WOODS HOLE OCEANOGRAPHIC INSTITUTION

Woods Hole, Massachusetts

Reference No. 53-1

PREDICTING WING LIFT LOADS, PBY-6A FROM ACCELEROMETER MEASUREMENTS

By

Given A. Brewer

Technical Report No. 21
Submitted to Geophysics Branch, Office of Naval Research
Under Contract N6onr-27702 (NR-082-021)

January 1953

APPROVED FOR DISTRIBUTION ________________
Director

PREFACE

With the loan, through the courtesy of the Office of Naval Research, of a PBY-6A aircraft to this project for the measurement and investigation of atmospheric turbulence and convection, numerous problems have arisen concerning the use of this airplane as a meteorological tool and concerning its instrumentation. These problems center around the detection of atmospheric motions, such as drafts and gusts, from an extended object which is itself in motion through the air. Much information concerning the aero-dynamics and structural characteristics of the aircraft itself has been needed in order to interpret reliably the readings of the meteorological instruments that are mounted on and within it.

For these purposes a consulting engineer, Given A. Brewer, has been retained by the project. The present report constitutes the results of one of the very essential studies of the aircraft made by him.

PREDICTING WIND LIFT LOADS, PBY-6A FROM ACCELEROMETER MEASUREMENTS

Abstract

The study of gust distribution and characteristics in the atmosphere is of importance in both of the separate fields of aeronautics and meteorology. To utilize properly an airplane for air sounding missions it is necessary to instrument the airplane so that the gust forces acting upon the aircraft may be determined by suitable instruments within the fuselage. The most convenient method for determining dynamic wing loads is through the use of a fuselage accelerometer and associating recording apparatus. Shifting span-wise lift distribution in accelerated flight, wing over-travel, flexibility of the accelerometer supports, and fuselage rotation all create false accelerations at the instrument. A test program was carried out to determine the correlation between wing lift loads and accelerometer measurements on the PBY-6A airplane. Wing lift loads of the aircraft were determined by means of electric strain gauges on the lift struts while two electric accelerometers fastened within the fuselage were used to record translational and rotational acceleration.

The aircraft was flown at various angles of attack in steady state and observations made of lift strut strains. A second flight in which the aircraft was put through a number of maneuvers comprising chandelles and pull-outs at high speed was made imposing accelerated loadings upon the wing. Readings of lift strut strain

and fuselage acceleration were oscillographically recorded during the accelerated maneuvers. Analysis of these data indicates that accelerometers maintained in the fuselage between the bracketing bulkheads adjacent to the airplane center of gravity may be used to predict wing lift loads within the range of .8G and 2.1G. This study indicates that the span-wise lift distribution is not altered by changes in angle of attack within the range of 4-1/2 to 12.8° or by acceleration loadings up to 2.1G.

-TABLE OF CONTENTS-

INTRODUCTION.

The study of gust distribution and character in the atmosphere is of importance in both of the separate fields of aeronautics and meteorology. Airplanes equipped with suitable recording instruments have been used over the past 20 years[1] to determine the frequency and magnitude of gust occurrence in the atmosphere. The information gained through these past experiments has been the basis of aircraft structural design criteria[2,3,4] both in this country and abroad. The Woods Hole Oceanographic Institution is one of the U.S. research organizations continuing investigations into the structure of atmospheric turbulence.

The Geophysics Branch of the Office of Naval Research has secured for the Oceanographic Institute a PBY-6A airplane, Navy 46683; for use in the exploration of atmospheric phenomena. To properly use this aircraft for sounding missions it was necessary to determine the correlation between acceleration measurements within the fuselage and aerodynamic forces acting upon the wing. The effects of wing whip or fuselage motions independent of the wing will give rise to accelerometer readings that are in no way related to the air loads acting upon the wing. Accordingly an experimental program was carried out wherein wing lifting loads were measured simultaneously with fuselage accelerations, permitting correlation of these two quantities.

PROCEDURE.

The wing lift struts of the PBY-6A airplane provide a means for the determination of wing lift loads. Assuming that the wing structure remains elastic throughout the loading regime and that the spanwise pressure distribution is also constant, the wing lift struts will carry a constant proportion of the wing lift load. Consequently by cementing electric strain gages to the struts these gages may be used to determine the portion of the total wing lift load carried by the struts. Under the conditions limited by the assumptions previously stated, the strain gages will yield readings correlating linearly with the aerodynamic load on the wing.

Eight electric strain gages of the SR-4 A-6 type were cemented to the leading and trailing edges of the lift struts as shown in the Figure 1. By locating these gages at these points of greatest curvature the possibility of error in reading, due to the presence of secondary strains, was eliminated. To eliminate thermal components of strain a non-stressed dummy D-1 was buried within the insulation covering the other gages on the left front strut. Lead-in wires from each of these gages were brought in through the fuselage skin to the recording instruments within the cabin. A considerable portion of the strut on both sides of the point of gage attachment was thermally insulated and both gages and insulation were waterproofed, the purpose being to reduce gage electrical drift.

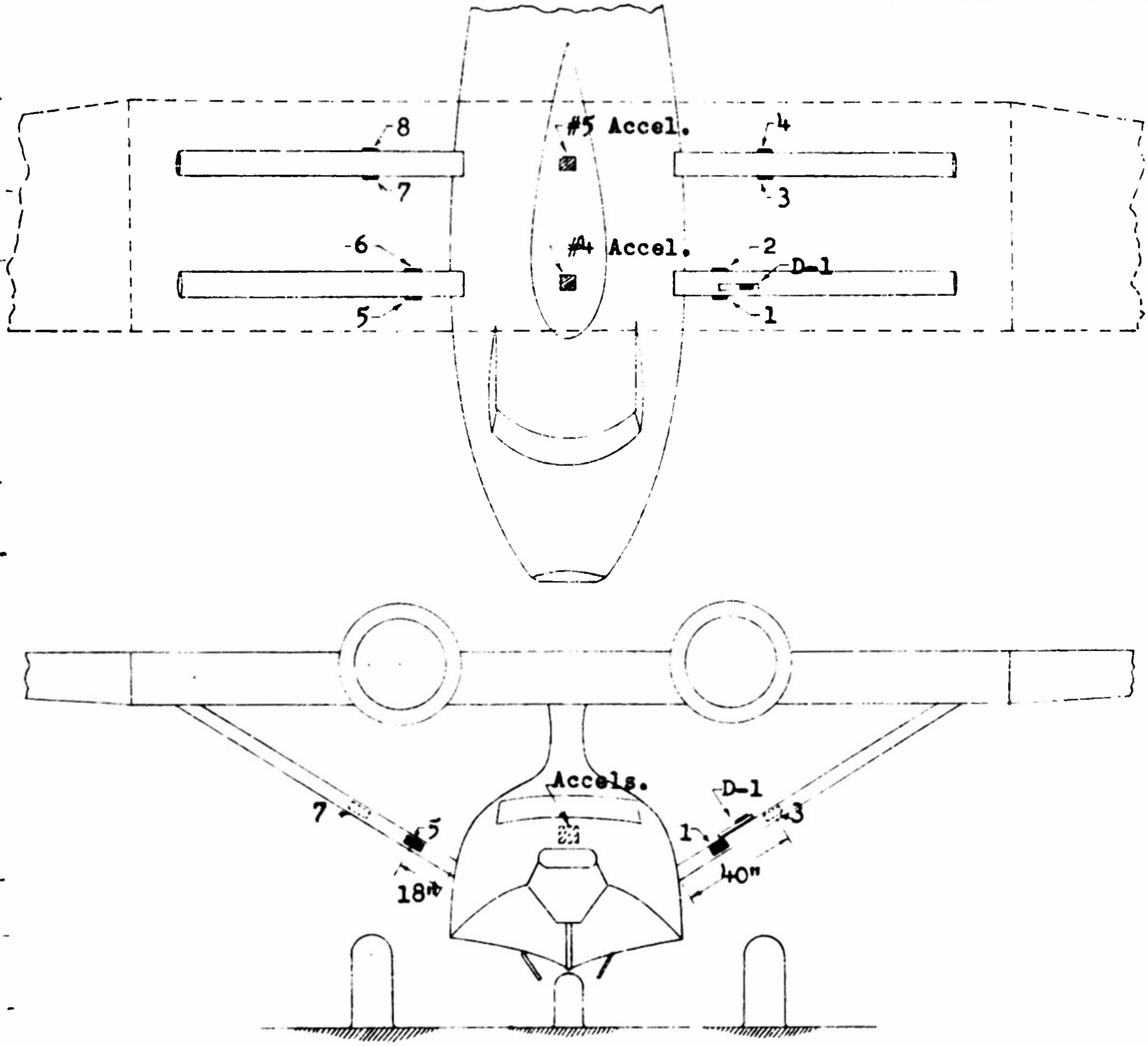


FIGURE 1. SKETCH OF PBY-6A, NAVY 46683 SHOWING LOCATION OF STRAIN GAGES ON LIFT STRUTS AND ACCELEROMETERS IN FUSELAGE, 9-8-52.

Two electric accelerometers of the fluid damped mass type[5] as manufactured by the Statham Laboratories, were attached to structural members within the fuselage. The 6 G accelerometer was fastened to the aluminum alloy conduit running across #4 bulkhead ring and the 12 G accelerometer was clamped to the #5 bulkhead ring, see Figure 1.

The recording instruments were placed upon one of the canvas bunks in the crew's quarters between bulkheads #4 and #5. The leads from the strain gages on the lift struts and the cables from the accelerometers were brought through the fuselage to the instrument location and secured. The entire system was grounded by clipping a lead from the amplifier to the fuselage structure.

Photographs of the installation and instruments are carried in the appendix no. 1 of this report.

FLIGHT I.

The individual strain gages were connected separately into a Baldwin SR-4 twenty channel switch which in turn was connected to a Baldwin Strain Indicator model L. The dummy D-1 was used to compensate all gages. The state of stress in the struts while the aircraft was at rest on the ground was arbitrarily taken as the zero reference. Assuming that the struts, at this low stress level, are as rigid in compression as in tension; the strut stress due to dead weight will be a constant and cancel out from incremental measurements.

The airplane's gross weight was determined and with the instruments connected to the strut gages, as previously described, take off was accomplished at 1:42 PM on 9-8-52. While airborne the aircraft was flown at constant altitude with variations in speed so that the effect of chordwise center of pressure shift could be evaluated. Strain gage observations were made at each value of angle of attack and recorded, see Table I. These observations permitted detection of spanwise pressure distribution changes, if any, with variations in angle of attack. The airplane was landed at 3:15 PM and the ground zero reference gage readings observed.

