USAAEFA PROJECT NO. 71-30-6

FLIGHT EVALUATION
ELLIOTT DUAL—AXIS LOW AIRSPEED SYSTEM
LASSIE II

LOW AIRSPEED SENSOR FINAL REPORT VI

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Tests were conducted to evaluate the airspeed and direction-sensing capability of the Elliott low airspeed sensing and indicating equipment system (LASSIE II). The system included the basic dual-axis probe, an electronic package including a linearization circuit, a pressure altitude sensor, and a vertical speed computer. The probe is a pivoted vane designed to align with resultant flow and incorporates equipment which measures angles in all directions from the vertical. The probe

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20. Abstract

also measures total and static pressures. The measured data are used to calculate airspeed components, sideslip angle, altitude, and vertical motion. The tests were conducted in an NUH-1M helicopter at Bishop, Oxnard, and Edwards Air Force Base, California, from December 1972 to September 1974. In its final configuration, the system provided repeatable airspeed components that were essentially linear except when operating in ground effect. The system also provided altitude and vertical motion information that was superior to that obtained from the aircraft standard systems. Incorporation of an ambient temperature probe and calculation of the true airspeed and angle of attack would yield a complete air data system.

TABLE OF CONTENTS

INTRODUCTION

BACKGROUND

1. Engineering flight test of helicopters and VSTOL aircraft requires accurate airspeed information from hover to approximately 35 knots rearward and sideward, and 200 knots forward. In addition, vertical speeds from zero to 4000 feet per minute (ft/min) must be measured to adequately assess aircraft performance and maneuvering capability. In 1968 a request for proposal (RFP) was issued (ref 1, app A) for design and development of a low airspeed system suitable for use during engineering flight tests. The United States Army Aviation Systems Command (AVSCOM) requested the United States Army Aviation Engineering Flight Activity (USAAEFA) to conduct theoretical or flight evaluations of low airspeed systems (ref 2). Five experimental or prototype low airspeed systems have been previously tested by USAAEFA. These systems include the single-axis Elliott system, the Aeroflex true airspeed vector system, the LORAS II system, the J-TEC system, and the Rosemount system (refs 3 through 7). The single-axis Elliott system measured only the resultant velocity and the angle between the vertical and longitudinal axes of the aircraft. This program was to evaluate the addition of the lateral axis to the Elliott system and incorporation of equipment to increase system capability and performance.

TEST OBJECTIVES

2. The overall test objective was to evaluate the Elliott low airspeed sensing and indicating equipment system (LASSIE II) as an accurate source for airspeed and other air data information. Specific objectives were to determine the following:

a. Effect of the dual-axis modification on airspeed system performance.

b. Accuracy of altitude and rate-of-climb indications.

c. The effectiveness of the electronics in compensating for the discontinuity which occurs when the probe transitions from rotor wake to free stream air.

DESCRIPTION

3. The Elliott low airspeed system is manufactured by Elliott Flight Automation Ltd, Airport Works, Rochester, Kent, England. In the United States the equipment is the responsibility of E-A Industrial Corporation, Chamblee, Georgia, the associate company.

4. The system includes a swiveling total and static pressure sensing probe, a computer, and airspeed indicators for three axes. System components are shown in photo A. The resultant downwash aligns the probe with local relative wind (vector sum of aircraft velocity and rotor induced velocity) and provides adequate dynamic pressure. The angle of the probe and the differential pressure are used to calculate aircraft speed and relative wind direction. Static pressure is measured and rate of change is calculated to provide rate-of-climb information. Photographs and a detailed description of the system and its operation are presented in appendix B. The airspeeds presented to the pilot are longitudinal, lateral, and vertical components. A resultant is not presented, nor is angle of attack or angle of sideslip calculated. Free air temperature is not measured and the computer does not calculate true airspeed.

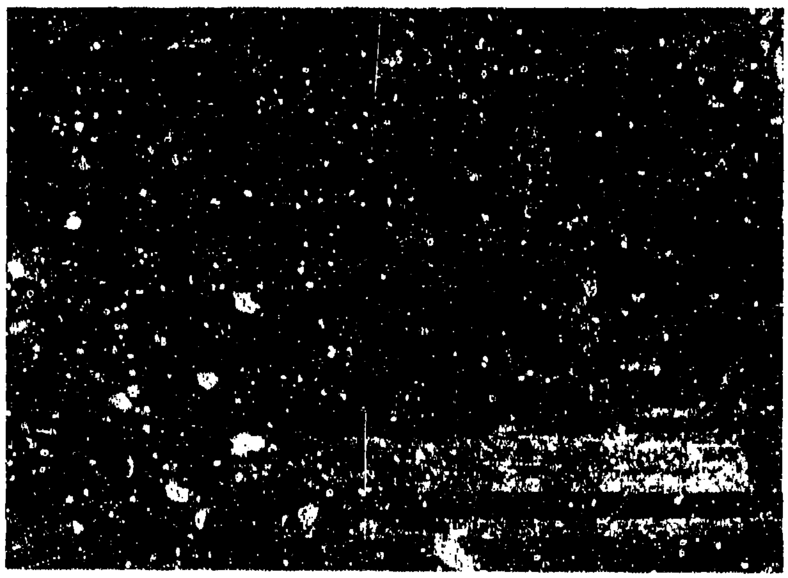


Photo A. Elliott Low Airspeed Sensing and Indicating Equipment.

5. The test aircraft was a UH-1M helicopter, serial number 63-8684, manufactured by Bell Helicopter Company. A detailed description is contained in the operator's manual (ref 8, app A).

TEST SCOPE

6. The Elliott low airspeed system was tested by USAAEFA between 6 December 1972 and 10 September 1974. Flight conditions were within the limitations contained in the safety-of-flight release and the operator's manual. Most flights were conducted at a mid center of gravity (cg) and an engine start gross weight of approximately 7000 pounds. One flight was conducted at an aft cg and one flight utilized an engine start gross weight of 8500 pounds to evaluate the effects of weight and cg.

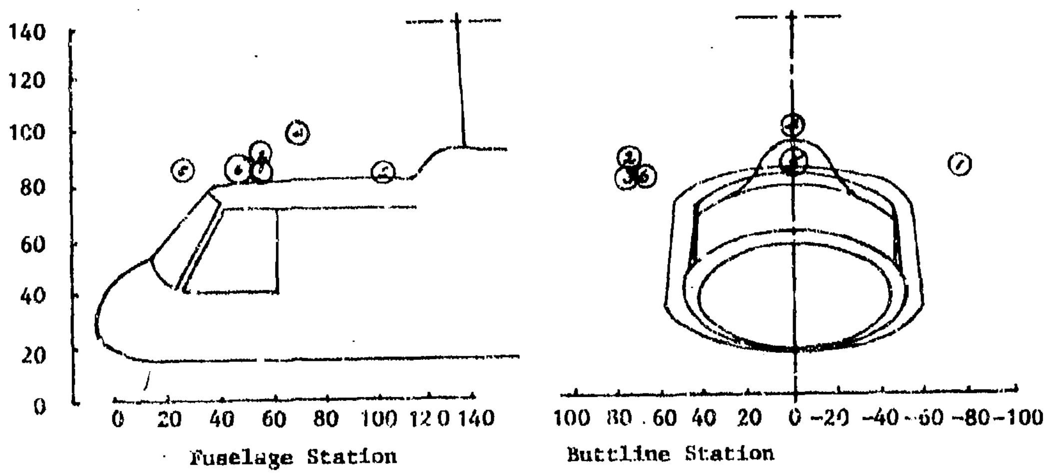
7. Tests were conducted in longitudinal and lateral flight, in ground effect (IGE) and out of ground effect (OGE), and during static and dynamic conditions. The probe was mounted in six different locations on the aircraft to determine the effects of varying position. The locations are shown in figure A.

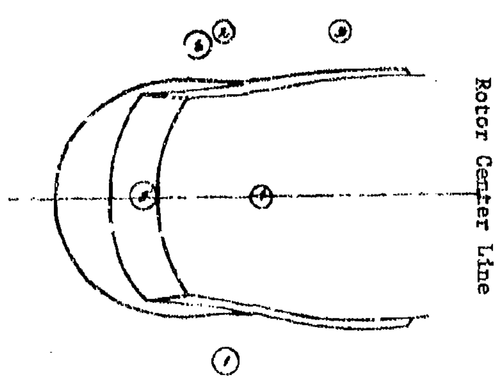
TEST METHODOLOGY

8. The Elliott low airspeed system was tested at low airspeeds (zero to 50 knots) near the ground, using the pace car calibration technique. A calibrated fifth wheel attached to the pace car was used to measure ground speed along the flight path. Ground speed was corrected for wind to obtain airspeed information. Tests were also conducted with the aircraft in a tethered hover at various ambient wind speeds and relative azimuths. The tethering equipment included a load cell which provided information concerning the thrust at each hover condition. During the hover tests, three wind towers were located around the helicopter 400 feet from the tether point (120-degree spacing). On each tower, local wind speeds and directions were measured at 6 feet, 14 feet, and 65 feet above the ground.

9. High-speed data (20 to 110 knots indicated airspeed) (KIAS) were referenced to the calibrated test boom system. The angles of attack and sideslip were measured with boom-mounted flow vanes. The rate of climb was derived from both the test boom pressure data and radar altimeter data.

Figure A. Sensor Locations on the UH-1M Helicopter.





Sensor Location		Longitudinal Fuselage Station	Butt Line	Waterline
Fwd Left	1	56	-74	8[illegible]
Fwd Right	2	55	+74	88
Aft Right	3	102.5	+74	82.5
Aft Cabin	4	71	0	98
Fwd Cabin	5	26	0	85
Fwd Right	6	47	+70	86

RESULTS AND DISCUSSION

GENERAL

10. The basic dual-axis probe provided longitudinal and lateral airspeed information with similar characteristics and quality to that obtained in the longitudinal direction with the single-axis probe. The application of an electronically generated correction to the system output produced an essentially linear airspeed indication with less than a 5-knot error at hover. The system provided altitude and rate-of-climb information superior to that available from the aircraft standard systems.

AIRSPEED SYSTEM

Basic Dual-Axis Probe

11. The characteristics of the basic dual-axis probe are shown in figures 1 through 24, appendix D. Data are presented for various locations to show the effects of downwash velocity and direction as well as interference from fuselage or tail rotor. As expected, each location produced unique position error data. All characteristics are similar and the results are equally good. In both cases, there is a discontinuity as the probe transitions from the rotor downwash to free stream air. Test results shown in figures 1 through 5 establish the repeatability of the data from each probe location. Figure 6 shows a comparison of data obtained with the aircraft ballasted to an aft cg compared to data at the normal mid cg. Aircraft cg would be expected to have an effect on the calibration since the angles of the probe are measured relative to the aircraft longitudinal axis and pitch attitude changes significantly with cg at low airspeed (approximately 1 degree per inch of cg change for the test aircraft). The data, however, do not show a significant effect. Possibly the accompanying vertical position change relative to the rotor (with attitude change) has a compensating effect.

12. System performance in sideward flight is illustrated by figures 7 through 10, appendix D. Characteristics are similar to those in forward and rearward flight, and are basically the same for both dual- and single-axis probes. The transition point occurs at a lower speed when flight is in the direction of the probe location, *ie*, right sideward flight with the probe mounted on the right side. Figures 9 and 10 show an essentially symmetrical curve when the probe was mounted near the fuselage center line. However, the transition appears to occur about 2 knots slower in right sideward flight than in left sideward flight, and the pressure change is more abrupt.

13. Sideslip effects in forward flight are presented in figures 11 through 15, appendix D. The dual-axis probe was influenced less by sideslip than was the single-axis probe, since it was able to align with and measure sideslip angle. In

all probe locations, the sideslip effect increased with forward speed. The smallest position error and the least change with sideslip angle occurred at an airspeed of [illegible]2 knots calibrated airspeed (KCAS). Other airspeeds tested did not show consistent trends or characteristics for the various probe locations.

Dual-Axis Probe With Airspeed Linearization

14. The effect of the electronic correction signal on the airspeed output is presented in figure 26, appendix D. A comparison of the basic probe results with the corrected output is shown in figure B. At airspeeds near hover the error with linearization applied is less than 5 knots, and the output is linear and repeatable. The longitudinal data in figure 26 suggest that the probe transitions from downwash to the free stream at an airspeed of 20 knots. The transition point is clearly evident in the lateral airspeed output. However, the pilot was not aware of longitudinal indicated airspeed change with transition, as was the case prior to adding the linearization network. In addition to improving the low-speed and transition characteristics, the error at 100 knots was reduced from 13 to 4 knots.

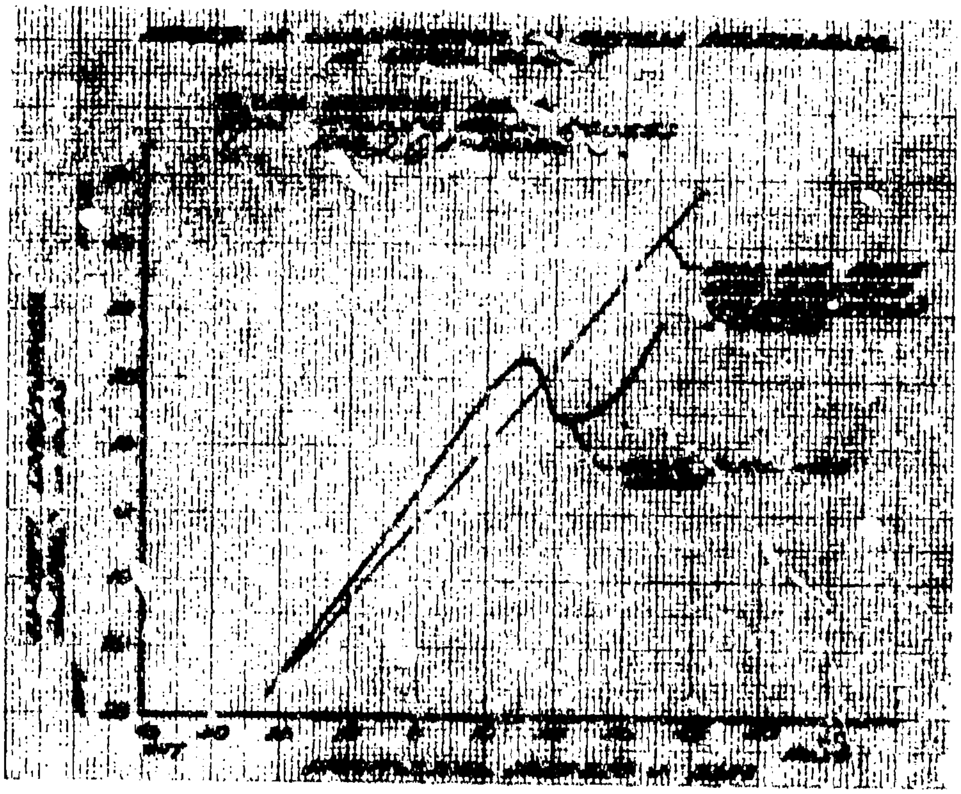


Figure B. Effects of Linearization on System Performance in Level Flight.

15. General system performance in sideward flight was not changed by the linearization, as is seen by comparing figures 8 and 27, appendix D. Characteristic errors caused by sideslip in forward flight are similar, although the position error near zero sideslip is considerably reduced by the longitudinal correction signal.

16. Prior to the linearization, the data above transition had a slope greater than 1 and crossed the line of zero error near 50 knots. The linearized data had a slope less than 1 at 50 knots in level flight, and the error at this airspeed was increased by the linearization, as shown by the trim point in figure 29, appendix D. Errors with angle of attack (rates of climb or descent) reflect the same characteristics found prior to linearization.

17. The linearization signal did not change the system performance with respect to ground effect, as shown by figures 22, 31, and 33, appendix D. In all cases the ground effect caused the airspeed system to read low by 5 to 10 knots. There were also added fluctuations in the output signal

18. Thrust (gross weight) effects on the Elliott low airspeed system are presented in figures 31 through 33, appendix D. The OGE tethered hover data shown in figure 32 encompass a thrust range from 6600 to 10,300 pounds and show essentially zero error for the total thrust variation. The data were recorded for various headwind velocities, and gusts contributed to the data scatter shown. The IGE tethered hover reflects the increased static pressure field, and shows a trend of reduced indicated airspeed with higher thrust.

ALTITUDE SYSTEM

19. The altitude sensing portion of the system was added when the linearization network was installed. Altimeter results can be correlated with pressures obtained with the basic dual-axis probe. The altimeter error in low-speed flight is presented in figure 34, appendix D. The error shown is the difference in the indicated altitude and a standard based on a barometric pressure reading at ground level, to which is added the height above ground level from a calibrated radar altimeter. A comparison of figures 2 and 34 shows a similar high static pressure area from 20 to 40 knots which causes the altimeter to read low by as much as 30 feet while OGE. The error is near zero at 50 knots. As airspeed increases the altimeter produces increasingly higher indicated values. Low-speed pace flight data in figure 35 show the same characteristics for OGE hover, and an increased static pressure field for IGE hover and low-speed conditions.

20. Increasing thrust while OGE causes no change in the altimeter error, as show by figure 36, appendix D. For IGE hover, increasing thrust from 7000 to 10,300 pounds caused a reduction of 10 to 15 feet in the altimeter indication.

VERTICAL SPEED SYSTEM

21. The Elliott vertical speed indication is obtained by differentiating the static pressure signal with respect to time. The rate-of-climb results are shown in figures 37 through 39, appendix D. Indicated values from the test system are compared to standards from the radar altimeter, radar vertical climb, and the calibrated pitot-static system mounted on the airspeed boom. The common characteristic in all the data was a slope less than 1. As a result, the LASSIE II system was accurate at low values of vertical velocity, but read low at high rates of climb or descent. The difficulty of choosing a standard with which to compare the test system is apparent from figures 37 through 39. On the basis of the instrument capabilities, the most accurate standard is obtained by reading the slo of the radar altitude versus time curve. The next best standard should be the ave of the radar rate-of-climb data. The differentiation circuit within the radar altimet introduces data uncertainty and probably accounts for the scatter shown in figure 39. The least accurate standard is the slope of the boom altitude versus time curve.

22. When first installed, the vertical speed indicator (VSI) had large, rapid, random fluctuations which rendered it unusable. A fault was found in the circuit design and was corrected. This correction improved the output significantly, but moderate erroneous fluctuations were still present. Increased damping of the signal improved the indication still further. The final modification provided usable vertical speed indications even in the low airspeed regime (less than 35 knots). Further optimization of the response and damping should improve system performance.

23. For comparative purposes, an evaluation of the aircraft standard VSI system was conducted. In addition, the static pressure from the test boom system was input to the standard indicator and the resulting performance was examined. Both test configurations showed vertical speed errors as large as 700 to 800 ft/min, which is unusable in the low-speed regime.

CONCLUSIONS

GENERAL

24. The dual-axis probe placed in the rotor wake provides a good source for airspeed and flow direction information, as well as static pressure and static pressure changes. The electronic shaping of the output can correct for position error and produce repeatable, accurate airspeed information OGE.

SPECIFIC

25. The LASSIE II indicated airspeed characteristics and data discontinuity at transition from the rotor wake to free stream were similar to the single-axis probe (para 12).

26. The linearization electronics greatly improved the system output and rendered the discontinuity imperceptible to the pilot (para 14).

27. Ground effect caused the airspeed system to read low by 5 to 10 knots when hovering at skid heights of 10 feet or less (para 17).

28. The vertical speed information from the Elliott low airspeed system is better than that produced by the standard system or the test boom system (paras 22 and 23).

RECOMMENDATIONS

29. Consideration should be given to development of a single cockpit instrument which displays airspeed and direction information (para 4).

30. A temperature probe and associated computer capability should be added so as to provide complete air data information (para 4).

31. The linearization electronics or the probe design should be further optimized to provide a zero error at all airspeeds (para 16).

32. The altitude measuring systems should be improved to account for ground proximity and airspeed effects (paras 19 and 20).

33. An improved rate-of-climb standard should be used in future tests to better define the actual performance of the Elliott low airspeed system (para 21).

APPENDIX A. REFERENCES

1. Request for Proposal, Air Force Flight Test Center, Edwards Air Force Base, California, RFP Nr. 04611-68-R-0080.

2. Letter, AVSCOM, AMSAV-EF, 20 July 1971, subject: Flight Test of Low Airspeed Sensors.

3. Final Report I, USAASTA, Project No. 71-30, *Flight Evaluation, Elliott Low Airspeed System*, September 1972.

4. Final Report II, USAASTA, Project No. 71-30, *Flight Evaluation, Aeroflex True Airspeed Vector System, Low Airspeed System*, March 1973.

5. Final Report III, USAASTA, Project No. 71-30, *Pacer Systems, Inc., LORAS II Low Airspeed System*, March 1974.

6. Final Report IV, USAASTA, Project No. 71-30, *Flight Evaluation, J-TEC Airspeed System, Low Airspeed Sensor*, April 1974.

7. Final Report V, USAAEFA, Project No. 71-30, *Flight Evaluation, Rosemount Orthogonal Low Airspeed System, Low Airspeed Sensor*, November 1974.

8. Technical Manual, TM 55-1520-220-10, *Operator's Manual, Army Model UH-1C/M Helicopter*, November 1968 with Changes 1 through 4.

APPENDIX B. SYSTEM DESCRIPTION AND THEORY OF OPERATIONS

1. The system consists of an airspeed probe, a rate transducer, a VSI, longitudinal and lateral airspeed indicators, and a computer. Photos 1 through 5 show the airspeed probe and typical test installations.

2. The swiveling dual-axis pitot-static probe (type 05-006-01) is a standard pitot-static sensing head with four peripheral static parts. The circular vane, with space wedges at 120 degrees, is slightly unbalanced to permit pendulous action. Two synchro resolvers are mounted within the assembly to measure the probe angular position. The total and static air pressures are piped to the airspeed computer along with the probe angle signals from the synchro resolvers.

3. The rate transducer (type 60-SK-3437) is an electromechanical design and has a gearbox to drive synchros and potentiometer outputs. Also contained in the unit is an electrical force balance transducer which is used as a pressure altitude sensor. This unit produces the pressure altitude and rate of climb which are displayed on the cockpit indicators. These signals may also be recorded by an instrumentation system.

4. The VSI (type 71-012-01) contains a servo amplifier, motor, and position feedback potentiometer. Input signals supplied from the rate transducer are fed into the instrument servo amplifier which, in turn, drives the motor. Position feedback from the potentiometer within the instrument is fed back to the rate transducer VSI control amplifier.

5. The longitudinal airspeed indicator (type 71-011-01) consists of a stepper motor and a feedback potentiometer. This provides an indicator rate signal and position signal which is fed back to the airspeed computer. The signals are summed with the computer longitudinal airspeed and are checked by the servo monitor. Detected failures are indicated by a warning flag on the indicator.

6. The lateral airspeed indicator (type 71-010-01) is similar to the longitudinal indicator and operates in the same manner. Pressure altitude is indicated on an AAU-19 servo altimeter.

7. If the pitot-static probe is mounted below the rotor, and is arranged to rotate such that it is always pointing into the resultant flow, then the sensed impact pressure will be proportional to the vectorial sum of the induced and transitional components of air velocity. The fundamental relationships involved are illustrated in figure 1.

