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**U. S. A R M Y**  
**TRANSPORTATION RESEARCH COMMAND**  
**FORT EUSTIS, VIRGINIA**

**AD No.**

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*6* PRELIMINARY FLIGHT TEST DATA.  
XH-51A RIGID ROTOR HIGH SPEED FLIGHT PROGRAM,

*9* INTERIM REPORT NO. 4.

*11* OCT ██████ 1964,

*12* 29 p.

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## SUMMARY

This report summarizes the flight test results of the three-bladed rotor testing on the XH-51A "rigid rotor" helicopter. The object of this testing was to obtain data on maneuver limits and center-of-gravity offsets needed to proceed with the high speed flight testing of the XH-51A with wing and jet pod installed. A total of 39 flights were made with 11.6 hours of flight time during this testing.

## Discussion and Results

### Maneuver Envelopes

Two maneuver envelopes were defined as a research objective for this testing, the smaller envelope being associated with the specified target C.G. offsets of 16,000 inch-pounds both longitudinally and laterally. Both envelopes are shown in figure 1, together with the points flown. None of the points were considered by the pilot to be beyond the acceptable limits of stability, handling, vibration, or performance. The pilot stated that the lines AA - BB would probably be a natural vibration boundary beyond which pilots would not go. There is no structural limit, however, and on the rare occasion when it is necessary to pull very high g's, the vibration level would be acceptable. The C.G. was extended to 16,000 inch-pounds in both lateral directions and tests were flown in excess of 95 knots. The aerodynamic nature of the ballast rig, being non-representative of any future configuration, negated the usefulness of any testing above this speed. The longitudinal C.G. range had been investigated to 8,000 inch-pounds aft and 11,000 inch-pounds forward prior to these tests. It was considered that the value of extending the investigation to 16,000 inch-pounds fore and aft did not warrant the aircraft and calendar time required at this stage. No longitudinal C.G. extension tests were made.

### Configuration

The configuration for this phase was exactly that flown at Patuxent River, Maryland, except that the speed sensor was not used.

### Structures

The results of the strain gauge program are presented here in terms of bending moments and stress. The calibrations were effected in terms of bending moment which are readily convertible into stresses from the known section structural properties along the span of any particular hub or blade design.

Preliminary measurements obtained on the main rotor early in the program indicated hub station 7.4 as the most critical area of the hub and blade. The primary objective of these tests was the extension of the flight envelope and the major effort during the program was, therefore, directed to the consideration of loads and stresses at the critical station. The stresses quoted for station 7.4 are calculated from the bending moments measured at station 6.0.

a. Average Bending Stresses - Station 7.4

The highest values recorded were in the flapping plane. The average flapping stress variation was linear with load factor, being zero at 1.3 g with a mid-C.G. and zero at 1.15 g with a lateral C.G. offset and increasing 32,000 psi for each 1.0 g increment. The change of load factor for zero bending stress is due to the somewhat higher average test weight at the offset C.G. The maximum flap bending stresses were 37,000 psi at 0.07 g and 34,000 psi at 2.3 g. The average chordwise stresses were not significantly g sensitive; the level varied from 1,300 psi to 4,800 psi generally.

b. Cyclic Stresses - Station 7.4

A stress concentration factor of less than 3 has been estimated for station 7.4. The conservative use of a factor of 3 realizes an endurance stress of 26,000 psi. For average pull-up conditions, the cyclic flapping stress is around 20,000 psi and the cyclic chordwise stress around 9,000 psi. Assuming the moments are in phase, the average combined stress in maneuvers is about 29,000 psi which is only slightly above the estimated endurance stress of 26,000 psi. The number of cycles of stress above the endurance limit that would be accumulated due to maneuvers is at 26,000 psi; therefore, normal maneuvers should have very little damaging affect on the fatigue life. The highest combined cyclic stresses for the whole series of maneuvers were obtained in the pushover to .063 g's at 50 knots airspeed. Assuming the loads are in phase, the combined stress would be 44,000 psi. The combined stresses for the pull-up to 2.34 g-s were 40,400 psi. These results illustrate that the cyclic stresses at the critical section are mainly a function of severity of pilot control input (which governs the blade flapping moment) rather than the load factor obtained (which has an affect mainly on the chordwise moments). The type of transient loads and stresses described above are included in the fatigue analysis and in the fatigue tests.

The lateral C.G. displacements did not have a deleterious effect on the stresses obtained at the load factors flown. Each stress value shown on all curves versus load factor is the maximum value recorded during the maneuver and is not necessarily associated with the maximum load factor or the maximum average stress.

The stresses recorded line up well with the values anticipated for this hub design and only minor design changes are required to reduce the levels should such a move be desired.

The hub for the four-blade rotor tests incorporates a design change that further improves the critical area and reduces the stress concentration. For a given set of loads, the stresses in the critical area will be reduced by about 5 per cent and the stress concentration factor should be lower. The bank angle versus velocity envelope flown during these tests is presented in figures 14 and 15.

#### Vibration

The vibration levels recorded during the testing are shown in figure 16.

#### Flying Qualities

The philosophy in this area was to rely on pilot qualitative evaluation with regard to handling characteristics and to investigate quantitatively only those areas in which problems were indicated. Static longitudinal stability characteristics were evaluated and the results are presented in figures 18 and 19. The control required to trim data presented in figure 17 is from the quasi-stabilized conditions employed in the structural tests. The flying qualities are considered very good from a qualitative standpoint. At the higher speeds, longitudinal control sensitivity increases and reduced cyclic pitch to stick gearings were tried. The results indicate that a change of gearing over the speed range may be necessary. This may be accomplished by a simple two position control selection device to be activated by the pilot as required, or a more sophisticated "q" sensed automatic device. The control forces recorded during the envelope expansion are plotted against the normal acceleration in figures 20 and 21. The trim or zero force point was recorded at the trim speed in level flight prior to the initiation of the turn. Cyclic pitch only was employed on the turns up to about 1.8 g; beyond this load factor, collective was added. Throughout the envelope, the helicopter has exhibited stick fixed, stick free static and dynamically stable characteristics.

#### Performance

The sea level standard day level flight speed power polar presented on figure 22 is in good agreement with previous results.