FLIGHT II

This second flight was programmed to investigate the spanwise lift distribution in accelerated flight and to observe the relationship between lift strut strains and fuselage accelerometer readings.

The strain gages on the front lift struts were put in series-parallel and inserted electrically into a wheatstone bridge, the other legs comprising 300 ohm non-inductive advance wire resistors. Similarly the gages of the two rear struts were put into a second bridge. The accelerometers each contain a balanced four legged bridge. The four bridge circuits were then connected into a four channel carrier amplifier,as sketched in the Figure 2, in turn connected to the first four channels of a recording oscillograph.

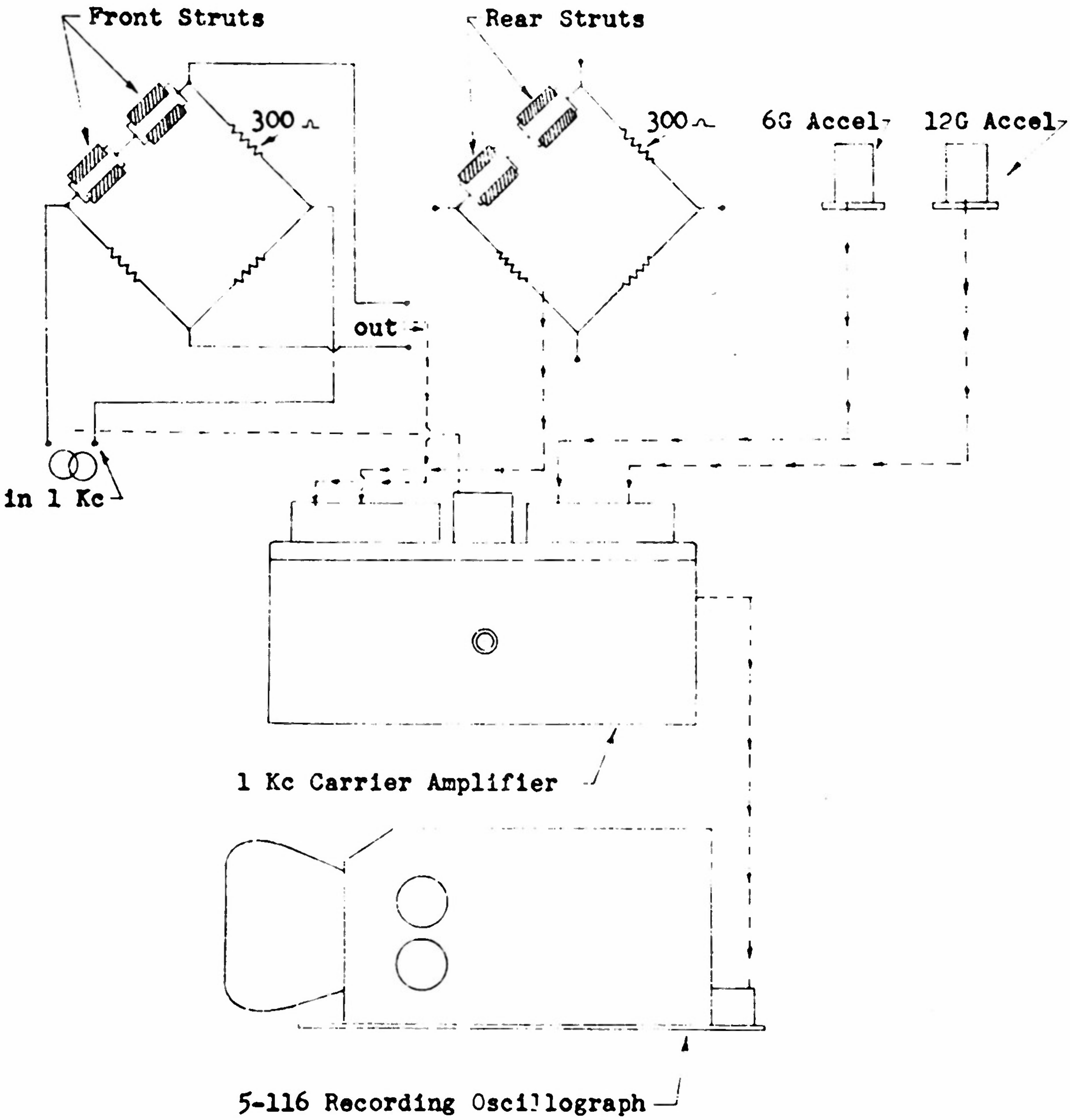


FIGURE 2. BLOCK DIAGRAM OF INSTRUMENTS USED FOR RECORDING STRUT STRAINS AND FUSELAGE ACCELERATIONS, 9-8-52.

FLIGHT II CONT.

With the instruments connected as described take off was accomplished at 4:29 PM on 9-8-52. In flight the airplane was put through a number of maneuvers including pull ups and chandelles. During each of those accelerated flight maneuvers bridge output readings from the struts and accelerometers were simultaneously recorded. The amplifier was adjusted so that a 1 G acceleration would produce approximately the same trace deflection for each of the four channels. The aircraft was landed at 4:58 PM and the ground zero reference taken for drift determination. An analysis of the data appears in Table II

The 110 volt power system of the aircraft was used to power the recording oscillograph and its galvanometer lamps. Due to an unnoticed drop in voltage of the 110 volt system on the ground the ground reference traces are weak but legible, see Appendix no. 2.

RESULTS.

The data recorded during flight I are presented in the Table I. Examining the lift strut data reveals the fact that the average lift strut stress is virtually the same over the range of attack angle investigated. For the strut stress to remain constant requires that the spanwise lift distribution must also be constant over the speed range investigated and under steady state flight conditions. The division of load between the front and rear struts changes but little with variations in angle of attack showing that the wing is suffici-

TABLE I

FLIGHT I, NAVY PBY-6A 46683; 9-8-52. STRUT STRAINS VS ANGLE OF ATTACK.

SPEED	0	0	104 K*	110 K*	100 K	90 K	80 K	70 K	0
TIME	1:32 PM	1:40	1:44	2:22	2:34	2:38	2:43	2:46	3:17
α	-	-	-	4.5°	5.8°	8.3°	9.2°	12.8°	-
P. ALT.	66	66	-	2100'	5220'	5200'	5200'	5240'	66
TEMP.C°	-	-	-	11	9	9	9	9	-
GAGE			Strain Micro inches/inch.						
1	-70	-90	495	520	540	540	532	525	0
2	-64	-59	406	411	431	443	441	441	0
3	-130	-110	540	540	530	520	512	495	0
4	-110	-100	290	300	290	300	290	270	0
5	-72	-72	538	538	558	558	550	536	0
6	-63	-58	422	412	437	452	442	440	0
7	-117	-92	563	593	560	566	543	543	0
8	-110	-100	290	310	305	310	310	302	0
Average front strut			466	471	492	498	491	486	0
Average rear strut.			421	436	422	424	414	402	0
Average front and rear.			443	453	456	461	453	444	0
Average strut stress psi.			4560	4670	4700	4750	4670	4580	0

NOTES:
1. Flight I, 9-8-52. Take off 1:42PM EDT; land 3:15 PM. Gross weight = 32408 lbs cg @ 256 inches @ 2:34 PM. cg limits 242.5 to 259, hydrodynamic; 260.7" aft limit of controllability in flight.
2. * Rough air, averaged swing of needle of Strain Indicator.
3. Temperature compensating aluminum alloy channel in left front lift strut leading edge. Covered with rubber tape and corrugated cardboard.
4. Barometric pressure, 30.48" Hg, Providence, R.I. 4:26 PM EDT.
5. Used 3:17 PM ground readings for zero reference.
6. α = angle of attack degrees.

RESULTS CONT.

ently rigid in torsion to resist appreciable warping with chordwise center of pressure shifts. The pylon connecting the main wing to the fuselage presents a more rigid path to the wing torsion couple than does the lift strut configuration hence the strut stresses, for all practical purposes, are solely a function of wing bending moment. Even if the wing were not so rigid in torsion the average of the front and rear struts would be solely a function of wing bending.

The data recorded during the accelerated flight program are presented in the Table II. The increments of strut strain recorded during take off are very nearly the same as those previously observed at 1 G during unaccelerated flight. The greatest acceleration reached was 2.09 G's during a chandelle to the right @ 152 Knots. The two accelerometers read virtually alike during all of the maneuvers indicating that accelerations due to pitching were negligible. The accelerometers also read alike during light turbulence encounter.

Assuming that spanwise lift distribution is the same for accelerated as for steady state flight, the lift strut strains resulting from various maneuvers may be predicted from the data recorded during Flight I. The computed lift strut stress is obtained by multiplying the average fuselage acceleration observed, by the average strut stress observed at 1 G. These calculations are presented in the Table III together with the measured values of average strut stress.

TABLE II
FLIGHT II, PBY-6A, NAVY 46683; 9-8-52
ACCELERATIONS & STRUT STRAINS.

NO.	MANEUVER	No.4 B'hd Accel. G's	No.5 B'hd Accel. G's	Front Struts Strain	Rear Struts Strain
1215	Calibrate 150000 ohms, four channel	.97	1.82	980	980
1216	On ground, 4:25 PM EDT.	1.00	1.00	0	0
1217	Take off 4:29 PM	1.00	1.00	457	460
1218	Pull up @ V_1 = 152 Knots, @ 2100'	1.88	1.94	787	820
1219	Pull up @ V_1 = 152 K, end @ 58 K.	1.72	1.74	735	811
1220	Chandelle left @ 150 Knots.	1.85	1.87	810	888
1221	Chandelle right @ 152 Knots.	*	2.09	894	986
1222	Two needle turn left 180° @ 110 K.	1.60	1.60	698	685
1223	Two needle turn right 180° @ 105 K. 4:44 PM	1.67	1.65	728	734
1224	Mild turbulence 4:50 PM @ 800' Alt V_1 = 112 - 108 K. Max. values.	1.22	1.21	569	571
1224	Mild turbulence, min. values	.85	.82	420	414
1226	On ground 4:58 PM EDT.	1.00	1.00	0	*
1228	Calibrate 150000 ohms four channels	.97	1.82	980	980

NOTES:
1. Gross weight = 31496 lbs, cg @ 254".
2. Oscillograph paper speed: .48"/second; 2.08 seconds/inch.
3. Galvanometer brightness: 3.5.
4. Accelerometer on #4 bulkhead drifted .043 G's; accel. on #5 bulkhead drifted .13 G's during test. Overall response decreased 6.6% average during test. Drift and response loss proportioned each run.
5. * Off paper edge.
6. Double needle turns averaged with planimeter over 14.3 second period, for run 1222, 1.60 G's corresponds to a turning rate of 11.8 deg/second. Airplane actually was being flown at 12°/sec.
7. Planimetering 15 seconds of #4 accelerometer, run 1224 = 1.041 G
8. 6-G Statham Accel. #4 bulkhead; 12 G on #5 bulkhead.