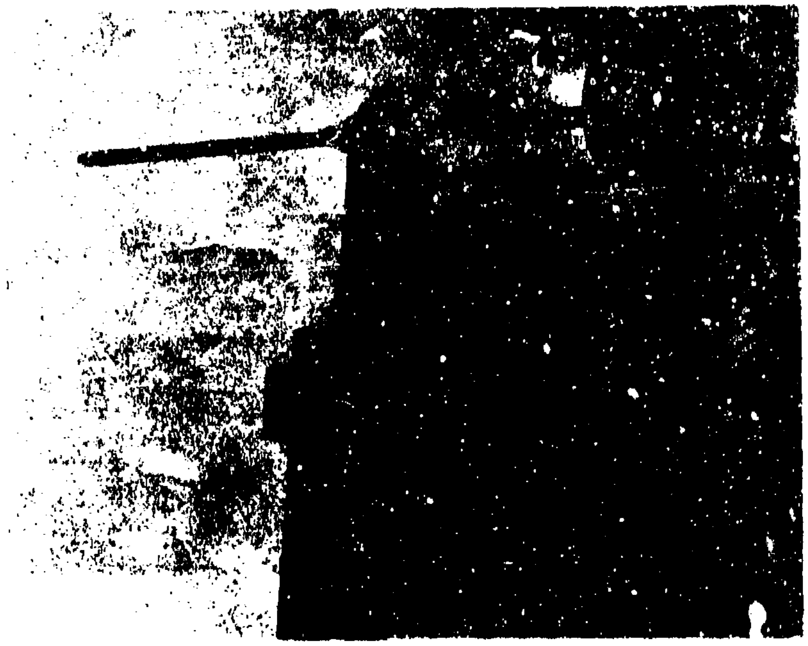


Photo 1. Airspeed Sensor.

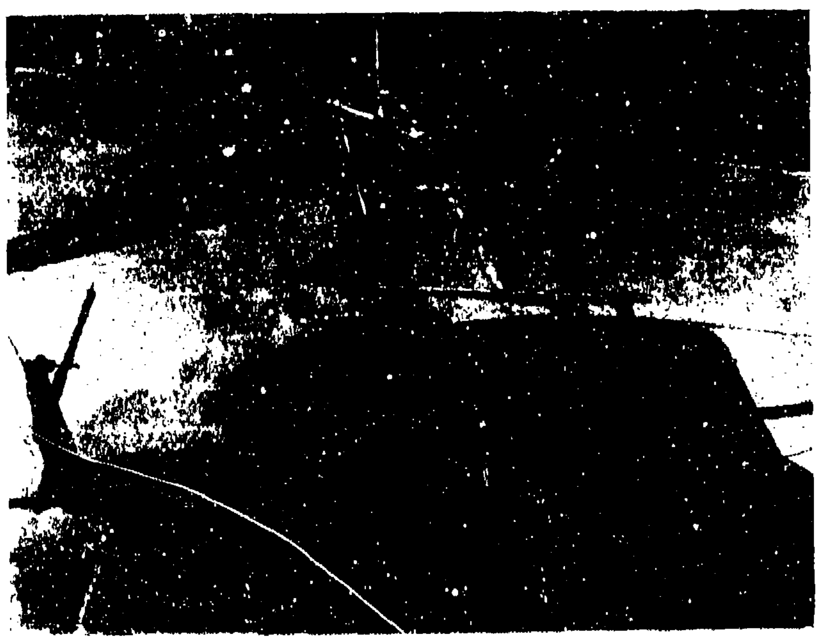


Photo 2. Side View, Forward Right Sensor Location.

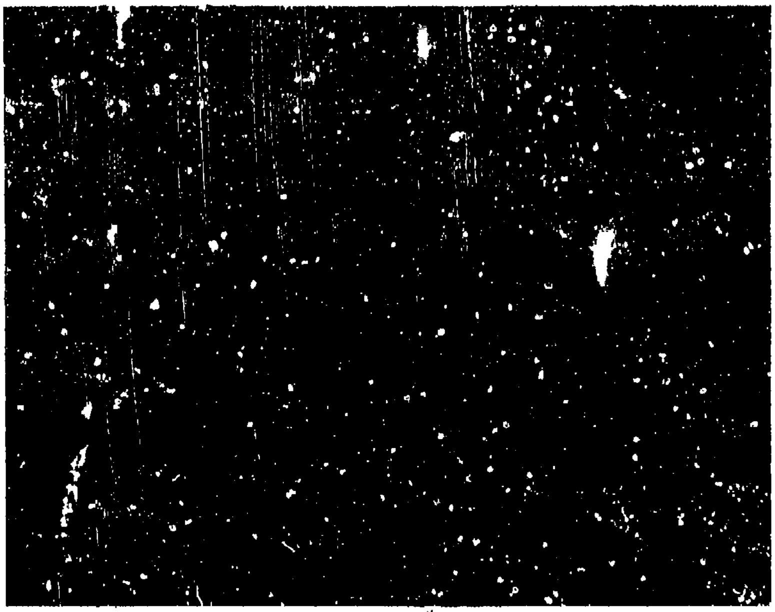


Photo 3. Front View, Forward Right Sensor Location.

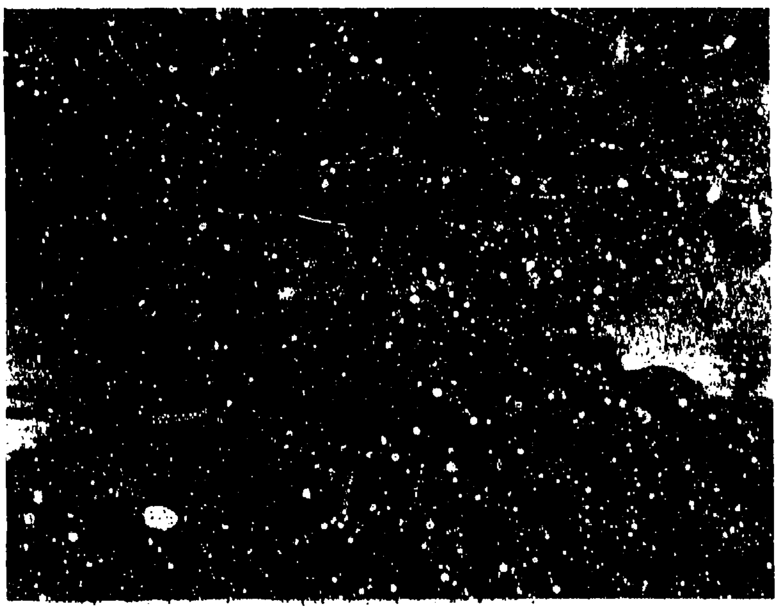


Photo 4. Aft Cabin Sensor Location.

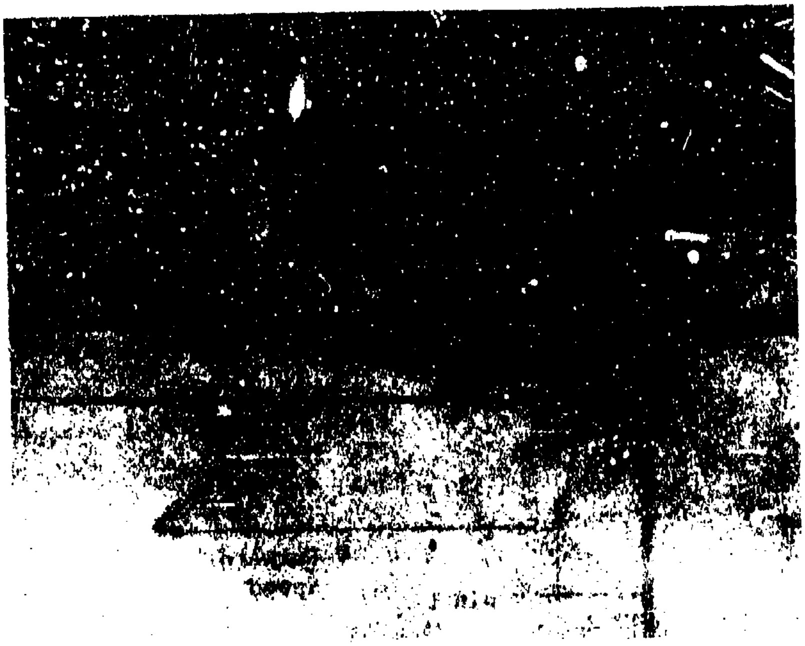


Photo 5. Forward Cabin Sensor Location.

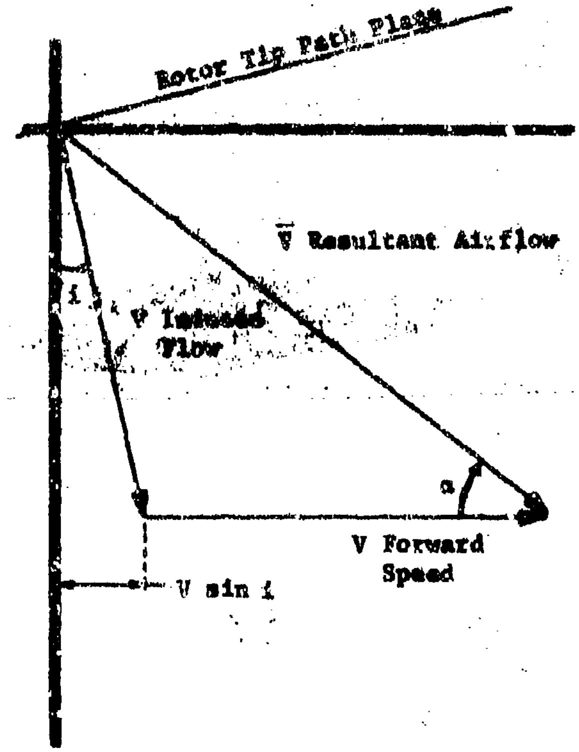


Figure 1. Resolution of Flow Under the Rotor.

Where:

$\bar{V}$ = Resultant airflow

V = Forward speed

v = induced flow

i = Rotor incidence angle

α = Probe angle relative to fuselage

8. Since at low airspeed i is small and at high airspeed v is small, the equation can be simplified and horizontal airspeed can be obtained from:

$V = \bar{V} \cos \alpha$

This arrangement has several fundamental advantages:

a. The sensor will never be required to measure impact pressure less than about 1.0 millibar (0.29 inch of mercury), since in every known operational helicopter the resultant flow ($\bar{V}$) exceeds 25 knots in a hover.

b. Reversal of flight direction produces a reversal of sign in the output, thus indicating direction of motion of airframe relative to heading.

c. The static source will be aligned with the local airstream, thus minimizing the effects of flight attitude, motion, and aircraft configuration (*ie*, doors open/shut, external weapon loads, etc.).

9. The vector geometry of the dual-axis system is illustrated in figure 2, from which it may be seen that:

Fore/aft airspeed (V_F) = $\bar{V} \cos \alpha \cos \beta$

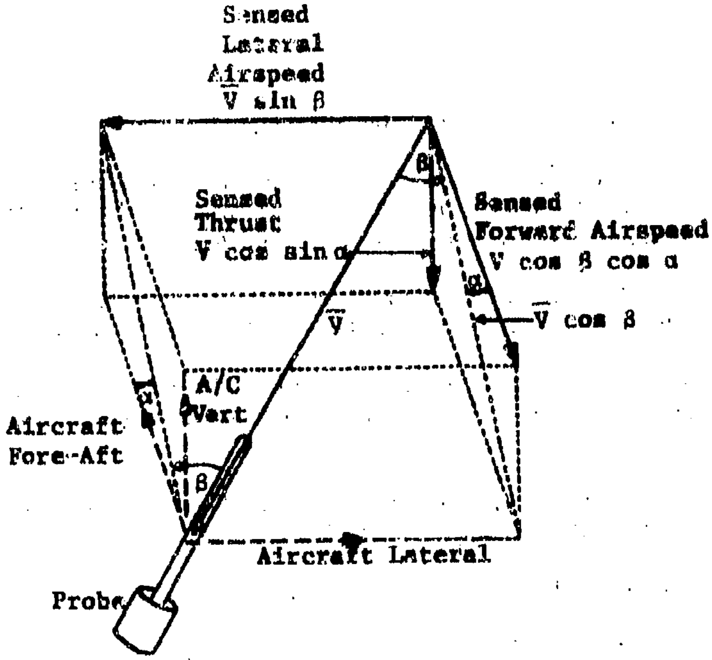
Sideward airspeed (V_L) = $\bar{V} \sin \beta$

Where:

$\bar{V}$ = Resultant airflow

α = Probe angle relative to fuselage

β = Probe angle relative to aircraft datum in roll/yaw plane



Solid lines = Resultant airstream vector (V̄), and components in aircraft axes.

Dashed lines = Aircraft reference axes.

(Dotted lines = Construction only)

Figure 2. Two-Axis Resolution of Flow Under Rotor.

It is also apparent from figure 2 that while the probe is within the downwash it is possible to compute the vertical component of velocity relative to the airframe from the available data. In addition, an indication of the magnitude and direction of the thrust vector is available.

APPENDIX C. TEST INSTRUMENTATION

1. The following parameters were recorded on board the aircraft on magnetic tape and transmitted via telemetry.

Parameter	Nominal Calibration Range
(B)[1] Time of day	Days, hr, min, sec, millisec
(B) Correlation counter	Zero to 127 counts
(B) Event	Off/zero, pilot/64, engr/128 counts
Cargo hook load (low range)	Zero to 2500 lb
Cargo hook load (high range)	2000 to 4500 lb
(B) Fuel used (fine)	Zero to 25.5 gal
(B) Fuel used (coarse)	25.5 gal/count
Fuel temperature	-10 to +50°C
Outside air temperature (total)	-10 to +50°C
Altitude #1 (boom)	-500 to 5000 ft
Altitude #2 (boom)	4500 to 10,000 ft
Altitude #3 (boom)	9000 to 18,000 ft
Airspeed (boom)	20 to 125 kt
Radar altitude (fine)	Zero to 100 ft AGL
Radar altitude (coarse)	Zero to 1000 ft AGL
Vertical velocity (fine)	±3000 ft/min
Longitudinal cyclic position	Zero (forward) to 100 percent
Lateral cyclic position	Zero (left) to 100 percent
Pedal position	Zero (left) to 100 percent
Collective position	Zero (down) to 100 percent
Twist grip position	Off, flight idle, flight governing
Rotor speed select position	Zero (full decrease) to 100 percent
Angle of attack (boom)	-45 (vane nose up) to +45 deg
Angle of sideslip (boom)	-45 (vane nose left) to +45 deg
Pitch attitude	-30 (nose down) to +30 deg
Roll attitude	-60 (bank left) to +60 deg
(B) Aircraft heading (magnetic)	Zero to 360 deg
Pitch rate	-30 (nose down) to +30 deg/sec
Roll rate	-60 (bank left) to +60 deg/sec
Yaw rate	-60 (nose left) to +60 deg/sec
CG longitudinal acceleration	±0.5g
CG lateral acceleration	±0.5g
CG vertical acceleration	-2.5 (upward) to zero g
Fuel flow rate	Zero to 120 gal/hr
Compressor speed (N_1)	65 to 105 percent

[1]B: Bilevel channel (all others zero to 5-volt DC analog)

Output shaft speed (N_2)	5800 to 6800 rpm
Rotor speed	250 to 350 rpm
(B) Rotor azimuth (blip)	Zero to 255 counts
Engine torque pressure	Zero to 61 psi
(E)[2] Longitudinal calibrated airspeed (coarse uncorrected)	-40 to +130 kt
(E) Longitudinal calibrated airspeed (fine uncorrected)	-40 to +40 kt
(E) Lateral calibrated airspeed	-40 to +40 kt
(E) Sin alpha (AHIS)	Zero to +1
(E) Cosine alpha (AHIS)	-1 to +1
(E) Sin beta (AHIS)	-1 to +1
(E) Cosine beta (AHIS)	-1 to +1
(E) Total velocity	Zero to 130 kt
(E) Downwash velocity	Zero to 40 kt
Ship's static pressure	Differential - boom reference
(E) Altitude (coarse)	Sea level to 20,000 ft
(E) Altitude #1 (fine)	2432 ft/turn
(E) Altitude #2 (fine)	2432 ft/turn
(E) Altitude (F-coil)	2.4 volt/100 ft
(E) Vertical velocity	±600 or ±3000 ft/min
(N)[3] Dew point temperature	-20 to +50°C
(TB)[4] Lift margin or effective gross weight or maximum standard torque	
(TB) HLMS flag	LM, EGW, or Q_{ms}, OGE or IGE
(T) Air density ratio, calculated	
(T) Effective gross weight	
(T) Compressor inlet temperature, numerator	
(T) Compressor inlet temperature, denominator	

2. The following parameters were tape-recorded or hand-recorded on the ground:

Parameter	Nominal Calibration Range
Wind speed stations 1 through 9	Zero to 35 kt
Wind direction stations 1 through 9	Zero to 360 deg

[2]E: Signal provided by E-A Industrial Corporation.
[3]N: Signal provided by National Bureau of Standards
[4]T: Signal provided by Trans-Sonics Inc. as output from HLMS.

3. The following parameters were hand-recorded on the ground:

Parameter	Nominal Calibration Range
Relative humidity	5 to 99 percent
Barometric pressure	13 to 31.5 in. of mercury
Wind speed stations 10 through 12	Zero to 35 kt
Wind direction stations 10 through 12	Zero to 360 deg

4. The following parameters were displayed on the engineer panel:

Parameter	Nominal Calibration Range
Time of day	Hours, min, sec
Record counter	Zero to 127 counts
Fuel flow	Not calibrated
Fuel used	0.1 gal/count to 999.9 gal
Radar altitude	Zero to 1000 feet AGL
Tethered thrust	Zero to 5000 lb
Outside air temperature (total)	-10 to +60°C
Dew point temperature	-20 to +50°C
Ship's airspeed	15 to 140 kt
Ship's altitude	-500 to 15,000 ft
AHIS altitude (AAU-19)	Sea level to 20,000 ft
Lift margin/effective gross weight (EGW)/maximum standard torque (Q_{ms})	

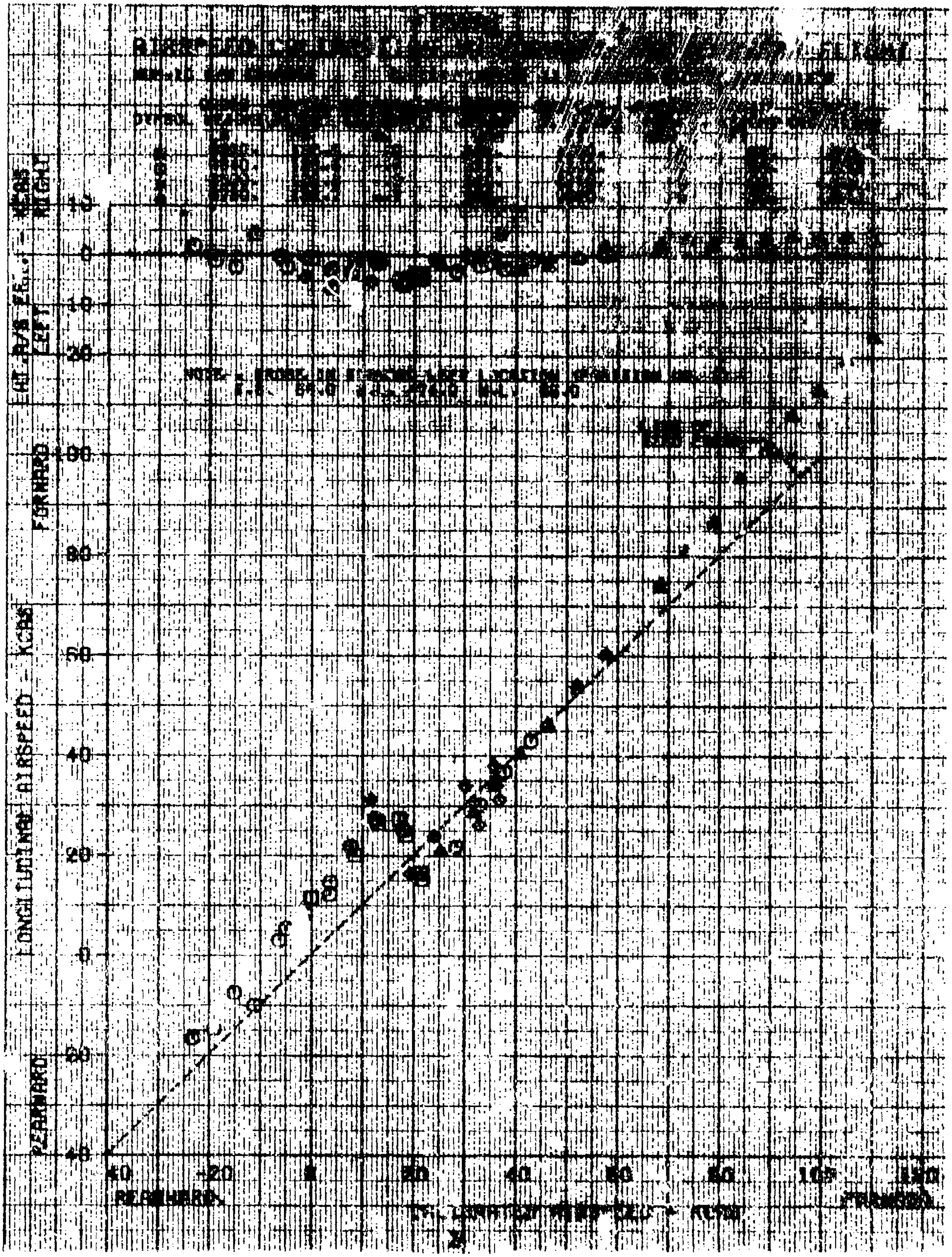
5. The following parameters were displayed on the pilot panel:

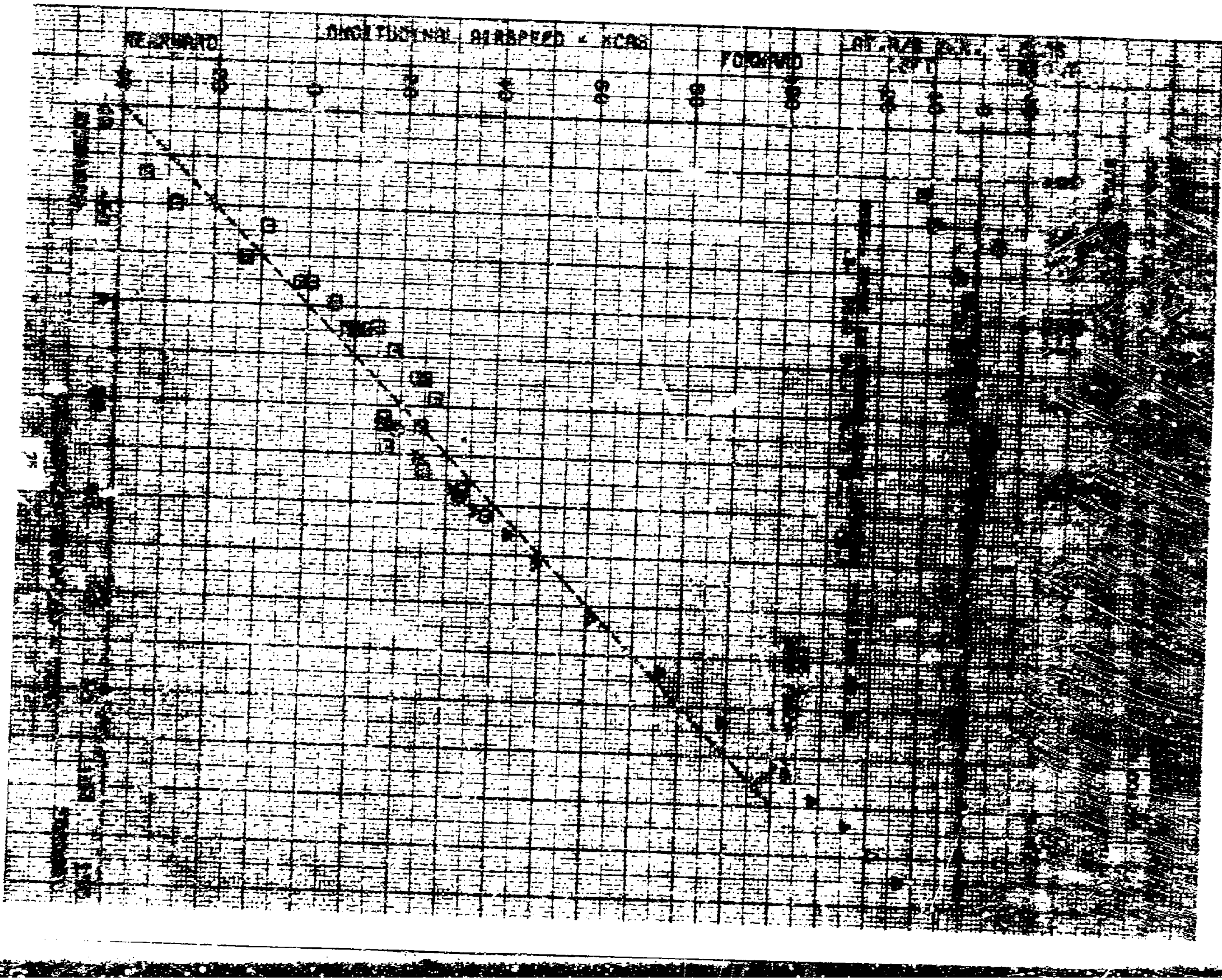
Parameter	Nominal Calibration Range
Test boom altitude	-500 to 15,000 ft
Test boom airspeed	15 to 140 kt
Angle of sideslip	±45 deg
Rotor speed (sensitive)	220 to 350 rpm
Rotor/output shaft speed (ship's)	Not calibrated
Engine torque pressure	Zero to 50 psi
Compressor speed	60 to 110 percent
Exhaust gas temperature	Not calibrated
Aircraft heading (magnetic)	Zero to 360 deg
Aircraft attitude (pitch and roll)	Not calibrated
Longitudinal airspeed (AHIS)	-40 to 130 kt
Lateral airspeed (AHIS)	±40 kt
Vertical speed (AHIS)	±600 or 3000 ft/min
Vertical speed (ship's)	Not calibrated
Fuel quantity (ship's)	Zero to 1100 lb (full)

