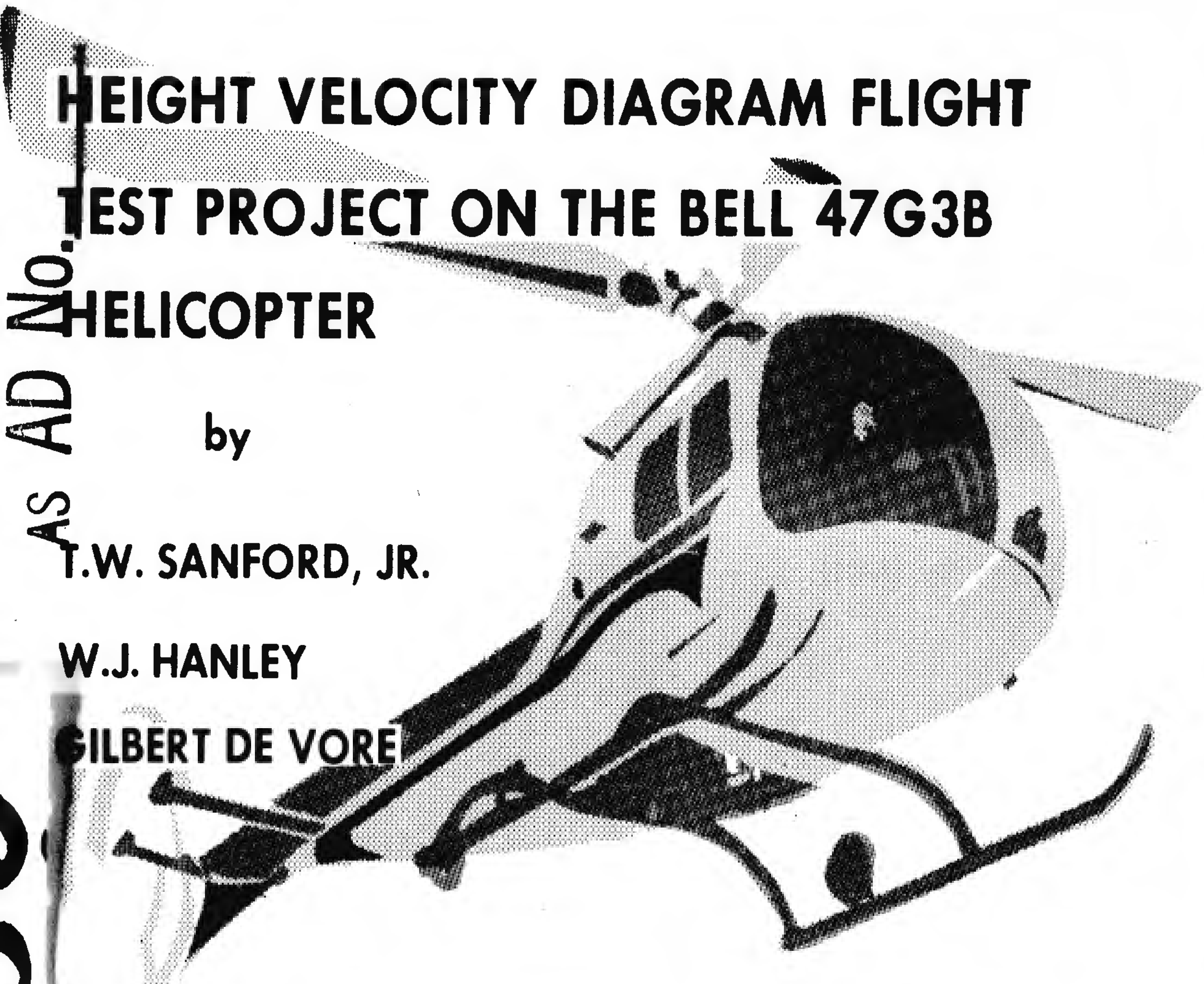
AMERICAN HELICOPTER SOCIETY, INC.
141 EAST 44th STREET TNEW YORK 17, N.Y.
TELEPHONE OXFORD 7-5168

HEIGHT VELOCITY DIAGRAM FLIGHT TEST PROJECT ON THE BELL 47G3B HELICOPTER



by

T.W. SANFORD, JR.
W.J. HANLEY
GILBERT DE VORE

FEDERAL AVIATION AGENCY

Presented at the
19th ANNUAL NATIONAL FORUM
WASHINGTON, D.C. MAY 1 - 3, 1963

Abstract

The variation of the Helicopter Height-Velocity Diagram with altitude was determined for the Bell 47G-3B aircraft by an FAA Aircraft Development Service flight test project. The FAA analysis of data of this project resulted in a definite set of empirical mathematical equations. These empirical equations are known as the De Vore equations. Height-Velocity Diagram flight test data recorded at one density altitude can be used to compute the Height-Velocity Envelope at any other density altitude using the De Vore equations. This project was conducted in California at field density altitudes of sea level, 4,000, 7,000, and 10,000 feet. The flight tests took place between September 19 and November 14, 1962. Over 500 autorotative Height-Velocity Diagram landings were completed. These tests produced a large amount of high quality flight test time history data recorded on instrumentation installed in the test helicopter and on instrumentation installed on the ground at the test site. A searching analysis of this flight test data has been completed by the Evaluation Division of the FAA at the National Aviation Facilities Experimental Center, Atlantic City, New Jersey. The Langley Laboratory of NASA is presently in the process of analyzing these data to assist them in producing a mathematical model of the Height-Velocity Diagram for autorotation landings for a helicopter using known configuration parameters.

Foreword

This technical paper of the Federal Aviation Agency on the Aircraft Development Service flight test project on the Height-Velocity Diagram of the Bell 47G-3B Helicopter is a summary of the high lights of the formal FAA report on this project scheduled for completion late this month. The latter report contains the complete test description, instrumentation, methodology, data, analysis, conclusions, and recommendations, much of which has been omitted from this paper for the American Helicopter Society. The FAA formal report is titled "The Effects of Altitude on the Height-Velocity Diagram of a Single Engine Helicopter." The authors of the formal report are Mr. William J. Hanley, NAFEC project manager, and Mr. Gilbert De Vore, a project consulting engineer to NAFEC. The formal report, when published, may be obtained upon written request to the Engineering and Safety Program Division, DS-40, Federal Aviation Agency, Washington 25, D. C.

Introduction

Safe autorotative landing performance of helicopters has long been of major concern to the manufacturer and the Federal Aviation Agency. The Height-Velocity Diagram (HVD) which appears in the FAA approved Rotorcraft Flight Manual for each type certificated helicopter has been based upon results of a flight test program. Each such flight test program of necessity embodied two undesirable elements: high cost and some risk for the flight crews involved. Until very recently these flight tests have been completed to prove only an adequate Height-Velocity Diagram for sea level airports. As helicopters with better altitude performance have been produced, the manufacturer and the FAA have considered it desirable to determine Height-Velocity Diagrams not only for sea level but also for the highest density altitude airport at which the use of the new type helicopter is contemplated by the manufacturer.

The Height-Velocity Diagram (see Figure 1) must allow a safe flight area for takeoff and landing. For a given type helicopter, if such a safe flight area exists at an airport of sea level density altitude at maximum gross weight, will an adequate area for this machine exist at an airport with a density altitude of say, five thousand feet? If a safe flight landing and takeoff area does not exist for this helicopter at a five thousand-foot density altitude airport, how much weight must we remove from the helicopter to restore the adequate safe flight area? In other words, how does the helicopter Height-Velocity Diagram vary with density altitude? Of equal importance with this question is a second question. Is there any way we can determine a "Height-Velocity Diagram" for a given type Design of Helicopter by flight test at one density altitude, and then using these data, compute the "Height-Velocity Diagram" for another density altitude without additional expensive flight testing? Early in 1962 the FAA reviewed these two questions on Rotorcraft Height-Velocity Diagrams, and it was decided to establish a research and development program to determine, if possible, the answers to these questions.

A meeting of FAA research and development personnel and NASA Langley Laboratory helicopter section personnel was held in February 1962. The Height-Velocity Diagram variation with altitude was studied at length. As a result of this meeting two projects were agreed upon by NASA and the FAA as necessary to develop satisfactory answers to the two primary helicopter Height Velocity Diagram questions. NASA Langley undertook the first project, that of establishing a mathematical model of generalized form for the Height-Velocity Diagram of the helicopter based upon its design parameters. The FAA accepted responsibility for the second project, that of determining by helicopter flight tests with adequate instrumentation how density altitude affected the helicopter Height-Velocity Diagram. A free exchange of planning, progress reports, comments, suggestions, and results between the FAA and NASA Langley has been maintained from the beginning on both of these projects. This paper is a summary report on the FAA helicopter HVD flight test project, its results and conclusions. Analysis of the flight test data of the FAA project has produced a set of simple empirical equations for the Bell 47G-3B Helicopter. These equations, designated here "the De Vore Equations" for their discoverer, Gilbert De Vore, can be used with flight test data on the HVD recorded at one density altitude to compute the HVD for a given gross weight at any other density altitude.

The FAA project flight tests were completed in the area of central

Introduction

Safe autorotative landing performance of helicopters has long been of major concern to the manufacturer and the Federal Aviation Agency. The Height-Velocity Diagram (HVD) which appears in the FAA approved Rotorcraft Flight Manual for each type certificated helicopter has been based upon results of a flight test program. Each such flight test program of necessity embodied two undesirable elements: high cost and some risk for the flight crews involved. Until very recently these flight tests have been completed to prove only an adequate Height-Velocity Diagram for sea level airports. As helicopters with better altitude performance have been produced, the manufacturer and the FAA have considered it desirable to determine Height-Velocity Diagrams not only for sea level but also for the highest density altitude airport at which the use of the new type helicopter is contemplated by the manufacturer.

The Height-Velocity Diagram (see Figure 1) must allow a safe flight area for takeoff and landing. For a given type helicopter, if such a safe flight area exists at an airport of sea level density altitude at maximum gross weight, will an adequate area for this machine exist at an airport with a density altitude of say, five thousand feet? If a safe flight landing and takeoff area does not exist for this helicopter at a five thousand-foot density altitude airport, how much weight must we remove from the helicopter to restore the adequate safe flight area? In other words, how does the helicopter Height-Velocity Diagram vary with density altitude? Of equal importance with this question is a second question. Is there any way we can determine a "Height-Velocity Diagram" for a given type Design of Helicopter by flight test at one density altitude, and then using these data, compute the "Height-Velocity Diagram"

California. Four test fields were used: Fresno Airport, 332 feet; Bishop Airport, 4,108 feet; Long Valley Airport, 7,112 feet; and Coyote Flat site, 9,870 feet elevation above sea level. The flight tests were completed at these test sites between September 19, 1962, and November 14, 1962. Except for some 19^{o}F. temperatures, snow, heavy rain, and high winds at the Coyote Flat site and some early morning fog at Fresno Airport, even the weather cooperated with the FAA test personnel during the flight tests of this project.

The FAA Helicopter HVD program planning, coordination, and control were accomplished by the Engineering and Safety Program Division of the Aircraft Development Service in Washington, D. C. The HVD flight test project was planned to center around a contract with a helicopter manufacturer to lease an instrumented helicopter, furnish a highly qualified test pilot who was completely familiar with the particular helicopter, and supply ground support of the necessary engineers, technicians, services, maintenance, parts, supplies, and equipment to complete the HVD tests at the four test sites at three gross weights of the helicopter. The Evaluation Division* of the National Aviation Facilities Experimental Center of the FAA at Atlantic City, New Jersey, was assigned the project management task. Meetings were held by the program manager to coordinate the FAA flight test project with not only the NASA Langley Laboratory engineers but the U. S. Navy at Patuxent and the helicopter industry as represented by some of the principal manufacturers. As a result of these meetings, the Bell 47G-3B Helicopter was selected as the test aircraft, and a contract negotiated by the NAFEC project manager with the Bell Helicopter Company.

The HVD flight test procedure is a highly dynamic maneuver. However,

*Systems Research and Development Service the height above the ground and airspeed at the point of engine chop must be accurately known to produce usable HVD data for the purpose of this project. Therefore, it was decided that all Height-Velocity Diagram flight test data recorded to achieve the purpose of this project would start from a known stabilized helicopter height and airspeed.

The Limitations of This Paper

The results obtained by this FAA flight test project on the Bell 47G-3B Helicopter cannot be considered as applicable to this type of rotorcraft when flown by any other pilot. These results are a baseline type of autorotative landing performance for the Bell 47G-3B Helicopter. These results represent the best possible autorotative landing performance for the Bell 47G-3B Helicopter which can only be obtained when flown by a highly experienced test pilot using the test procedures of this test project.

This project is the first step in an FAA Aircraft Development Service program on helicopter HVD landing performance. The NASA mathematical model on the helicopter HVD landing performance is the second step. Other steps and/or flight test projects are being planned.

Test Criteria and Procedures

A set of conditions or test criteria fundamental to obtaining consistent and usable data were established for the test program. These criteria were in addition to the level flight entry technique utilized which was discussed previously. The unaccelerated level flight approach was purposely chosen for a number of reasons. Foremost of these is that this technique lends itself to a much greater degree of repeatability by eliminating the many variables involved in accelerated climbout which are difficult to control; thus, a more accurate analysis of the altitude effects could be obtained.

Rotor speed in autorotation was kept constant by adjusting the low pitch blade angle at each altitude tested for steady state autorotation at a constant calibrated airspeed.

Weight was eliminated as a variable by adding ballast and refueling frequently so that each weight tested was maintained within approximately $\pm \frac{1}{2}\%$.

Limitations were placed on allowable wind velocities measured at a twelve-foot height. Hovering and slow speed tests were not conducted in winds above two mph, and all other tests were discontinued when the wind exceeded five mph. Only the runway component was used in entry speed computations.

While the prime purpose of the program was to determine the effects of altitude, it was considered that in view of all the other variables involved, small variations in altitude would have little effect on the results at any given test site. A usable but limited latitude with respect to the density altitude range was therefore accepted for any given weight at each test site. All weights at each site were tested over a common range of density altitude of $\pm$ 600 feet.

All airspeeds used in the program and contained in this paper are the pilot's calibrated airspeeds. The entry airspeed used for each data point on the H-V Diagram was obtained from the photographic record as ground speed and converted to calibrated airspeed. Entry airspeeds below twenty mph were generally obtained with a car pace.