TABLE III

FLIGHT II, NAVY PBY-6A 46683; 9-8-52

MEASURED & COMPUTED LIFT STRUT STRESSES VS LOAD FACTOR

RUN NO.	AVE. LOAD FACTOR G's	AVE. STRUT STRESS - Psi	COMPUTED * STRUT STRESS
1217	1.00	4720	4515
1218	1.92	8280	8670
1219	1.73	7960	7810
1220	1.86	8745	8400
1221	2.09	9690	9450
1222	1.60	7110	7230
1223	1.66	7540	7500
1224	1.22	5870	5510
1224	0.84	4300	3795

NOTES: 1. * Computed from 1 G steady state flight measurements ie: Flight I, Gross weight = 32408 Lbs. cg @ 256" average strut stress = 4650 psi; reduced to 31496 lbs equals 4515 psi.

2. Load factor is average of two accelerometer readings, one at #4 the other at #5 bulkhead. Strut stress is the average of all four lift struts, assume $E = 10.3 \cdot 10^6$

3. Values given for runs 1222 and 1223 average of planimeter readings over a 14.3 second period.

RESULTS CONT.

The theoretically predicted and observed values of lift strut stress have been plotted against load factor on the Figure 3. The Figure 3. indicates that a linear extrapolation of the strut stress at 1 G will fall through the test points established during accelerated flight. The linear relationship between strut stress and load factor indicates that the spanwise lift distribution remains constant during accelerated flight at least up to 2.1 G's. Despite the poor aerodynamic form of the fuselage it does not noticeably affect the distribution of lift along the wing throughout the ranges in speed, angle of attack and acceleration investigated. It seems evident that wing lift loads may be accurately predicted from fuselage accelerometer readings in the case of the PBY-6A airplane.

WATER COLUMN VS ELECTRIC ACCELEROMETERS.

During Flight II, fuselage accelerations were also recorded by means of a simple water column accelerometer located on the table within the navigation compartment of the airplane. Accelerations from this instrument were recorded by means of a direct writing inked pen. The chart made by the water accelerometer has been analyzed and compared to the data from the electric accelerometers, this comparison is carried in the Table IV and shows good correlation.

WING WHIP.

At this date it has been impossible to obtain any engineering information on the PBY airplane from either the manufacturer or the present

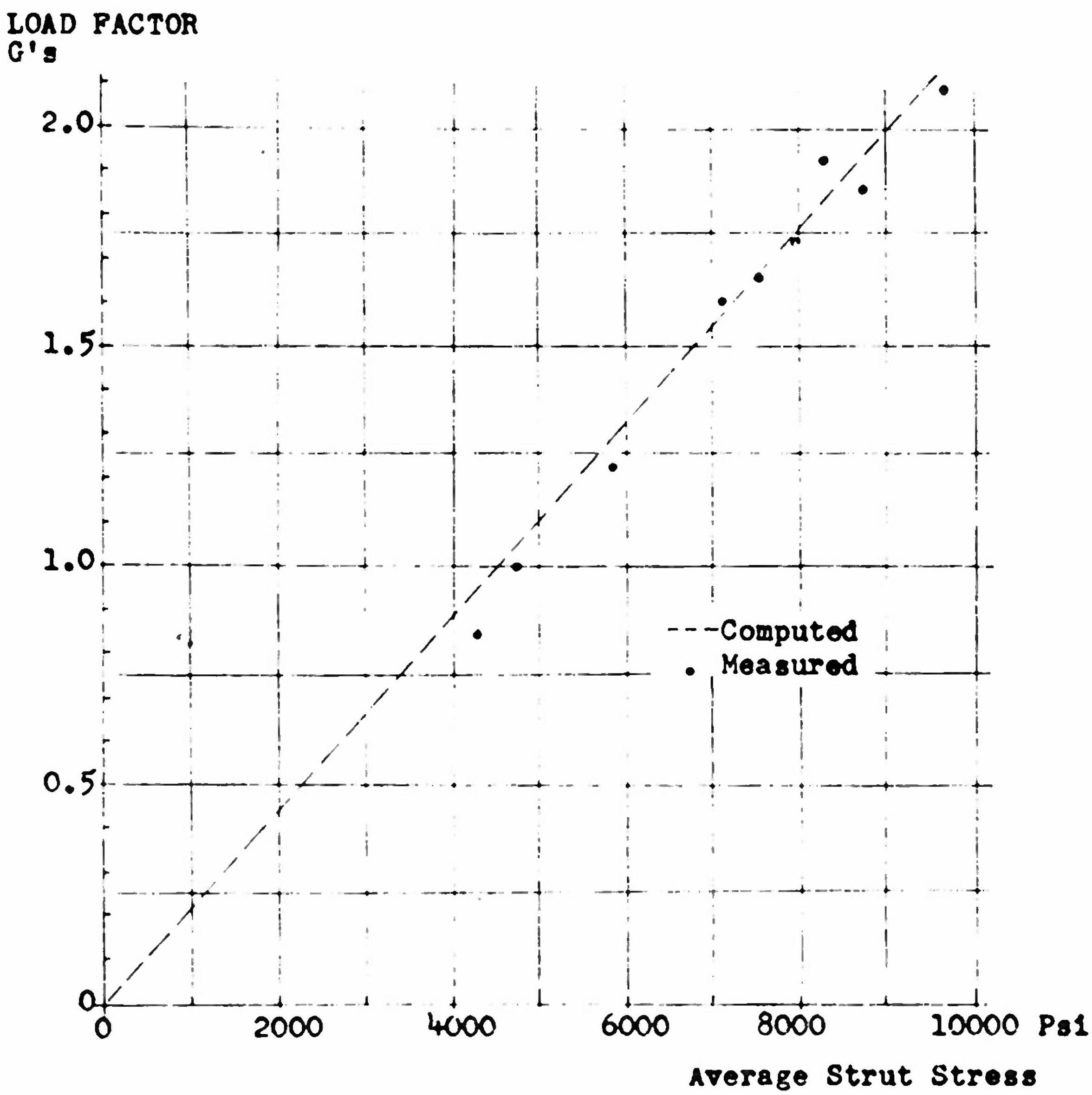


FIGURE 3. DYNAMIC LIFT STRUT STRESS, MEASURED VS COMPUTED.
FLIGHT II PBY-6A NAVY 46683; 9-8-52.

TABLE IV

COMPARISON WATER COLUMN WITH ELECTRIC ACCELEROMETERS. 9-8-52

RUN NO.	AVE. ELECTRIC	WATER COLUMN	% DIFFERENCE
1218	1.92	1.77	8
1219	1.73	1.66	4
1220	1.86	1.76	5
1221	2.09	1.90	9
1222	1.60	1.52	5
1223	1.66	1.60	4
1224	1.22	1.22	0
1224	0.84	0.88	5

NOTES: 1. Above data from analysis of records taken during Flight II on 9-8-52.

2. Electric accelerometer readings are the average of the readings from the Statham 6 G model R-6-350 and the Statham 12 G model AR-12-250. Recorded on Consolidated Engineering oscillograph type 5-116 driven by four channel 1 Kc carrier amplifier.

3. Water column accelerometer direct coupled to ink recording pen.

WING WHIP CONT.

licencee, the C.H. Babb Co. Consequently the fundamental bending frequency of the wing is not known and therefore cannot be identified among the various frequencies observed in the oscillograph traces. Acceleration errors due to wing whip in a strut braced wing should be less likely as compared to the case of a cantilevered wing. Moreover it seems certain that wing over travel would produce fuselage reactions of opposite sign to those resulting from the strut loads consequent on wing whip. Wing whip then should be identifiable from the oscillograph records wherein the strut strain traces should exhibit oscillations of greater amplitude than the corresponding oscillations in acceleration. Examination of the oscillographic records of appendix no. 2 indicates that, except for take off, the strut and accelerometer traces correlate in both amplitude and frequency. It appears that for this airplane, errors in accelerometer readings due to wing whip are negligible, over the range investigated.

REFERENCES.

