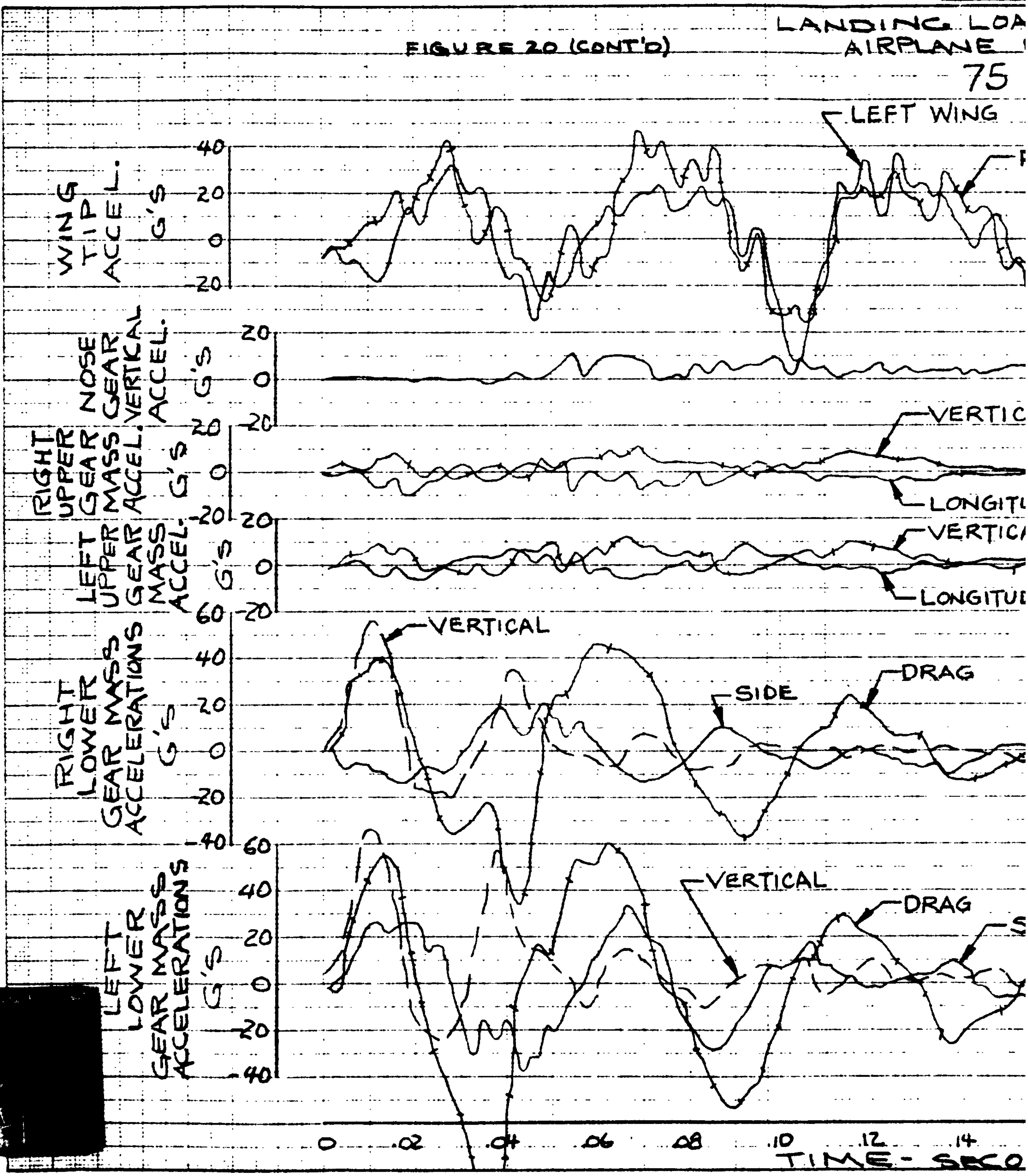
TIME - SECONDS

PREPARED BY: L.
CHECKED BY: F.
DATE: August
TITLE: DROP T

FIGURE 20 (CONT'D)



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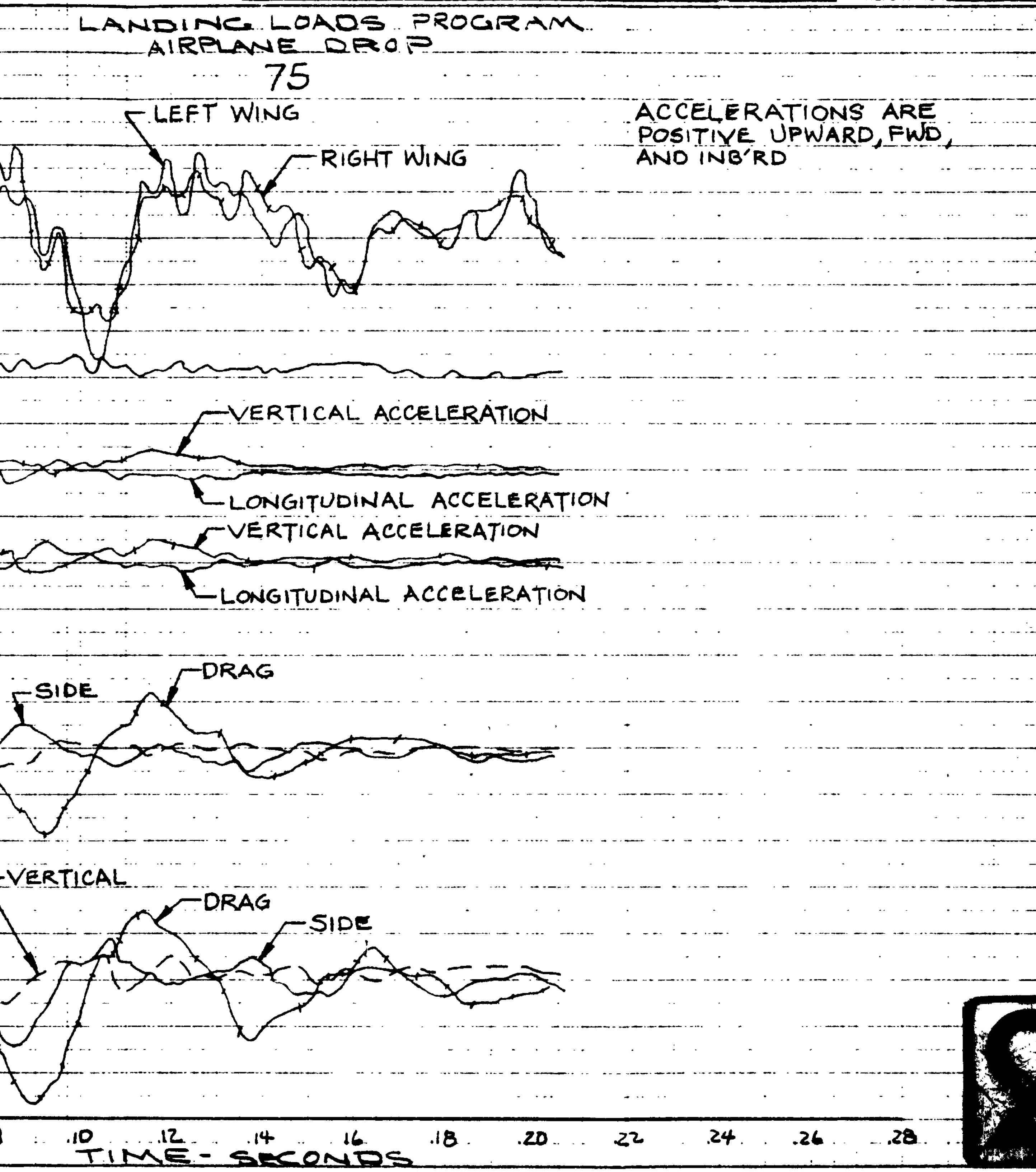

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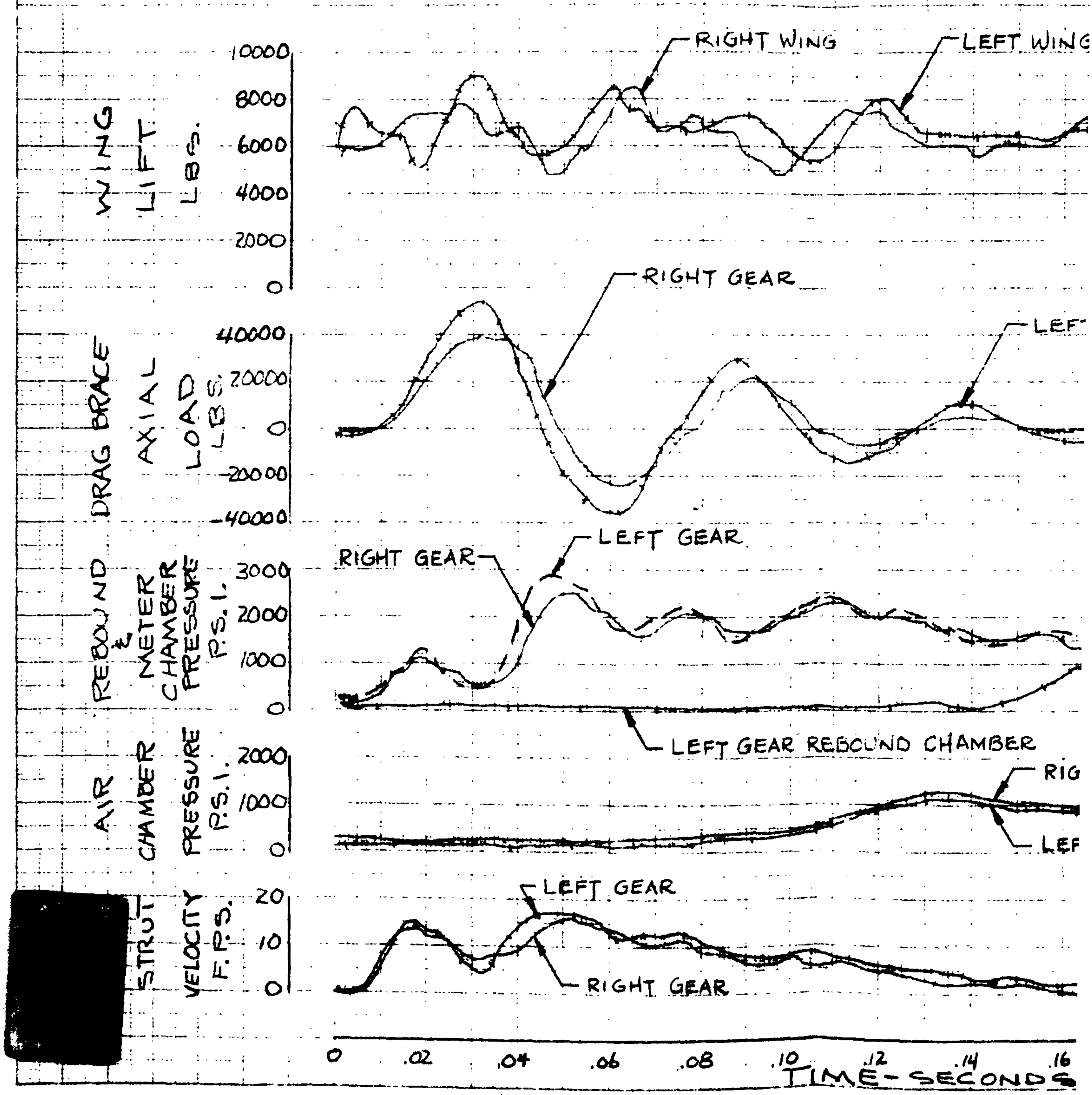
DATE: August 196
TITLE: DROP TESTS

FIGURE 20 (CONT'D)

LANDING LOADS F
AIRPLANE DRO
75



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DATE: August 1962
TITLE: DROP TESTS FOR LANDING LOADS INVESTIGATION

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AIRCRAFT DIVISION

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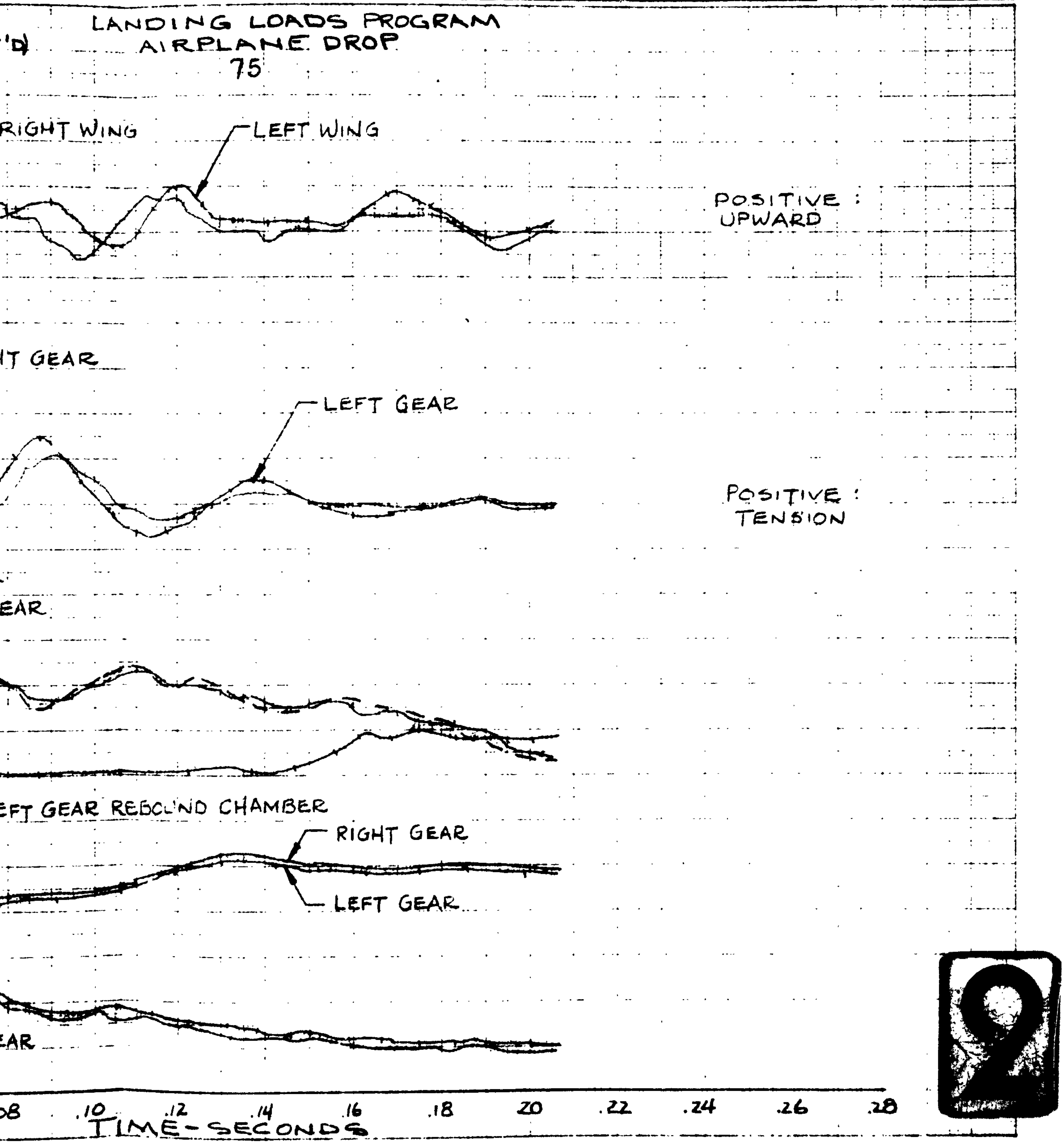

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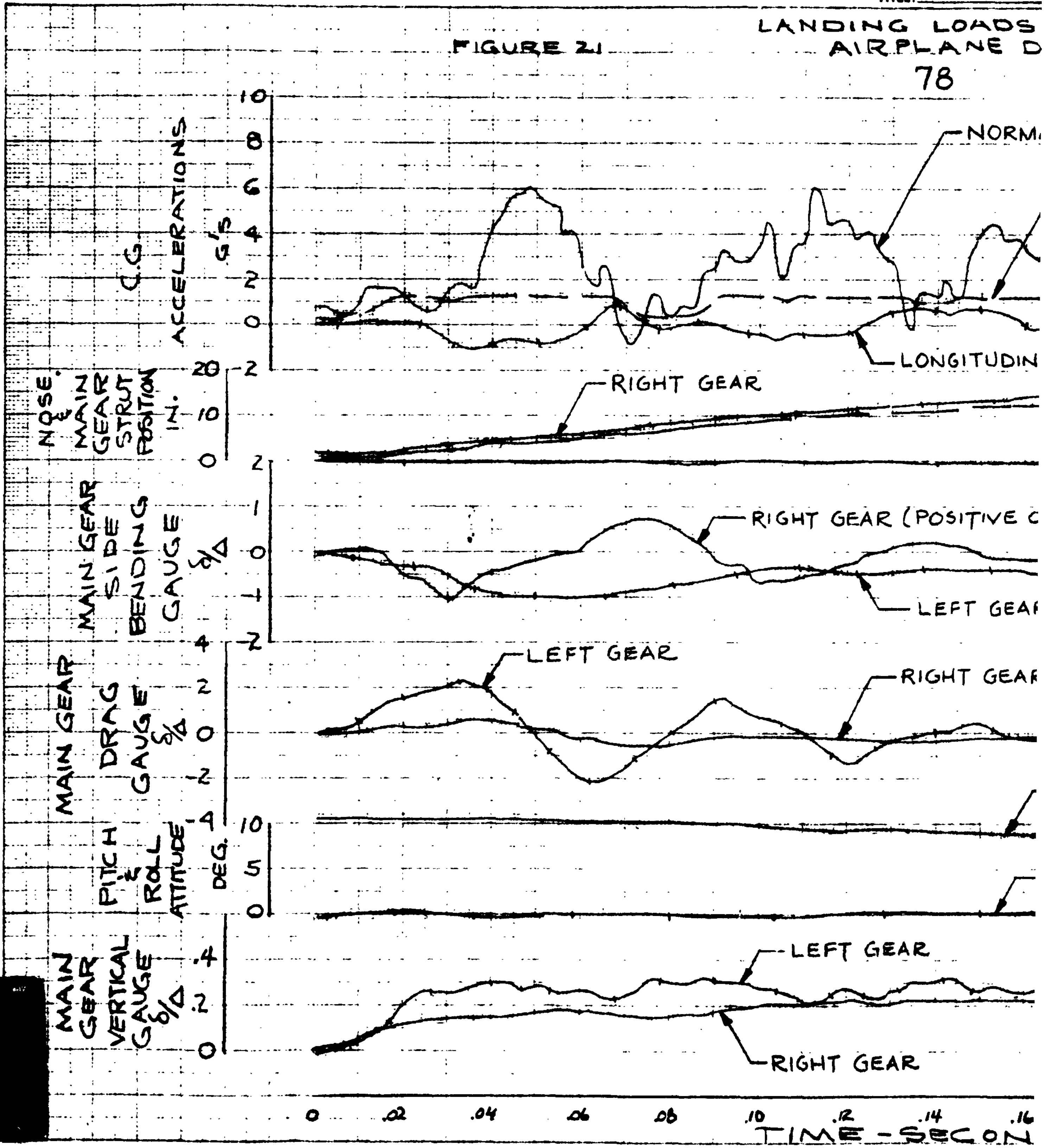
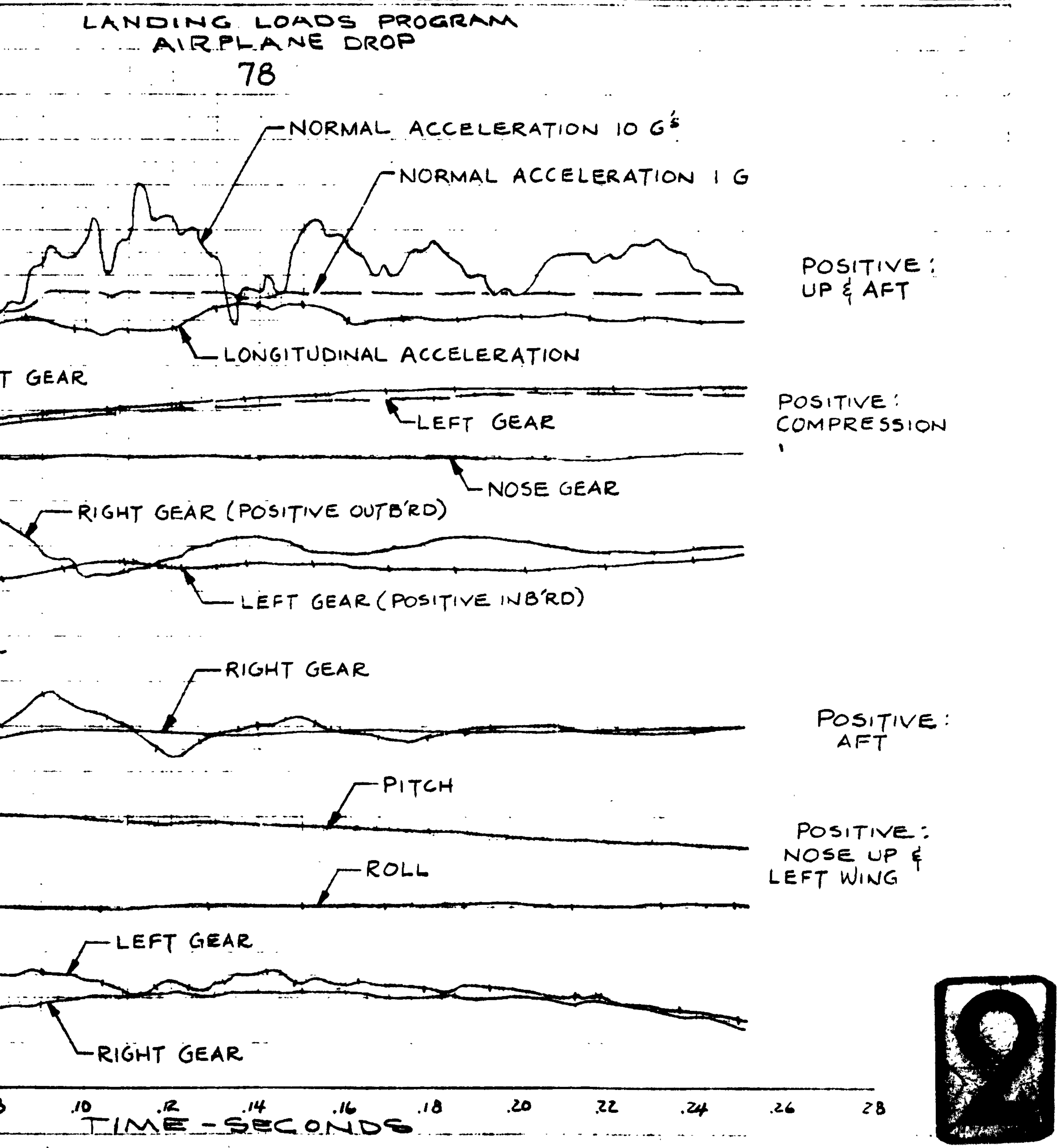
TITLE: DROP TESTS




