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# Heliport MLS Siting Evaluation

Scott B. Shollenberger

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16. Abstract

This report documents a series of tests designed to provide recommended range of locations for a landing pad which would be satisfactory sites for Microwave Landing Systems (MLS) precision heliport approaches during instrument meterological conditions (IMC) for minimally equipped helicopters. The dependent variable for this experiment was deceleration distance and the independent variables were decision height (DH), range rate, and elevation angle. Twenty-eight data flights, using 56 flight hours and eight subject pilots to complete, were conducted at the Federal Aviation Administration (FAA) Technical Center parallel to runway 13/31. The subject pilots were required to fly hooded, inbound 125° or 310° azimuth, through elevation angle capture and DH, to a visual deceleration landing to full stop. Real estate availability was not considered as a constraint in this study. The data show that as the elevation angle to a desired DH is increased, an angle will be reached which requires that the antenna system be moved from a location adjacent to the heliport to a location in front of the heliport. This separation distance increases as a function of increasing elevation angle (i.e., the helicopter must fly past the MLS antenna to reach the heliport). For a given elevation angle, as the DH is decreased, a DH will be reached which requires that the MLS antenna again be moved from a location adjacent to the heliport to locations in front of the heliport. This separation increases in distance as a function of decreasing decision height. In situations where real estate is limited, steeper angle approaches and lower minima could be obtained by increasing the capabilities of the aircraft and/or the crew.

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TABLE OF CONTENTS


| | Page |
|---|---|
| EXECUTIVE SUMMARY | vii |
| 1. OBJECTIVES | 1 |
| 2. BACKGROUND | 1 |
| 2.1 Microwave Landing System | 1 |
| 3. RELATED DOCUMENTS | 2 |
| 4. SYSTEM DESCRIPTION | 2 |
| 5. DATA COLLECTION AND REDUCTION | 3 |
| 6. RESULTS | 7 |
| 7. CONCLUSIONS | 37 |

APPENDICES

A - Accumulated Profiles
B - Deceleration Force (G's)
C - UH-1H Instrument Console and Aicraft Specifications
D - Deceleration Distance, Deceleration Force, and Peak Pitch-Up Angle Data Tables from Figures 4 through 11 Showing Means, Standard Deviations, and Samples that were Plotted
E - Subject Pilot Background Profiles

LIST OF ILLUSTRATIONS


| Figure | | Page |
|---|---|---|
| 1 | Flight Profile | 4 |
| 2 | Flowchart of Profiles for Each Subject Pilot | 5 |
| 3 | Top view of Course Profile Showing Ground Theodolite Angle Measurement | 6 |
| 4 | Deceleration Distance (ft), Beyond the Collocated MLS Antenna System for All Decision Heights as a Function of Elevation Angle for 90 Knots | 14 |
| 5 | Deceleration Distance (ft), Beyond the Collocated MLS Antenna System for All Decision Heights as a Function of Elevation Angle for 60 Knots | 15 |
| 6 | Deceleration Distance (ft), Beyond the Collocated MLS Antenna System for All Elevation Angles as a Function of Decision Height for 90 Knots | 16 |
| 7 | Deceleration Distance (ft), Beyond the Collocated MLS Antenna System for all Elevation Angles as a Function of Decision Height for 60 Knots | 17 |
| 8 | Peak Pitch-Up Angle (deg) and Peak Deceleration Force (G's) for All Decision Heights as a Function of Elevation Angle for 90 Knots Range Rate | 18 |
| 9 | Peak Pitch-Up Angle (deg) and Peak Deceleration Force (G's) for All Decision Heights as a Function of Elevation Angle for 60 Knots Range Rate | 19 |
| 10 | Peak Pitch-Up Angle (deg) and Peak Deceleration Force (G's) for All Elevation Angles as a Function of Decision Height for 90 Knots Range Rate | 20 |
| 11 | Peak Pitch-Up Angle (deg) and Peak Deceleration Force (G's) for All Elevation Angles as a Function of Decision Height for 60 Knots Range Rate | 21 |
| 12 | Maximum Descent Elevation Angle (deg) as a Function of Decision Height for 90-and 60-Knot Range Rates | 25 |
| 13 | Mean Deceleration Distance Beyond the Collocated Antenna System and Second Order Curve Fit for 50' DH, 90 Knots | 26 |
| 14 | Mean Deceleration Distance Beyond the Collocated Antenna System and Second Order Curve Fit for 100' DH, 90 Knots | 27 |
| 15 | Mean Deceleration Distance Beyond the Collocated Antenna System and Second Order Curve Fit for 150' DH, 90 Knots | 28 |

LIST OF ILLUSTRATIONS (Continued)


| | | Page |
|---|---|---|
| 16 | Mean Deceleration Distance Beyond the Collocated Antenna System and Second Order Curve Fit for 200' DH, 90 Knots | 29 |
| 17 | Mean Deceleration Distance Beyond the Collocated Antenna System and Second Order Curve Fit for 50' DH, 60 Knots | 30 |
| 18 | Mean Deceleration Distance Beyond the Collocated Antenna System and Second Order Curve Fit for 100' DH, 60 Knots | 31 |
| 19 | Mean Deceleration Distance Beyond the Collocated Antenna System and Second Order Curve Fit for 150' DH, 60 Knots | 32 |
| 20 | Mean Deceleration Distance Beyond the Collocated Antenna System and Second Order Curve Fit for 200' DH, 60 Knots | 33 |
| 21 | Distance (ft) Beyond Collocated Antenna System to Touchdown for 90 Knot Approaches | 35 |
| 22 | Distance (ft) Beyond Collocated Antenna System to Touchdown for 60 Knot Approaches | 36 |
| 23 | Recommended Range of Locations at or in Front of the Landing Pad for the Collocated MLS Antenna System as a Function of Elevation Angle and Decision Height for 90-Knot Range Rate Approaches | 38 |
| 24 | Recommended Range of Locations at or in Front of the Landing Pad for the Collocated MLS Antenna System as a Function of Elevation Angle and Decision Height for 60-Knot Range Rate Approaches. | 39 |

## LIST OF TABLES


| Table | | Page |
|---|---|---|
| 1 | Data Collection Flights for the Eight Subject Pilots | 8 |
| 2 | 90-Knot Range Rate Deceleration Distance Data | 9 |
| 3 | 60-Knot Range Rate Deceleration Distance Data | 10 |
| 4 | 90-Knot Range Rate Deceleration Distance (ft) Beyond Collocated MLS Antenna System | 11 |
| 5 | 60-Knot Range Rate Deceleration Distance (ft) Beyond Collocated MLS Antenna System | 12 |
| 6 | Maximum Peak Deceleration Force (G's) for All Decision Heights and Elevation Angles | 22 |
| 7 | Maximum Descent Elevation Angle Data | 24 |
| 8 | Visual Approach Data | 24 |
| 9 | Second Order Curve Fit Equations | 34 |

## EXECUTIVE SUMMARY

This report documents a series of tests designed to provide a recommended range of locations for a landing pad which would be satisfactory sites for collocated Microwave Landing Systems (MLS) precision heliport approaches during instrument meterological conditions (IMC) for minimally equipped helicopters. Twenty-eight data flights, using 56 flight hours and eight subject pilots to complete, were conducted at the Federal Aviation Administration (FAA) Technical Center. The subject pilots were required to fly hooded the inbound headings, parallel to runway 13/31, through elevation angle capture and decision height (DH), to a visual deceleration landing to full stop. The results show that as the elevation angle to a desired DH is increased, an angle will be reached which requires that the antenna system be moved from a location adjacent to the heliport to a location in front of the heliport to allow enough deceleration distance. For a given elevation angle, as the DH is decreased, a DH will be reached which requires that the MLS antenna be moved from a location adjacent to the heliport to locations in front of the heliport. This separation distance increases as a function of decreasing DH. Plots are displayed to aid in siting collocated antenna systems.

## 1. OBJECTIVES.

This series of tests are designed to provide a recommended range of locations for a landing pad which would be satisfactory sites for Microwave Landing Systems (MLS's) precision heliport approaches during instrument meterological conditions (IMC) for minimally equipped helicopters. The dependent variable for this experiment was deceleration distance and the independent variables were decision height (DH), range rate, and elevation angle. The specific objective of this test program was to determine the relationship between MLS site locations and the approach angles (DH's), and deceleration rates between the DH fix and the helipad.

## 2. BACKGROUND.

The Helicopter MLS Siting Evaluation Test Program is being conducted as a joint program between the Federal Aviation Administration (FAA) Technical Center, Atlantic City Airport, New Jersey, and the U.S. Army Avionics Research and Develoment Activity (AVRADA), Fort Monmouth, New Jersey, through Interagency Agreement DTFA 01-80-Y-10530. This agreement was initiated to provide a joint FAA/AVRADA effort to collect data as a basis for developing and updating criteria standards and procedures directed at the safe and efficient operation of helicopters within the National Airspace System (NAS).

Helicopter activities in the United States have been growing noticeably in the past few years. This trend is expected to continue for the foreseeable future. To operate in the most productive and efficient manner possible, helicopter regulations, standards, procedures, and navigation systems must be reviewed for possible modification. When necessary, new ones must be developed that specifically include helicopter operation capability. The FAA has undertaken this effort to develop criteria and procedures pertaining to the use of MLS for helicopter operations. In the context of this test program the MLS angle guidance system is designed to provide the pilot with the required radio signal to accurately navigate to a defined DH toward the helipad at a constant velocity or airspeed. Upon reaching the DH, the pilot either proceeds to the helipad under visual conditions and lands, or he executes a missed approach (MA). Ideally, the helipad should be directly ahead of the pilot at DH and at a suitable distance that allows the pilot enough time to decelerate the aircraft to a landing. If the helipad is not directly ahead, a change of direction is required to reach the landing pad. If a special volume can be defined to include all acceptable points from which to begin the visual approach segment, the acceptable MLS site may be defined given the required obstruction clearance plane and obstruction free zones. Heliports are usually located in areas where land space is limited. This limitation becomes a critical factor when selecting a suitable MLS site within this space, however, real estate availability was not considered as a constraint in this siting study.

### 2.1 MICROWAVE LANDING SYSTEM

The C-band Time Reference Scanning Beam (TRSB) MLS with the L-band Distance Measuring Equipment/Precision (DME/P) was developed to provide a standardized

approach and landing system (for both civilian and military use) improved performance over existing navigation/approach aids, and more flexibility in field implementation over the standard ultra high frequency (UHF)/very high frequency (VHF) instrument landing system (ILS). It has been adopted by the International Civilian Aviation Organization (ICAO) as a future international standard and will eventually replace the instrument landing system.

MLS approach and landing navigation information are aircraft derived, based on reception and processing of ground transmitted signals. Elevation and azimuth signals in the 5030-5090 megahertz (MHz) (C-band) range can be combined with DME/P to provide precision landing approach guidance within a wide volume of airspace (azimuth of up to $\pm 60°$ from runway centerline and from 1° to 15° in elevation). The signal format and system flexibility lends itself to a variety of implementation forms ranging from the basic MLS consisting of approach azimuth, approach elevation, basic data, and DME functions, to the total ground system consisting of the basic system, flare elevation, back azimuth, auxiliary data on data channel, and range (ICAO Circular 165-AN/104).

## 3. RELATED DOCUMENTS

a. Helicopter Operations Development Plan, Report No. FAA-RD-78-01 September 1978.

b. Terminal Instrument Procedures Handbook No. 8260.33, July 1976.

c. NASA/FAA Flight Test Investigation of Helicopter Microwave Landing System Approaches, Reprint No. 80-55, American Helicopter Society, 1980.

d. FAA Technical Center Program 04-150, Evaluation of MLS for IFR Helicopter Operations, 1983.

e. Rationale for Siting Heliport MLS Transmitter, PTN-001-80, July 16, 1980.

f. ICAO Circular 165-AN/104, 1981.

g. Advances in Decelerating Steep Approach and Landings for Helicopter Instrument Approaches, Presented at the 35th Annual National Forum of the American Helicopter Society, Reprint No. 79-16, May 1979.

## 4. SYSTEM DESCRIPTION.

A non-TRSB MLS was used for the MLS siting flight tests. It is a military tactical MLS weighing 70 pounds which can be setup and made operational within 5 minutes. This non-TRSB MLS was selected because a 24-volt battery operation and single mainframe collocated azimuth and elevation antennas makes breakdown and setup convenient enough to be performed during outbound flight (a portable TRSB MLS is still in the development process). It was developed by the AIL Division of Eaton Corporation for the U.S. Army Avionics R&D Activity. It operates within a frequency range of 15.4 to 15.7 gigahertz (GHz) (Ku band) and employs the pulse coded scanning beam technique. The MLS, including avionics, consists of two principal components:

a. AN/TRQ - 36 Ground Unit consisting of:

1. Azimuth Transmitter - provides lateral signal guidance of ±30° from the 0° reference radial.

2. Elevation Transmitter - provides vertical signal guidance from 0° up to 20° (as influenced by line-of-sight).

3. Precision Distance Measurement Equipment - provides precision DME guidance of ±50 feet (1-sigma contractor's specification), within a coverage of 0° to 20° elevation and ±30° from the 0° azimuth reference radial.

b. AN/ARQ-31 Airborne Receiver/DME Transmitter - processes the MLS ground signal and drives the helicopter's navigation displays and flight director system.

## 5. DATA COLLECTION AND REDUCTION.

Data Collection for the first phase of the MLS siting project was begun in January 1982 and completed in April. There were 28 data flights, using 56 flight hours and eight subject pilots to complete. The Army's Bell UH-1H helicopter, tail number 16344, was used as the test bed vehicle under the AVARADA and FAA interagency agreement. There were eight subject pilots, four from the FAA and four from the Army Electronics Research and Development Common Flight Test (EFTA) Activity, Lakehurst Naval Air Engineering Center (NAEC).

The flight profile used for this project is shown in figure 1. Range rate will be flown as pilot commands must be based on ground speed to land at zero forward velocity. The range rates of 90 and 60 knots were chosen to conform with the upper airspeed limit defined in the Terminal Instrument Procedures Manual (TERPS) and the average minimum instrument flight rules (IFR) airspeed, respectively. As per the test plan, subjects were started at 90 knots with a 3° elevation angle to a 50-foot DH. The elevation angles are increased in 1° increments until a practical limit (pilot's subjective analysis) was attained. At that point, the range rate was decreased to 60 knots and the limiting elevation angle from the 90 knot approaches decreased by 1° or 2°. The subject then flew until attaining a 60-knot limiting elevation angle. After the 50-foot DH elevation angle limit was reached, the DH was increased 50 feet and range rate increased again to 90 knots. For the new DH, the elevation angle started 1° or 2° less than the previous 90-knot DH limiting angle. See figure 2 for a flowchart depicting the profile flight strategy.

The subject pilots were required to fly hooded, the inbound 125° or 310° azimuth (wind direction dictating course direction), through elevation angle capture and DH, to a visual deceleration landing to full stop. The safety/project pilot performed outbound flight, course setup, handled radio communication workload, and annunciated "100 feet above," "50 feet above," and "DH visual to landing" warnings to the subject pilot. Once on the ground, the deceleration distance from the MLS transmitter was measured using a ground station portable theodolite. The measurement was made as shown in figure 3. After having performed each hooded instrument approach, each subject pilot was asked to rate the approach as to its safety, practicality, and other subjective

FIGURE 1 FLIGHT PROFILE

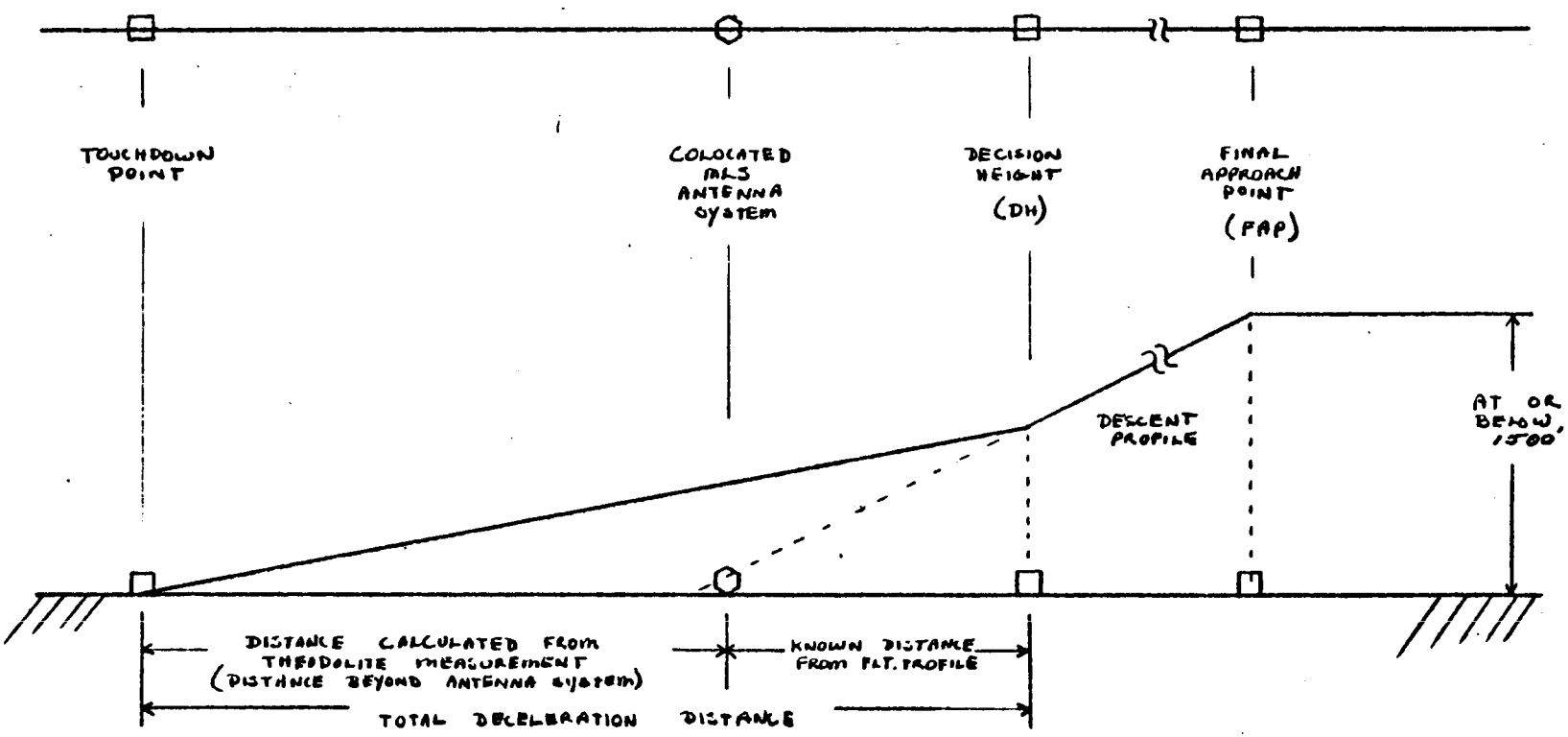
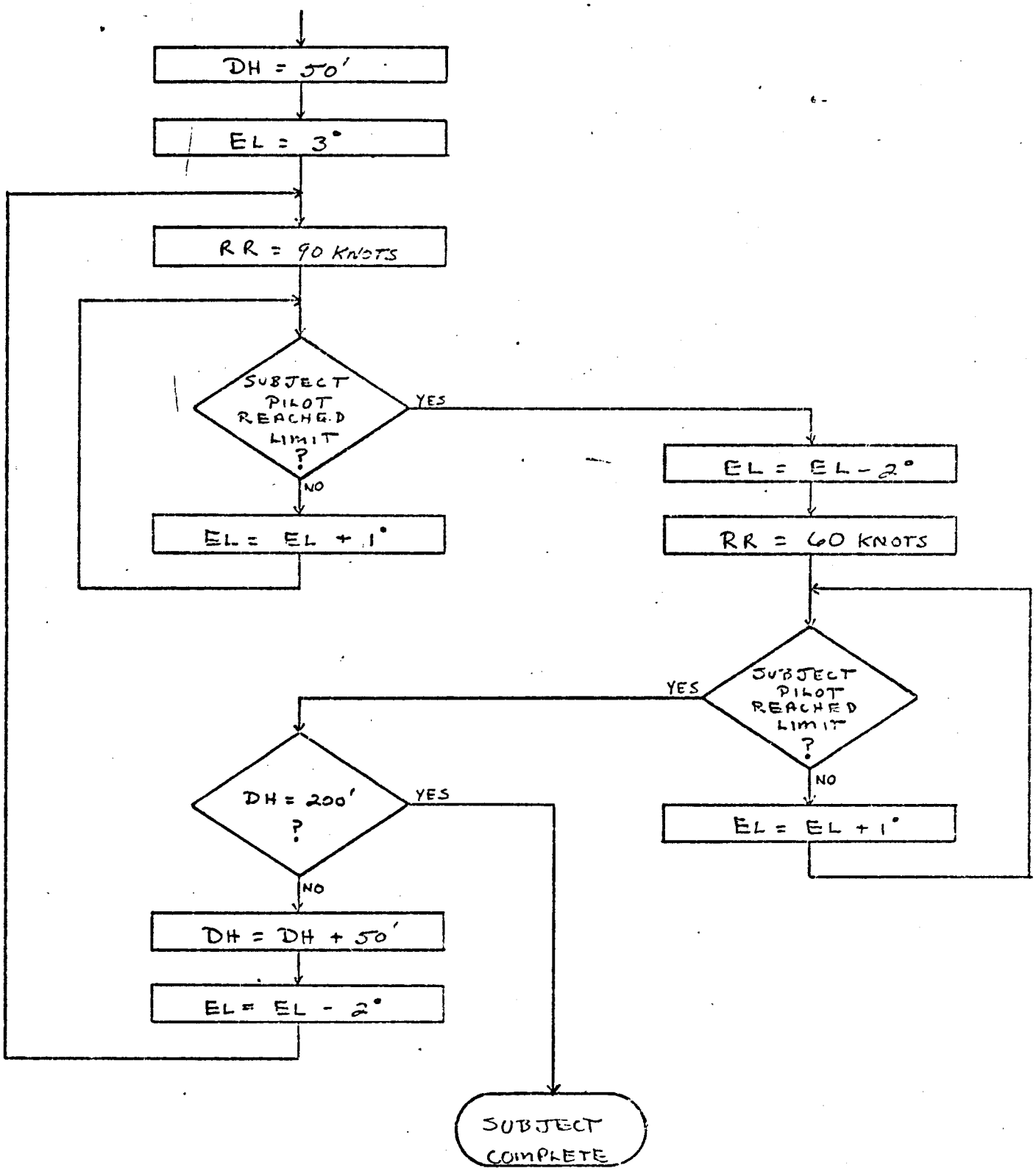


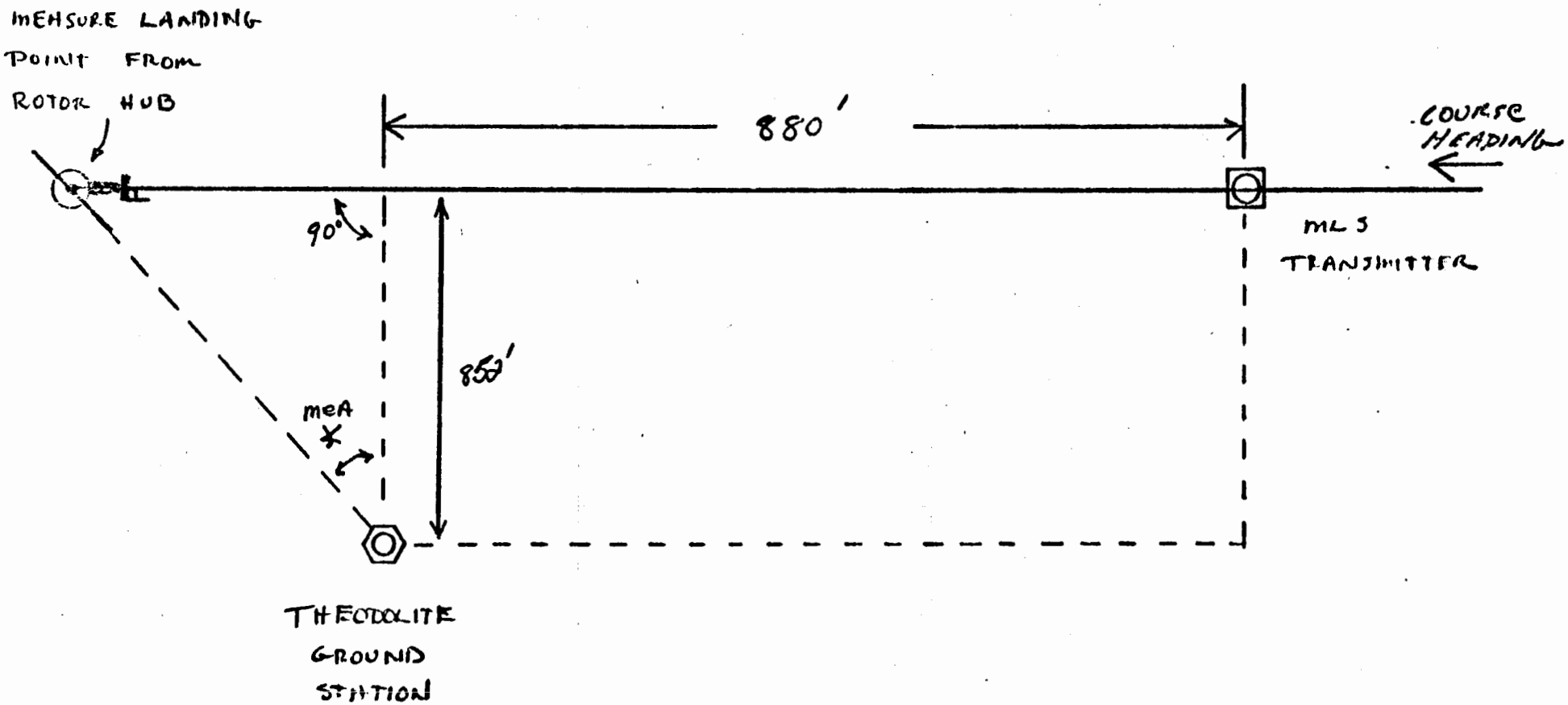
FIGURE 2. FLOWCHART OF PROFILES FOR EACH SUBJECT PILOT




NOTE: DH = DECISION HEIGHT
EL = ELEVATION ANGLE (MAXIMUM 12°)
RR = RANGE RATE

FIGURE 3

TOP VIEW OF COURSE PROFILE SHOWING GROUND THEODOLITE ANGLE MEASUREMENT



criteria. After completing a family of hooded approaches, each pilot was asked to perform what they felt was their normal visual approach or their steep visual approach.

The deceleration distance and profile tracking information was processed from the theodolite distance measurements and the strip chart recordings of elevation deviation, azimuth deviation, slant range, range rate, deceleration force, and pitch attitude. It was found after flying two subject pilots that data processing could be streamlined by recording height above plane (horizontal plane of the MLS transmitter antenna, approximately 2 feet above ground level) in place of pitch attitude. Pitch attitude was found to be linearly related to deceleration force and, subsequently, calculated during post-flight data reduction.