There were no restrictions placed on the pilot with respect to horizontal touchdown velocity. The criterion for landing was to remain within the limit landing load factor and safe landing gear stresses (vertical contact velocity). The specific techniques of handling the helicopter and the determination of whether a test point was acceptable were left entirely to the pilot. His evaluation was based upon whether he felt he had any usable reserve energy remaining in the form of rotor speed (collective pitch) or airspeed (flare). Since a consistent degree of conservatism could not be obtained, it was necessary to extract the maximum capability of the helicopter during each and every test point for the entire operation. Thus, in spite of the extreme hazard involved, the pilot made a sincere and conscientious effort to obtain maximum performance points, some of which were achieved at the expense of bent cross tubes. Out of approximately 450 landings made over the range of weights and altitudes tested, only 180 were considered to be acceptable as valid test points. The one limitation in technique which was imposed upon the pilot, however, was a one-second delay between throttle chop and pitch reduction for all points above the knee (V_{cr} h_{cr}).*

---

*See symbols at the end of the paper.

Test data for each of the three areas of the H-V Diagram; the upper boundary (high hover to V_{cr} area), the lower boundary (low hover to V_{cr} area), and the knee (V_{cr}, h_{cr} area) were obtained by reducing airspeed while holding constant height or by varying height while holding constant airspeed until a maximum performance point was reached. It was sometimes necessary to make several landings in order to obtain an acceptable maximum performance entry point. Occasionally, an extremely hard landing was discounted by the pilot because, in his opinion, the landing was a result of poor technique or execution, and he actually had energy left with which to recover.

Results and Analysis

H-V Diagrams were faired through the data points obtained for each weight and altitude tested. An average density altitude was selected for each site for the plotting of the diagrams by averaging the density altitudes of the test points. In general, it can be said that points above the average density altitude fall outside the diagrams, and points below the average density altitude fall inside. The diagrams thus obtained are shown in Figure 2 through Figure 12 as final faired curves. These Height-Velocity Diagrams were first constructed around the test data without regard to a relationship which might exist between the diagrams for the altitudes and weights tested. Data from the various diagrams were then cross-plotted, using values of V_{cr}, h_{cr}, h_{max}, and h_{min} (see Figure 1), to determine if a family of diagrams existed. The diagrams were then corrected by refairing from cross-plotted values and examined to determine if they still fit the test data. This process required very little change from the original fairing and all the final H-V Diagrams fit the test data exceptionally well. There were only two general areas where data missed the curves. The 2650 lb. data at 4,500 feet fell outside the curve, and since these were the initial runs, it is understandable that they were somewhat conservative. The 2415 lb. data at sea level showed excessive scatter and reflects the effects of light disc loadings and some tail wind in the first tests conducted at sea level. Time histories were plotted of all essential recorded data and examined with respect to data point analysis. A typical time history plot is shown in Figure 25. Thus, a set of Height-Velocity Diagrams was developed for a series of weights and altitudes and is defined by the family of curves as shown in Figures 13 through 15 for varying altitude at constant weight and in Figures 16 through 19 for varying weight at constant altitude. One of the factors which enhances the validity of the results as a family of curves is the sequence in which the tests were conducted. The sequence was not orderly from weight to weight and altitude to altitude but was dictated by existing and forecast weather conditions. Therefore, the pilot was continually going from one extreme to another without the benefit of a graduated procedure. Thus, the yardstick for a maximum performance point was based on the particular run in question without any influence from some previous reference.

Referring again to Figure 1, note that the basic control points are the H-V Diagrams V_{cr}, h_{cr}, h_{max}, h_{min}, define the basic size of the diagram. The cross-plots constructed, utilizing these control points, were established for V_{cr} vs. weight and altitude and for the low hover height, h_{max}, vs. weight and altitude. These cross-plots are shown on Figures 20 through 23. The high hover height, h_{min}, was found to plot against the square of the critical speed, and all test points fell on a common line as shown in Figure 24, independent of weight and altitude. Note that when the variables were plotted against altitude, the slopes were constant for varying weight; when plotted against weight, the slopes were constant for varying altitude. This made it possible to develop a set of simple straight line equations which are expressed as a function of the critical velocity, V_{cr}, or the height and which define the relationships of the H-V Diagrams as affected by weight and altitude.

Equations

1) $V_{cr} = V_{cr}\ \text{test} + C_1 \Delta W + C_2 \Delta H$

where V_{cr} = critical velocity at a weight and altitude

V_{cr} test = critical velocity obtained through test

$$C_1 = \frac{dV_{cr}}{dW}$$

$$C_2 = \frac{dV_{cr}}{dH}$$

2) $h_{max} = h_{max}\ \text{test} + C_3 \Delta W + C_4 \Delta H$

where h_{max} = low hover height at a weight and altitude

h_{max} test = low hover height obtained through test

$$C_3 = \frac{dh_{max}}{dW}$$

$$C_4 = \frac{dh_{max}}{dH}$$

3) $h_{min} = K + C_5 V_{cr}^2$

where K = a constant (h intercept)

$$C_5 = \frac{dH}{dV_{cr}^2}$$

The expression for V_{cr} also holds true for speeds at heights above and below the height for V_{cr} for approximately fifty feet which facilitates construction of H-V Diagrams at other weights and altitudes. It should be noted that throughout the range of altitudes tested, there was no variation in the height, h_{cr}, with respect to the ground. For the test vehicle, this height remained constant at approximately 95 feet. This fact further facilitates the construction of a family of H-V Diagrams from the equations shown.

The H-V Diagrams developed in these tests from steady state level flight entry conditions exhibit a smooth return from h_{cr}, V_{cr} to the low hover height; whereas, the general run of H-V Diagrams previously developed exhibits a rather sharp turn below h_{cr} with V_{cr} occurring generally at a higher ratio of h_{min}/h_{cr} as shown in Figure 26. This is undoubtedly the result of a combination of accelerated climbout data in the lower boundary regime and steady level flight data in the upper and "knee" area boundary regime. It is reasonable to expect that the cross-hatched portion shown in Figure 26 would bear the same growth factor with altitude and weight that the basic diagrams of this paper exhibit.

Given a set of empirical equations, such as those shown herein, it is possible to develop a family of H-V Diagrams from one set of test data at any normal operating weight and altitude. For the helicopter tested, the Bell 47G-3B, the equations with the constants included are as follows:

$$V_{cr} = V_{cr}\ \text{test} + .02075 \Delta W + .00157 \Delta H$$

$$h_{max} = h_{max}\ \text{test} + (-.00675 \Delta W) + (-.0007 \Delta H)$$

$$h_{min} = 179.5 + .1705\ V_{cr}^{2}$$

These constants are, of course, only applicable to the Bell 47G-3B, and unfortunately there are no other data available with which to verify that helicopters having different basic parameters would fall within the variations obtained for the Bell. It is conceivable, however, that these relationships will hold true and that only the basic size and/or shape of the H-V Diagram is affected by different helicopter parameters such as disc loading, solidity, and rotor inertia.

Equations

1) $V_{cr} = V_{cr}\ \text{test} + C_1 \Delta W + C_2 \Delta H$

where V_{cr} = critical velocity at a weight and altitude

V_{cr} test = critical velocity obtained through test

$$C_1 = \frac{dV_{cr}}{dW}$$

$$C_2 = \frac{dV_{cr}}{dH}$$

2) $h_{max} = h_{max}\ \text{test} + C_3 \Delta W + C_4 \Delta H$

where h_{max} = low hover height at a weight and altitude

h_{max} test = low hover height obtained through test

$$C_3 = \frac{dh_{max}}{dW}$$

$$C_4 = \frac{dh_{max}}{dH}$$

3) $h_{min} = K + C_5 V_{cr}^2$

where K = a constant (h intercept)

$$C_5 = \frac{dH}{dV_{cr}^2}$$

The expression for V_{cr} also holds true for speeds at heights above and below the height for V_{cr} for approximately fifty feet which facilitates construction of H-V Diagrams at other weights and altitudes. It should be noted that throughout the range of altitudes tested, there was no variation in the height, h_{cr}, with respect to the ground. For the test vehicle, this height remained constant at approximately 95 feet. This fact further facilitates the construction of a family of H-V Diagrams from the equations shown.

The H-V Diagrams developed in these tests from steady state level flight entry conditions exhibit a smooth return from h_{cr}, V_{cr} to the low hover height; whereas, the general run of H-V Diagrams previously developed exhibits a rather sharp turn below h_{cr} with V_{cr} occurring generally at a higher ratio of h_{min}/h_{cr} as shown in Figure 26. This is undoubtedly the result of a combination of accelerated climbout data in the lower boundary regime and steady level flight data in the upper and "knee" area boundary regime. It is reasonable to expect that the cross-hatched portion shown in Figure 26 would bear the same growth factor with altitude and weight that the basic diagrams of this paper exhibit.

Given a set of empirical equations, such as those shown herein, it is possible to develop a family of H-V Diagrams from one set of test data at any normal operating weight and altitude. For the helicopter tested, the Bell 47G-3B, the equations with the constants included are as follows:

$$V_{cr} = V_{cr} \text{ test} + .02075 \Delta W + .00157 \Delta H$$

$$h_{max} = h_{max} \text{ test} + (-.00675 \Delta W) + (-.0007 \Delta H)$$

$$h_{min} = 179.5 + .1705 V_{cr}^2$$

These constants are, of course, only applicable to the Bell 47G-3B, and unfortunately there are no other data available with which to verify that helicopters having different basic parameters would fall within the variations obtained for the Bell. It is conceivable, however, that these relationships will hold true and that only the basic size and/or shape of the H-V Diagram is affected by different helicopter parameters such as disc loading, solidity, and rotor inertia.

Conclusions

Based upon tests conducted with a Bell 47G-3B Helicopter and an analysis of the test results, it is concluded that:

1) The Height-Velocity Diagrams for varying weights and altitudes evolve into a family of curves for the weights and altitudes tested.

2) This family of curves has the following relationships with respect to the key points on the H-V Diagram:

   a) V_{cr} varies as a straight line function of weight or altitude.

   b) h_{max} varies as a straight line function of weight or altitude.

   c) h_{min} varies as a straight line function of V_{cr}^2.

Recommendations

It is recommended that an additional program be conducted on another helicopter whose parameters are quite different from those of the test aircraft. Such items as disc loading, W/A, and rotor mass factor should be widely removed from Bell 47G-3B values. This will establish whether the constants of the equations defining the H-V Diagram for the test aircraft are applicable to all single engine, single rotor helicopters and that only the basic size of the H-V Diagram is affected by the helicopter parameters noted above.

<u>Reference</u>

"An Evaluation of the Effects of Altitude on the Height-Velocity Diagram of a Single Engine Helicopter" by William J. Hanley, Project Manager, and Gilbert De Vore, Project Consulting Engineer, Federal Aviation Agency, Systems Research and Development Service, Evaluation Division, May 1963.

Glossary of Terms and Symbols

V_{cr} = critical velocity, mph. The speed above which an autorotative landing can be made from any height after power failure in the low speed regime.

h_{cr} = the height above the ground where V_{cr} is maximum.

h_{min} = the high hover height - minimum height above the ground from which a safe autorotative landing can be made after power failure at zero airspeed.

h_{max} = the low hover height - maximum height above the ground from which a safe autorotative landing can be made after power failure at zero airspeed.

H = altitude as used in this report has to do with density altitude.

h = height as used in this report refers to the distance of the helicopter above the ground.

W = helicopter weight - lbs.

Acknowledgments

The authors are most grateful to the pilot, Mr. Irvin Franklin, and the other Bell Helicopter Company engineers and technicians whose skill and fine work made this paper possible. Appreciation is expressed to Mr. W. D. Howell and other staff members of the FAA's Systems Research and Development Service for their assistance in the preparation of this paper.