LANDING LOADS PROGRAM
AIRPLANE DROP
78
NORMAL ACCELERATION 10 G's
NORMAL ACCELERATION 1 G
POSITIVE: UP & AFT
LONGITUDINAL ACCELERATION
T GEAR
LEFT GEAR
POSITIVE: COMPRESSION
NOSE GEAR
RIGHT GEAR (POSITIVE OUTB'RD)
LEFT GEAR (POSITIVE INB'RD)
RIGHT GEAR
POSITIVE: AFT
PITCH
POSITIVE: NOSE UP & LEFT WING
ROLL
LEFT GEAR
RIGHT GEAR
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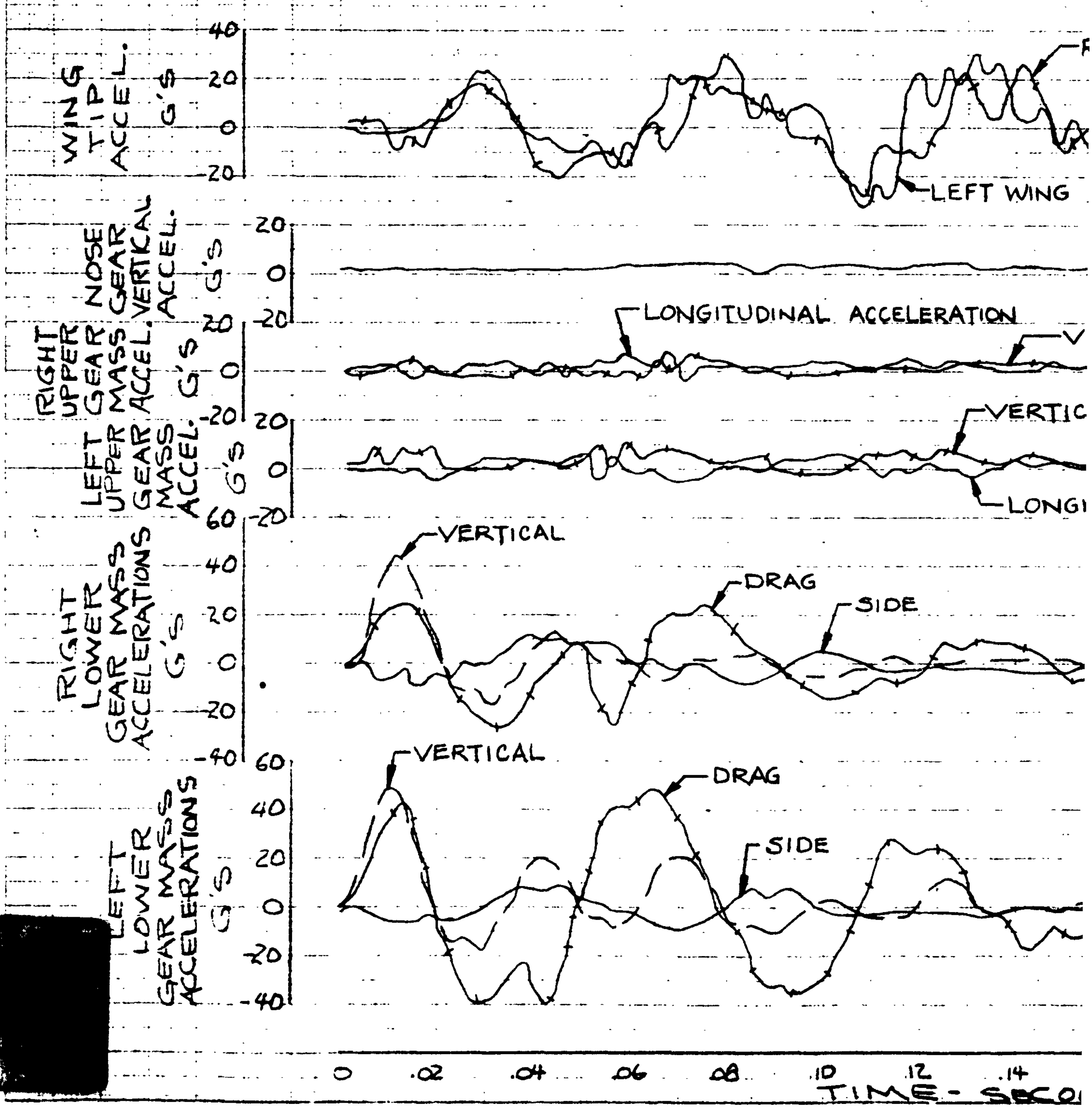
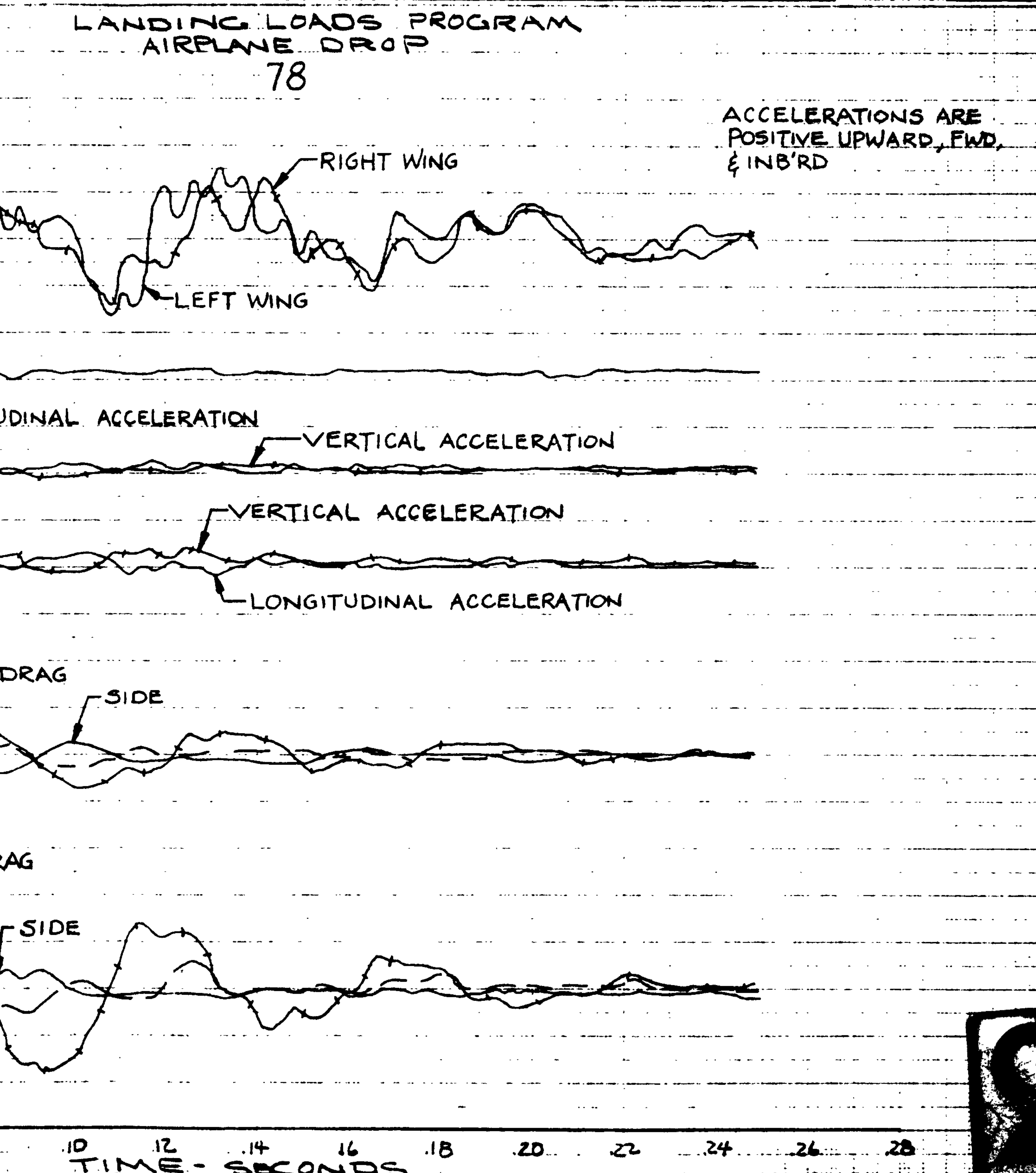
.26
.28
TIME - SECONDS

PREPARED BY: L.I
CHECKED BY: F.C
DATE: August
TITLE: DROP TE

LANDING LOA
AIRPLANE

FIGURE 21 (CONT'D)





LANDING LOADS PROGRAM
AIRPLANE DROP
78
ACCELERATIONS ARE POSITIVE UPWARD, FWD, & INB'RD
RIGHT WING
LEFT WING
UDINAL ACCELERATION
VERTICAL ACCELERATION
VERTICAL ACCELERATION
LONGITUDINAL ACCELERATION
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.12
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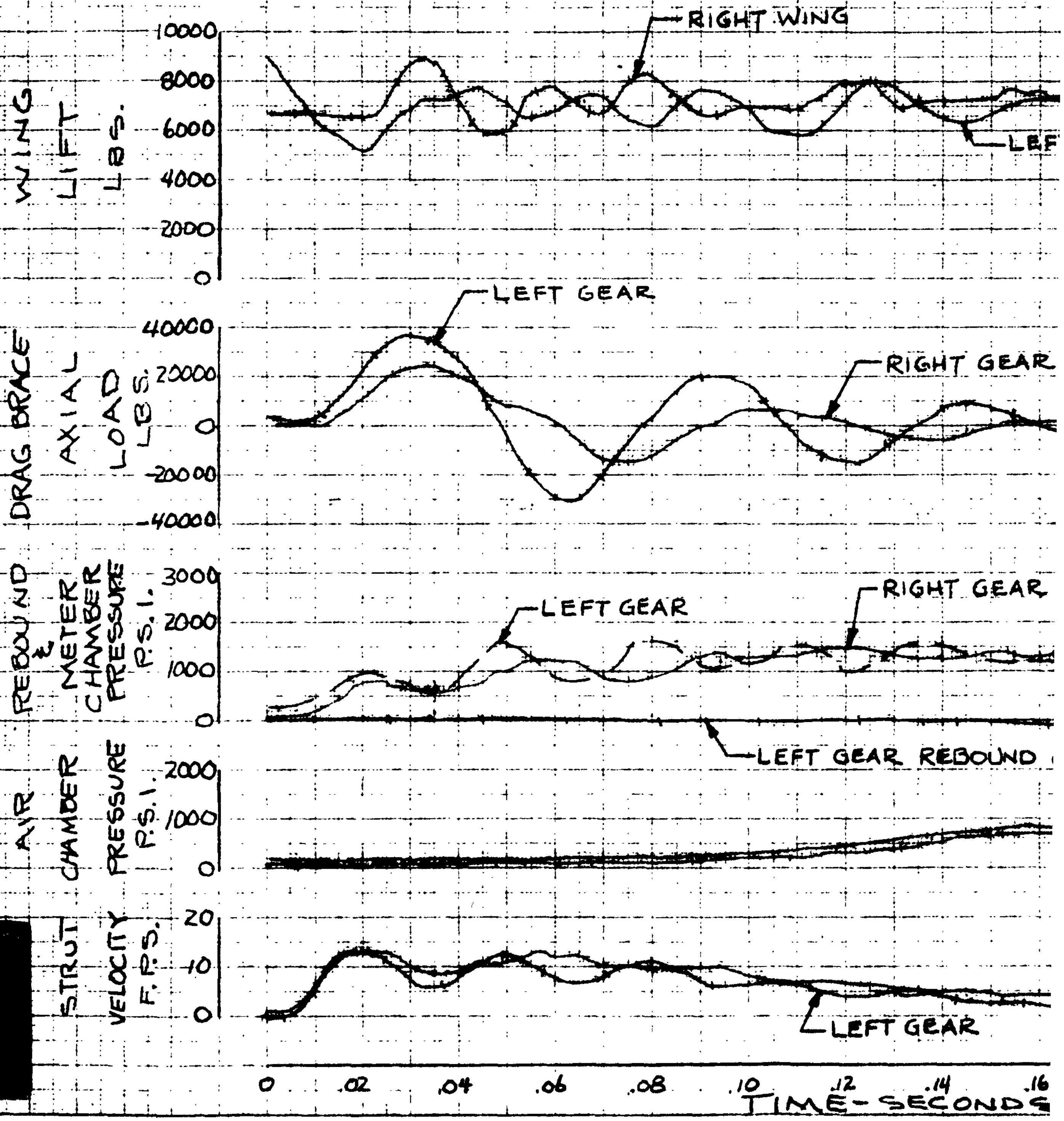
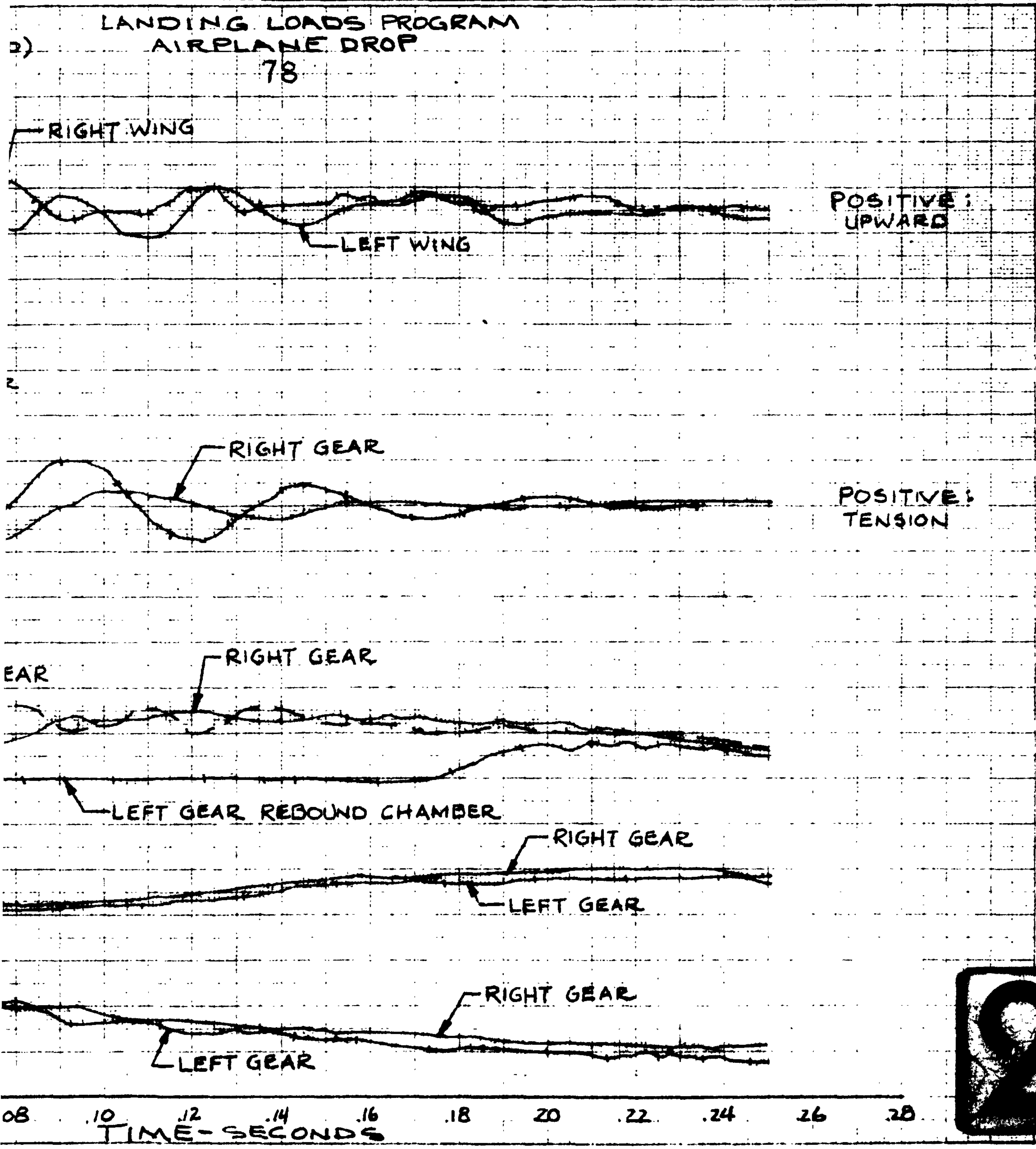
.22
.24
.26
.28
TIME - SECONDS