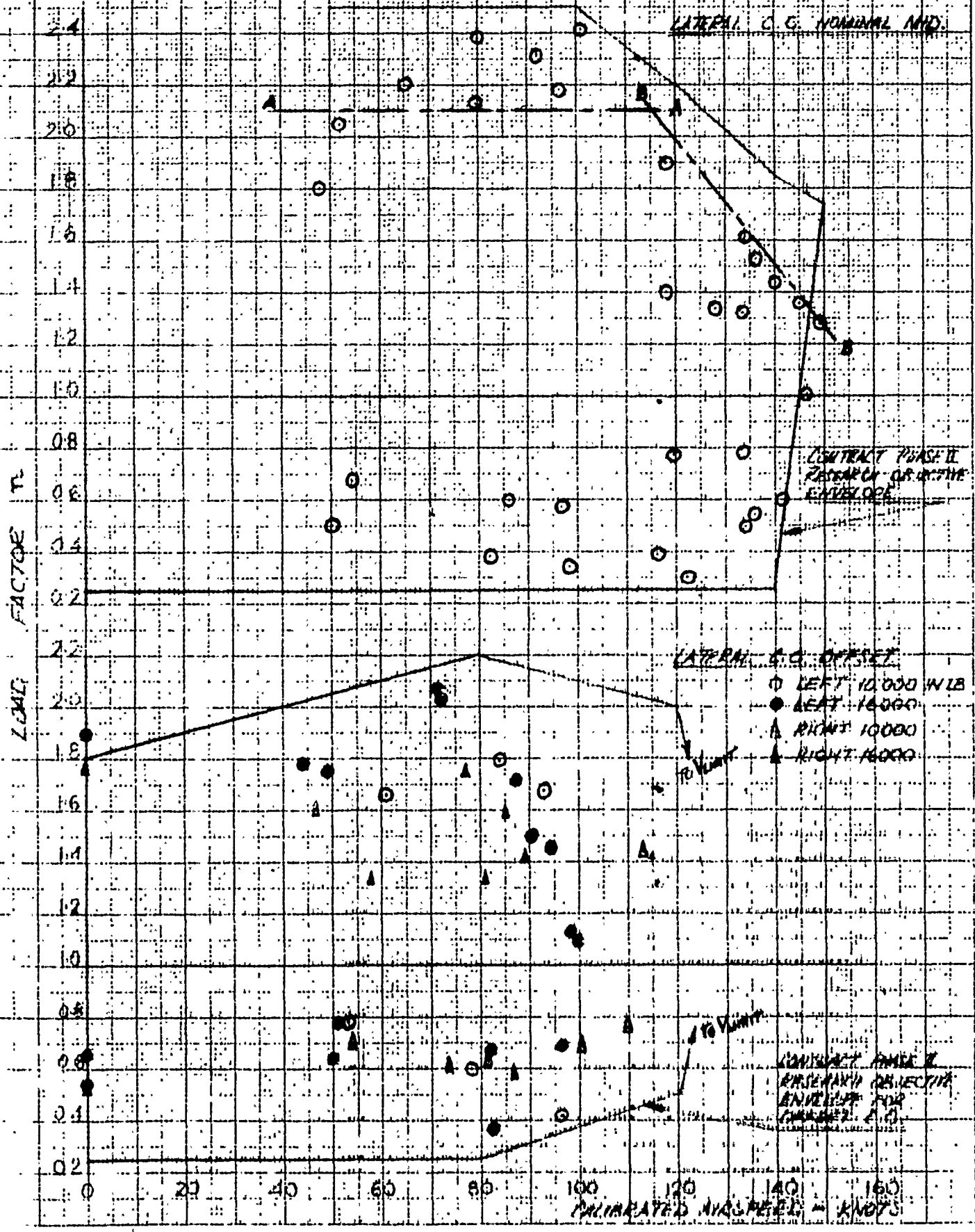
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 B77ND 151262  
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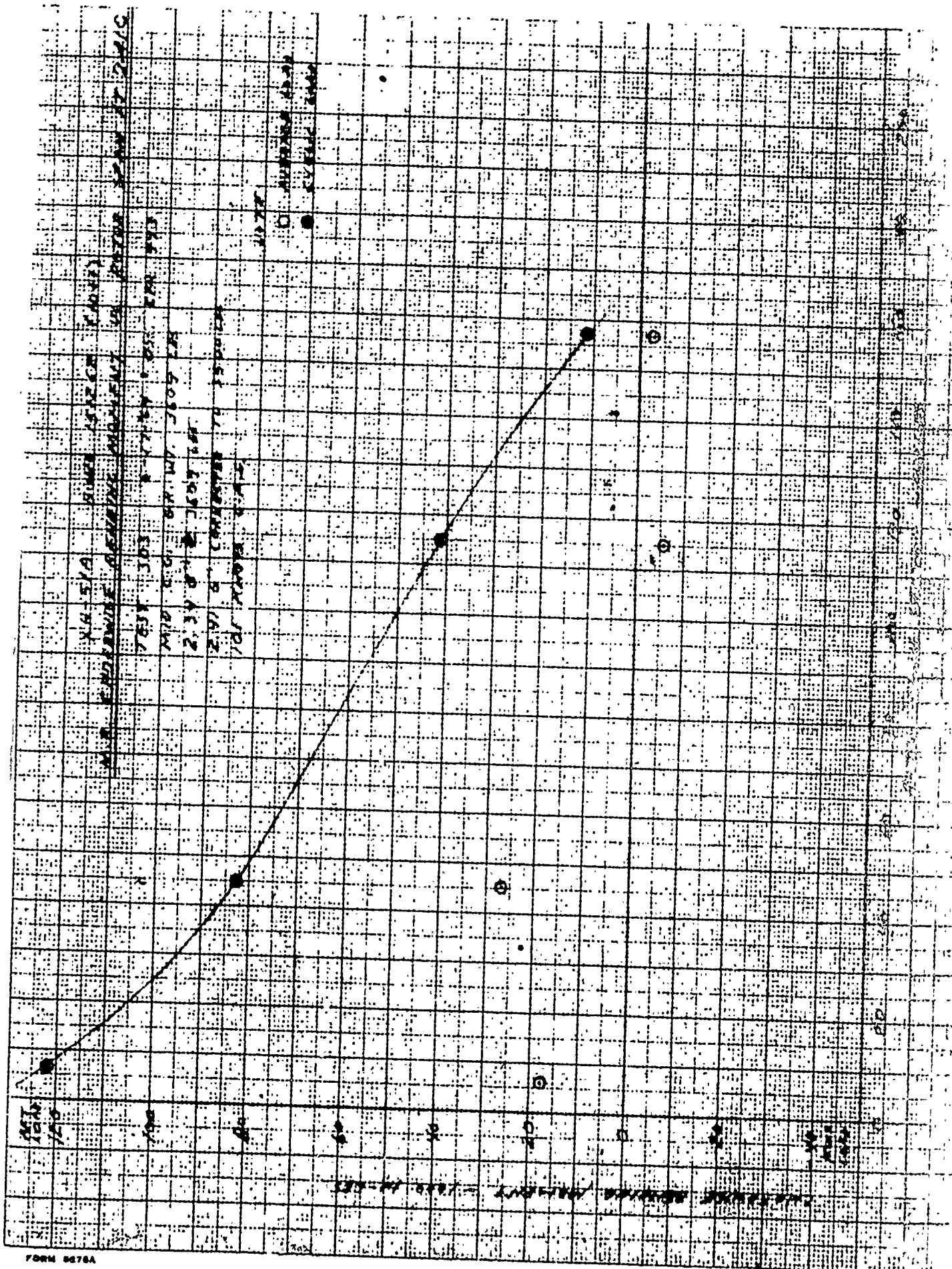
VIB DIAGRAM  
 GROSS WT 3500 LB  
 LONG. C.G.



FORM 8278A

FIGURE 1





FORM 8678A

FIGURE 3



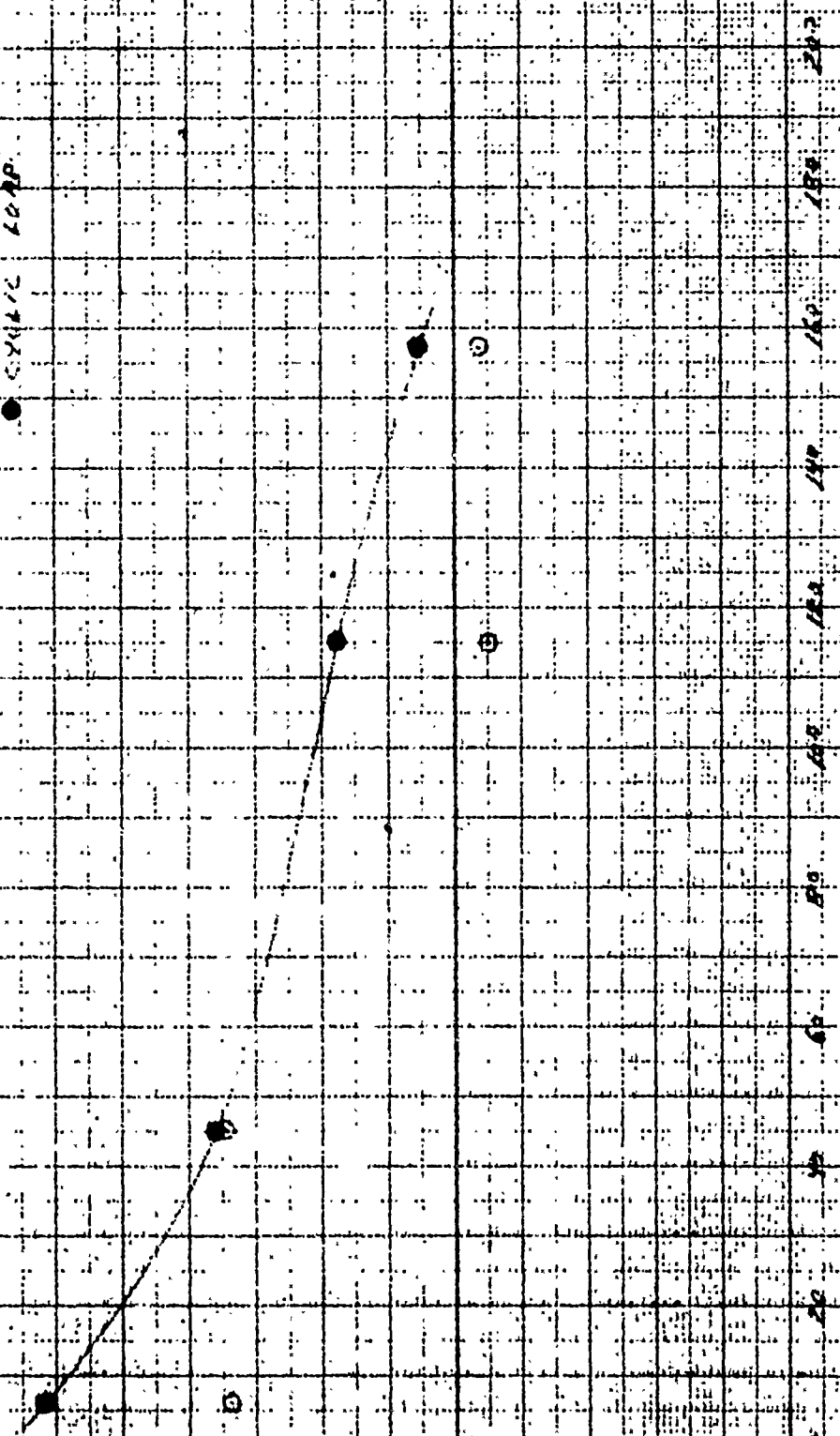
M.A. CROSSWISE BENDING MOMENT VS. ROTOR SPAN AT 143.5 KT LEVEL  
 RUMBLEBURG (10011)

TEST 301 GRWWT 3642.03  
 GRWWT 3642.03  
 LEVEL FLIGHT AT 143.5 KNOTS C.A.S.