1. STRESSES PRODUCED IN AIRPLANE WINGS BY GUSTS. Kussner, H.G. NACA Technical Memo 654, 1932.

2. SUMMARY OF INFORMATION RELATING TO GUST LOADS ON AIRPLANES. Donely, P. NACA Technical Note 1976. November 1949.

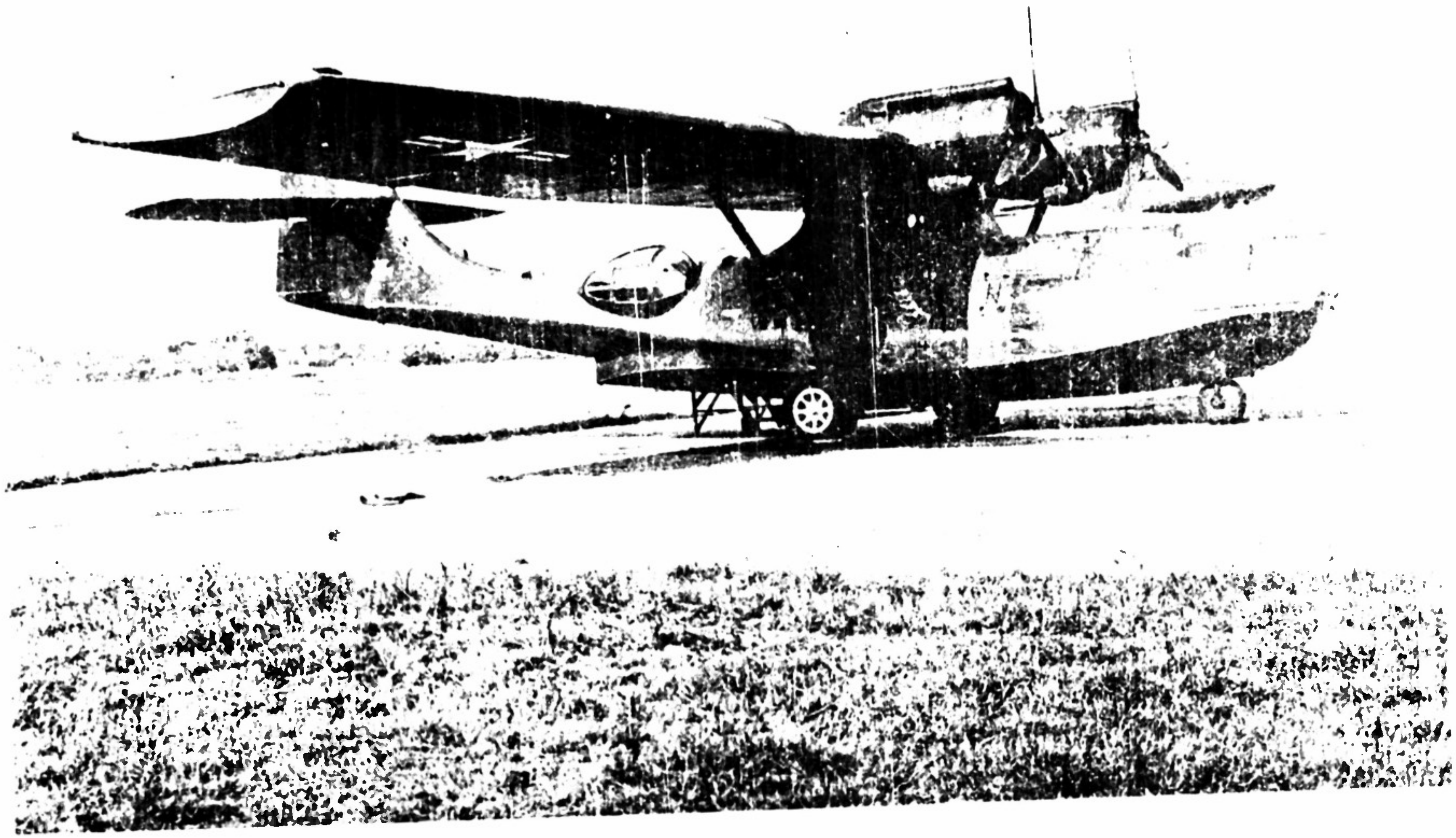
3. AN EVALUATION OF THE IMPORTANCE OF FATIGUE PHENOMENA IN AIRCRAFT. A Symposium. Institute of Aeronautical Sciences Preprint No. 105. July, 1946.

4. AIRPLANE AIRWORTHINESS. CAM 04. U.S. Government Printing Office, 1945.

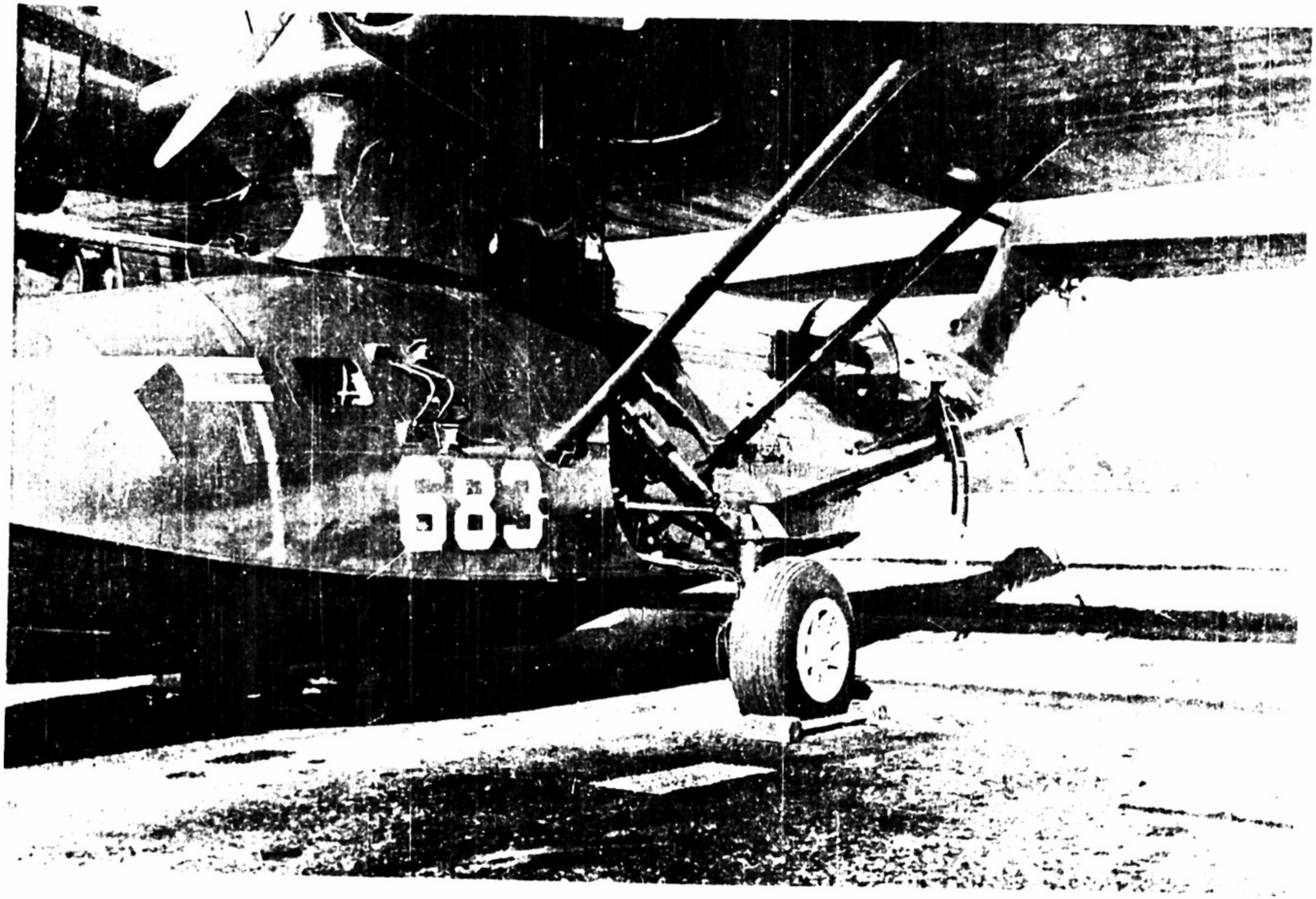
5. TESTS OF STATHAM ACCELEROMETER MODEL AE-2. Progress Report 8 Bureau of Aeronautics Project 4025. January 26, 1945.