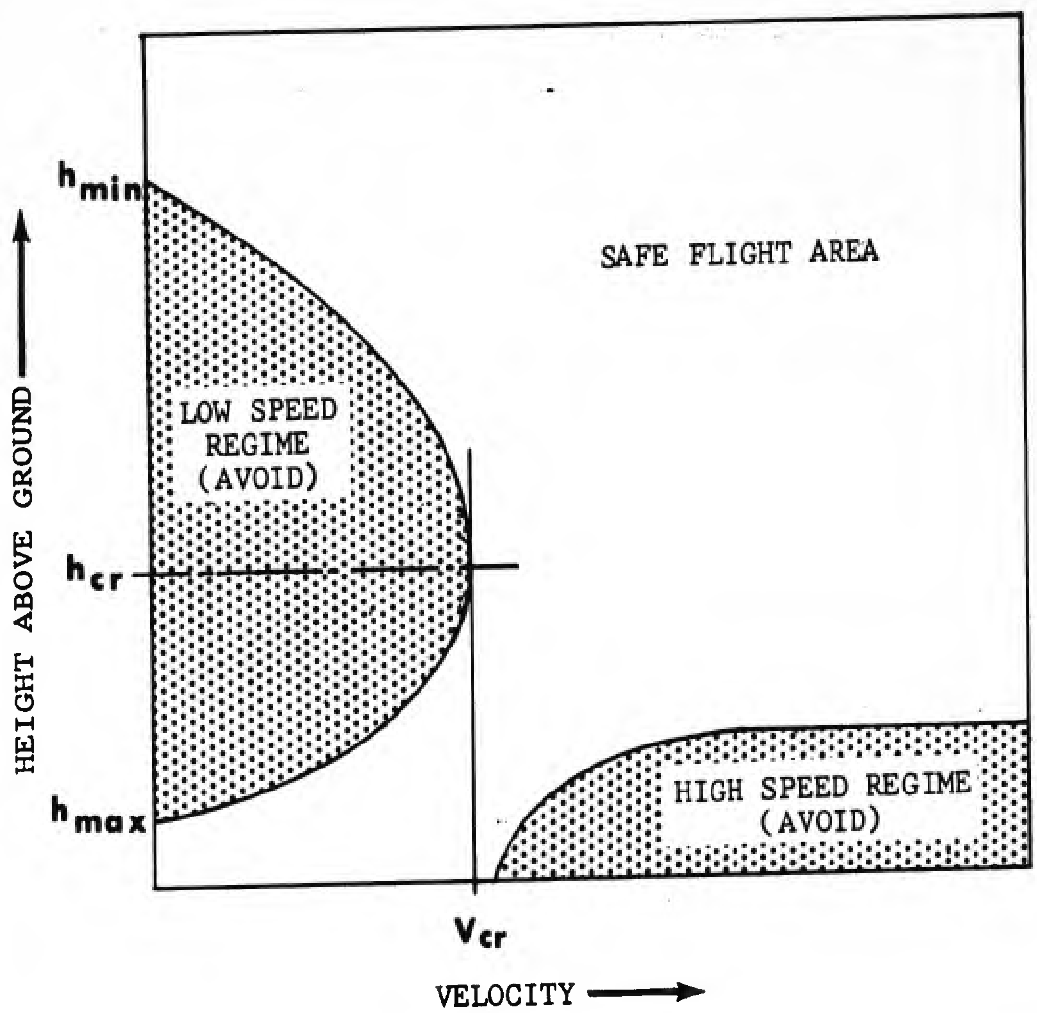


FIG. 1 TYPICAL HEIGHT-VELOCITY DIAGRAM

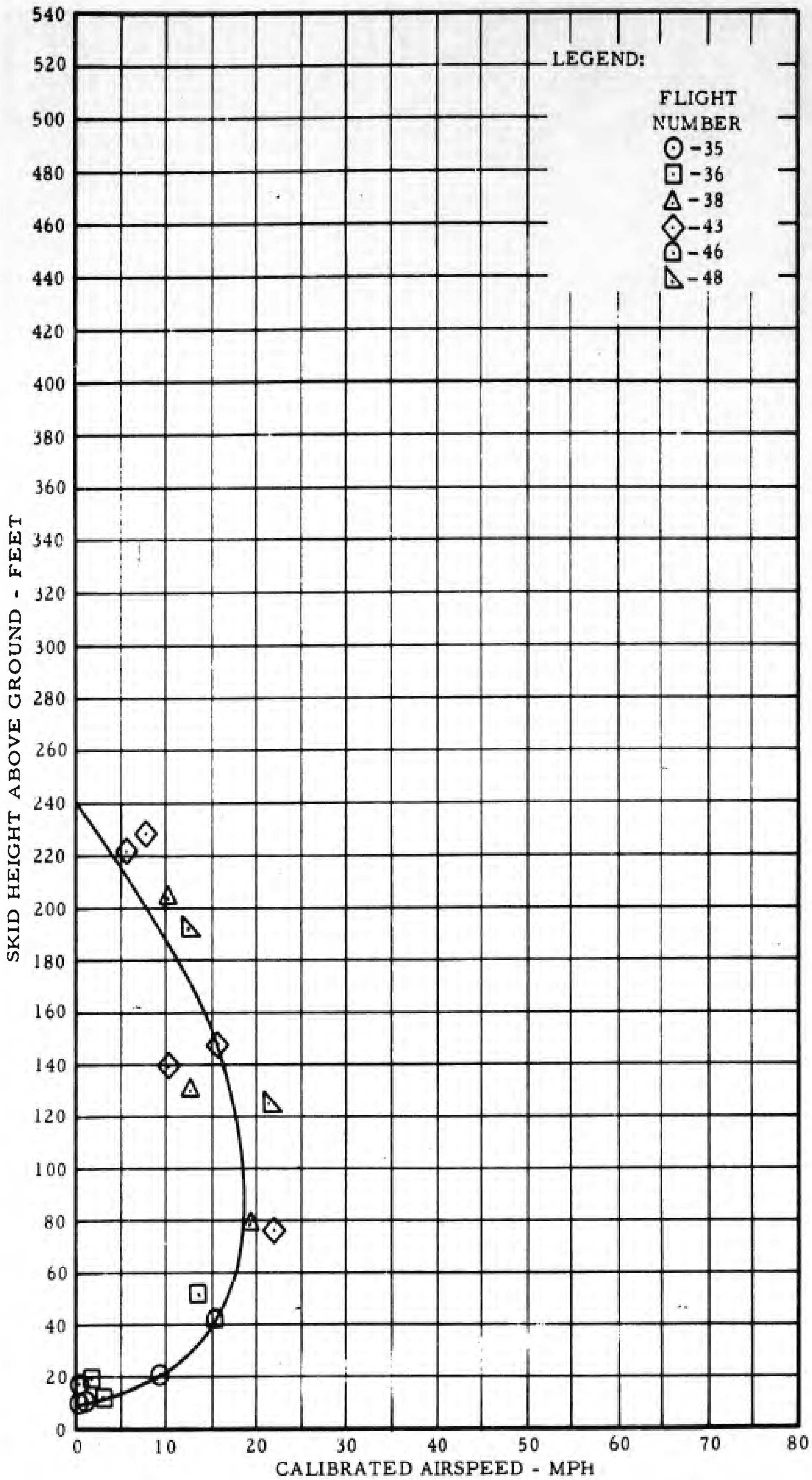


FIG. 2 HEIGHT-VELOCITY DIAGRAM - BASIC DATA
HELICOPTER GROSS WEIGHT 2,415 POUNDS
AVERAGE DENSITY ALTITUDE 200 FEET

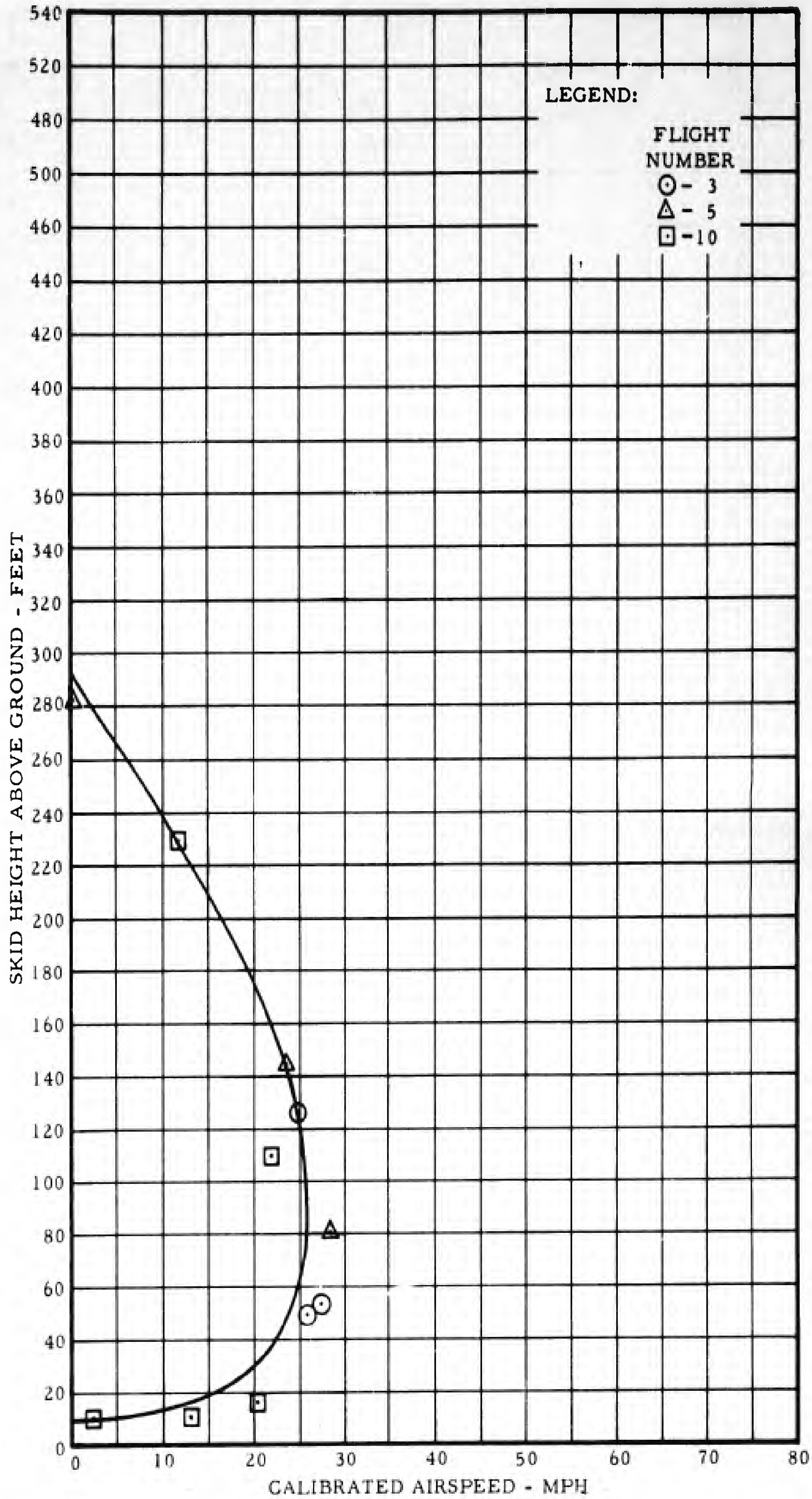


FIG. 3 HEIGHT-VELOCITY DIAGRAM - BASIC DATA
HELICOPTER GROSS WEIGHT 2,415 POUNDS
AVERAGE DENSITY ALTITUDE 4,500 FEET

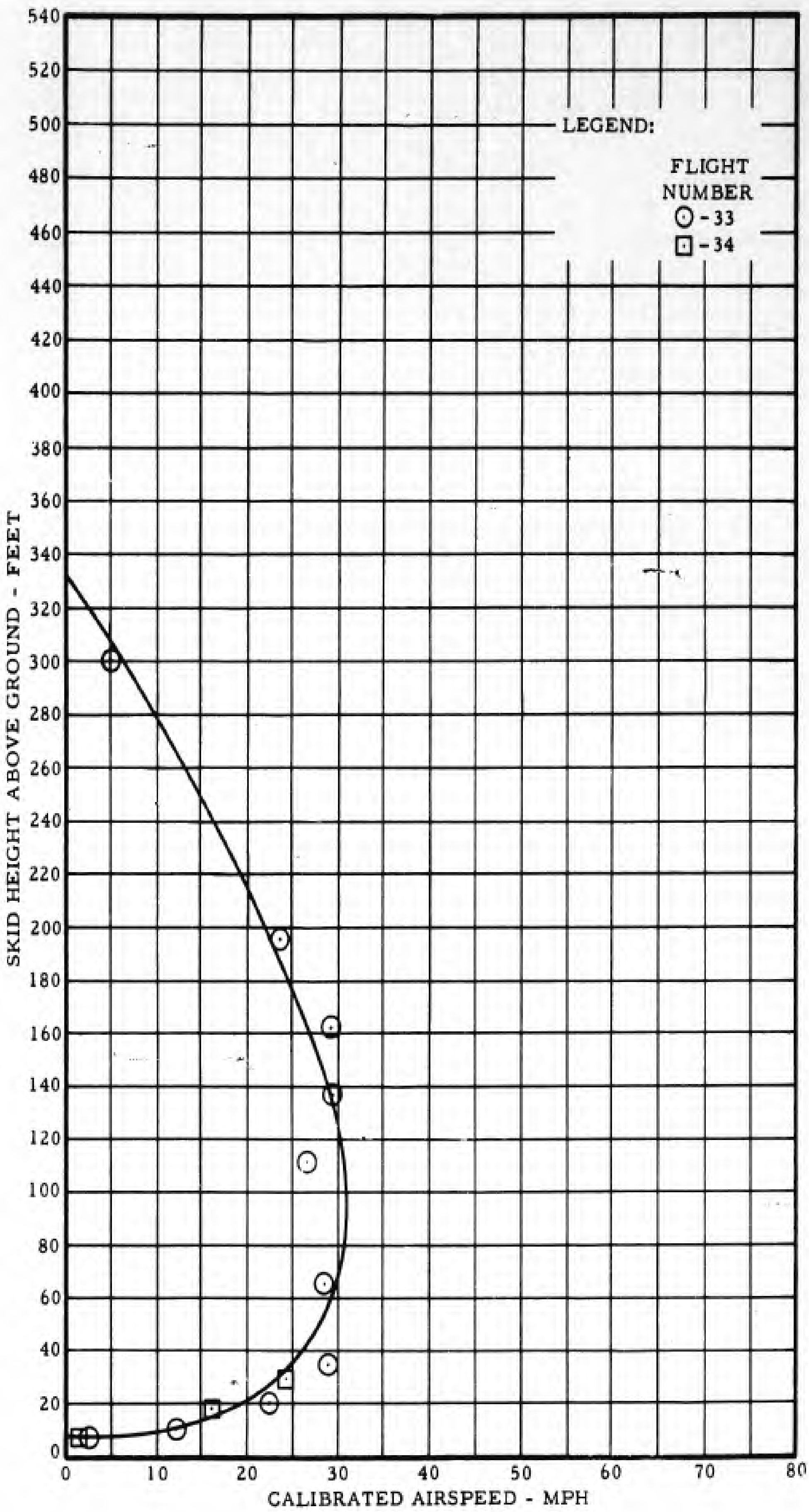


FIG. 4 HEIGHT-VELOCITY DIAGRAM - BASIC DATA
HELICOPTER GROSS WEIGHT 2,415 POUNDS
AVERAGE DENSITY ALTITUDE 7,350 FEET