NOTE:  
 O AVERAGE LOAD  
 ● CYCLIC LOAD

LEFT  
 1000  
 800

ROTOR SPAN STATION NUMBER



ROTOR SPAN STATION NUMBER

FIGURE 5

TEST NO.	MOMENT (K-FT)	WT.
271	2288 AT	3718
284	2288 AT	3640
292	2288 AT	3640
273	2288 AT	3640
291	2104 AT	3648
302	2104 AT	3645
303	2104 AT	3640
314	2104 AT	3600

FLAPWISE BENDING MOMENT - IN LBS. FT. (Y-axis label)

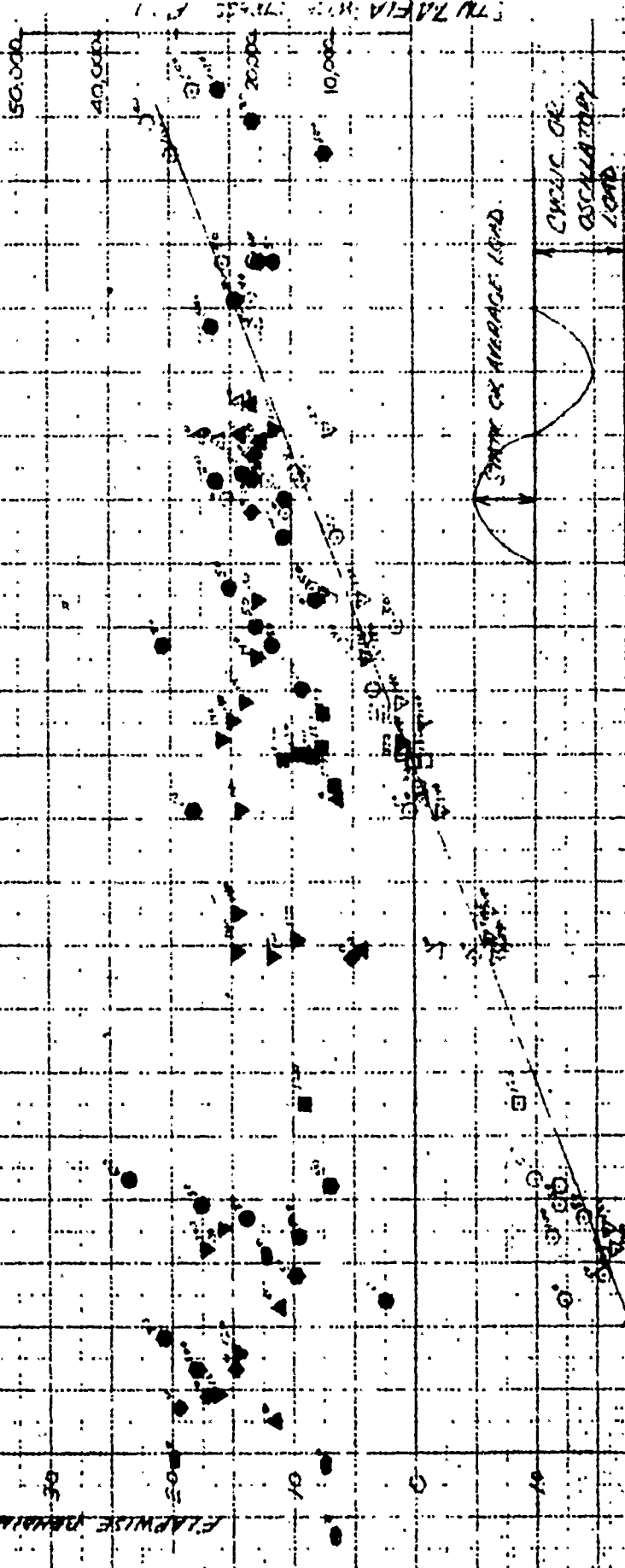
WING FLAP BENDING MOMENT STA. 6 VS. LOAD FACTOR

MID. C.B.

APPLIED SYMBOLS = CYCLIC LOAD

OPEN SYMBOLS = AVERAGE LOAD

NUMBERS, TO AT OF SYMBOLS = APPROX. AIRSPEED



LOAD FACTOR

1.0 1.2 1.4 1.6 1.8 2.0 2.2 2.4

FIGURE 6

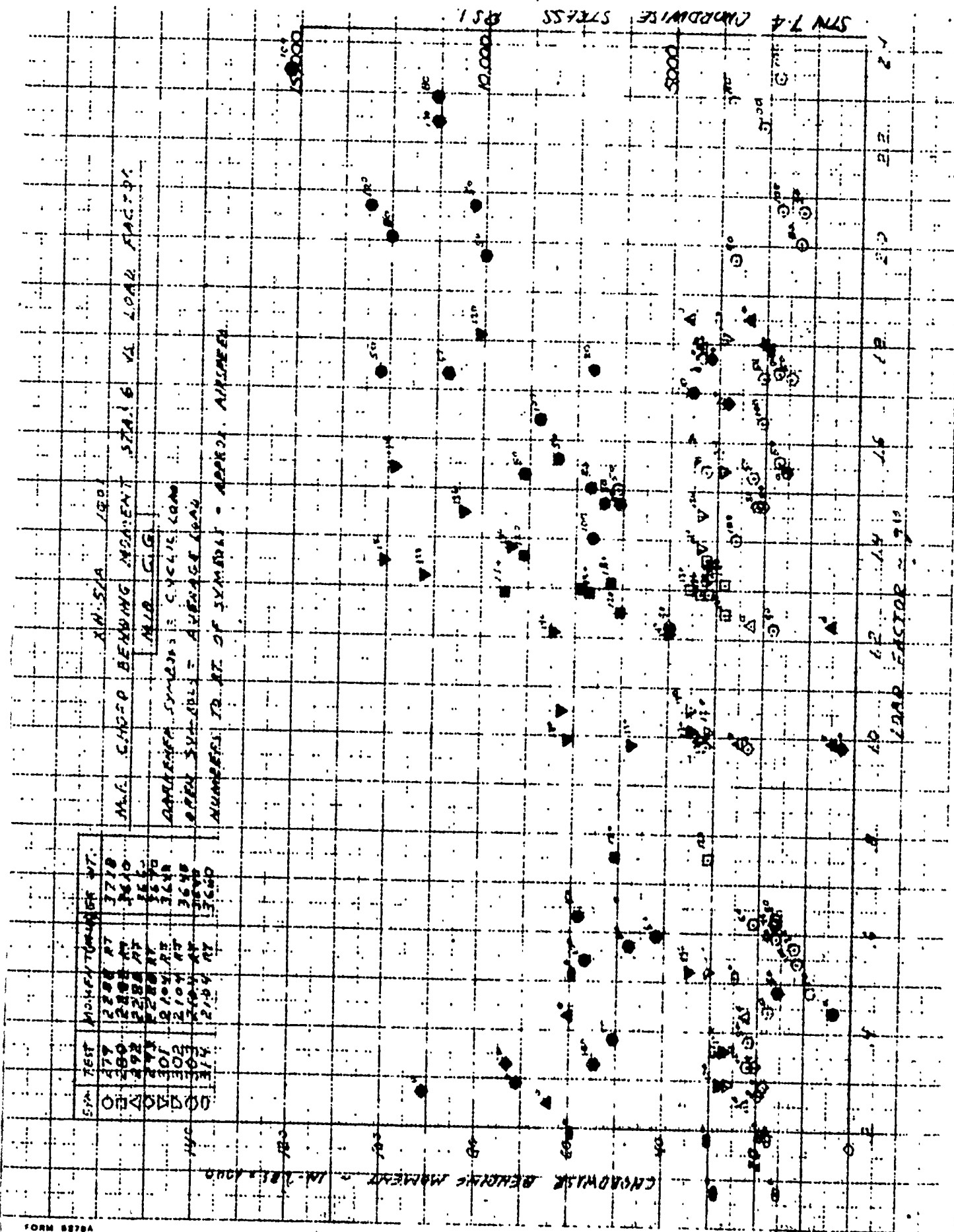
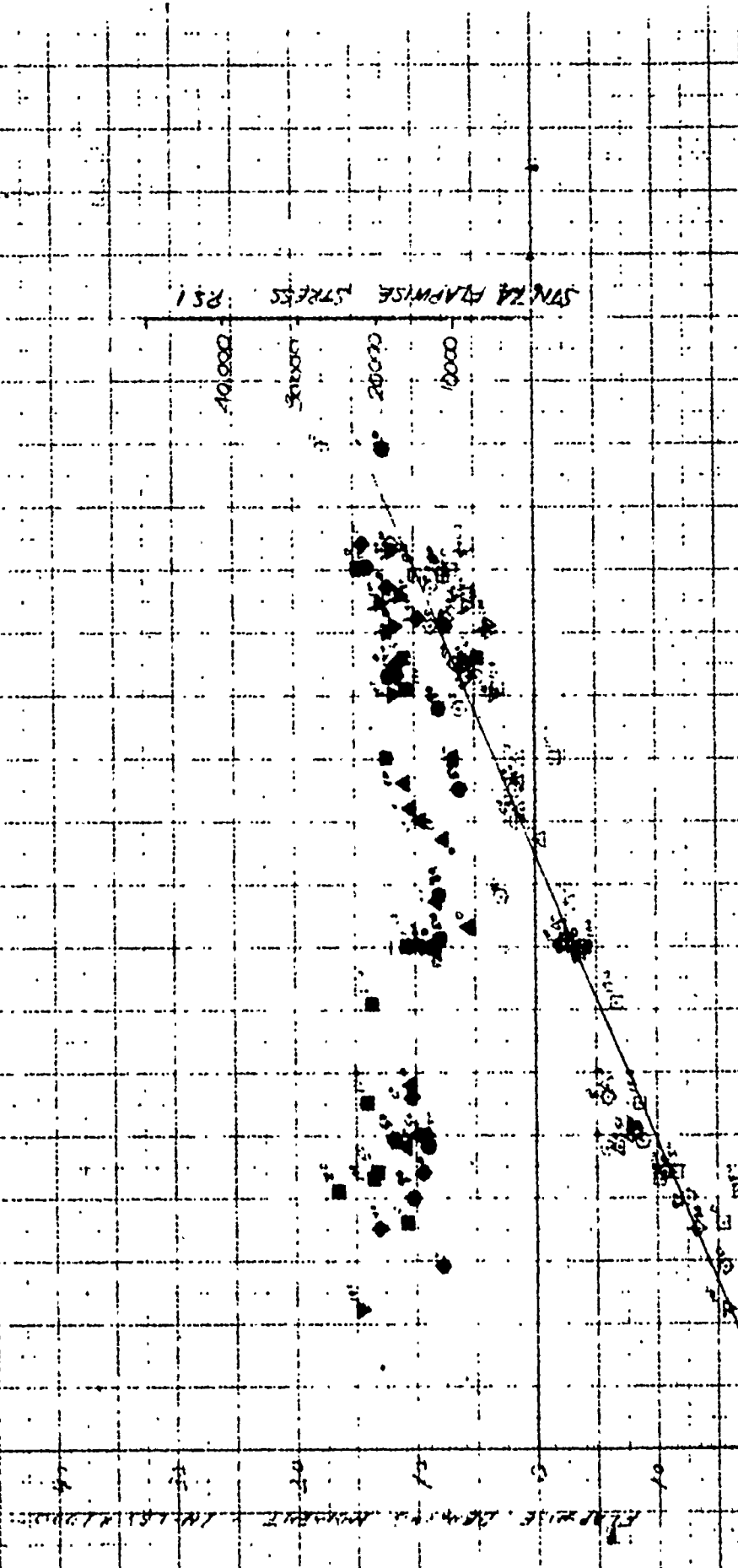