The deceleration data from the eight subject pilots were correlated into profile categories and processed for arithmetic mean and standard deviation. Individual data collection runs were analyzed for:

a. Elevation tracking accuracy up to and through DH (full-scale up or down course deviation indicator (CDI) deflections at or prior to reaching target DH designate an MA and data run was not used in the data base).

b. Azimuth tracking accuracy up to and through DH (full-scale right or left CDI deflections at or prior to reaching target DH designate an MA and data run was not used in the data base).

c. Range rate (or ground speed) tracking accuracy up to and through DH ($\pm$15-knot excursions from designated 90- or 60-knot range rates at or prior to reaching DH designate an MA and data run was not used in the data base).

d. Maximum peak longitudinal deceleration force excursions during the approach and landing maneuver.

e. Maximum pitch attitude excursions during the approach and landing maneuver.

f. Total deceleration distance from DH to touchdown.

Parameters of elevation, azimuth, and range rate tracking specified above determine the validity of individual data flights for processing in the data base. Flights where the parameters were violated were considered an MA.

## 6. RESULTS.

The total number of runs initiated was 366 of which 227 were valid data runs, 44 were familiarization, 59 resulted in MA's, 5 were MA's due to antenna system problems, 5 were safety pilot demonstration approaches, and 26 were the pilots' normal and steep visual approaches (see table 1). Elevation tracking accuracy, azimuth tracking accuracy and range rate tracking accuracy specified previously were used to determine a valid data run or an MA. Familiarization, MA's, system problem missed approaches, demonstrations, visual normal and visual steep approaches were not used in the data base calculations.

The individual data profiles of each subject pilot and pilot background are tabulated in appendix A. The runs designated MA in the profile list are those which did not meet the approach criteria and were not used in the calculations of deceleration distance and maximum deceleration force. The results of total deceleration distance data reduction are displayed in tables 2 and 3. Table 2 contains mean total (from the DH to the landing zone) deceleration distance in feet (reference figure 1), standard deviation for the deceleration distance, and number of samples used in the profile calculation performed at the 90-knot range rate. Table 3 is the same information but performed at the 60-knot range rate.

TABLE 1. DATA COLLECTION FLIGHTS FOR THE EIGHT SUBJECT PILOTS

| Subject Pilot # | Total Runs | Valid Runs | FAM | MA Pilot | MA System | PD Demo | Visual |
|---|---|---|---|---|---|---|---|
| 1 | 41 | 30 | 2 | 5 | 1 | - | 3 |
| 2 | 34 | 26 | - | 4 | 1 | - | 3 |
| 3 | 42 | 30 | 8 | 1 | 1 | - | 2 |
| 4 | 29 | 13 | 4 | 10 | - | - | 2 |
| 5 | 52 | 22 | 6 | 15 | 2 | 2 | 5 |
| 6 | 63 | 41 | 10 | 8 | - | 1 | 3 |
| 7 | 58 | 39 | 6 | 9 | - | - | 4 |
| 8 | 47 | 26 | 8 | 7 | - | 2 | 4 |
| Totals | 366 | 227 | 44 | 59 | 5 | 5 | 26 |

The total deceleration distance data in tables 2 and 3 contain the known deceleration distance from the flight profile (i.e., 3° elevation angle with 50 feet DH has 954 feet of ground range from the DH point of the helicopter to the MLS antenna, figure 1) and the deceleration distance beyond the antenna to the landing zone. By subtracting out the known portion from the total distance, the result is the deceleration distance beyond the collocated antenna system. The data in tables 4 and 5 are the deceleration distances beyond the collocated antenna system from tables 2 and 3.

Deceleration force data (along the helicopter's longitudinal axis) was collected synchronous to the elevation, azimuth, range rate, pitch attitude, and slant range information on the strip chart recordings. After processing the first five data collection sessions (using a data base of 56 samples) it was calculated that maximum pitch-up attitude data was linearly related to the maximum peak deceleration force data. The data pairs from each profile were processed in a linear regression resulting in the equation: with a (0.795 quality of fit)

Deceleration Force (G's) = (0.014 Pitch-Up Angle (Deg) + (0.011).

TABLE 2. 90-KNOT RANGE RATE TOTAL DECELERATION DISTANCE DATA (FT) (MEAN DECELERATION DISTANCE (FT), STANDARD DEVIATION, AND NUMBER OF SAMPLES)

| Descent Angle (Deg) | 50 foot DH | 100 foot DH | 150 foot DH | 200 foot DH |
|---|---|---|---|---|
| 3 | 2308 | * | * | * |
| | 213 | * | * | * |
| | 5 | * | * | * |
| 4 | 2349 | 1924 | * | 3722 |
| | 646 | - | * | - |
| | 4 | 1+ | * | 1+ |
| 5 | 2327 | 1849 | 2308 | 2965 |
| | 460 | 293 | - | - |
| | 5 | 5 | 1+ | 1+ |
| 6 | 1822 | 2366 | 2797 | 3015 |
| | 556 | 568 | 740 | - |
| | 7 | 7 | 2 | 1+ |
| 7 | 2300 | 2405 | 2593 | 2596 |
| | 622 | 505 | 578 | 178 |
| | 4 | 6 | 7 | 5 |
| 8 | - | 1764 | 2258 | 2758 |
| | - | 184 | 374 | 726 |
| | - | 4 | 5 | 6 |
| 9 | 1292 | 1990 | 2118 | 2293 |
| | - | 335 | 672 | 794 |
| | 1+ | 4 | 4 | 5 |
| 10 | - | 1568 | 2143 | 2146 |
| | - | 87 | 229 | 242 |
| | - | 2 | 3 | 4 |
| 11 | - | 1670 | 1968 | 2141 |
| | - | - | - | 339 |
| | - | 1+ | 1+ | 2 |
| 12 | - | 2328 | 1980 | 2534 |
| | - | - | 71 | 497 |
| | - | 1+ | 2 | 2 |

*Profiles within all pilot's capability but not flown for data.

+ Single data samples not used in second order curve fit equation calculations.

TABLE 3. 60-KNOT RANGE RATE TOTAL DECELERATION DISTANCE DATA (FT) (MEAN DECELERATION DISTANCE (FT), STANDARD DEVIATION, AND NUMBER OF SAMPLES)

| Descent Angle (Deg) | 50 foot DH | 100 foot DH | 150 foot DH | 200 foot DH |
|---|---|---|---|---|
| 3 | 2005 | * | * | * |
| | - | * | * | * |
| | 1+ | * | * | * |
| 4 | 400 | 1377 | 1385 | * |
| | - | - | - | * |
| | 1+ | 1+ | 1+ | * |
| 5 | 739 | 1617 | 1528 | 1727 |
| | - | - | 185 | - |
| | 1+ | 1+ | 2 | 1+ |
| 6 | 960 | 1392 | 1571 | 1860 |
| | 160 | 162 | 161 | 106 |
| | 5 | 5 | 3 | 2 |
| 7 | 940 | 1327 | 1529 | 1816 |
| | 186 | 317 | 426 | 245 |
| | 6 | 6 | 5 | 6 |
| 8 | 934 | 1135 | 1397 | 1691 |
| | 105 | 171 | 102 | 356 |
| | 5 | 6 | 6 | 6 |
| 9 | 823 | 1089 | 1536 | 1661 |
| | 211 | 184 | 153 | 91 |
| | 3 | 4 | 6 | 6 |
| 10 | 823 | 1273 | 1373 | 1567 |
| | - | 445 | 180 | 484 |
| | 1+ | 4 | 4 | 4 |
| 11 | 731 | 1376 | 1234 | 1574 |
| | - | 807 | 94 | 190 |
| | 1+ | 2 | 2 | 3 |
| 12 | - | 1214 | 1302 | 1287 |
| | - | 710 | 265 | 326 |
| | - | 2 | 3 | 3 |

*Profiles within all pilot's capability but not flown for data.

+ Single data samples not used in second order curve fit equation calculations.

TABLE 4. 90-KNOT RANGE RATE DECELERATION DISTANCE, (FT) BEYOND COLLOCATED MLS ANTENNA SYSTEM (MEAN DECELERATION DISTANCE (FT), STANDARD DEVIATION, AND NUMBER OF SAMPLES)

| Elevation Angle (Deg) | 50 foot DH | 100 foot DH | 150 foot DH | 200 foot DH |
|---|---|---|---|---|
| 3 | 1354 | * | * | * |
| | 213 | * | * | * |
| | 5 | * | * | * |
| 4 | 1634 | 494 | * | 862 |
| | 646 | - | * | - |
| | 4 | 1+ | * | 1+ |
| 5 | 1756 | 706 | 593 | 679 |
| | 460 | 293 | - | - |
| | 5 | 5 | 1+ | 1+ |
| 6 | 1346 | 1415 | 1370 | 1112 |
| | 556 | 568 | 740 | - |
| | 7 | 7 | 2 | 1+ |
| 7 | 1893 | 1591 | 1371 | 967 |
| | 622 | 505 | 578 | 178 |
| | 4 | 6 | 7 | 5 |
| 8 | - | 1052 | 1191 | 1335 |
| | - | 184 | 374 | 726 |
| | - | 4 | 5 | 6 |
| 9 | 976 | 1359 | 1171 | 1030 |
| | - | 335 | 672 | 794 |
| | 1+ | 4 | 4 | 5 |
| 10 | - | 1001 | 1292 | 1012 |
| | - | 87 | 229 | 242 |
| | - | 2 | 3 | 4 |
| 11 | - | 1156 | 1191 | 1112 |
| | - | - | - | 339 |
| | - | 1+ | 1+ | 2 |
| 12 | - | 1858 | 1274 | 1593 |
| | - | - | 71 | 497 |
| | - | 1+ | 2 | 2 |

*Profiles within all pilot's capability but not flown for data.

+ Single data samples not used in second order curve fit equation calculations

TABLE 5. 60-KNOT RANGE RATE DECELERATION DISTANCE (FT) BEYOND COLLOCATED MLS ANTENNA SYSTEM (MEAN DECELERATION DISTANCE (FT), STANDARD DEVIATION, AND NUMBER OF SAMPLES)

| Elevation Angle (Deg) | 50 foot DH | 100 foot DH | 150 foot DH | 200 foot DH |
|---|---|---|---|---|
| 3 | 1051 | * | * | * |
| | - | * | * | * |
| | 1+ | * | * | * |
| 4 | -315 | -53 | -760 | * |
| | - | - | - | * |
| | 1+ | 1+ | 1+ | * |
| 5 | 168 | 474 | -187 | -559 |
| | - | - | 185 | - |
| | 1+ | 1+ | 2 | 1+ |
| 6 | 484 | 441 | 144 | -43 |
| | 160 | 162 | 161 | 106 |
| | 5 | 5 | 3 | 2 |
| 7 | 533 | 513 | 307 | 187 |
| | 186 | 317 | 426 | 245 |
| | 6 | 6 | 5 | 6 |
| 8 | 578 | 423 | 330 | 268 |
| | 105 | 171 | 102 | 356 |
| | 5 | 6 | 6 | 6 |
| 9 | 507 | 458 | 589 | 398 |
| | 211 | 184 | 153 | 91 |
| | 3 | 4 | 6 | 6 |
| 10 | 539 | 706 | 522 | 433 |
| | - | 445 | 180 | 484 |
| | 1+ | 4 | 4 | 4 |
| 11 | 474 | 862 | 462 | 545 |
| | - | 807 | 94 | 190 |
| | 1+ | 2 | 2 | 3 |
| 12 | - | 774 | 596 | 346 |
| | - | 710 | 265 | 326 |
| | - | 2 | 3 | 3 |

*Profiles within all pilot's capability but not flown for data.

+ Single data samples not used in second order curve fit equation calculations.

This equation was developed for the UH-1H and may not be applicable to other aircraft. This relationship was used in continued flight data processing; the pitch attitude angular data on the strip chart recorder was replaced with height above the ground (horizontal plane of the MLS transmitter antenna) information from the MLS receiver. This height above plane information facilitated more rapid post processing of all following data collection information from the strip chart recordings.

Deceleration distances beyond the collocated antenna system were calculated as a function of elevation angle, DH, and total samples using data from tables 4 and 5. The deceleration distances as a function of elevation angle, figures 4 and 5, show no particular trend for the 90-knot data, but an increasing distance trend in the 60-knot data. As elevation angle increased, the separation between the antenna system and the mean touchdown point increased. The data in figures 6 and 7 show a more definitive trend for both 90- and 60-knot data. As the DH increases, the separation distance between the antenna system and the mean touchdown point decreased. The most important fact from figures 4 through 7 is that at the 90-knot range rate, at any elevation angle, the subjects could not land at the antenna system in the event a helipad was located adjacent to the MLS antenna.

At the 60-knot range rate (figure 5), only angles of 5° or less could be used (3° elevation data at 60 knots has limited subject pilot data). This information shows that in order to attain safe landings at a helipad located adjacent to the MLS antenna, one of four things must happen. First, the range rate at DH must be lower than 60 knots. The lower airspeed would shorten the deceleration distance as shown by figures 6 and 7, but aircraft stability and MA departure criteria may be hindered by the lower airspeed. The second option would be a more abrupt deceleration maneuver to stop the helicopter; but this would restrict the pilot's view of the landing zone due to increased pitch attitude and would not facilitate a passenger comfort maneuver as was exercised in these data collection approaches. The third option would be a decelerating approach along the descent path so at DH the airspeed is less than 60 knots (i.e., start the approach at 90 knots and constantly decelerated along the descent to perhaps 40 knots at DH, and then visually decelerate to the helipad). There is still a problem with this option at DH in aircraft stability flying less than 60 knots and power available for MA procedures. The fourth and most viable option would be to increase the DH. As shown by figures 6 and 7, the deceleration distance beyond the antenna system decreases as the DH increases. This distance will decrease to zero if the DH is increased sufficiently. The major disadvantage of this option is the higher minimums.

Figures 8 through 11 show deceleration force and pitch-up angle by elevation angle and DH. The total sampled data in table 6 gives the best representation for G force experienced in these tests which were performed without an absolute landing zone. These G levels experienced (0.20 for 90 knots and 0.17 for 60 knots) were within subjective passenger comfort ranges for peak deceleration force; but it must be kept in mind that a helicopter approach is unlike an airplane approach (i.e., steeper angle approaches, the pitch up angle during transmition to deceleration maneuver, etc.) and the passenger should be briefed to expect deceleration forces greater than those experienced for a visual normal approach.

**FIGURE 4**
**DECELERATION DISTANCE (FT), BEYOND THE COLLOCATED MLS ANTENNA SYSTEM FOR ALL DECISION HEIGHTS AS A FUNCTION OF ELEVATION ANGLE FOR 90 KNOTS**

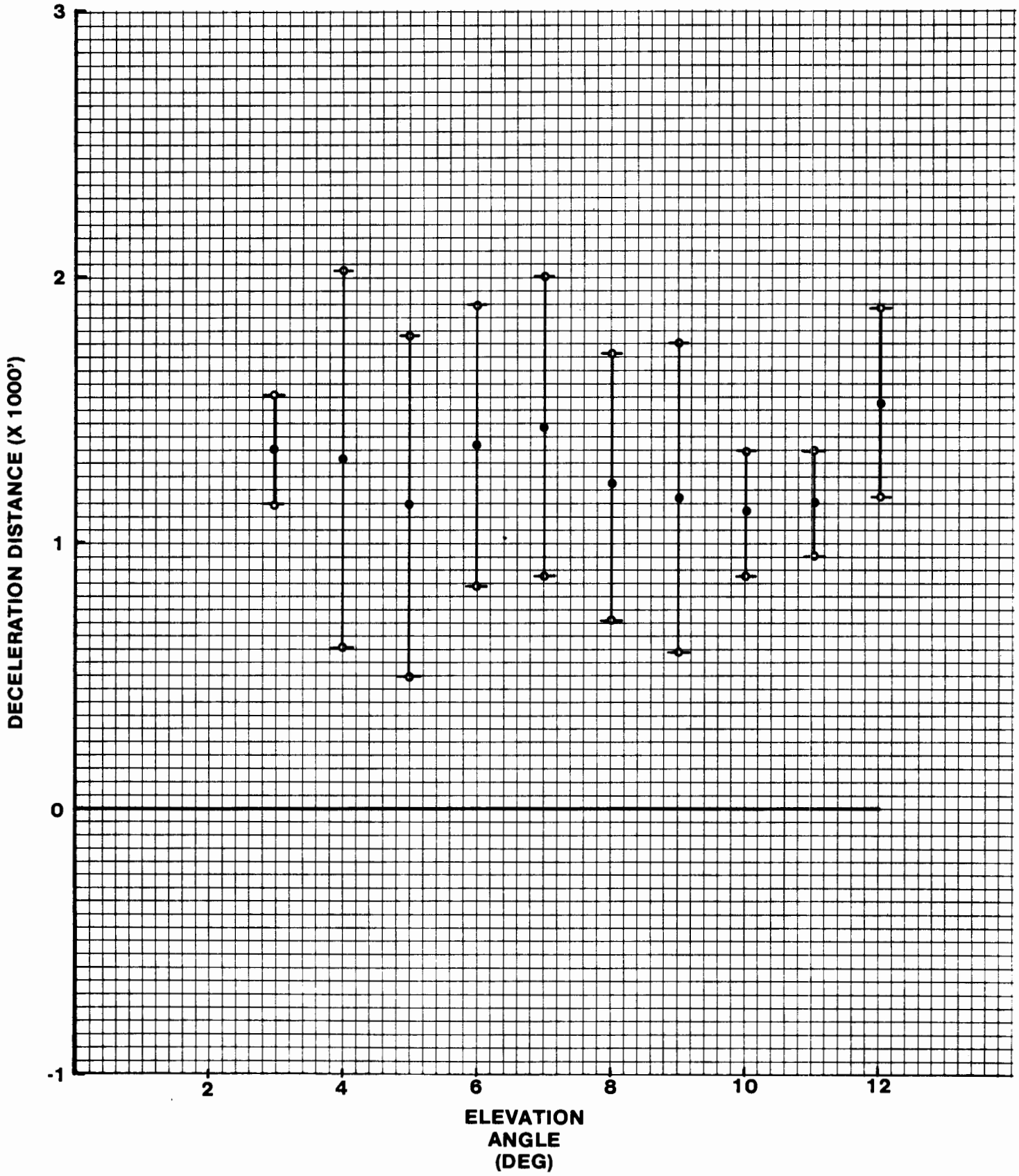


FIGURE 5
DECELERATION DISTANCE (FT), BEYOND THE COLLOCATED MLS ANTENNA SYSTEM FOR ALL DECISION HEIGHTS AS A FUNCTION OF ELEVATION ANGLE FOR 60 KNOTS

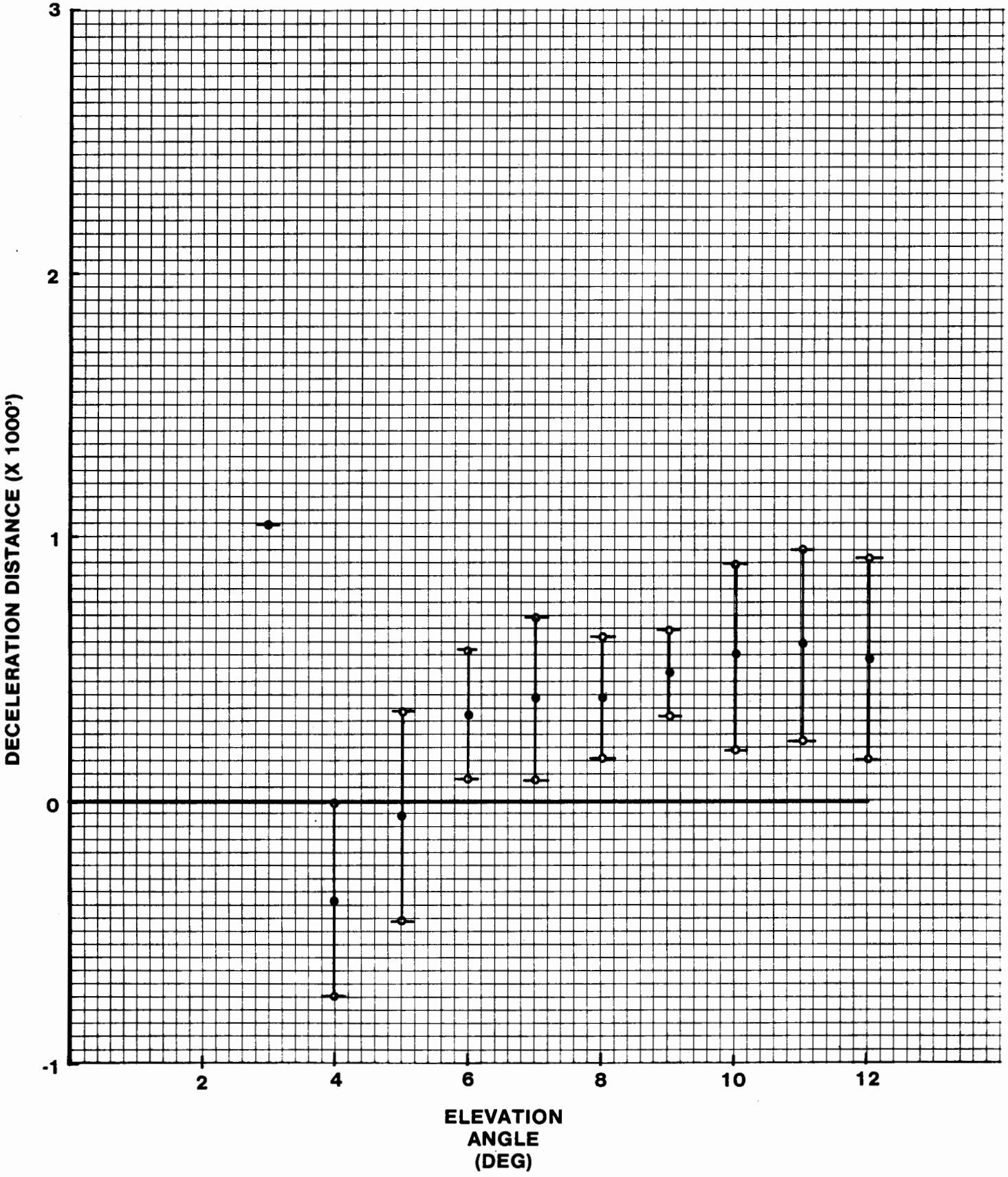


**FIGURE 6**
**DECELERATION DISTANCE (FT), BEYOND THE COLLOCATED MLS ANTENNA SYSTEM FOR ALL DECISION HEIGHTS AS A FUNCTION OF DECISION HEIGHT FOR 90 KNOTS**

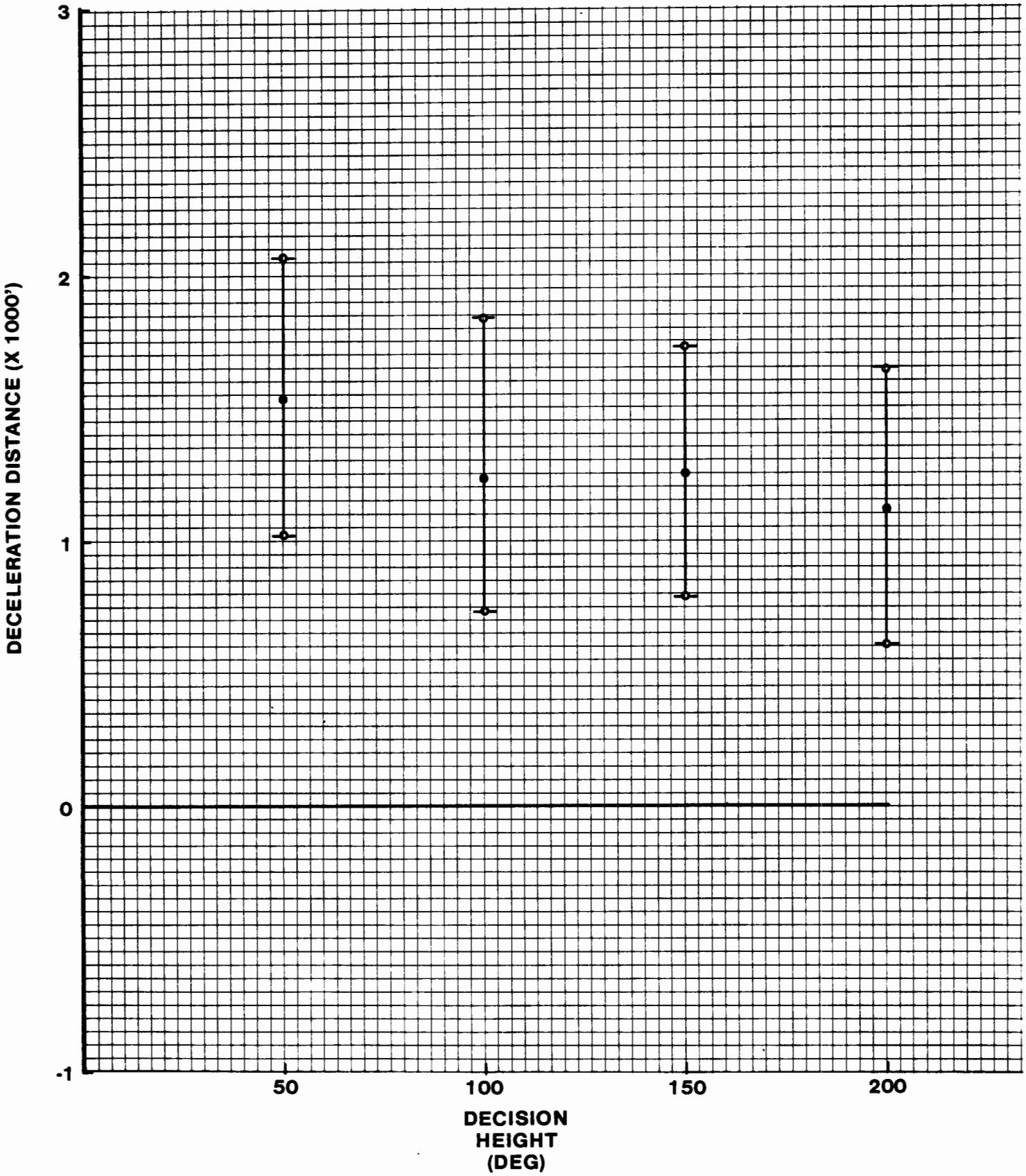


FIGURE 7
DECELERATION DISTANCE (FT), BEYOND THE COLLOCATED MLS ANTENNA SYSTEM FOR ALL ELEVATION ANGLES AS A FUNCTION OF ELEVATION HEIGHT FOR 60 KNOTS