APPENDIX NO. 1

PHOTOGRAPHS OF AIRPLANE AND TEST INSTALLATION

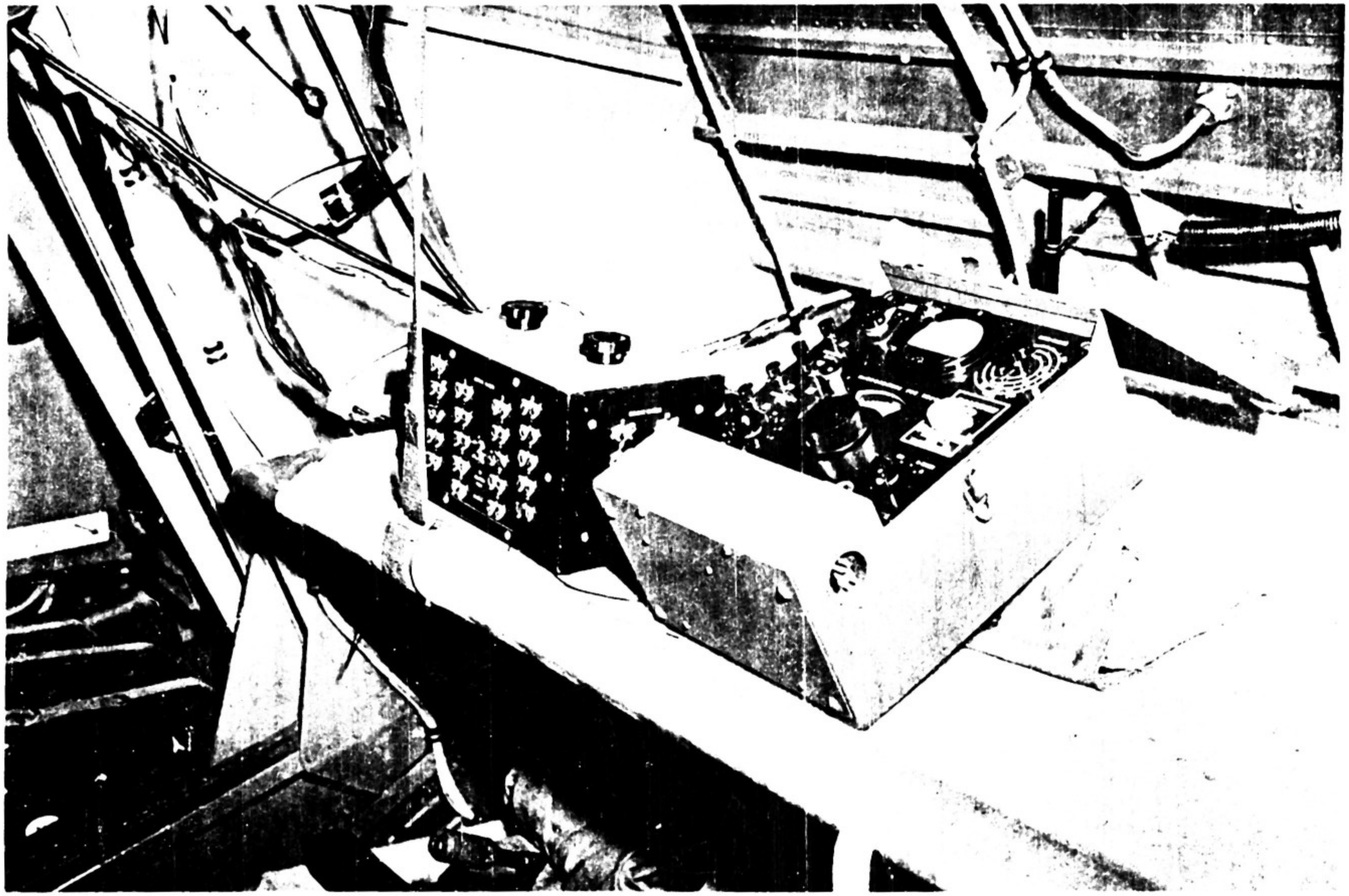


VIEW OF PBY 6A-NAVY 46683

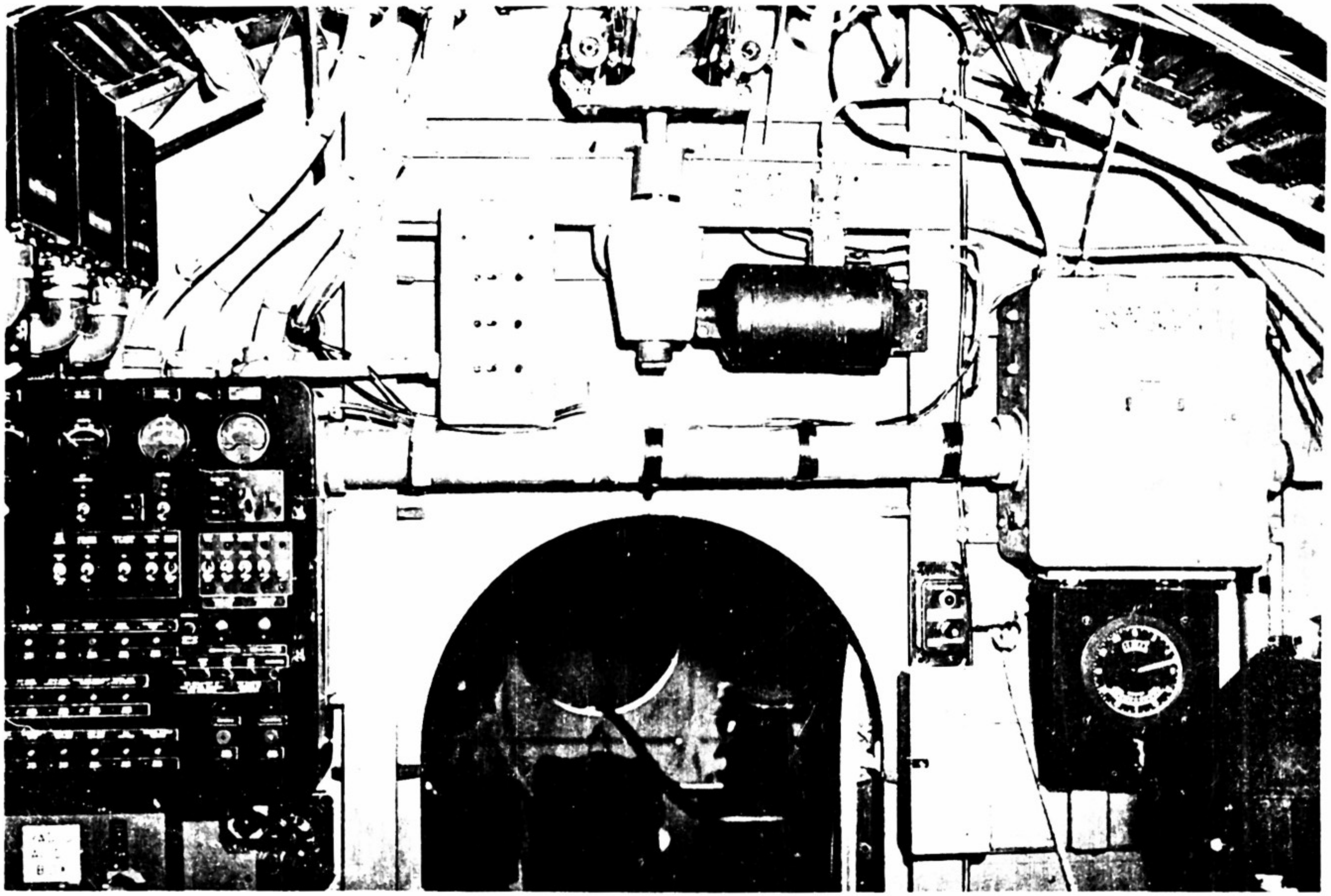


LIFT STRUTS SHOWING GAGES NO. 1 & NO. 3

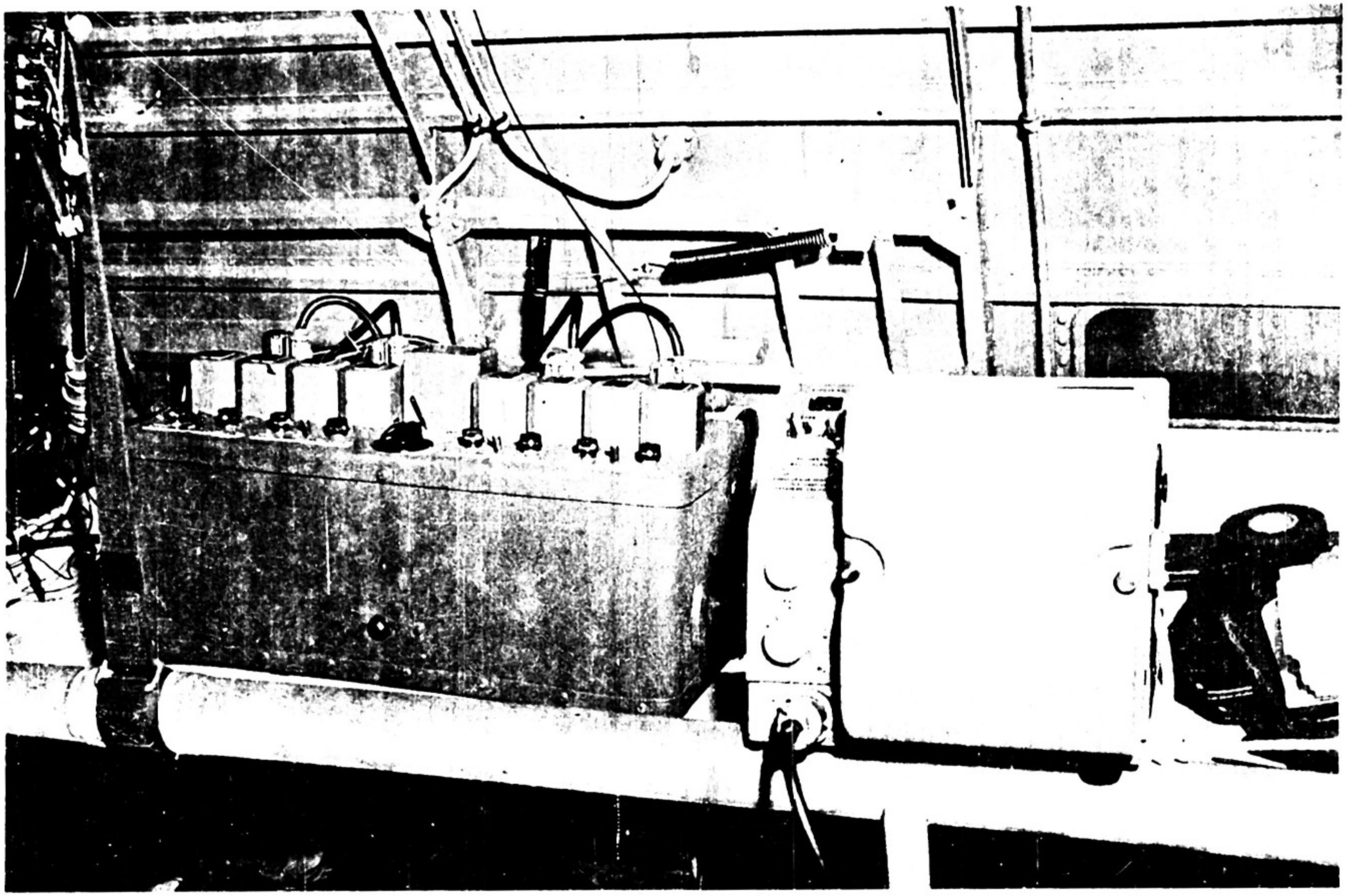
GAGES NO. 5 & NO. 6, COVERED



FLIGHT I RECORDING INSTRUMENTS



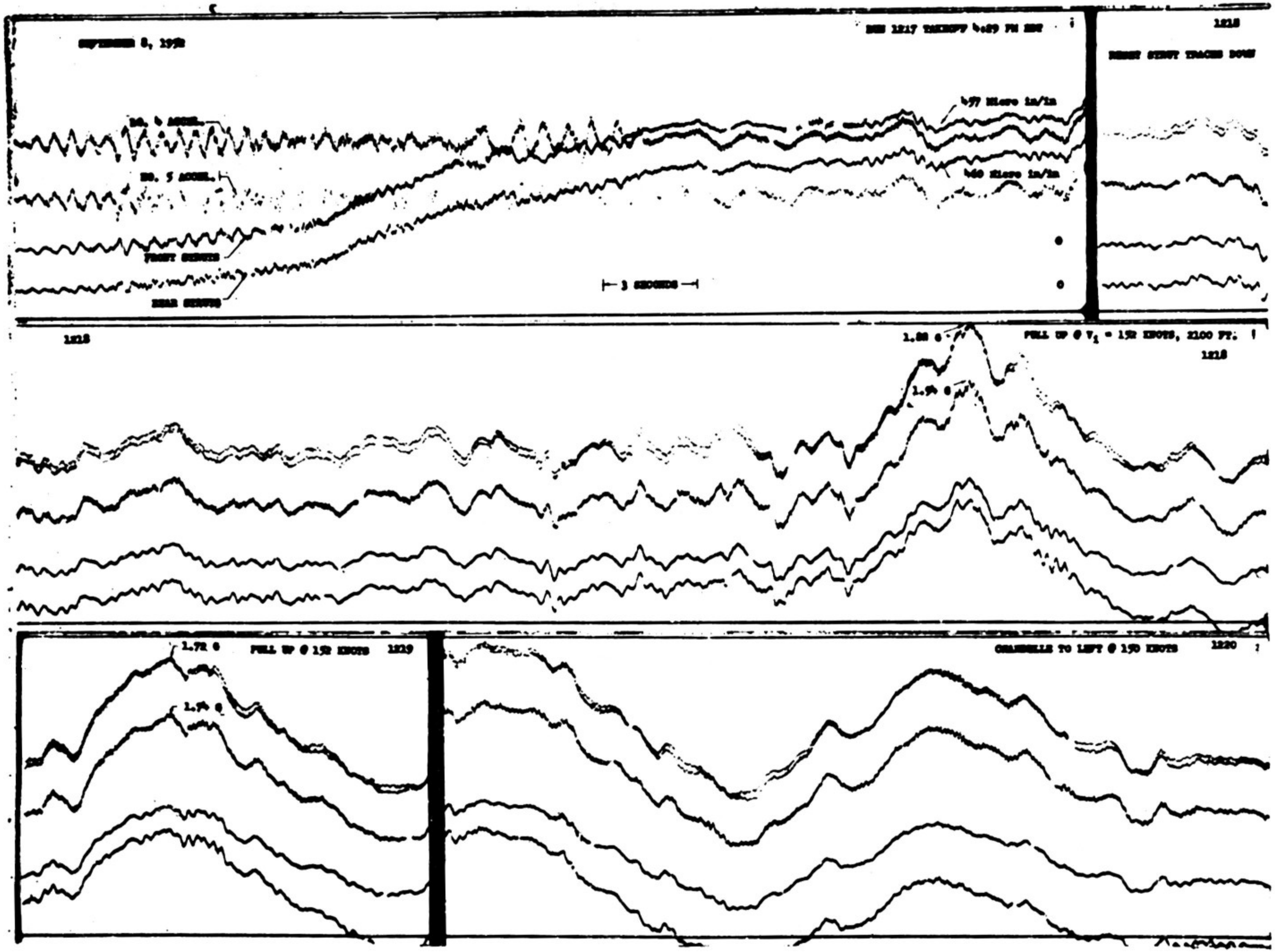
6 G ACCELEROMETER

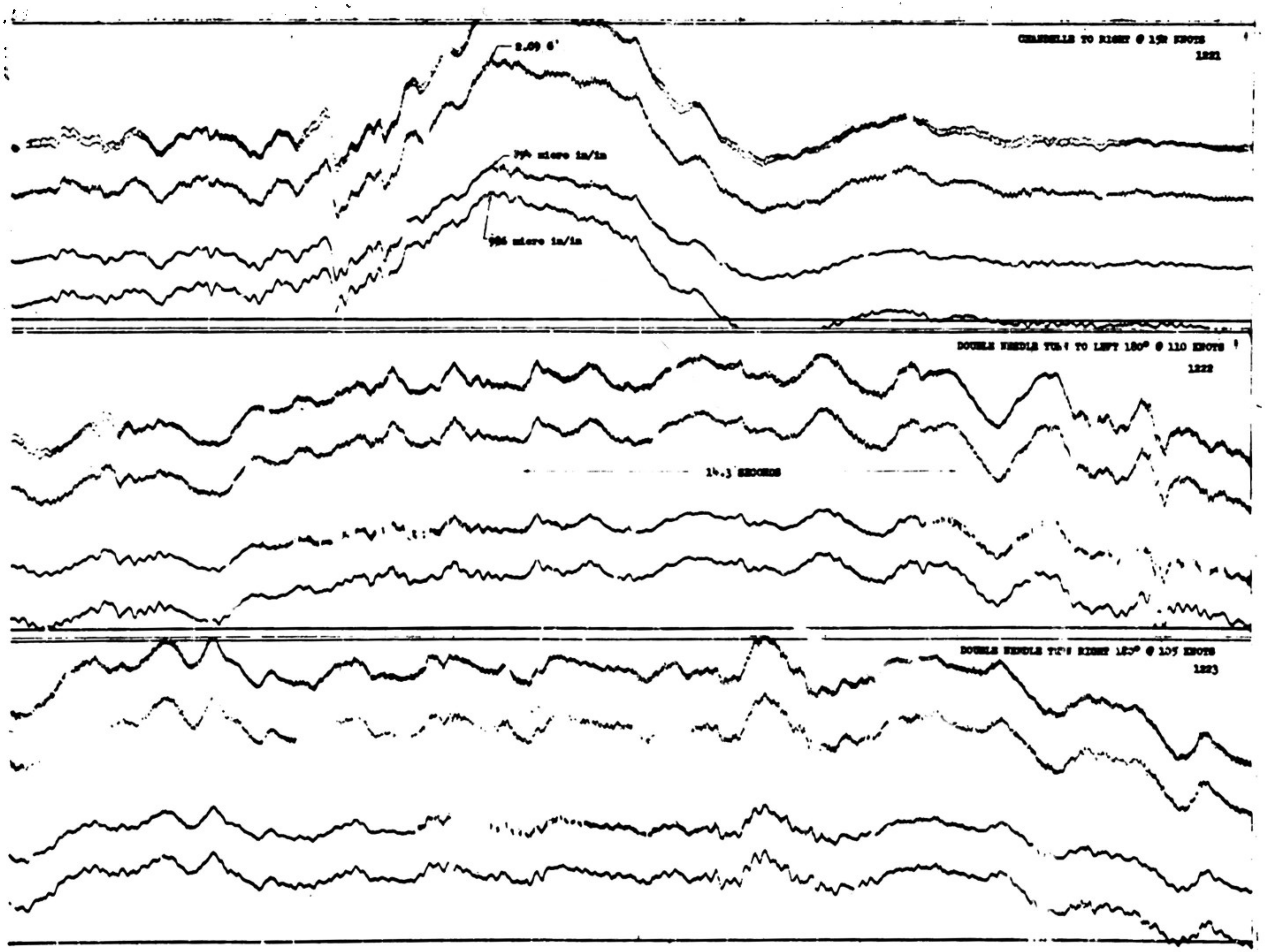


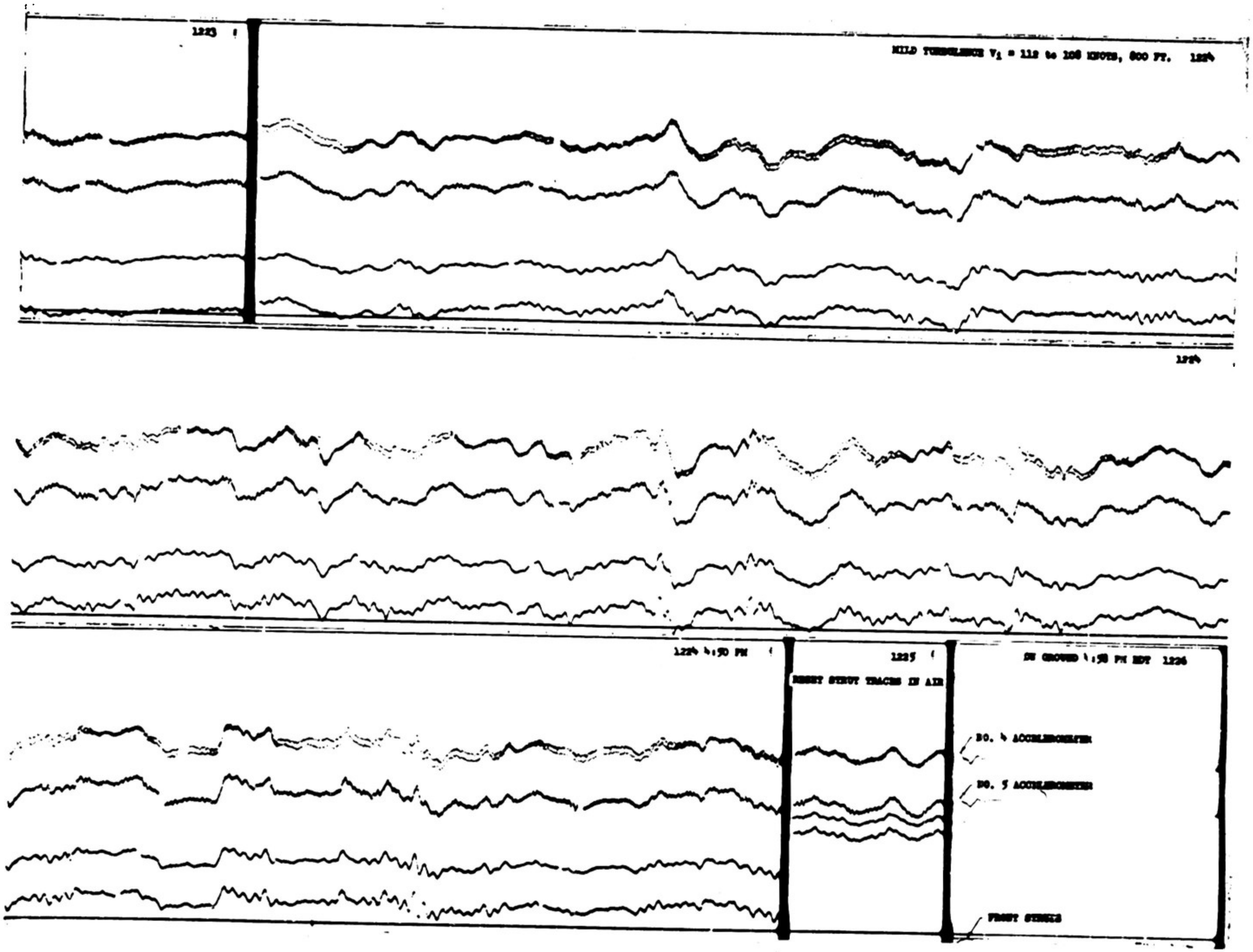
FLIGHT II RECORDING INSTRUMENTS

APPENDIX NO. 2

REPRODUCTIONS OF OSCILLOGRAPH RECORDS


3 SECONDS
1218
PULL UP @ V_1 = 152 KNOTS, 2100 FT.
1218
1.88 G
1.94 G
1.72 G
1.74 G
PULL UP @ 152 KNOTS
1219
CHANDELLE TO LEFT @ 150 KNOTS
1220


CHANDELLE TO RIGHT
1221
2.09 G
micro in/in
micro in/in
DOUBLE NEEDLE
TO LEFT 180° @ 110 KNOTS
1222
14.3 SECONDS
DOUBLE NEEDLE
@ 105 KNOTS
1223


1223
MILD TURBULENCE V_i = 112 to 108 KNOTS, 800 FT. 1224
1224
1224 4:50 PM
1225
RESET STRUT TRACES IN AIR
ON GROUND 4:58 PM EDT 1226
NO. 4 ACCELEROMETER
NO. 5 ACCELEROMETER
FRONT STRUTS

APPENDIX NO. 3

WEIGHT AND BALANCE DATA

TABLE I

WEIGHING PBY-6A, NAVY 46683 ON 9-6-52

TIME	WHEEL	JACK PRESSURE	WEIGHT	J. TRAVEL	θ
3:25 PM	Left Main	4750 psi	14850 Lbs	3.875"	1.1°
-	Right Main	4300	13430	3.938	1.1
4:02 PM	Nose Gear	825	2580	2.250	0.6

NOTES: 1. 464 gallons of gasoline @ 6 lbs/gal; 82 gallons of oil @ 7.5 lbs/gal. aboard at this date.