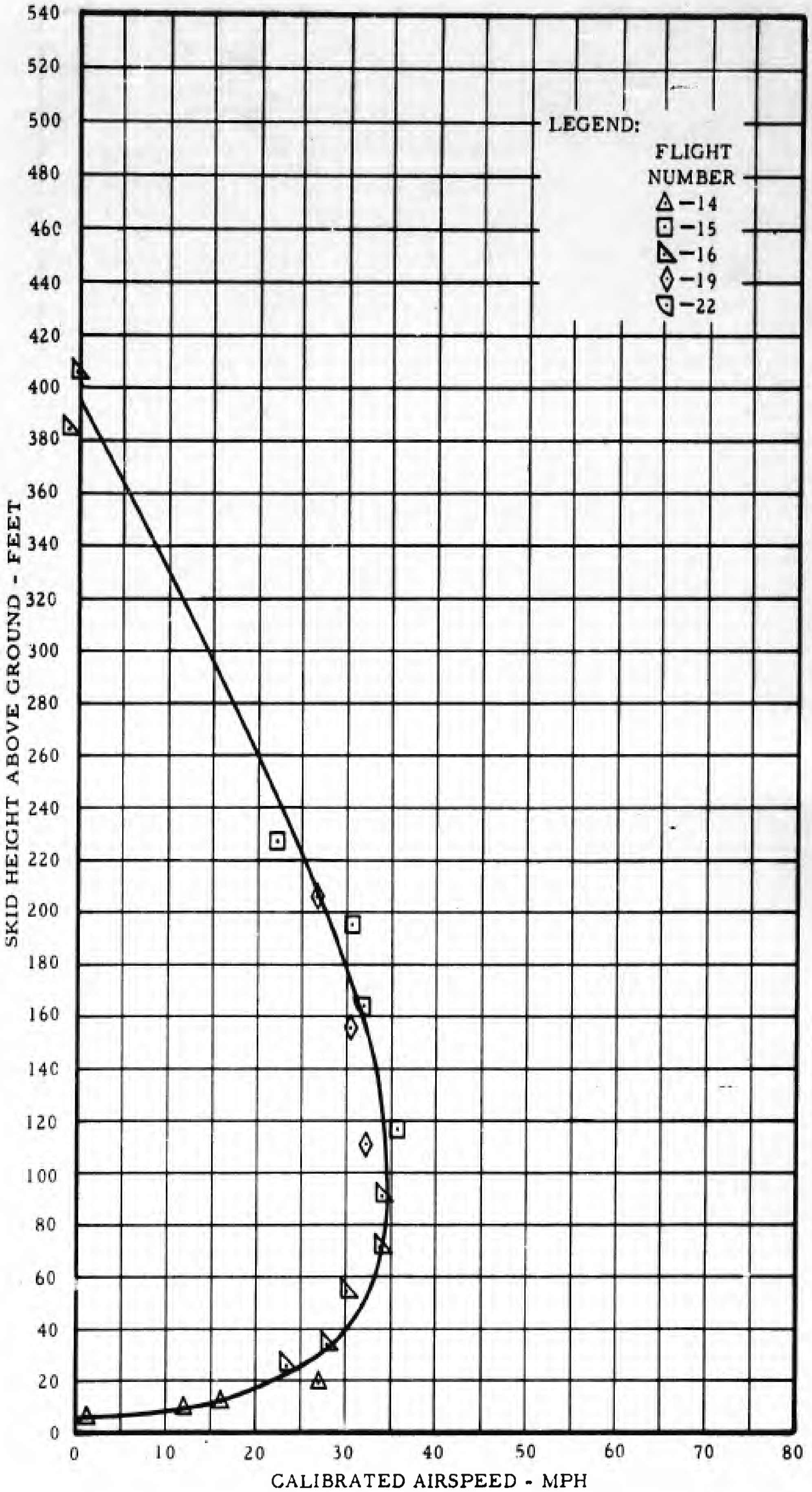


FIG. 5 HEIGHT-VELOCITY DIAGRAM - BASIC DATA
HELICOPTER GROSS WEIGHT 2,415 POUNDS
AVERAGE DENSITY ALTITUDE 10,250 FEET

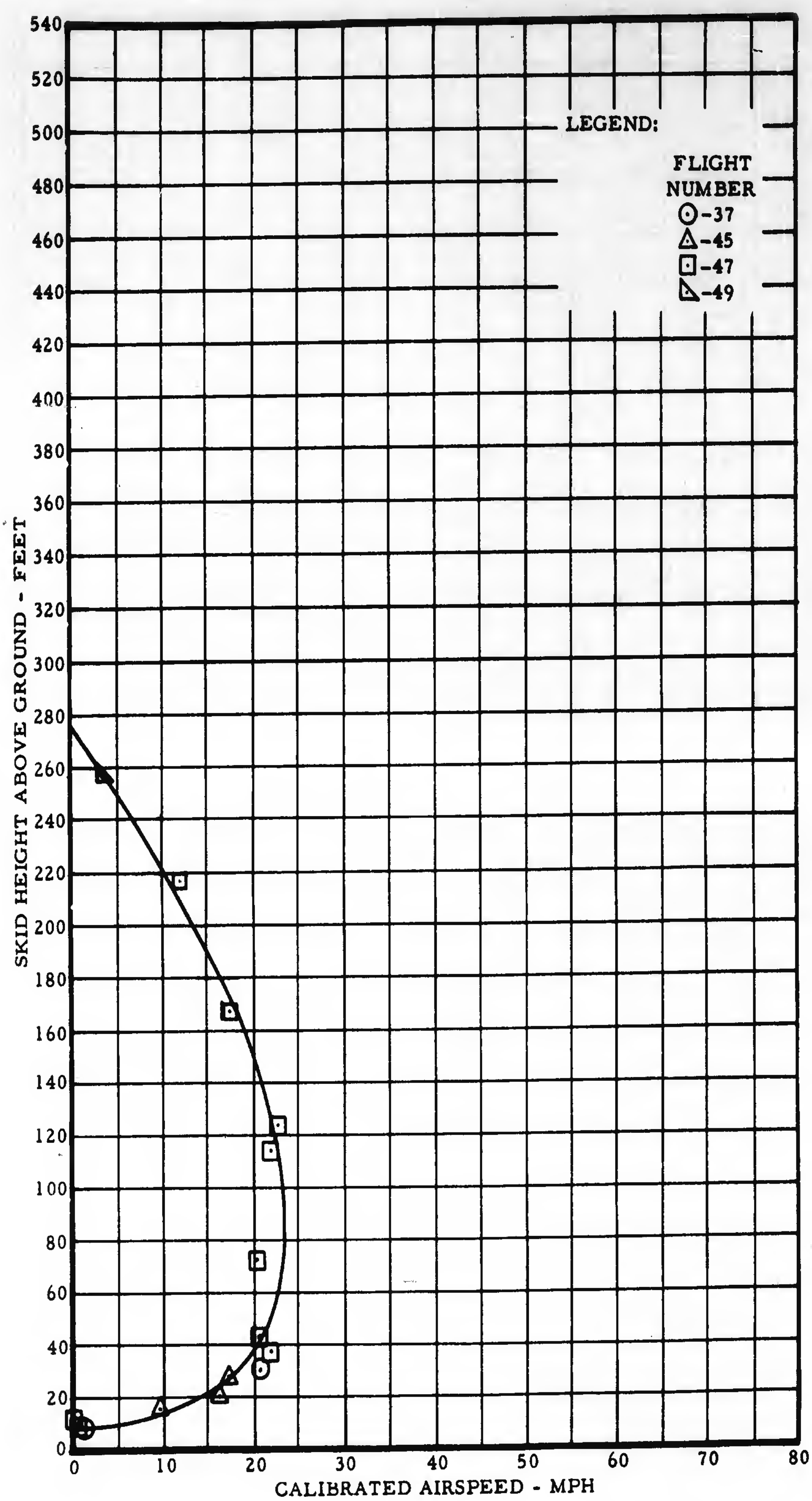


FIG. 6 HEIGHT-VELOCITY DIAGRAM - BASIC DATA
HELICOPTER GROSS WEIGHT 2,650 POUNDS
AVERAGE DENSITY ALTITUDE 200 FEET

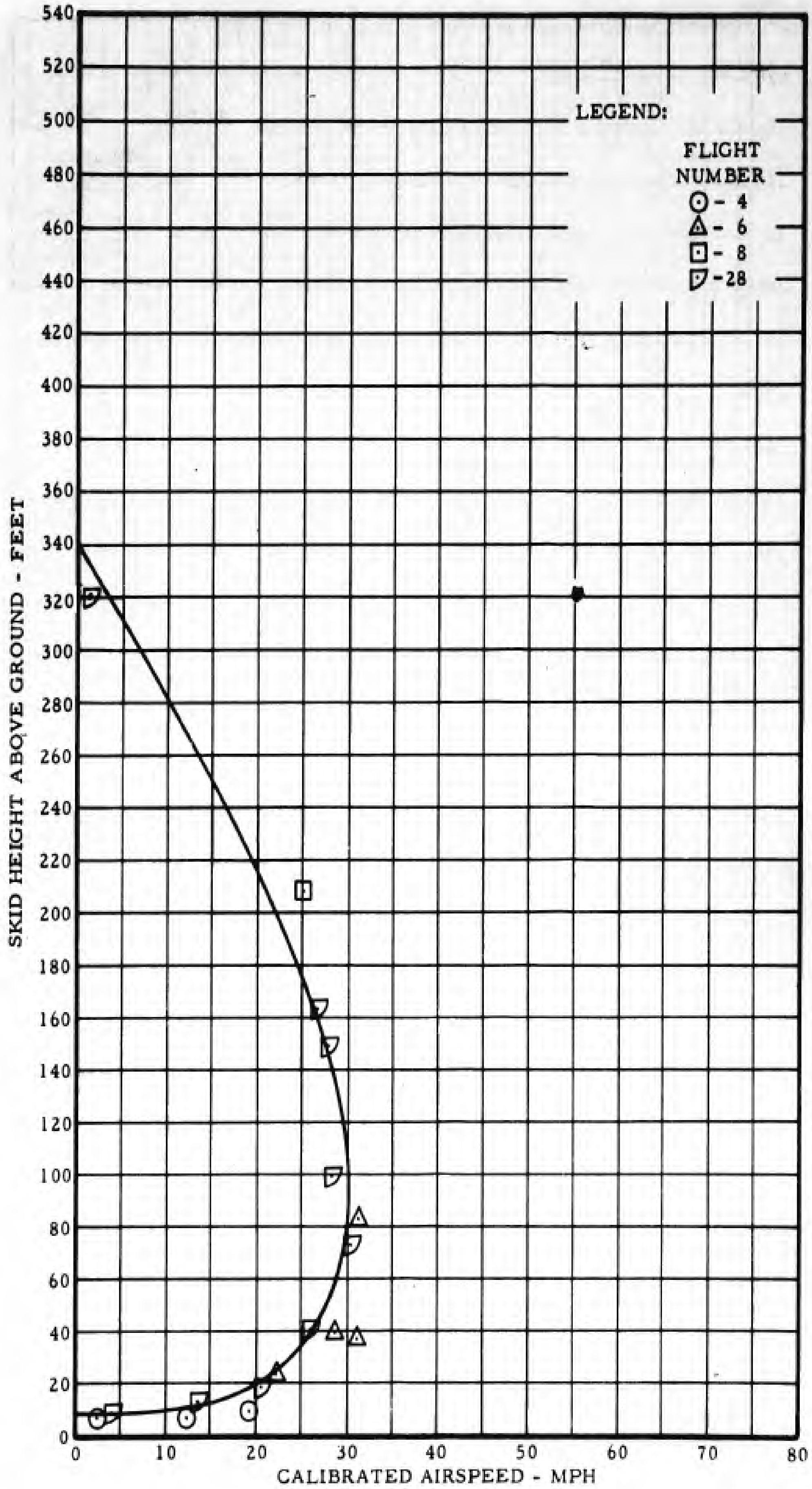


FIG. 7 HEIGHT-VELOCITY DIAGRAM - BASIC DATA
HELICOPTER GROSS WEIGHT 2,650 POUNDS
AVERAGE DENSITY ALTITUDE 4,500 FEET

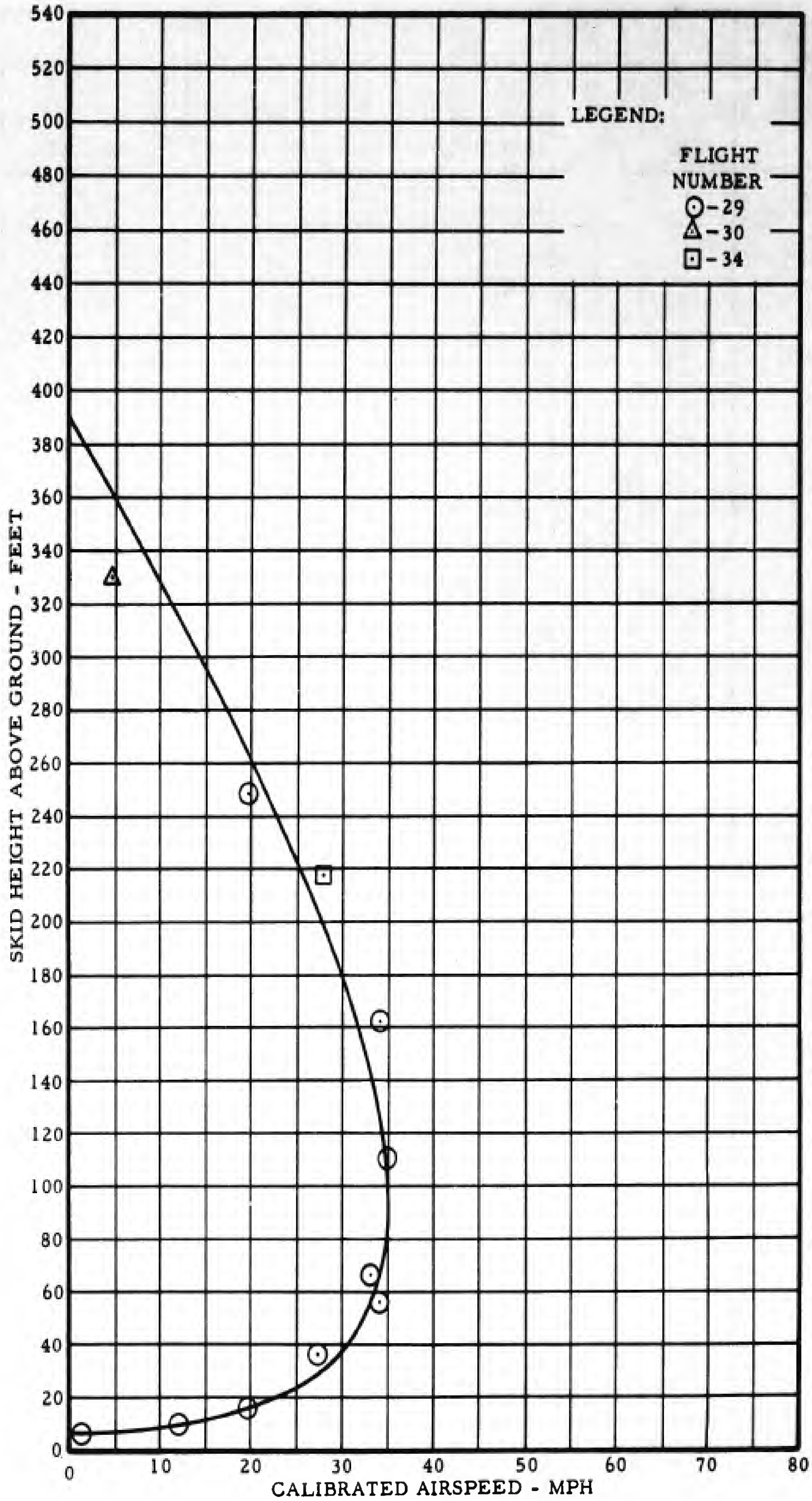