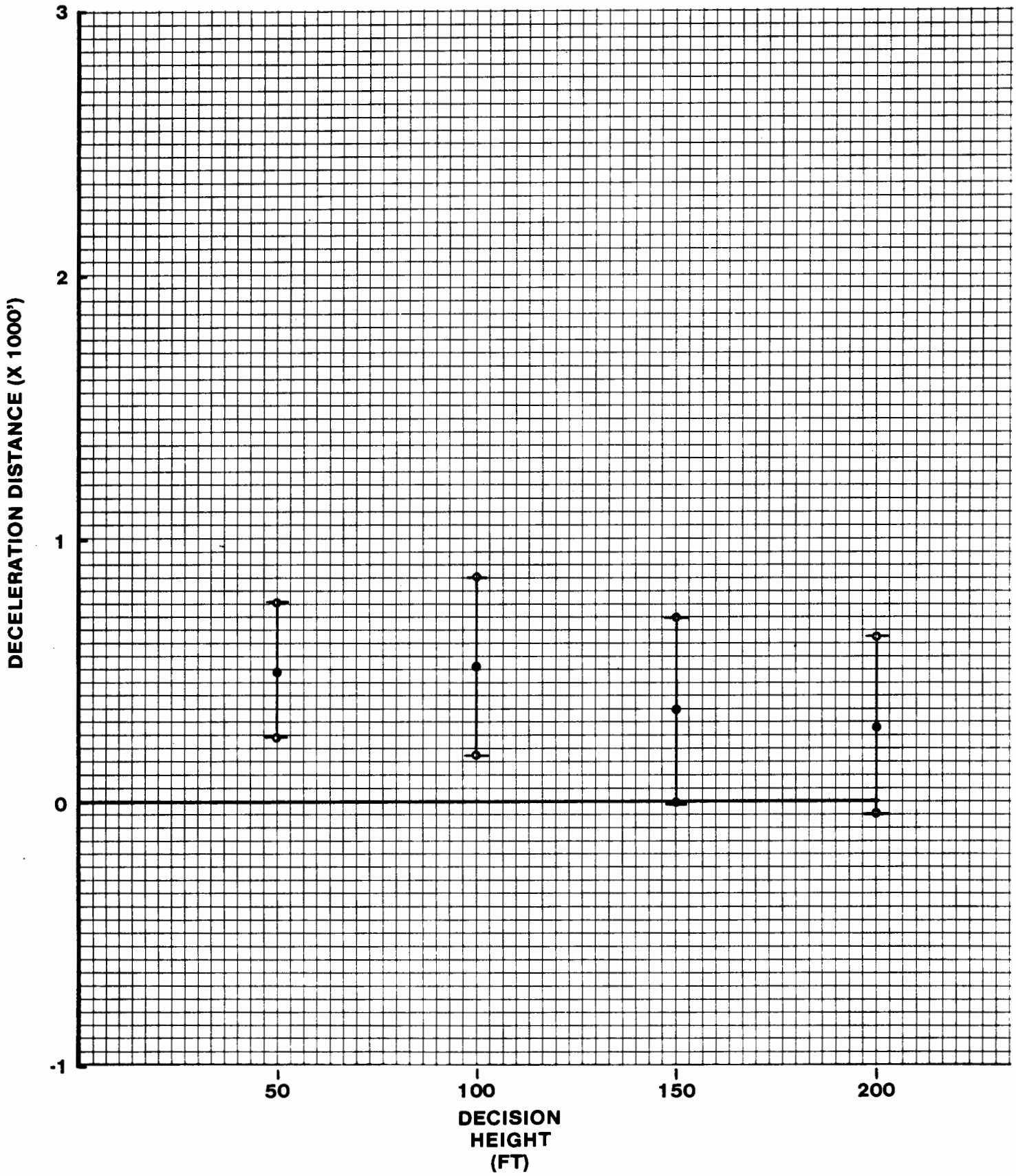


FIGURE 8
PEAK PITCH-UP ANGLE (DEG) AND PEAK DECELERATION FORCE (G's) FOR ALL ELEVATION ANGLES AS A FUNCTION OF ELEVATION ANGLE FOR 90 KNOTS RANGE RATE

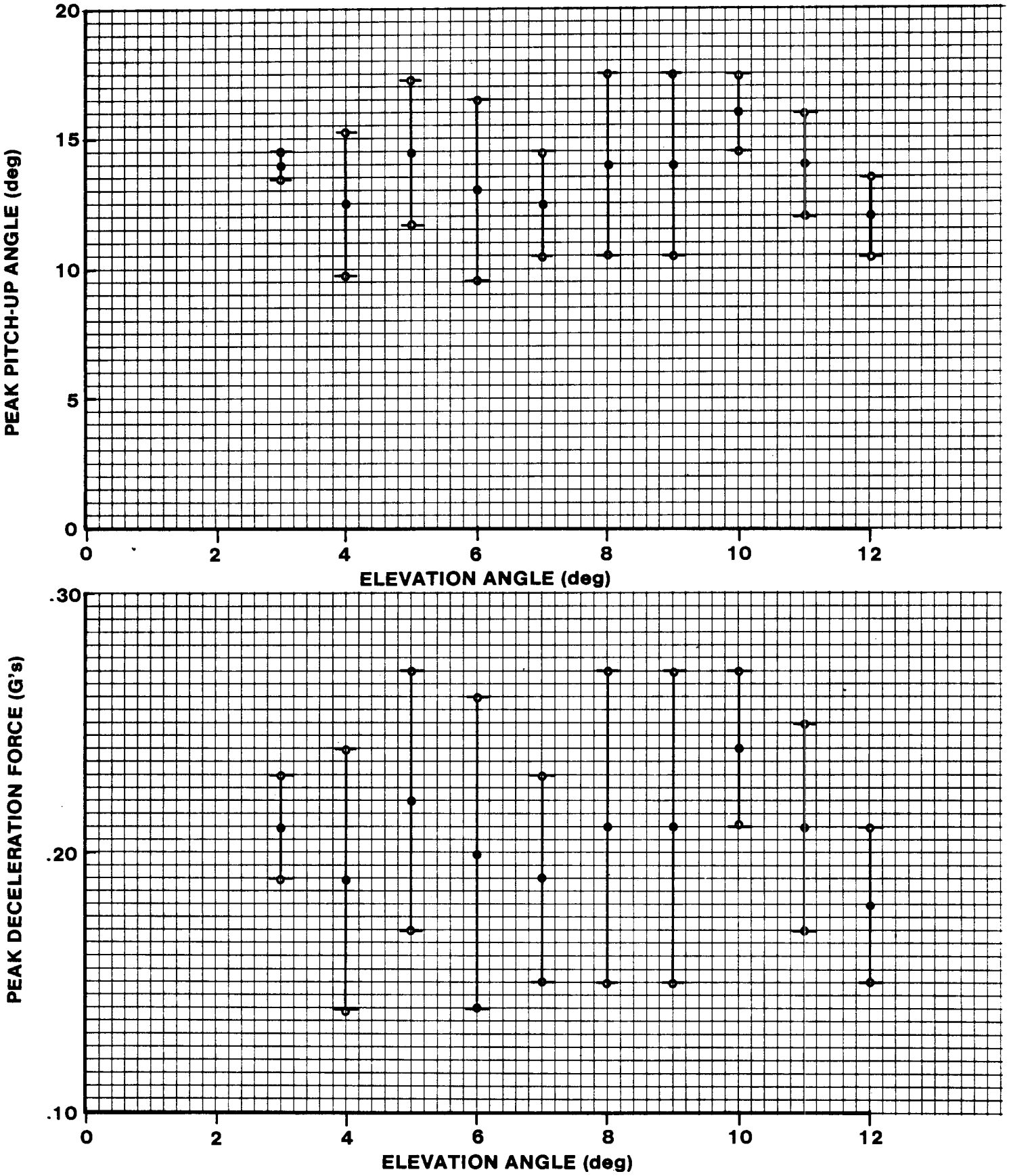
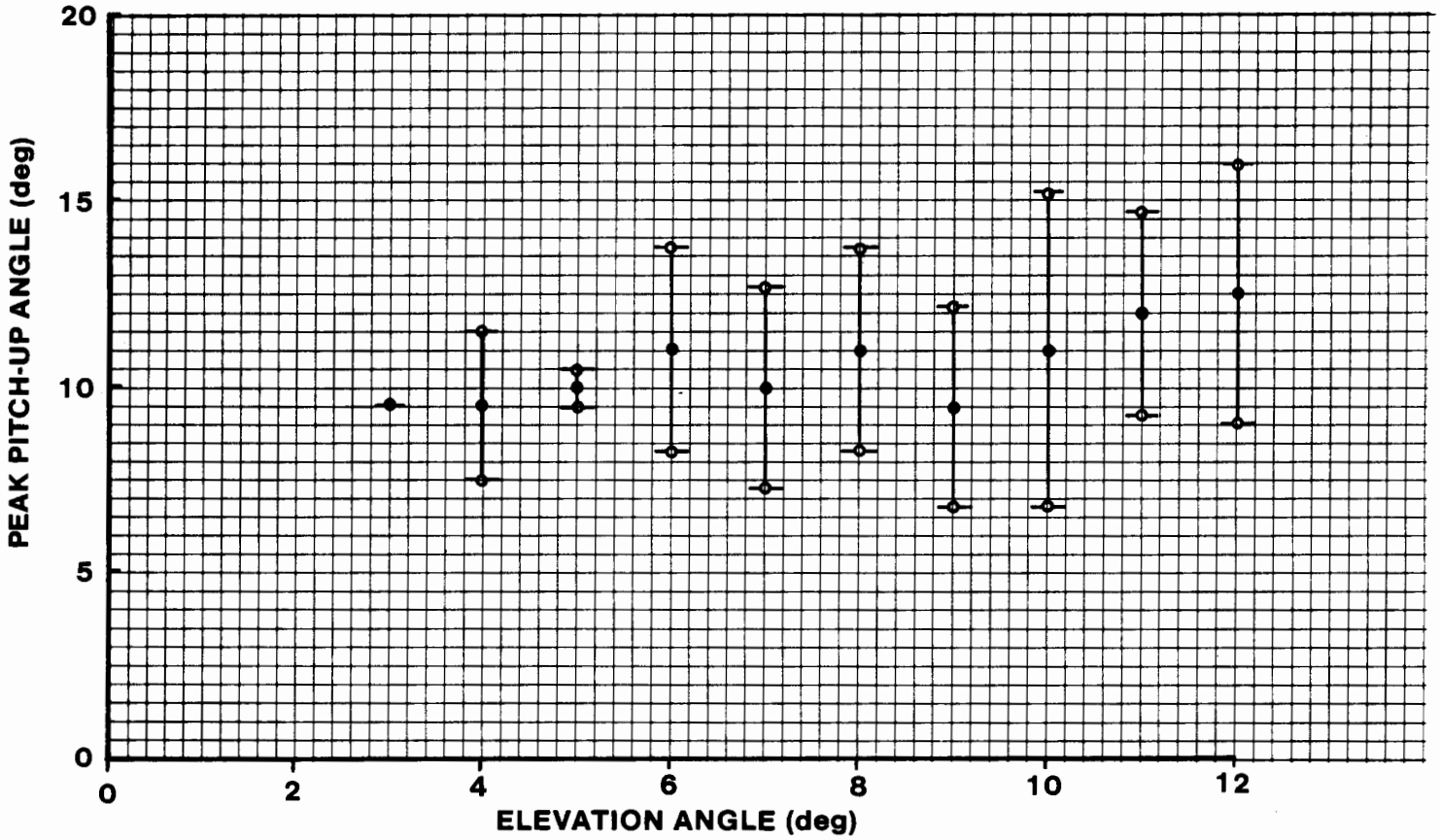


**FIGURE 9**
**PEAK PITCH-UP ANGLE (DEG) AND PEAK DECELERATION FORCE (G's) FOR ALL DECISION HEIGHTS AS A FUNCTION OF ELEVATION ANGLE FOR 60 KNOTS RANGE RATE**



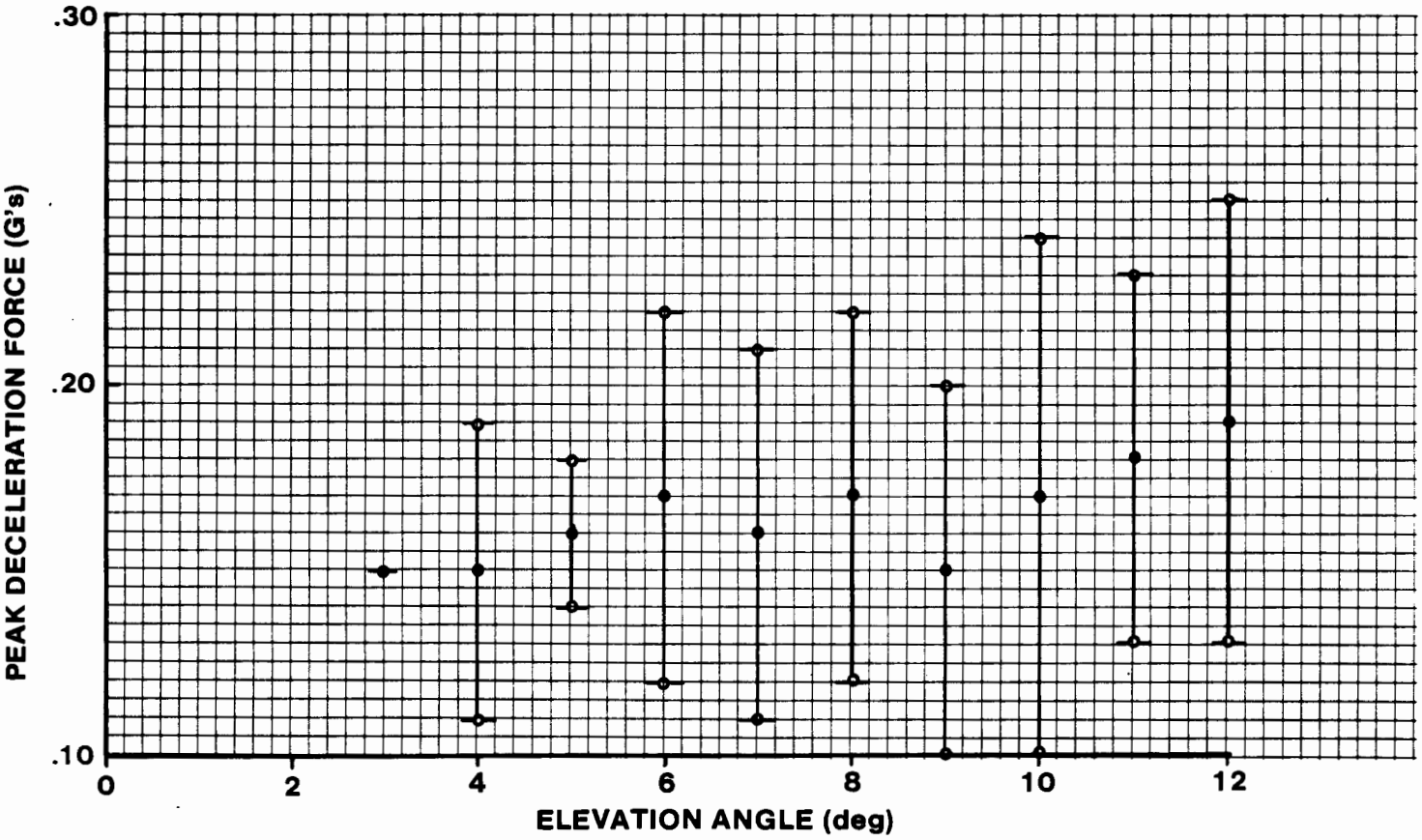



FIGURE 10
PEAK PITCH-UP ANGLE (DEG) AND PEAK DECELERATION FORCE (G's) FOR ALL ELEVATION ANGLES AS A FUNCTION OF DECISION HEIGHT FOR 90 KNOTS RANGE RATE

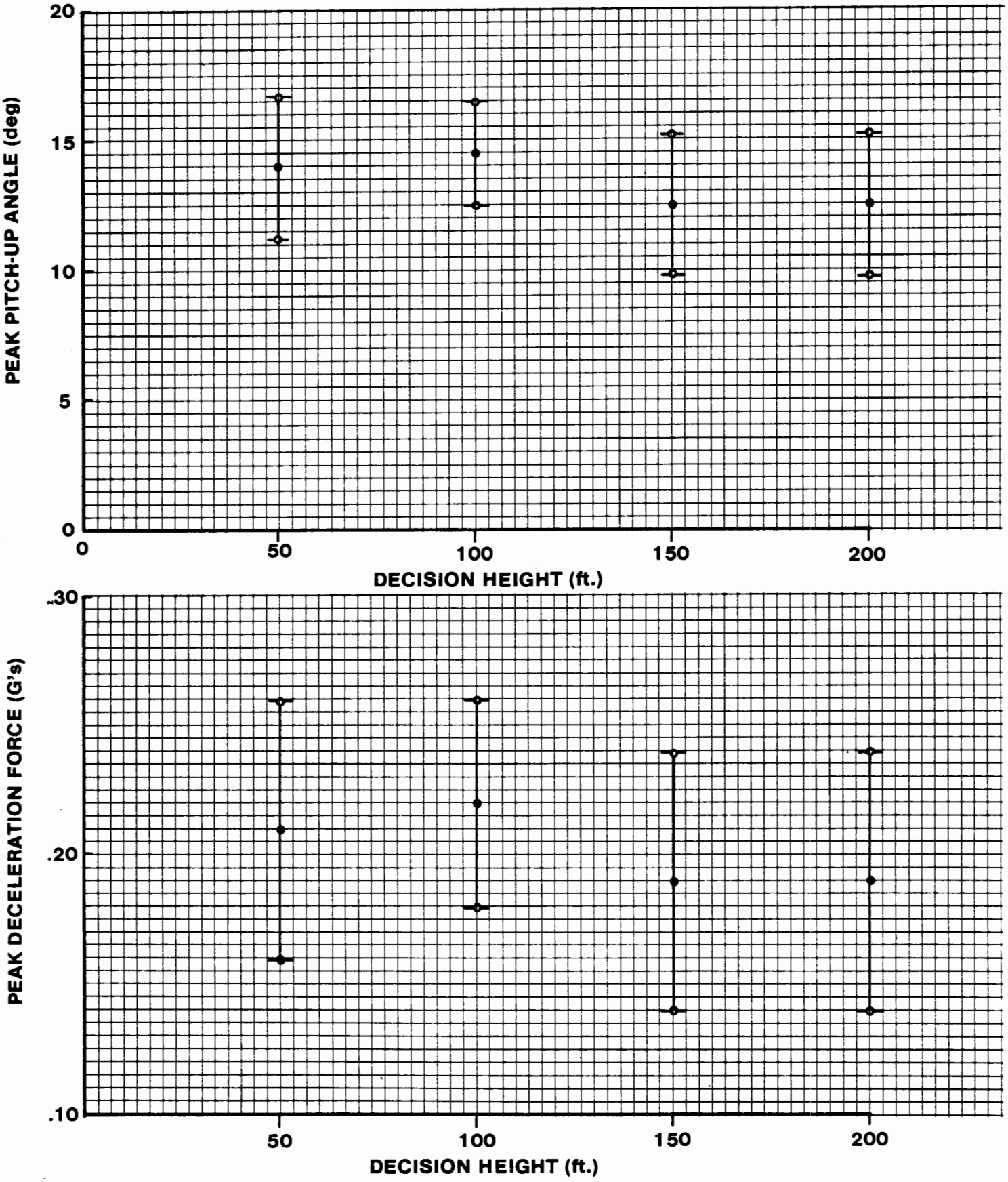


FIGURE 11
PEAK PITCH-UP ANGLE (DEG) AND PEAK DECELERATION FORCE (G's) FOR ALL ELEVATION ANGLES AS A FUNCTION OF DECISION HEIGHT FOR 60 KNOTS RANGE RATE

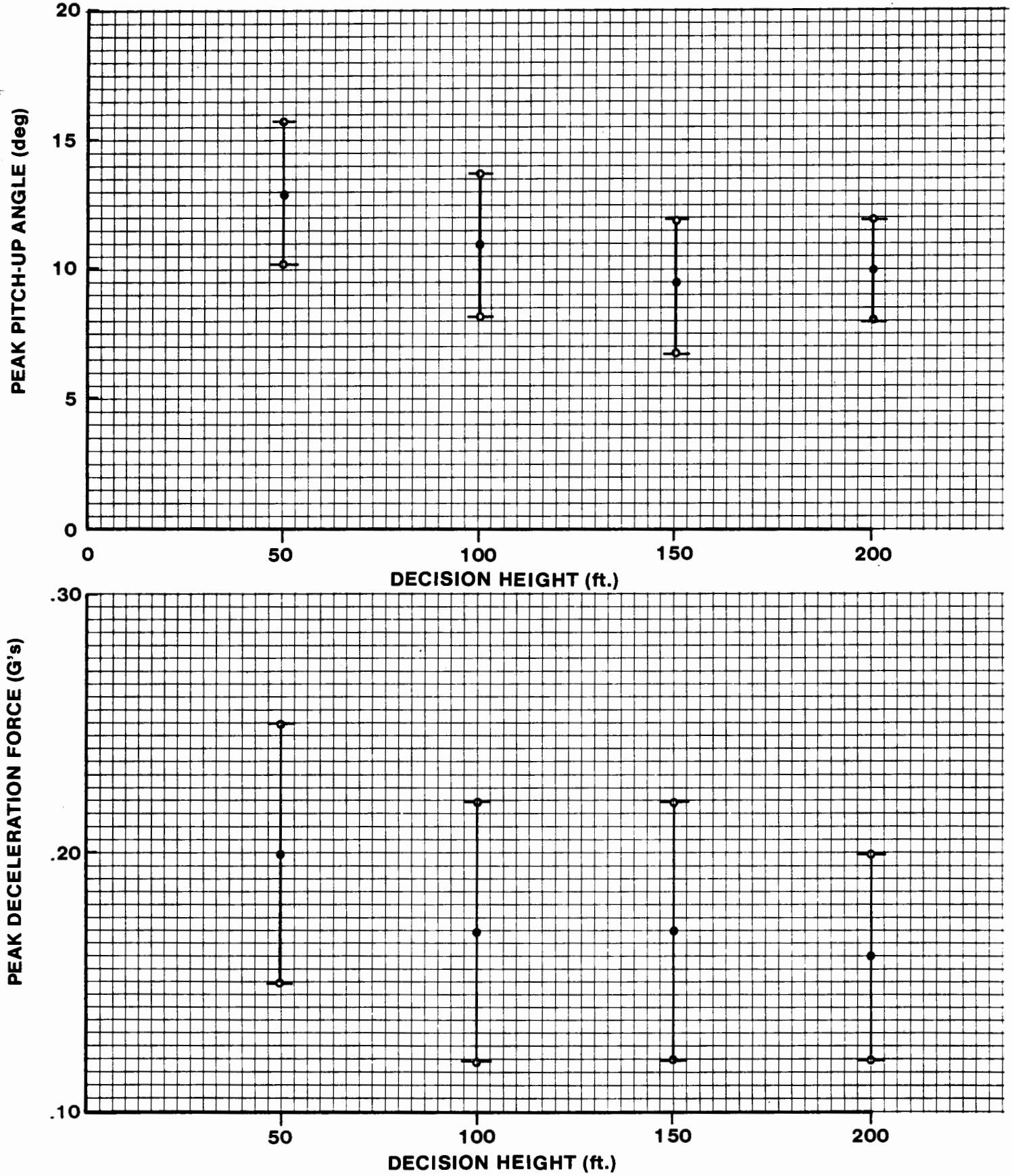


TABLE 6. MAXIMUM PEAK DECELERATION FORCE (G's) FOR ALL DECISION HEIGHTS AND ELEVATION ANGLES

| Range Rate (Knots) | Deceleration Force (Mean/Std Dev/Samples) |
|---|---|
| 90 | 0.20/0.05/109 |
| 60 | 0.17/0.05/118 |

The maximum pitch-up attitude, figures 8 through 11, show the mean rotations of the helicopter in degrees during the transition from the instrument glidepath segment to the visual deceleration maneuver. The angular measurement was referenced to straight and level flight (zero on the recorder pen). During the transition to visual flight, subject pilots were free to use all visual cues (i.e., chin bubble and side windows). Post-data collection analysis showed the viewing cutoff angle of the UH-1H instrument console to be approximately 18° for a helipad located straight ahead (data collection results shown in appendix C). This viewing angle along with the data in figures 8 through 11 will have to be taken into consideration when the helicopter makes its approaches to a distinct helipad as continuous visual contact with the landing zone is imperative during the deceleration segment.

In the data collection phase, the subject pilots flew to one DH at 90 knots until subjective (pilot's personal gut reaction) limiting descent elevation angle was attained. The subject then flew to the same DH at the 60-knot range rate until subjective limiting descent angle was reached (reference figure 2). These maximum descent angles and their means are displayed in table 7 and figure 12 for each subject pilot for each descent profile. Table 8 shows the visual normal approaches performed each subject pilot. The mean for the visual normal approaches was 6.3° (15 samples) and for the visual steep it was 9.2° (9 samples). Deceleration G-forces experienced during the visual approaches were comparable to those experienced in the 60-knot instrument transition decelerations.

The deceleration distance data from tables 4 and 5 were plotted as a function of elevation angle. Only means computed from two or more samples were used for improved statistical analysis. These trend data are plotted in figures 13 through 20 as the solid lines and second order curve fitting as the broken lines. Second order curve fitting techniques were applied to the data and the resulting equations are shown in table 9. The equations were used with elevation angle of 2° through 12° to plot the dashed curves in figures 13 through 20. From these eight curve fit plots, the data were rearranged and plotted with elevation angle versus DH for various deceleration distances at or beyond the antenna system for 90-knot approaches (figure 21) and 60-knot approaches (figure 22). These graphs show a clear relationship between airspeed, DH, elevation angle, and antenna to heliport (touchdown point) separation. The data show that as the elevation angle to a DH is increased, an angle will be reached which requires that the antenna system be moved from a location adjacent to the heliport to a location in front of the heliport. This separation distance increases as a function of increasing elevation angle (i.e., the helicopter must fly past the MLS antenna to reach the heliport). For a given elevation angle, as the DH is decreased a DH will be reached which requires that the MLS antenna again be moved from a location adjacent to the heliport to locations in front of the heliport. This separation increases in distance as a function of decreasing DH.