2. No personnel aboard, magnetic towing reel aboard. L & N Recorder and water column accelerometer in Navigation compartment. Large box of tools in crew's quarters. Twin channel L & N, amplifiers and homing coil usually in blister compartment not aboard for this weighing.

3. Main wheel spacing ℄ to ℄ = 201 inches.

4. Jack load = Jack pressure x 3.125.

TABLE II

CALCULATING BASIC WEIGHT & CG LOCATION PBY-6A, NAVY 46683, 9-6-52

ITEM	WEIGHT	ARM	WEIGHT x ARM Lb-in
Left main	14850	273.3	4060000
Right main	13430	273.3	3678000
Nose gear	2580	68.4	176300
Fuel	-2785	267.0	-744000
Oil	-615	208.0	-128100
Total	27460 Lbs.		7042200 Lb-in

cg = 7042200/27460 = 256 inches.

TABLE III

WEIGHT & BALANCE DATA PBY-6A, NAVY 46683 FROM AN-01-1B-40

ITEM	ARM-STATION
Nose wheel	68.4"
Pilot's Seats	113.0
Radar Seat	170.8
Navigation Table	170.8
Mechanics Seat	260.0
Main Wheels	273.3
Fuel	267.0
Trapped Oil	208.0
Crew's Quarters	351.3
Blister Compartment	425.0

Mean Aerodynamic Chord, M.A.C. = 165.3"

Most forward permissable cg = 23% MAC = 242.47"

Most aft cg limit, hydrodynamic = 33% MAC = 256.0"

Most aft cg limit controllability in flight = 34% MAC = 260.7"

Reference chart E AN-01-1B-40

TABLE IV

WEIGHTS OF MISCELLANEOUS INSTRUMENTS

ITEM	WEIGHT
5-116 Consolidated Oscillograph	55.0 Lbs.
Opad-Green Rectifier	38.5
Four Channel, 1 Kc Amplifier	30.0
Large Tool Box (GAB)	15.4
Instrument Box (GAB)	6.2
SR-4 Strain Indicator	25.5
SR-4 Twenty Channel Switch	8.5
Speed Graphic Camera & Case	10.2
Experimental Pitot Tube	~10.0

NOTES: Instruments weighed on Chadwick & Carr balance scale, inspected by H. Catlon New Bedford Department of Weights and Measures September 1952

TABLE V

WEIGHTS OF INDIVIDUAL CREW MEMBERS

PERSONNEL	WEIGHTS
N. Gingras	180 Lbs
R. Fournier	190
K. McCasland	140
L. Rose	180
A. Bunker	180
E. Miller	145
C. Kiernan	180
D. Leeper	180
G. Brewer	176

NOTES: Above weights are individual estimates.

TABLE VI

COMPUTING WEIGHT AND BALANCE FLIGHT I; 9-8-52

ITEM	WEIGHT	ARM	WEIGHT x ARM
Airplane	27460 Lbs	256.0	7042200
Fuel, 464 gallons	2785	267.0	744000
Oil, 82 gallons	615	208.0	128100
N. Gingras	180	113.0	20350
R. Fournier	190	113.0	21500
D. Leeper	180	170.8	30720
A. Bunker	180	170.8	30720
C. Kiernan	180	170.8	30720
L. Rose	180	260.0	46800
E. Miller	145	351.3	50900
G. Brewer	176	351.3	61700
Strain Indicator	25.5	351.3	8960
SR-4 Switch	8.5	351.3	2950
Power Supply	38.5	351.3	13500
Pitot Tube	10.0	-36.0	-360
L & N plus Amplifiers	~155	425	65800
Two men	~330	425	140200
Total	32838.5		8438760

NOTES: 1. Take off 1:42 PM EDT, land 3:15 PM; fuel consumption approximately 78 gph.

2. Time of strain gage records, 2:22 to 2:46PM, average 2:34 PM. Fuel consumed at this point 405 lbs (67.5 gal) and 25 lbs oil. G.W. at time of test = 32408 lbs.

TABLE VII

COMPUTING WEIGHT AND BALANCE FLIGHT II; 9-8-52

ITEM	WEIGHT	ARM	WEIGHT x ARM
Airplane	27460 Lbs	256.0	7042200
Fuel, 343 gallons	2060	267.0	550000
Oil, 76 gallons	570	208.0	118500
N. Gingras	180	113.0	20350
D. Leeper	180	113.0	20350
R. Fournier	190	170.8	32450
A. Bunker	180	170.8	30720
C. Kiernan	180	170.8	30720
L. Rose	180	260.0	46800
Tools (E. Miller)	-25	351.3	-8780
G. Brewer	176	351.3	61700
5-116 Oscillograph	55.0	351.3	19300
Power Supply	38.5	351.3	13500
Amplifier	30.0	351.3	10520
Tool Box	15.4	351.3	5400
Tool Box (Instrument)	6.2	351.3	2160
Camera & Case	10.2	351.3	3560
Pitot Tube	10	-36	-360
Total	31496.3		7999090

NOTES: 1. Take off 4:29 PM, land 4:58 PM, 9-8-52

2. Tests completed 15 minutes after take off, neglect weight change. Gross weight = 31496 Lbs, cg @ 254"

TABLE VIII

CALIBRATING HEIN-WERNER 12 TON JACK, M.I.T. 9-16-52

DIAL PRESSURE PSI.	MACHINE LOAD LBS.	PISTON EXTENSION Inches.
• 0	0	0.25
• 500	1190	-
• 1000	2560	-
• 1500	4010	-
• 2000	5600	-
• 3000	8790	-
• 4000	11880	-
• 5000	15150	-
• 6000	18200	-
• 7000	21250	-
• 8000	24350	0.438
+ 5000	15700	1.75
+ 8000	25000	1.75

NOTES: 1. Hein-Werner 12 Ton Jack, model E 12.9A, 9 to 18" travel.

2. Jack cylinder pressure measured on Ashcroft 0-10000 psi pressure gage.

3. Jack load measured on Tinius Olsen beam balance testing machine. Department of Mechanical Engineering M.I.T.

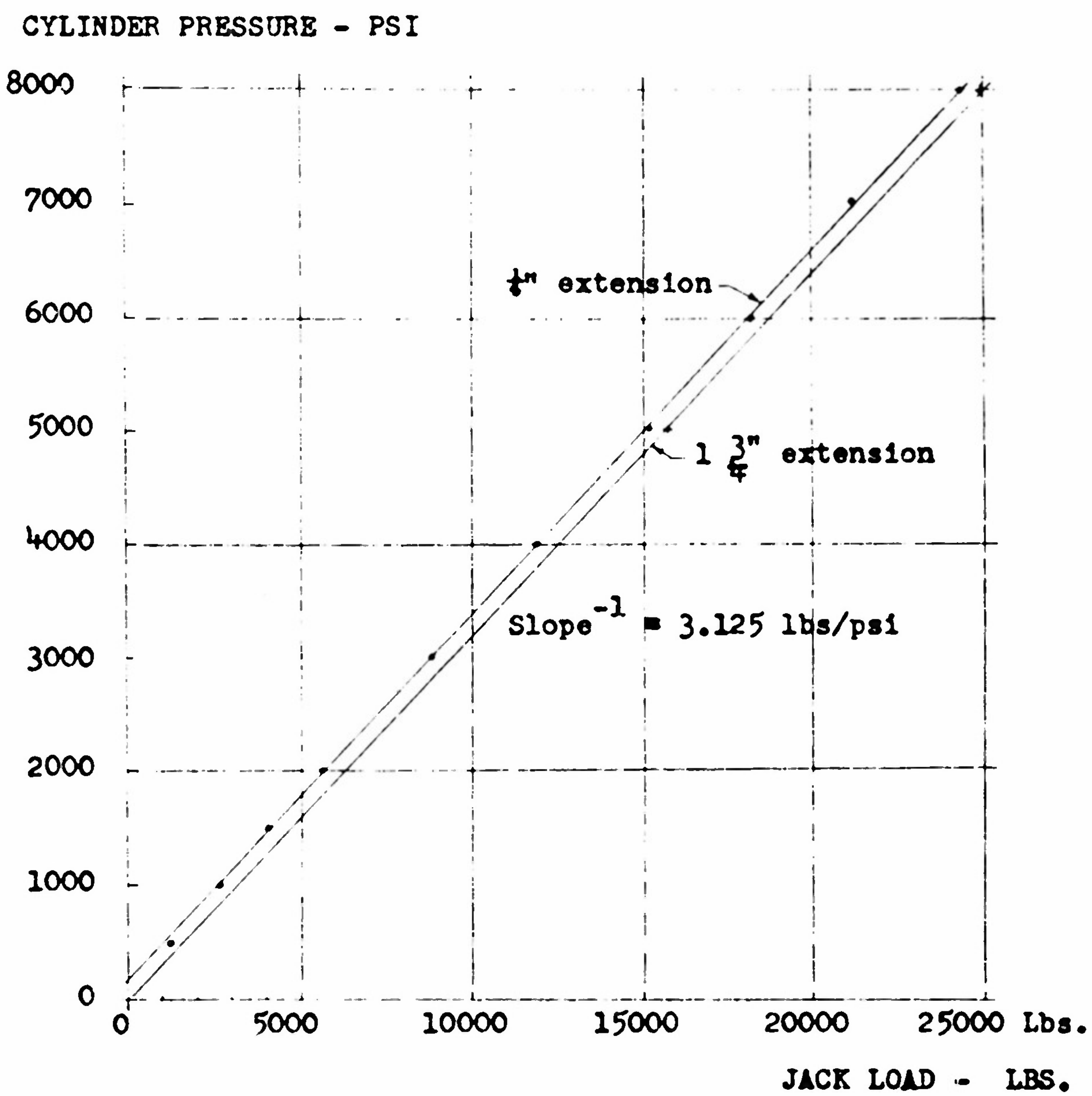


FIGURE 1. PLOT JACK CYLINDER PRESSURE VS JACK LOAD.