LANDING LOADS F
AIRPLANE DRO
78

FIGURE 21 (CONT'D)




LANDING LOADS PROGRAM
AIRPLANE DROP
78
RIGHT WING
LEFT WING
POSITIVE: UPWARD
RIGHT GEAR
POSITIVE: TENSION
EAR
RIGHT GEAR
LEFT GEAR REBOUND CHAMBER
RIGHT GEAR
LEFT GEAR
RIGHT GEAR
LEFT GEAR
.08
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.12
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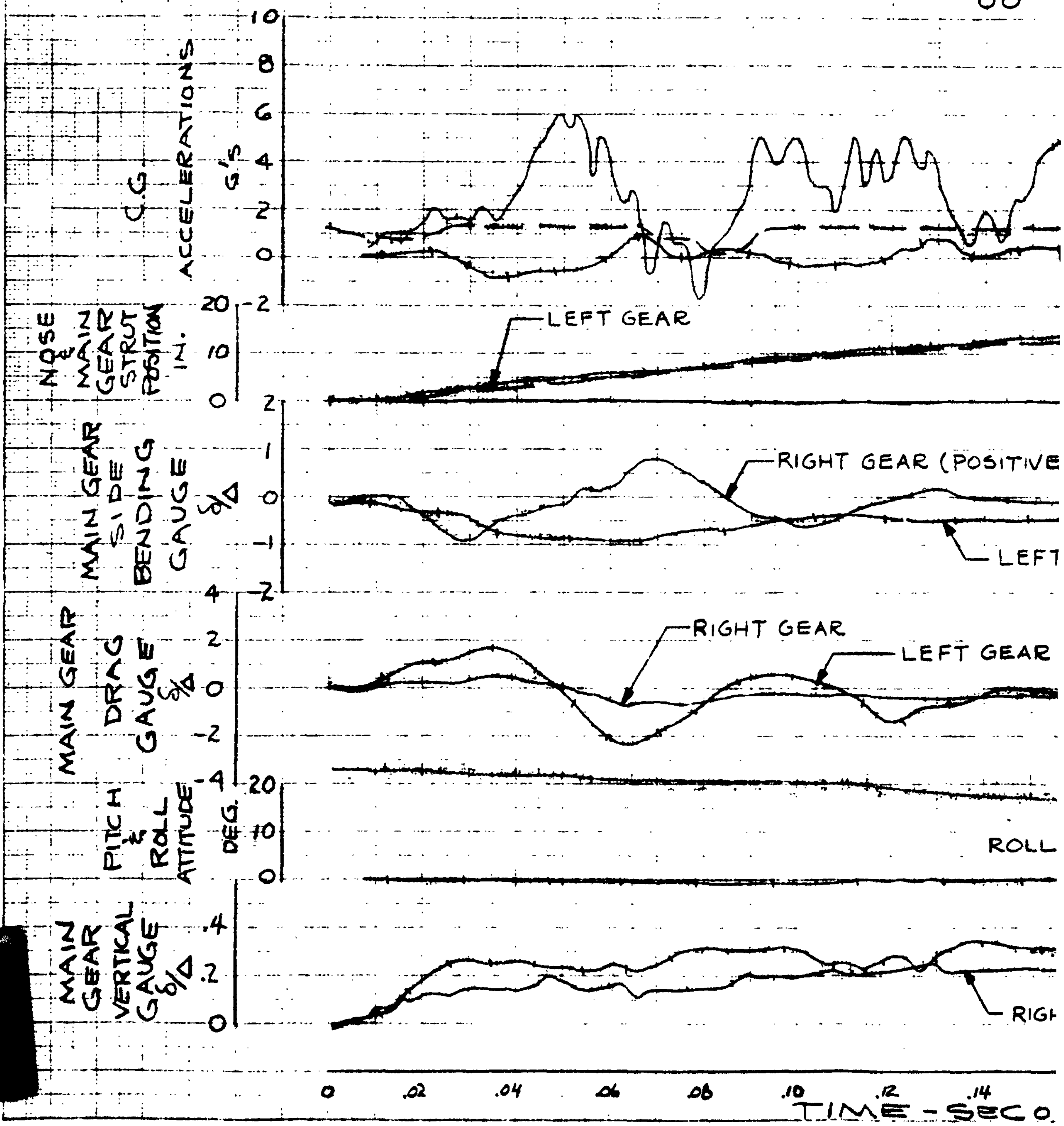
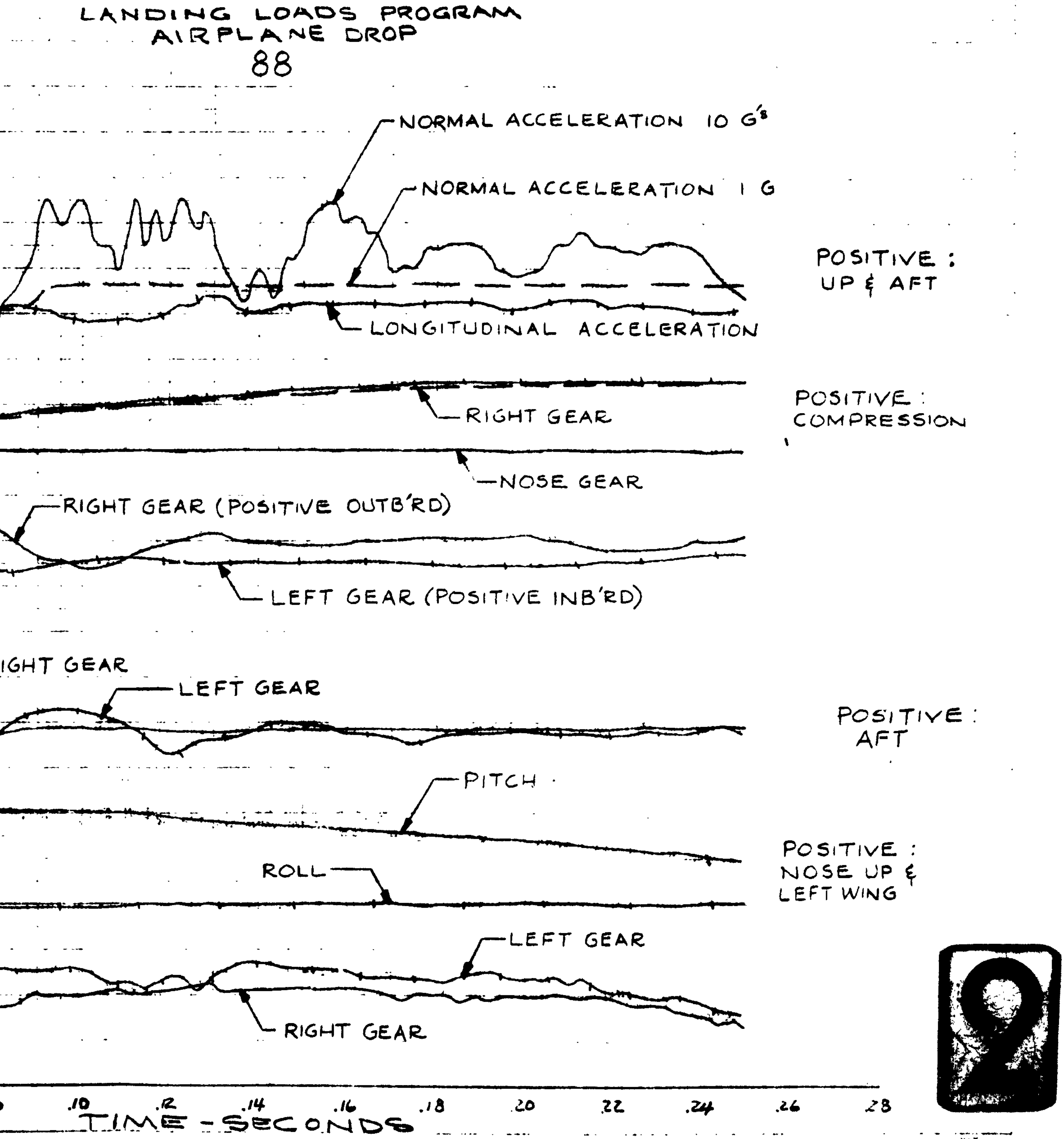
.26
.28
TIME-SECONDS

PREPARED BY: L.F
CHECKED BY: F.C
DATE: August
TITLE: DROP TE

FIGURE 22

LANDING LOAD
AIRPLANE
88




LANDING LOADS PROGRAM
AIRPLANE DROP
88
NORMAL ACCELERATION 10 G's
NORMAL ACCELERATION 1 G
POSITIVE: UP & AFT
LONGITUDINAL ACCELERATION
RIGHT GEAR
POSITIVE: COMPRESSION
NOSE GEAR
RIGHT GEAR (POSITIVE OUTB'RD)
LEFT GEAR (POSITIVE INB'RD)
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LEFT GEAR
POSITIVE: AFT
PITCH
POSITIVE: NOSE UP & LEFT WING
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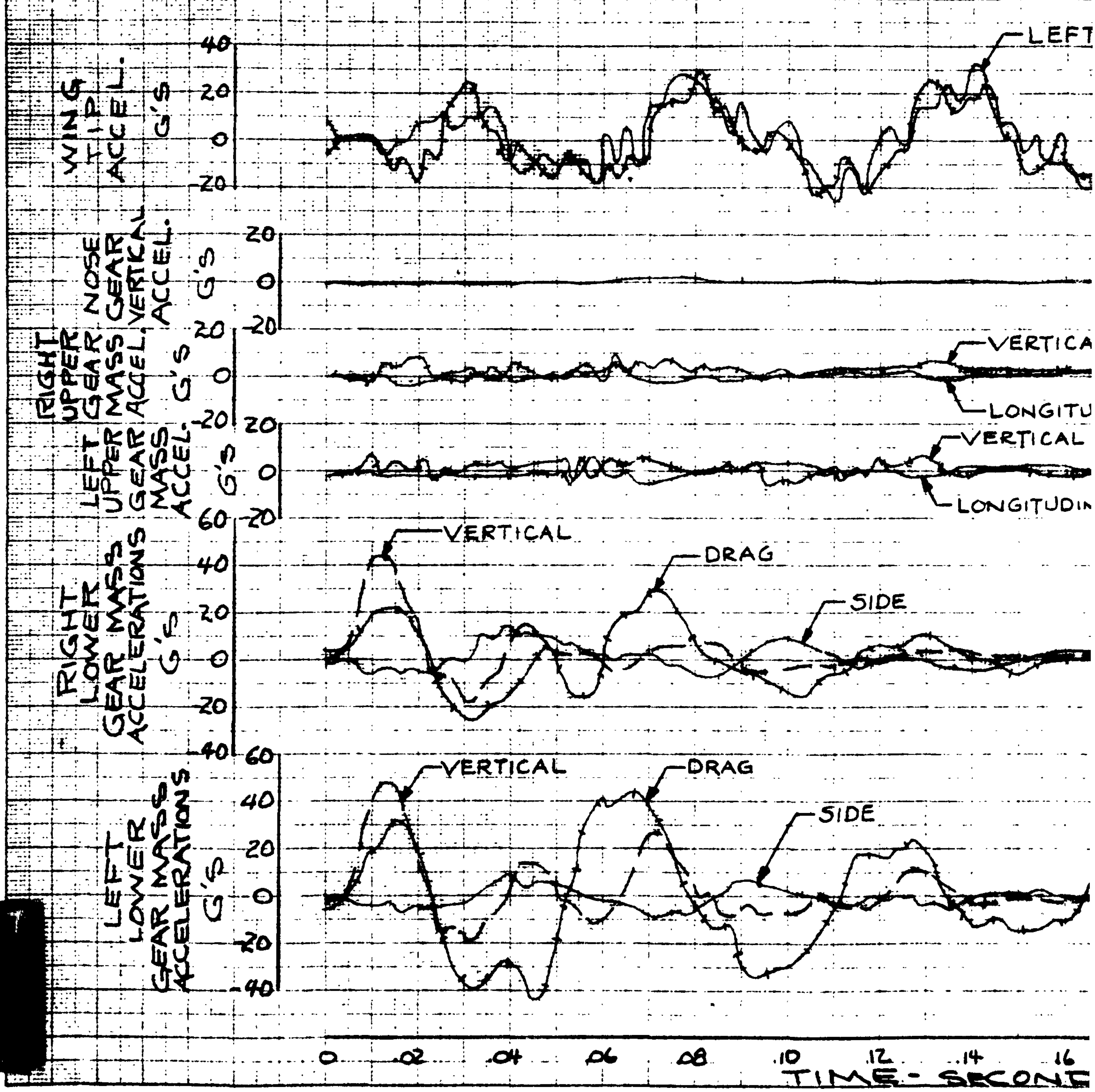
TIME - SECONDS

LANDING LOADS
AIRPLANE DR

88

FIGURE 22 (CONT'D)



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CHECKED BY: F.?.A.
DATE: August 1962

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AIRCRAFT DIVISION

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REPORT NO.: ES-40641

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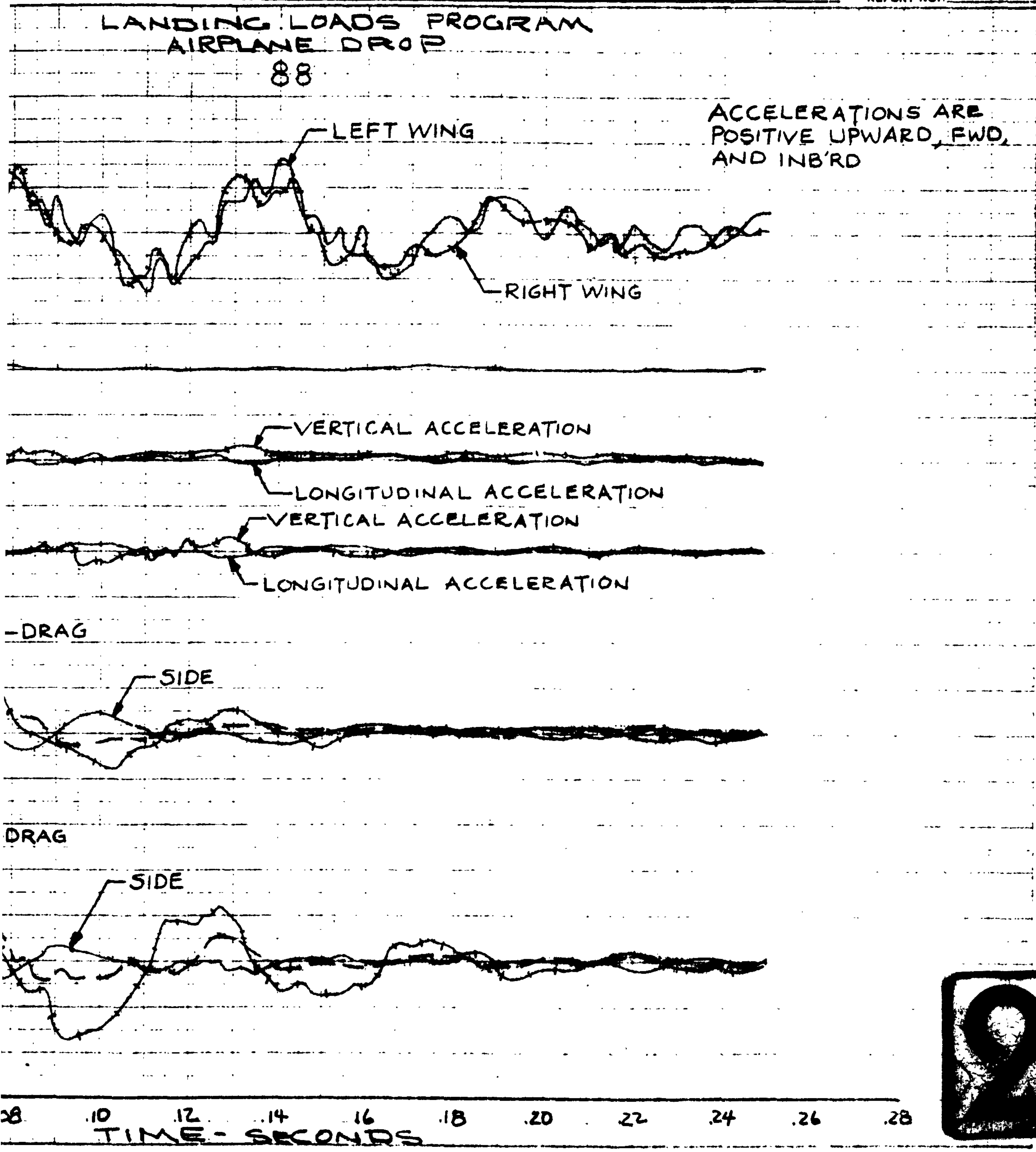