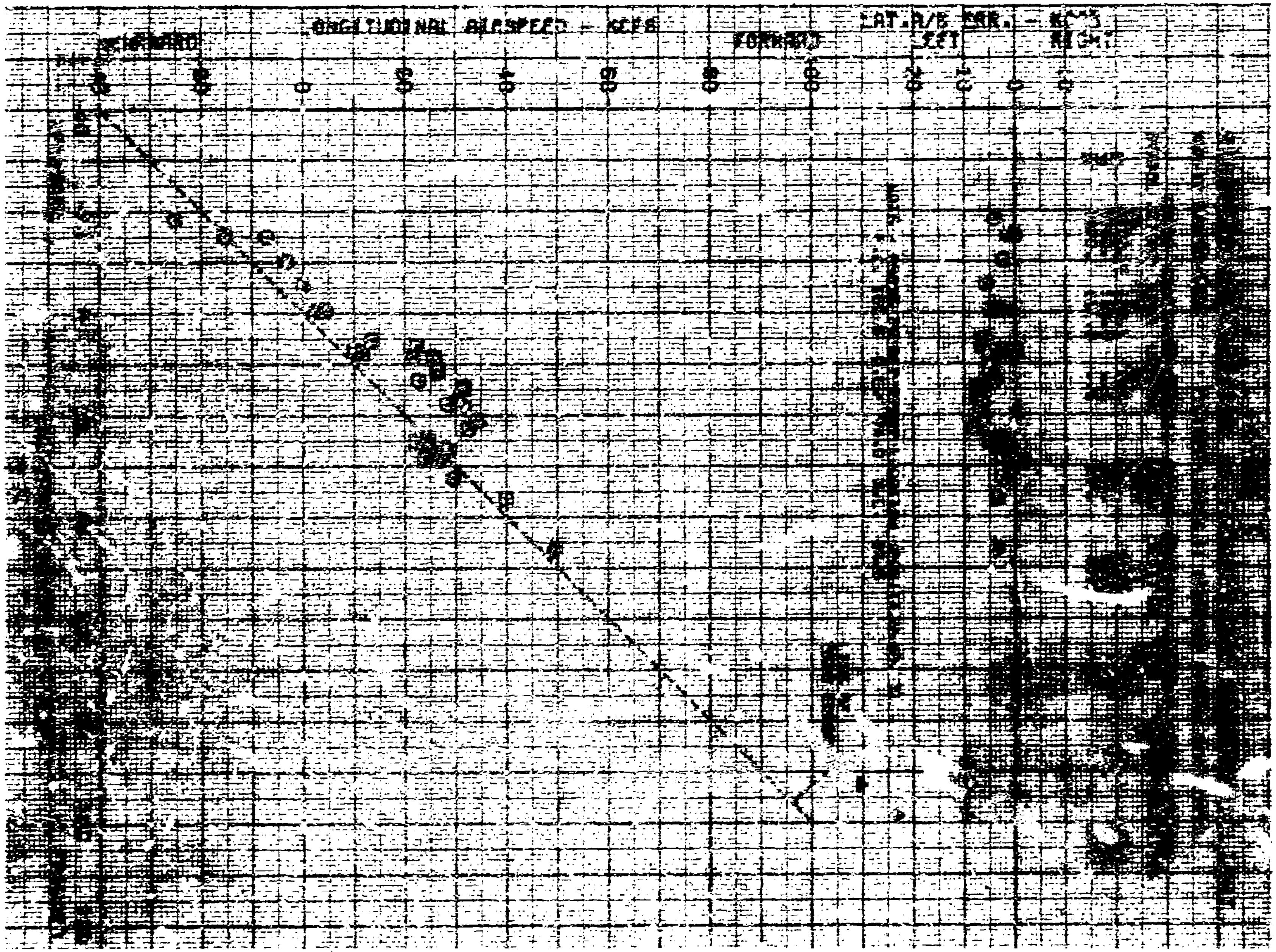
Collective position	Zero (full down) to 100 percent
Pedal position	Zero (full left) to 100 percent
Lateral cyclic position	Zero (full left) to 100 percent
Longitudinal cyclic position	Zero (full forward) to 100 percent
Tethered cable angle	±30 deg
Tail rotor blade angle	-8 to + 23 deg

APPENDIX D. TEST DATA

INDEX




REARWARD
LONGITUDINAL AIRSPEED ~ KCAS
FORWARD


LONGITUDINAL AIRSPEED - KCAS
REARWARD
FORWARD
LEFT
RIGHT

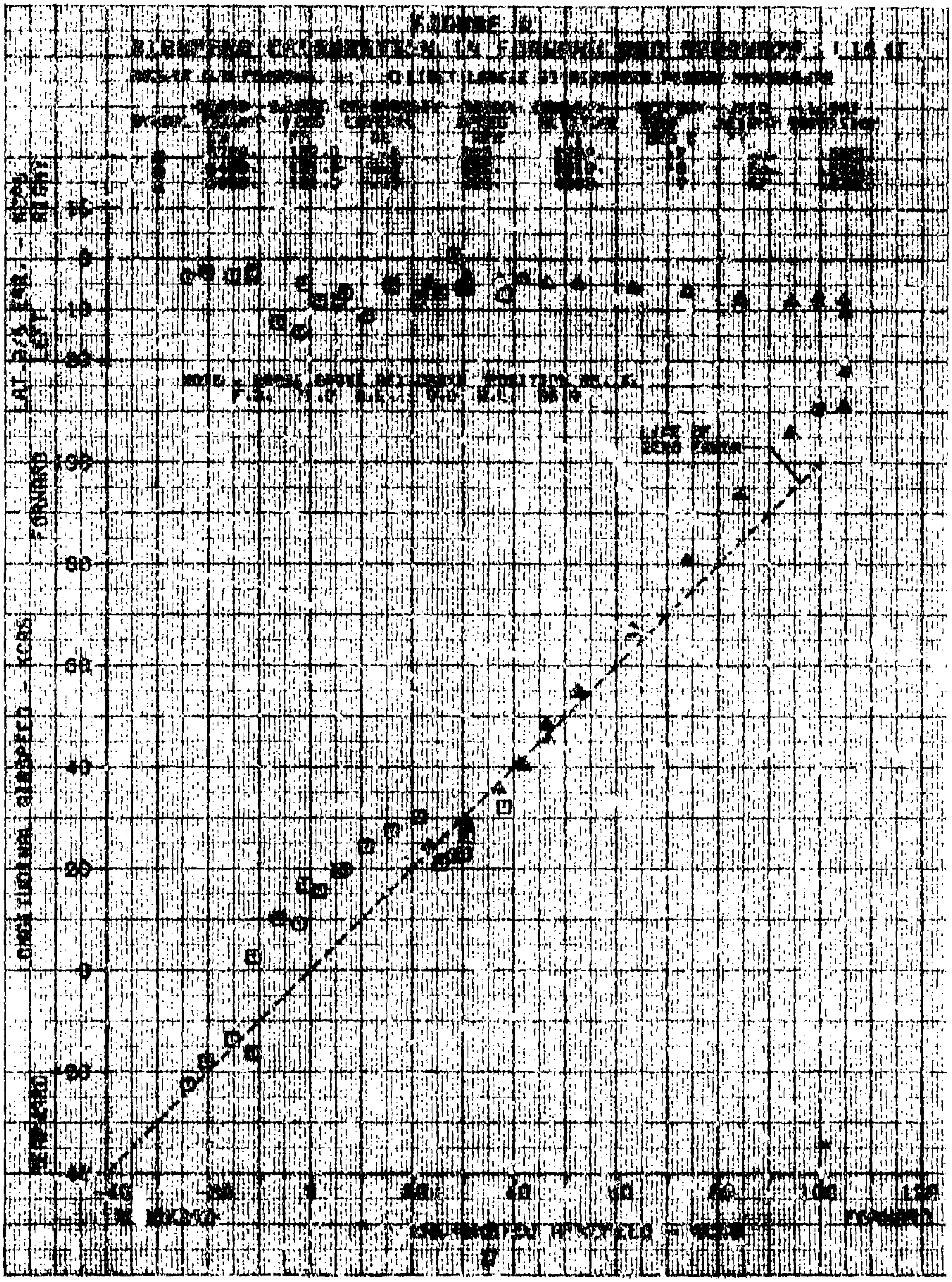
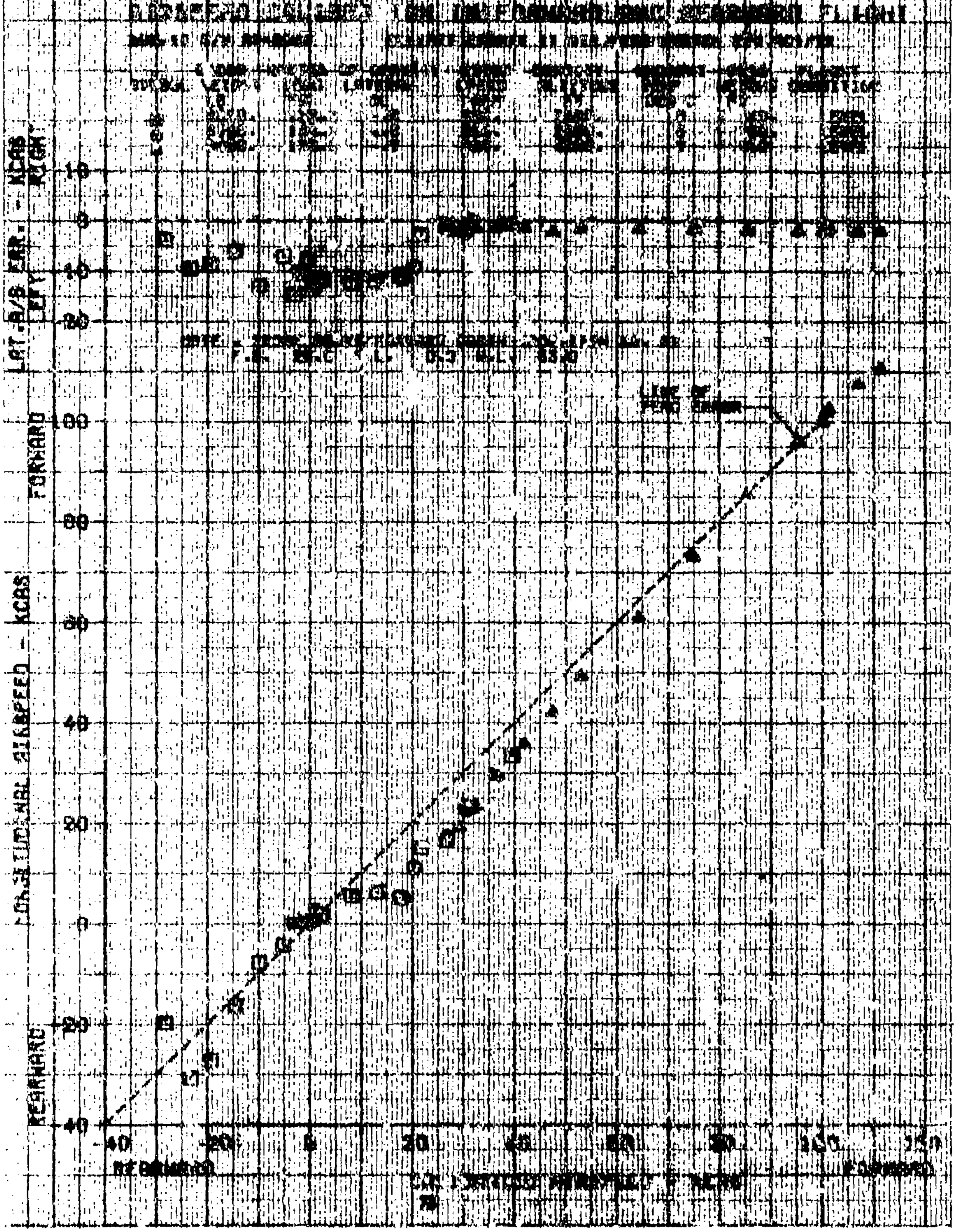
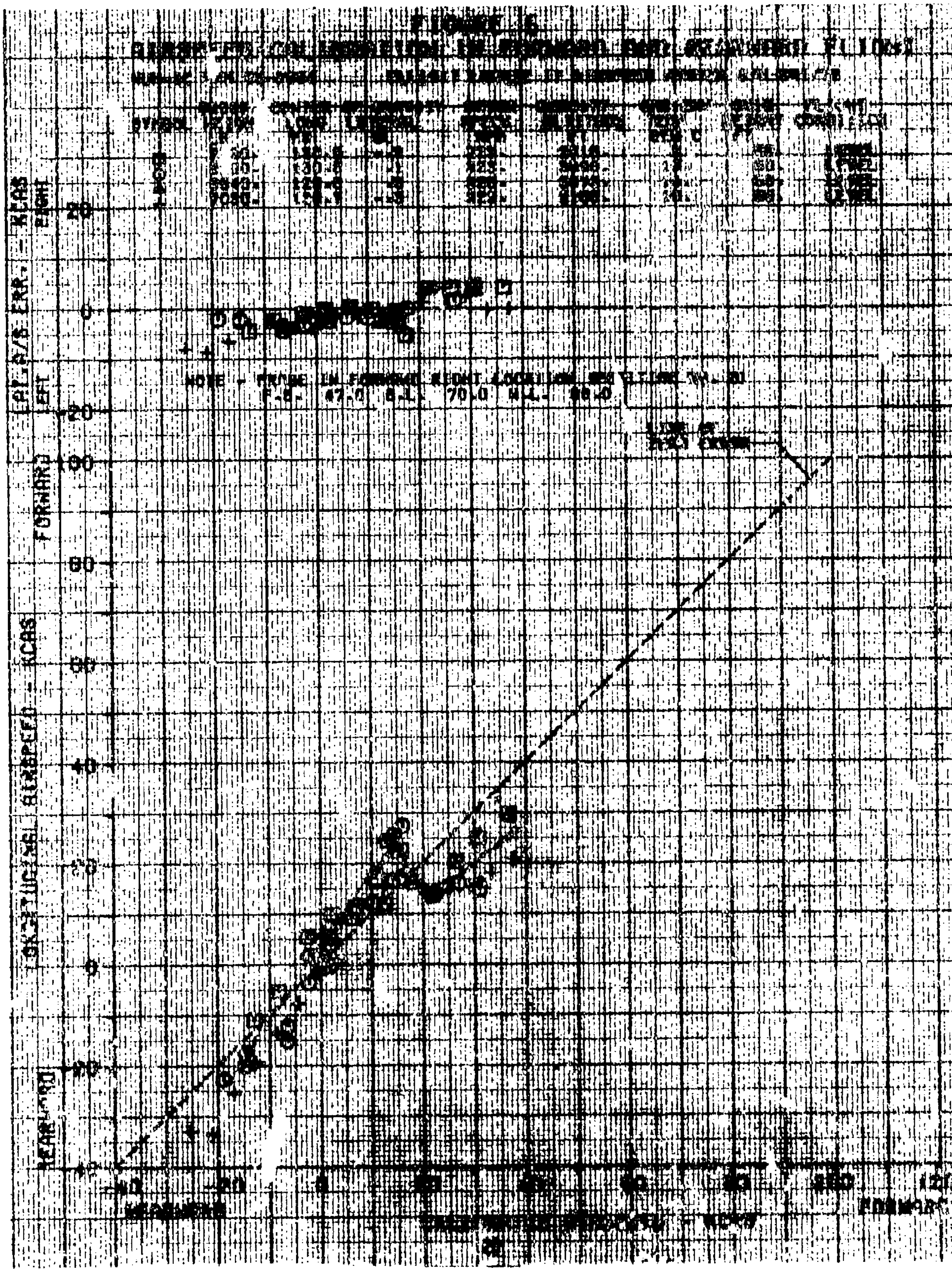


FIGURE 5



RIGHT
LEFT
LAT. A/S CAL. - KCAS
FORWARD
REARWARD
LONGITUDINAL AIRSPEED - KCAS
10
0
10
20
100
80
60
40
20
0
20
40
-40
-20
0
20
40
60
80
100
120
REARWARD
FORWARD