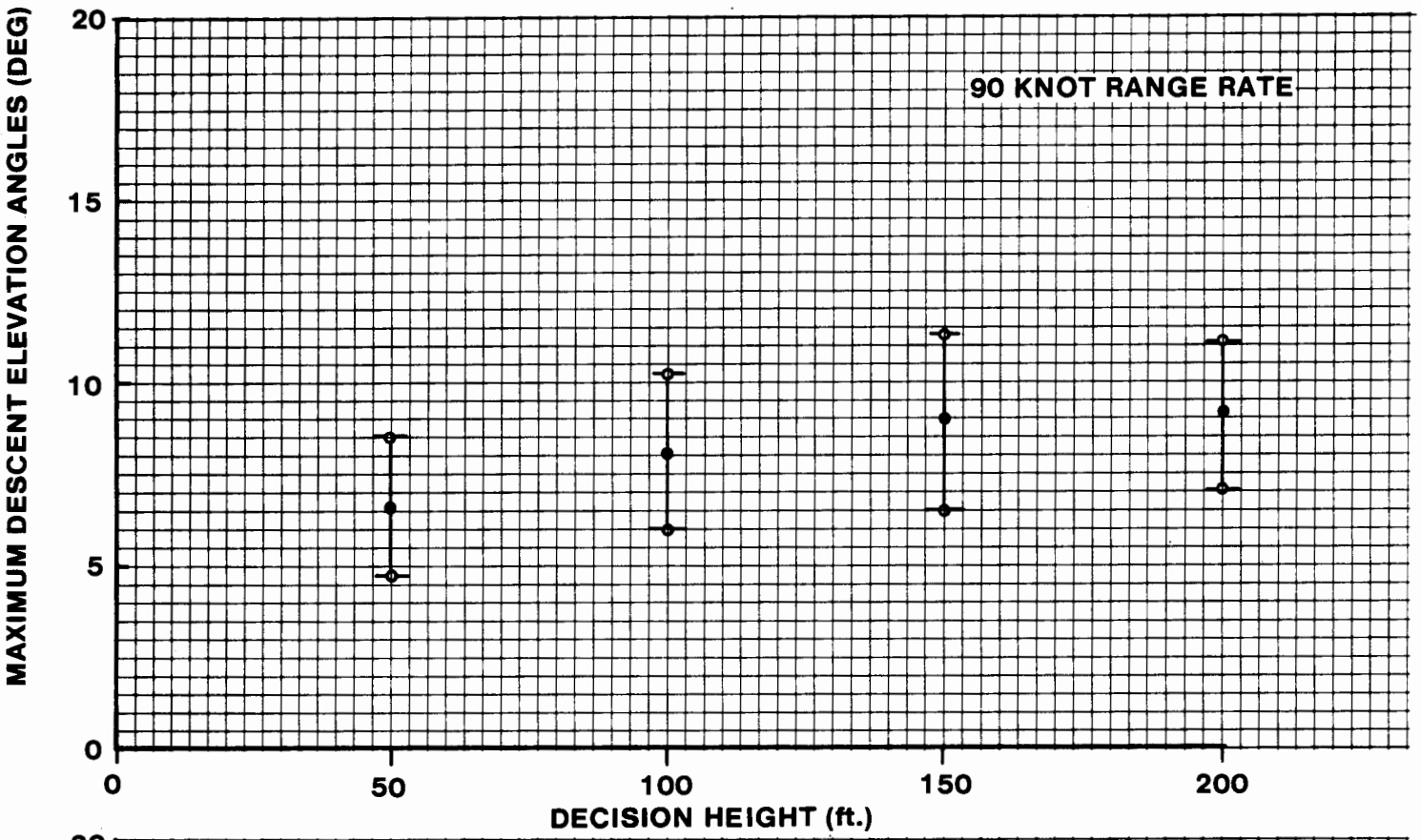
TABLE 7. MAXIMUM DESCENT ELEVATION ANGLE DATA

| Subject Number | 90 Knot Range Rate | | | | 60 Knot Range Rate | | | |
|---|---|---|---|---|---|---|---|---|
| | Decision Heights (Ft) | | | | | | | |
| | 50 | 100 | 150 | 200 | 50 | 100 | 150 | 200 |
| 1 | 7° | 8° | 8° | 7° | 9° | 8° | 10° | 10 |
| 2 | 6° | 9° | 12° | 10° | 10° | 12° | 12° | 12 |
| 3 | 7° | 7° | 9° | 8° | 8° | 9° | 9° | 9 |
| 4 | 4° | - | 5° | 7° | 3° | 8° | 7° | 8 |
| 5 | 6° | 6° | 8° | 9° | 8° | 9° | 10° | 11 |
| 6 | 10° | 12° | 12° | 12° | 11° | 12° | 12° | 12 |
| 7 | 8° | 9° | 10° | 12° | 9° | 9° | 9° | 12 |
| 8 | 5° | 6° | 7° | 8° | 7° | 6° | 7° | 8 |
| Mean | 6.6° | 8.1° | 8.9° | 9.1° | 8.1° | 9.1° | 9.5° | 10 |
| Std Dev | 1.85 | 2.12 | 2.42 | 2.03 | 2.42 | 2.03 | 1.93 | 1.75 |
| Samples | 8 | 7 | 8 | 8 | 8 | 8 | 8 | 8 |

TABLE 8. VISUAL APPROACH DATA

| Subject No. | Visual Normal Approach Data | | Visual Steep Approach Data | |
|---|---|---|---|---|
| | Descent Elevation Angles (Degrees) | Peak Deceleration Force (G's) | Descent Elevation Angles (Degrees) | Peak Deceleration Force (G's) |
| 1 | 5° | .02 | 9° | .03 |
| | 7° | .11 | | |
| 2 | 6° | .03 | | |
| | 7° | .09 | | |
| 3 | 6° | .11 | 7° | .04 |
| 4 | 6° | .06 | | |
| 5 | 5° | .11 | 9° | .09 |
| | 7° | .13 | 12° | .13 |
| | 8° | .11 | | |
| 6 | 6° | .04 | 10° | .04 |
| | 6° | .03 | | |
| 7 | 6° | .13 | 9° | .08 |
| | 7° | .14 | | .13 |
| 8 | 6° | .05 | 7° | .13 |
| | 7° | .12 | 10° | .08 |
| Mean | 6.3° | Mean .09 | Mean 9.2° | Mean .08 |
| Std. Dev | .82° | Std. Dev .04 | Std. Dev 1.56° | Std. Dev .04 |
| Samples | 15 | Samples 15 | Samples 9 | Samples 9 |