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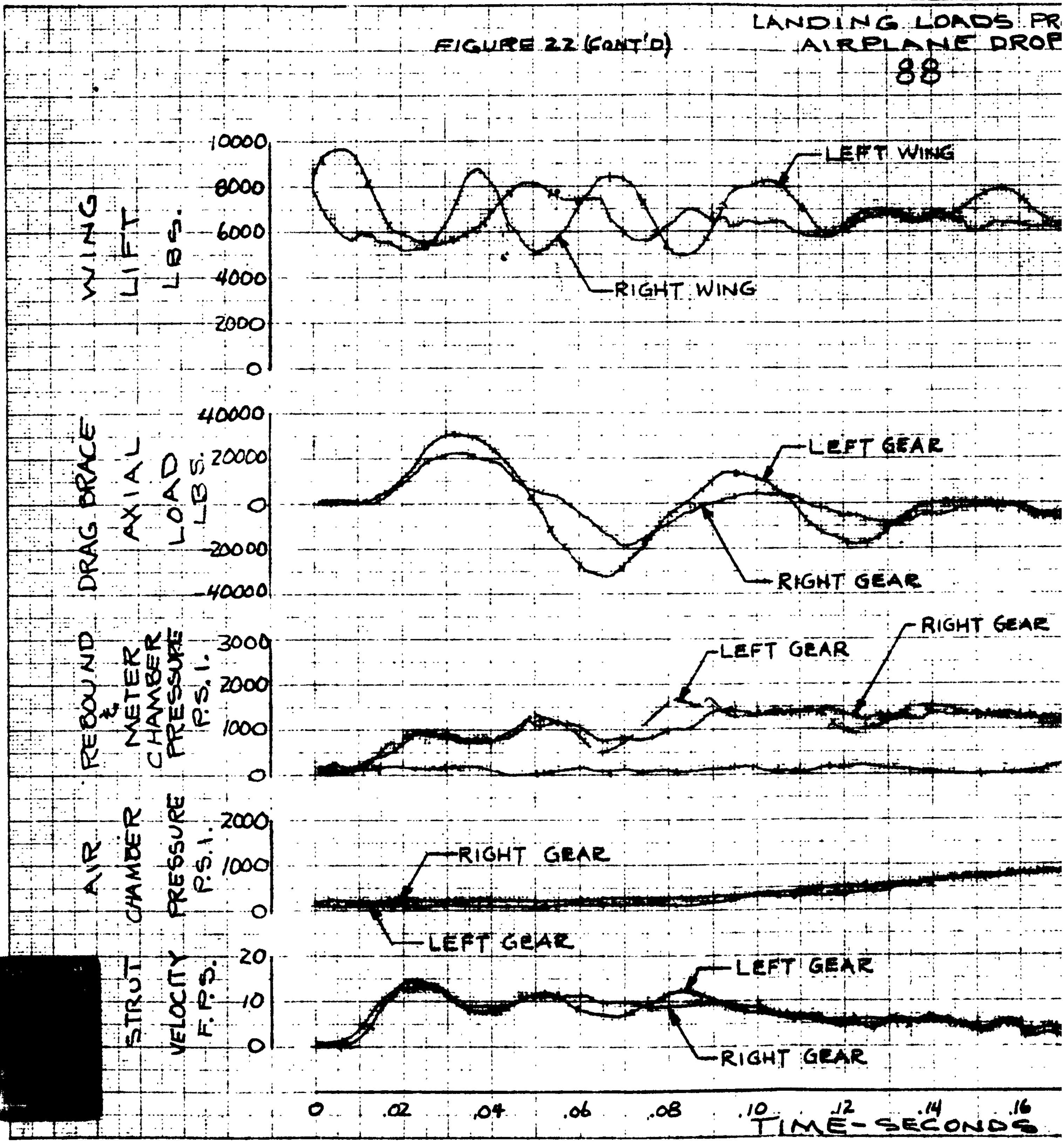
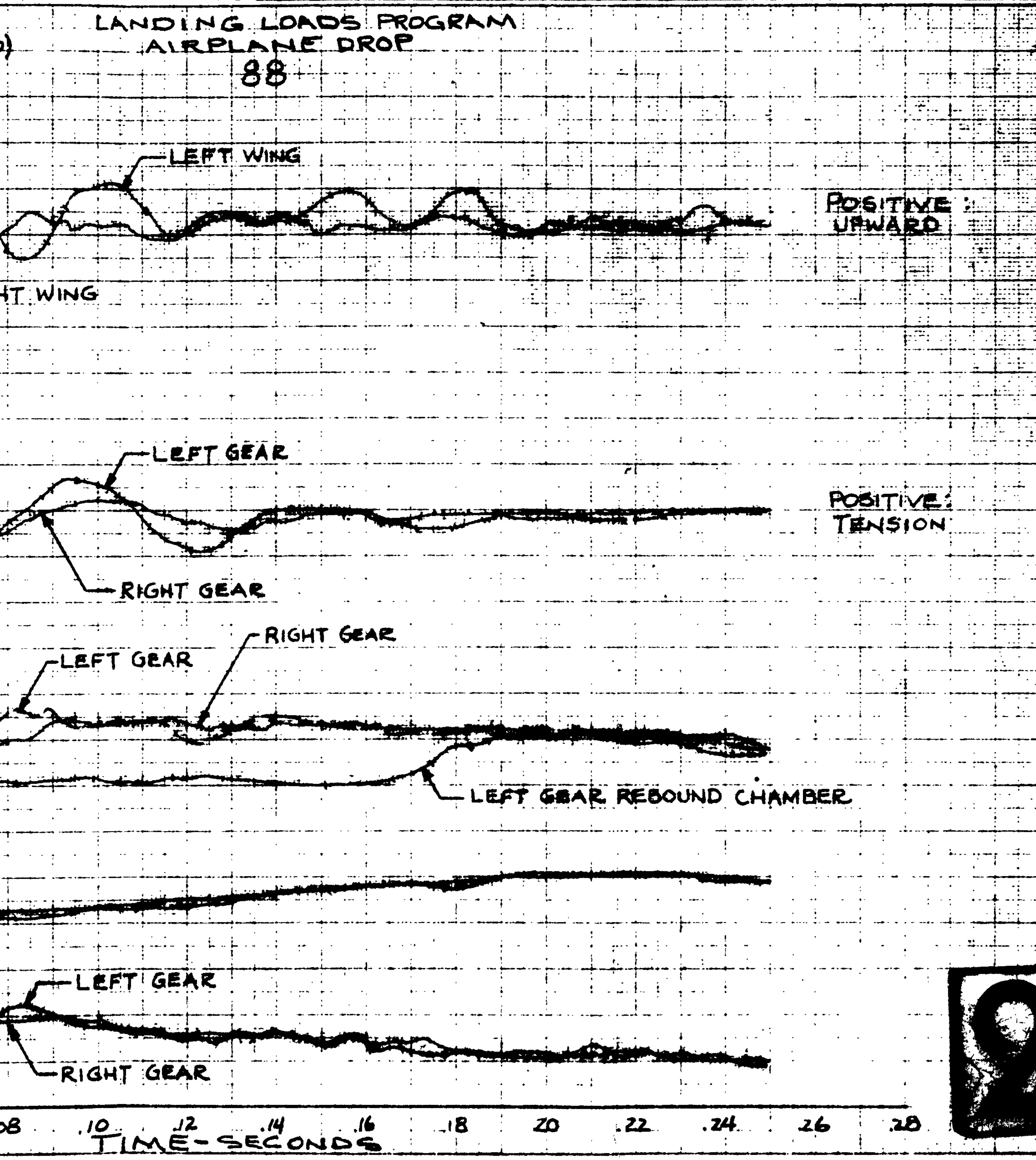
CHECKED BY: F.C.A.
DATE: August 1962
TITLE: DROP TESTS F




LANDING LOADS PROGRAM
AIRPLANE DROP
88
LEFT WING
HT WING
POSITIVE: UPWARD
LEFT GEAR
RIGHT GEAR
POSITIVE: TENSION
RIGHT GEAR
LEFT GEAR
LEFT GEAR REBOUND CHAMBER
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TIME-SECONDS

GROUND LOADS

GROUND LOADS

Vertical and horizontal loads at the ground obtained from the strut instrumentation and the equations on Page 24 are presented on Pages 69 to 84. A comparison is made with the loads registered on the reaction platform.

In discussing the probable accuracy and reliability of these data, it is desireable to review briefly the procedure used in the calibration of the axle strain gauges which supply the primary input for the "strut" ground loads data. A complete discussion of the calibration procedure is contained in Reference 1.

This procedure consisted of comparing the vertical ground load from strut data computed by Equation 12, with the vertical readings of the reaction platform. The comparison was made at .002 second intervals and the strain gauge constants were chosen such that the average error was minimum. Since the reaction platform drag measurement was not considered to be reliable, comparisons were made for the drag direction in perfectly vertical drops without spin-up, in which the drag load was known to be zero.

Thus, good agreement between the average vertical platform load and the average vertical strut load could be expected by the nature of the calibration. At any instant of time, however, differences might be expected, such differences being introduced primarily by relative accuracy of the dynamic responses of the strut instrumentation and the platform.

It is noted that in the first .03 seconds the peak vertical load from the reaction platform always exceeds the peak vertical load measured by the strut. This phenomenon is attributed to the response characteristic of the platform. Although a complete investigation of the dynamic characteristics of the platform has not been made, it has been determined (Reference 5) that the fundamental frequency in the vertical direction is 22 cycles per second which is close to the frequency of the first load peak. The high reaction platform load at this point is, therefore, believed to be dynamic overshoot. In view of this fact, the load variation shown by the strut in this region is considered more reliable.

Substantial differences are noted between the strut drag load and the reaction platform drag load. Readings of the reaction platform in the drag direction have been viewed with skepticism for some time inasmuch as there is a high coefficient of friction between the plate and the rollers under high load which inhibits an accurate response to high frequencies. This lack of high frequency response is evident both in the initial peak drag loads and in the subsequent oscillations where the reaction platform appears to be a rough average between the peaks of the load obtained by the strut instrumentation. On the other hand, the coefficients of friction computed from the left hand gear strut loads are higher than any known previous observation, and in view of the differences between the left and right hand coefficients, some skepticism regarding the accuracy of the left gear drag load readings is warranted. The following paragraphs discuss this point in detail.

Table VI summarizes the coefficients of friction data.

Table VI

COEFFICIENTS OF FRICTION AND SPIN-UP TIME

Drop No.	Source	Coefficient of Friction				Spin-Up Time** Seconds	
		Left Gear		Right Gear			
		Average	Maximum*	Average	Maximum*	Left	Right
84	Strut	.73	1.28	.48	.76	.044	.050
	Platform	.52	.64	.30	.42	.044	.048
70	Strut	.65	1.19	.55	.68	.047	.059
	Platform	.63	.63	.46	.60	.046	.058
68	Strut	.66	1.04	.53	.75	.041	.050
	Platform	.46	.59	.44	.61	.040	.047
93	Strut	.80	1.33	.54	.70	.036	.040
	Platform	.47	.58	.46	.70	.036	.040
82	Strut	.76	1.14	.65	.72	.042	.048
	Platform	.50	.64	.54	.78	.041	.048
75	Strut	.72	1.10	.52	.66	.035	.042
	Platform	.48	.63	.51	.63	.035	.043
78	Strut	.72	1.36	.44	.68	.047	.054
	Platform	.48	.66	.50	.91	.043	.053
88	Strut	.87	1.55	.62	1.03	.048	.057
	Platform	.47	.62	.45	.61	.045	.053

* Points prior to t = .01 are ignored.

** To be precise, in drop tests this is "spin-down" time.

The data are further summarized in the following table in which the peculiar nature of the left gear data is apparent:

	Coefficient of Friction		Avg.
	Average Maximum	Average Average	Spin-Up Time-Sec
Left gear - Strut	1.25	.74	.43
Platform	.63	.50	.41
Right gear - Strut	.75	.54	.50
Platform	.66	.46	.49

This table shows that the strut instrumentation (both right and left) gives higher drag loads than the platform. It also shows that the left gear spin-up time is on the average substantially less than the right, hence higher drag loads would be expected for the left gear.

To further explore the accuracy of the drag data, the wheel RPM was computed from the equation

$$RPM = \frac{60}{2\pi I_p}\int (R - C) \cdot FHG \cdot dt$$

where I_p = the polar moment of inertia of the rotating mass,

R = Tire radius

C = Tire deflection

FHG = Drag force at the ground

The integration was carried out from time of contact to the time that FHG reduces to zero. The following results were obtained:

Table VII

Comparison of Calculated and Measured Wheel Angular Velocity

Drop No.	Source	Wheel Rotational Velocity Left Gear RPM	Left Gear Dev. From Meas. %	Right Gear RPM	Right Gear Dev. From Meas. %
84	Direct Measurement	1811		1794	
	Calculated - Strut Data	2112.8	+16	1671	- 7.1
	Calculated - Platform Data	1734.6	-4.3	928	-48.4
70	Direct Measurement	2097		2089	
	Calculated - Strut Data	2082	- .1	2037	- 2.8
	Calculated - Platform Data	2035	- .3	1937	- 7.9
68	Direct Measurement	1925		1918	
	Calculated - Strut Data	2138	+11	2137	+11
	Calculated - Platform Data	1670	-15	1810	- 5.7
93	Direct Measurement	1936		1912	
	Calculated - Strut Data	2352	+21	2016	+ 5.1
	Calculated - Platform Data	1628	-19	1781	- 7.1
82	Direct Measurement	2074		2044	
	Calculated - Strut Data	2542	+22	2257	+10
	Calculated - Platform Data	1794	-15	1921	- 6.3

Average Deviation from Measured RPM

	Left	Right
Strut	+14.4	+ 3.3
Platform	-10.1	- 6.8 *

* Neglects Drop 84

The calculations associated with the foregoing table are inherently of low accuracy because of the possible variation in polar moment of inertia of the wheel and tire. The value used in these calculations, 11.26 slug-in^2, was obtained from manufacturer's data and is considered accurate within ±15%. In addition to variations caused by dimensional tolerances and wear of the tire, I_p will vary with rotational velocity and with age, these latter variations tending to increase the moment of inertia by approximately 10%. If the left hand gear moment of inertia were 10% higher than the right, Table VII would show reasonable correlation for the left hand gear (i.e., the deviations shown would be reduced by 10%). Definite conclusions regarding the accuracy of the drag data cannot, therefore, be drawn from the spin-up calculations.

The high coefficient of friction for the left gear still remains to intrude an element of doubt on the accuracy of the left gear drag data. Before the possibility of drag coefficients in excess of 1.0 is abandoned, it is recommended that a low speed sliding coefficient of friction test be conducted using the actual platform surface. Reference (6), Page 23, shows a rough correlation between sliding coefficient of friction and values obtained from dynamic tests. Should the sliding coefficient of friction for the platform be substantially higher than that shown in Reference (6), there would be cause to believe that dynamic coefficients in excess of 1.0 could be reached in drop test.

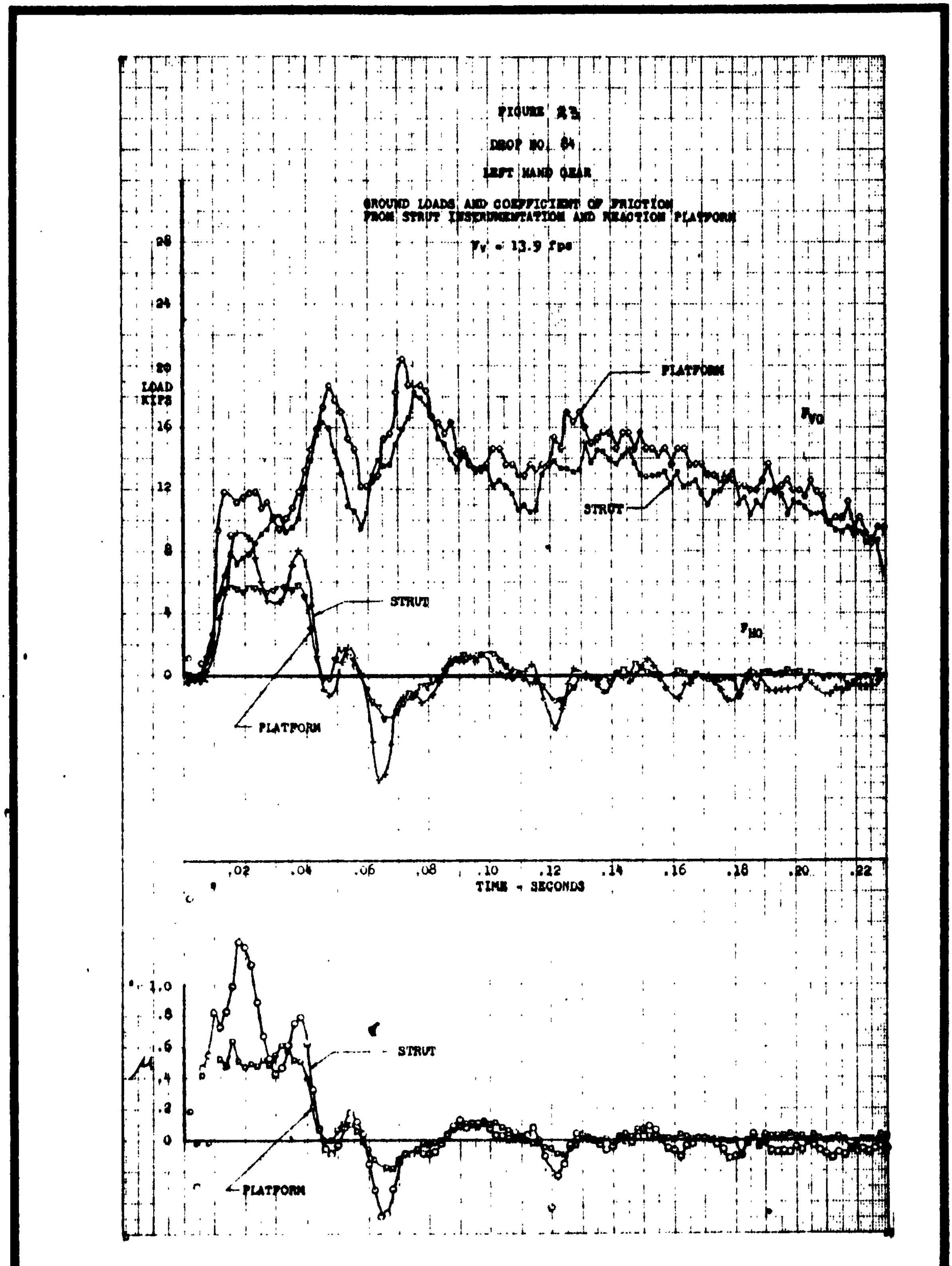


FIGURE
DROP NO. 84
LEFT HAND GEAR
GROUND LOADS AND COEFFICIENT OF FRICTION
FROM STRUT INSTRUMENTATION AND REACTION PLATFORM
V_V = 13.9 fps
LOAD KIPS
28
24
20
16
12
8
4
0
PLATFORM
STRUT
F_{VG}
F_{HG}
.02
.04
.06
.08
.10
.12
.14
.16
.18
.20
.22
TIME - SECONDS
μ
1.0
.8
.6
.4
.2
0

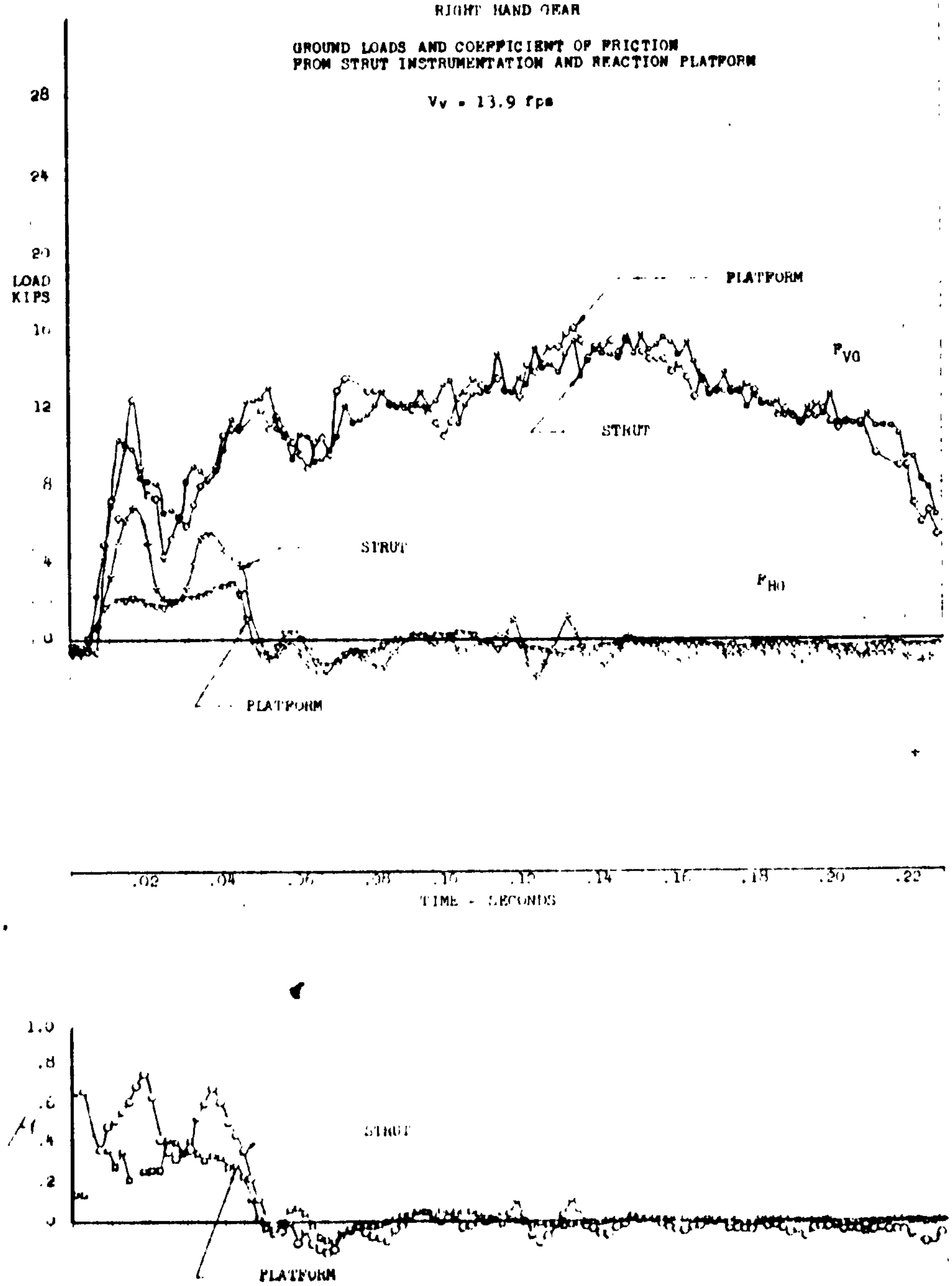
FIGURE 24

DROP NO. 84

RIGHT HAND GEAR

GROUND LOADS AND COEFFICIENT OF FRICTION FROM STRUT INSTRUMENTATION AND REACTION PLATFORM

V_V = 13.9 fps



FORM LB25-5 1A (3-52)

PREPARED BY: L. B. Mosby DATE

CHECKED BY: F. C. A. DATE

DOUGLAS AIRCRAFT COMPANY, INC.