KCAS
FORWARD
F.S. 47.0 B.L. 70.0 W.L. 90.0
20
0
-20
100
80
60
40
-40

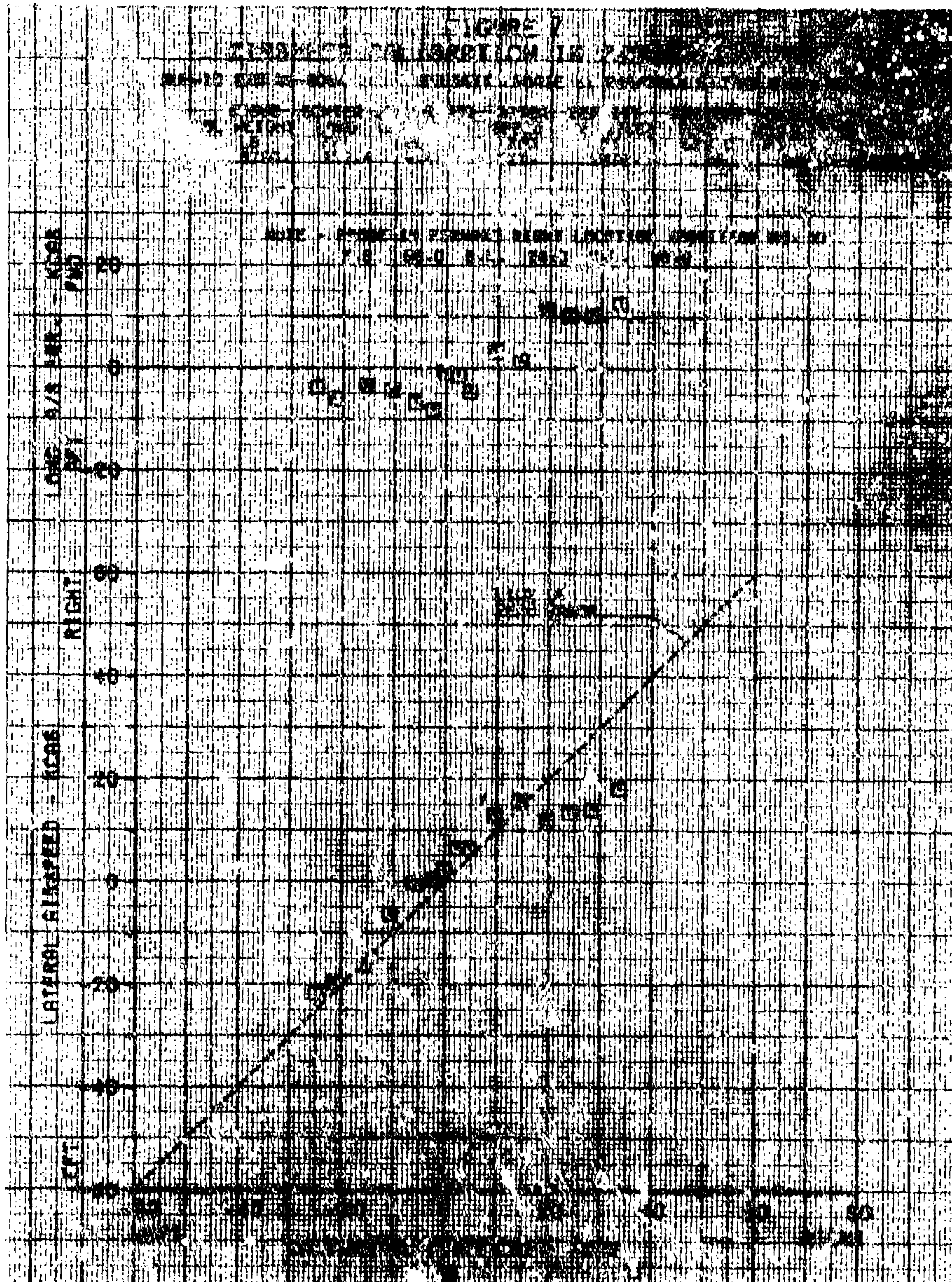
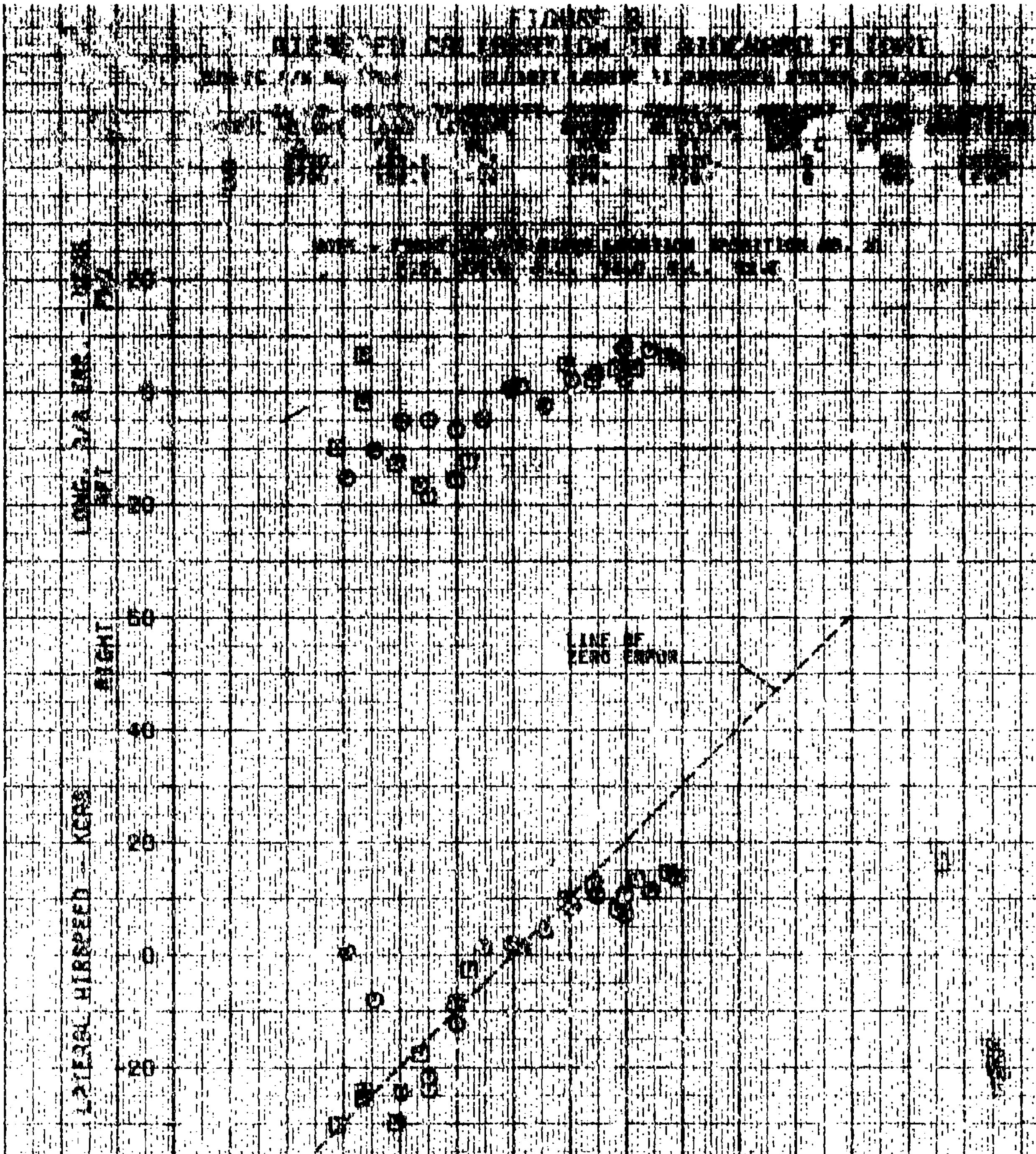
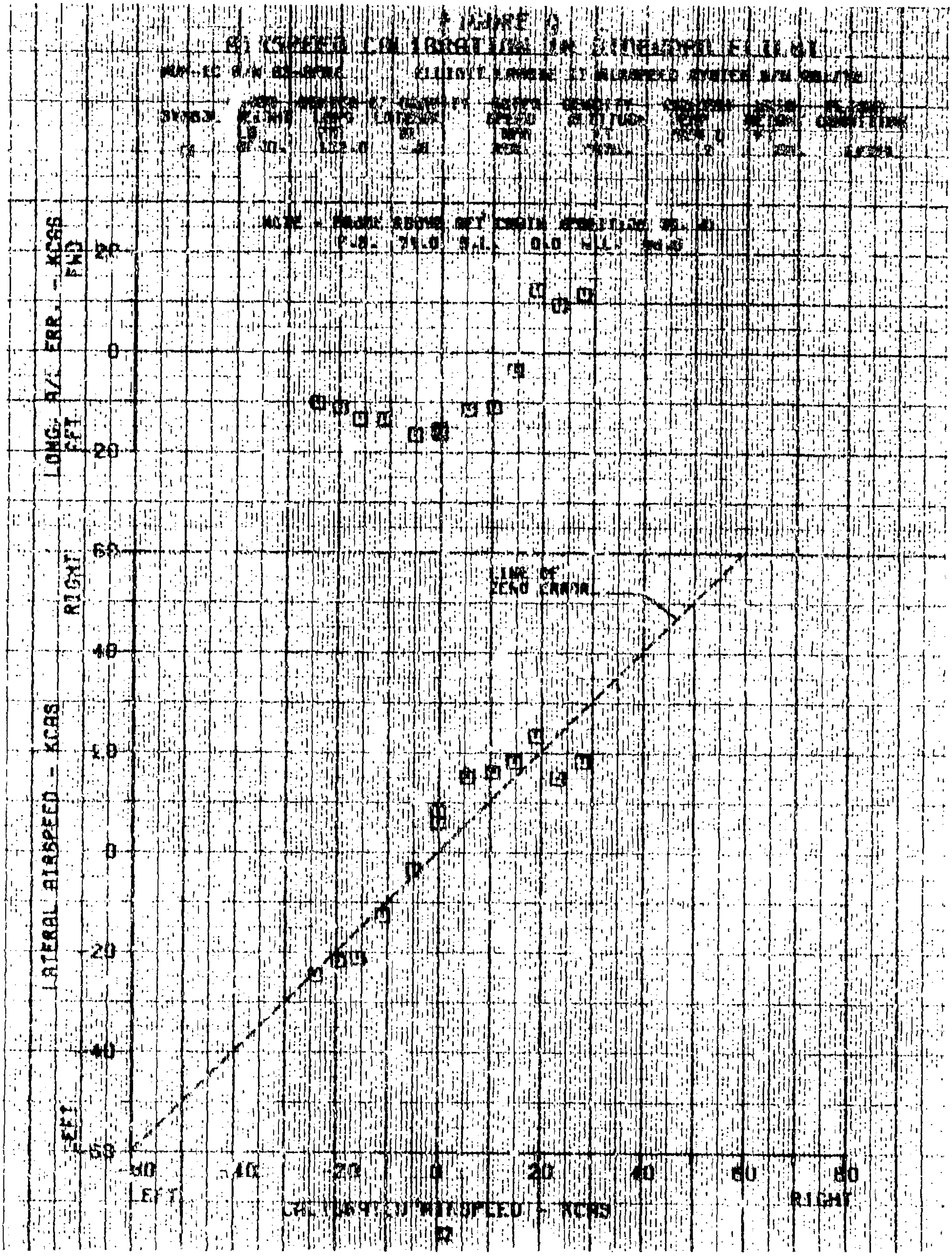
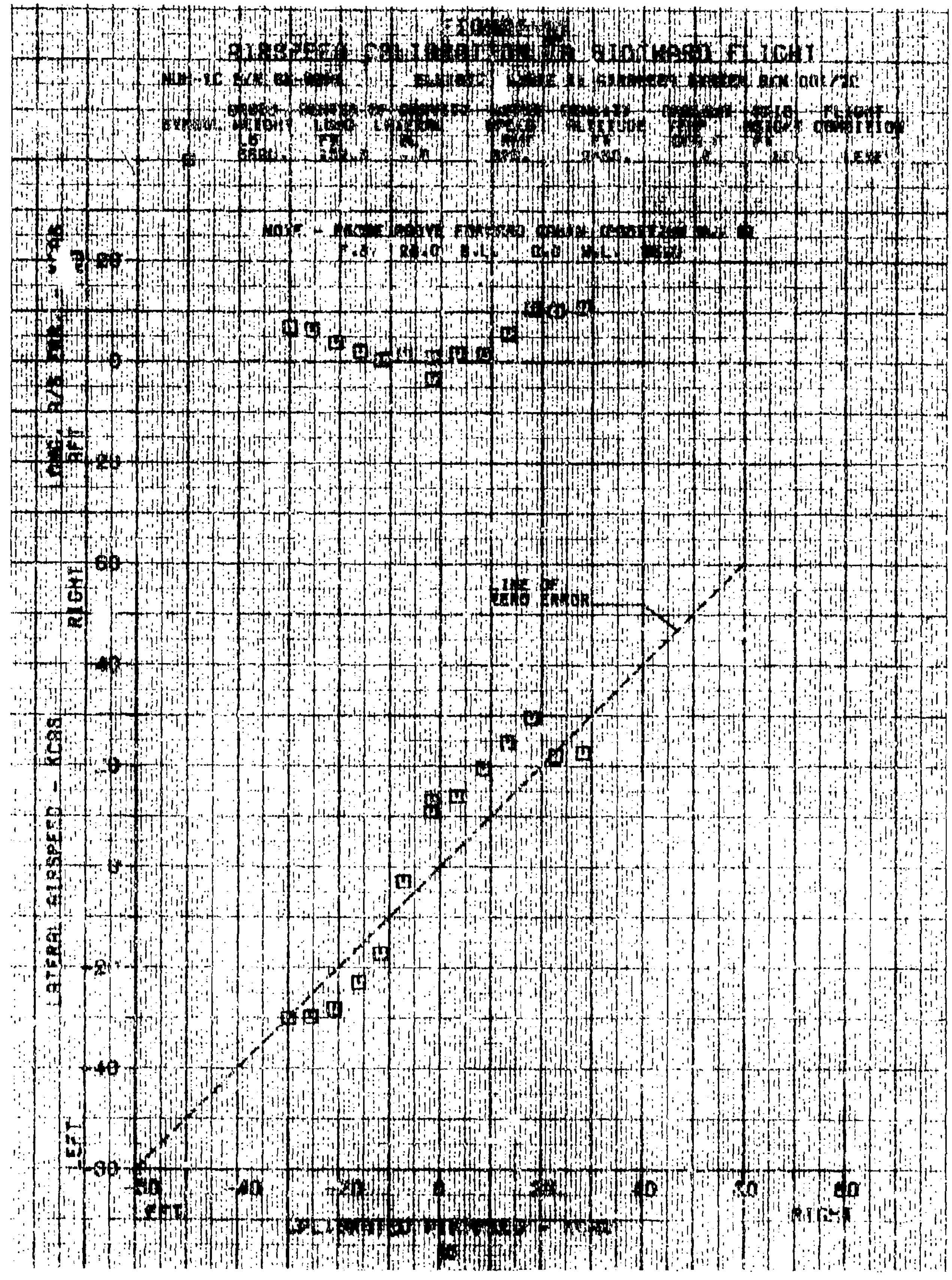


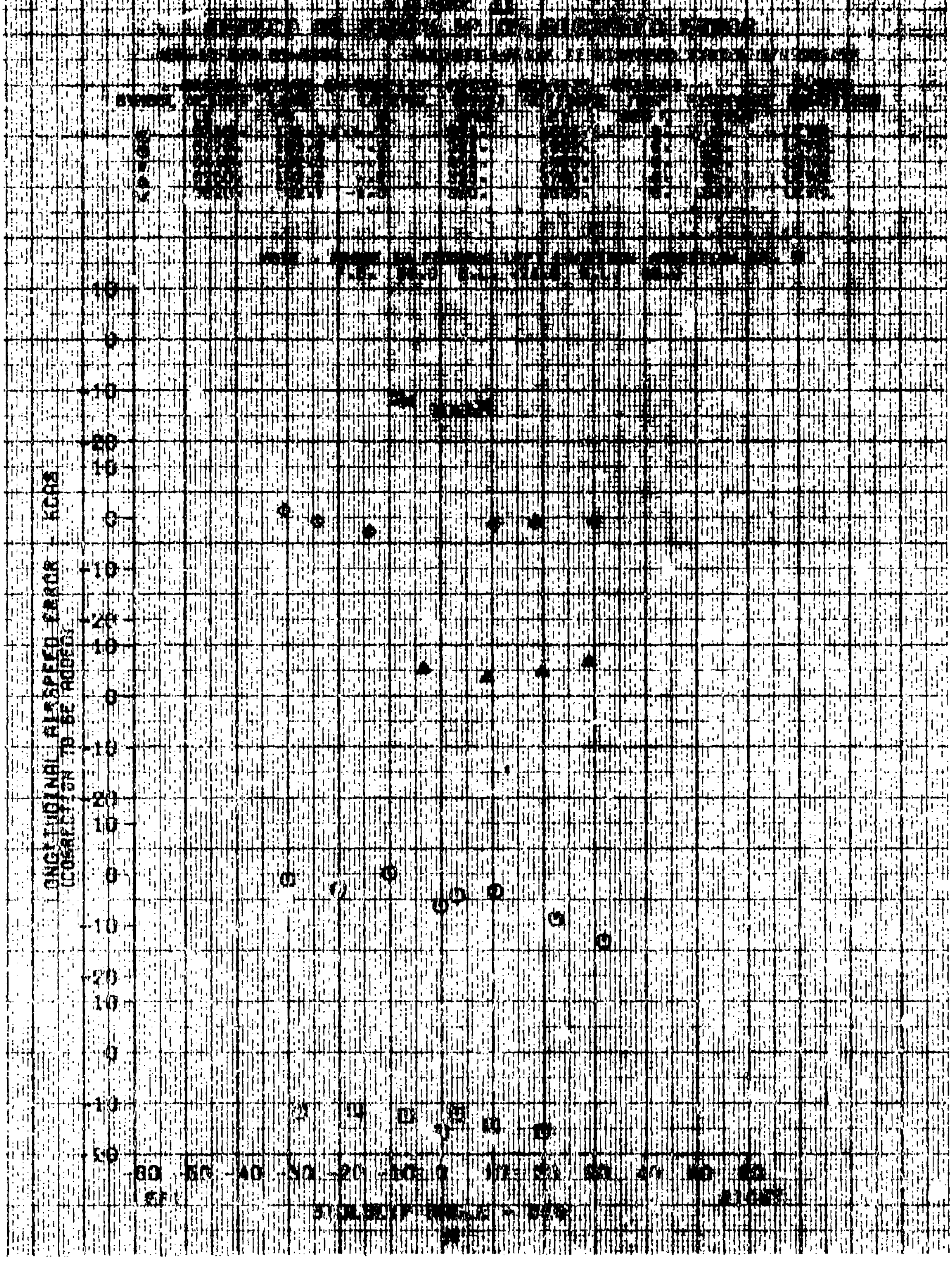
FIGURE 7
LATERAL AIRSPEED - KCAS
RIGHT
LEFT



LINE OF ZERO ERROR
LATERAL AIRSPEED - KEAS
RIGHT
LEFT
60
40
20
0
20
40
60


LONG. A/S ERR. - KCAS
FWD
AFT
LATERAL AIRSPEED - KCAS
RIGHT
LEFT
LINE OF ZERO CRAB
20
0
-20
60
40
20
0
-20
-40
-60
-60
-40
-20
0
20
40
60
80
LEFT
RIGHT
KCAS