FIG. 8 HEIGHT-VELOCITY DIAGRAM - BASIC DATA
HELICOPTER GROSS WEIGHT 2,650 POUNDS
AVERAGE DENSITY ALTITUDE 7,350 FEET

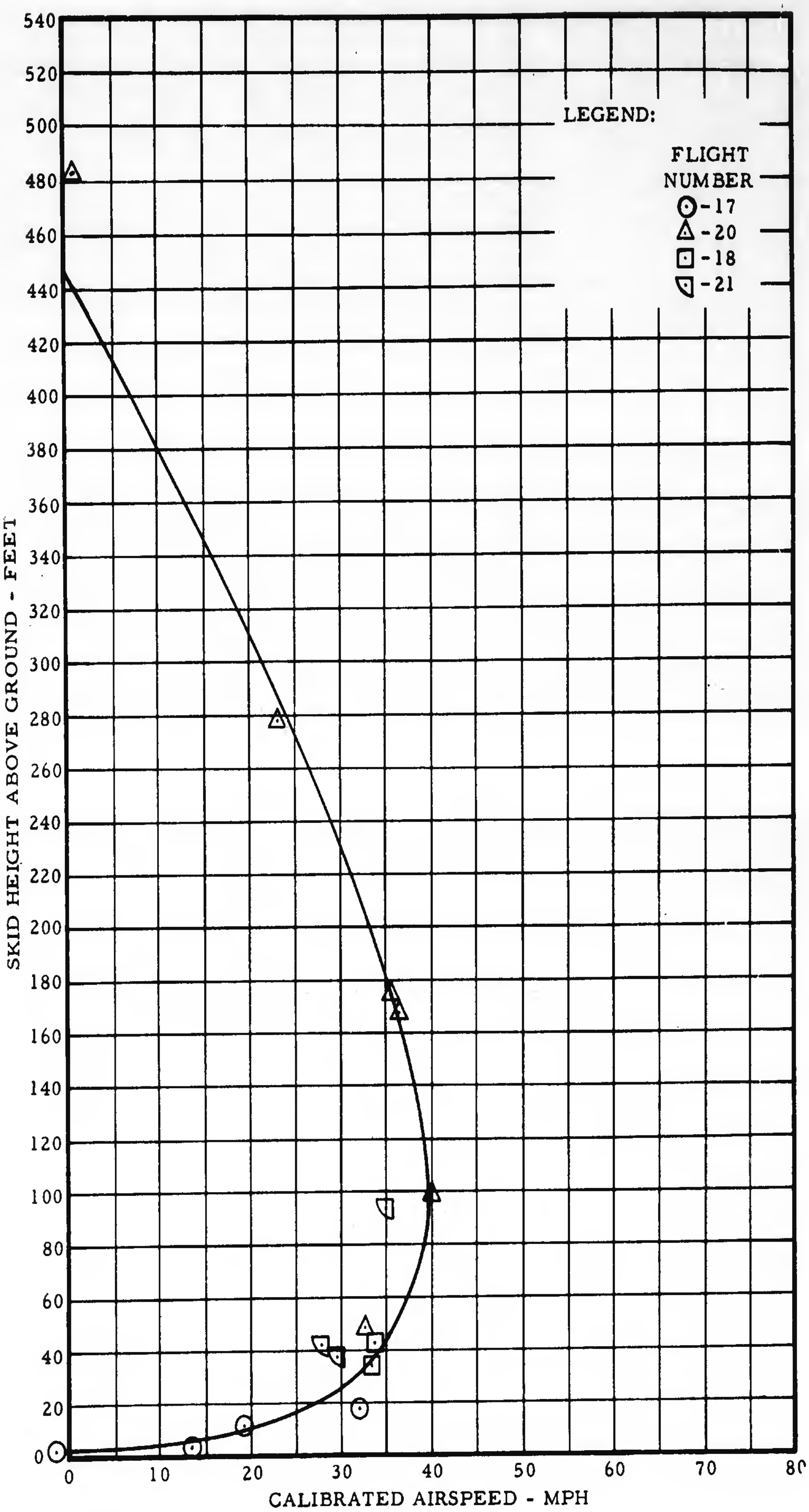


FIG. 9 HEIGHT-VELOCITY DIAGRAM - BASIC DATA
HELICOPTER GROSS WEIGHT 2,650 POUNDS
AVERAGE DENSITY ALTITUDE 10,250 FEET

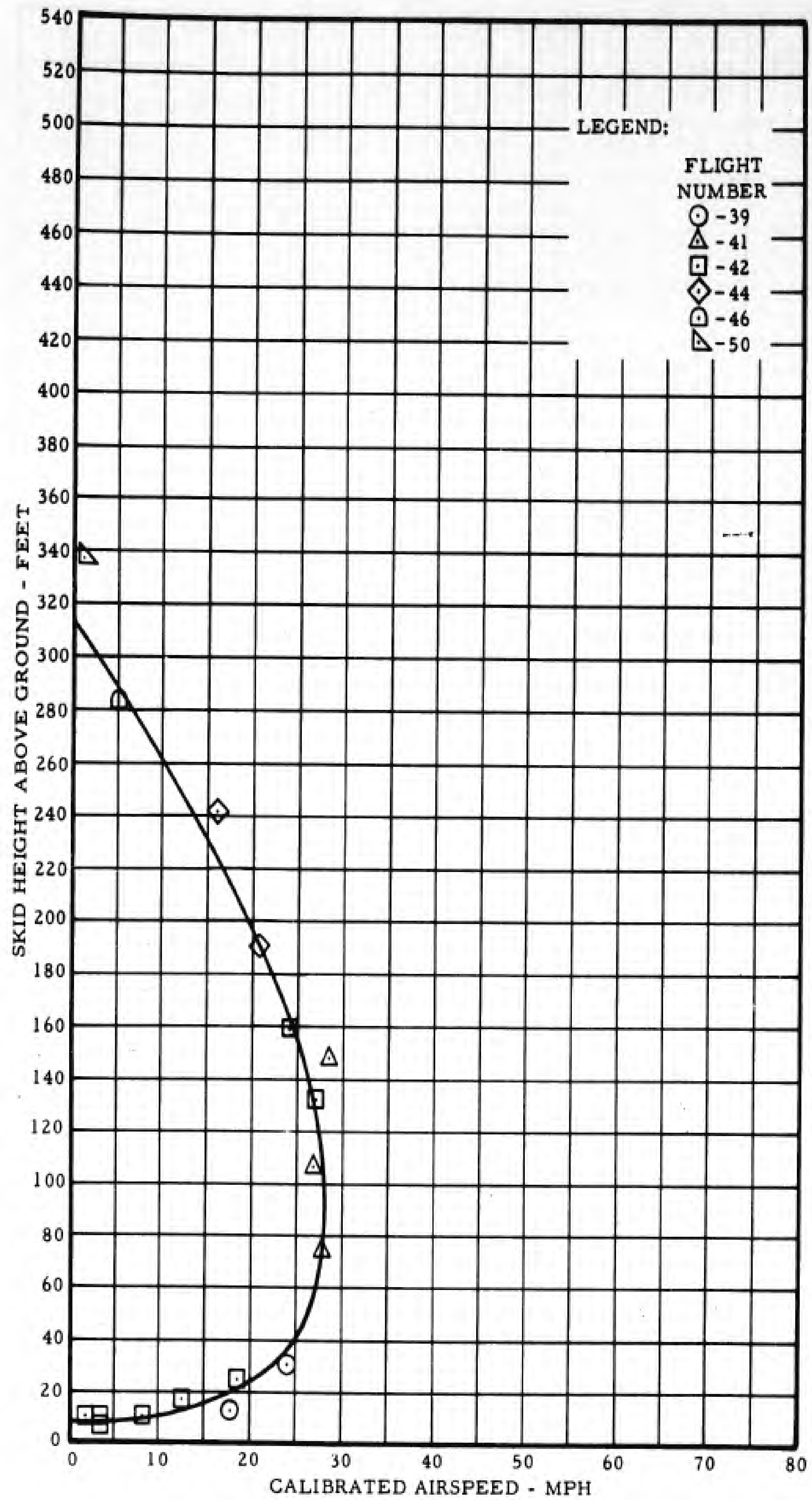


FIG. 10 HEIGHT-VELOCITY DIAGRAM - BASIC DATA
HELICOPTER GROSS WEIGHT 2,850 POUNDS
AVERAGE DENSITY ALTITUDE 200 FEET

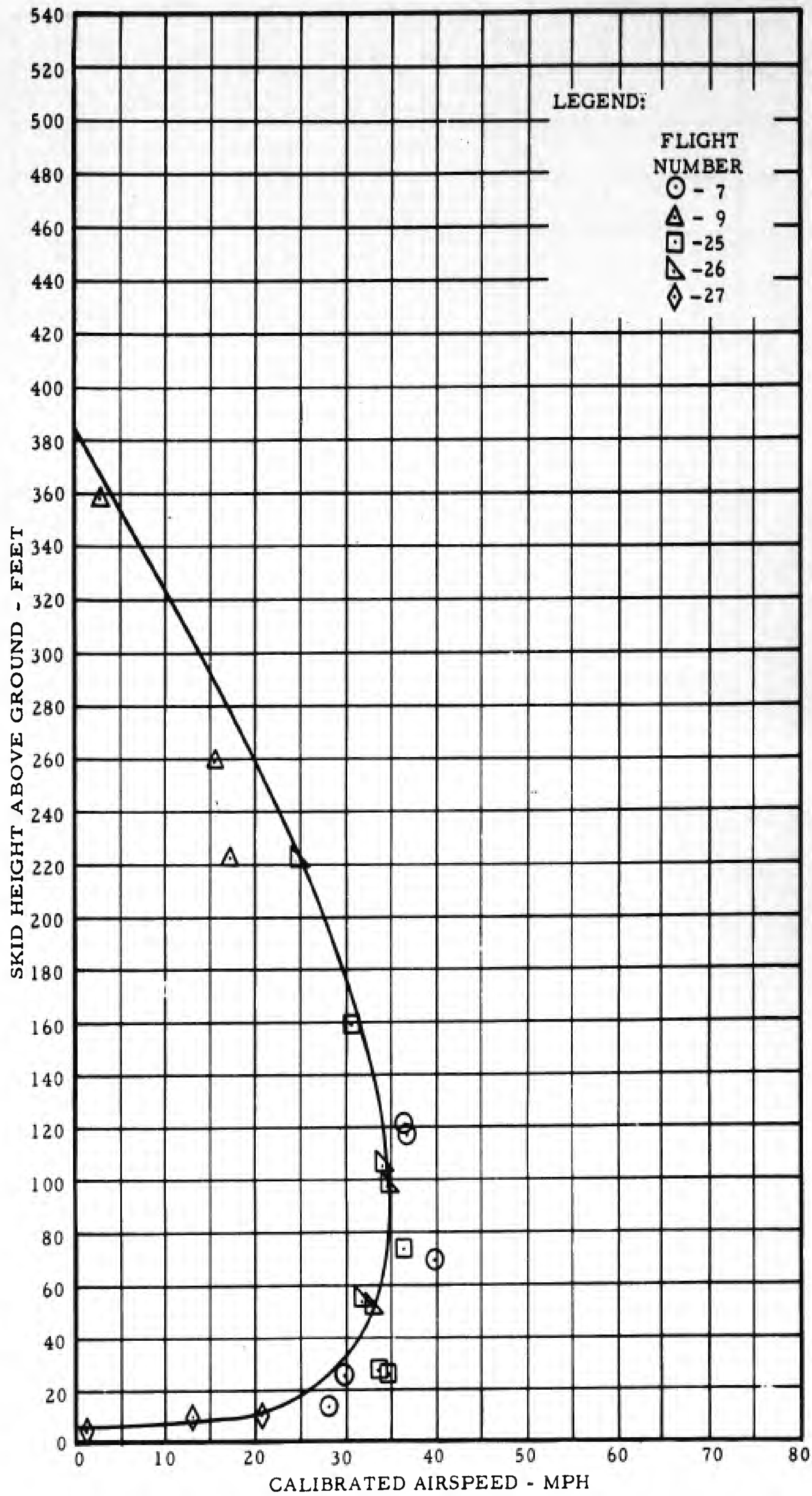


FIG. 11 HEIGHT-VELOCITY DIAGRAM - BASIC DATA
HELICOPTER GROSS WEIGHT 2,850 POUNDS