FIGURE 12
MAXIMUM DESCENT ELEVATION ANGLE (DEG) AS A FUNCTION OF DECISION HEIGHT FOR 90-AND 60-KNOT RANGE RATES



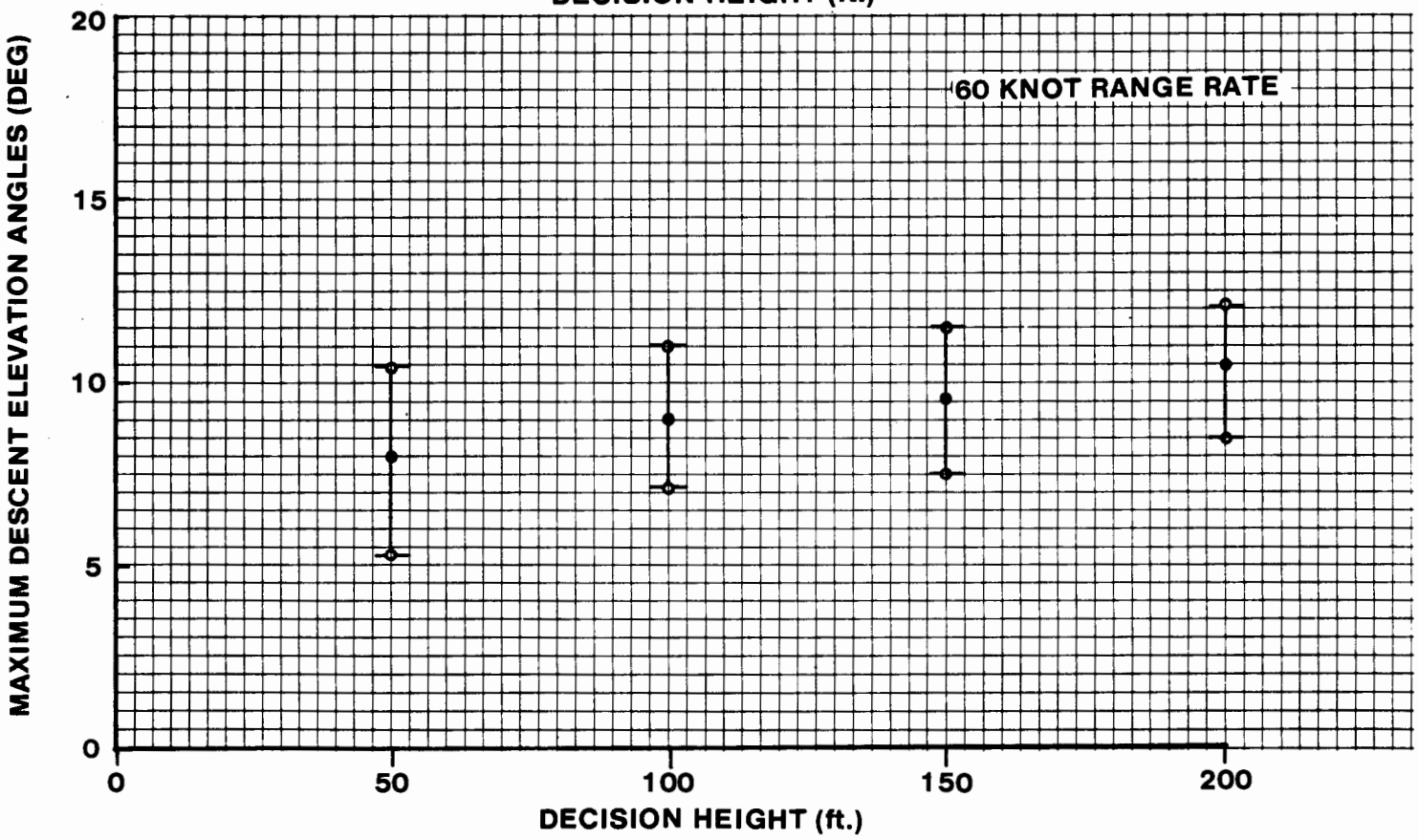



FIGURE 13
MEAN DECELERATION DISTANCE BEYOND THE COLLOCATED ANTENNA SYSTEM AND SECOND ORDER CURVE FIT FOR 150' DH

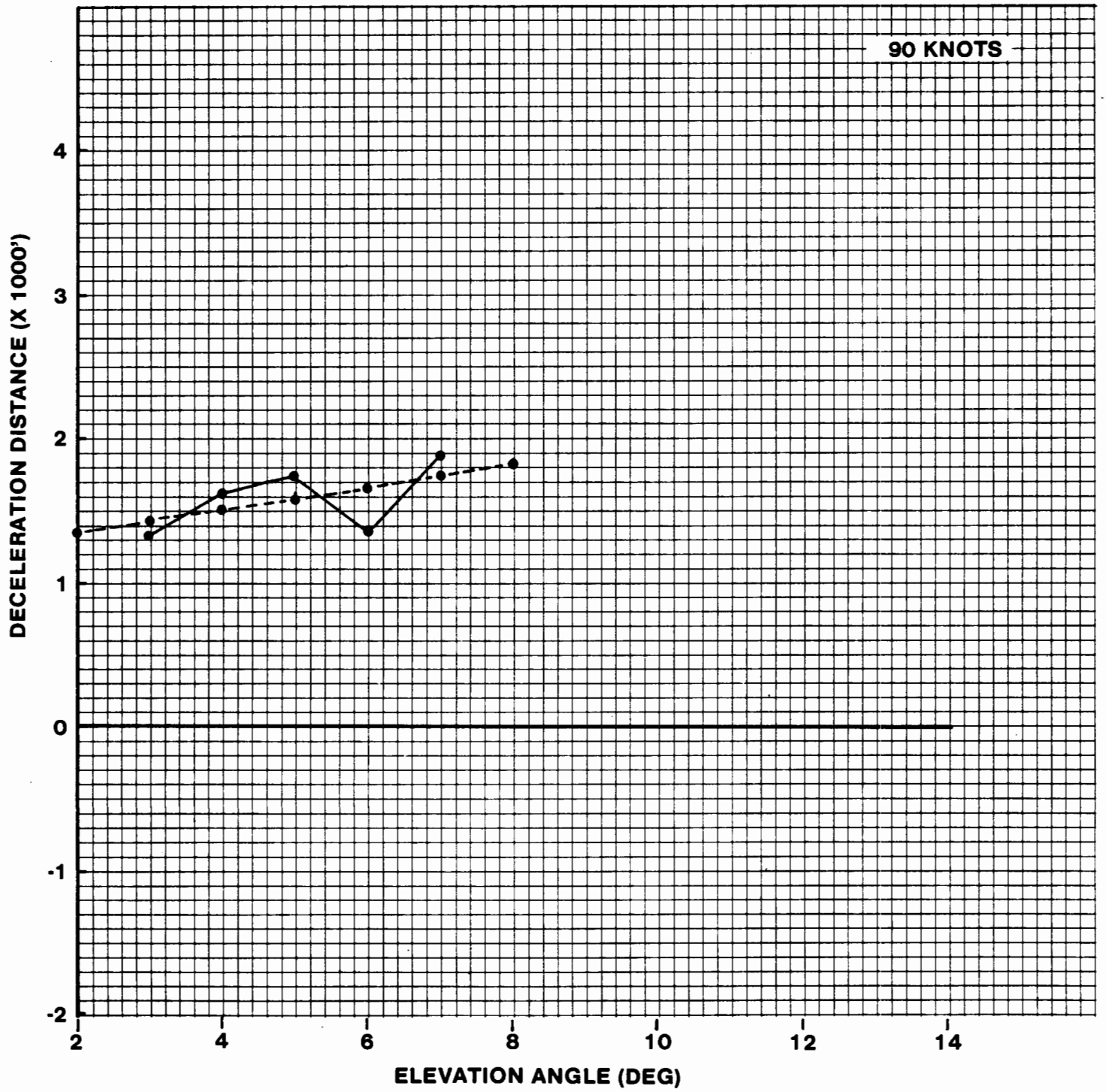


**FIGURE 14**
**MEAN DECELERATION DISTANCE BEYOND THE COLLOCATED ANTENNA SYSTEM AND SECOND ORDER CURVE FIT FOR 150' DH**

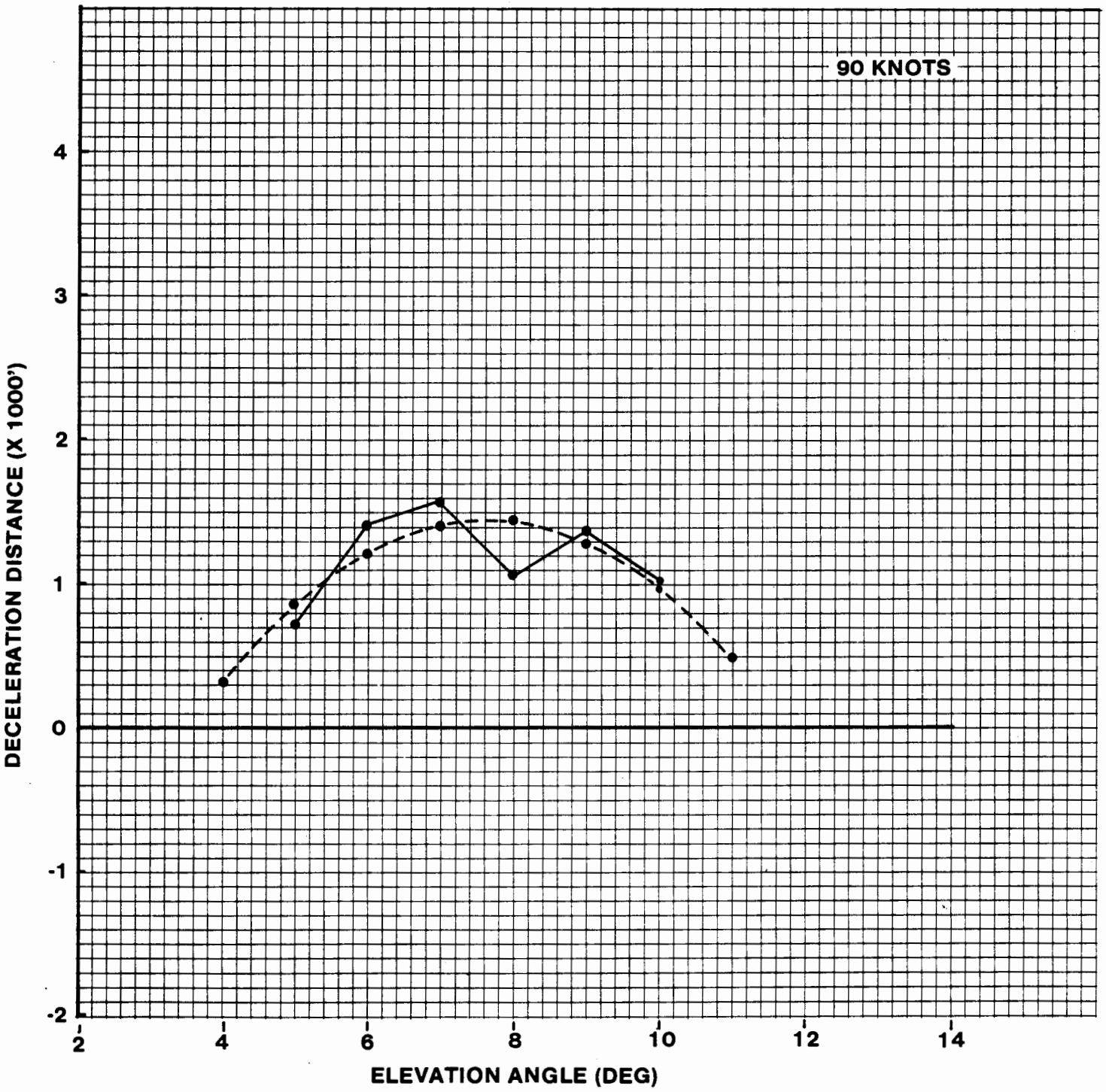


**FIGURE 15**
**MEAN DECELERATION DISTANCE BEYOND THE COLLOCATED ANTENNA SYSTEM AND SECOND ORDER CURVE FIT FOR 150' DH**

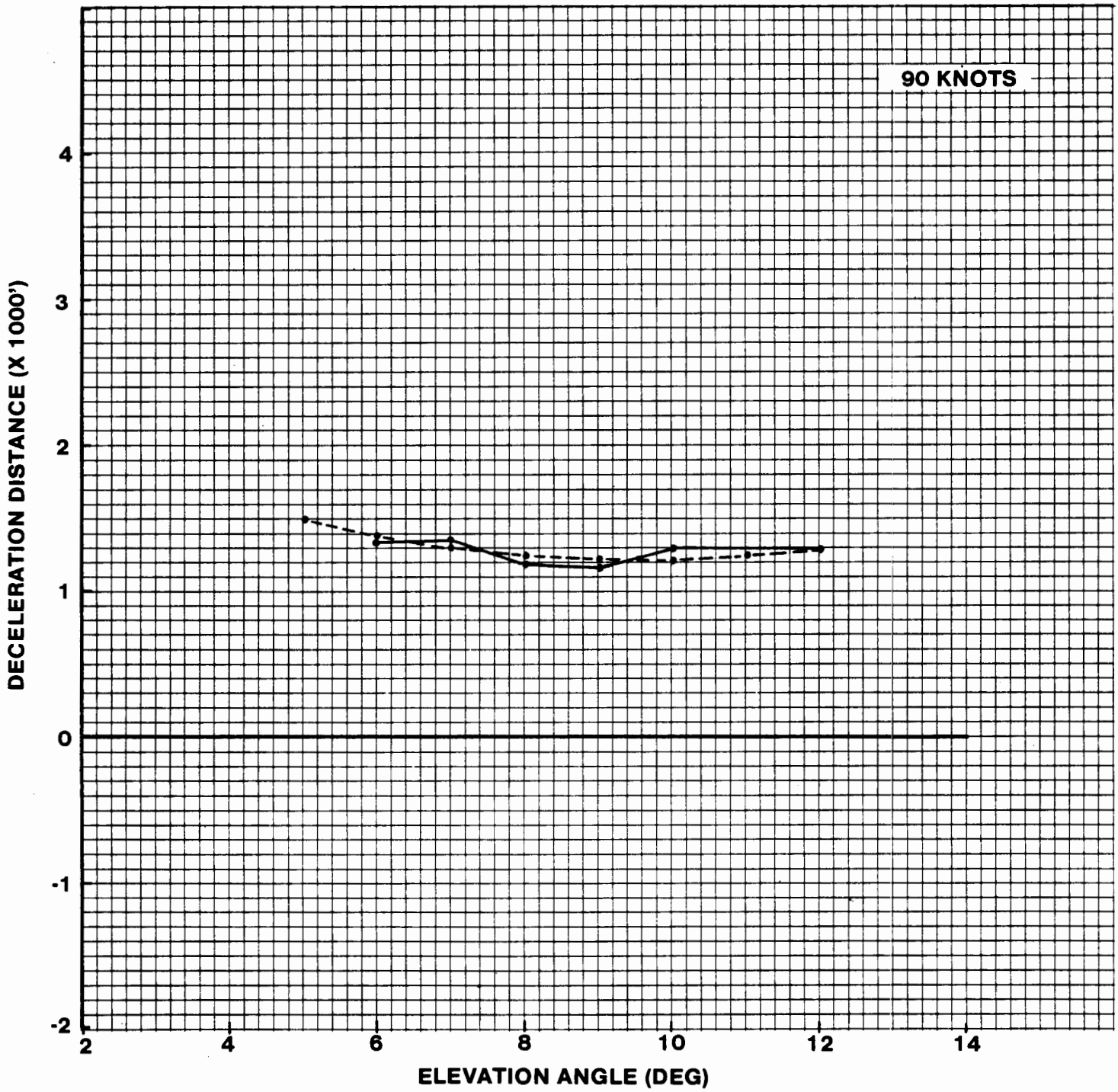


**FIGURE 16**
**MEAN DECELERATION DISTANCE BEYOND THE COLLOCATED ANTENNA SYSTEM AND SECOND ORDER CURVE FIT FOR 200' DH**

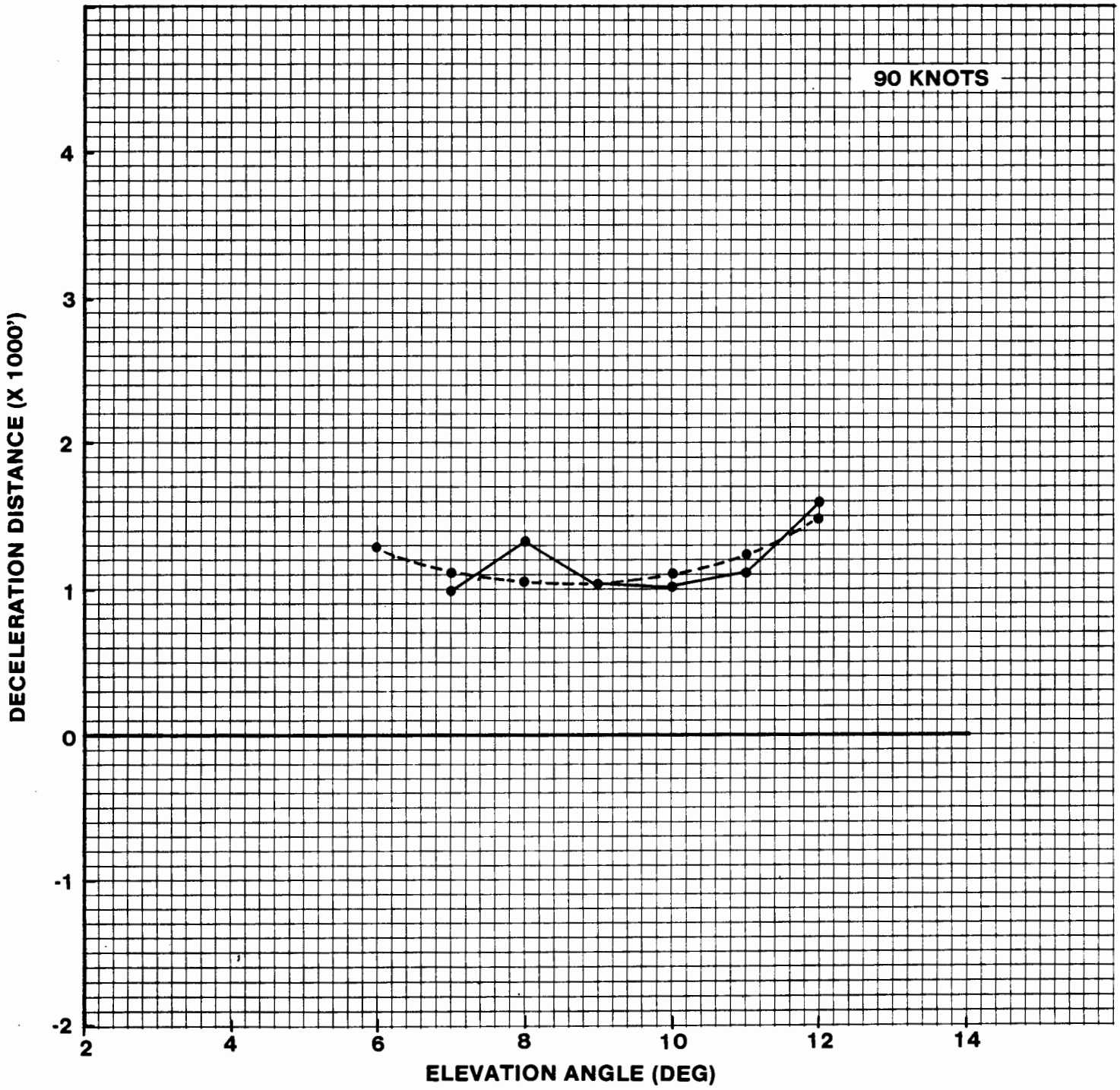


FIGURE 17
MEAN DECELERATION DISTANCE BEYOND THE COLLOCATED ANTENNA SYSTEM AND SECOND ORDER CURVE FIT FOR 50' DH

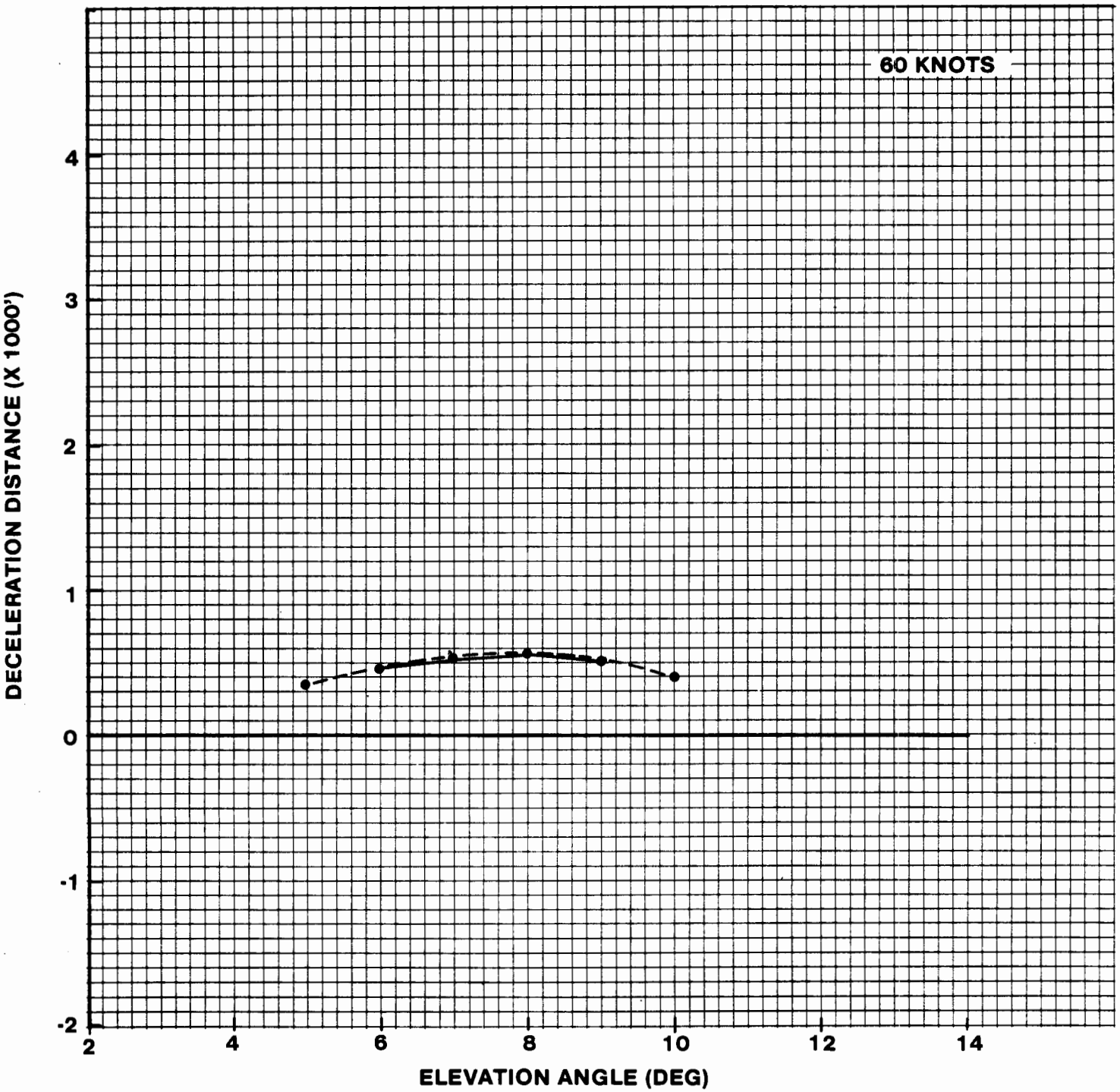


**FIGURE 18**
**MEAN DECELERATION DISTANCE BEYOND THE COLLOCATED ANTENNA SYSTEM AND SECOND ORDER CURVE FIT FOR 100' DH**

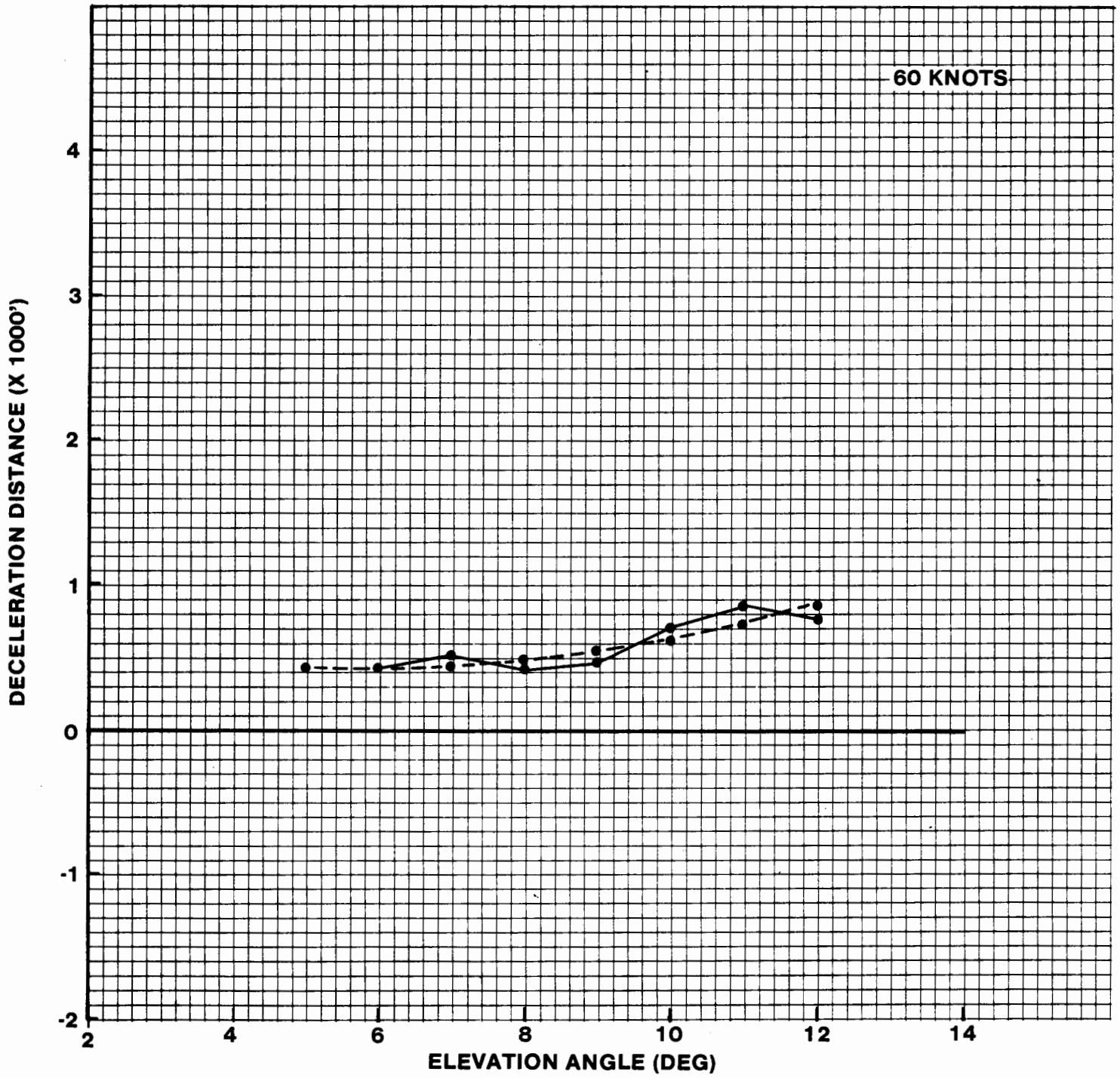


**FIGURE 19**
**MEAN DECELERATION DISTANCE BEYOND THE COLLOCATED ANTENNA SYSTEM AND SECOND ORDER CURVE FIT FOR 150' DH**

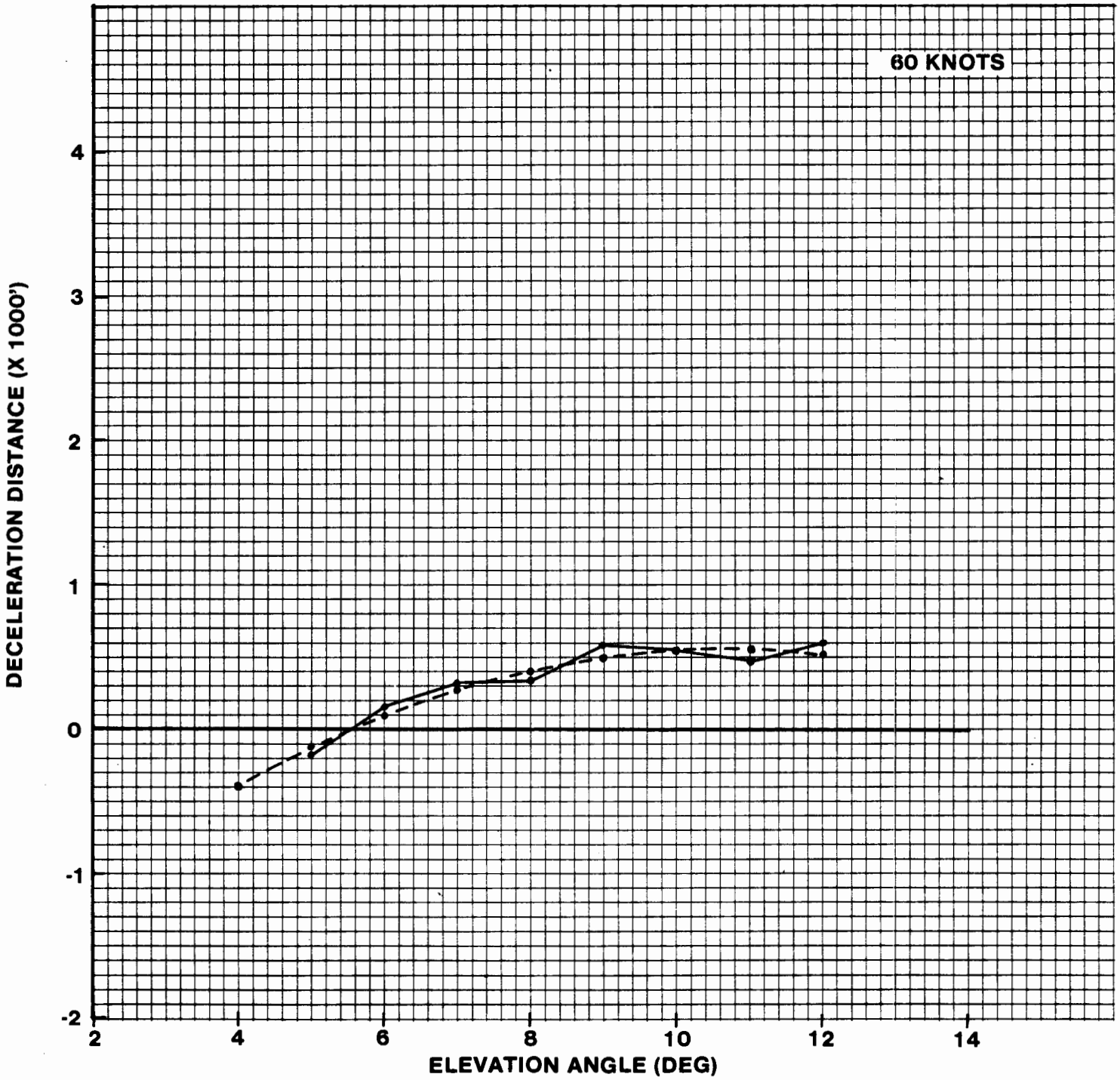


**FIGURE 20**
**MEAN DECELERATION DISTANCE BEYOND THE COLLOCATED ANTENNA SYSTEM AND SECOND ORDER CURVE FIT FOR 200' DH**

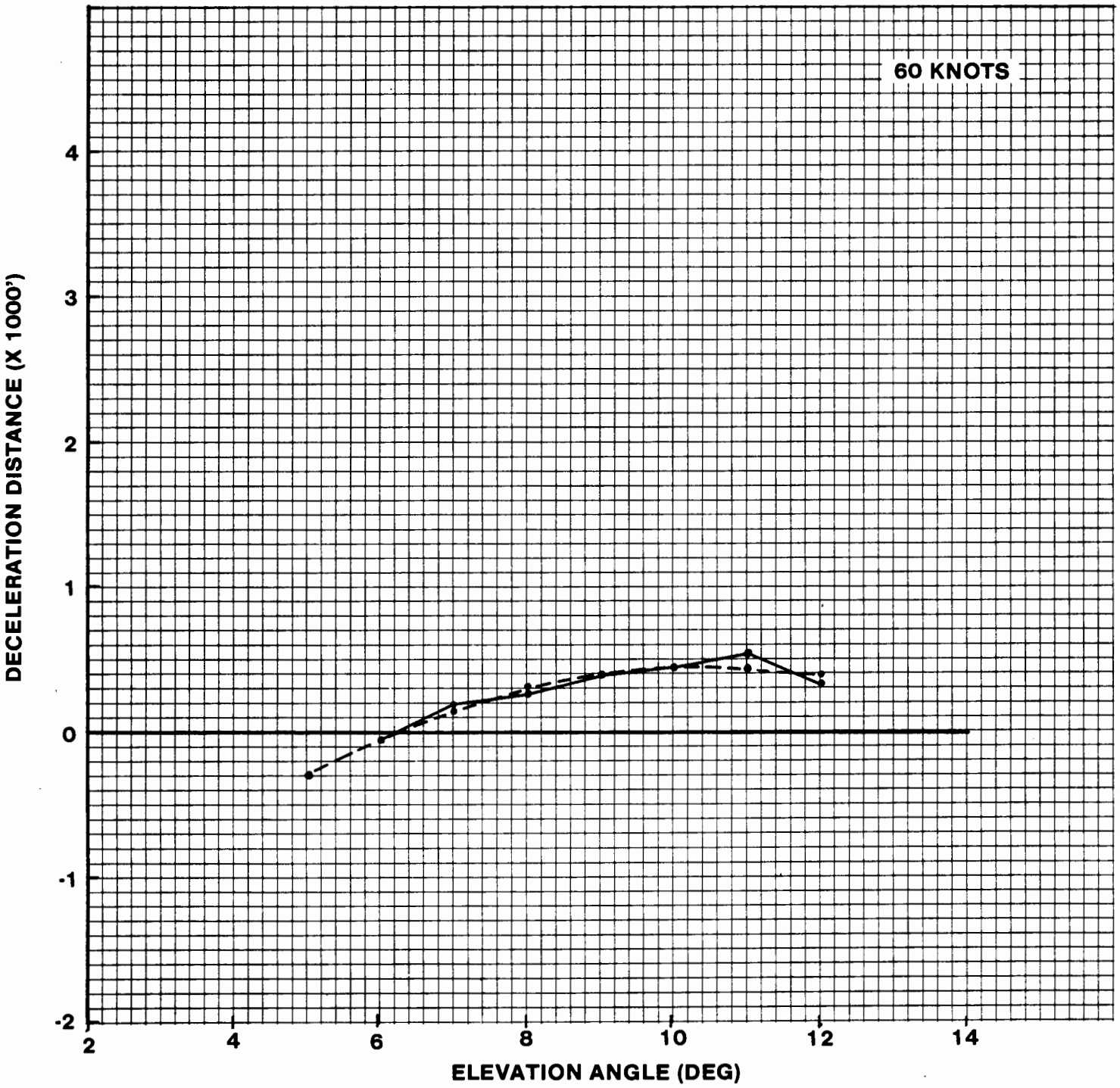


TABLE 9. SECOND ORDER CURVE FIT EQUATIONS

Second Order Curve Fit Equations

X = Elevation Angle (Degrees)
Y = Deceleration Distance (Feet)

90 Knots

| DH (Ft) | Equations |
|---|---|
| 50 | $Y = (.14)x^2 + (77.57)x + (1204.89)$ |
| 100 | $Y = (-85.91)x^2 + (1310.60)x - (3559.14)$ |
| 150 | $Y = (12.94)x^2 - (248.90)x + (2413)$ |
| 200 | $Y = (39.02)x^2 - (671.54)x + (3919.29)$ |

60 Knots

| DH (Ft) | Equations |
|---|---|
| 50 | $Y = (-30)x^2 + (461.40)x - (1210)$ |
| 100 | $Y = (10.91)x^2 - (112.71)x + (744.95)$ |
| 150 | $Y = (-21.51)x^2 + (460.54)x - (1902.52)$ |
| 200 | $Y = (-25.95)x^2 + (540.29)x - (2351.76)$ |

FIGURE 21
DISTANCE (FEET) BEYOND COLLOCATED ANTENNA SYSTEM TO TOUCHDOWN FOR 90 KNOT APPROACHES

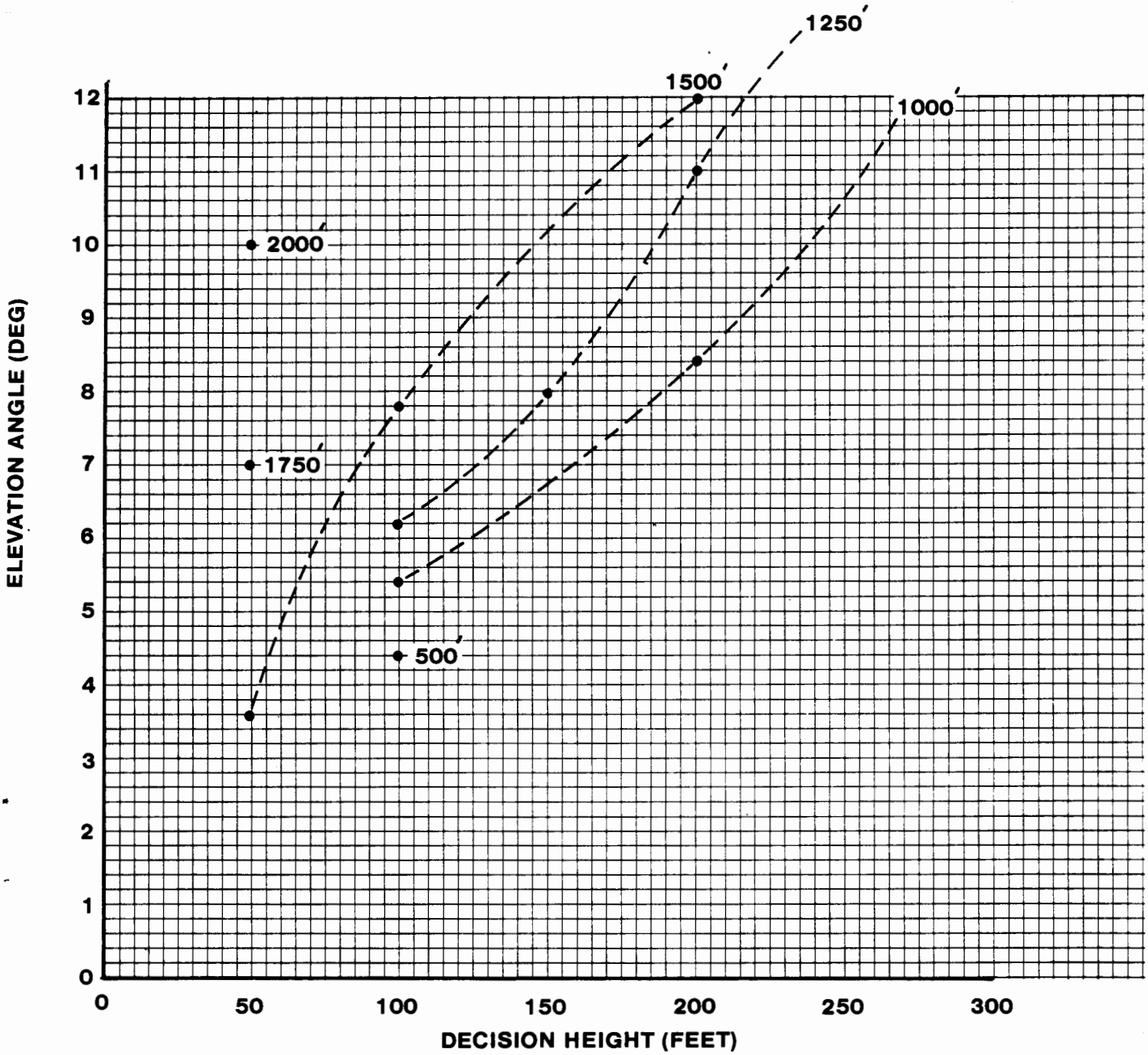
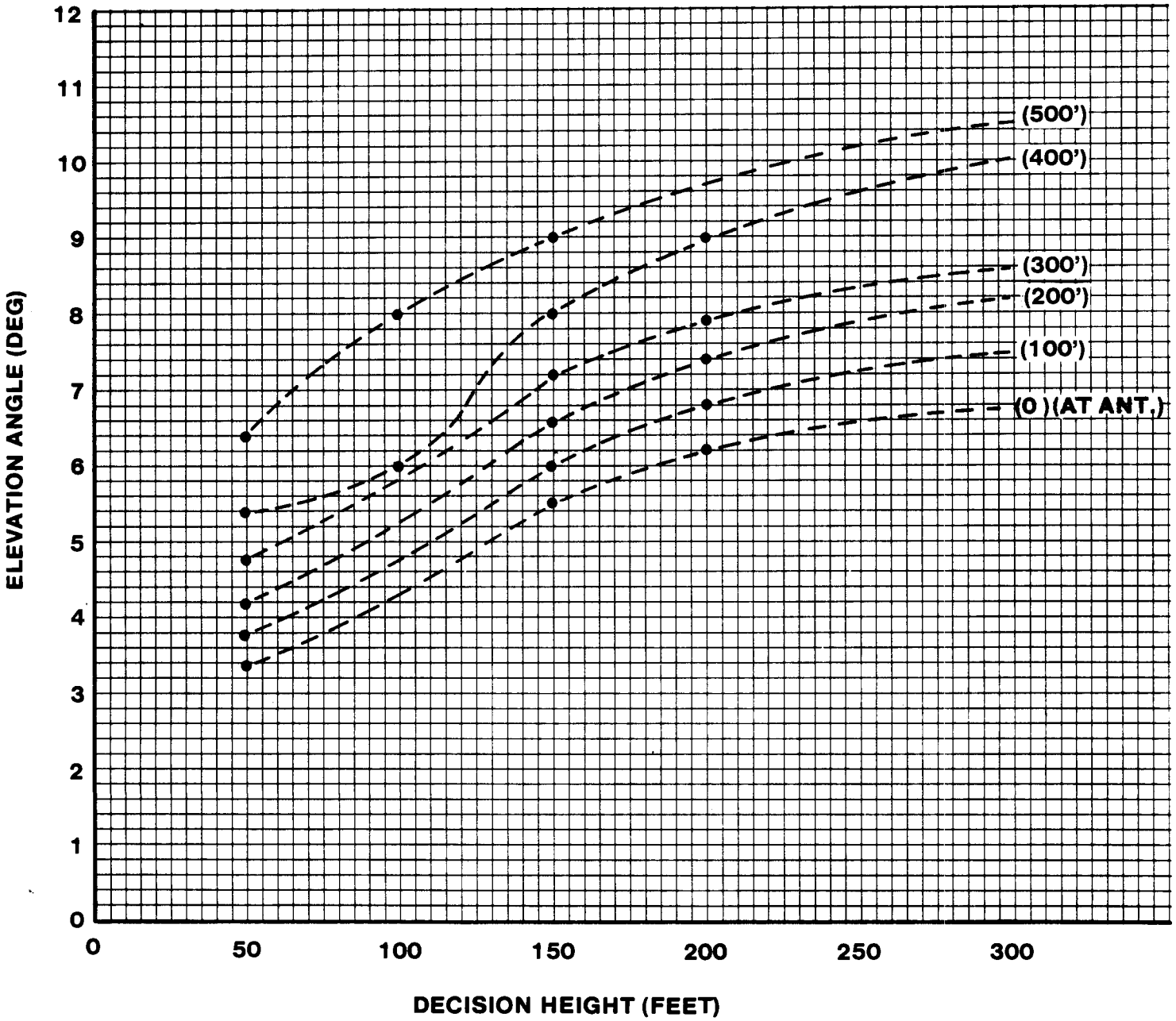


**FIGURE 22**
**DISTANCE (FEET) BEYOND COLLOCATED ANTENNA SYSTEM TO TOUCHDOWN FOR 60 KNOT APPROACHES**



## 7. CONCLUSIONS.

The recommended range of locations for the Microwave Landing System (MLS) collocated antenna system in relation to a landing pad for precision heliport approaches during IMC for minimally equipped helicopters are shown in figures 23 and 24. Figure 23 shows the relationships using a 90-knot range rate and figure 24 using a 60-knot range rate. Mean deceleration forces of 0.2 G's for 90 knots and 0.17 G's for 60 knots were experienced in this test and for the measured deceleration distance were not uncomfortable. Aircraft mean peak pitch-up attitudes of 13° for 90 knots and 11° for 60 knots were comfortable for pilot and passengers while facilitating a smooth deceleration to the landing zone.

This study did not limit real estate and further testing is recommended using similar flight profiles but more sophisticated cockpit instrumentation (i.e., Flight Director with Horizontal Situation Indicator) to lower the minimum decision height (DH) altitude using the steeper elevation angles.