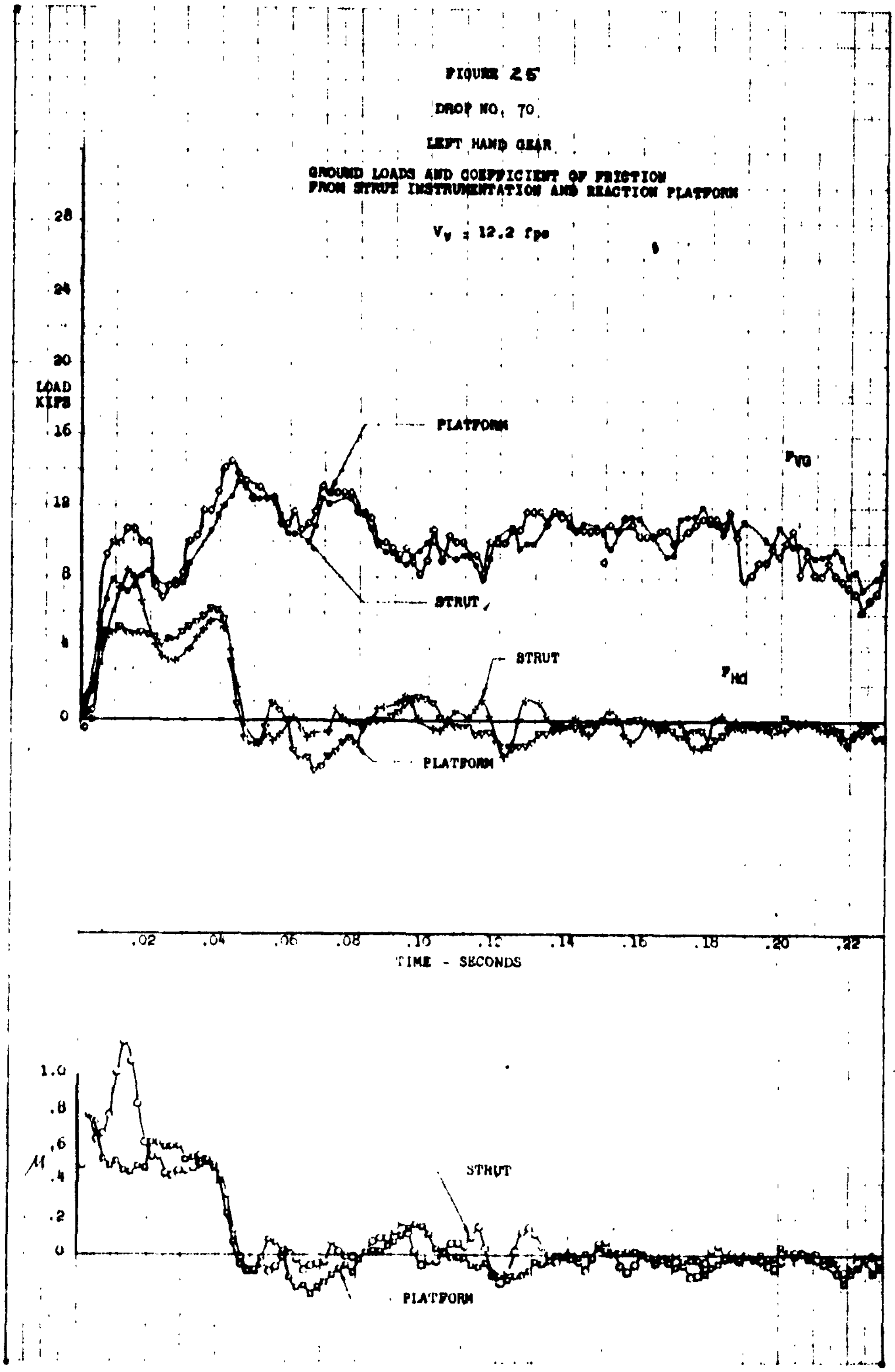
LONG BEACH DIVISION

PAGE: 71

MODEL: A4D-2

TITLE: LANDING LOADS INVESTIGATION LABORATORY DROP TESTS

REPORT NO. ES-40641



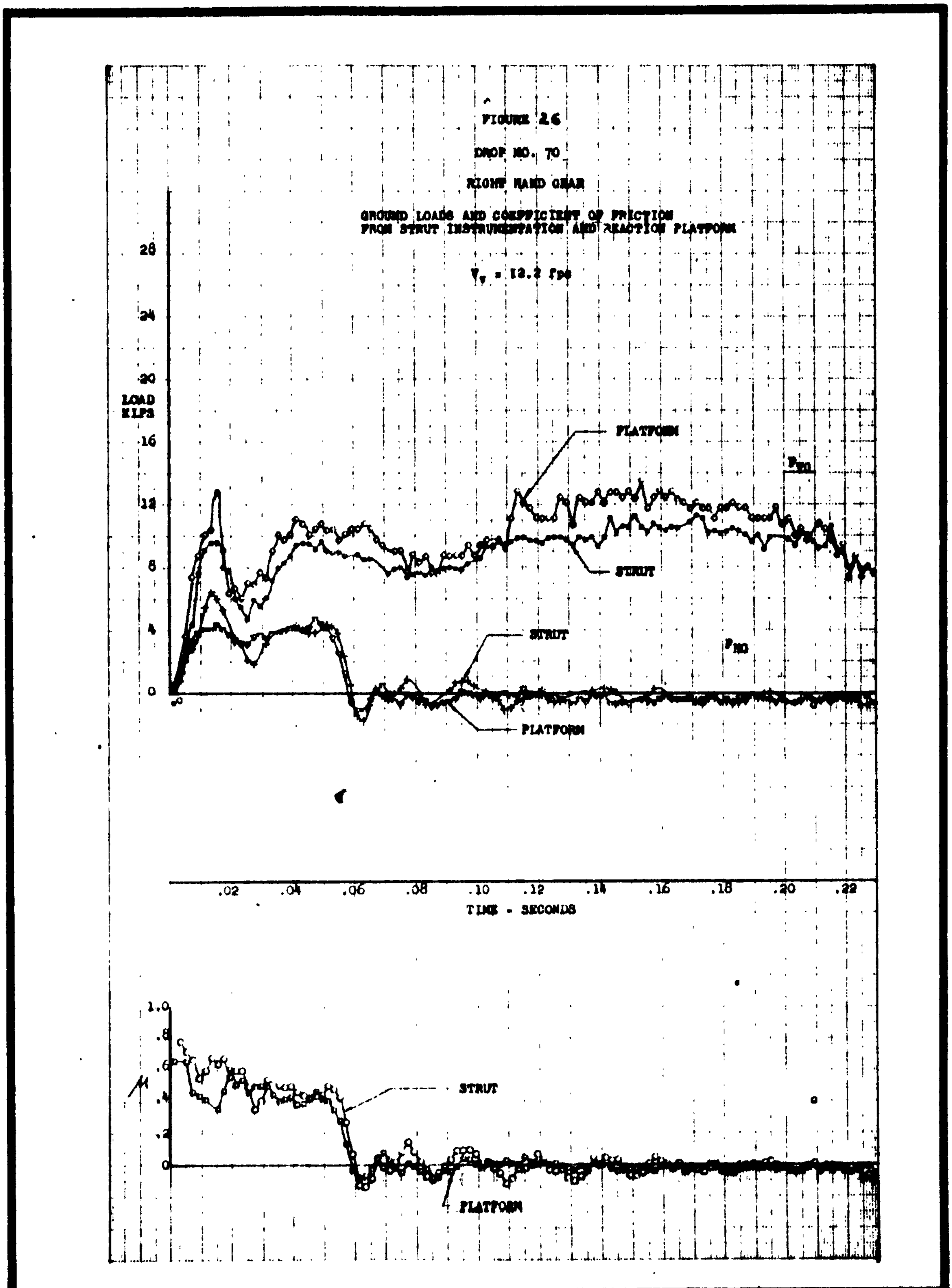


FIGURE 26
DROP NO. 70
RIGHT HAND GEAR
GROUND LOADS AND COEFFICIENT OF FRICTION FROM STRUT INSTRUMENTATION AND REACTION PLATFORM
LOAD KIPS
28
24
20
16
12
8
4
0
PLATFORM
STRUT
STRUT
PLATFORM
.02
.04
.06
.08
.10
.12
.14
.16
.18
.20
.22
TIME - SECONDS
1.0
.8
.6
.4
.2
0
μ
STRUT
PLATFORM

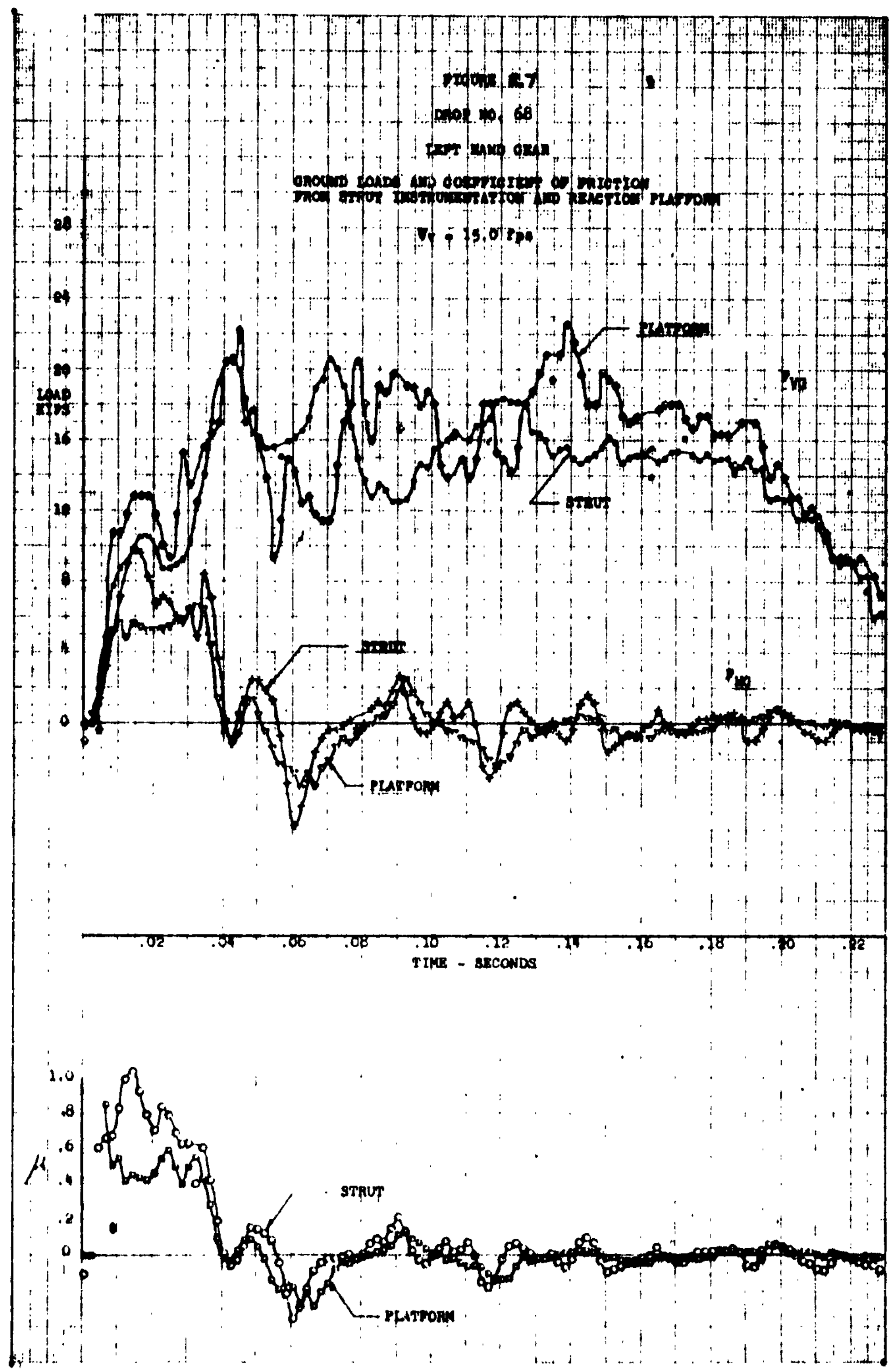


FIGURE
DROP NO. 68
LEFT HAND GEAR
GROUND LOADS AND COEFFICIENT OF FRICTION
FROM STRUT INSTRUMENTATION AND REACTION PLATFORM
V_v = 15.0 Fps
LOAD KIPS
28
24
20
16
12
8
4
0
PLATFORM
STRUT
F_{VG}
F_{HG}
.02
.04
.06
.08
.10
.12
.14
.16
.18
.20
.22
TIME - SECONDS
1.0
.8
.6
.4
.2
0
μ
STRUT
PLATFORM

FORM LB85 S-1A
(3-52)

PREPARED BY: L. R. Mosby DATE

CHECKED BY: F. C. A. DATE

TITLE: LANDING IMPACT INVESTIGATION LABORATORY DROP TESTS

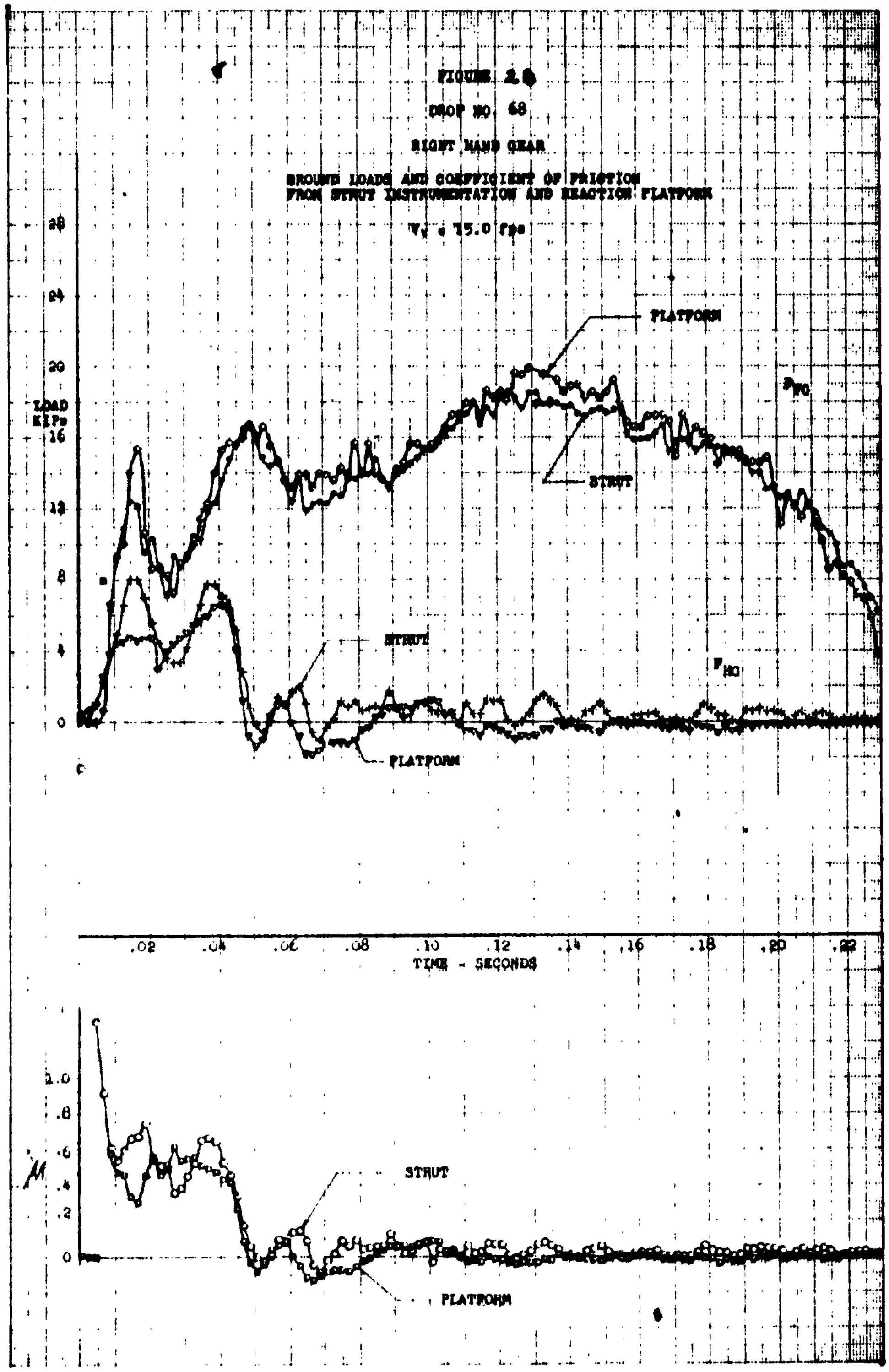
DOUGLAS AIRCRAFT COMPANY, INC.