AVERAGE DENSITY ALTITUDE 4,500 FEET

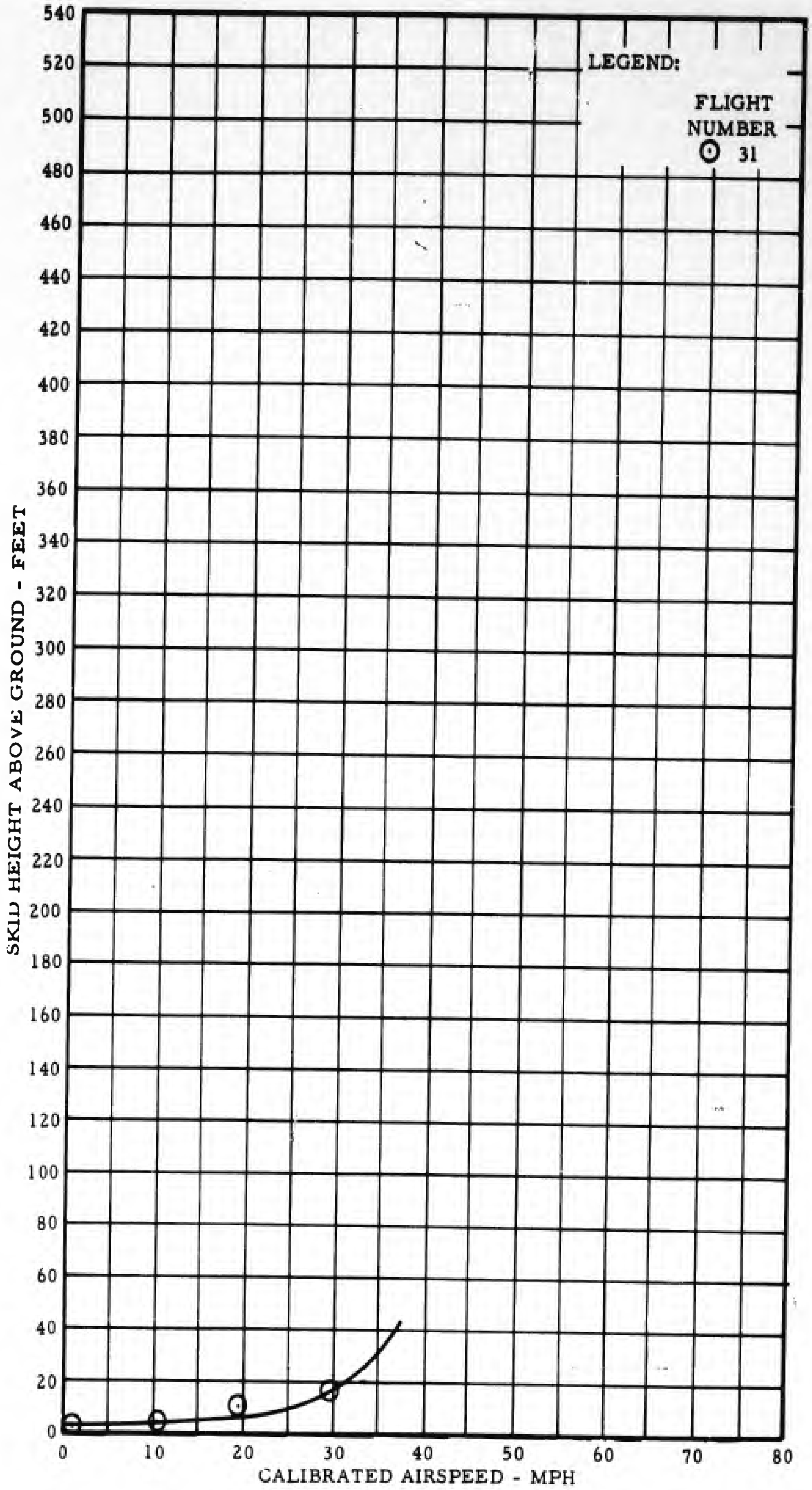


FIG. 12 HEIGHT-VELOCITY DIAGRAM - BASIC DATA
HELICOPTER GROSS WEIGHT 2,850 POUNDS
AVERAGE DENSITY ALTITUDE 7,350 FEET

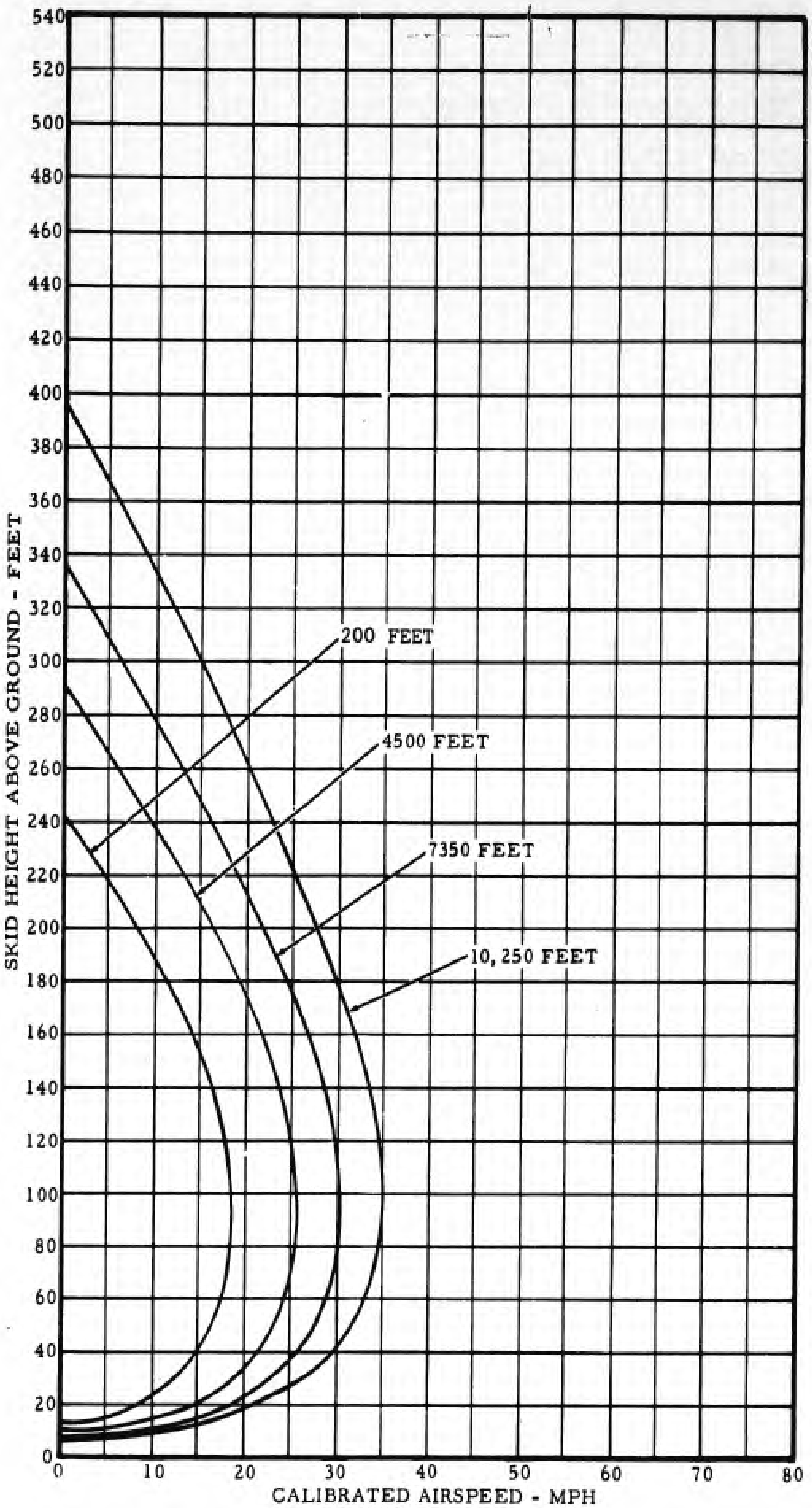


FIG. 13 HEIGHT-VELOCITY DIAGRAM
VARIATION WITH ALTITUDE
GROSS WEIGHT 2, 415 POUNDS

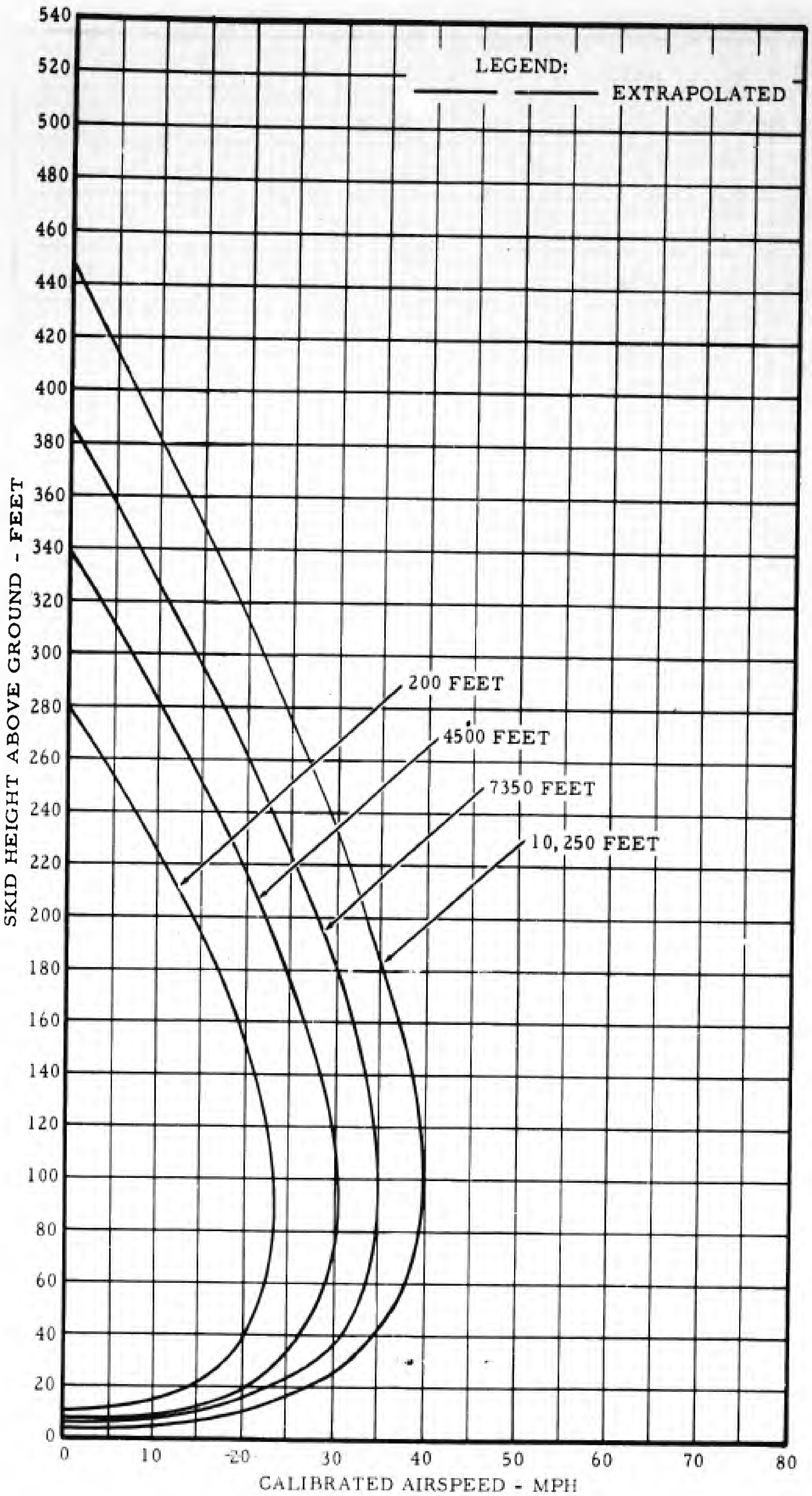


FIG. 14 HEIGHT-VELOCITY DIAGRAM
VARIATION WITH ALTITUDE
GROSS WEIGHT 2,650 POUNDS

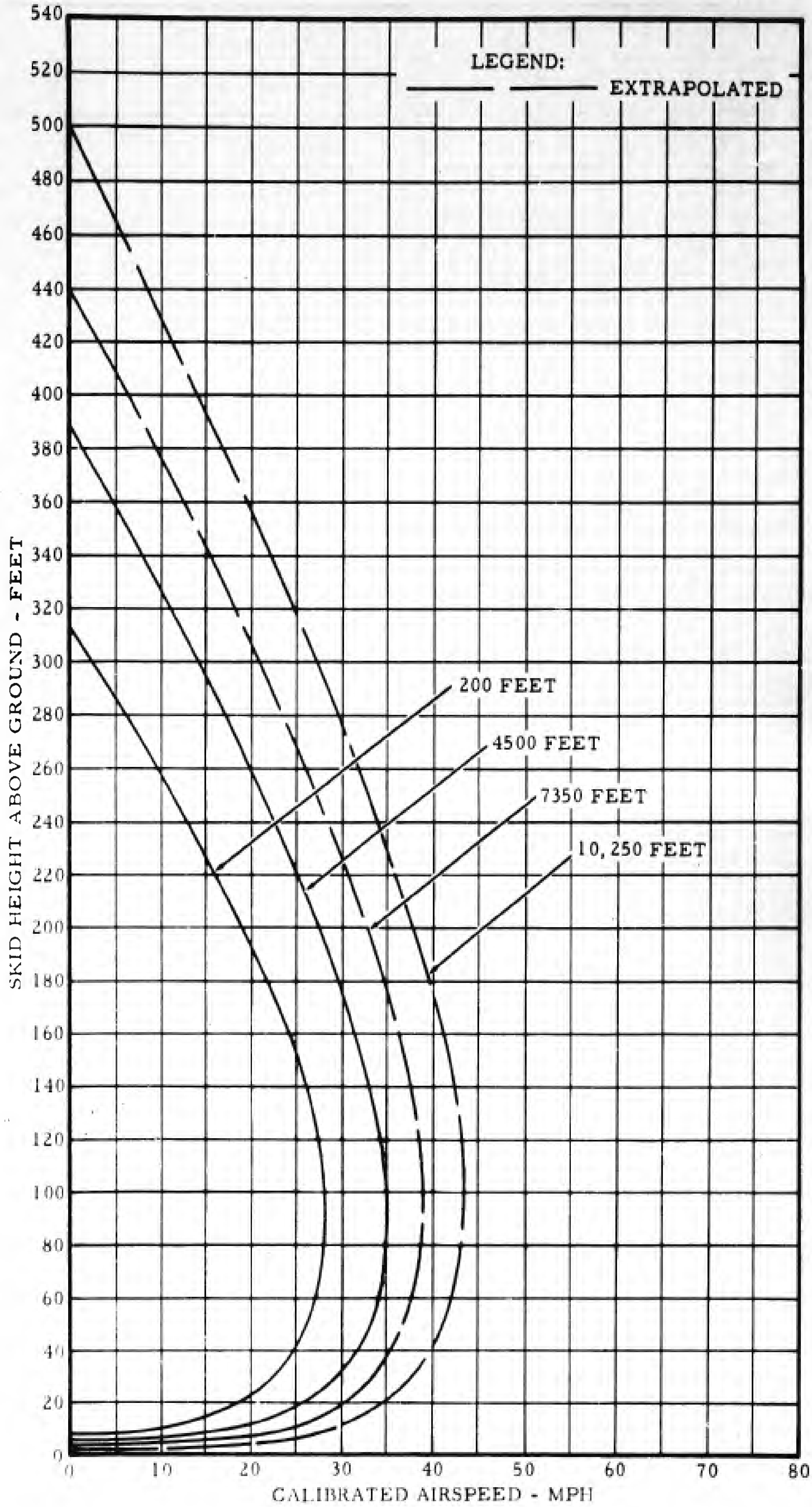


FIG. 15 HEIGHT-VELOCITY DIAGRAM
VARIATION WITH ALTITUDE
GROSS WEIGHT 2,850 POUNDS