FIGURE 7

IN. DIA.	WAVELENGTH	TIME	WT.
3.5	10.88	17.17	37.65
3.5	10.58	17.14	38.42
3.5	10.57	17.14	39.00
3.5	10.72	17.14	38.70
3.5	10.72	17.14	38.70
3.5	10.72	17.14	38.70
3.5	10.72	17.14	38.70

X.H. S.A. 120'  
 W.R. FLAR BENDING MOMENT STA. 6. VOL. 400 FACTOR  
 10,000 IN. LBS. LATERAL C.G.  
 DATA FROM SYMBOLS: CYCLIC LOAD  
 OPEN SYMBOLS: AVERAGE LOAD  
 F.M.S. = LEFT AXIS  
 NUMBERS TO RT OF SYMBOLS = APPROX. AVERAGE



FLARE WISE BENDING MOMENT IN LBS. INCHES  
 STRAKE FLARE WISE STRESS PSI  
 100,000  
 80,000  
 60,000  
 40,000  
 20,000  
 0  
 0  
 20,000  
 40,000  
 60,000  
 80,000  
 100,000

FIGURE 8

M.H. STA 1001  
 M.R. CHOS: BENDING MOMENT STA. 6 VI ROAD FACTORY  
 10,000 IN LBS LATERAL C.F.

STATION	MOMENT	GR. WP
0	9,797	77 A 3745
1	10,529	87 A 1810
2	10,407	87 A 1726
3	10,172	87 A 1583
4	10,972	87 A 1582

MARKER SYMBOLS: CYCLIC LOAD  
 OPEN SYMBOLS: AVERAGE LOAD  
 FLAG > LEFT 1000L  
 NUMBERS TO RT. OF SYMBOLS: APPROX AIRSPRINGS

CHORDWISE BENDING MOMENT IN LBS IN ROAD

CHORDWISE STRESS PSI STA 7 A

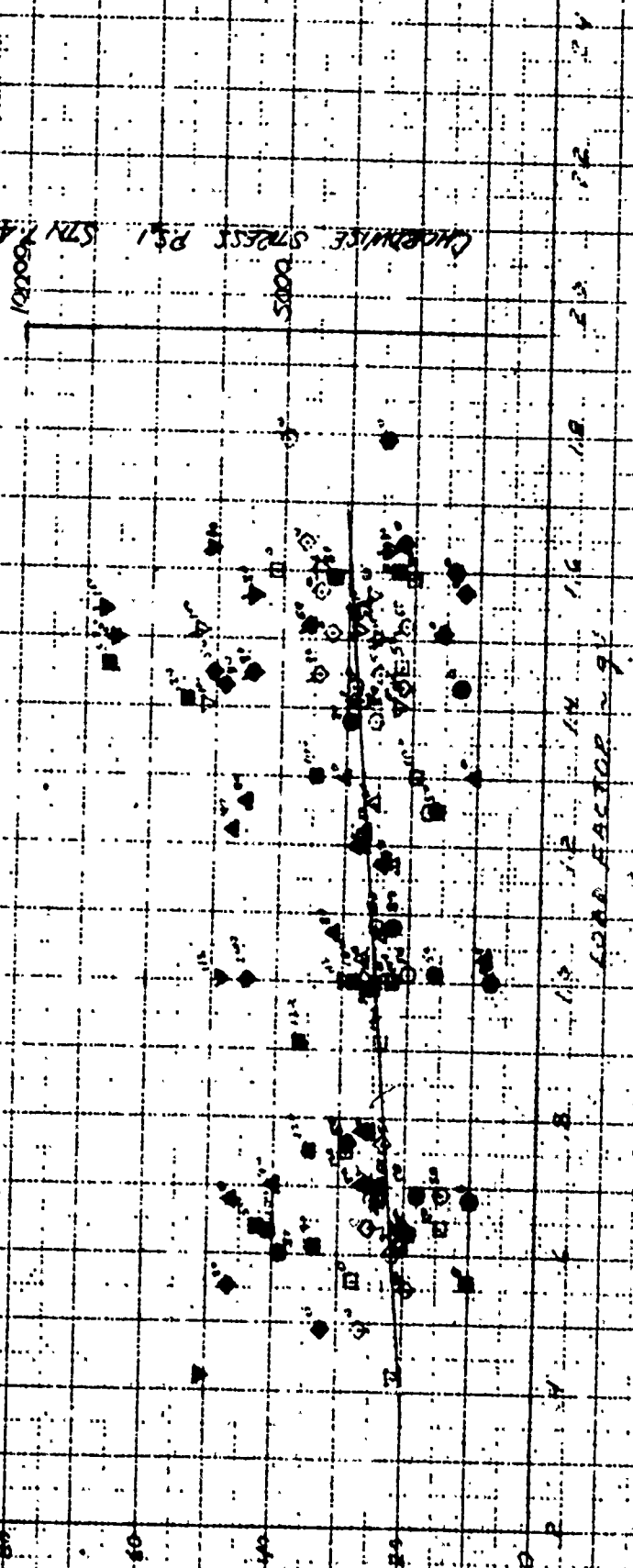


FIGURE 9

14.51A 22  
 MAX. FEAR BENDING MOMENT STA. 6 V. LOAD FACTOR  
 15.003 IN. LB. LATERAL C.