LONG BEACH DIVISION

PAGE: 74

MODEL: A4D-2

REPORT NO. ES-40641



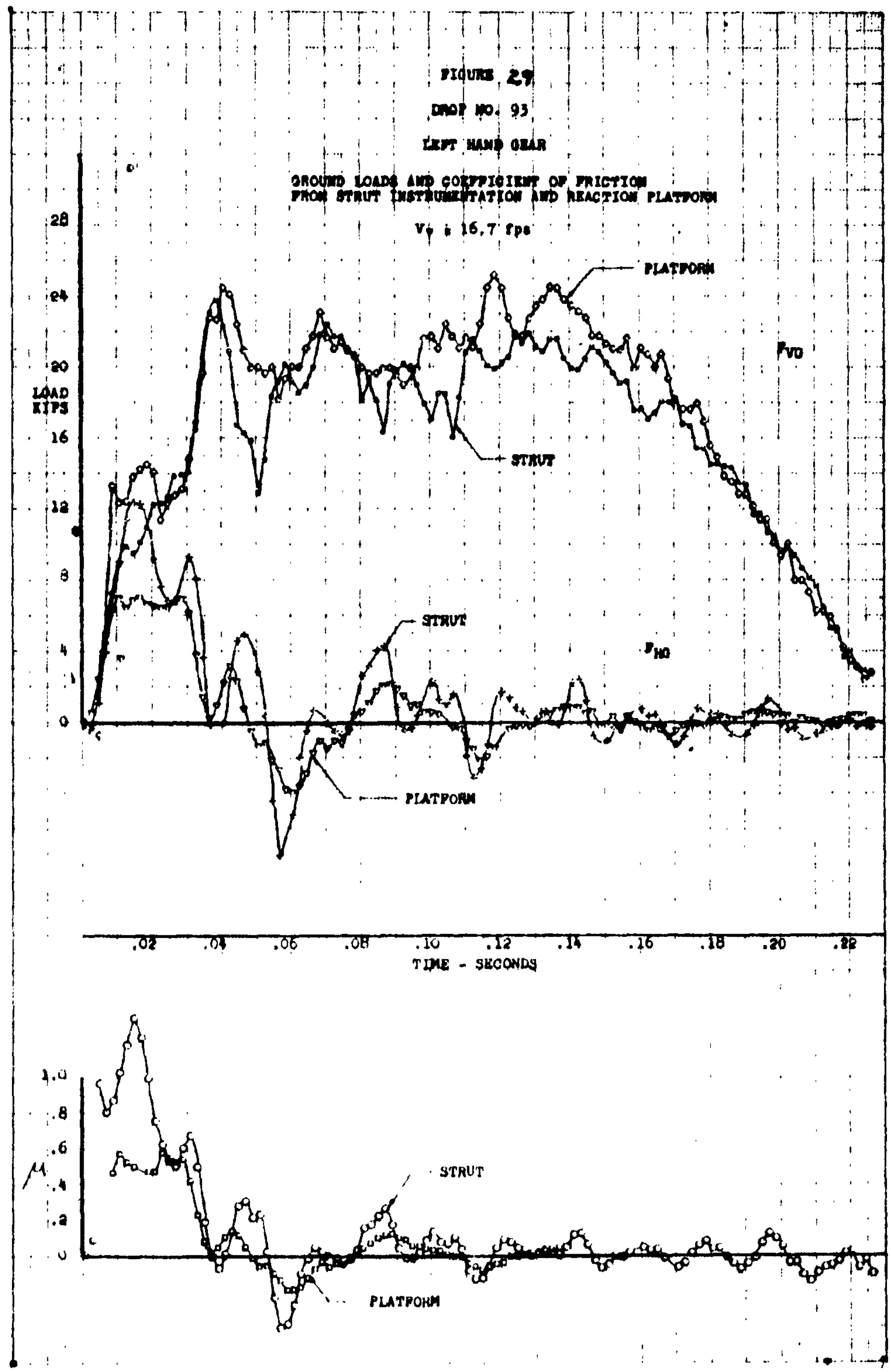


FIGURE 29
DROP NO. 93
LEFT HAND GEAR
GROUND LOADS AND COEFFICIENT OF FRICTION
FROM STRUT INSTRUMENTATION AND REACTION PLATFORM
V_V = 16.7 fps
LOAD KIPS
28
24
20
16
12
8
4
0
PLATFORM
STRUT
F_{VO}
STRUT
F_{HO}
PLATFORM
.02
.04
.06
.08
.10
.12
.14
.16
.18
.20
.22
TIME - SECONDS
1.0
.8
.6
.4
.2
0
μ
STRUT
PLATFORM

FORM LB25-S-1A (1-52)

PREPARED BY: L. B. Mosby DATE

CHECKED BY: F. C. A. DATE

DOUGLAS AIRCRAFT COMPANY, INC.

LONG BEACH DIVISION

PAGE: 76

MODEL: A4D-2

REPORT NO. ES-40641

TITLE: LANDING LOADS INVESTIGATION LABORATORY DROP TESTS

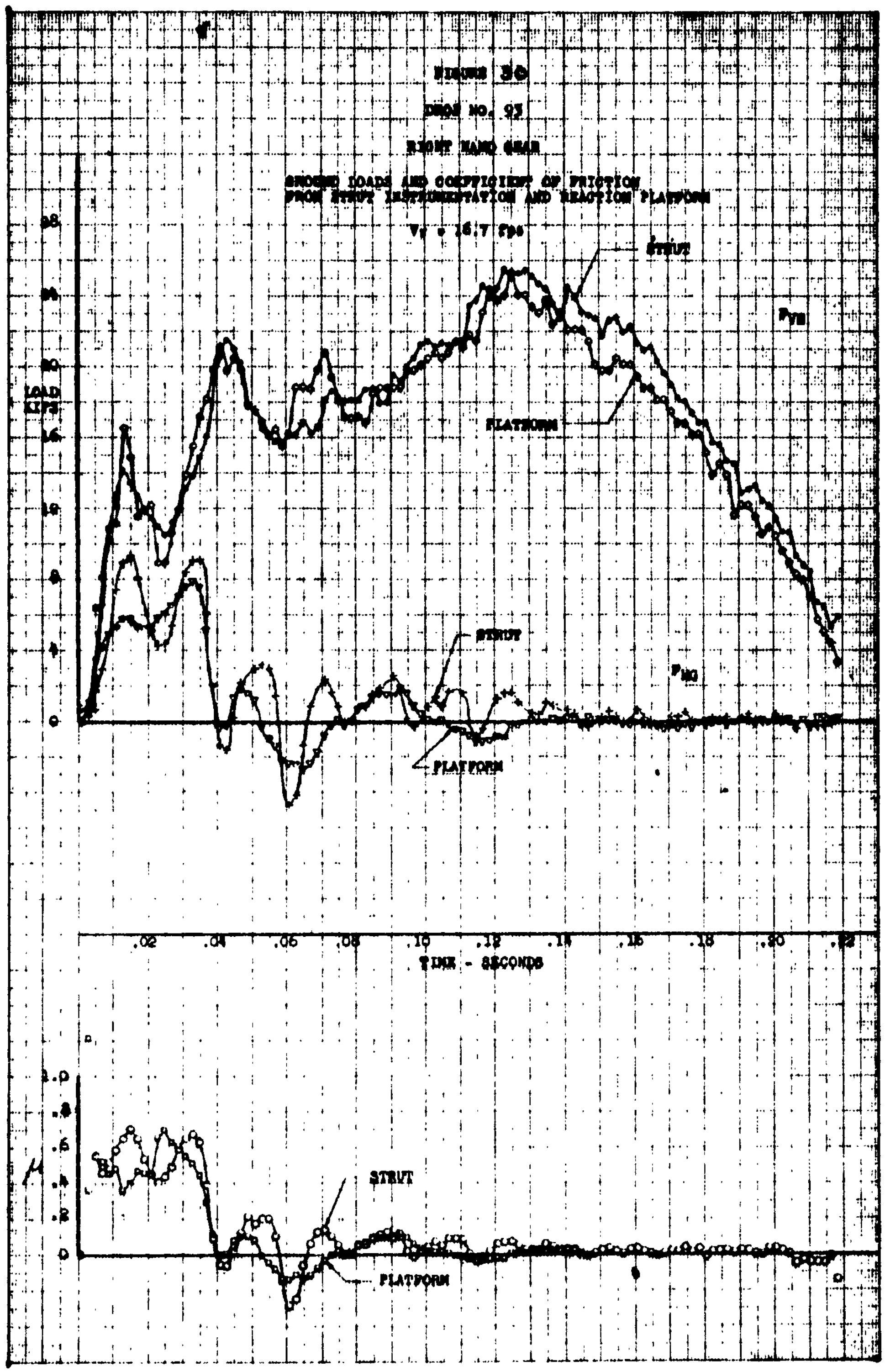
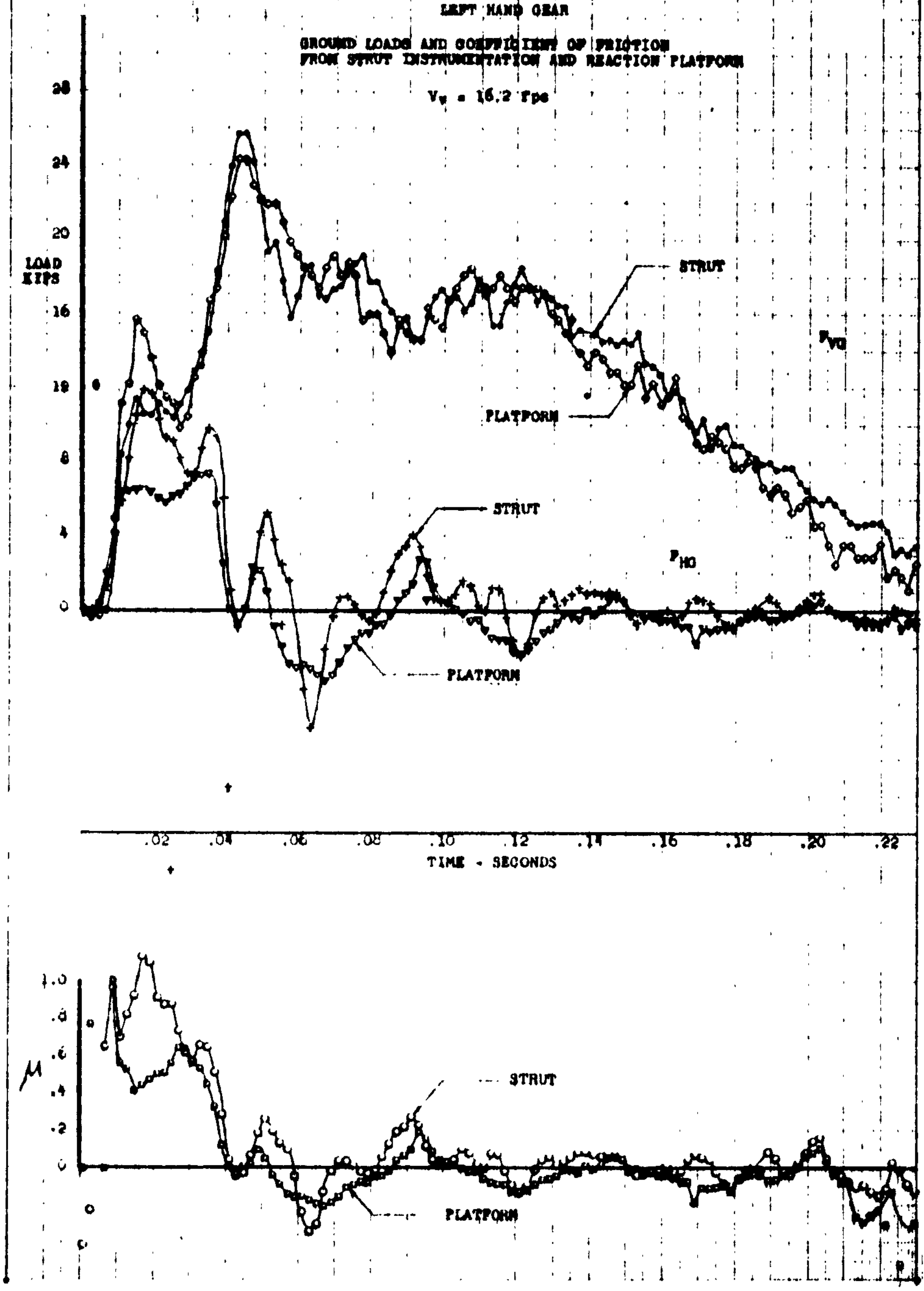


FIGURE 31
DROP NO. 82
LEFT HAND GEAR
GROUND LOADS AND COEFFICIENT OF FRICTION FROM STRUT INSTRUMENTATION AND REACTION PLATFORM
V_v = 16.2 Fps



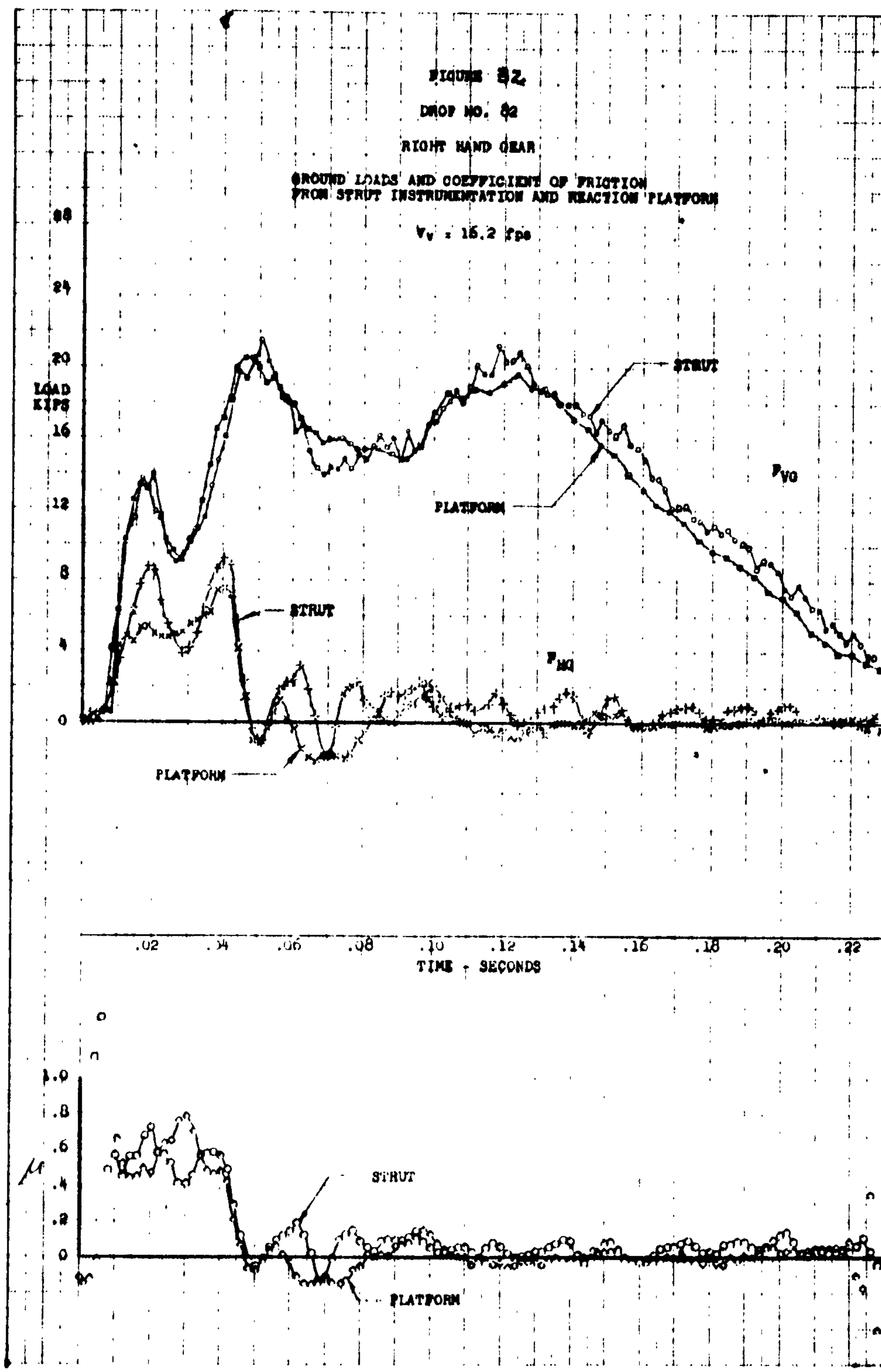


FIGURE 82
DROP NO. 82
RIGHT HAND GEAR
GROUND LOADS AND COEFFICIENT OF FRICTION
FROM STRUT INSTRUMENTATION AND REACTION PLATFORM
V_V = 16.2 fps
LOAD KIPS
STRUT
PLATFORM
F_{VG}
F_{HG}
TIME - SECONDS
STRUT
PLATFORM
μ

FORM LB25-S-1A (1-52)

PREPARED BY: I. B. Mosby DATE

CHECKED BY: F. C. A.

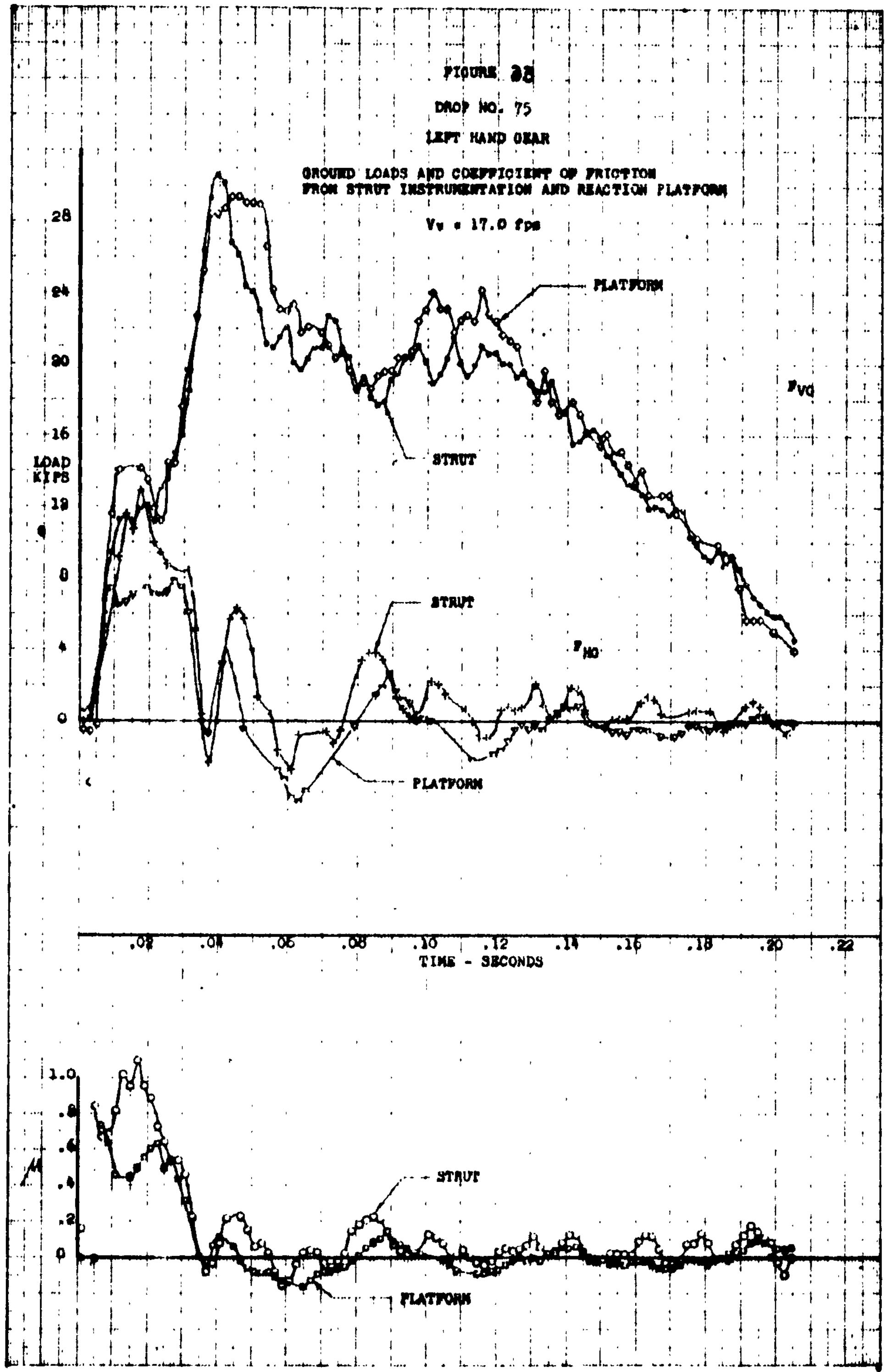
DOUGLAS AIRCRAFT COMPANY, INC.

LONG BEACH DIVISION

TITLE: LANDING LOADS INVESTIGATION LABORATORY DROP TESTS

MODEL: A4D-2

REPORT NO. ES-40641



FORM LB25 S 1A (1-52)

PREPARED BY: L. R. Mosby DATE

CHECKED BY: F. C. A.