**FIGURE 23**
**RECOMMENDED RANGE OF LOCATIONS AT OR IN FRONT OF THE LANDING PAD FOR THE COLLOCATED MLS ANTENNA SYSTEM AS A FUNCTION OF ELEVATION ANGLE AND DECISION HEIGHT FOR 90 KNOT RANGE RATE APPROACHES**

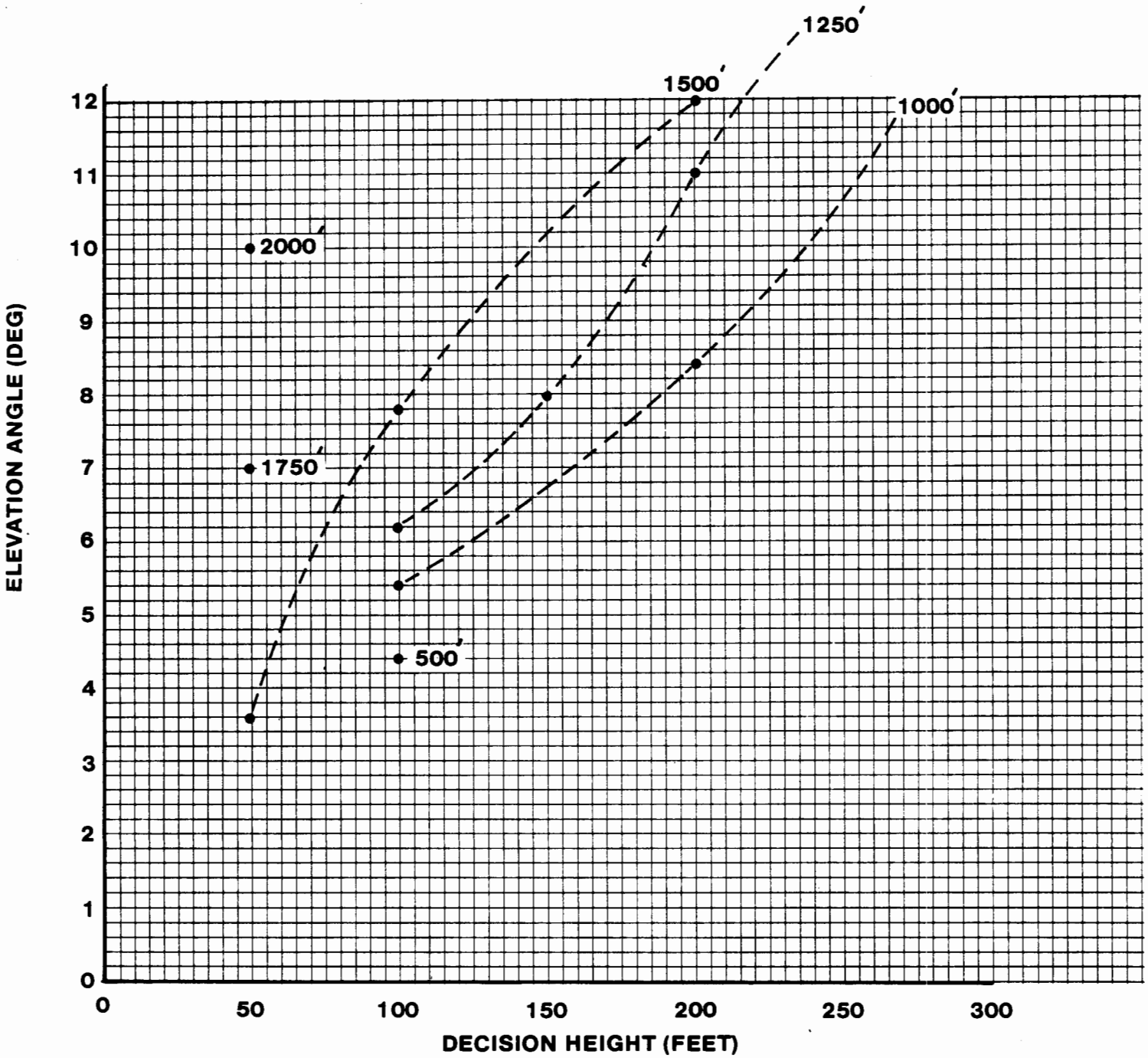
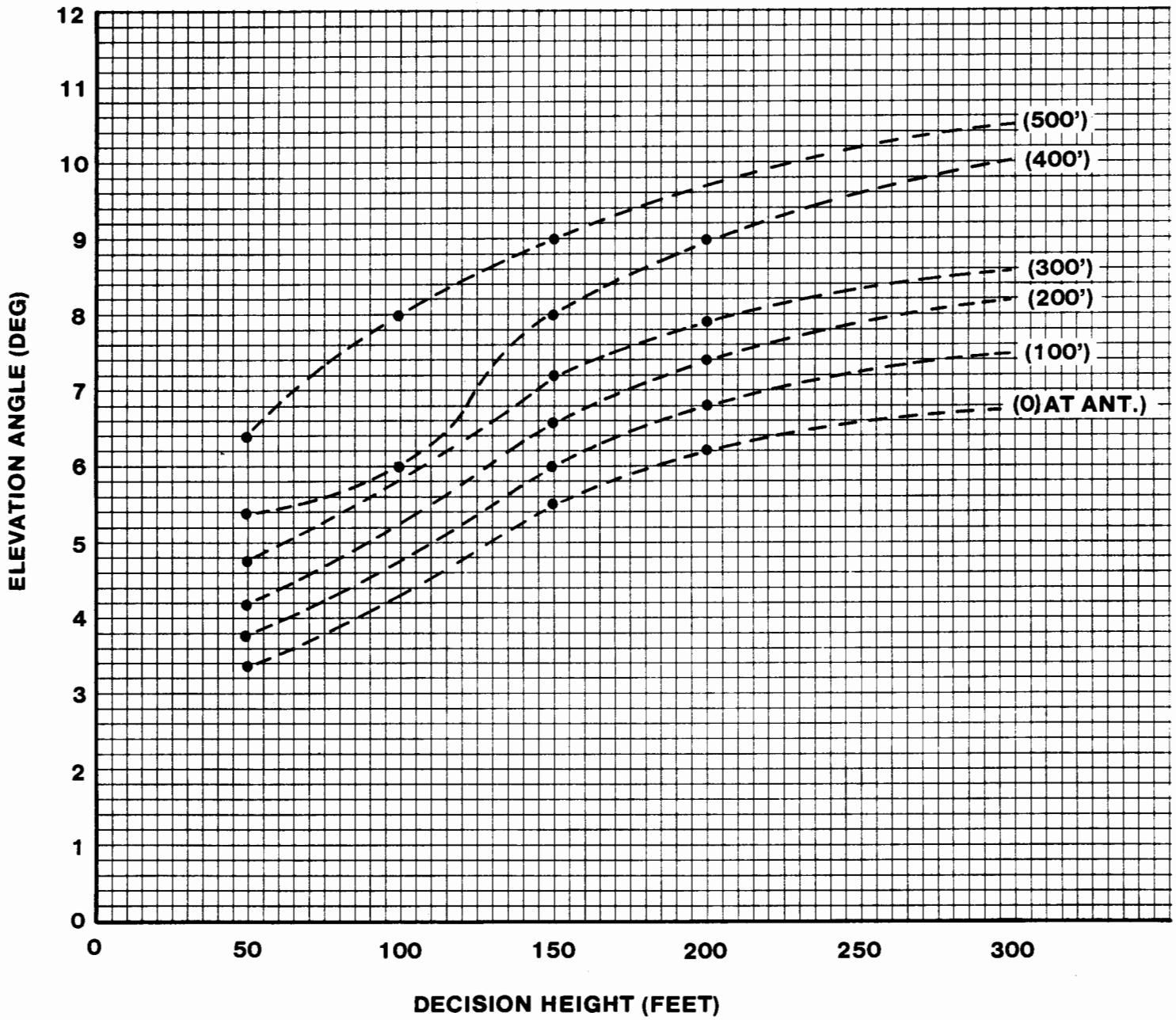


**FIGURE 24**
**RECOMMENDED RANGE OF LOCATIONS AT OR IN FRONT OF THE LANDING PAD FOR THE COLLOCATED MLS ANTENNA SYSTEM AS A FUNCTION OF ELEVATION ANGLE AND DECISION HEIGHT FOR 60 KNOT RANGE RATE APPROACHES**



# APPENDIX A

# ACCUMULATED PROFILES

TABLE A1

SUBJECT PILOT #1 ACCUMULATED PROFILES

| | 1/28/82 AM | 2/22/82 AM | 2/22/82 PM |
|---|---|---|---|
| 1 | FAM | FAM | 6° 90k 150' |
| 2 | MA | 5° 90k 100' | 7° 90k 150' |
| 3 | MA | 6° 90k 100' | 8° 90k 150' |
| 4 | MA | 7° 90k 100' | 9° 90k 150' |
| 5 | 5° 90k 50' | 8° 90k 100' | 7° 60k 150' |
| 6 | 6° 90k 50' | 9° 90k 100' | 8° 60k 150' |
| 7 | MA | 6° 60k 100' | 8° 60k 150' |
| 8 | 6° 60k 50' | 7° 60k 100' | 9° 60k 150' |
| 9 | 7° 60k 50' | MA | 10° 60k 150' |
| 10 | 8° 60k 50' | 8° 60k 100' | 11° 60k 150' |
| 11 | MA | 9° 60k 100' | 12° 60k 150' |
| 12 | Visual 7° | Visual 5° | 7° 90k 200' |
| 13 | | | 8° 90k 200' |
| 14 | | | 7° 60k 200' |
| 15 | | | 9° 60k 200' |
| 16 | | | 10° 60k 200' |
| 17 | | | Visual Stp. 9° |
| 18 | | | |
| 20 | | | |

| LIMITS | 50' | 100' | 150' | 200' |
|---|---|---|---|---|
| 90k | 7° | 8° | 8° | 7° |
| 60k | 9° | 8° | 10° | 10° |

TABLE A2

SUBJECT PILOT #2 ACCUMULATED PROFILES

| | 1/25/82 AM | 1/26/82 AM | 1/26/82 PM |
|---|---|---|---|
| 1 | 3° 90k 50' | 5° 90k 100' | 8° 90k 150' |
| 2 | 4° 90k 50' | 6° 90k 100' | MA |
| 3 | MA | 7° 90k 100' | 10° 90k 150' |
| 4 | 6° 90k 50' | 8° 90k 100' | 12° 90k 150' |
| 5 | 6° 90k 50' | 9° 90k 100' | 10° 60k 150' |
| 6 | 7° 60k 50' | 8° 60k 100' | 12° 60k 150' |
| 7 | 8° 60k 50' | MA | 8° 90k 200' |
| 8 | 9° 60k 50' | 10° 60k 100' | 10° 90k 200' |
| 9 | MA | 11° 60k 100' | MA |
| 10 | Visual 8°/7° | 12° 60k 100' | 8° 60k 200' |
| 11 | | Visual 6° | 10° 60k 200' |
| 12 | | | 12° 60k 200' |
| 13 | | | Visual Stp' |
| 14 | | | |
| 15 | | | |
| 16 | | | |
| 17 | | | |
| 18 | | | |
| 19 | | | |
| 20 | | | |

| LIMITS | 50' | 100' | 150' | 200' |
|---|---|---|---|---|
| 90k | 6° | 9° | 12° | 10° |
| 60k | 10° | 12° | 12° | 12° |

TABLE A3

SUBJECT PILOT #3 ACCUMULATED PROFILES

| | 2/11/82 am | 3/12/82 am | 4/29/82 pm |
|---|---|---|---|
| 1 | FAM | FAM | FAM |
| 2 | FAM | 6° 90k 100' | FAM |
| 3 | FAM | 7° 90k 100' | 6° 60k 150' |
| 4 | FAM | 7° 90k 100' | 7° 60k 100' |
| 5 | 4° 90k 50' | MA | 8° 60k 150' |
| 6 | 5° 90k 50' | 6° 60k 100' | 9° 60k 150' |
| 7 | 6° 90k 50' | 7° 60k 100' | 10° 60k 150' |
| 8 | 7° 90k 50' | 8° 60k 100' | 7° 90k 200' |
| 9 | 6° 60k 50' | 9° 60k 100' | 8° 90k 200' |
| 10 | 7° 60k 50' | 10° 60k 100' | 9° 90k 200' |
| 11 | 8° 60k 50' | 6° 90k 150' | 7° 60k 200' |
| 12 | | 7° 90k 150' | 8° 60k 200' |
| 13 | | 8° 90k 150' | 9° 60k 200' |
| 14 | | NO DATA | 10° 60k 200' |
| 15 | | 7° 60k 150' | Visual Stp 7° |
| 16 | | Visual 6° | |
| 17 | | | |
| 18 | | | |
| 19 | | | |
| 20 | | | |

| LIMITS | 50' | 100' | 150' | 200' |
|---|---|---|---|---|
| 90k | 7° | 7° | 9° | 8° |
| 60k | 8° | 9° | 9° | 9° |

TABLE A4

SUBJECT PILOT #4 ACCUMULATED PROFILES

| | 2/29/82 AM | 1/29/82 AM |
|---|---|---|
| 1 | FAM | MA |
| 2 | FAM | MA |
| 3 | FAM | 4° 60k 150' |
| 4 | FAM | 5° 60k 150' |
| 5 | 3° 90k 100' | MA |
| 6 | MA | MA |
| 7 | MA | 4° 90k 200' |
| 8 | 4° 60k 100' | 5° 90k 200' |
| 9 | MA | 6° 90k 200' |
| 10 | 6° 60k 100' | MA |
| 11 | 7° 60k 100' | 5° 60k 200' |
| 12 | MA | MA |
| 13 | Visual | 6° 60k 200' |
| 14 | | 7° 60k 200' |
| 15 | | 8° 60k 200' |
| 16 | | Visual Stp. |
| 17 | | |
| 18 | | |
| 19 | | |
| 20 | | |

| LIMITS | 50' | 100' | 150' | 200' |
|---|---|---|---|---|
| 90k | 4° | | 5° | 7° |
| 60k | 3° | 8° | 7° | 8° |

TABLE A5

SUBJECT PILOT #5 ACCUMULATED PROFILES

| | 2/12/82 AM | 3/23/82 AM | 3/11/82 AM | 3/11/82 PM |
|---|---|---|---|---|
| 1 | FAM | FAM | FAM | 7° 90k 200' |
| 2 | FAM | FAM | MA | 8° 90k 200' |
| 3 | FAM | 5° 90k 100' | MA | MA |
| 4 | 3° 90k 50' | 6° 90k 100' | 7° 90k 150' | 9° 90k 200' |
| 5 | MA | 7° 90k 100' | 8° 90k 150' | 10° 90k 200' |
| 6 | 5° 90k 50' | 6° 60k 100' | MA | 7° 60k 200' |
| 7 | 6° 90k 50' | MA | 6° 60k 150' | 8° 60k 200' |
| 8 | MA | 8° 60k 100' | MA | 9° 60k 200' |
| 9 | MA | MA | MA | MA |
| 10 | 7° 60k 50' | MA | MA | 11° 60k 200' |
| 11 | MA | MA | 8° 60k 150' | Visual 5° |
| 12 | Visual 8° | 6° 90k 100' | 9° 60k 150' | |
| 13 | Visual 7° | Visual Stp 9° | MA | |
| 14 | | | MA | |
| 15 | | | Visual Stp 12 | |
| 16 | | | | |
| 17 | | | | |
| 18 | | | | |
| 19 | | | | |
| 20 | | | | |

| LIMITS | 50' | 100' | 150' | 200' |
|---|---|---|---|---|
| 90k | 6° | 6° | 8° | 9° |
| 60k | 8° | 9° | 10° | 11° |

TABLE A6

SUBJECT PILOT #6 ACCUMULATED PROFILES

| | 2/23/82 AM | 2/24/82 AM | 2/24/82 PM | 3/03/82 AM | 3/3/82 AM |
|---|---|---|---|---|---|
| 1 | FAM | FAM | 6° 90k 100' | FAM | FAM |
| 2 | FAM | FAM | 7° 90k 100' | FAM | FAM |
| 3 | FAM | FAM | 8° 90k 100' | 7° 60k 100' | 9° 90k 100' |
| 4 | MA | 7° 90k 50' | 9° 90k 100' | 8° 60k 100' | 10' 90k 150' |
| 5 | 4° 90k 50' | MA | 10° 90k 100' | 9° 60k 100' | 11° 90k 150' |
| 6 | 5° 90k 50' | 9° 90k 50' | 11° 90k 100' | 10° 60k 100' | 12° 90k 150' |
| 7 | 6° 90k 50' | MA | 12° 90k 100' | 11° 60k 100' | 9° 60k 150' |
| 8 | 7° 90k 50' | MA | 7° 60k 100 | 12° 60k 100' | 11° 60k 150' |
| 9 | Visual 6° | MA | | 7° 90k 150' | 12° 60k 150' |
| 10 | | MA | | MA | 9° 90k 200' |
| 11 | | 6° 60k 50' | | 9° 90k 150' | 11° 90k 200' |
| 12 | | 7° 60k 50' | | 6° Visual | 12° 90k 200' |
| 13 | | 8° 60k 50' | | | 9° 60k 200' |
| 14 | | 9° 60k 50' | | | 11° 60k 200' |
| 15 | | 10° 60k 50' | | | 12° 60k 200' |
| 16 | | MA | | | Visual Stp 10' |
| 17 | | MA | | | |
| 18 | | 11° 60k 50' | | | |
| 19 | | | | | |
| 20 | | | | | |

| LIMITS | 50' | 100' | 150' | 200' |
|---|---|---|---|---|
| 90k | 10° | 12° | 12° | 12° |
| 60k | 11° | 12° | 12° | 12° |

TABLE A7

## SUBJECT PILOT #7 ACCUMULATED PROFILES

| | 2/26/82 pm | 3/02/82 am | 3/03/82 pm | 3/08/82 pm |
|---|---|---|---|---|
| 1 | FAM | FAM | FAM | FAM |
| 2 | FAM | 5° 90k 100' | 7° 90k 150' | MA |
| 3 | FAM | 6° 90k 100' | 8° 90k 150' | 7° 90k 200' |
| 4 | 3° 90k 50' | 7° 90k 100' | 9° 90k 150' | 8° 90k 200' |
| 5 | 4° 90k 50' | 8° 90k 100' | MA | 9° 90k 200' |
| 6 | 5° 90k 50' | MA | 10° 90k 150' | 10° 90k 200' |
| 7 | 6° 90k 50' | 9° 90k 100' | MA | 10° 90k 200' |
| 8 | 7° 90k 50' | 10° 90k 100' | 8° 60k 150' | 11° 90k 200'' |
| 9 | MA | MA | 9° 60k 150' | 12° 90k 200' |
| 10 | MA | 7° 60k 100 | MA | 7° 60k 200' |
| 11 | 6° 60k 50' | 8° 60k 100' | 10° 60k 150' | 8° 60k 200' |
| 12 | 7° 60k 50' | 9° 60k 100' | Visual 7° | 9° 60k 200' |
| 13 | 8° 60k 50' | 10° 60k 100' | | 10° 60k 200' |
| 14 | 9° 60k 200' | Visual Stp 9° | | 11° 60k 200' |
| 15 | MA | | | 12° 60k 200' |
| 16 | Visual 6° | | | Visual Stp 10° |
| 17 | | | | |
| 18 | | | | |
| 19 | | | | |
| 20 | | | | |

| LIMITS | 50' | 100' | 150' | 200' |
|---|---|---|---|---|
| 90k | 8° | 9° | 10° | 12° |
| 60k | 9° | 9° | 9° | 12° |

TABLE A8
SUBJECT PILOT #8 ACCUMULATED PROFILES

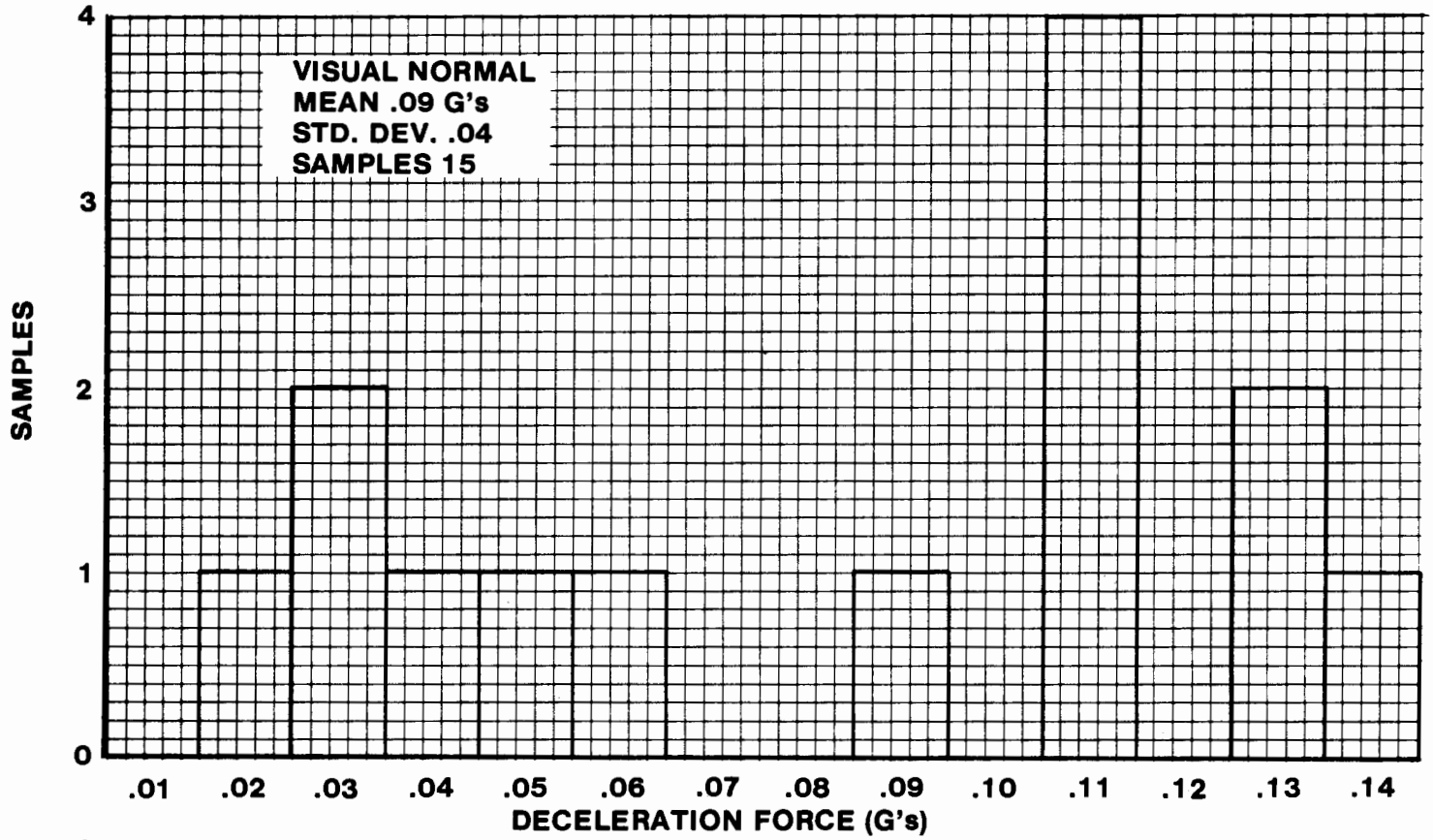
| | 2/11/82 PM | 3/04/82 AM | 3/05/82 PM | 3/08/82 PM |
|---|---|---|---|---|
| 1 | FAM | FAM | FAM | FAM |
| 2 | FAM | FAM | 5° 90k 150' | MA |
| 3 | FAM | FAM | MA | MA |
| 4 | 3° 90k 50' | 4° 90k 100' | 7° 90k 150' | MA |
| 5 | 3° 60k 50' | 5° 90k 100' | 7° 90k 150' | 7° 90k 200' |
| 6 | 4° 60k 50' | 6° 90k 100' | 5° 60k 150' | 8° 90k 200' |
| 7 | 5° 60k 50' | MA | 6° 60k 150' | 9° 90k 200' |
| 8 | MA | 5° 60k 100' | 7° 60k 150' | 6° 60k 200' |
| 9 | 6° 60k 50' | 6° 60k 100' | 7° 60k 150' | 7° 60k 200' |
| 10 | MA | MA | 8° 60k 150' | 8° 60k 200' |
| 11 | Visual Stp 7° | Visual 7° | 9° 60k 150' | 8° 60k 200' |
| 12 | | | Visual Stp 10° | MA |
| 13 | | | | Visual 6° |
| 14 | | | | |
| 15 | | | | |
| 16 | | | | |
| 17 | | | | |
| 18 | | | | |
| 19 | | | | |
| 20 | | | | |

| LIMITS | 50' | 100' | 150' | 200' |
|---|---|---|---|---|
| 90k | 5° | 6° | 7° | 8° |
| 60k | 7° | 6° | 7° | 8° |

# APPENDIX B

## DECELERATION FORCE (G's)

**FIGURE B-1**
**DECELERATION FORCE, (G's) VERSUS SAMPLES FOR VISUAL NORMAL AND VISUAL STEEP APPROACHES**



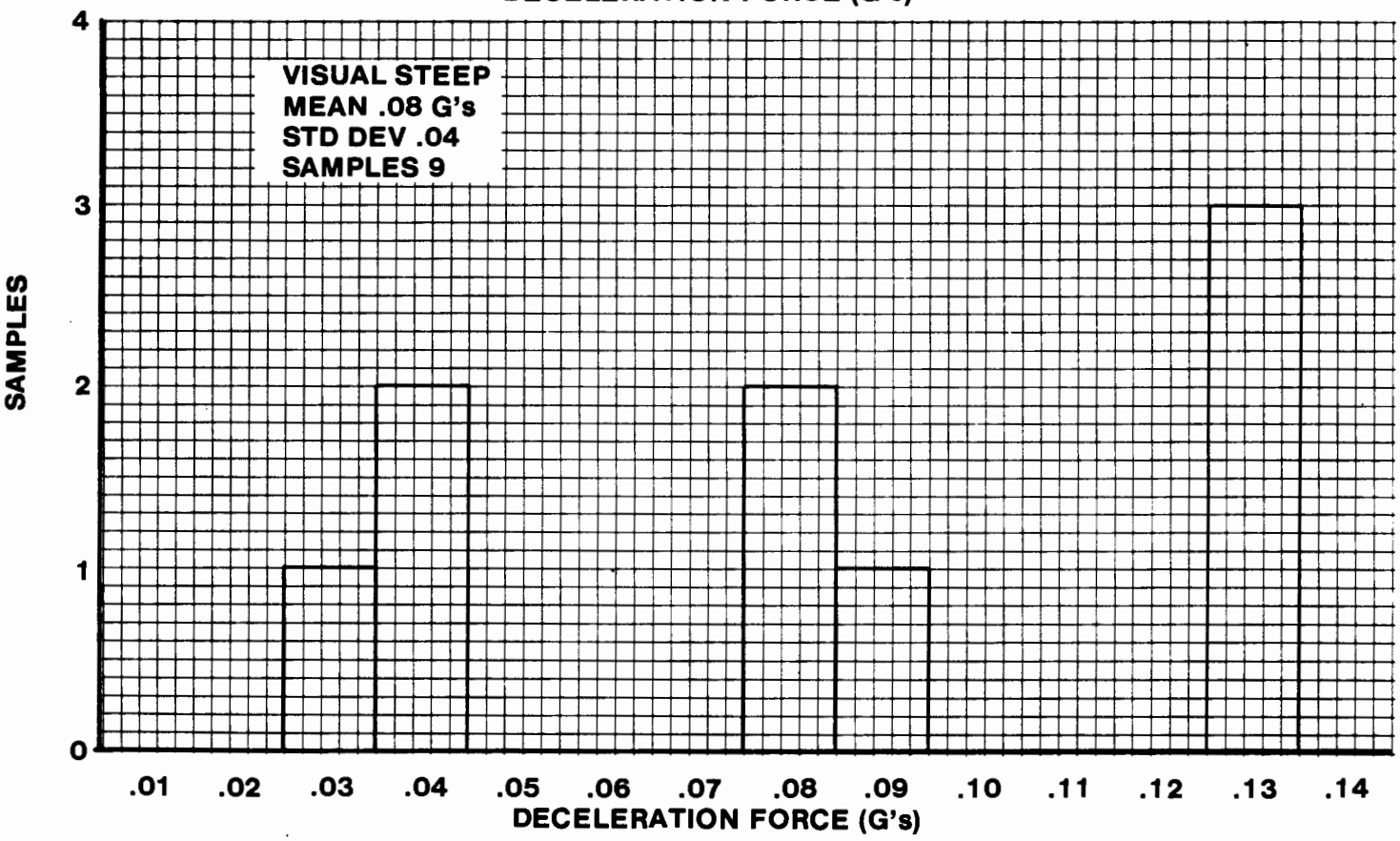
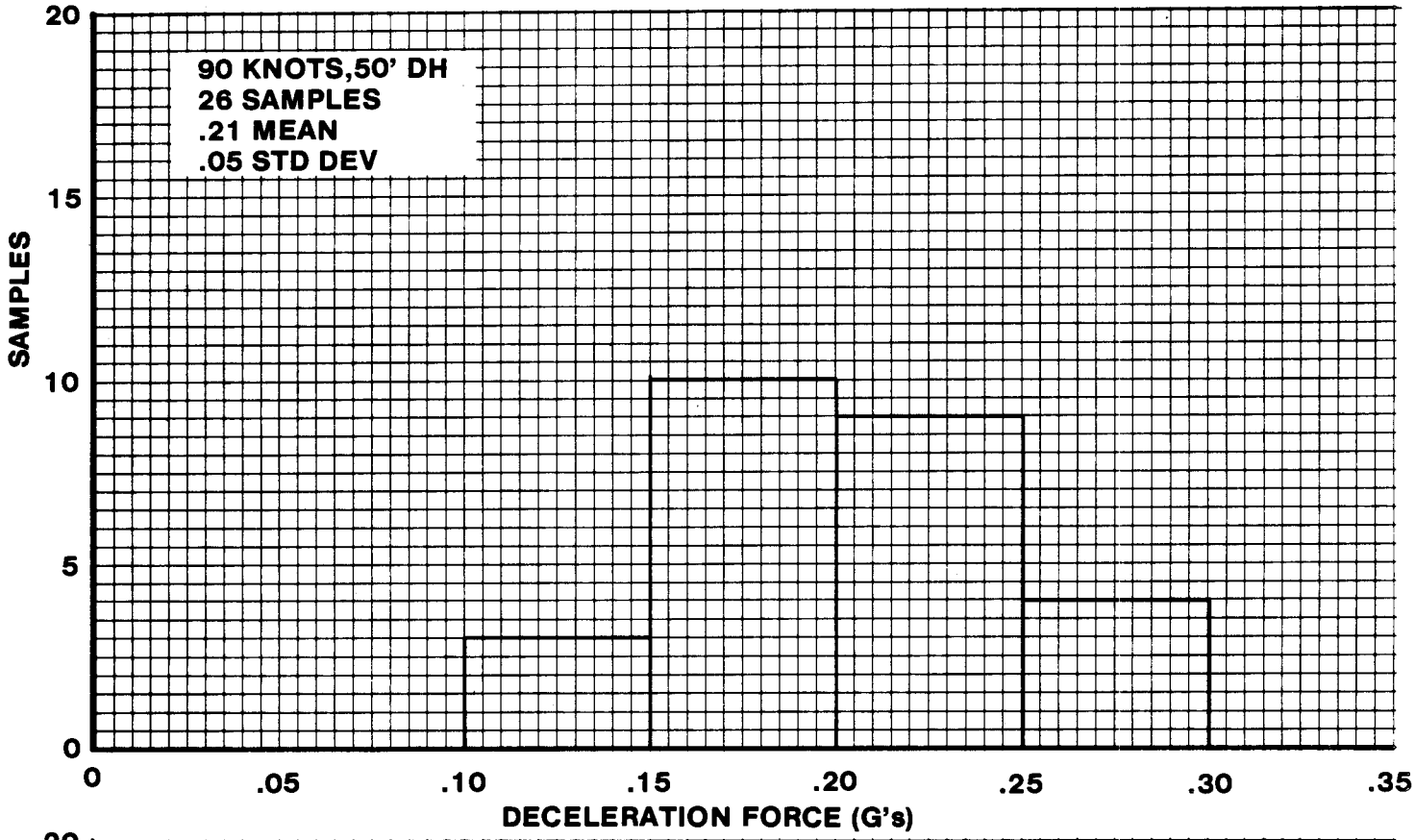