SYM	TEST	MOMENT	IN. LB.
○	104	17,000	RT
○	113	17,250	RT
△	115	17,000	LT

CIRCLED SYMBOLS = CYCLIC LOAD  
 OPEN SYMBOLS = AVERAGE LOAD  
 NUMBERS TO RT. OF SYMBOLS = APPROX. NUMBER

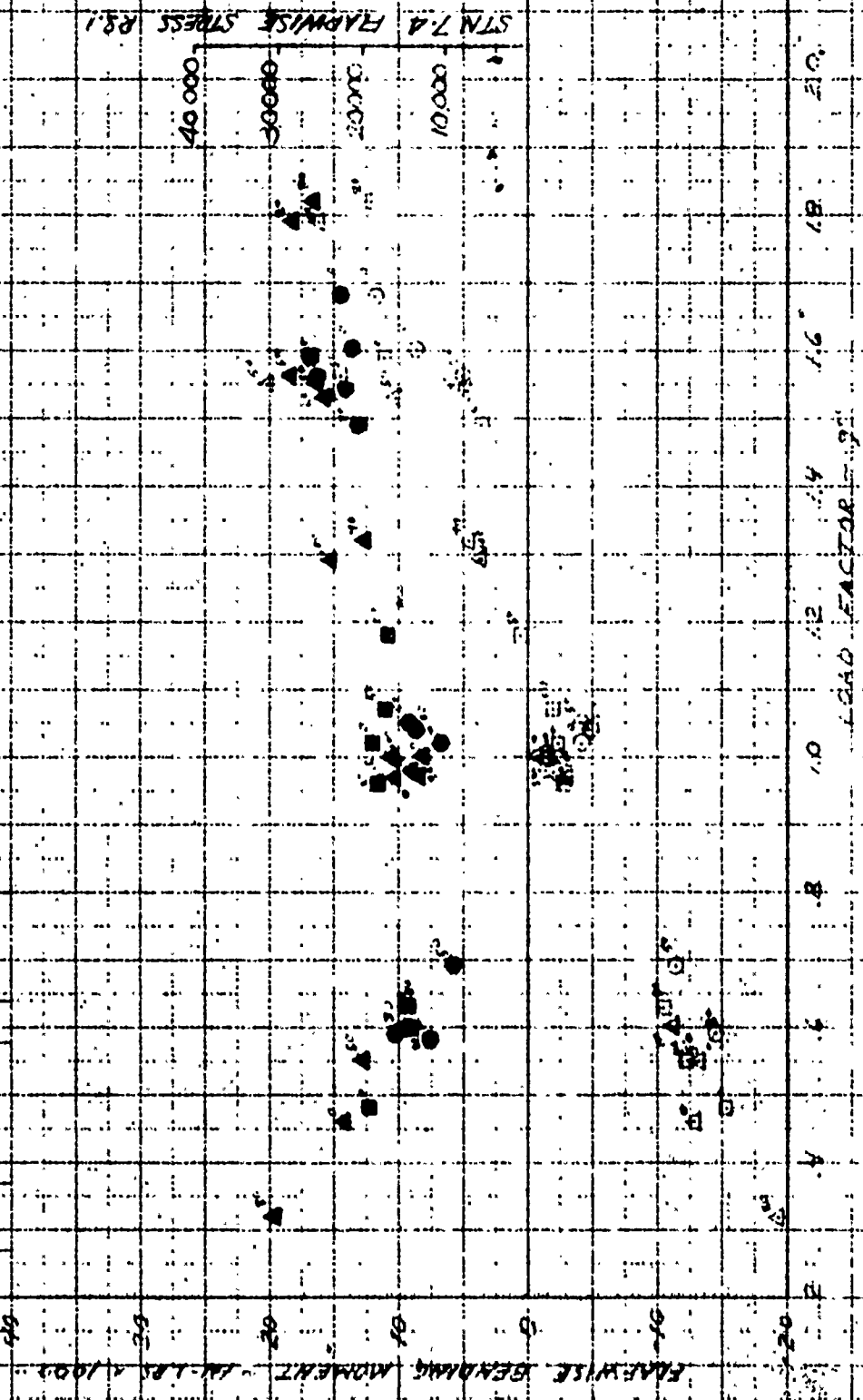
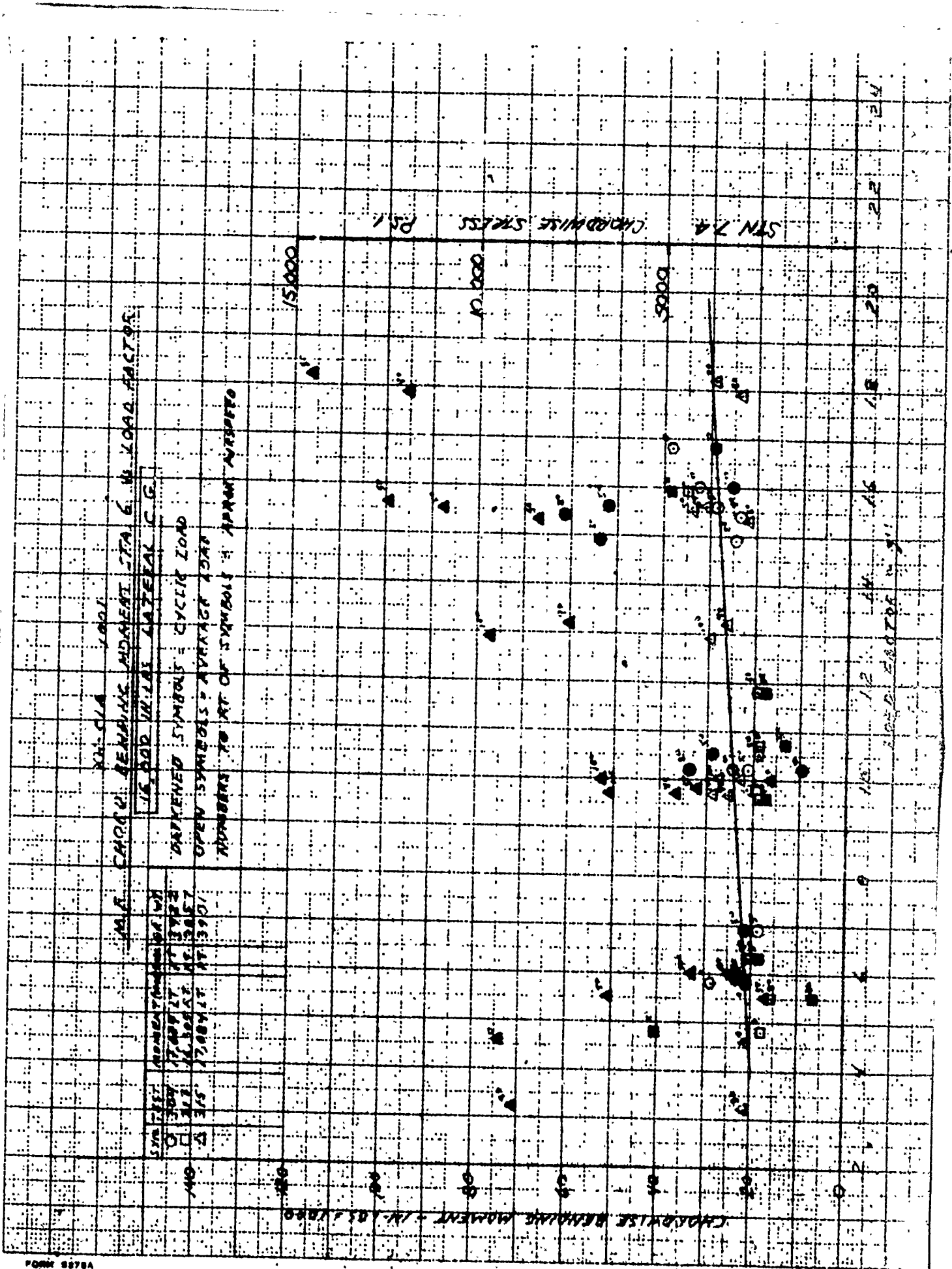


FIGURE 10



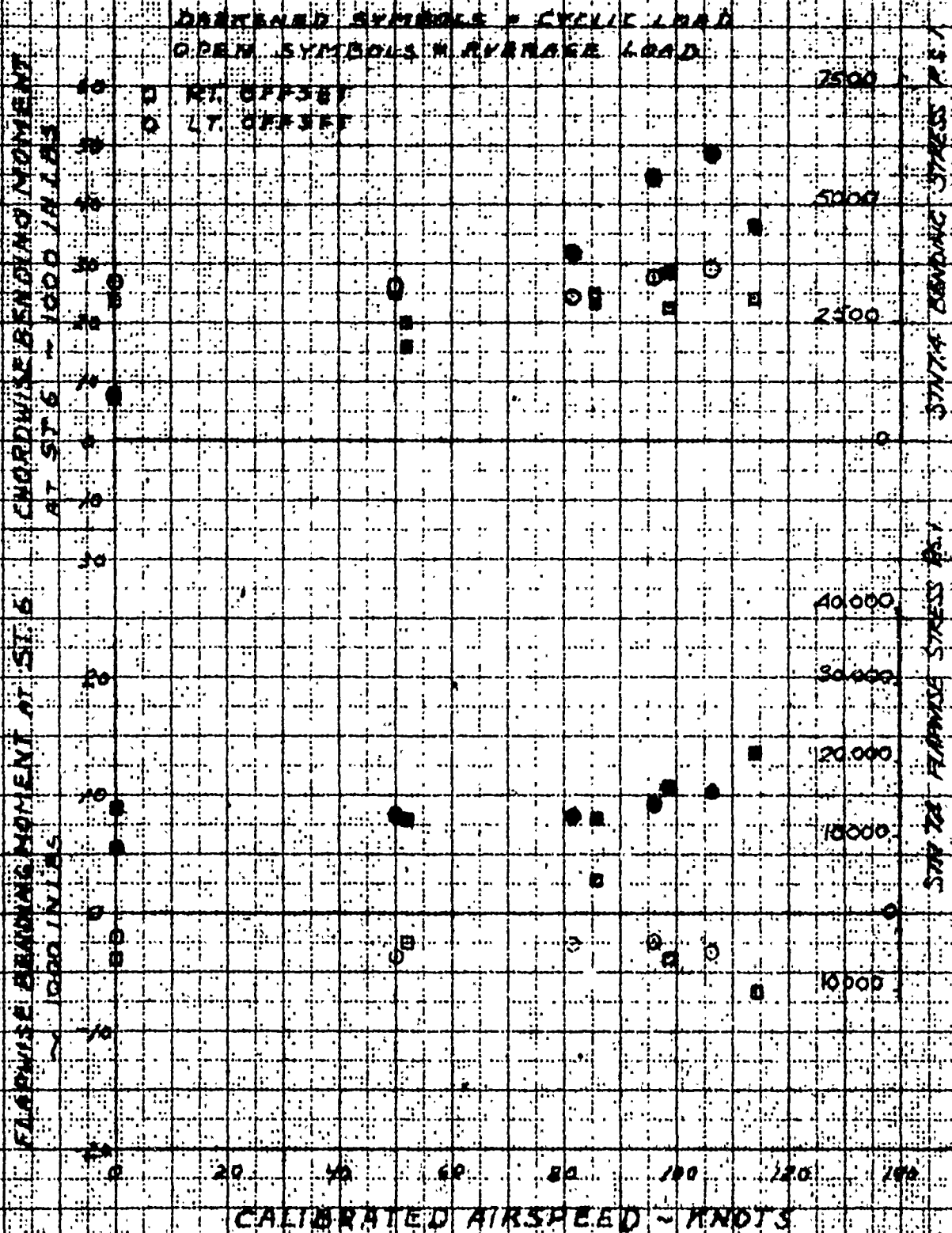
STA. 1  
 STA. 2  
 STA. 3  
 STA. 4  
 STA. 5  
 STA. 6  
 STA. 7  
 STA. 8  
 STA. 9  
 STA. 10  
 STA. 11  
 STA. 12  
 STA. 13  
 STA. 14  
 STA. 15  
 STA. 16  
 STA. 17  
 STA. 18  
 STA. 19  
 STA. 20  
 STA. 21  
 STA. 22  
 STA. 23  
 STA. 24