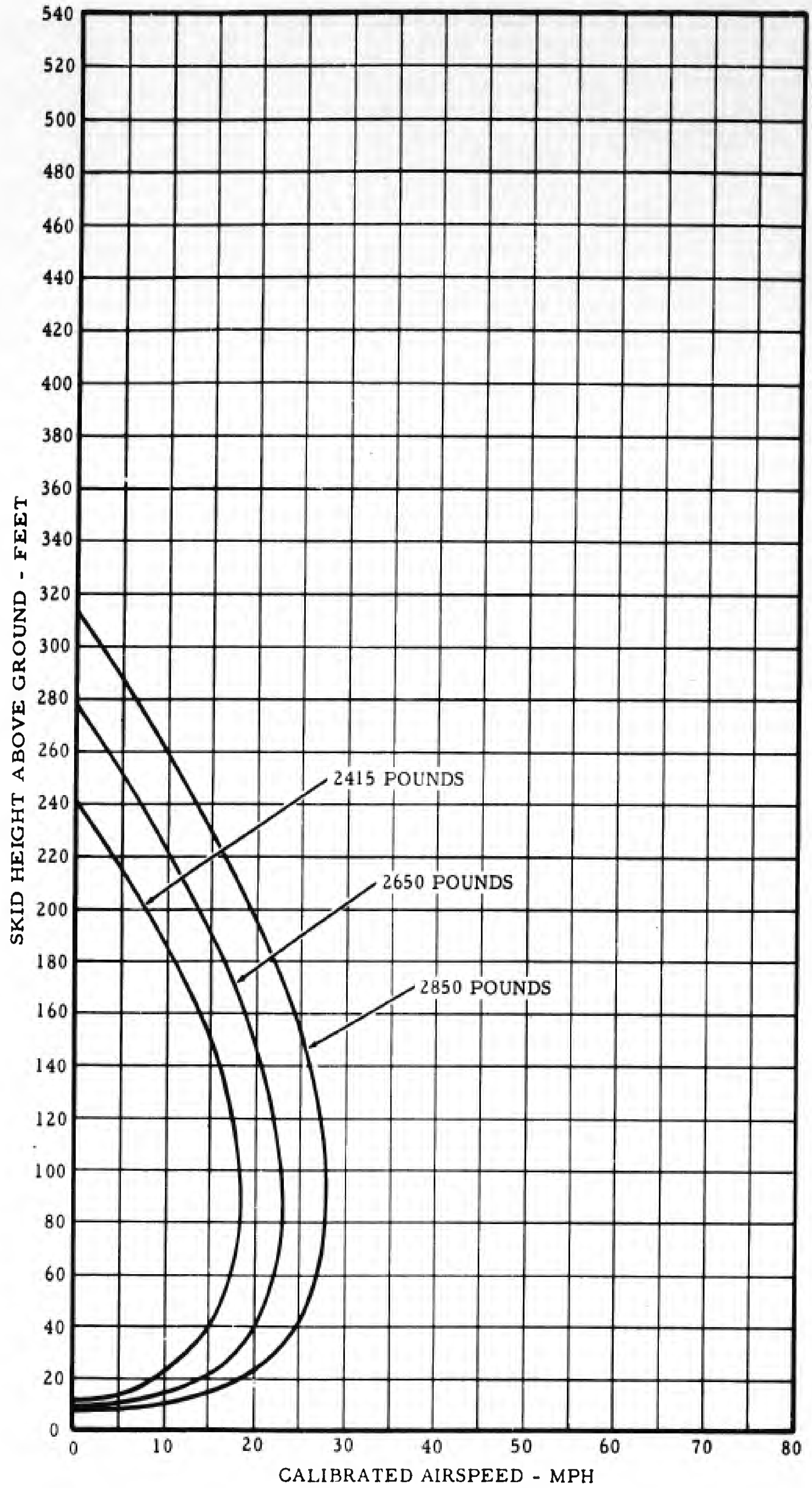


FIG. 16 HEIGHT-VELOCITY DIAGRAM
VARIATION WITH GROSS WEIGHT
AVERAGE DENSITY ALTITUDE 200 FEET

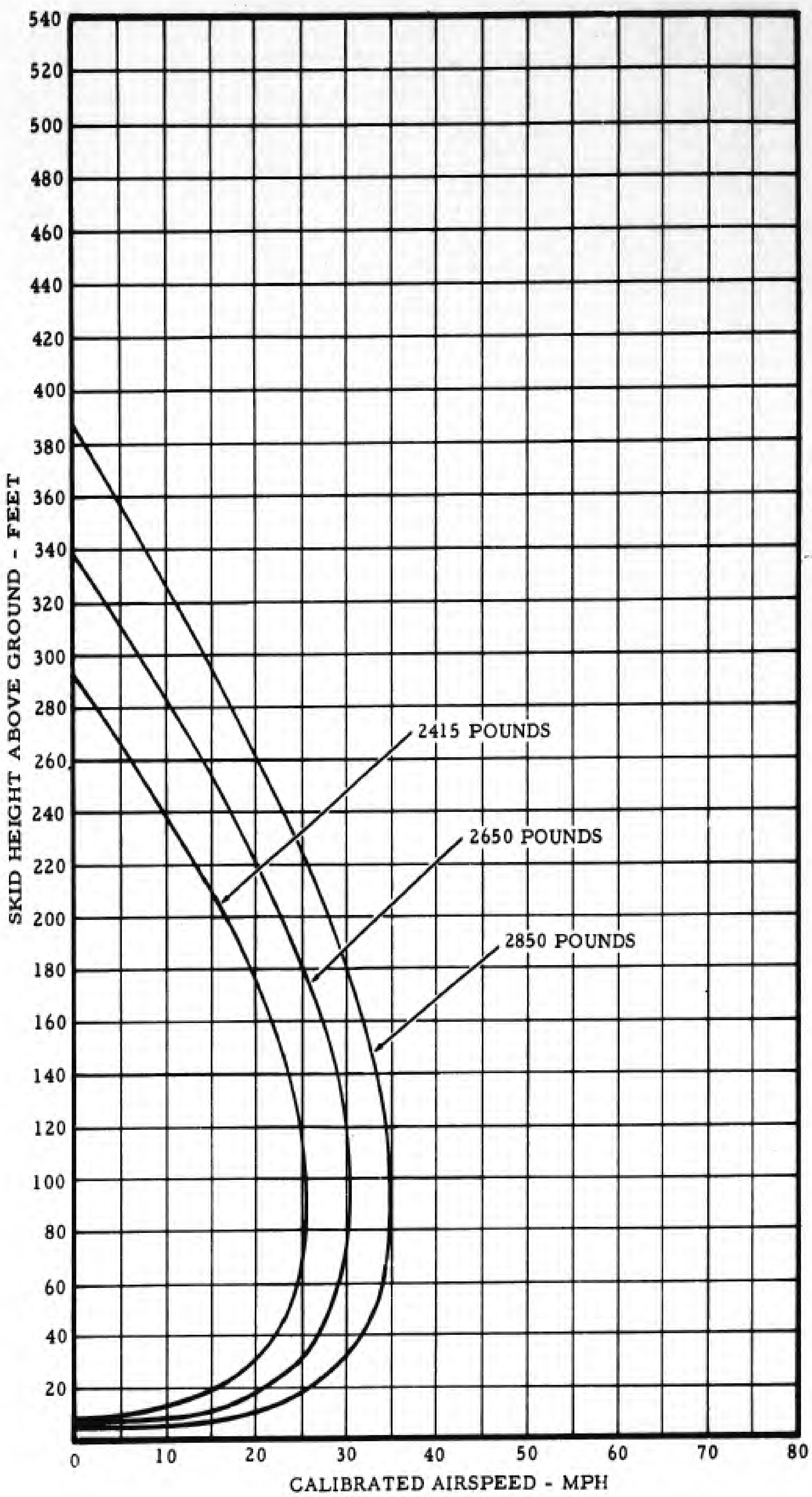


FIG. 17 HEIGHT-VELOCITY DIAGRAM
VARIATION WITH GROSS WEIGHT
AVERAGE DENSITY ALTITUDE 4,500 FEET

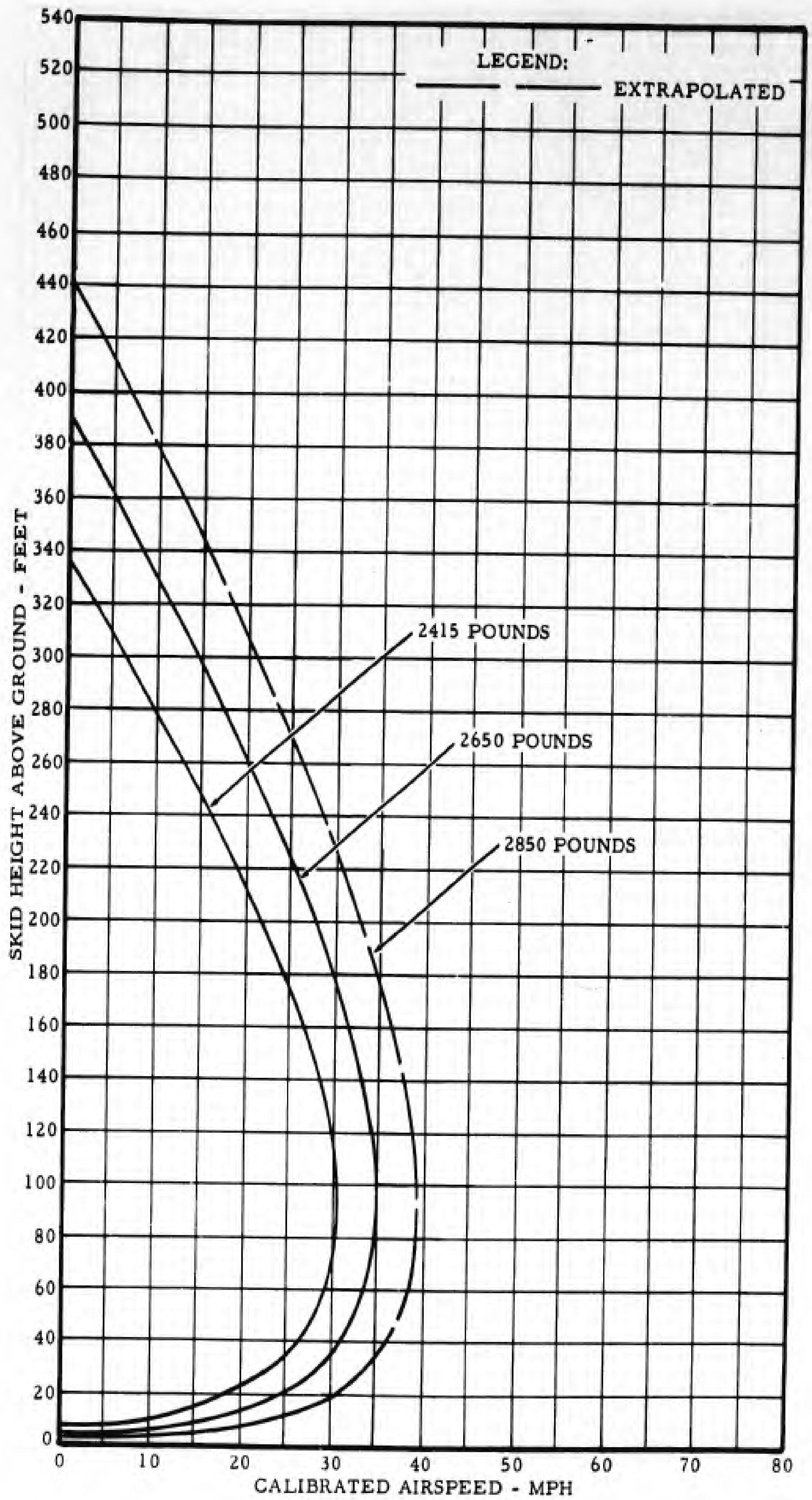


FIG. 18 HEIGHT-VELOCITY DIAGRAM
VARIATION WITH GROSS WEIGHT
AVERAGE DENSITY ALTITUDE 7,350 FEET

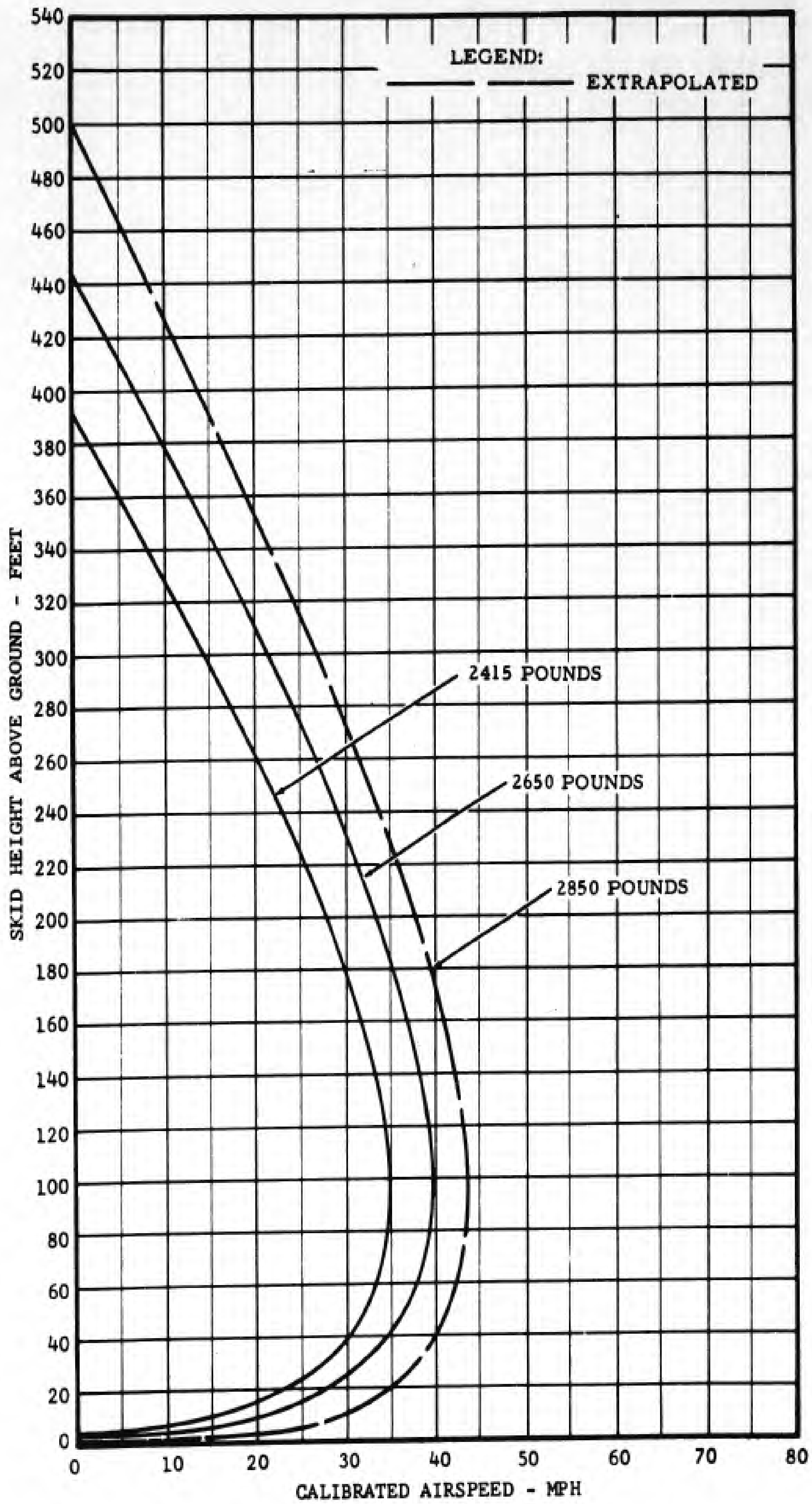


FIG. 19 HEIGHT-VELOCITY DIAGRAM
VARIATION WITH GROSS WEIGHT
AVERAGE DENSITY ALTITUDE 10,250 FEET