LINE OF
ZERO ERROR
RIGHT
LEFT
-60
-40
-20
0
20
40
60
80



LONGITUDINAL AIRSPEED ERROR - KNOTS
(CORRECTION TO BE ADDED)
-60 -50 -40 -30 -20 -10 0 10 20 30 40 50 60

FIGURE 12

EFFECT OF SIDESLIP ON AIRSPEED ERROR

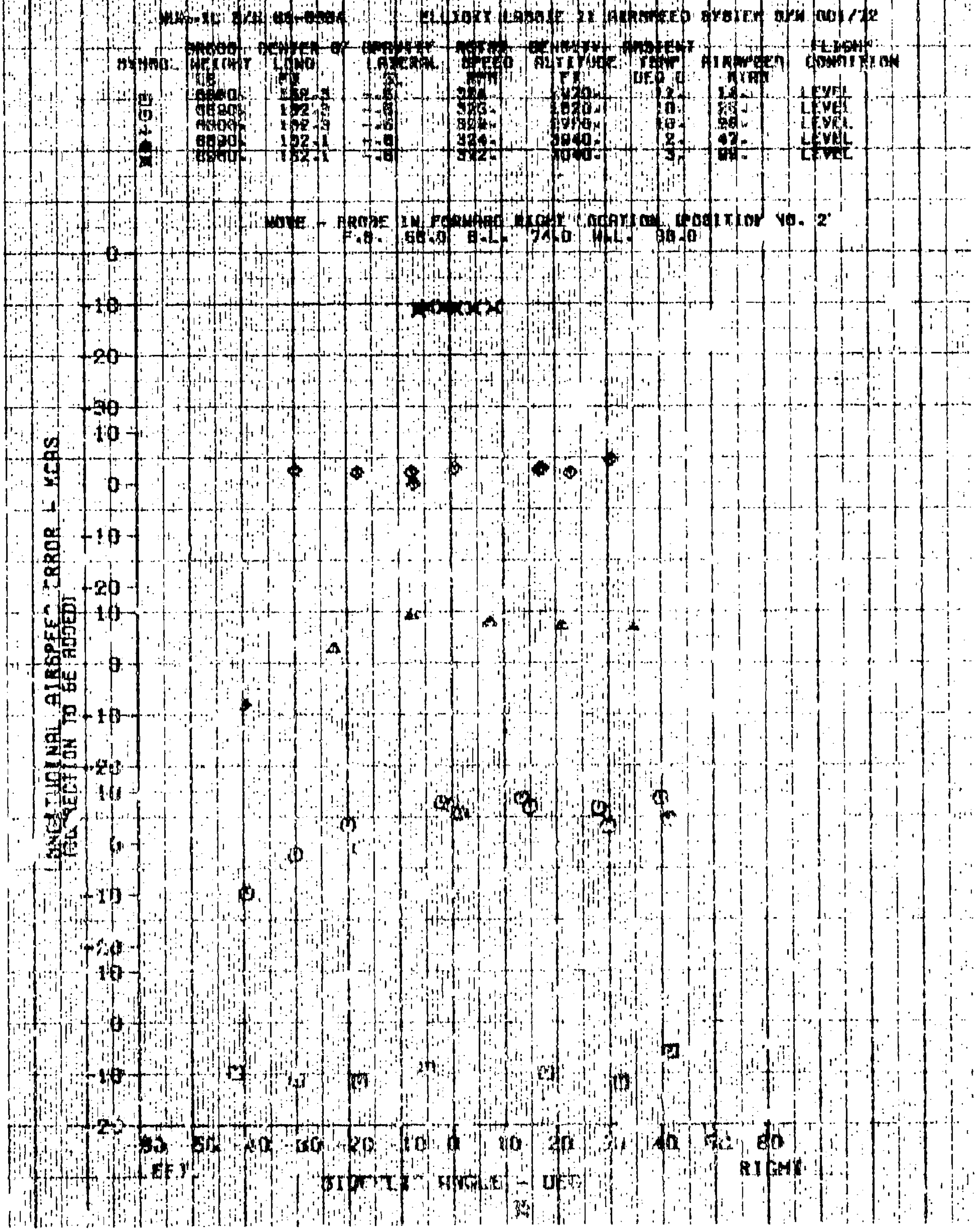
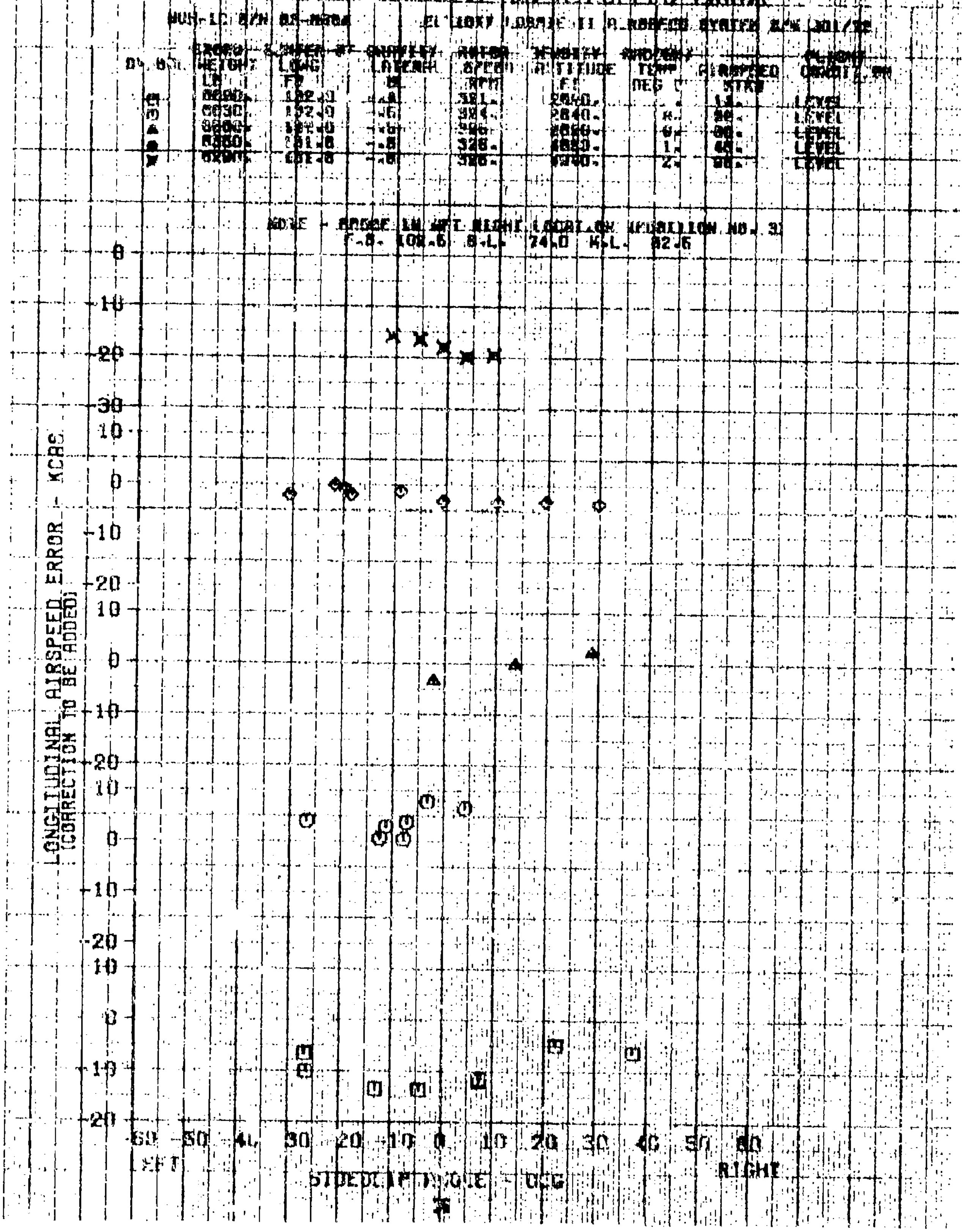
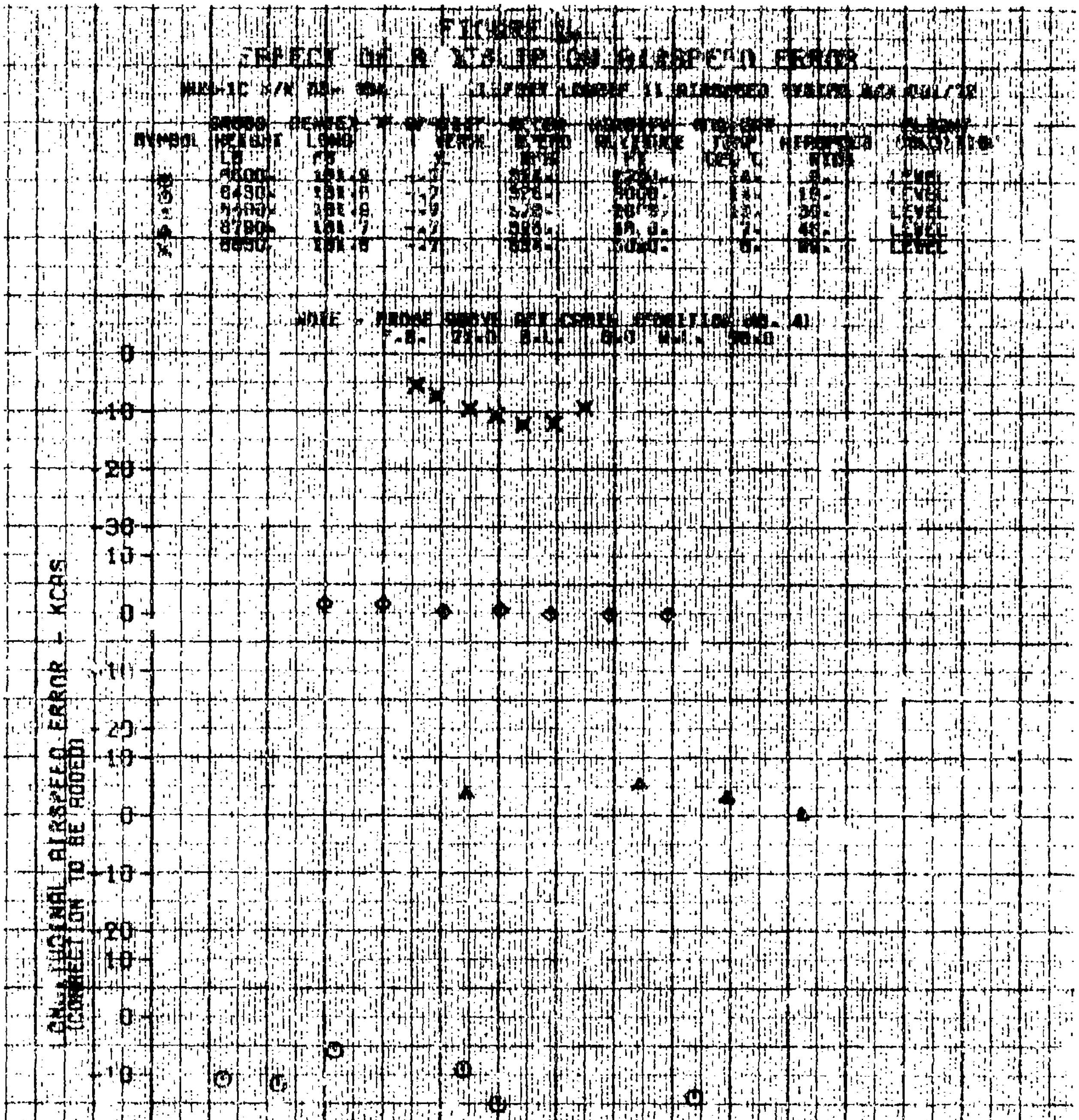
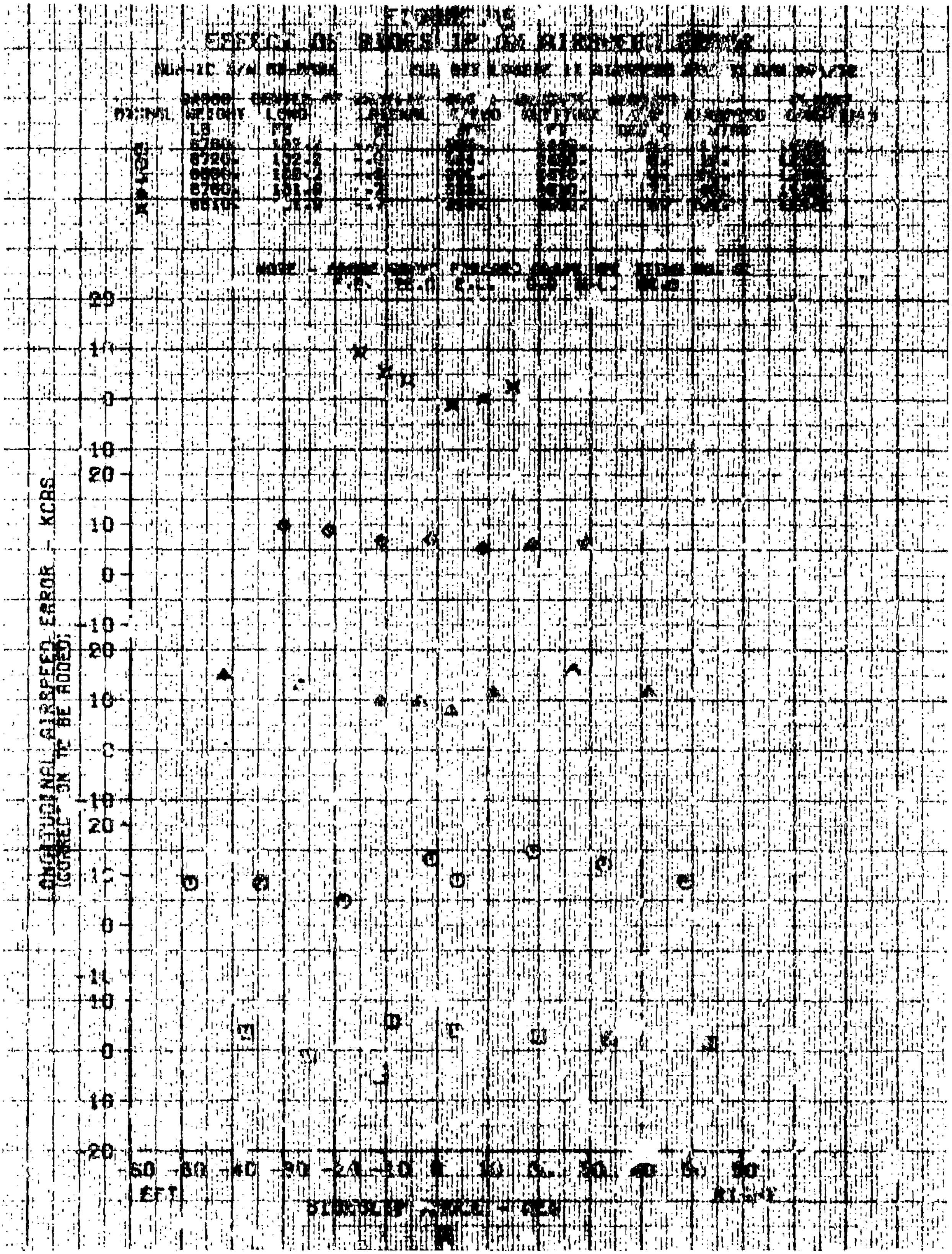
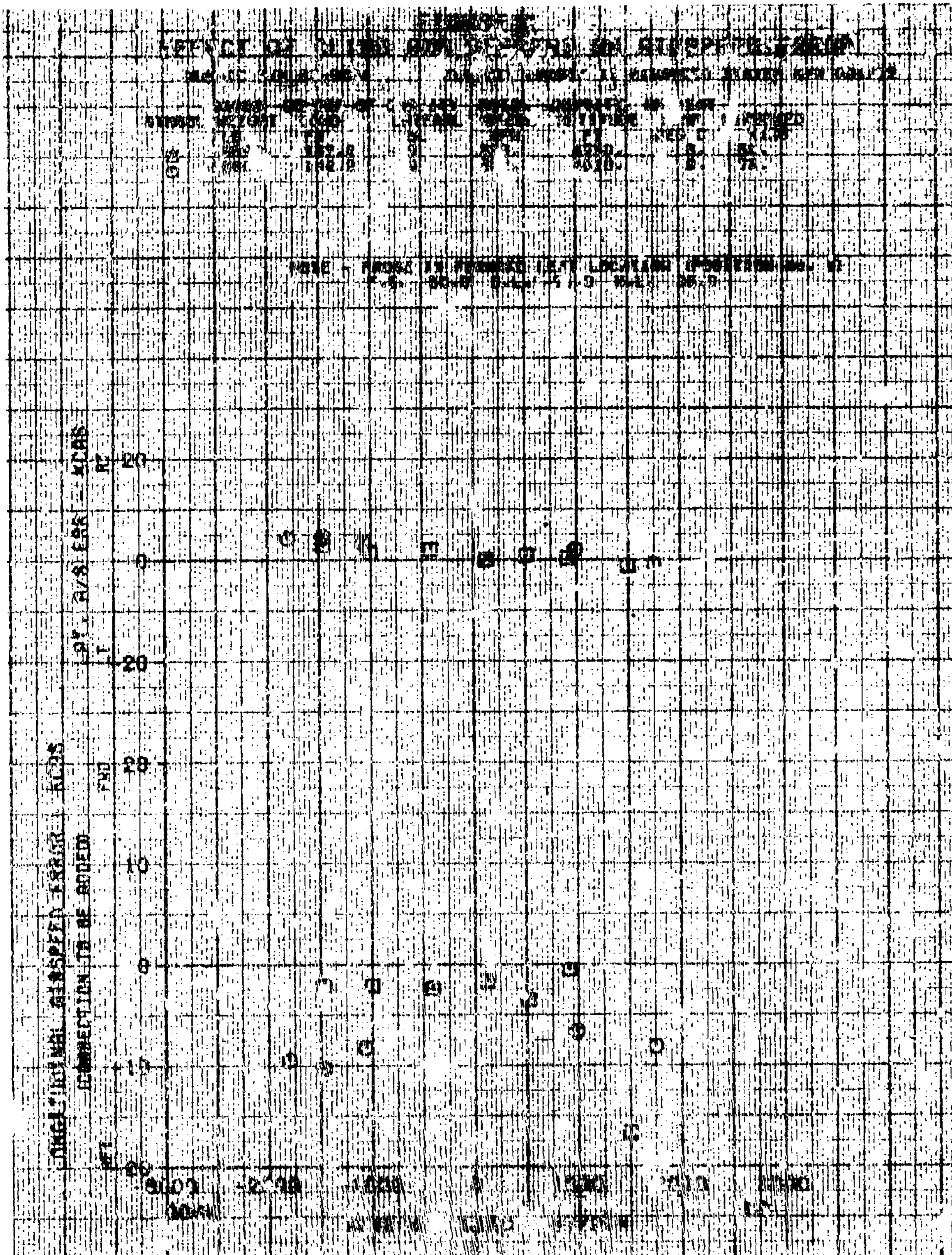


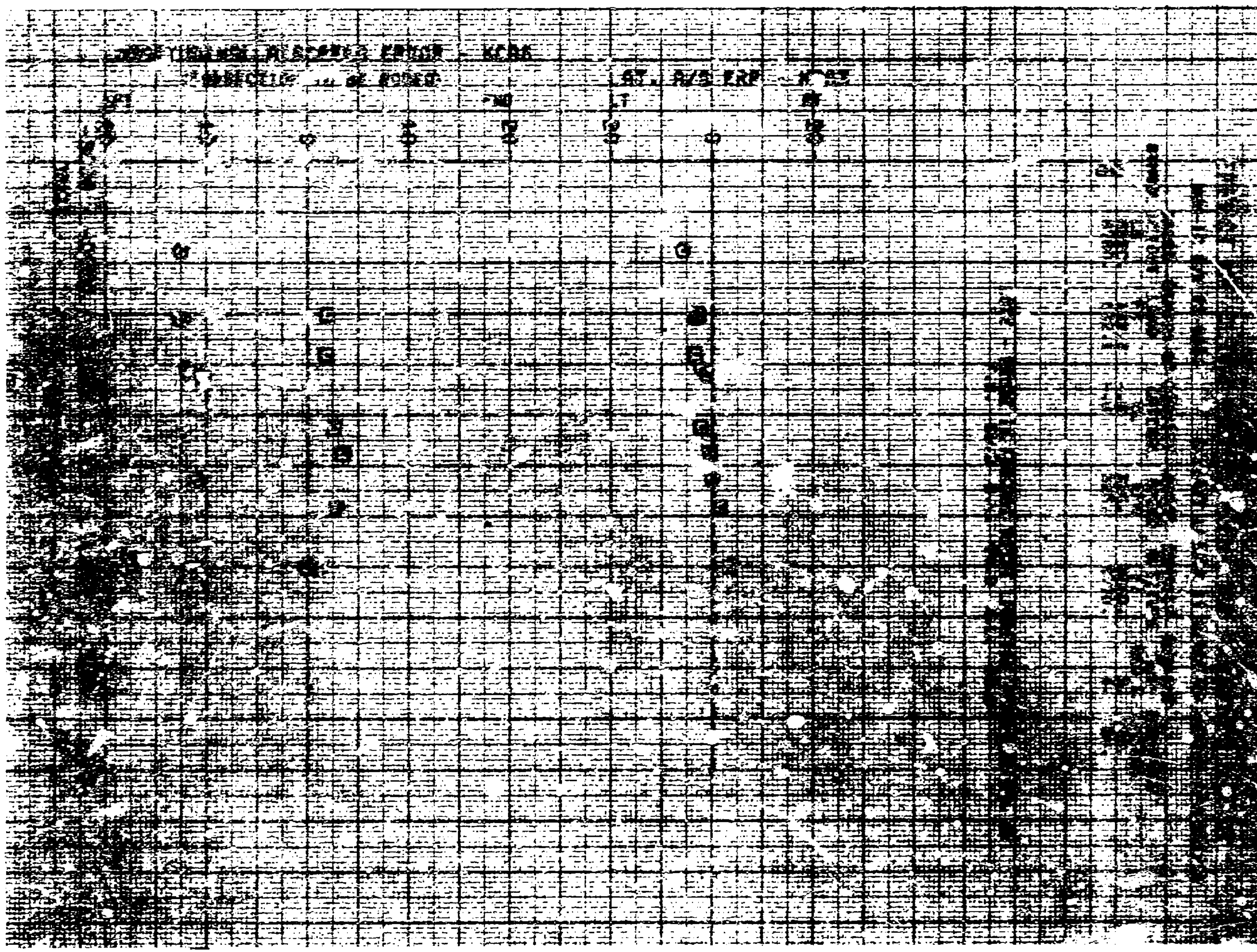
FIGURE 15
EFFECT OF SIDESLIP ON AIRSPEED ERROR