FIGURE 11

XH-51A-1001 BUNG 151.262

LATERAL C.G. ~ 10,000 IN LB

### MAIN ROTOR BLADE LOADS VS CALIBRATED AIRSPEED



FORM 8278A

FIGURE 12

XM-51A - 1001 RUN 151262

LATERAL G.G. = 16,000 W-LB

### MAIN ROTOR BLADE LOADS VS CALIBRATED AIRSPEED

FILLED SYMBOLS = CYCLIC LOAD  
OPEN SYMBOLS = AVERAGE LOAD

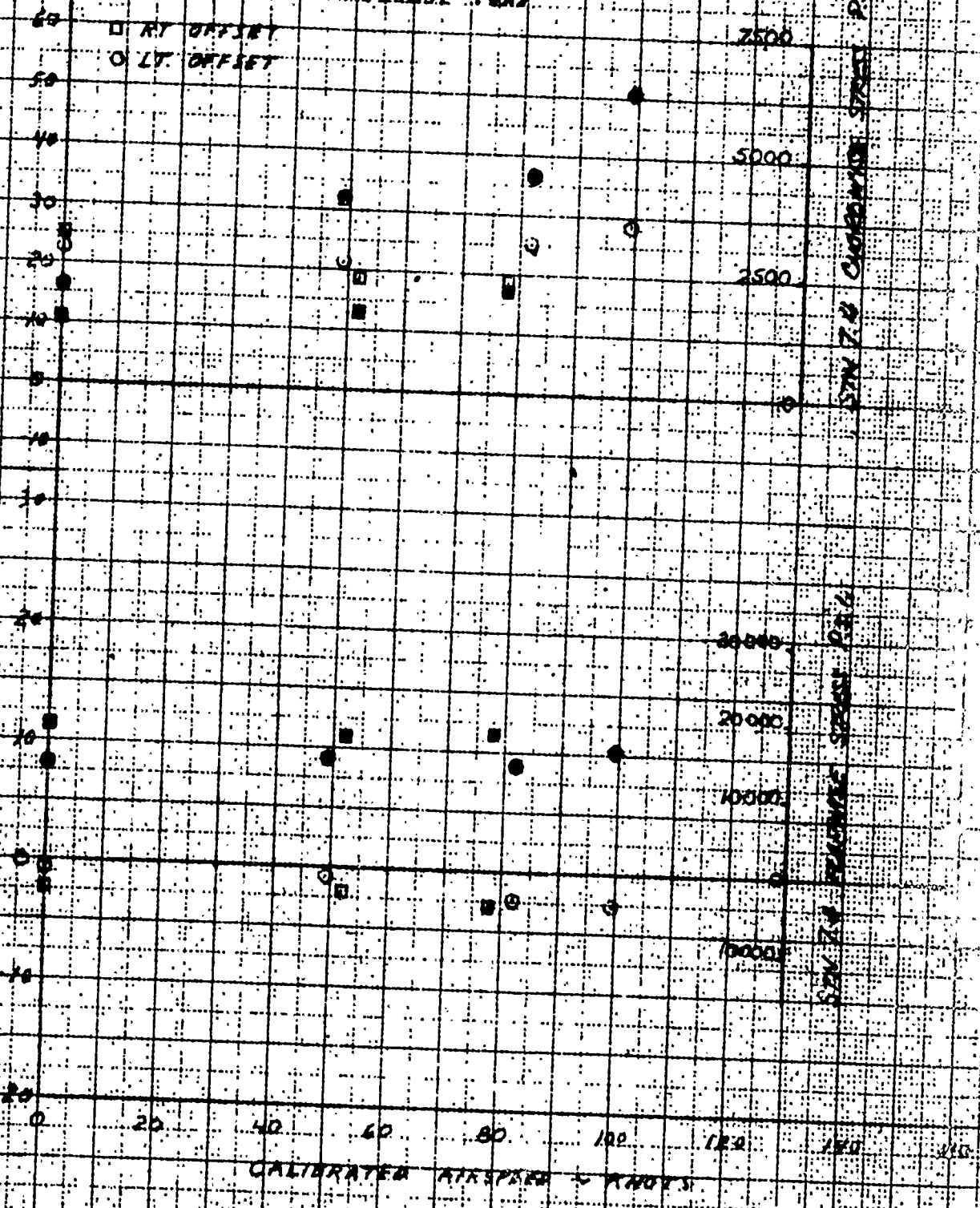
□ RT OFFSET  
○ LT. OFFSET

COUNTERWISE BENDING MOMENT STB  
in 1000 W-LB

CLOCKWISE BENDING MOMENT STB  
in 1000 W-LB

STB T.B. COUNTERWISE STRESS PSI

STB T.B. CLOCKWISE STRESS PSI



FORM 878A

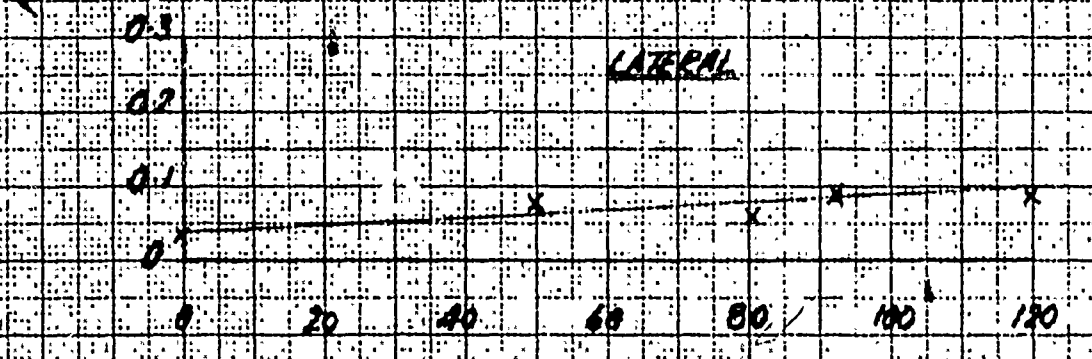
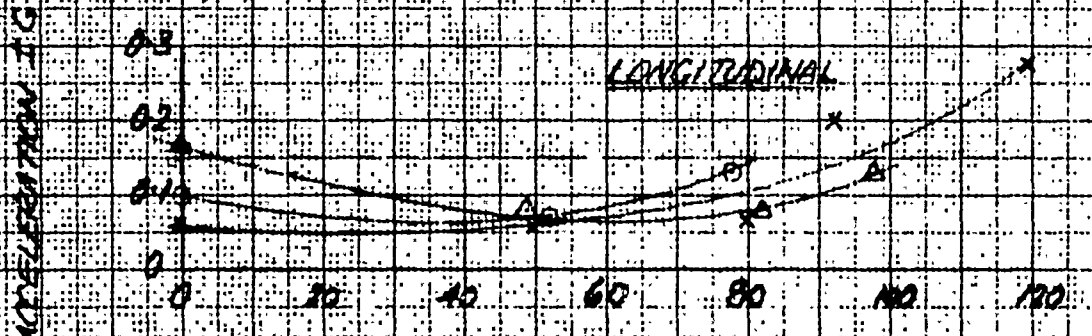
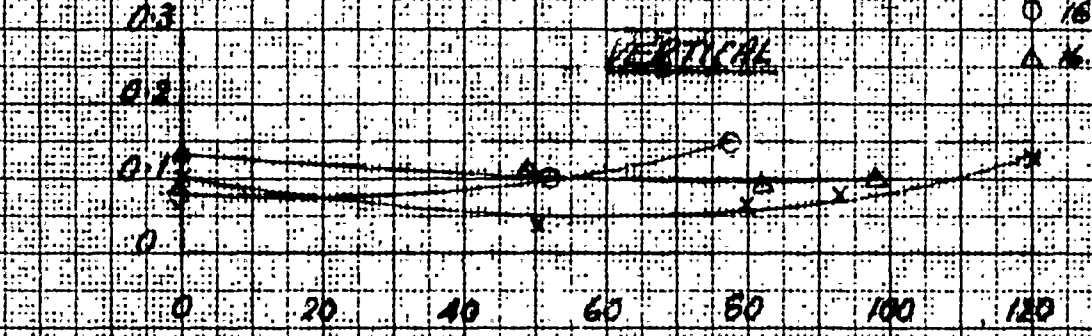
FIGURE 13