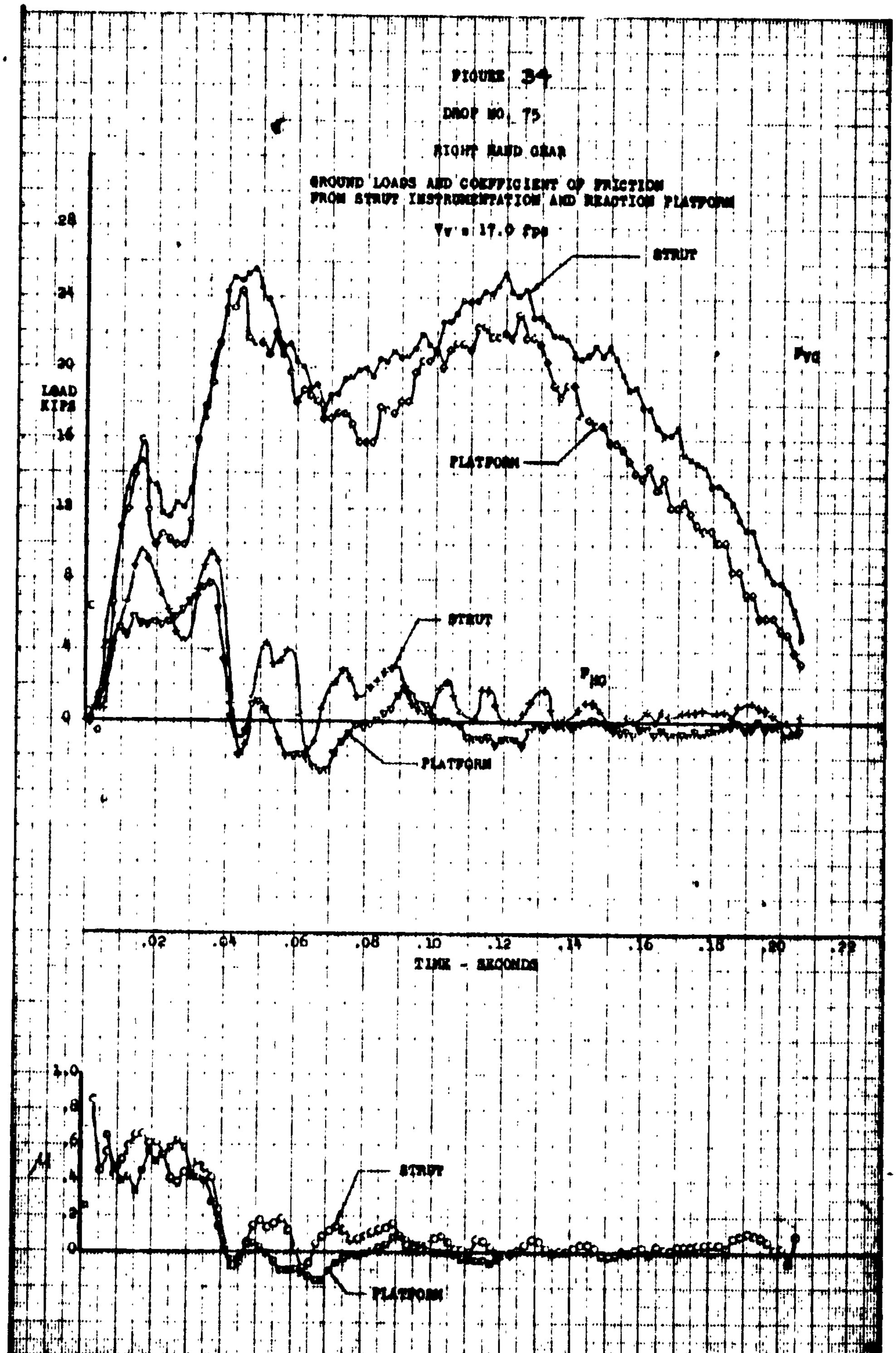
TITLE: LANDING LOADS INVESTIGATION LABORATORY DROP TESTS

DOUGLAS AIRCRAFT COMPANY, INC.

LONG BEACH DIVISION

MODEL: A4D-2

REPORT NO. ES-40641



FORM LB25 S 1A (3 52)

PREPARED BY: L. B. Mosby DATE

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DOUGLAS AIRCRAFT COMPANY, INC.

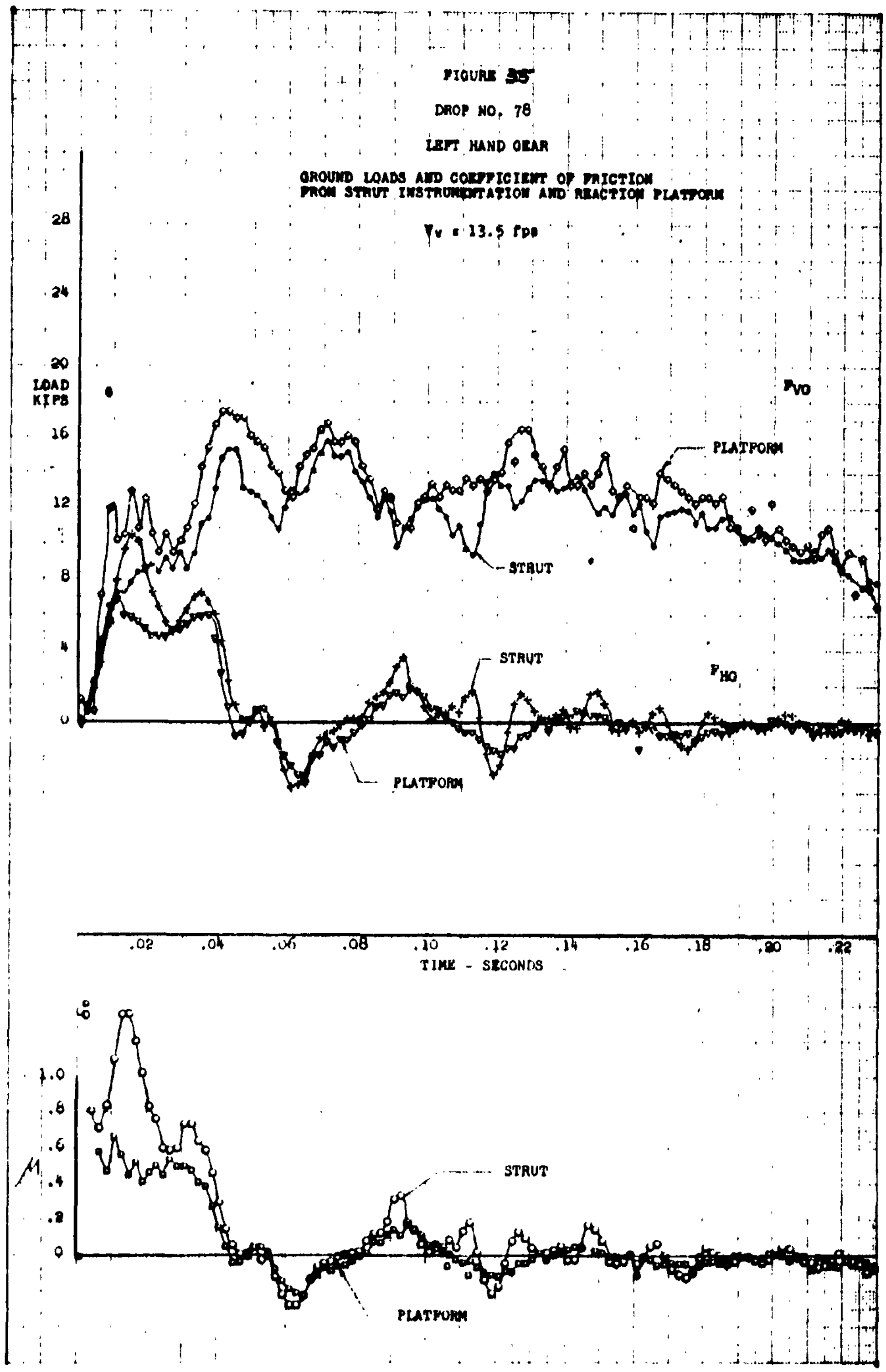
LONG BEACH DIVISION

PAGE: 81

MODEL: A4D-2

TITLE: LANDING LOADS INVESTIGATION LABORATORY DROP TESTS

REPORT NO. ES-40641



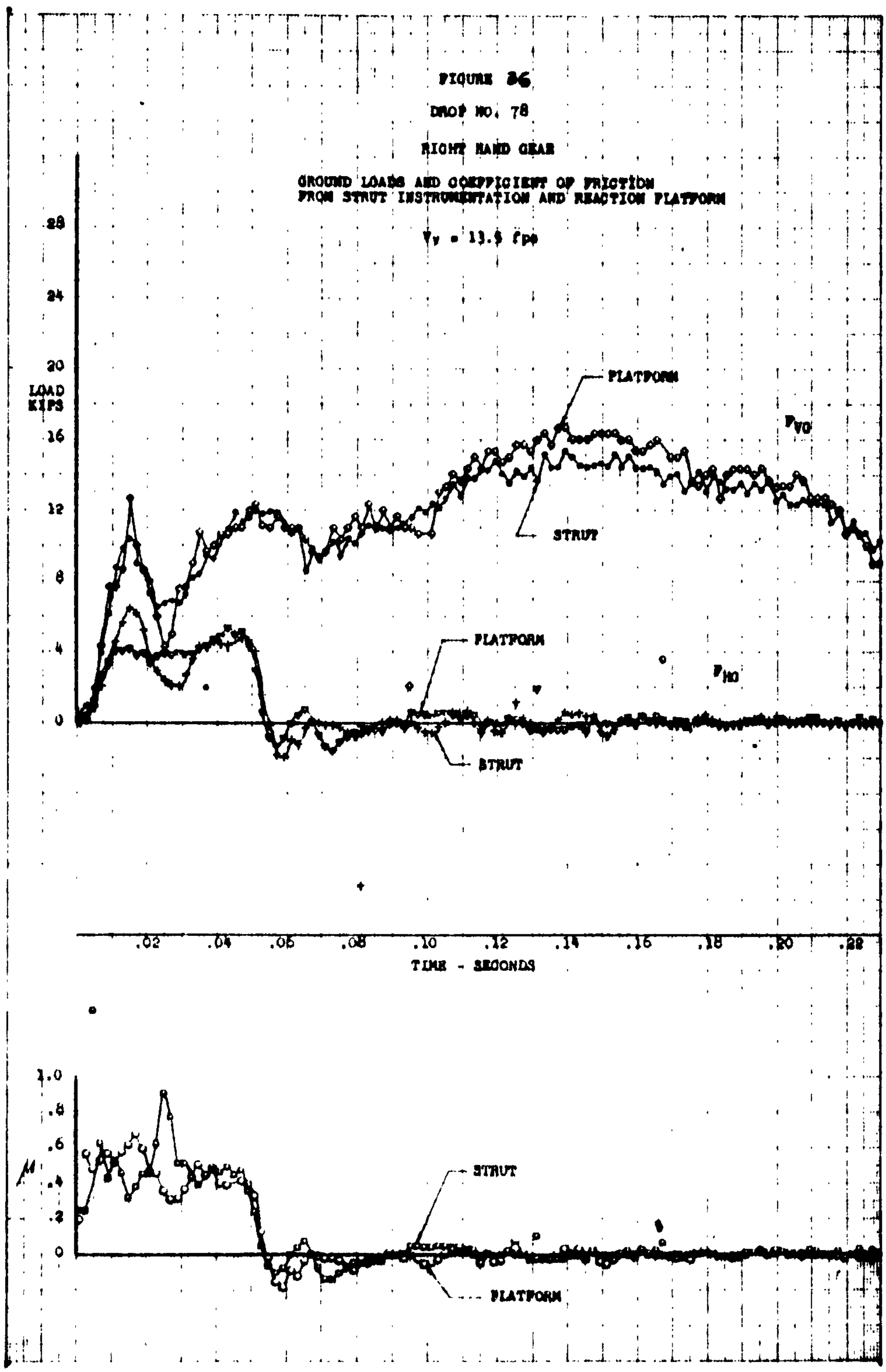


FIGURE 36
DROP NO. 78
RIGHT HAND GEAR
GROUND LOADS AND COEFFICIENT OF FRICTION
FROM STRUT INSTRUMENTATION AND REACTION PLATFORM
V_V = 13.9 fps
LOAD KIPS
28
24
20
16
12
8
4
0
PLATFORM
STRUT
F_{VO}
F_{HO}
.02
.04
.06
.08
.10
.12
.14
.16
.18
.20
.22
TIME - SECONDS
μ
1.0
.8
.6
.4
.2
0

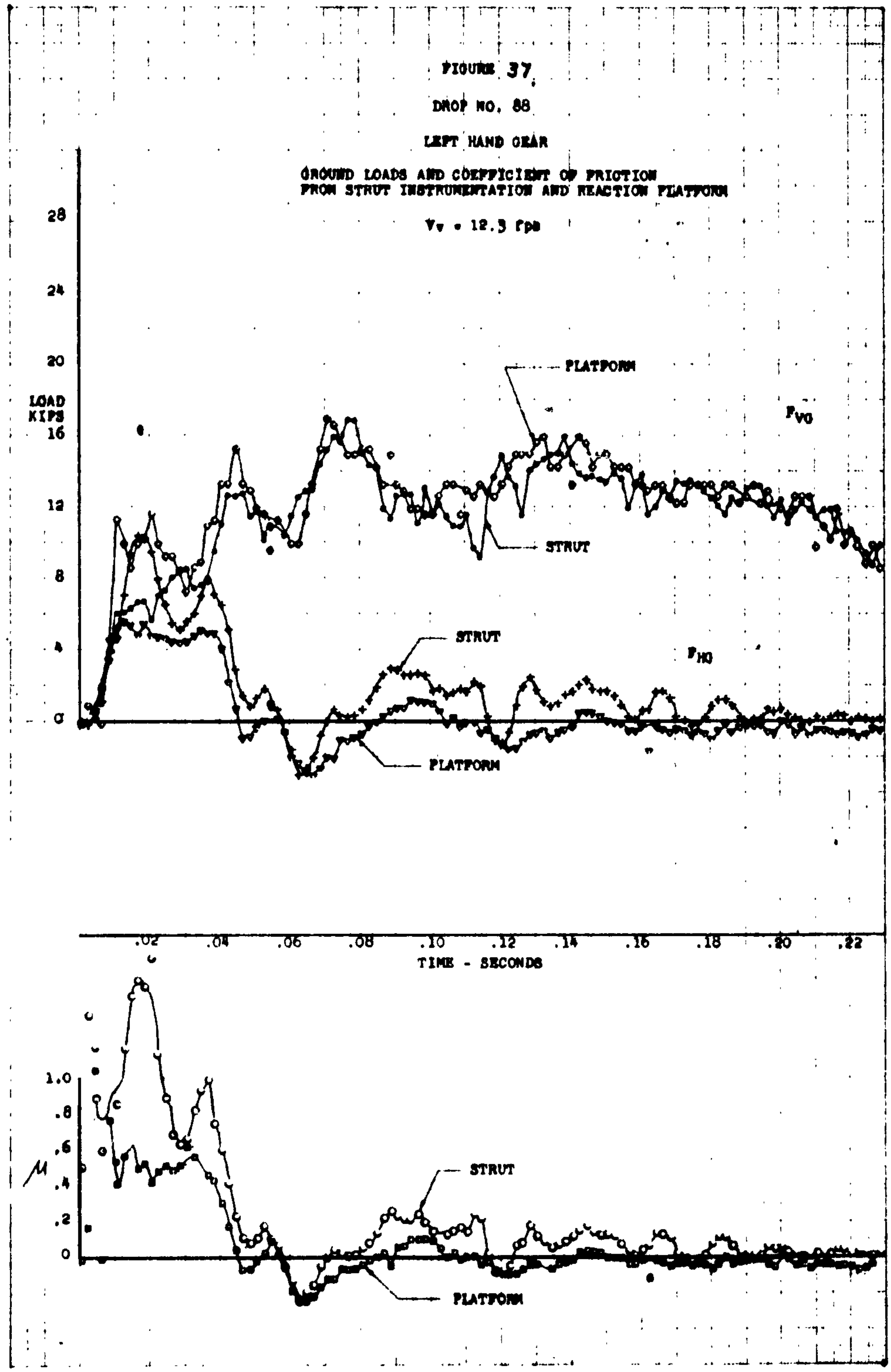


FIGURE 37
DROP NO. 88
LEFT HAND GEAR
GROUND LOADS AND COEFFICIENT OF FRICTION
FROM STRUT INSTRUMENTATION AND REACTION PLATFORM
Vv = 12.5 fps
LOAD KIPS
28
24
20
16
12
8
4
0
PLATFORM
STRUT
FVG
STRUT
FHG
PLATFORM
.02
.04
.06
.08
.10
.12
.14
.16
.18
.20
.22
TIME - SECONDS
μ
1.0
.8
.6
.4
.2
0
STRUT
PLATFORM

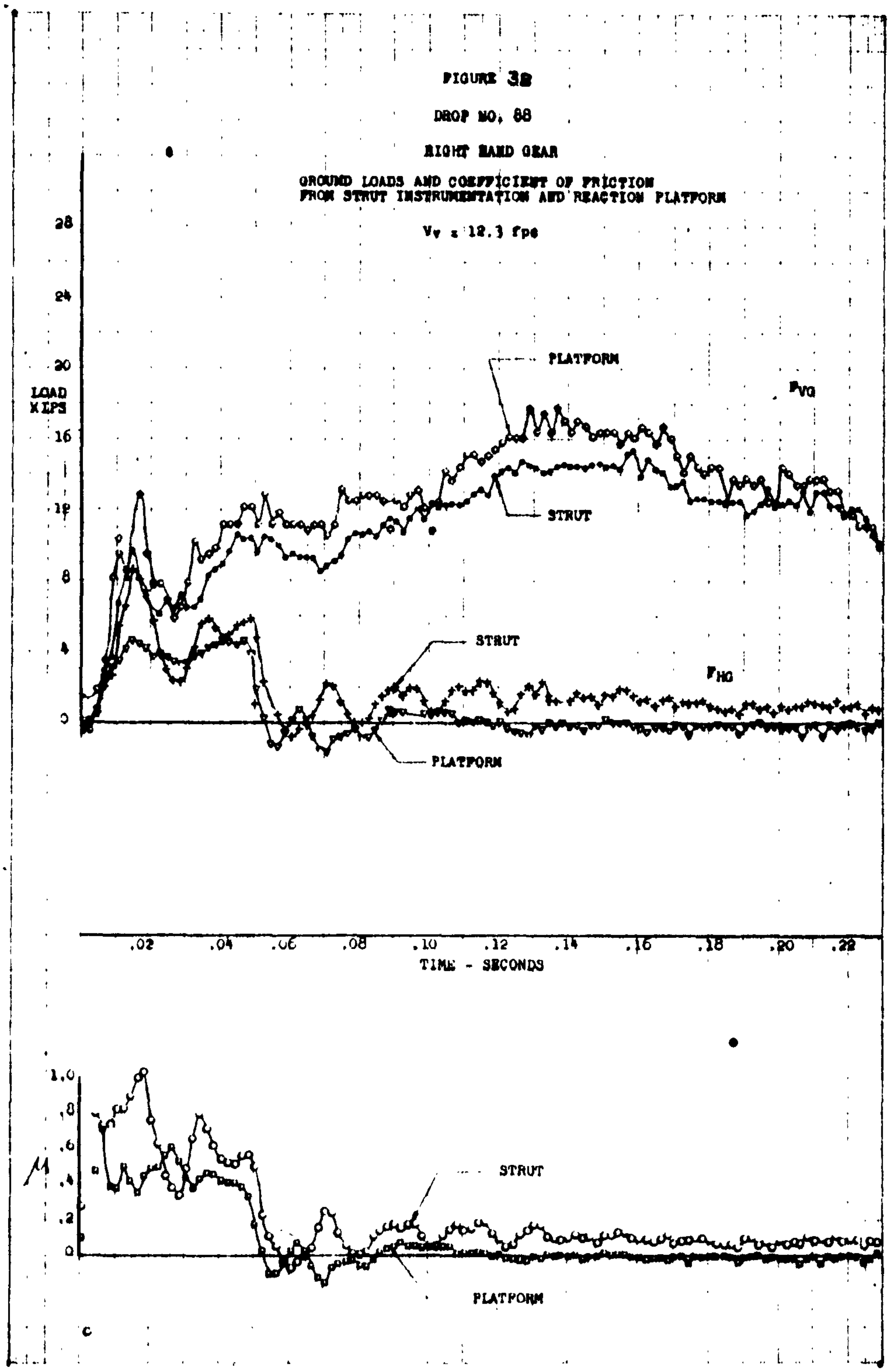


FIGURE 38
DROP NO. 88
RIGHT HAND GEAR
GROUND LOADS AND COEFFICIENT OF FRICTION
FROM STRUT INSTRUMENTATION AND REACTION PLATFORM
Vv = 12.3 fps
LOAD KIPS
28
24
20
16
12
8
4
0
PLATFORM
STRUT
FVG
FHG
.02
.04
.06
.08
.10
.12
.14
.16
.18
.20
.22
TIME - SECONDS
1.0
.8
.6
.4
.2
0
μ

SUMMARY OF RESULTS AND CONCLUSIONS

The significance of these drop test data and comparisons with flight landings, theory and NASA data are considered in the summary report (Reference (3)). The present report is more concerned with the presentation of data and an evaluation of the overall accuracy of the instrumentation under test conditions.