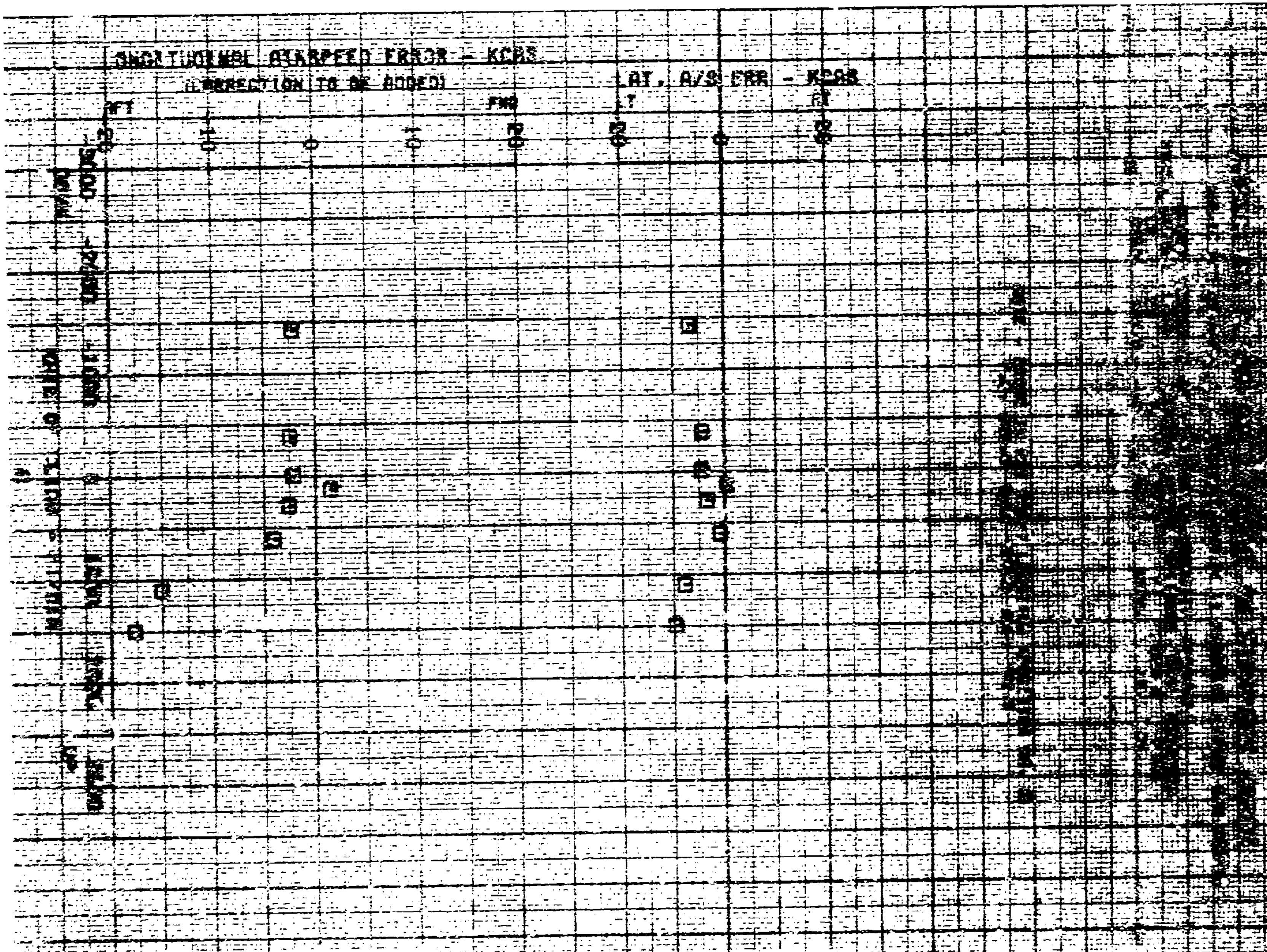


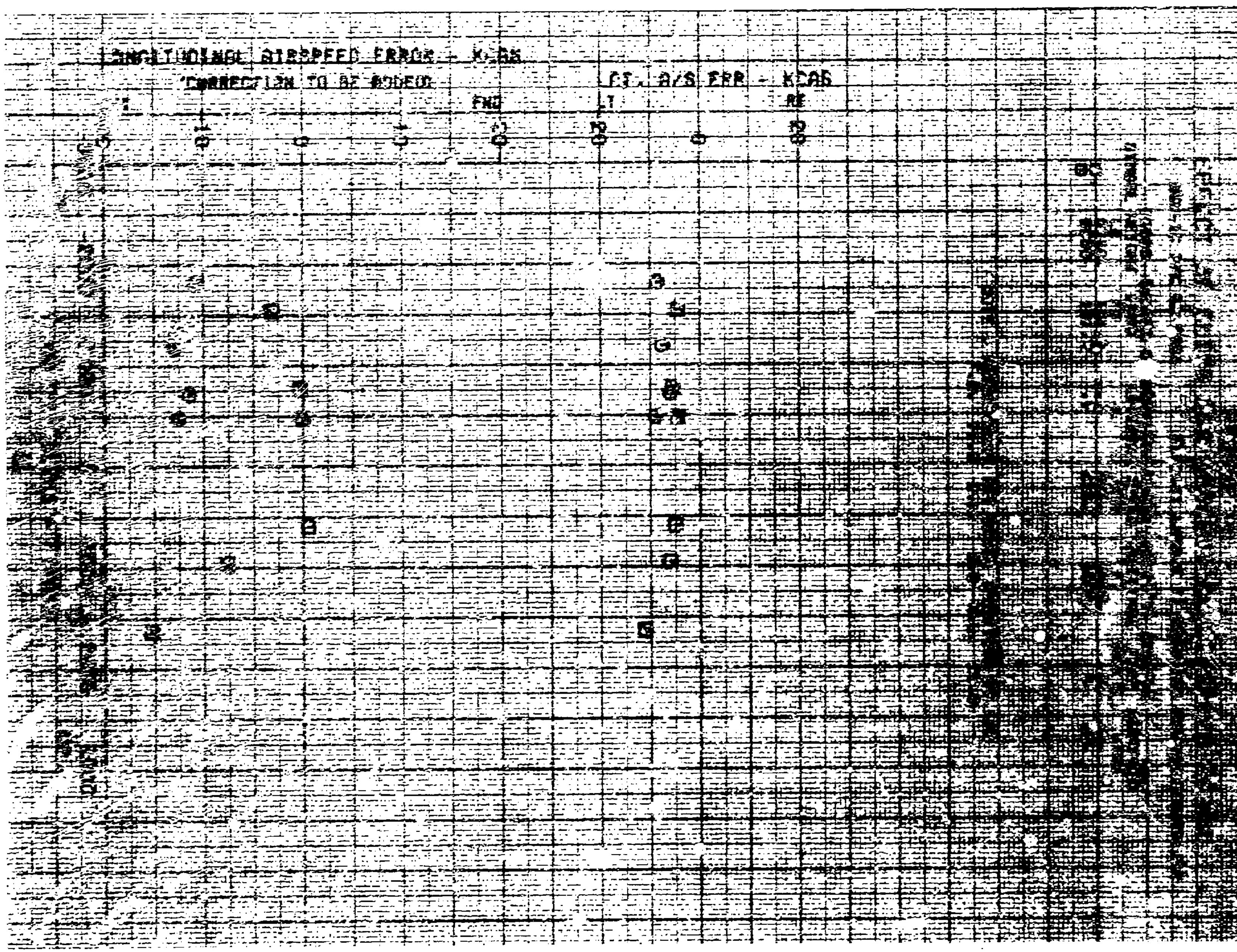

LONGITUDINAL AIRSPEED ERROR - KCAS
(CORRECTION TO BE ADDED)
-50 -40 -30 -20 -10 0 10 20 30 40 50
LEFT
RIGHT


LONGITUDINAL AIRSPEED ERROR - KCAS
50 30 40 20 10 0 10 20 30 40 50





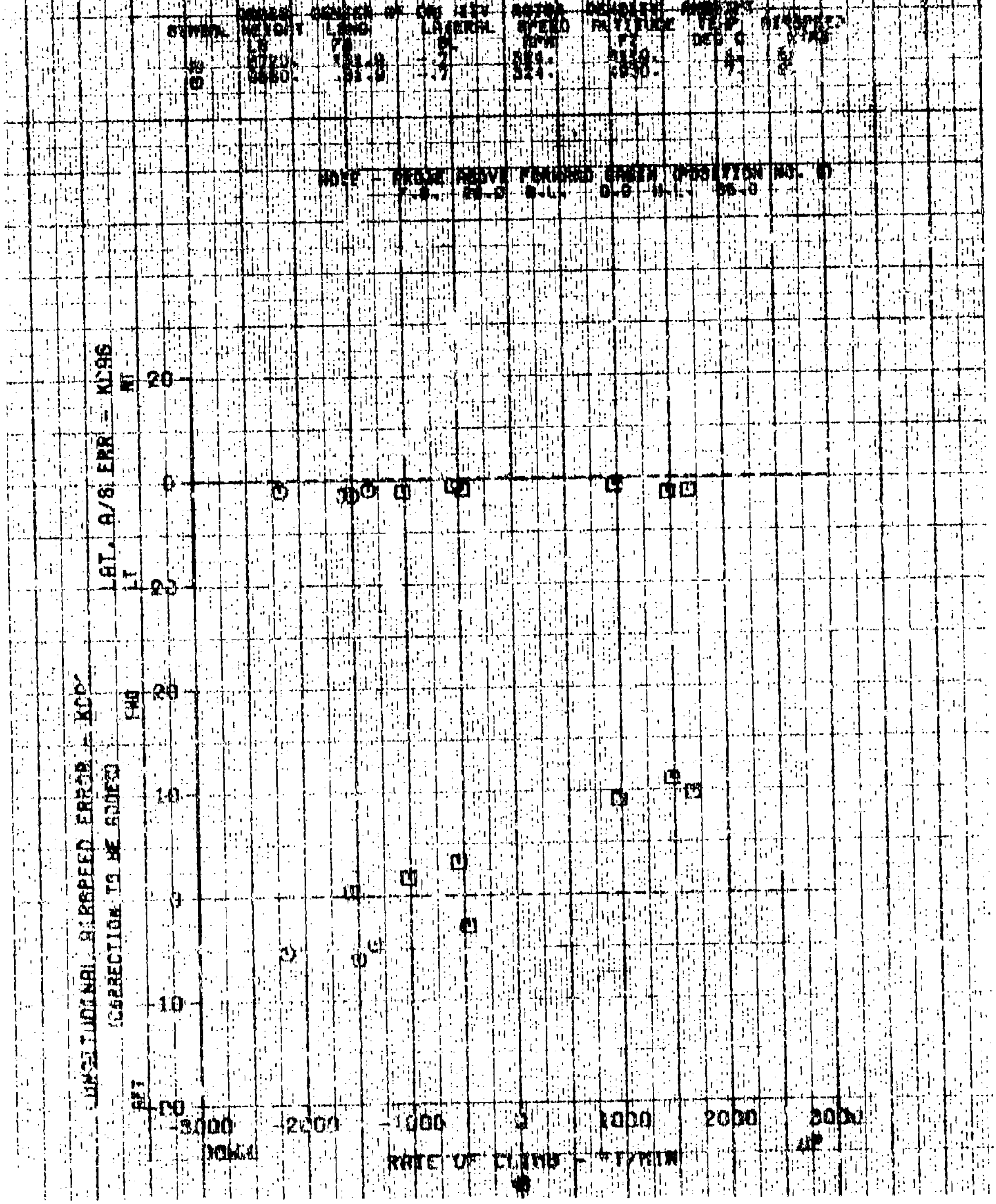

LONGITUDINAL AIRSPEED ERROR - KCAS
(CORRECTION TO BE ADDED)
LAT. A/S ERR - KCAS
AFT
FWD
RT

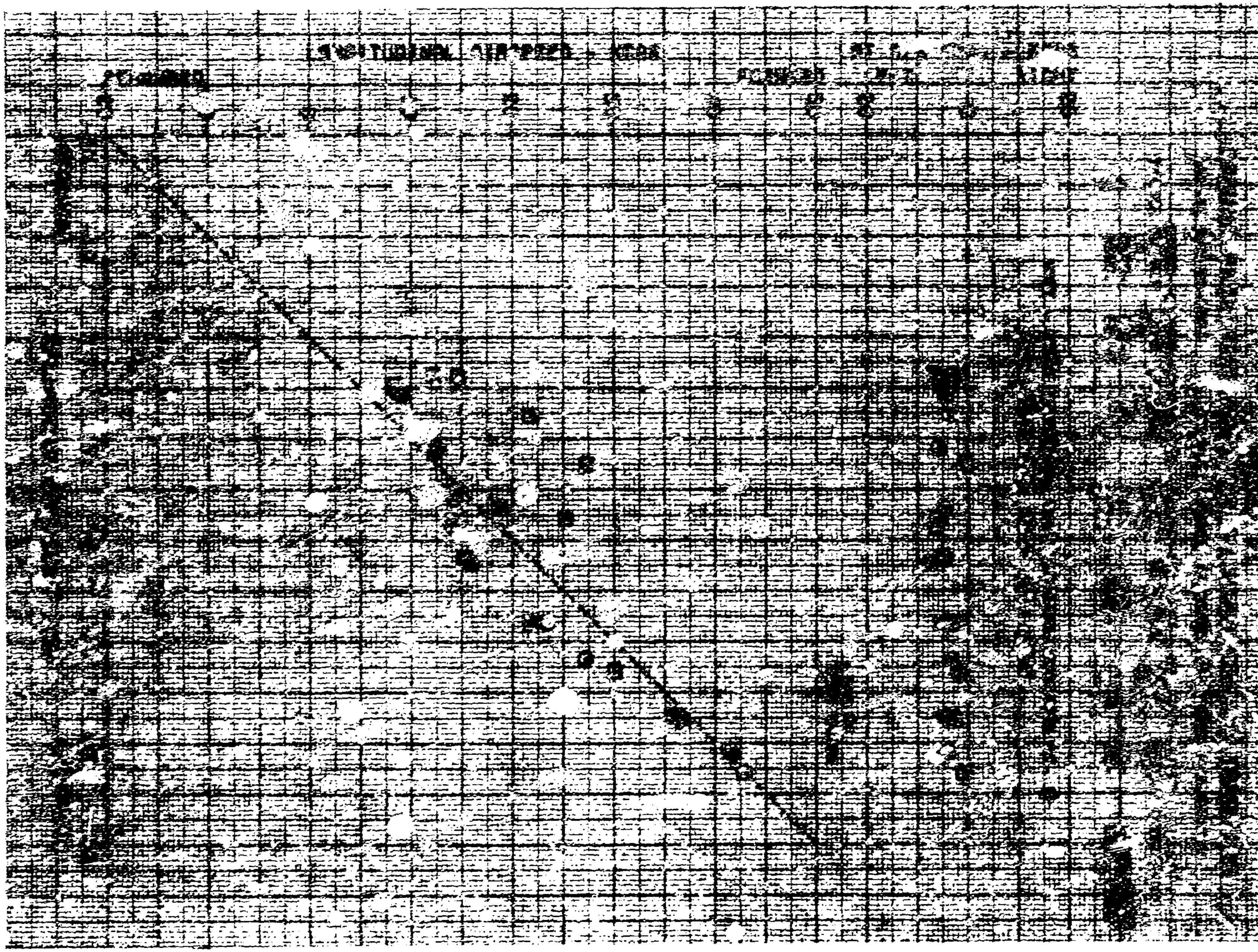


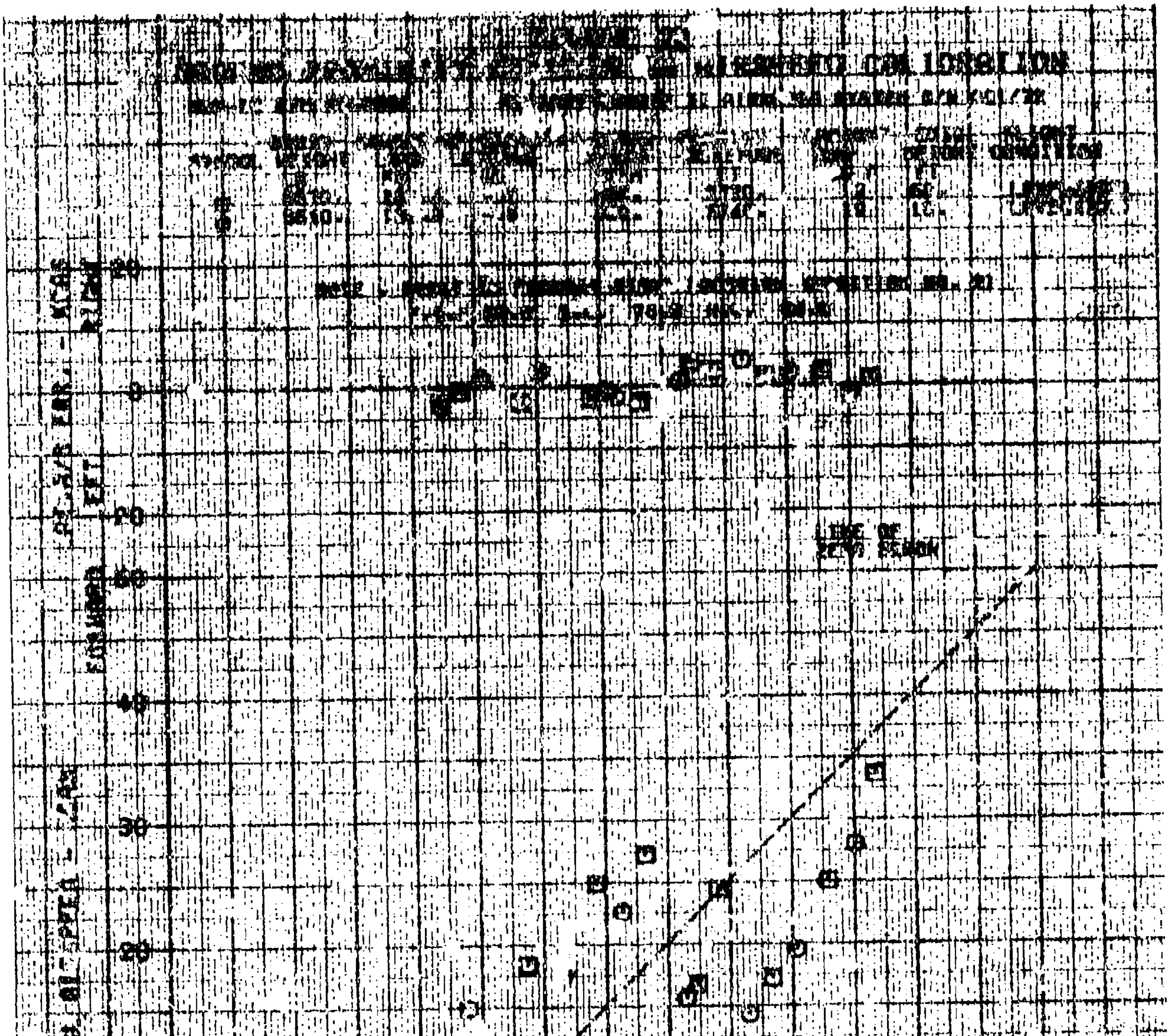
LONGITUDINAL AIRSPEED ERROR - KCAS
CORRECTION TO BE ADDED
FWD
LT
RE

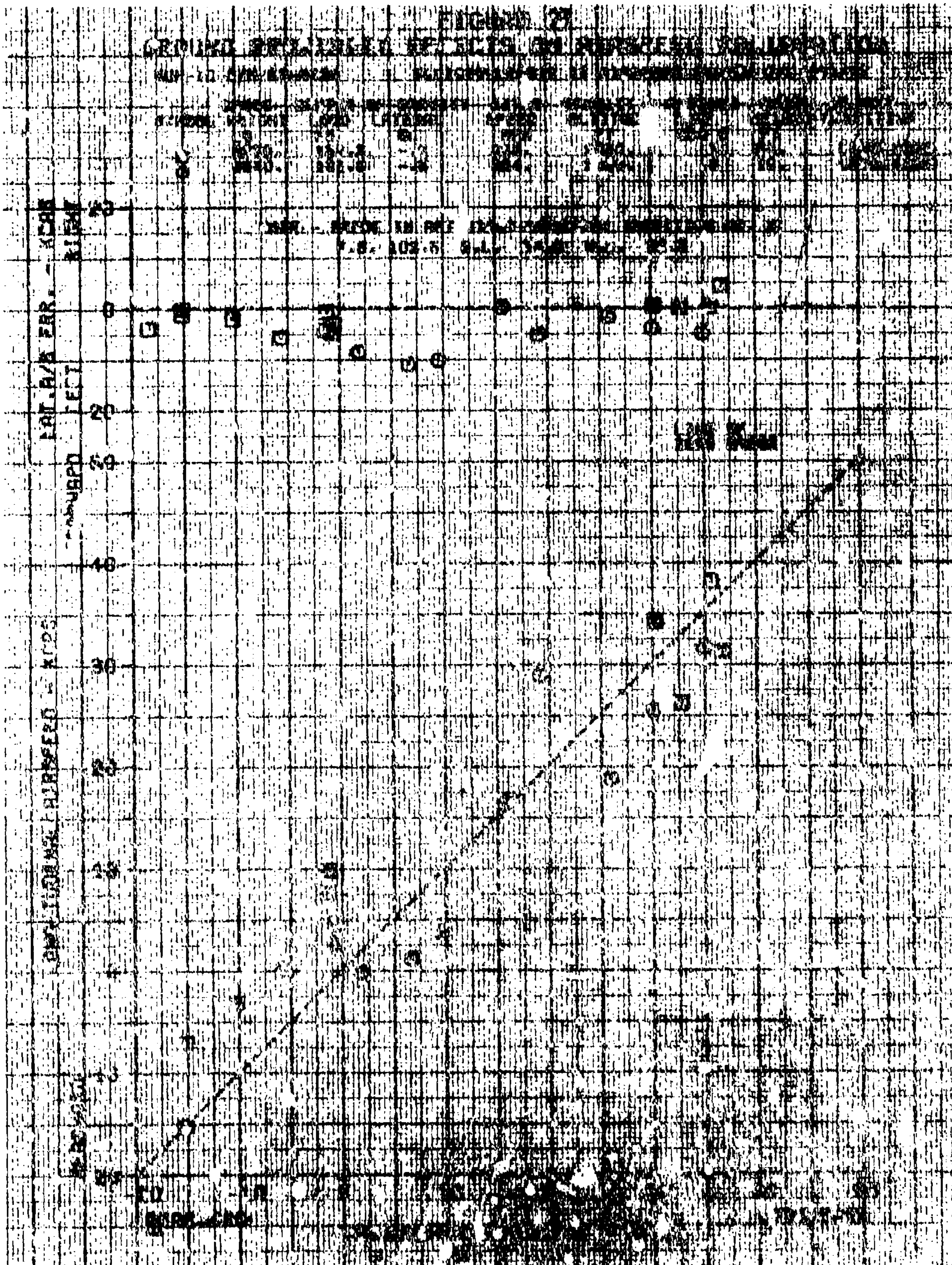
FIGURE 20

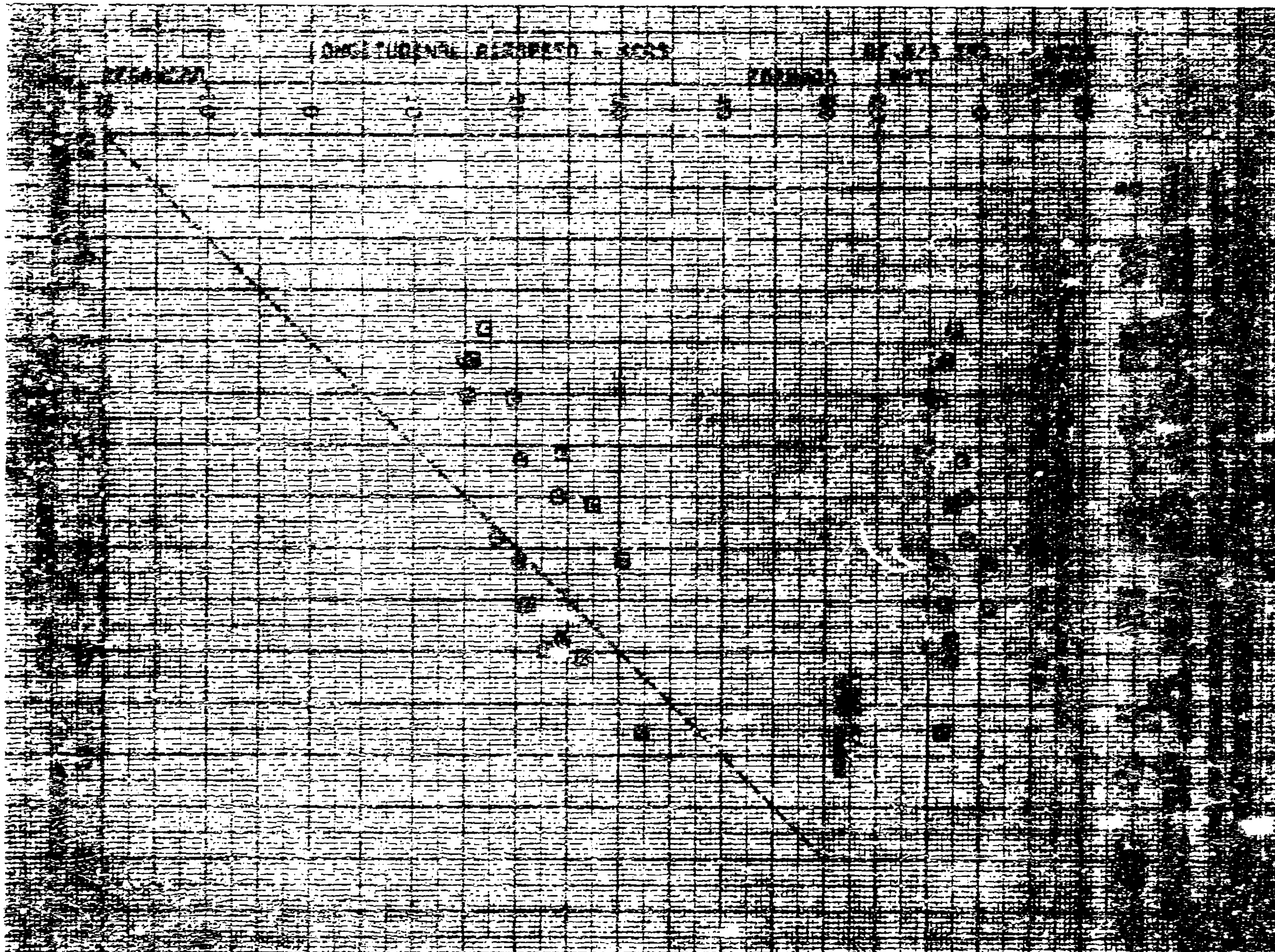
EFFECT OF CLIMB AND DESCENT ON AIRSPEED ERROR