### CABIN SILENCE VIBRATION LEVELS LATERAL C.G. ASPECT

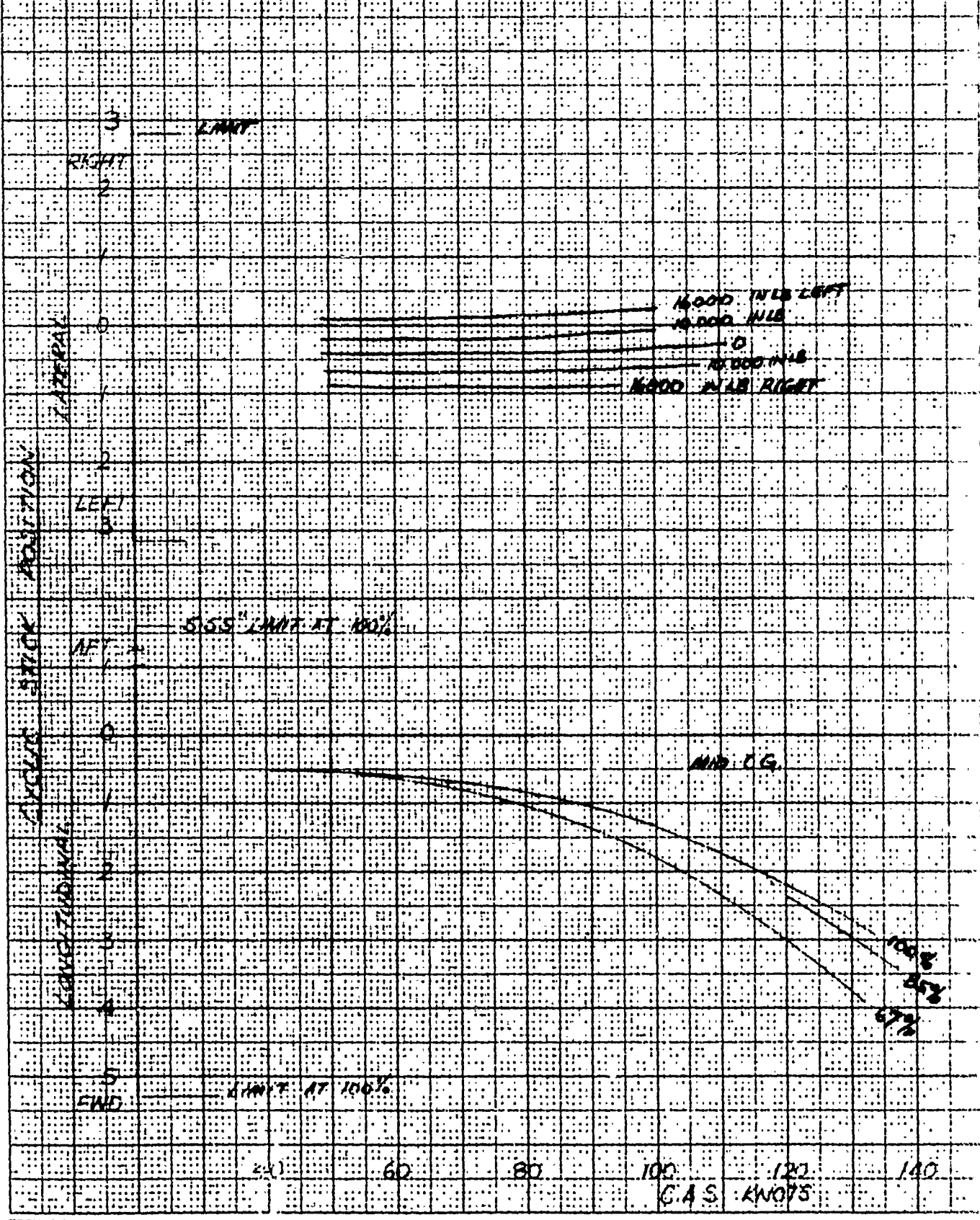
\* MID. C.G.  
O 16,000 IN LB. WT.  
Δ 16,000 IN LB. DEF.



C.A.S. KNOTS

FIGURE 16

CYCLIC CONTROL TO TRIM - LEVEL FLIGHT



FORM 927a

Figure 17

# STATIC LONGITUDINAL STABILITY

BASIC KH-51A AIRCRAFT

S/N: BUONO 15262

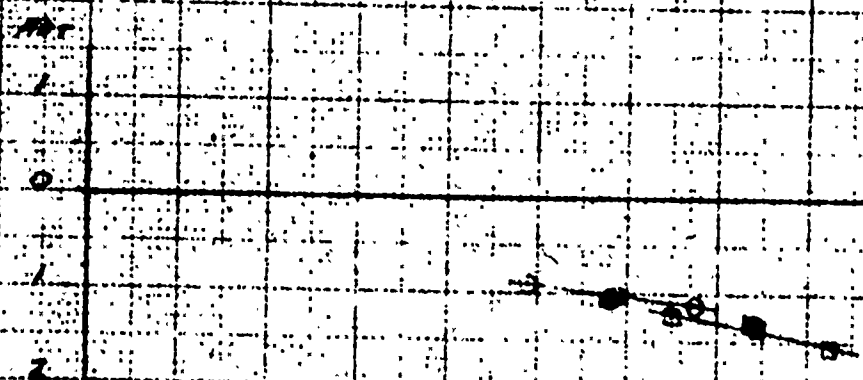
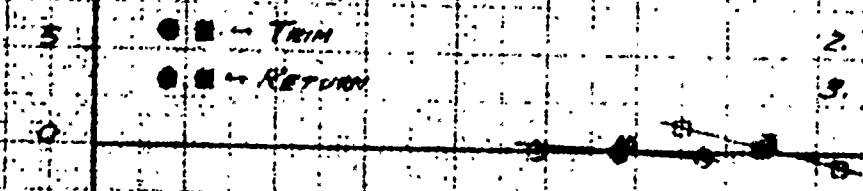
CYCLIC STICK AREA FORCE - LB

PULL	SWT	TEST	WIND KAS	DEN ATM	LONG. TRIM	LAN. TRIM
10	0	0	306	3635	1750	225 KAS 10-15-52

CONFIGURATION NOTES:

1. CYCLIC STICK PITCH SENSITIVITY = 100%
2. LANDING GEAR DOWN
3. SPEED SENSOR OFF

CYCLIC STICK AREA POSITIONING



20 40 60 80 100 120 140  
CALIBRATED AIRSPEED - KNOTS

FIGURE 18

STATIC LONGITUDINAL STABILITY

RIGHT HAND LATERAL OFFSET = 10,000 N-LB

SNIP: BU 110 151262

PULL	SN	TEST	WIND KTS	DRY ALT FT	LOGS PERIOD	LOG TIME
2	0	Δ	3 1/2	3 1/2	000	003 010007

CONFIGURATION NOTES

1. CYCLE STICK PITCH SENSITIVITY = 100%
2. LANDING GEAR DOWN.
3. SPEED SENSITIVE OFF.

CYCLE STICK PITCH FORCE - LB

CYCLE STICK PITCH POSITION - IN

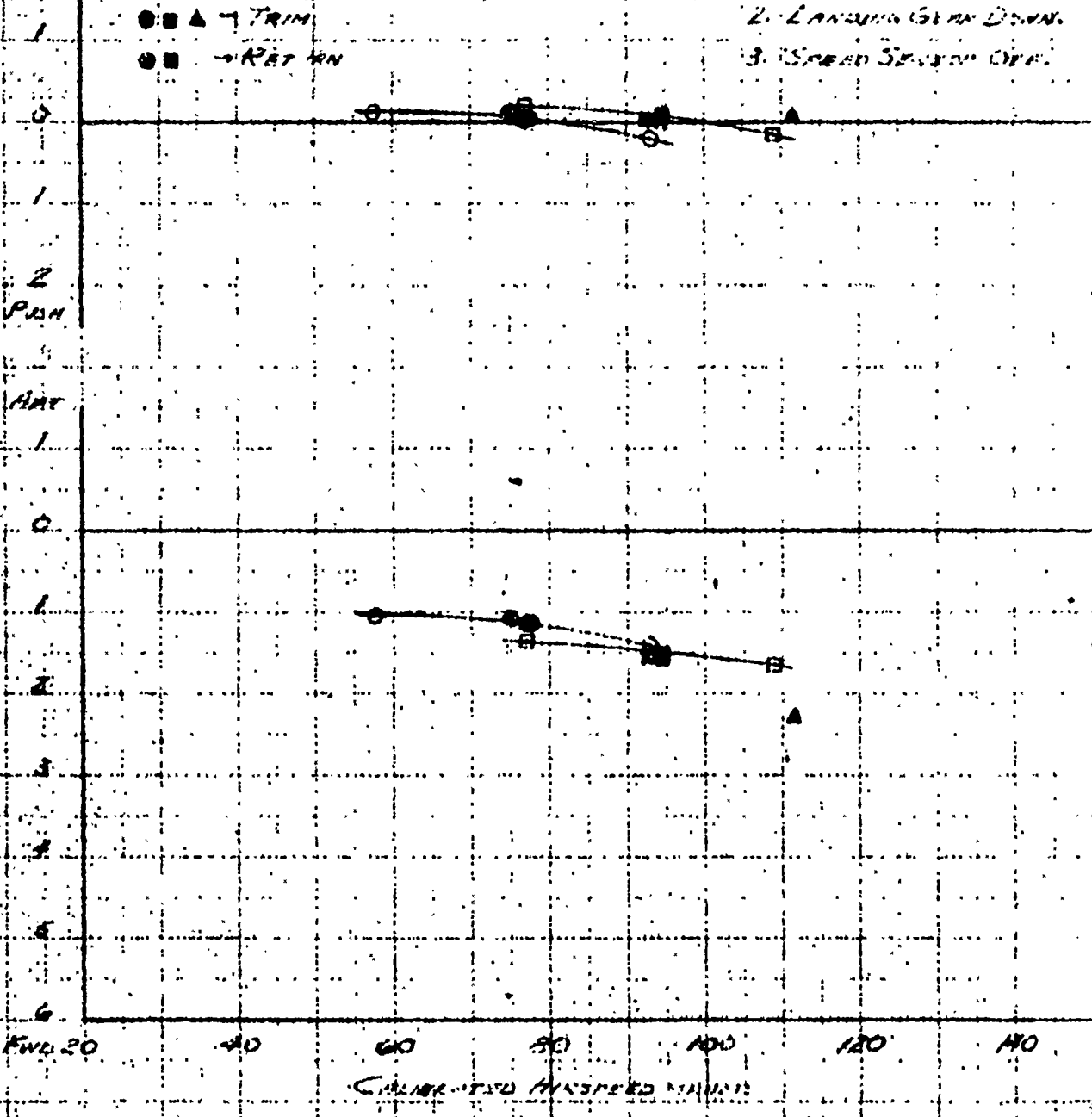


FIGURE 19

# MANEUVERING STABILITY

MIA C. S. LOCHTAN

Serial BUNG 151262

SYM	TEST	WIND SPEED	DEN ALT. FT.	LONG TANG.	LAE MOM.
$\theta \Delta$	212	370	3600	0	2207 IN. P. R.
$\theta \Delta$	505	3630	2930	588 WIND-AT	2174 - FT

COMPARISON NOTES:

1. CYCLIC STICK PITCH SENSITIVITY = 100%.
2. LANDING GEAR RETRACTED
3. SPEED SENSOR OFF.

CYCLIC STICK PITCH MOMENT

20

C.A.S. = 173 = 50

55

95

70

10

12

14

16

18

20

Load Factor = 9's

Figure 20

# MANEUVERING STABILITY

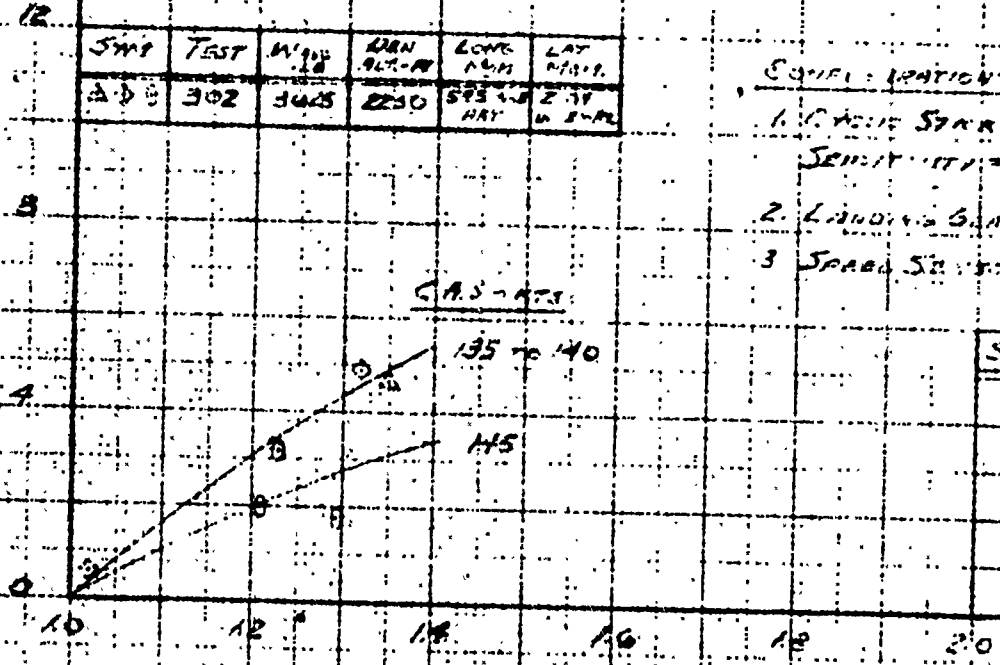
MID C.G. LOCATION  
 SWIM BUOY 151262

SWIM TEST	WIND	DEN	LONG	LAT
A B C	302	3425	2250	593 N 2 31 W

CONFIGURATION NOTES:

1. CIRCLE SPARK PITCH SENSITIVITY = 65%
2. LANDING GEAR RETRACTED
3. SPEED SENSOR OFF

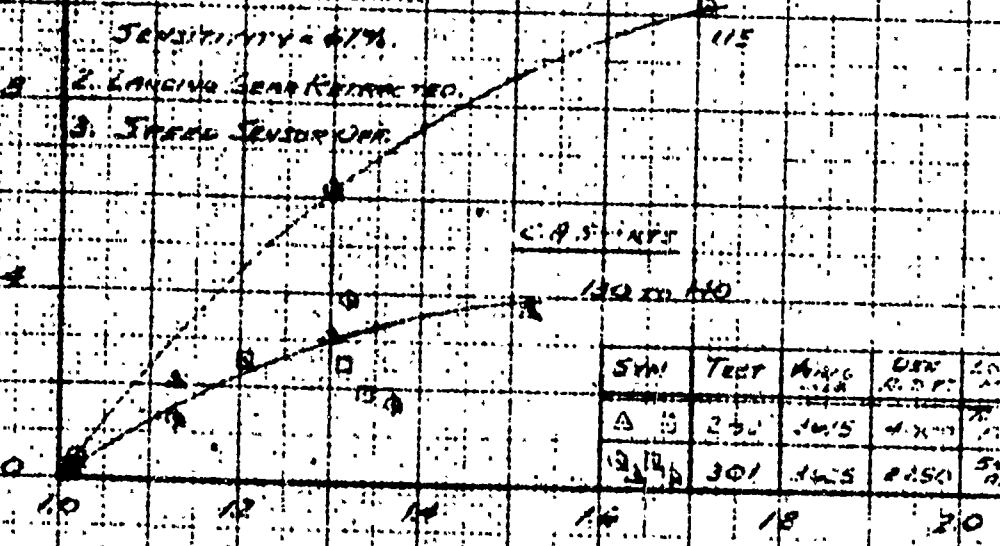
CIRCLE SPARK PITCH COEFFICIENT



SWIM TEST	WIND	DEN	LONG	LAT
0	115			
1	120			
2	125			
3	130			
4	135			
5	140			
6	145			

CONFIGURATION NOTES:

1. CIRCLE SPARK PITCH SENSITIVITY = 67%
2. LANDING GEAR RETRACTED
3. SPEED SENSOR OFF



SWIM TEST	WIND	DEN	LONG	LAT
A B C	250	3425	2250	593 N 2 31 W
0 1 2 3 4	301	3425	2250	593 N 2 31 W

LONG FACTOR = 93

FIGURE R1

Ka-50 Helicopter  
MORALE MATRY

LEVEL FLIGHT PERFORMANCE

Sea Level Standard Day - 100% Thrust

Landing Gear Retracted

W/S 3165.2

Serial: 014015122  
P. 1: 100% Thrust

Time	Altitude	Speed	Power
0	501	3450	575
10	502	3465	580
20	501	3450	575
30	500	3440	570

Previous Test Results  
with 50% Thrust 15122

SHRIFT HORSEPOWER

TEST TRUE AIRSPEED IN KNOTS

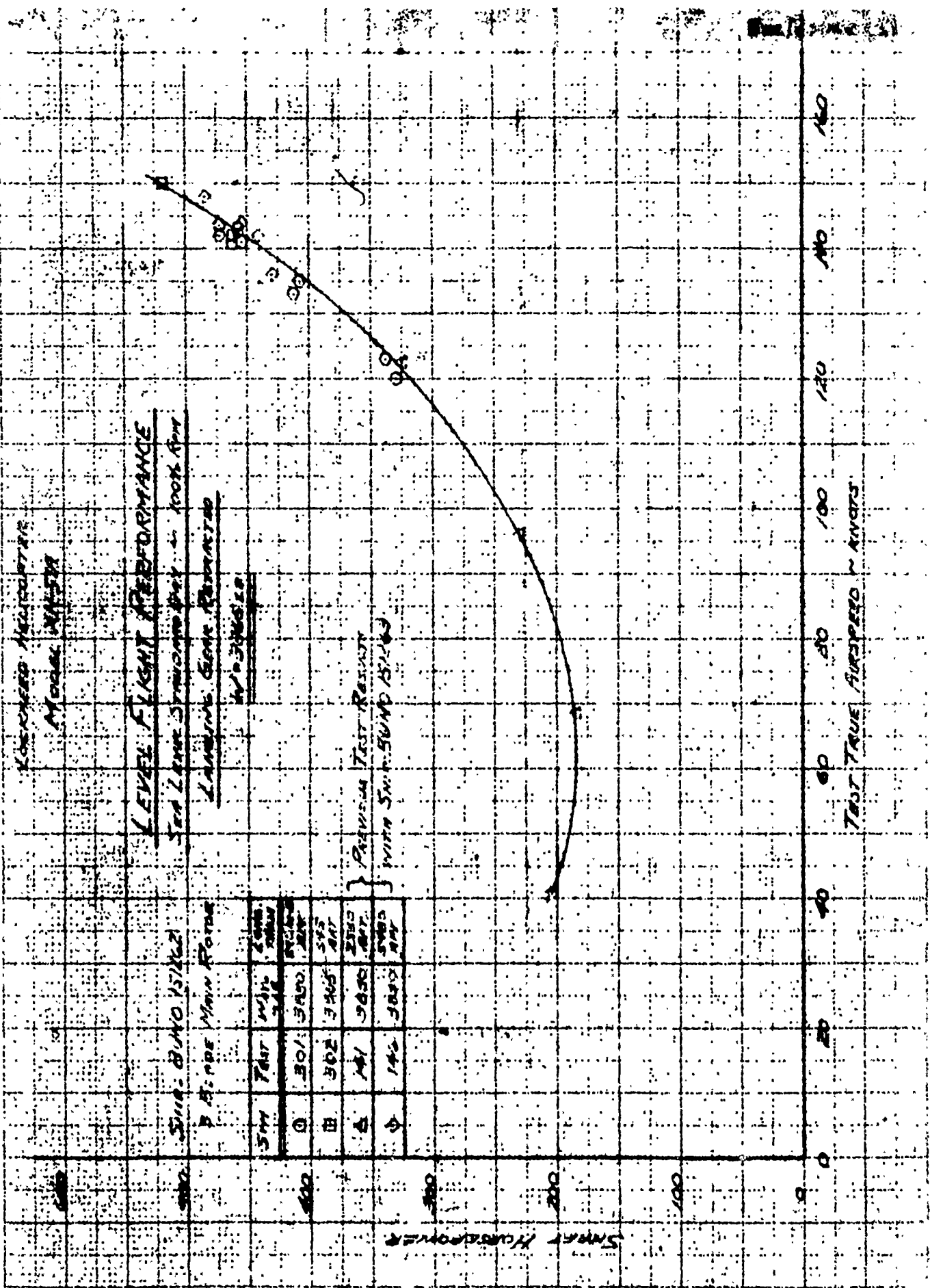


FIGURE 22