APPENDIX NO. 4

GAGE HISTORY

TABLE I

SCHEDULE OF GAGE ATTACHMENT N 46683

GAGE NO.	TYPE	RESISTANCE	FACTOR	ATTACHED	COVERED
1	A-6	300 ± 1 Ω	2.04 ± 1%	9-5-52, 5:00P	9-6-52 8:30 AM
2	A-6	300 ± 1 Ω	2.04 ± 1%	5:10 PM	
3	A-6	300 ± 1 Ω	2.04 ± 1%	5:28 PM	-
4	A-6	300 ± 1 Ω	2.04 ± 1%	5:33 PM	-
5	A-6	300 ± 1 Ω	2.04 ± 1%	5:58 PM	-
6	A-6	300 ± 1 Ω	2.04 ± 1%	6:03 PM	-
7	A-6	300 ± 1 Ω	2.04 ± 1%	6:20 PM	9-6-52 5:00 PM
8	A-6	300 ± 1 Ω	2.04 ± 1%	6:25 PM	
D-1	A-6	300 ± 1 Ω	2.04 ± 1%	8:00 PM	9-6-52 8:30 AM

NOTES: 1. Gages glued to wing lift struts with SR-4 cement then after drying overnight covered with A-2 cement & activator. Then covered with rubber tape gages #5, #6, #7 & #8 and friction tape gages #1, #2, #3, #4 and D-1. Entire gage area of struts then wrapped with heavy corrugated cardboard and masking tape.Cardboard covered with 2-3 coats white shellac.

2. Gage leads doubled over and connected to #20 solid lead in wires using AMP 36551 fittings, three crimps.

3. Dummy D-1 had end metal to metal contact with front strut for thermal contact, remainder of dummy riding on masking tape to prevent mechanical connection with strut. Dummy was light aluminum alloy sheet metal channel, gage on web.

4. Lead in wires clamped to fuselage by sheet metal clips and screws. Wires protected from chafing at fuselage by means of rubber grommets through the skin.

5. September 5th. dry, sunny and warm.

Address	Copies
Chief of Naval Research, Navy Department, Washington 25, D. C. Attention: Code 416	3
Director, Naval Research Laboratory, Washington 25, D. C. Attention: Technical Information Officer, Code 2000	9
Commanding Officer, Office of Naval Research Branch Office, 346 Broadway, New York 13, New York	1
Commanding Officer, Office of Naval Research Branch Office, 844 North Rush Street, Chicago 11, Illinois	1
Commanding Officer, Office of Naval Research Branch Office, 1030 E. Green Street, Pasadena 1, California	1
Commanding Officer, Office of Naval Research Branch Office, 1000 Geary Street, San Francisco, California	1
Commanding Officer, Office of Naval Research Branch Office, 150 Causeway Street, Boston, Massachusetts	1
Officer in Charge, Office of Naval Research, Navy No. 100 Fleet Post Office, New York, New York	7
Department of Aerology, U. S. Naval Post Graduate School, Monterey, California	1
Aerology Branch, Bureau of Aeronautics (Ma-5), Navy Department, Washington 25, D. C.	1
Mechanics Division, Naval Research Laboratory, Anacostia Station, Washington 20, D. C., Attention: J. E. Dinger, Code 3820	1
Radio Division I, Code 3420, Naval Research Laboratory, Anacostia Station, Washington 20, D. C.	1
Meteorology Section, Navy Electronics Laboratory, San Diego 52, California, Attention: L. J. Anderson	1
Library, Naval Ordnance Laboratory, White Oak, Silver Spring 19, Maryland	1
Bureau of Ships, Navy Department, Washington 25, D. C. Attention: Code 851	1

Address	Copies
Bureau of Ships, Navy Department, Washington 25, D. C. Attention: Code 814	1
Bureau of Ships, Navy Department, Washington 25, D. C. Attention: Code 327	2
Chief of Naval Operations, Navy Department, Washington 25, D. C. Attention: OP-533D	2
Oceanographic Division, U. S. Navy Hydrographic Office, Suitland, Maryland	1
Library, Naval Ordnance Test Station, Inyokern, China Lake, California	1
Project AROWA, U. S. Naval Air Station, Building R-48, Norfolk, Virginia	1
The Chief, Armed Forces Special Weapons Project, P. O. Box 2610, Washington, D. C.	1
Office of the Chief Signal Officer, Engineering and Technical Service, Washington 25, D. C., Attention SIGGE-M	1
Meteorological Branch, Evans Signal Laboratory, Belmar, New Jersey	1
Office of the Quartermaster General, 2nd and T Streets, S. W., Washington 25, D. C., Attention: Environmental Protection Section	1
Office of the Chief, Chemical Corps, Research and Engineering Division, Research Branch, Army Chemical Center, Maryland	2
Commanding Officer, Air Force Cambridge Research Laboratories, 230 Albany Street, Cambridge, Massachusetts, Attention: ERHS-1	1
Headquarters, Air Weather Service; Andrews A. F. Base, Washington 20, D. C., Attention: Director Scientific Services	2
Commanding General, Air Materiel Command, Wright Field, Dayton, Ohio, Attention: MCREEO	1

Address	Copies
Commanding General, Air Force Cambridge Research Center, 230 Albany Street, Cambridge 39, Massachusetts, Attention: CRHSL	1
Commanding General, Air Research and Development Command P. O. Box 1395, Baltimore 3, Maryland, Attention: RDDG	1
Department of Meteorology, Massachusetts Institute of Technology, Cambridge, Massachusetts, Attention: H. G. Houghton	1
Department of Meteorology, University of Chicago, Chicago, 37, Illinois, Attention: H. R. Byers	2
Institute for Advanced Study, Princeton, New Jersey, Attention: J. von Neumann	1
Scripps Institute of Oceanography, La Jolla, California, Attention: R. Revelle	1
General Electric Research Laboratory, Schenectady, New York, Attention: I. Langmuir	1
St. Louis University, 3621 Olive Street, St. Louis 8, Missouri, Attention: J. B. Macelwane, S. J.	1
Department of Meteorology, University of California at Los Angeles, Los Angeles, California, Attention: M. Neiburger	1
Department of Engineering, University of California at Los Angeles, Los Angeles, California, Attention: L. M. K. Boelter	1
Texas A. and M., Department of Oceanography, College Station, Texas, Attention: D. Leipper	1
Massachusetts Institute of Technology, Department of Meteorology, 77 Massachusetts Avenue, Cambridge, Massachusetts, Attention: T. F. Malone	1
Cornell University, Department of Agronomy, Division of Meteorology, Ithaca, New York	1
Pennsylvania State College, School of Mineral Industries, Department of Earth Science, State College, Pennsylvania, Attention: H. Neuberger	1

Address	Copies
Rutgers University, College of Agriculture, Department of Meteorology, New Brunswick, New Jersey	1
University of Texas, Department of Aeronautical Engineering, Austin, Texas, Attention: K. H. Jehn	1
University of Utah, Department of Meteorology, Salt Lake City, Utah, Attention: V. Hales	1
University of Wisconsin, Department of Meteorology, Madison, Wisconsin, Attention: V. Suomi	1
National Advisory Committee of Aeronautics, 1724 F. Street, N. W., Washington 25, D. C.	2
U. S. Weather Bureau, 24th and M. Street, N. W., Washington 25, D. C., Attention: Scientific Services Division	2
Committee on Geophysics and Geography, Research and Development Board, Washington 25, D. C.	2
Air Coordinating Committee, Subcommittee on Aviation Meteorology, Room 2D889-A, the Pentagon, Washington 25, D. C.	1
American Meteorological Society, 3 Joy Street, Boston 8, Massachusetts, Attention: The Executive Secretary	1
Laboratory of Climatology, Johns Hopkins University, Seabrook, New Jersey, Attention: M. Halstead	1
Department of Meteorology, Florida State University, Tallahassee, Florida, Attention: W. A. Baum	1
Woods Hole Oceanographic Institution, Woods Hole, Massachusetts, Attention: C. Iselin	1
The Johns Hopkins University, Department of Civil Engineering, Baltimore, Maryland, Attention: R. Long	1
The Lamont Geological Observatory, Torrey Cliff, Palisades, New York, Attention: M. Ewing	1
The Johns Hopkins University, Department of Physics, Homewood Campus, Baltimore, Maryland, Attention: G. Plass	1

Address	Copies
New Mexico Institute of Mining and Technology, Research and Development Division, Socorro, New Mexico, Attention: E. Workman	1
University of Chicago, Department of Meteorology, Chicago 37, Illinois, Attention: H. Riehl	1
Woods Hole Oceanographic Institution, Woods Hole, Massachusetts, Attention: A. Woodcock	1
Iowa State College, Department of Physics, Ames, Iowa, Attention: J. E. MacDonald	1
Blue Hill Meteorological Observatory, Harvard University, Milton 86, Massachusetts, Attention: C. Brooks	1
Department of Meteorology, University of Washington, Seattle 5, Washington, Attention: P. E. Church	1
Laboratory of Climatology, Johns Hopkins University, Seabrook, New Jersey, Attention: C. W. Thornthwaite	1
Institute of Geophysics, University of California at Los Angeles, Los Angeles, California, Attention: J. Kaplan	1
Department of Meteorology, New York University, New York 53, New York, Attention: B. Haurwitz	1
U. S. Naval War College, Newport, Rhode Island	1

Additional Distribution List

Person or Organization	Copies
Brookhaven National Laboratory, Upton, L. I., N. Y. Meteorology Group	1
Chief, Meteorological Division, Biological Department Chemical Corps, Camp Detrick, Frederick, Maryland	1
Dr. August Raspet, Engineering and Industrial Research Station, Mississippi State College, State College, Mississippi	2
Dr. E. W. Hewson, Diffusion Project, Round Hill, South Dartmouth, Massachusetts	1

3 April 1952

Person or Organization	Copies
Dr. Hunter Rouse, Director, Iowa Institute of Hydraulic Research, State University of Iowa, Iowa City, Iowa	1
Head, Department of Physics, University of New Mexico, Albuquerque, New Mexico	1
Mr. Wendell A. Mordy, Hawaiian Pineapple Research Institute, Honolulu, Hawaii	1