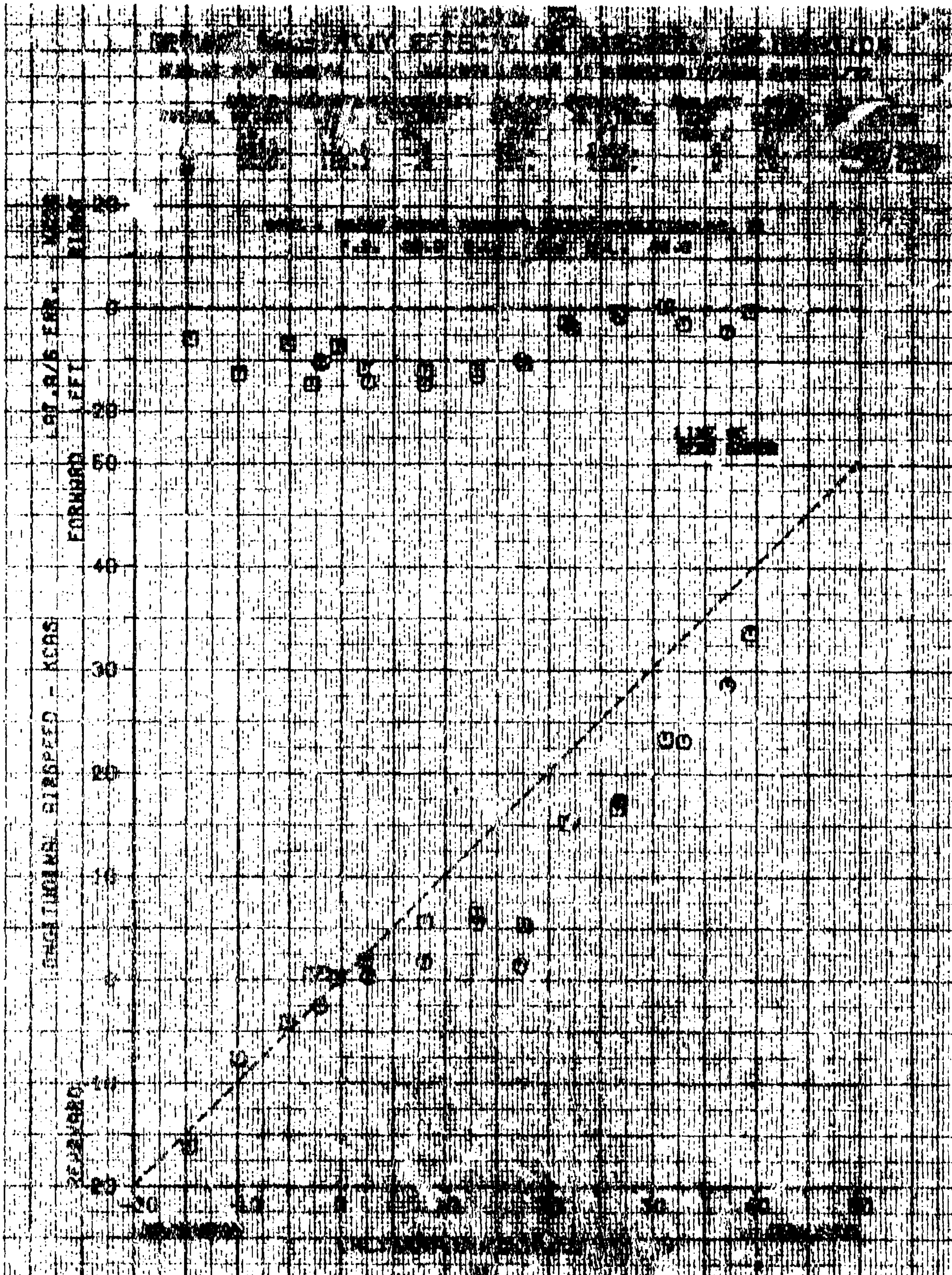


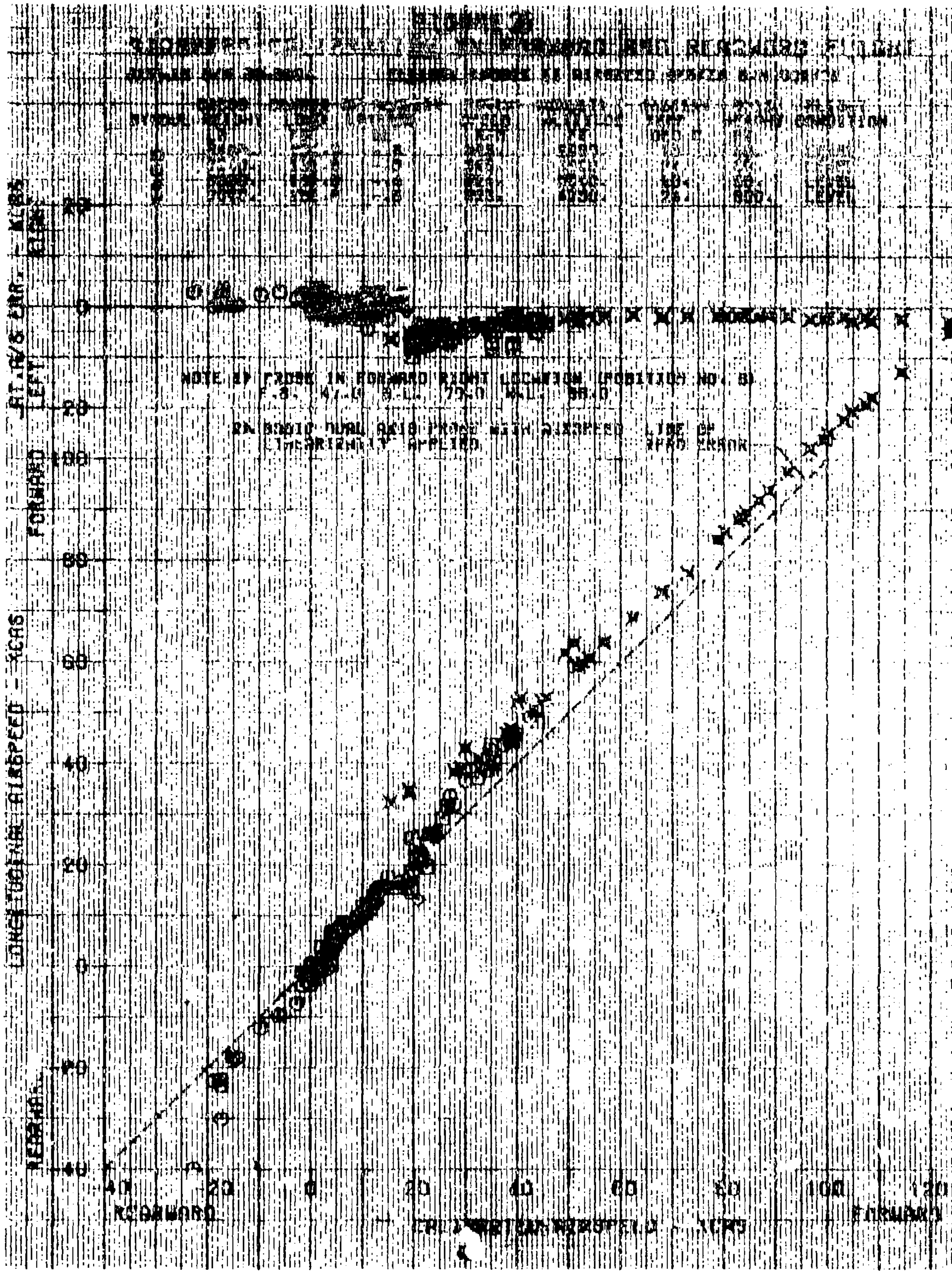

LONGITUDINAL AIRSPEED - KNOTS
FORWARD



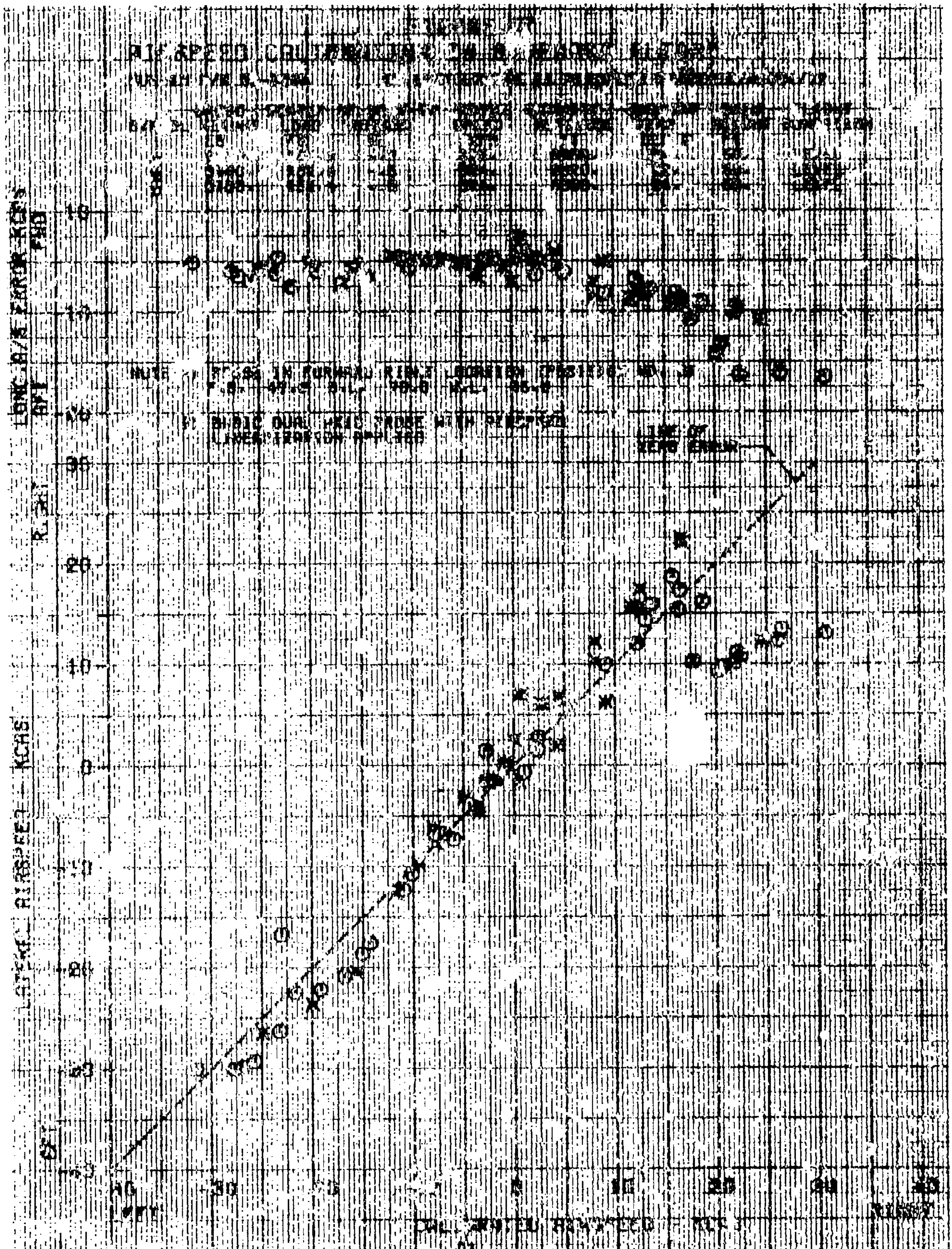


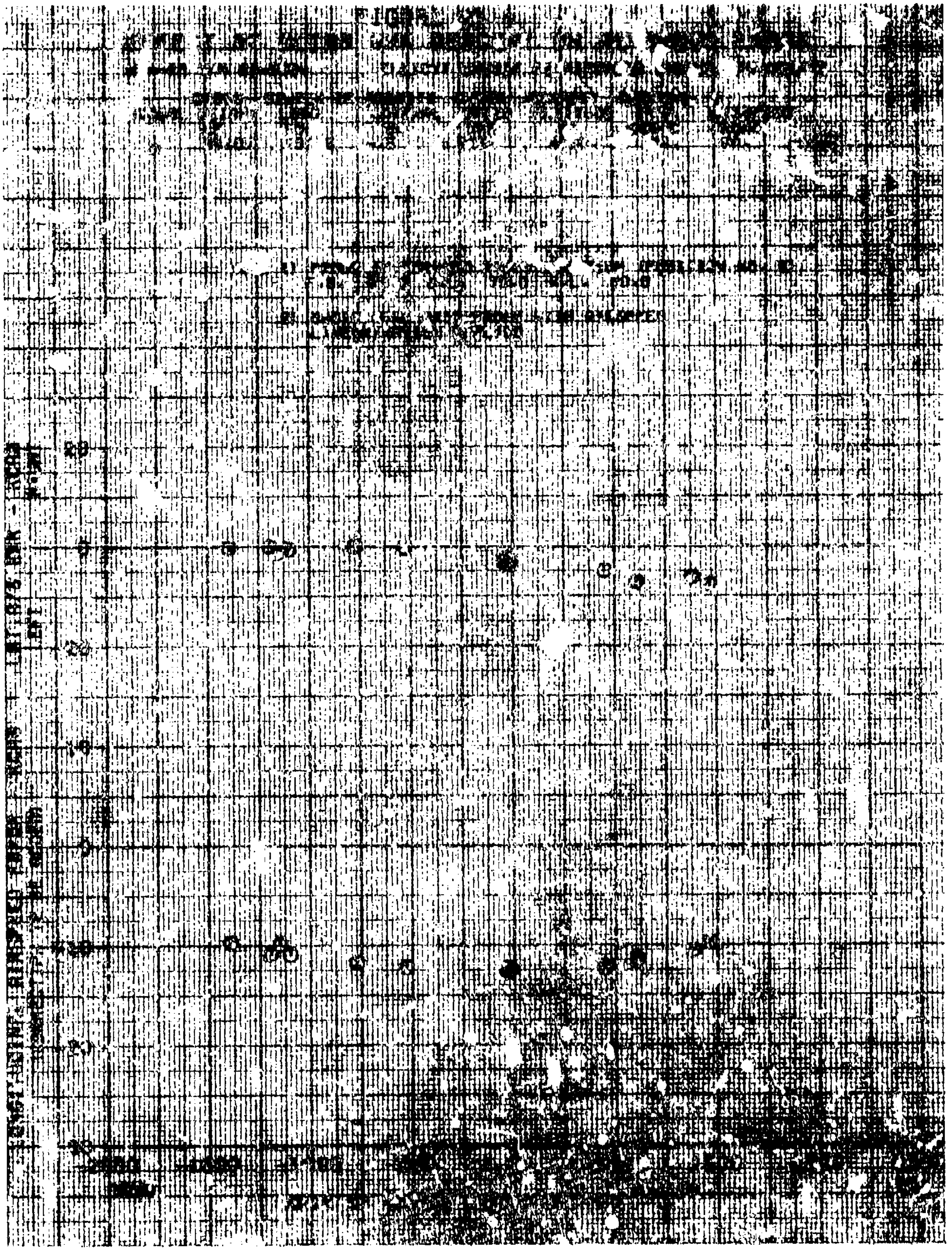


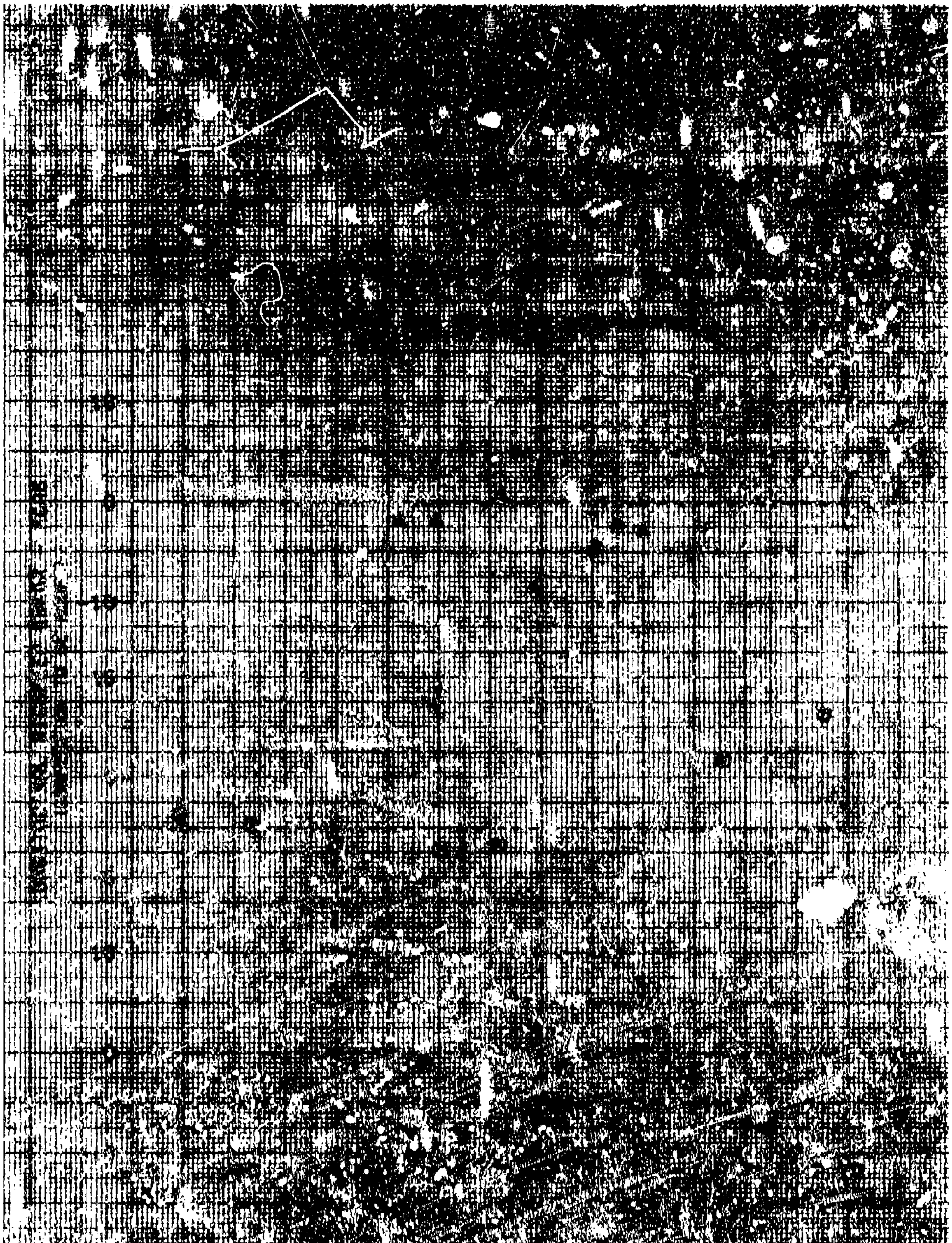


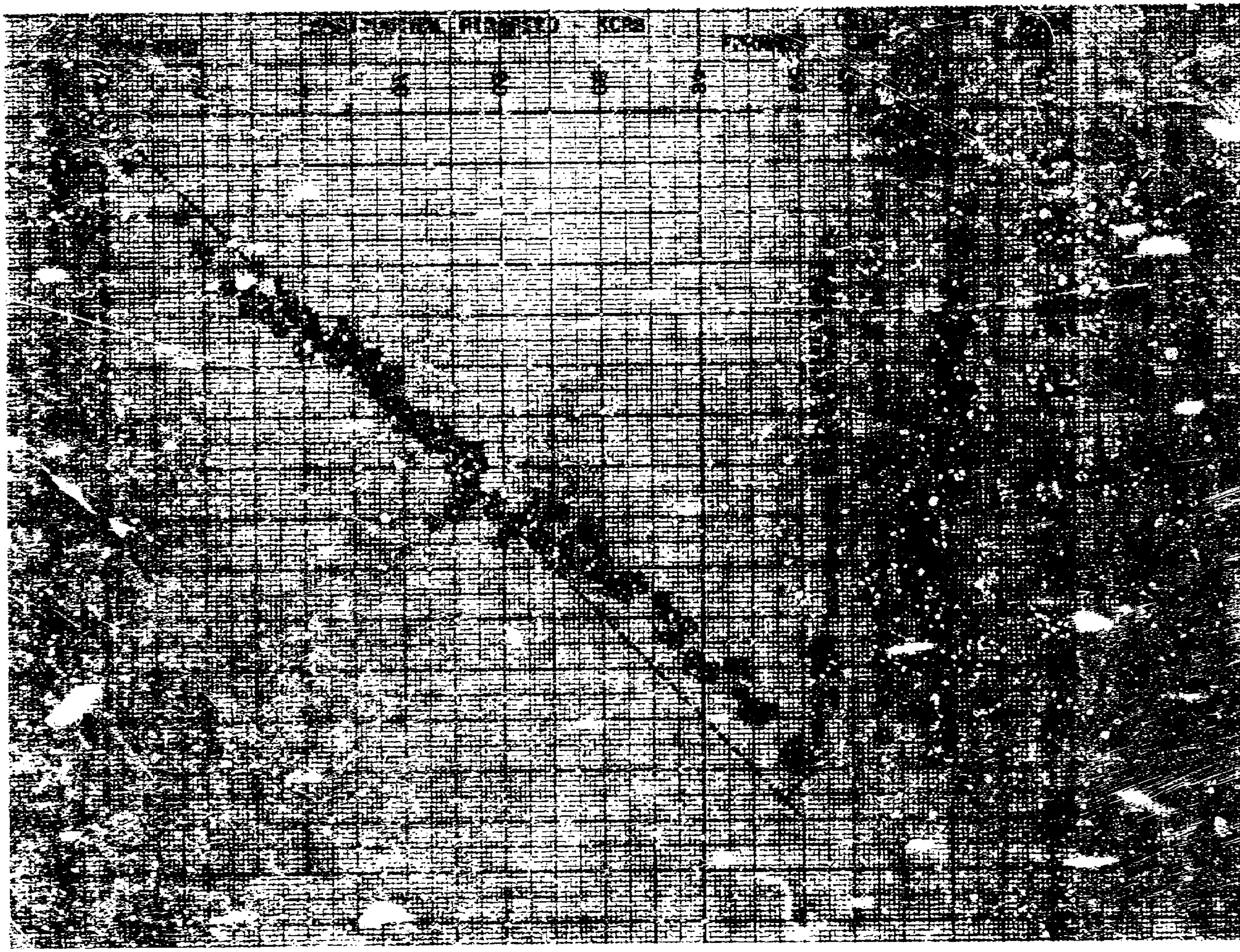


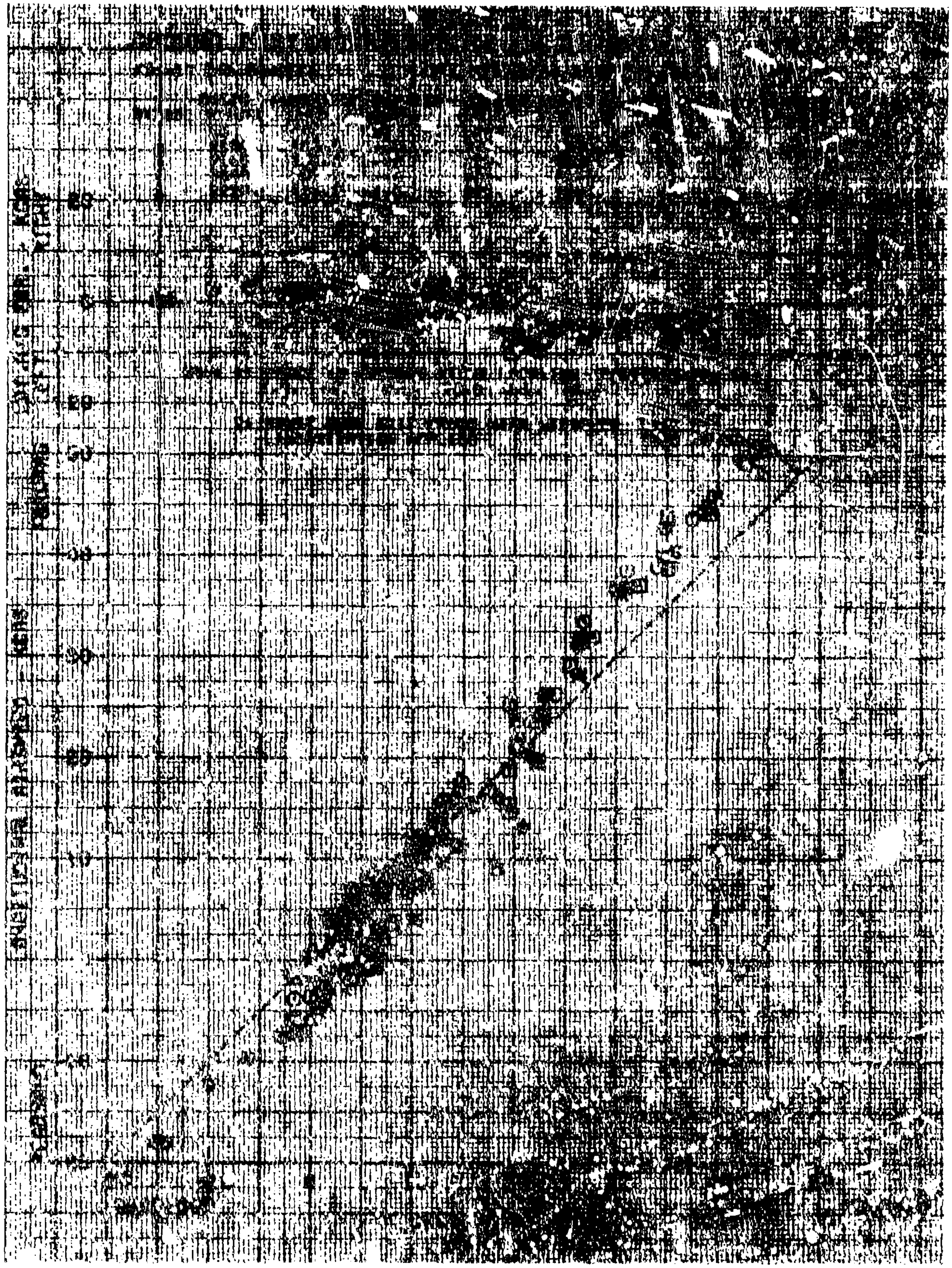
NOTE 1) PROBE IN FORWARD RIGHT LOCATION (POSITION NO. 8)
2) BASIC DUAL AXIS PROBE WITH AIRSPEED LINE OF LINEARITY APPLIED
LONGITUDINAL AIRSPEED - KCAS
FORWARD
LEFT
REARWARD
-40
-20
0
20
40
60
80
100
120
FORWARD