The estimated accuracy of the individual instruments supplied by Reference (1) and summarized in Table IV is for the most part substantiated by a study of the resulting data and by subsequent usage in the comparisons carried out in Reference (3). Areas of concern have been noted and discussed in previous sections and consist principally of the following:

1. Sinking Speed

   Accurate measurement of the sinking speed, V_V, has proved difficult even under laboratory conditions. As noted on Page 19, the determination of sinking speed by the elapsed time method is the most accurate and is limited by the determination of the precise moments of release and contact. Instrument accuracy is sufficient to determine time to .001 seconds or less, but since the airplane is flexible, accelerations created by operation of the release mechanism and by contact with the ground are not felt simultaneously by all parts of the airplane. Hence, $\bar{t}$, can be ascertained only to $\pm$.004 seconds which introduces a possible error of $\pm$.13 feet per second. This, in turn, creates a possible error of 2% in the kinetic energy of a nominal 13 fps drop.

   The difficulties described above will probably be encountered with any existing method of measurement and considerable effort would be required to improve accuracy. It is believed, however, that the accuracy obtained is sufficient for the purposes of this project.

2. Strut Position

Strut position was obtained from two sources, namely, the slide-wire device and by integration of the velocity generator reading. Differences up to 1.5 inches have been noted in data from these two instruments. Since the slide wire is the more direct measurement and is less complicated, its readings would normally be considered the more reliable. However, the data from the velocity generator agrees better with theory and, hence, some doubt is cast on the slide-wire reading. This discrepancy can only be resolved by additional testing or calibration. Such work should consist of (a) simultaneous readings of the two instruments while the strut is being moved rapidly through a known displacement and (b) with the strut fixed, simultaneous readings during the application of a high load. The first test would determine the effects of velocity on instrument accuracy, and the second, the effects of structural deformations.

3. Ground Loads

The comparison of vertical ground loads provided on Pages 69 to 84 indicates general agreement between strut instrumentation and reaction platform. One exception is on the first peak where the reaction platform is consistently higher. This has been attributed to dynamic overshoot of the reaction platform.

Agreement between drag loads obtained from strut instrumentation and the reaction platform is generally poor. This lack of agreement was expected since lack of accuracy of the reaction platform in the drag direction under dynamic conditions has been previously noted in other work. The right hand gear drag loads from strut instrumentation appear to be generally consistent and reasonable. The left hand gear drag loads from strut instrumentation appears to be high by a factor of 10 to 20% although definite proof of this fact is not available.

Conclusions

1. The drop test data presented herein can generally be used with confidence within the limits of accuracy specified in Table IV with the following exceptions:

   a. Sinking speed, V_v, accuracy is within ±0.13 feet per second.

   b. Strut position given by the slide wire is in question since results obtained therefrom differ from the velocity generator data by as much as 1.5 inches.

   c. Vertical ground loads and right hand gear drag loads are considered to be accurate within ±5%. Left hand gear drag loads appear to be high and should be used with discretion.

2. Additional calibration of the slide wire and velocity generator is recommended in order to resolve the discrepancy noted above. A dynamic calibration of the reaction platform is also recommended in order to provide better data on future tests. A test is recommended for determining the sliding coefficient of friction of the tire on the platform surface.

REFERENCES

1. Harris, I. E. and Meriwether, H. D.: Landing Loads Investigation Instrumentation. Douglas Aircraft Co. Report ES 40636, September 1962.

2. Harris, I. E. and Tydeman, S. F.: Flight Test Measurement of Landing Loads on the A4D-2 Airplane. Douglas Aircraft Co. Report DEV 3616, October 1962.

3. Mosby, L. B.: An Investigation of the Landing Loads Experienced by the A4D-2 Airplane During Flight Tests and Drop Tests and a Comparison with Theory. Douglas Aircraft Co. Report LB-31038, October 1962.

4. Horne, Walter B.: Experimental Investigation of Spin-Up Friction Coefficients on Concrete and Non-Skid Carrier Deck Surfaces. NASA TN D-214, April 1960.

5. Cook, F. E.: Analysis of Model A3D Series Landing Gear and Flexible Airplane Structure During Landing Impact. Douglas Aircraft Co. Report ES 26886, November 1957.

6. Battersen, Sidney A.: Investigation of the Maximum Spin-Up Coefficients of Friction Obtained During Tests of a Landing Gear Having a Static Load Rating of 20,000 Pounds. NASA Memo 12-20-58L.

APPENDIX A

TEST LOG

LANDING LOADS INVESTIGATION - DROP TEST LOG

DATE	DROP	HT.	POT PRESS.	COUNTS	TRODI	COMMENTS
3/14/1	0	3	80	0	-	System check out, no spin up, landing no. 49 simulated
3/14/1	1	9	80	0	5.2	Instrumentation check out, no spin up
3/14/1	2	9	80	1635	5.1	Instrumentation check out, corrected instrumentation malfunctions, moved some traces, let out links, 2 RH, 1 LH
3/15/1	3	21	87	1640	10.0	Tire and strut pressures checked. Main strut 25 psi, nose strut 210 psi, main tires 325 psi
3/15/1	4	27	82	1640	11.0	Reversed LH drag brace trace direction, moved some more channels
3/16/1	5	21	80	1650	9.7	
3/16/1	6	36	78	1640	13.0	Raised Osc. 2 traces 33 and 35 1/2 inch, spin up rpm has been too high, added two disks to wing lift attach rods
3/16/1	7	36	82	1450	13.0	
3/16/1	8	34	82	1460	12.5	Wing lift too spongy, removing 3 disks, lengthening RH chain 1 link
3/17/1	9	33	81	1400	12.4	Attitude reset to 15.1° from 15.8°
3/17/1	10	32	85	1410	12.3	Shut down to balance wheels, shortened LH chain 4 links, RH 5 links and to repair RH velocity generator
3/20/1	11	33	85	1400	12.0	RH wheel statically balanced
3/20/1	12	33	85	0	12.3	RH wheel looks good, fix LH wheel (static balance) RH pot OK, LH to be shortened 2 links, RH velocity generator OK

LANDING LOADS INVESTIGATION - DROP TEST LOG

DATE	DROP	HT.	POT PRESS.	COUNTS	TRODI	COMMENTS
3/21/1	13	36	85	1400	12.3	Main gear strut and tire pressures checked. LH wheel statically balanced, LH chain shortened 2 links, aft safety hung up on dummy horizontal stabilizer
3/21/1	14	36	85	1400	12.4	Dropped on spin up rig, repaired shaft, installed new balance panels to increase amplitude of platforms and metering pressure pick ups, installed rebound chamber pressure pick up
3/27/1	15	36	87	1400	no drop	Strut and tire pressures checked, broke spin up motor shaft, failed LH wheel position pick up mount, LH lower mass lateral accelerometer, and tore out aircraft balance panels power wires
4/10/1	15	36	80	1200	12.2	Strut and tire pressures checked, new wheel spin up right in use, schedule 2 in effect, oscillograph 1 inoperative
4/10/1	16	36	87	1200	12.5	Oscillograph 1 inoperative
4/10/1	17	36	86	*1127	12.6	*at contact
4/10/1	18	36	86	1100	12.5	Dirty slidewire, LH; LH drag brace out, RH velocity generator going bad, rebound pressure wrong direction, move LH platform up, pitch attitude acting up
4/12/1	19	36	87	1107	12.5	Fastax taken, 1801 rpm, galvo 551cg bad, RH vert. platform inoperative, RH velocity generator opening, RH oscillograph 2 pitch
4/12/1	20	36	87	1100	12.4	Platform OK, velocity generator still opens, 400~ on both velocity generators

LANDING LOADS INVESTIGATION - DROP TEST LOG

DATE	DROP	HT.	POT PRESS.	COUNTS	TRODI	COMMENTS
4/12/1	21	36	87	1090	12.5	Micro press. fitting on spin up rig failed, 50~ Time Standarddisconnected, RH oscillograph shored up with rubber pads, galvo 551cg replaced by 13213
4/13/1	22	36	87	1117	12.3	LH platform opens up - no vertical load recorded
4/13/1	23	36	87	1142	12.5	LH platform open up, no vertical load, no pitch recorded, changing strain gage voltage circuit
4/18/1	24	36	87	1090	12.3	Pressure pick up No. 7B RH metering chamber, new voltage monitor circuit - new galvo, deepened cut in RH engine mount beam - new strain gage
4/18/1	25	36	87	1180	12.5	
4/18/1	26	36	87	1060	12.5	
4/19/1	27	36	87	1040	12.6	
4/19/1	28	36	87	1100	12.6	
4/19/1	29	36	87	1140	12.5	
4/20/1	30	39	91	1120	13.2	12876 lbs. @ 232.9, added 50 lbs. shot bags each wing at station 258.5 (outboard of fuselage)
4/20/1	31	39	90	1070	13.3	
4/24/1	32	39	89	1070	13.2	Nose and LH platforms switched } Landing No. 121
4/24/1	33	39	89	1120	13.0	} Landing No. 121
4/24/1	34	39	89	1100	13.1	} Landing No. 121

LANDING LOADS INVESTIGATION - DROP TEST LOG

DATE	DROP	HT.	POT PRESS.	COUNTS	TRODI	COMMENTS	
4/25/1	35	36	86	1110	12.5	Removed 50 lb. shot bags each wing 12776 lbs. @ 232.7	Landing No. 49
4/25/1	36	36	86	1220	12.5		
4/25/1	37	36	86	1110	12.5		
4/25/1	38	54	89	1300	16.0	Added 50 lb. shot bags at each wing @ 258.5, 12876 lbs. at 232.9, (basic configuration - 12776 lbs. at 232.7)	Landing No. 70
4/25/1	39	54	89	1300	16.0	LH wheel spin up magnetic pick up unscrewed during this drop	
4/25/1	40	54	89	1300	16.0		
4/27/1	41	40	90	1210	13.4	Added 210 lb. shot bags each wing at 261.5, 13196 lbs. - c.g. at 233.6 - (basic configuration 12776 lbs. - cg at 232.7) LH wheel binding	Landing No. 26
4/27/1	42	40	90	1210	13.5	Changed wheels - LH gear	
4/27/1	43	40	90	1190	13.5		
4/27/1	44	63	92	1310	17.5	Added 20 lb. each wing at 266.0, 13236 lbs. cg at 233.7 (basic configuration 13196 at 233.6)	Landing No. 68
4/27/1	45	63	92	1320	17.4		
4/27/1	46	63	92	1400	----	Drops No. 44-46, inclusive - Oscillograph No. 1 switch turned off by wire bundle	

DOUGLAS AIRCRAFT COMPANY, INC.

EL SEGUNDO DIVISION

DATE April 1962
PREPARED BY H. Meriwether
TITLE Ldg. Loads - Drop Tests

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MODEL A4D-2
REPORT 40641

LANDING LOADS INVESTIGATION - DROP TEST LOG

DATE	DROP	HT.	POT PRESS.	COUNTS	TRODI	COMMENTS	
4/28/1	47	63	92	1400	17.8	Excessive hash on Oscillograph No. 2	LANDING No. 68
4/28/1	48	63	92	1400	17.4		
4/28/1	49	63	92	1350	17.4	LH and RH wing tip accelerometer inactivated, installed hard rubber shock pads on Oscillograph No. 1 and No. 2 to check effect of shock mounting	
4/28/1	50	63	92	1360	17.4		
5/1/1	51	60	89	1210	17.2	Added 20 lbs. each wing at station 300.0 (basic configuration - 13236 lbs. at 233.7) 13276 lbs. at 233.9	Landing No. 126
5/1/1	52	60	89	1150	16.7		
5/1/1	53	48	89	1210	15.6	Added 80 lb. each wing at sta. 282.0 13436 lbs. at 234.3 (basic configuration - 13276 lbs. at 233.9)	Landing No. 125
5/1/1	54	45	91	1150	14.3	Reactivated LH and RH wing tip accelerometer, drops 53-56 inclusive	
5/1/1	55	48	91	1160	14.3		
5/1/1	56	51	91	1170	15.5		
5/2/1	57	51	91	1320	15.4		Landing No. 125
5/2/1	58	51	91	1320	15.3		
5/2/1	59	48	90	1120	15.0	Slide wire and velocity generator re-adjusted	

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LANDING LOADS INVESTIGATION - DROP TEST LOG

DATE	DROP	HT.	POT PRESS.	COUNTS	TRODI	COMMENTS
5/3/1	60	30	91	1360	11.0	Added 40 lbs. each wing @ sta. 268.0) 13516 lbs. @ 234.5 (basic configuration - 13436 lbs. at 234.3 } Landing No. 8
5/3/1	61	34	91	1280	11.6	
5/3/1	62	34	91	1320	11.6	
5/5/1	63	34	91	LANDING 8	12.0	Store replaced with 1000 lbs. bomb aircraft re-weighed (100 lbs. removed). Trodi recalibrated engine mount strain gage 3 installed, oscillograph 3
5/5/1	64	32	91	8	11.8	
5/5/1	65	31	91	8	11.6	RH vel. generator inoperative last 3 drops
5/5/1	66	50	91	125	15.4	Osc. 1 and 2 paper speeds 100 in/sec.
5/5/1	67	48	91	125	15.0	
5/5/1	68	48	91	125	14.8	Platform cleaned
5/8/1	69	31	91	8	11.2	
5/8/1	70	33	90	8	12.0	
5/8/1	71	32	91	8	11.7	LH upper mass vertical accelerometer loose, struts to be checked
5/8/1	72	60	90	126	16.6	Platform cleaned, sprocket jumped off spin up motor
5/8/1	73	61	91	126	16.4	RH vertical axle opened, sprocket jumped off spin up motor
5/8/1	74	65	91	68	17.0	Vertical/gage channel repaired, sprocket fixed axle

LANDING LOADS INVESTIGATION - DROP TEST LOG

DATE	DROP	HT.	POT PRESS.	LANDING	TRODI	COMMENTS
5/8/1	75	68	91	68	17.0	
5/8/1	76	70	91	Counts 1290 Land.68	17.9	No record - osc. 1 and 2
5/9/1	77	40	90	26	13.8	Platforms cleaned
5/9/1	78	39	90	26	13.5	
5/9/1	79	39	90	26	13.5	
5/9/1	80	54	89	70	15.4	
5/9/1	81	56	89	70	15.8	Wheel bound up - lefthand
5/9/1	82	56	89	70	15.8	
5/9/1	83	56	89	70	15.9	
5/9/1	84	40	89	121	13.8	
5/9/1	85	39	89	121	13.9	
5/9/1	86	36	90	121	13.3	
5/9/1	87	36	87	49	----	
5/9/1	88	36	87	49	12.3	
5/9/1	89	36	87	49	----	Trodi sensitivity control set too low, re-adjusted
5/9/1	90	36	87	49	12.3	Pitch attitude Osc. 2 out, last 4 drops
5/11/1	91	65	89	126	17.8	Norm
5/11/1	92	60	89	126	17.4	Norm

LANDING LOADS INVESTIGATION - DROP TEST LOG

DATE	DROP	HT.	POT PRESS.	LANDING	TRODI	COMMENTS
5/11/1	93	58	89	126	16.8	Norm
5/11/1	94	59	89	126	17.0	Norm
5/11/1	95	59	89	126A	17.0	120 knots
5/11/1	96	59	89	126A	17.0	90 knots
5/11/1	97	59	89	126A	17.0	60 knots
5/11/1	98	59	89	126A	16.9	0 knots
5/11/1	99	57	59	126A	16.5	2/3 wing lift (not enough sink)
5/11/1	100	59	59	126A	16.8	2/3 wing lift (not enough sink)
5/11/1	101	61	59	126A	16.3	2/3 wing lift (not enough sink)
5/11/1	102	61	59	126A	17.1	2/3 wing lift - OK
5/11/1	103	57	0	126A	17.0	0 wing lift
5/11/1	104	60	89	126A	16.7	200 psi in tires (found wheel LH bound up) (and loosened it up)
5/11/1	105	61	89	126A	16.3	200 psi in tires - not enough sink
5/11/1	106	61	89	126A	16.2	200 psi in tires - not enough sink
5/11/1	107	61	89	126A	16.4	400 psi in tires
5/11/1	108	64	89	126A	17.3	400 psi in tires
5/11/1	109	62	89	126A	17.1	400 psi in tires
5/11/1	110	62	89	126A	16.6	200 psi in tires
5/11/1	111	62	89	126A	17.1	200 psi tire pressure spin up too low

LANDING LOADS INVESTIGATION - DROP TEST LOG

DATE	DROP	HT.	POT PRESS.	LANDING	TRODI	COMMENTS
5/11/1	112	62	89	126A	17.0	200 psi tire pressure - OK
5/11/1	113	62	89	126A	16.9	Platform restraint in lateral direction - platform cleaned
5/12/1	114	62	89	126A	17.0	6° ANU - no wheel spin-up
5/12/1	115	57	89	126A	16.1	2° ANU - touched tail
5/12/1	116	57	89	126A	16.0	2° ANU
5/12/1	117	72	89	126A	18.5	2° ANU
5/12/1	118	57	89	126A	16.7	12° ANU - osc. set to 2000 cps
5/12/1	119	57	89	126A	16.8	No spin up, 12° ANU
5/12/1	120	72	89	126A	18.5	12° ANU
5/12/1	121	72	89	126A	19.0	12° ANU - no spin up
5/15/1	122	57	89	126A	16.1	Tapped tail - 3 point
5/15/1	123	72	89	126A	18.6	Tapped tail - 3 point
5/15/1	124	57	89	126A	15.9	Tapped tail - 3 point
5/15/1	125	72	89	126A	18.4	Tapped tail - 3 point, engine mount beam strain gage channel tab broke
5/15/1	126	72	89	126A	18.8	12° ANU - tapped tail
5/18/1	127	72	89	126A	18.8	
5/22/1	128	60	59	126A	----	Show for Brazilian Navy brass

Douglas Aircraft Co., Aircraft Div., Long Beach, Calif. Report No. ES 40641. Prepared for Bureau of Naval Weapons, Wash. D. C. LANDING LOADS INVESTIGATION LABORATORY DROP TESTS, Sept. 1962. Final Report 104 p. inc illus., tables, refs.

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1. Loads, Landing
2. Landing Gear Loads
3. Drop Tests
4. Tests, Airplane Drop

I. Contract NOa(s) 59-6226c
II. Douglas Aircraft Co., Inc. Aircraft Div. Long Beach, Calif.
III. F. C. Allen, L. B. Mosby
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