**FIGURE B-2**
**DECELERATION FORCE, (G's) VERSUS SAMPLES FOR 50 FOOT AND 100 FOOT DECISION HEIGHTS AT 90 KNOTS RANGE RATE**



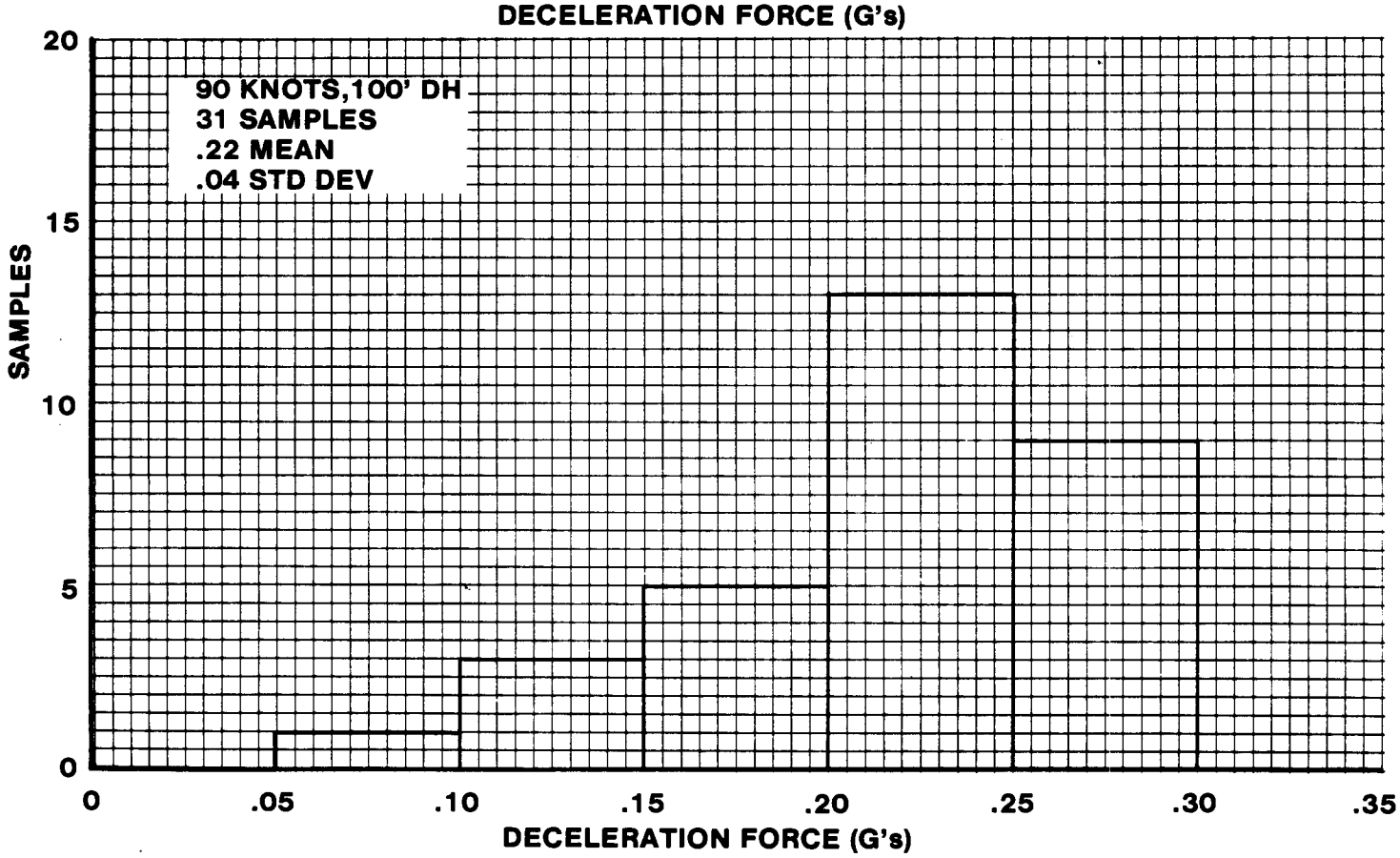
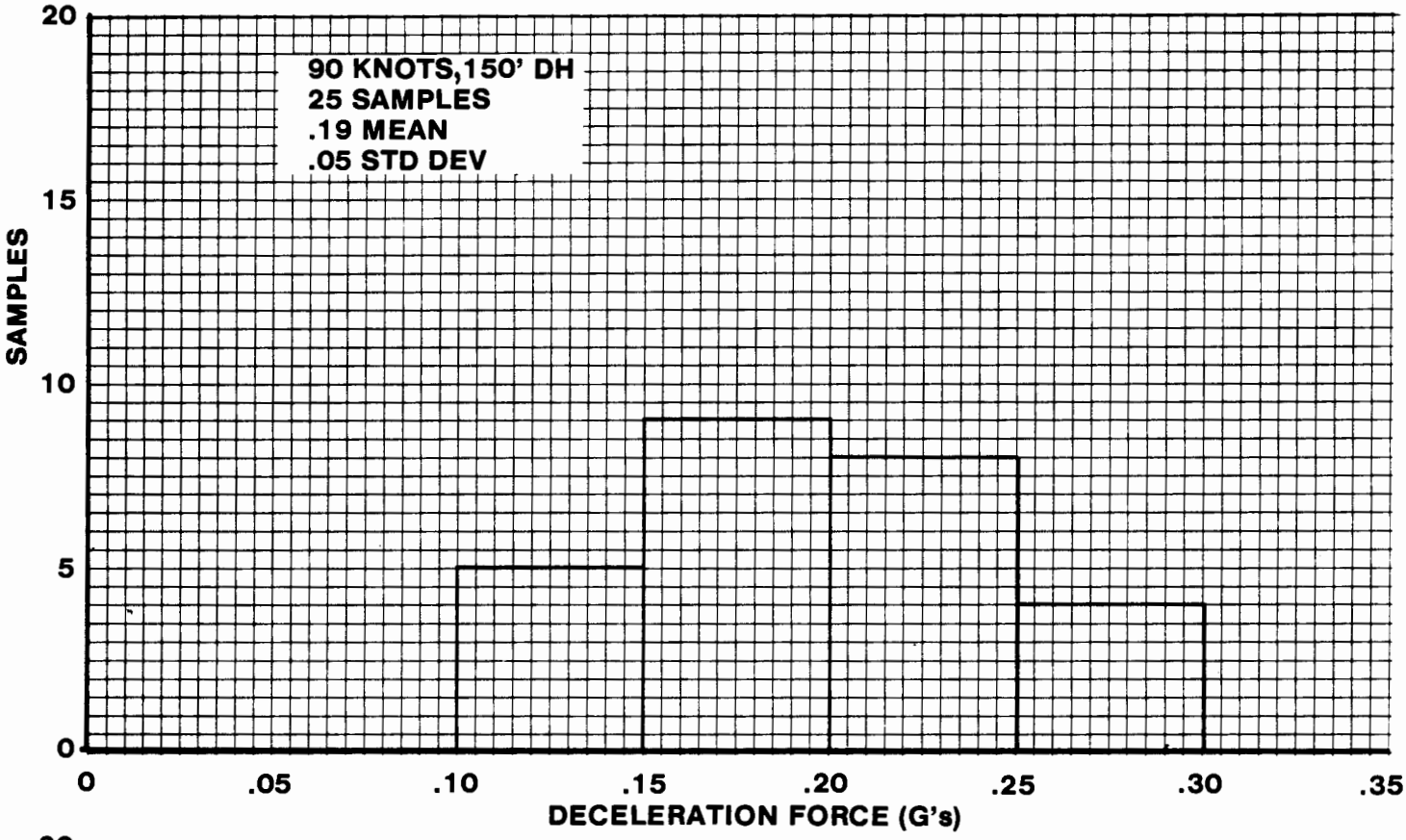



**FIGURE B-3**
**DECELERATION FORCE, (G's) VERSUS SAMPLES FOR 150 FOOT AND 200 FOOT DECISION HEIGHTS AT 90 KNOTS RANGE RATE**



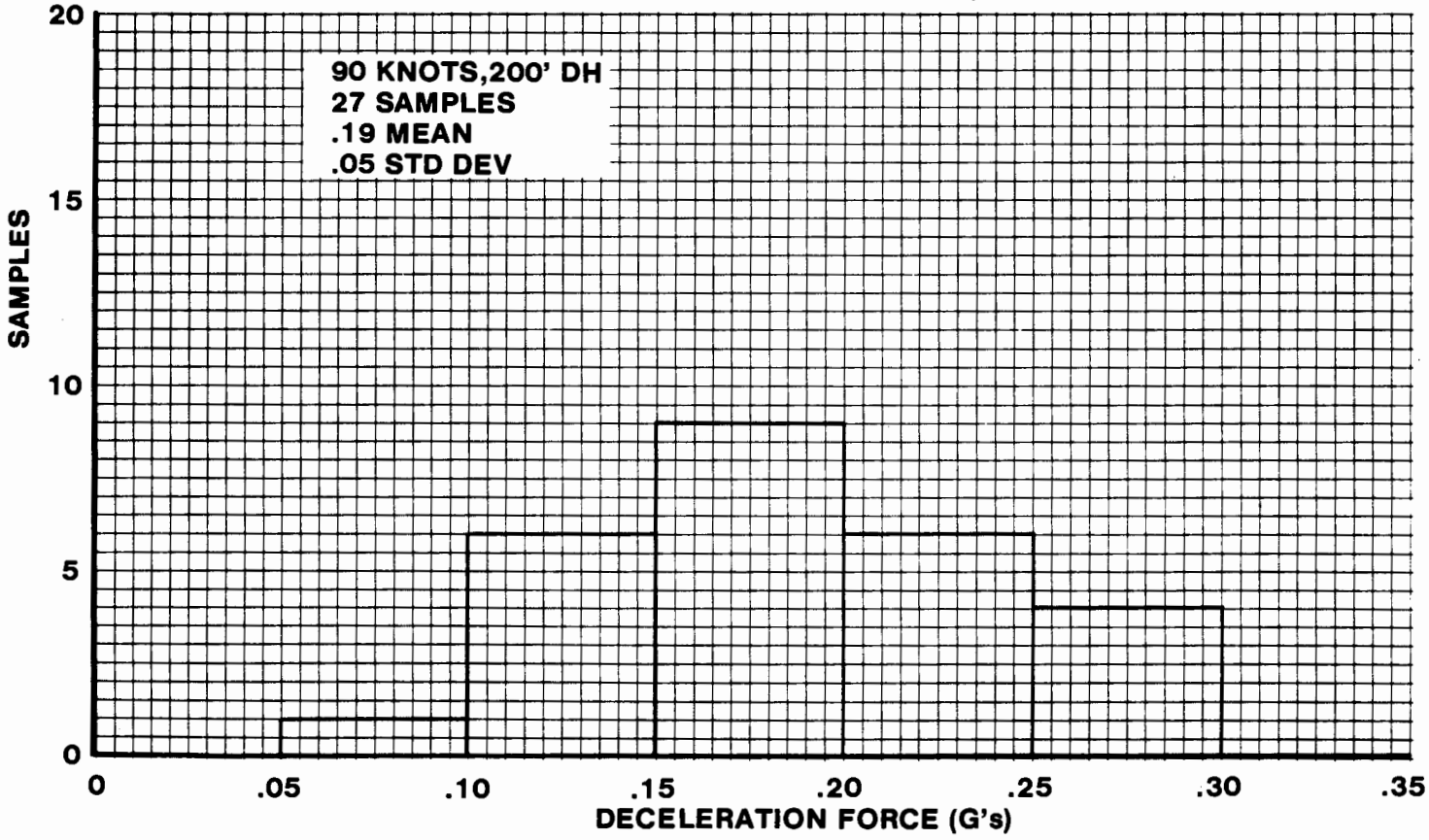
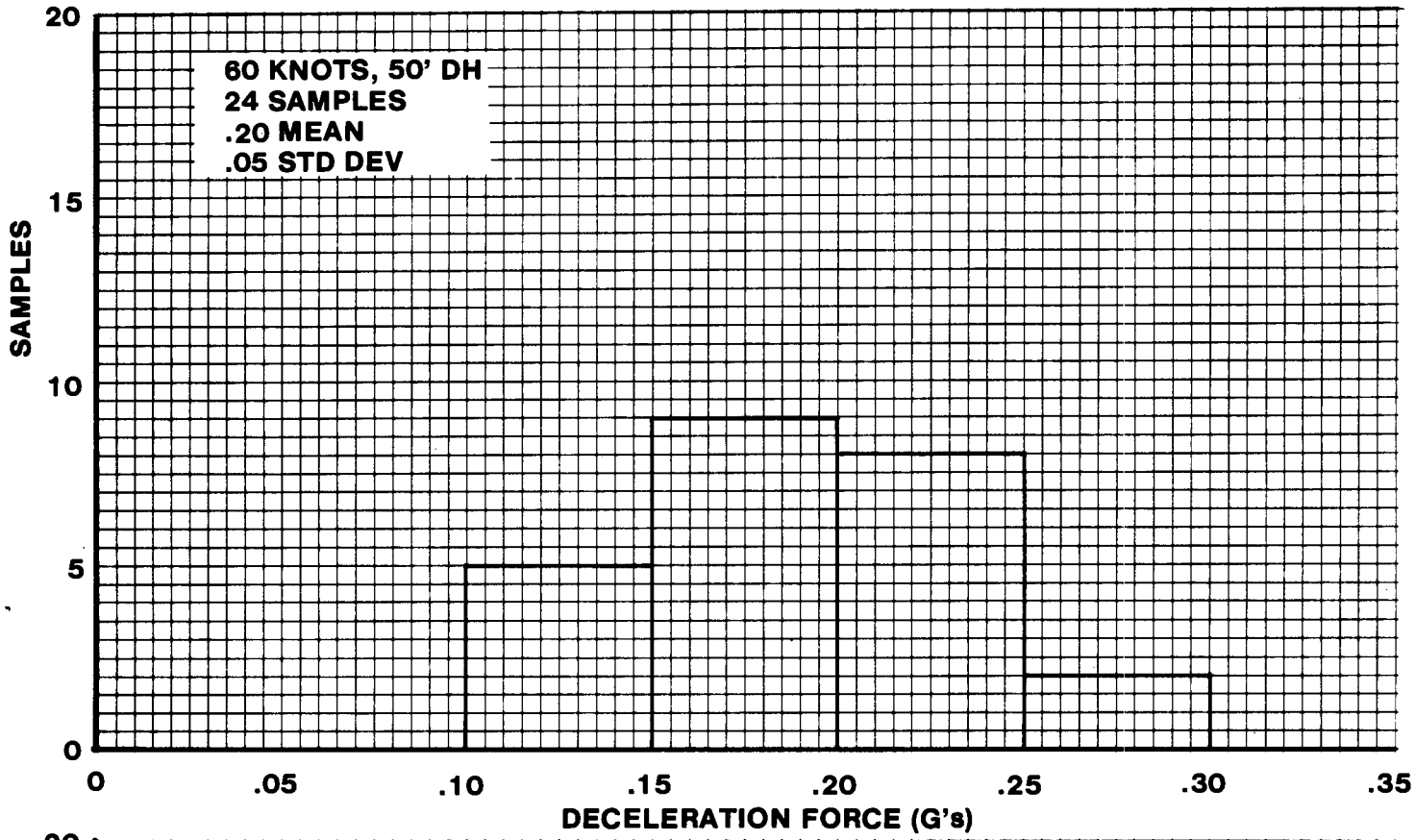



**FIGURE B-4**
**DECELERATION FORCE, (G's) VERSUS SAMPLES FOR 50 FOOT AND 100 FOOT DECISION HEIGHTS AT 60 KNOTS RANGE RATE**



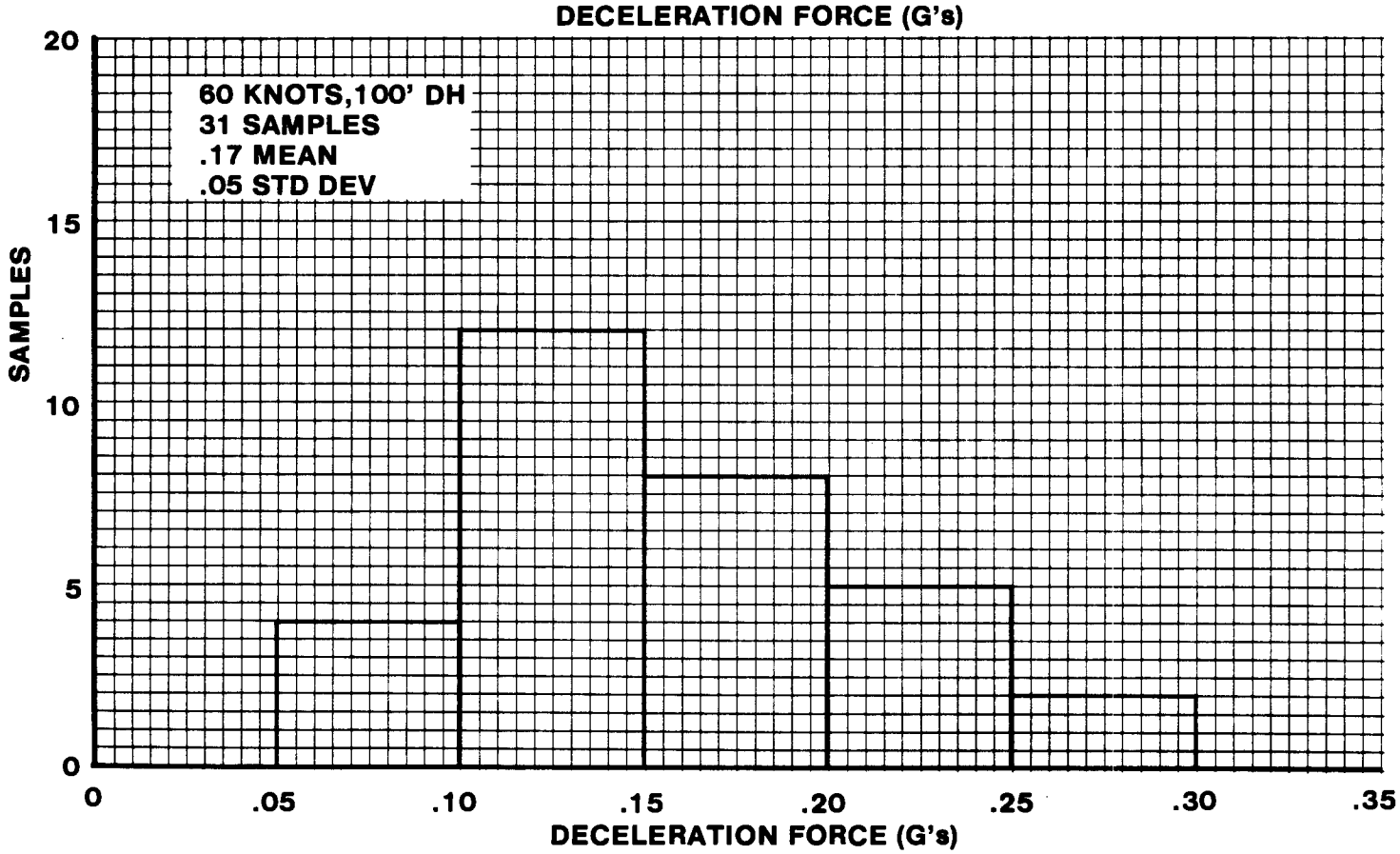
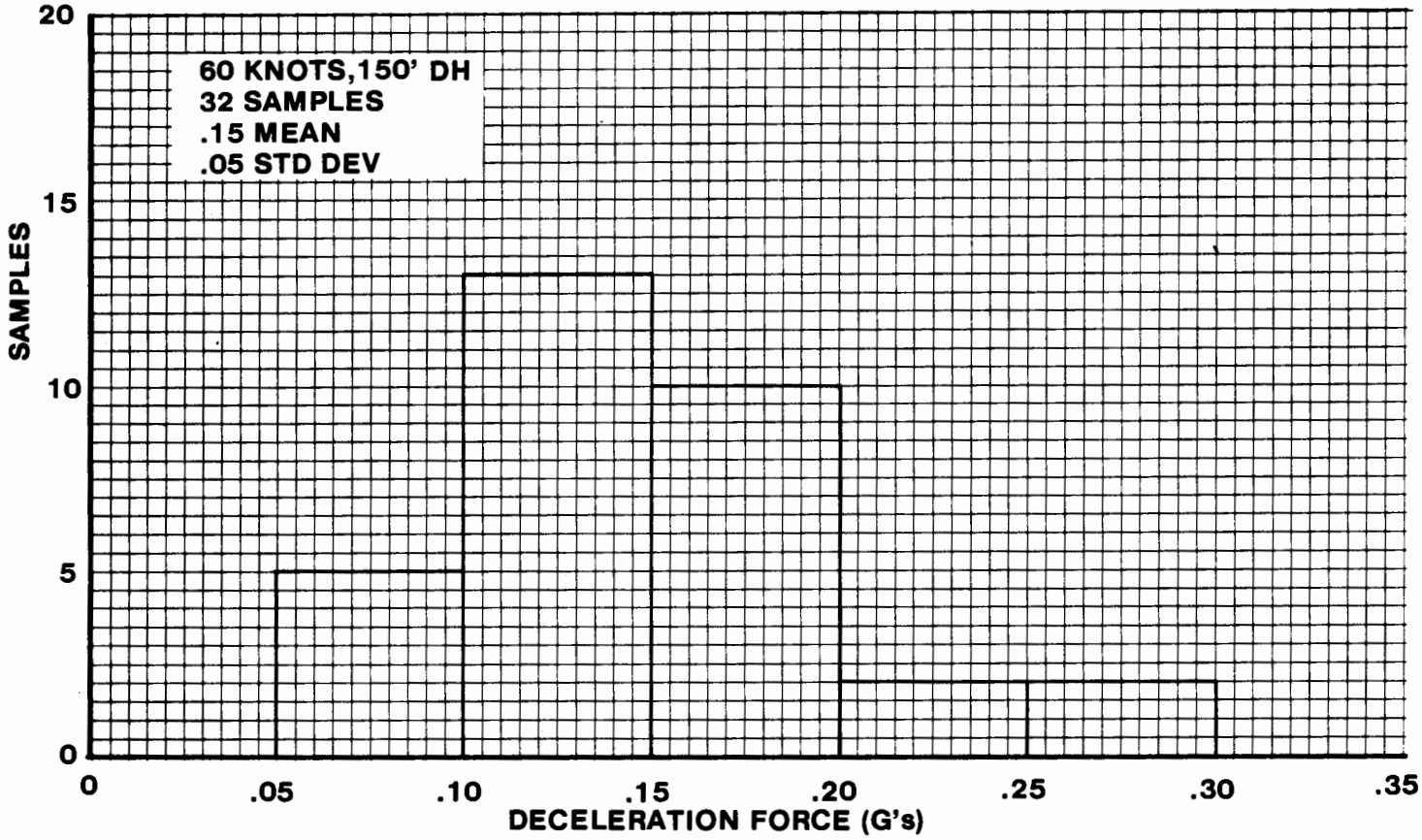
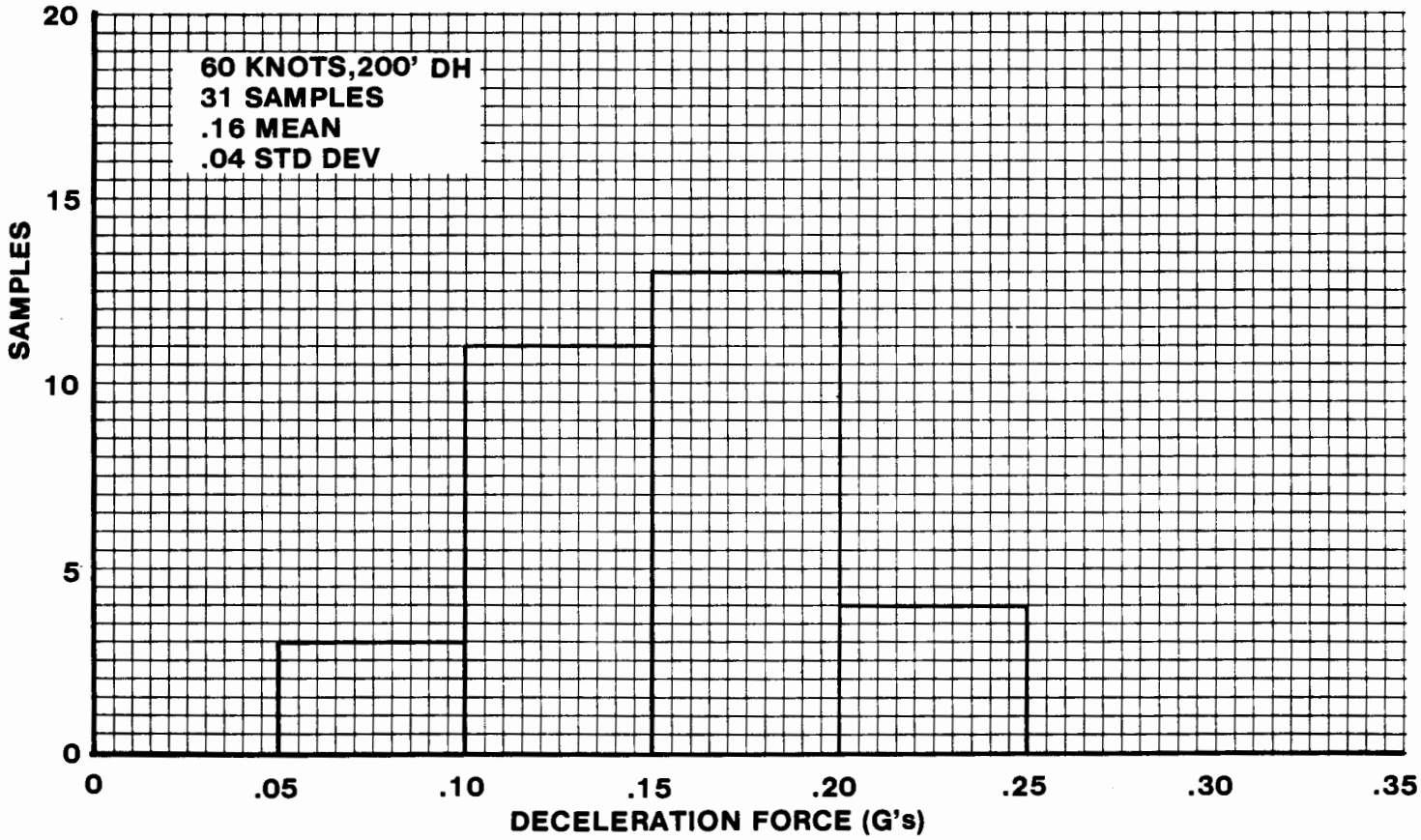



FIGURE B-5
DECELERATION FORCE, (G's) VERSUS
SAMPLES FOR 150 FOOT AND 200 FOOT
DECISION HEIGHTS AT 60 KNOTS RANGE RATE



# APPENDIX C

# UH-1H INSTRUMENT CONSOLE

# AND AIRCRAFT SPECIFICATIONS

Two subject pilots were used to compute the instrument console viewing cutoff angle for the UH-1H helicopter. Radials were measured from the aircraft (as shown in figure C-1) by the subjects in the pilot's seat and the subject pilot's seat. The mean minimum distance to the aircraft which could be viewed along the radials from over the instrument console are recorded in table C-1. These data were plotted in figure C-2 which show a visibility contour for the subject pilot's seat. Using a vertical distance of 6'6" to the subject's eye level, cutoff angles can be computed for the centerline visual clearance and ±37° from centerline visual clearance. The cutoff angles are computed in table C-1 for the pilot's side and subject pilot's side. The mean for the two sets of data was used for the centerline computation of 18°.