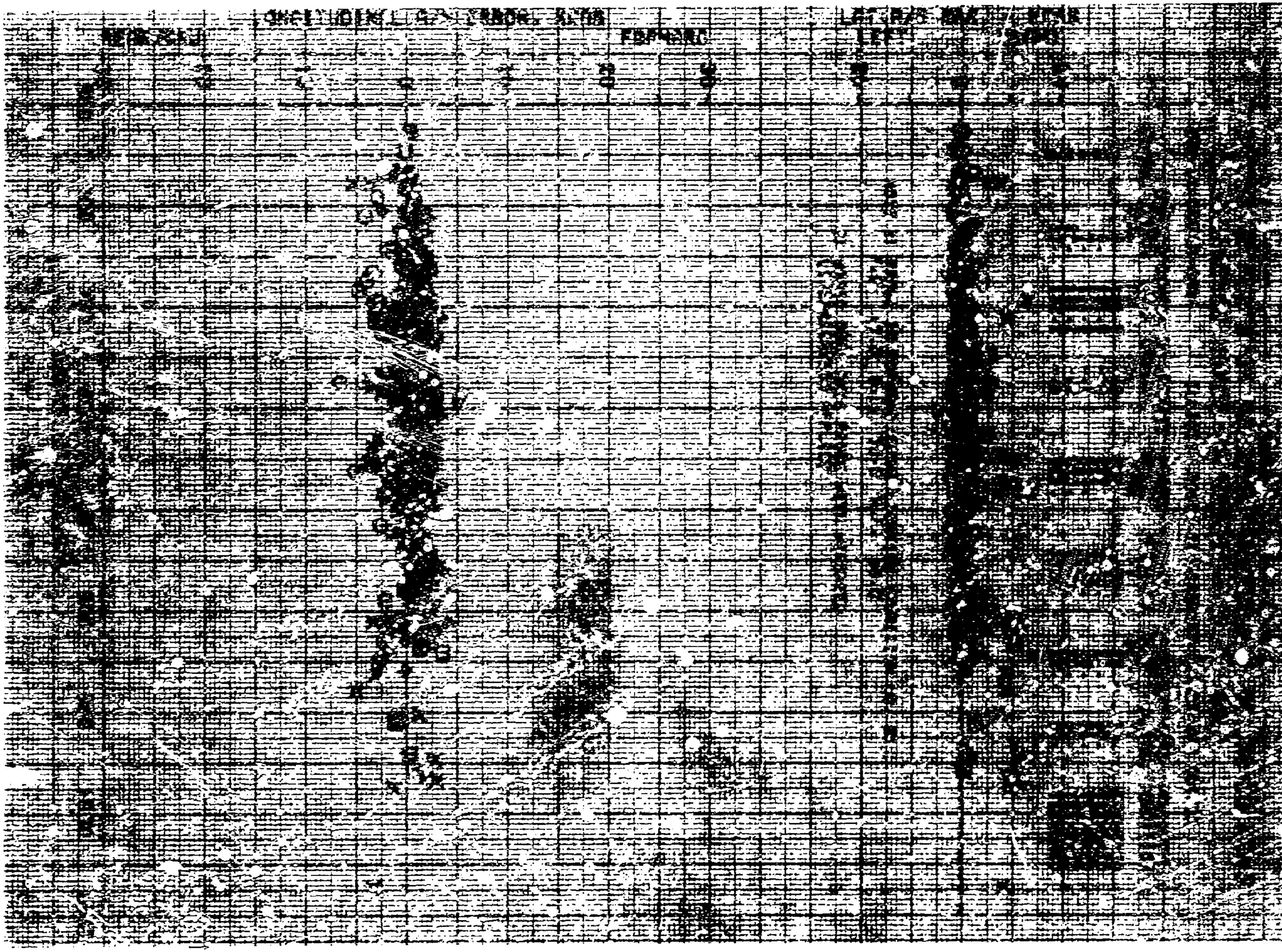

LINE OF ZERO ERROR
LEFT
RIGHT
KCAS

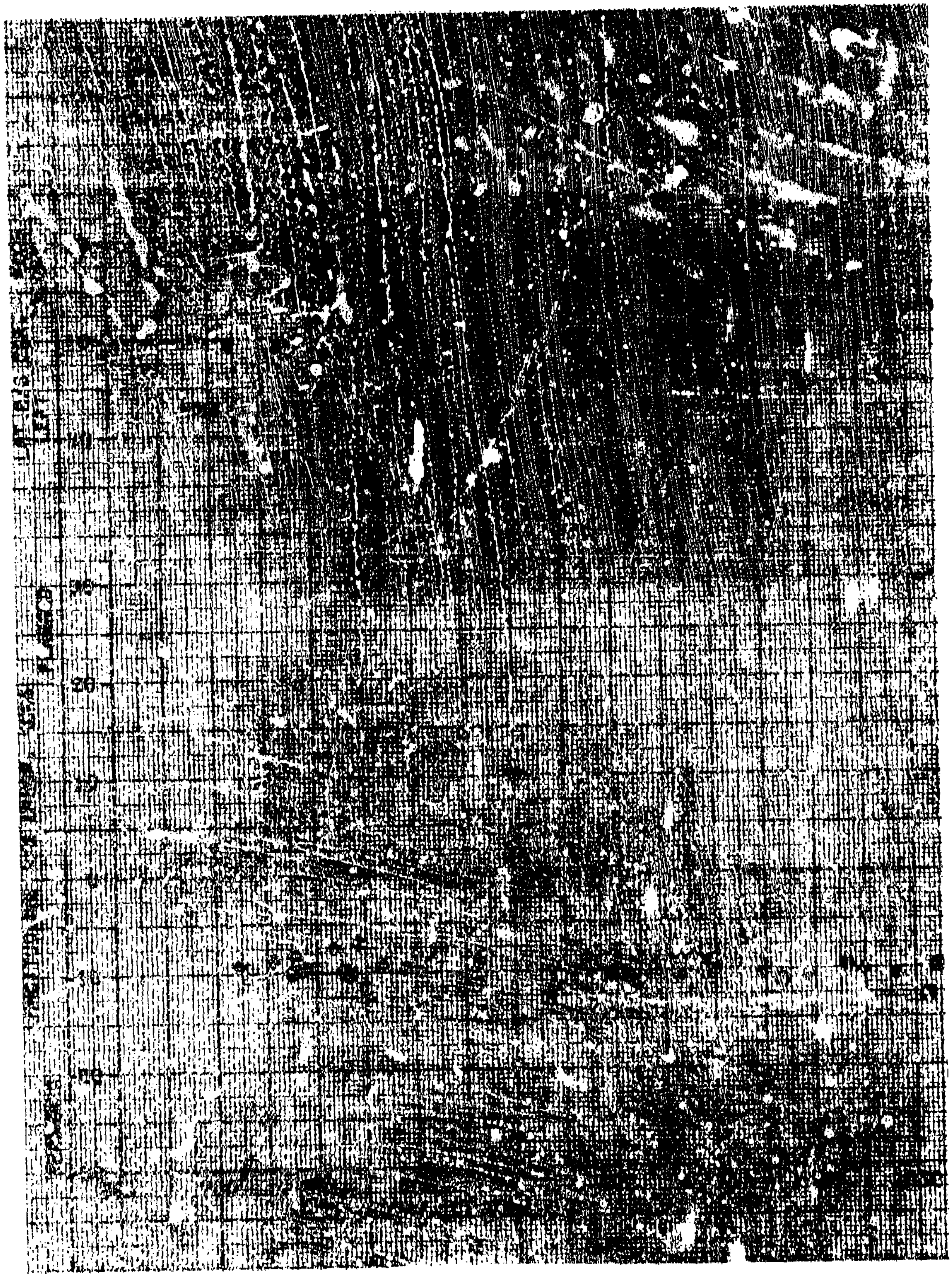


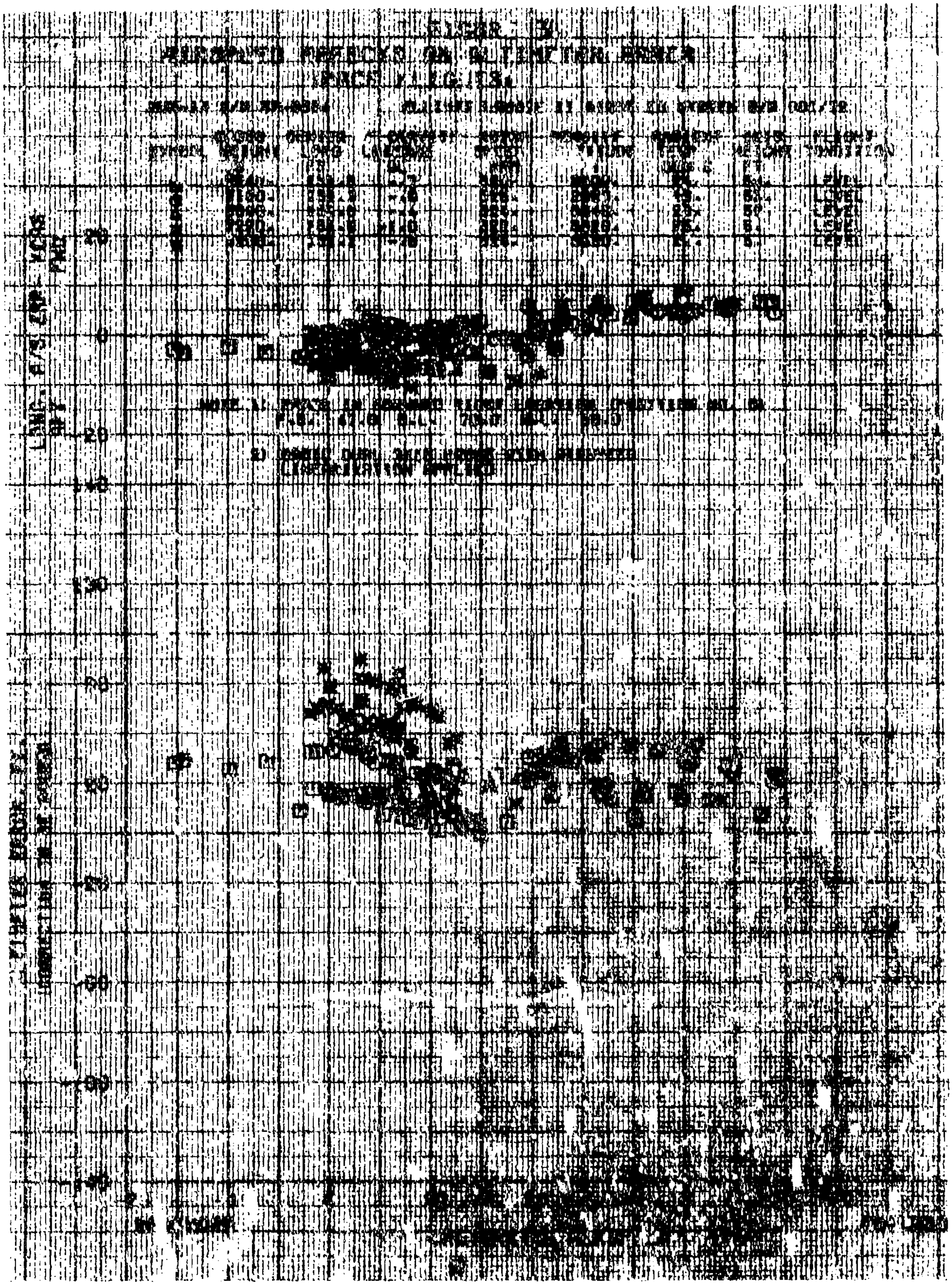


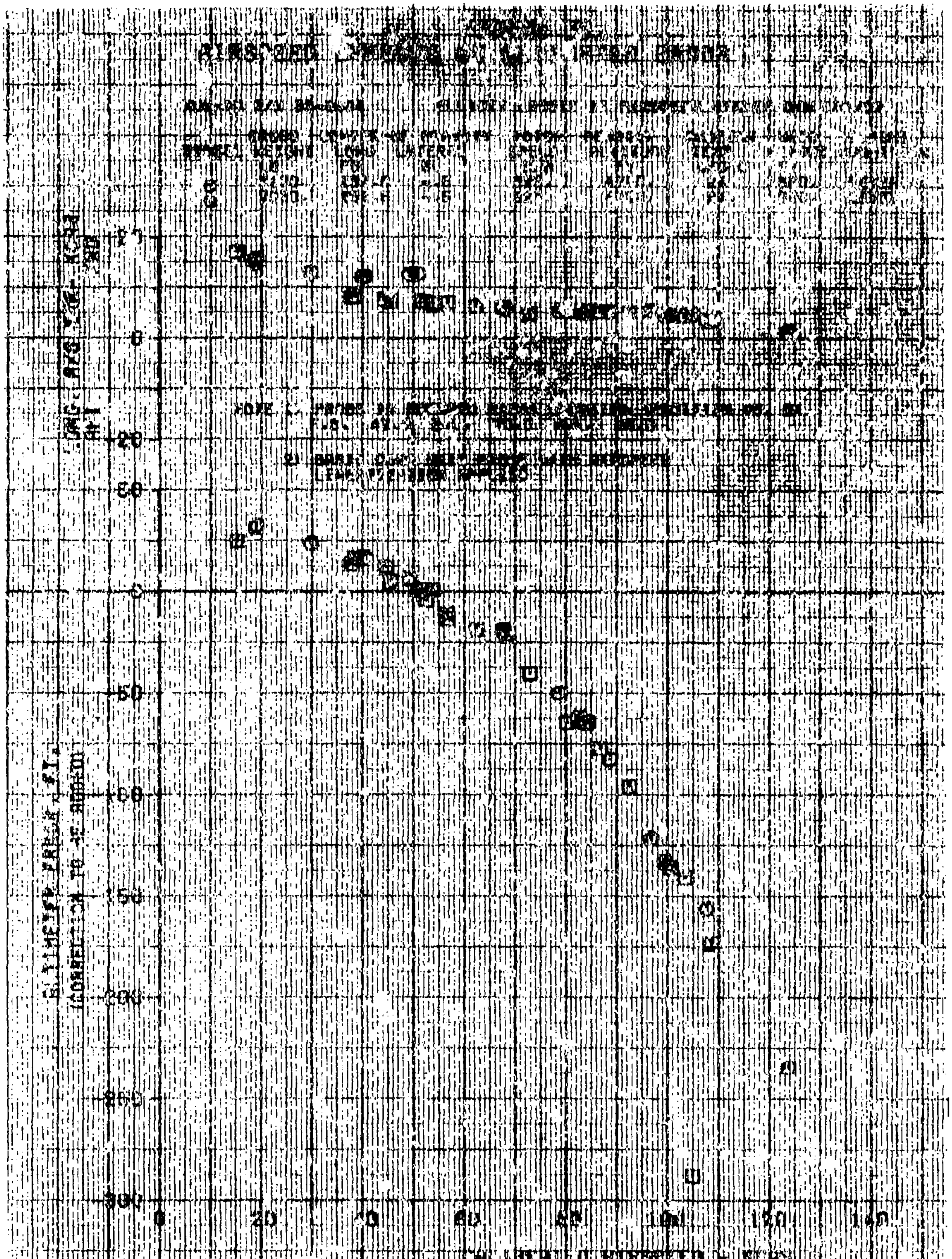












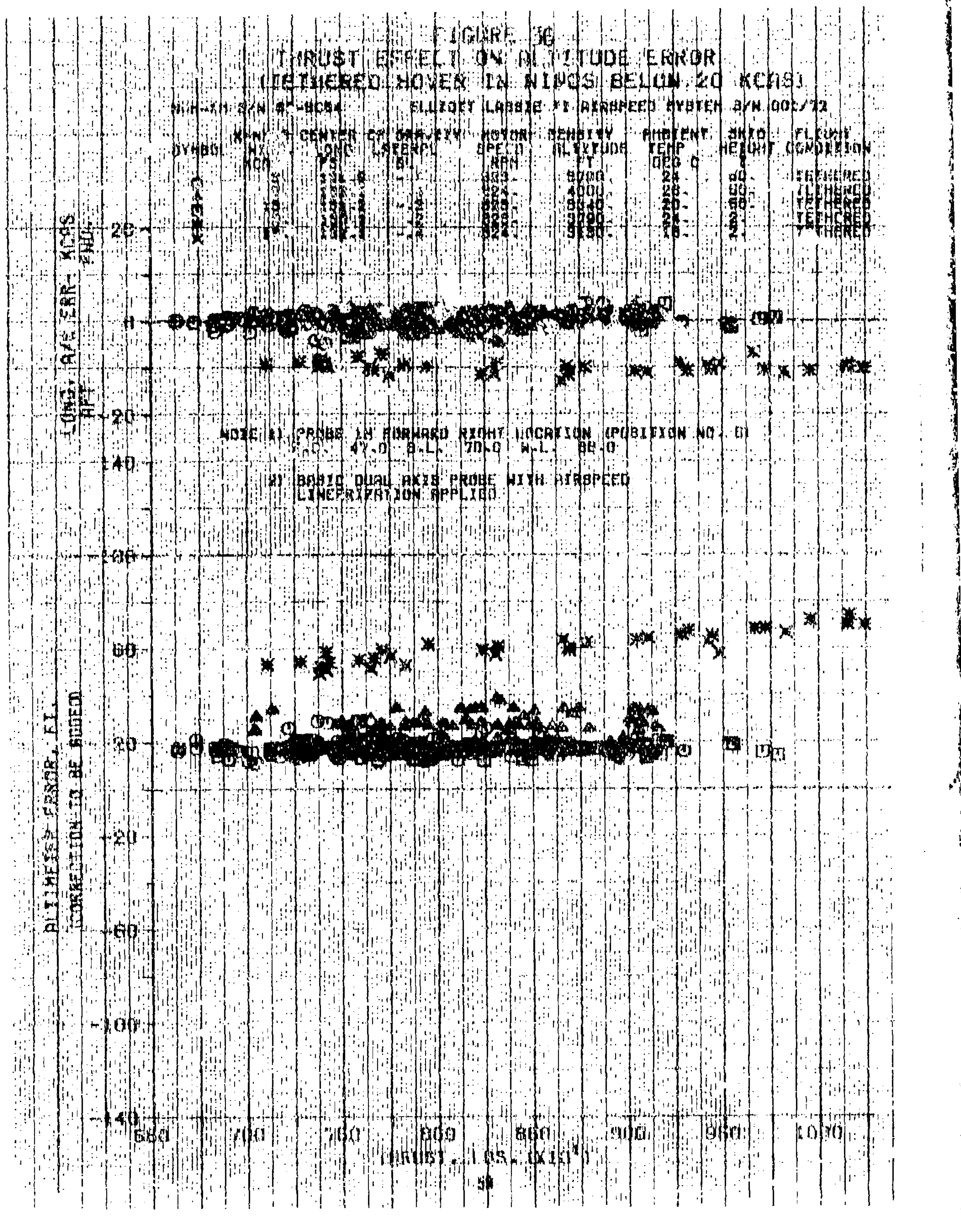
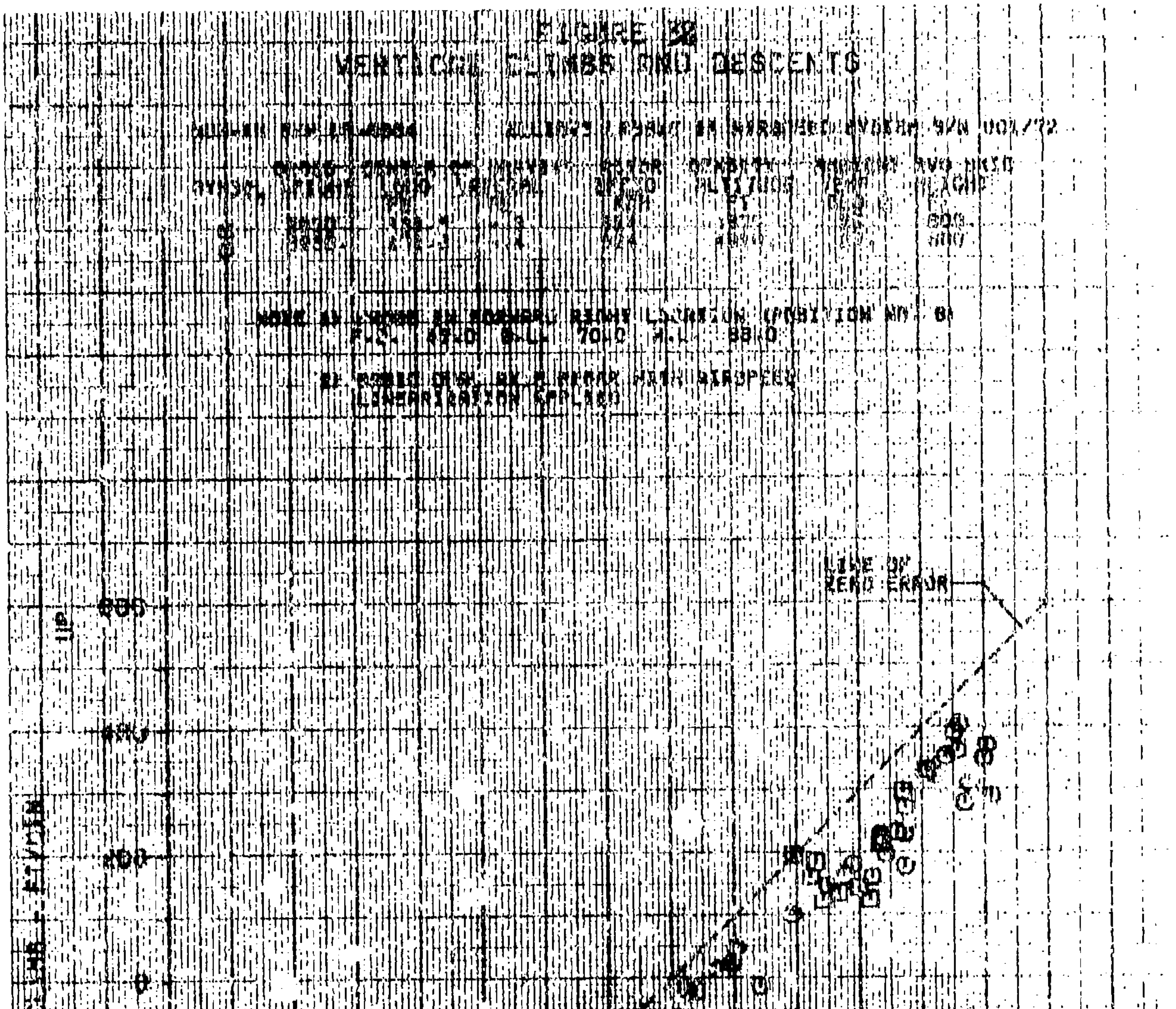
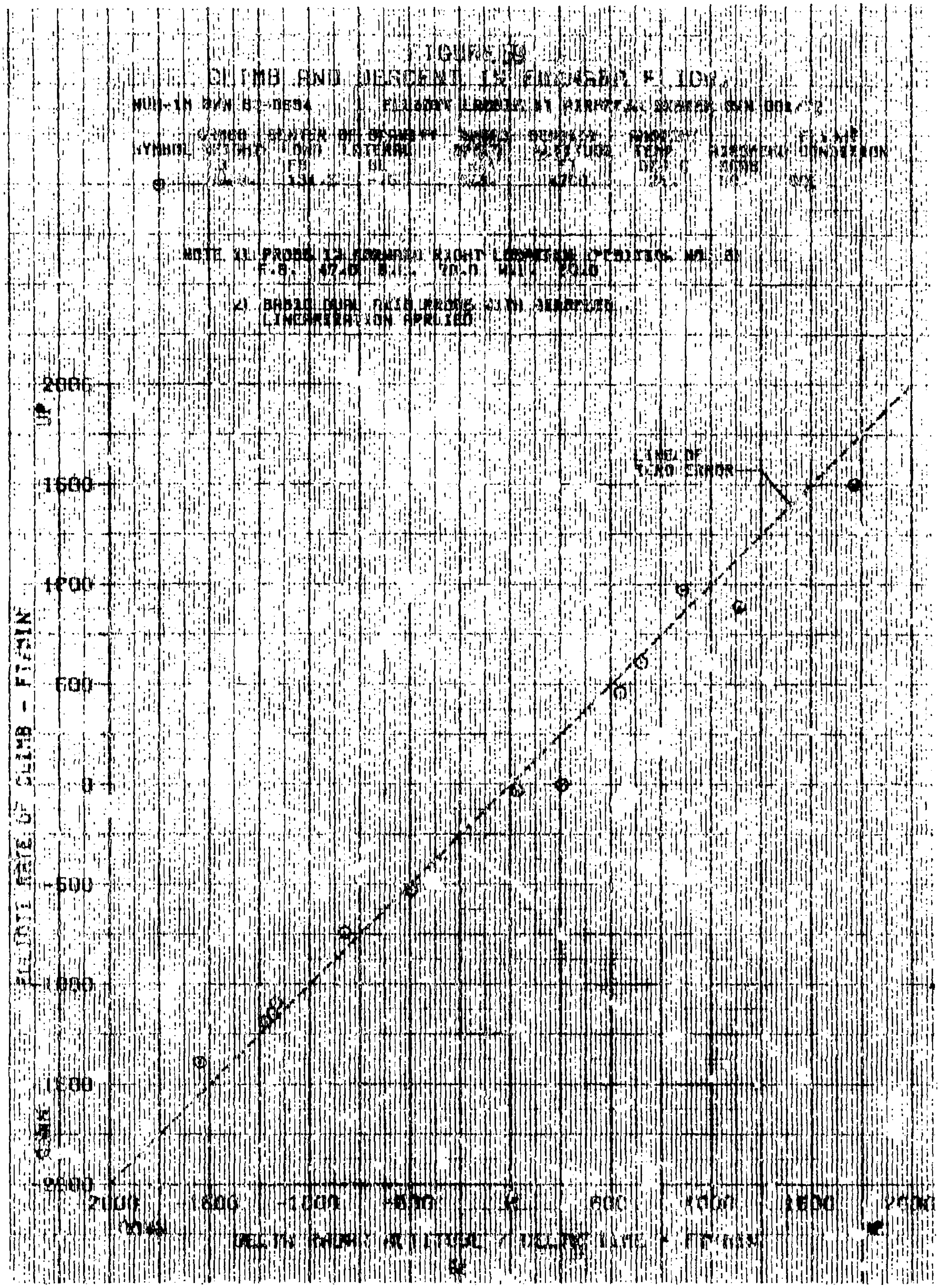


FIGURE 38
THRUST EFFECT ON ALTITUDE ERROR
(TETHERED HOVER IN NIPOS BELOW 20 KCAS)
SYMBOL
CENTER OF GRAVITY
LONG
LATERAL
ROTOR SPEED
RPM
DENSITY ALTITUDE
FT
AMBIENT TEMP
DEG C
SKID HEIGHT
FLIGHT CONDITION
TETHERED
NOTE (1) PROBE IN FORWARD RIGHT LOCATION (POSITION NO. 6)
(2) BASIC DUAL AXIS PROBE WITH AIRSPEED LINEARIZATION APPLIED
THRUST ~ LBS (X10)
ALTIMETER ERROR, FT
700
750
800
850
900
950
1000
20
40
60
100
140


VERTICAL CLIMBS AND DESCENTS
LINE OF ZERO ERROR
RADAR RATE OF CLIMB - FT/MIN
600
400
200
0
200
400
600
800
-400
-200
0
200
600


CLIMB AND DESCENT
NOTE
LINE OF ZERO ERROR
2000
1600
UP

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