Figure C-3 shows the UH-1H physical dimensions and figure C-4 is a copy of the weight and balance specifications of the UH-1H during project data collection.

Figure C-2
UH-1H Instrument Console
Obstruction Clearance Measurements

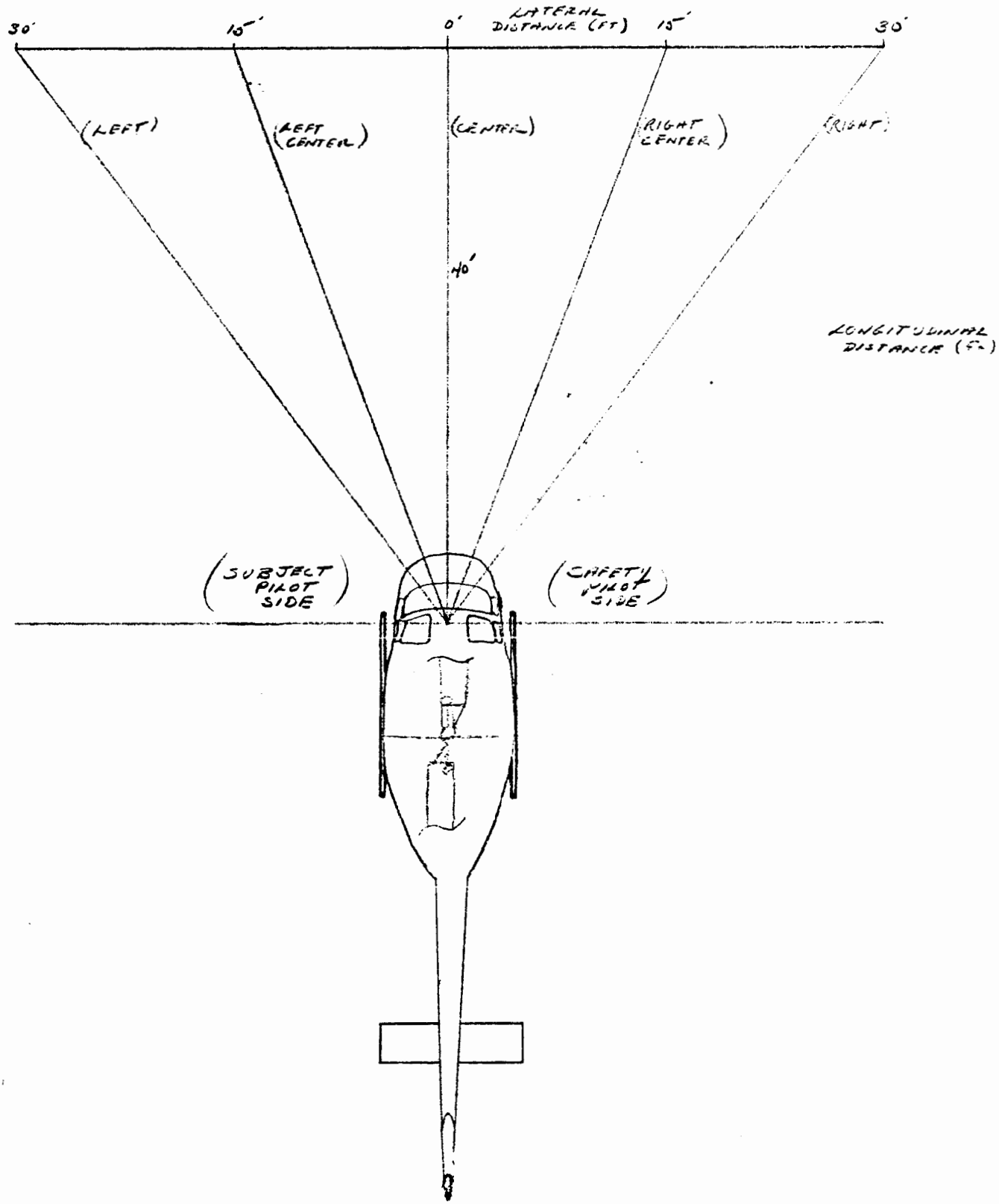


TABLE C-3. UH-1H INSTRUMENT CONSOLE OBSTRUCTION CLEARANCE DATA

| Measurement Position | Mean Dist. From Helo (Ft) | Lateral Dist. From Helo (Ft) | Longitudinal Dist. From Helo (Ft) | Cockpit Cutoff Angle (Deg) |
|---|---|---|---|---|
| Subject Pilot's View | | | | |
| Left | 11.375 | -6.825 | 9.1 | 29.7° |
| Left Center | 13.875 | -4.87 | 12.99 | 25.1° |
| Center | 20.25 | 0 | 20.25 | 17.8° |
| Right Center | 25.5 | 8.95 | 23.88 | 14.3° |
| Right | 30.75 | 18.45 | 24.6 | 11.9° |
| Pilot's View | | | | |
| Left | 29.5 | -17.70 | 23.6 | 12.4° |
| Left Center | 25.625 | - 9.0 | 24.0 | 14.2° |
| Center | 19.875 | 0 | 19.875 | 18.1° |
| Right Center | 13.625 | 4.78 | 12.76 | 25.5° |
| Right | 11.375 | 6.825 | 9.1 | 29.7° |

Figure C-4
UH-1H Instrument Console
Obstruction Clearance

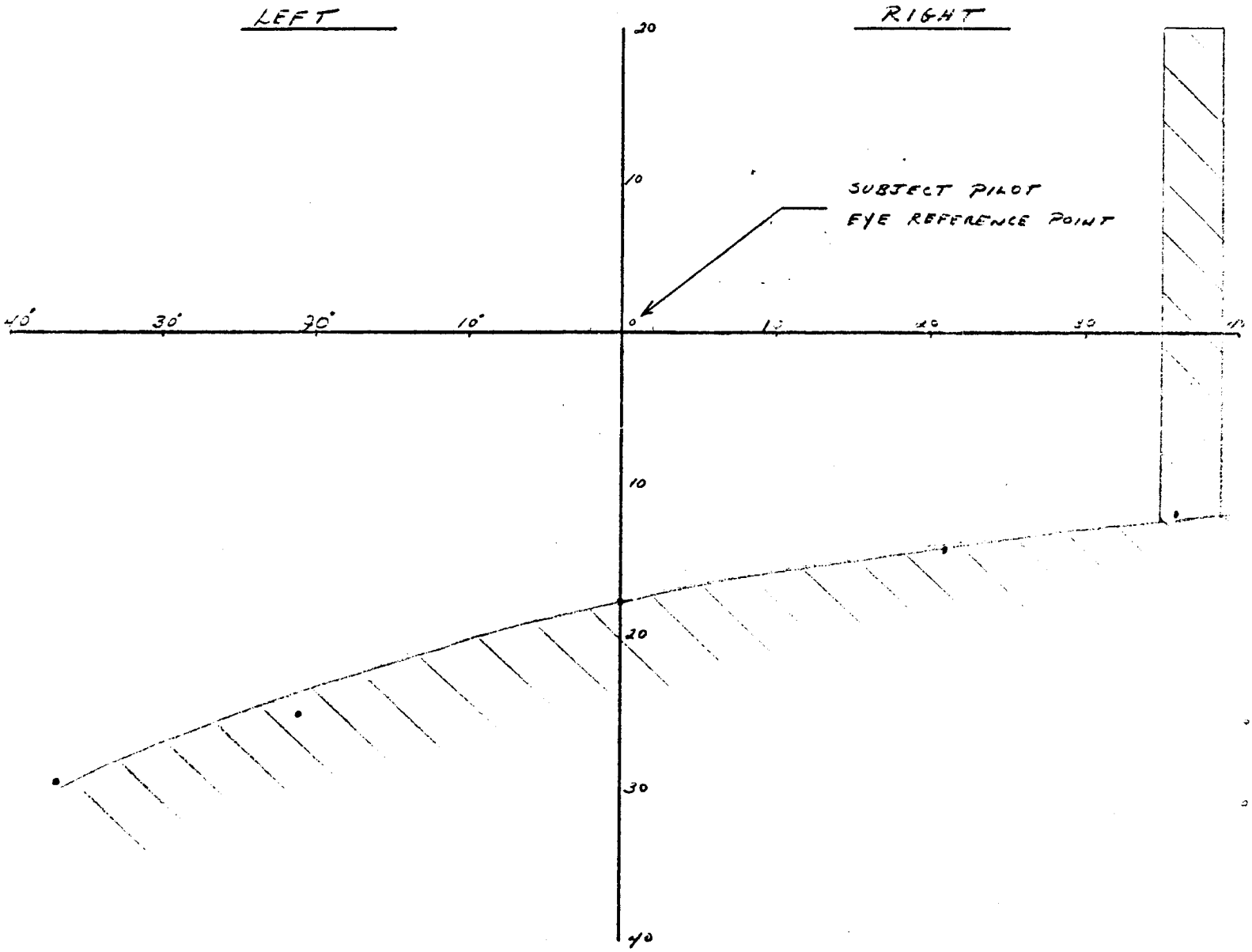


FIGURE C-5
UH-1H AIRCRAFT DIMENSIONS

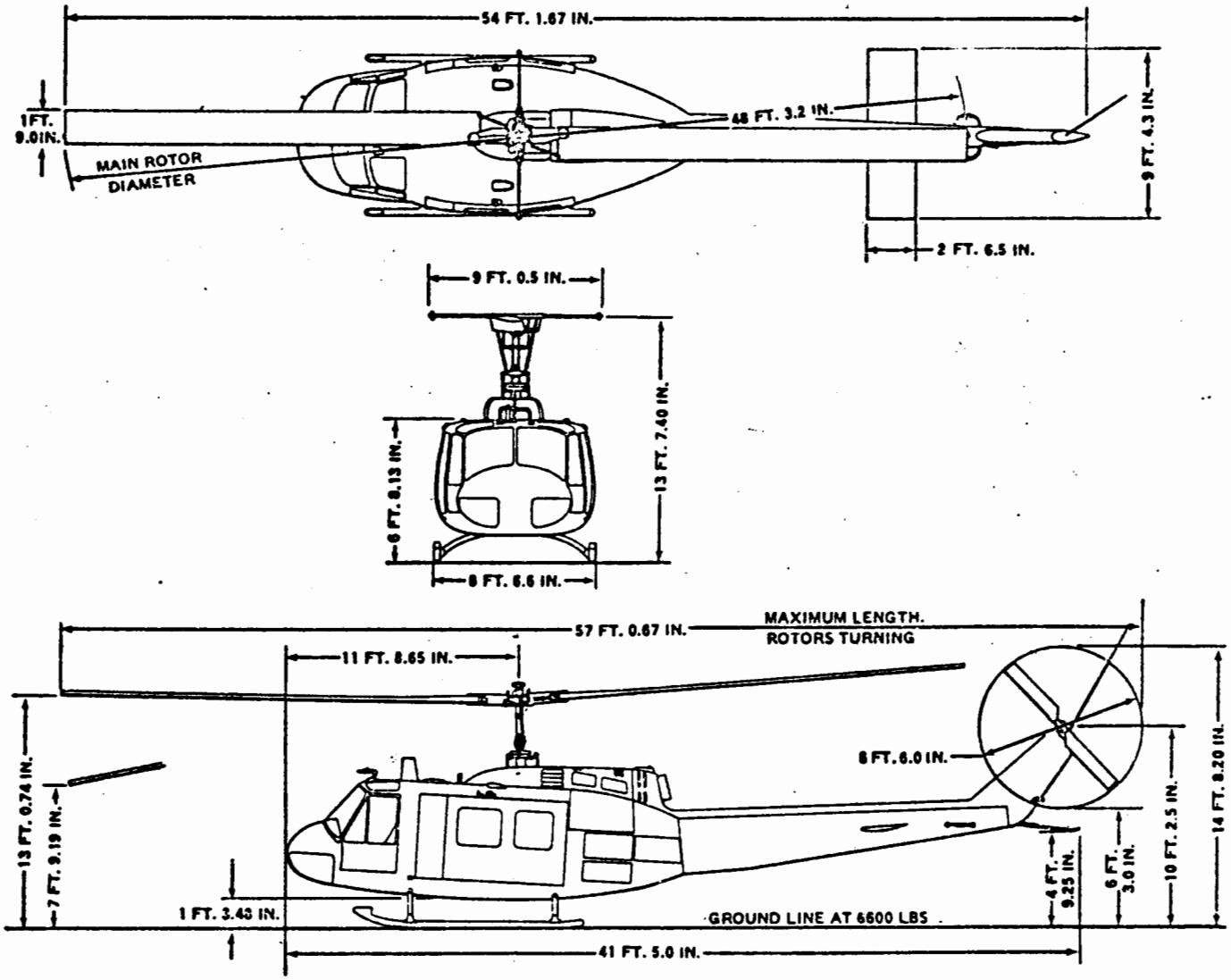


FIGURE C-6

# WEIGHT AND BALANCE CLEARANCE FORM F
## TRANSPORT
*(USE REVERSE FOR TACTICAL MISSIONS)*

Cross Reference RAF Form 2870 RCAF Form F. 115 C 50M 5-51 (6797)

FOR USE IN T.O. 1-1B-40 AN 01-1B-40 & TM 55-405-9

| DATE | AIRCRAFT TYPE | FROM | HOME STATION |
|---|---|---|---|
| | JUH-1H | | NEL |
| **MISSION/TRIP/FLIGHT/NO.** | **SERIAL NO.** | **TO** | **PILOT** |
| As Required | 70-16344 | | P. Denko |

**LIMITATIONS**

| CONDITION | TAKEOFF | LANDING | LIMITING WING FUEL |
|---|---|---|---|
| [1] ALLOWABLE GROSS WEIGHT | 9500 | 9500 | |
| TOTAL AIRCRAFT WEIGHT (Ref. 11) | 7750 | | |
| OPERATING WEIGHT PLUS ESTIMATED LANDING FUEL WEIGHT | | 6867 | |
| OPERATING WEIGHT (Ref. 8) | | | 6392 |
| ALLOWABLE LOAD (Ref. 12) (use SMALLEST figure) | 1750 | 2633 | — |
| [3] PERMISSIBLE C. G. TAKEOFF | FROM 130 | TO (~~% M.A.C. or~~ IN.) 144 | |
| [4] PERMISSIBLE C. G. LANDING | FROM 130 | TO (~~% M.A.C. or~~ IN.) 144 | |
| [5] LANDING FUEL WEIGHT | 475 | | |

| REF | ITEM | WEIGHT | [1] INDEX OR MOM/100 |
|---|---|---|---|
| 1 | BASIC AIRCRAFT (From Chart C) | 5992 | 3[illegible] |
| 2 | OIL (IN BASIC Gal.) | | |
| 3 | CREW (No.) 2 | 400 | 13[illegible] |
| 4 | CREW'S BAGGAGE | | |
| 5 | STEWARD'S EQUIPMENT | | |
| 6 | EMERGENCY EQUIPMENT | | |
| 7 | EXTRA EQUIPMENT | | |
| 8 | OPERATING WEIGHT | 6392 | 8874 |
| 9 | TAKEOFF FUEL (JP4-209 Gal.) | 1358 | 2074 |
| 10 | WATER INJ. FLUID ( — Gal.) | | |
| 11 | TOTAL AIRCRAFT WEIGHT | 7750 | 10948 |

**12 DISTRIBUTION OF ALLOWABLE LOAD (PAYLOAD)**

| COMPT | UPPER COMPARTMENTS PASSENGERS NO. | WEIGHT | CARGO | COMPT | LOWER COMPARTMENTS PASSENGERS NO. | WEIGHT | CARGO | WEIGHT | INDEX OR MOM/100 |
|---|---|---|---|---|---|---|---|---|---|
| A | | | | | | | | | |
| B | 2 | 400 | FS 85.0 | | | | | 400 | 33[illegible] |
| C | | | | | | | | | |
| D | | | | | | | | | |
| E | | | | | | | | | |
| F | | | | | | | | | |
| G | | | | | | | | | |
| H | | | | | | | | | |
| I | | | | | | | | | |
| J | | | | | | | | | |
| K | | | | | | | | | |
| L | | | | | | | | | |
| M | | | | | | | | | |
| N | | | | | | | | | |
| O | | | | | | | | | |
| P | | | | | | | | | |
| FWD | BELLY | | | | | | | | |
| AFT | BELLY | | | | | | | | |

REMARKS

MLS HELIPORT SITING CRITERIA A/C CONFIGURATION

SOLO CG 143.85

TOTAL FREIGHT

TOTAL MAIL

COMPUTER PLATE NUMBER (If used) CHART E

[1] Enter constant used.
[2] Enter values from current applicable T.O./TM
[3] Applicable to gross weight (Ref. 15).
[4] Applicable to gross weight (Ref. 20).
[5] Ref. 9 minus Ref. 17.

**CORRECTIONS (Ref. 14)**

| COMPT | ITEM | CHANGES (+ or −) WEIGHT | [1] INDEX OR MOM/ |
|---|---|---|---|
| | | | |
| TOTAL WEIGHT REMOVED | | − | − |
| TOTAL WEIGHT ADDED | | + | + |
| NET DIFFERENCE (Ref. 14) | | | |

| | | WEIGHT | INDEX OR MOM/100 |
|---|---|---|---|
| 13 | TAKEOFF CONDITION (Uncorrected) | 8150 | 11284 |
| 14 | CORRECTIONS (If required) | | |
| 15 | TAKEOFF CONDITION (Corrected) | | |
| 16 | TAKEOFF C. G. ~~IN % M. A. C. OR~~ IN. | 138.45 | |
| 17 | LESS FUEL 135.8 GAL | -883 | -1466 |
| 18 | LESS AIR SUPPLY LOAD DROPPED | | |
| 19 | MISC. VARIABLES | | |
| 20 | ESTIMATED LANDING CONDITION | 7267 | 9813 |
| 21 | ESTIMATED LANDING C. G. ~~IN % M. A. C. OR~~ IN. | 135.1 | |

COMPUTED BY Paul E. Denko DAC
SIGNATURE

WEIGHT AND BALANCE AUTHORITY
SIGNATURE

PILOT Paul E. Denko DAC
SIGNATURE

NOTE.—THIS TRANSPORT CLEARANCE FORM HAS RESULTED FROM TRIPARTITE AGREEMENT AND NO FURTHER CHANGES MAY BE MADE TO IT WITHOUT PRIOR CONSIDERATION BY TRIPARTITE AUTHORITIES.

DD FORM 1 SEPT 54 365F

# APPENDIX D

## DECELERATION DISTANCE, DECELERATION FORCE, AND PEAK PITCH-UP ANGLE DATA TABLES FROM FIGURES 4 THROUGH 11 SHOWING MEANS, STANDARD DEVIATIONS, AND SAMPLES THAT WERE PLOTTED

TABLE D-1
DECELERATION DISTANCE (FT) BEYOND THE COLLOCATED MLS ANTENNA SYSTEM FOR ALL DECISION HEIGHTS AS A FUNCTION OF ELEVATION ANGLE

| Elevation Angle (Deg) | 90 Knots Range Rate (Mean/Std Dev/Samples) | 60 Knots Range Rate (Mean/Std Dev/Samples) |
|---|---|---|
| 3 | 1354/213/5 | 1051/-/1 |
| 4 | 1315/713/6 | -376/367/3 |
| 5 | 1132/642/12 | -58/404/5 |
| 6 | 1364/526/17 | 331/244/15 |
| 7 | 1434/564/22 | 388/316/23 |
| 8 | 1210/500/15 | 392/231/23 |
| 9 | 1160/588/14 | 488/161/19 |
| 10 | 1103/237/9 | 552/360/13 |
| 11 | 1143/200/4 | 594/365/8 |
| 12 | 1518/353/5 | 540/389/8 |

TABLE D-2
DECELERATION DISTANCE (FT) BEYOND THE COLLOCATED MLS ANTENNA SYSTEM FOR ALL ELEVATION ANGLES AS A FUNCTION OF DECISION HEIGHT

| Decision Height (ft) | 90 Knots Range Rate (Mean/Std Dev/Samples) | 60 Knots Range Rate (Mean/Std Dev/Samples) |
|---|---|---|
| 50 | 1541/522/26 | 498/258/24 |
| 100 | 1229/505/31 | 519/342/31 |
| 150 | 1248/465/25 | 348/352/32 |
| 200 | 1114/520/27 | 286/334/31 |

TABLE D-3
MAXIMUM PEAK DECELERATION FORCE (G's) MAXIMUM PEAK DECELERATION FORCE (G's) FOR ALL DECISION HEIGHTS AS A FUNCTION OF ELEVATION ANGLE

| Elevation Angle (Deg) | 90 Knots Range Rate (Mean/Std Dev/Samples) | 60 Knots Range Rate (Mean/Std Dev/Samples) |
|---|---|---|
| 3 | 0.21/0.02/5 | 0.15/-/1 |
| 4 | 0.19/0.05/6 | 0.15/0.04/3 |
| 5 | 0.22/0.05/12 | 0.16/0.02/5 |
| 6 | 0.20/0.06/17 | 0.17/0.05/15 |
| 7 | 0.19/0.04/22 | 0.16/0.05/23 |
| 8 | 0.21/0.06/14 | 0.17/0.05/23 |
| 9 | 0.21/0.06/14 | 0.15/0.05/19 |
| 10 | 0.24/0.03/9 | 0.17/0.07/13 |
| 11 | 0.21/0.04/4 | 0.18/0.05/8 |
| 12 | 0.18/0.03/5 | 0.19/0.06/8 |

TABLE D-4
MAXIMUM PEAK DECELERATION FORCE (G's) FOR ALL ELEVATION ANGLES AS A FUNCTION OF DECISION HEIGHT

| Decision Height (Ft) | 90 Knots Range Rate (Mean/Std Dev/Samples) | 60 Knots Range Rate (Mean/Std Dev/Samples) |
|---|---|---|
| 50 | 0.21/.05/26 | 0.20/0.05/24 |
| 100 | 0.22/.04/31 | 0.17/0.05/31 |
| 150 | 0.19/.05/25 | 0.17/0.05/32 |
| 200 | 0.19/.05/27 | 0.16/0.04/31 |

TABLE D-5
MAXIMUM PITCH-UP ANGLE (DEG) FOR ALL DECISION HEIGHTS AS A FUNCTION OF ELEVATION ANGLE

| Elevation Angle (Deg) | 90 Knots Range Rate (Mean) | 60 Knots Range Rate (Mean) |
|---|---|---|
| 3 | 14° | 9.5° |
| 4 | 12.5° | 9.5° |
| 5 | 14.5° | 10° |
| 6 | 13° | 11° |
| 7 | 12.5° | 10° |
| 8 | 14° | 11° |
| 9 | 14° | 9.5° |
| 10 | 16° | 11° |
| 11 | 14° | 12° |
| 12 | 12° | 12.5° |

TABLE D-6
MAXIMUM PITCH-UP ANGLE (DEG) FOR ALL ELEVATION ANGLES AS A FUNCTION OF DECISION HEIGHT

| Decision Heights (Ft) | 90 Knots Range Rate (Mean) | 60 Knots Range Rate (Mean) |
|---|---|---|
| 50 | 14° | 13° |
| 100 | 14.5° | 11° |
| 150 | 12.5° | 9.5° |
| 200 | 12.5° | 10° |

# APPENDIX E

## SUBJECT PILOT BACKGROUND PROFILES

SUBJECT PILOT AIRCRAFT BACKGROUND PROFILES

| Subject Pilot # | Total Aircraft Flight Hours | Total Helicopter Flight Hours | Total Flight Hours UH-1H Helicopter |
|---|---|---|---|
| 1 | 3480 | 344 | 175 |
| 2 | 7229 | 5773 | 2800 |
| 3 | 1800 | 1800 | 1500 |
| 4 | * | * | * |
| 5 | 2500 | 2000 | 500 |
| 6 | 3825/600 IFR | 620 VFR | 0 |
| 7 | 4000 | 120/40 IFR | 20 Hrs Simulator<br>6 Aircraft<br>5.5 IFR |
| 8 | 6650 | 3900/200 IFR | 3400/200 IFR |

*Not Available at Time of Printing