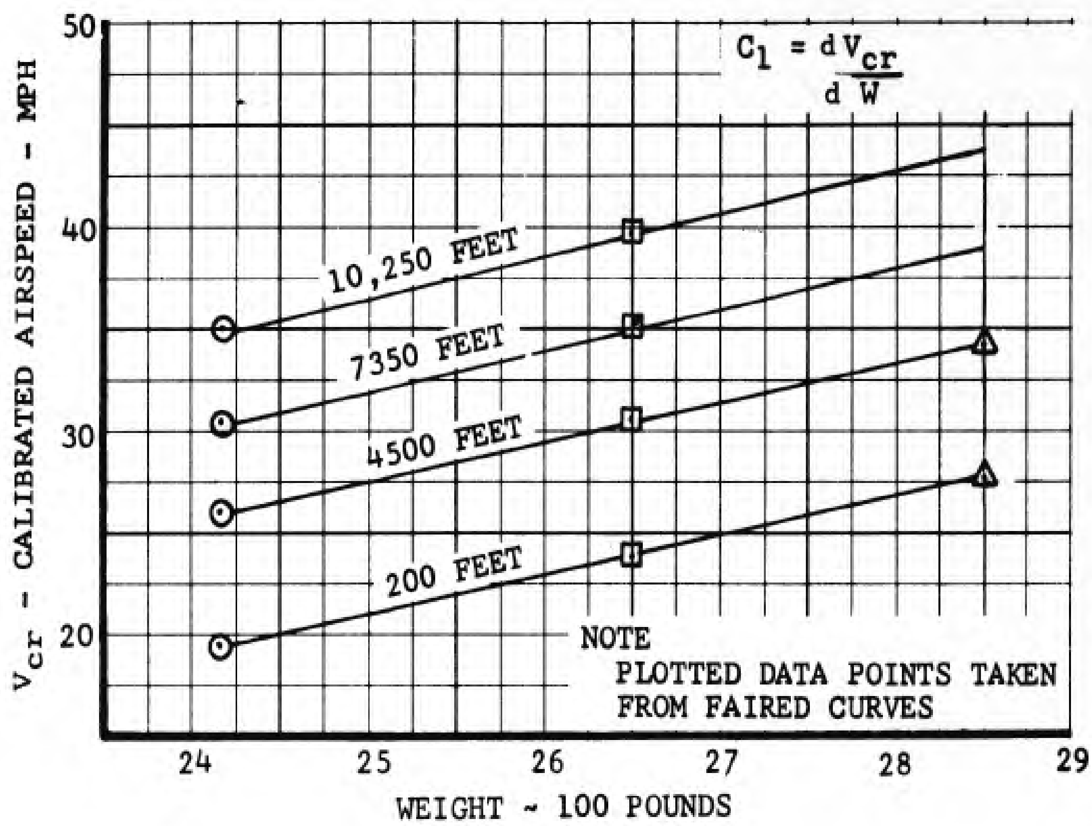


FIG. 20 CRITICAL VELOCITY (V_{cr}) VERSUS AIRCRAFT GROSS WEIGHT FOR THE RANGE OF TEST ALTITUDES

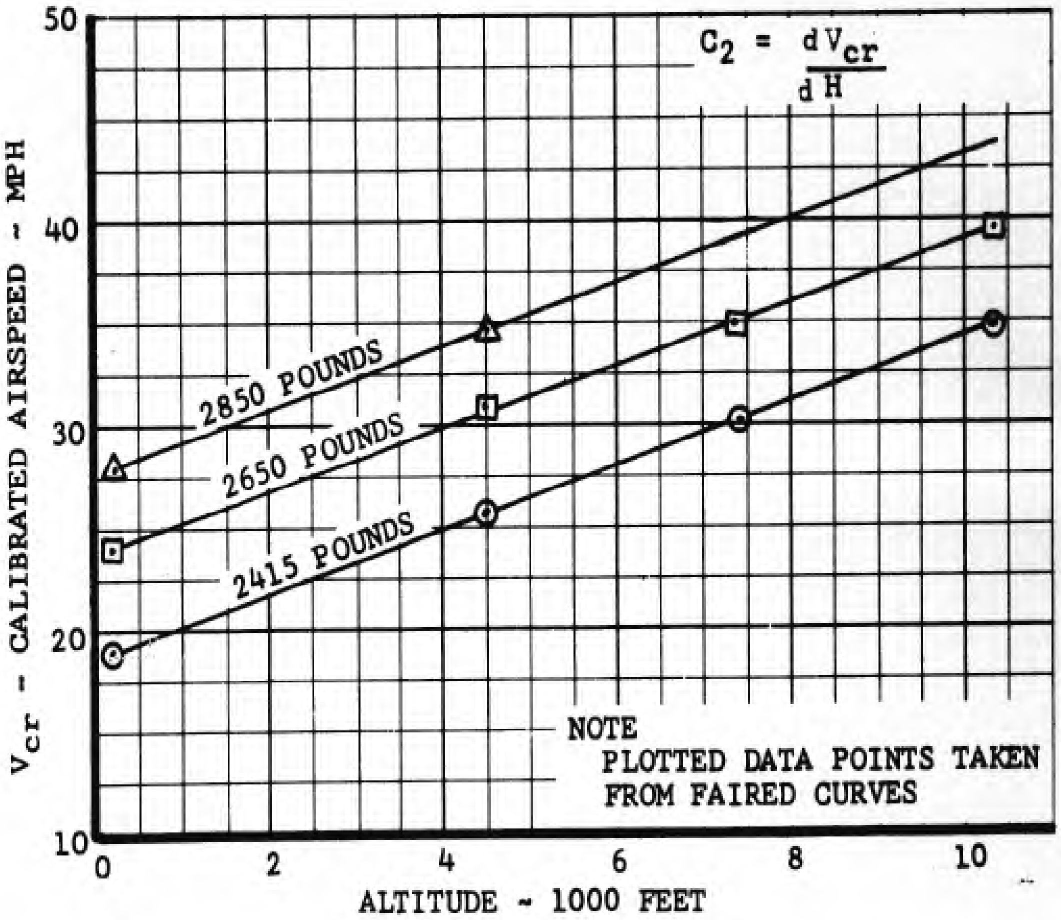


FIG. 21 CRITICAL VELOCITY (V_{cr}) VERSUS TEST ALTITUDE FOR THE RANGE OF TEST WEIGHTS

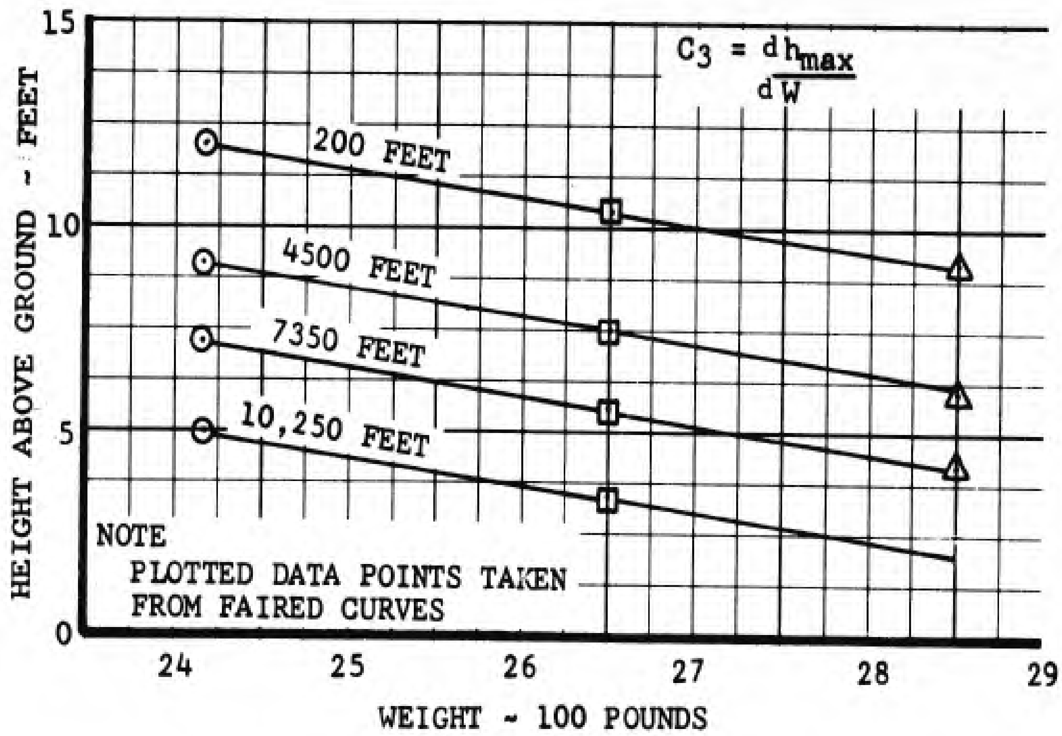


FIG. 22 LOW HOVER HEIGHT (h_{max}) VERSUS AIRCRAFT GROSS WEIGHT FOR THE RANGE OF TEST ALTITUDES

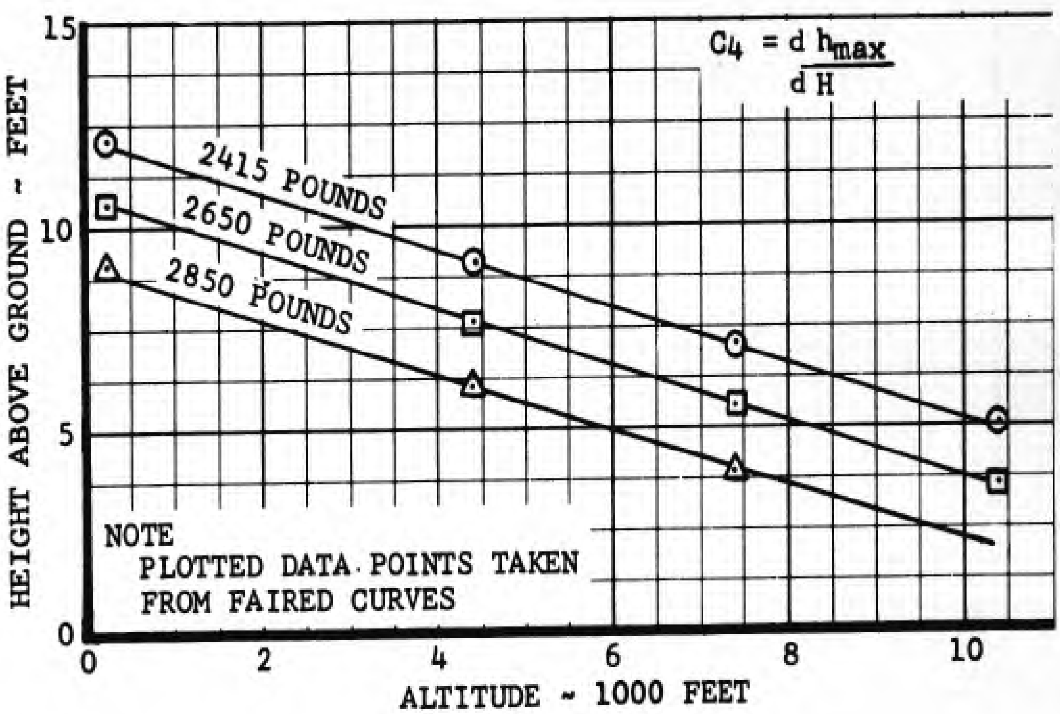


FIG. 23 LOW HOVER HEIGHT (h_{max}) VERSUS TEST ALTITUDE FOR THE RANGE OF TEST WEIGHTS

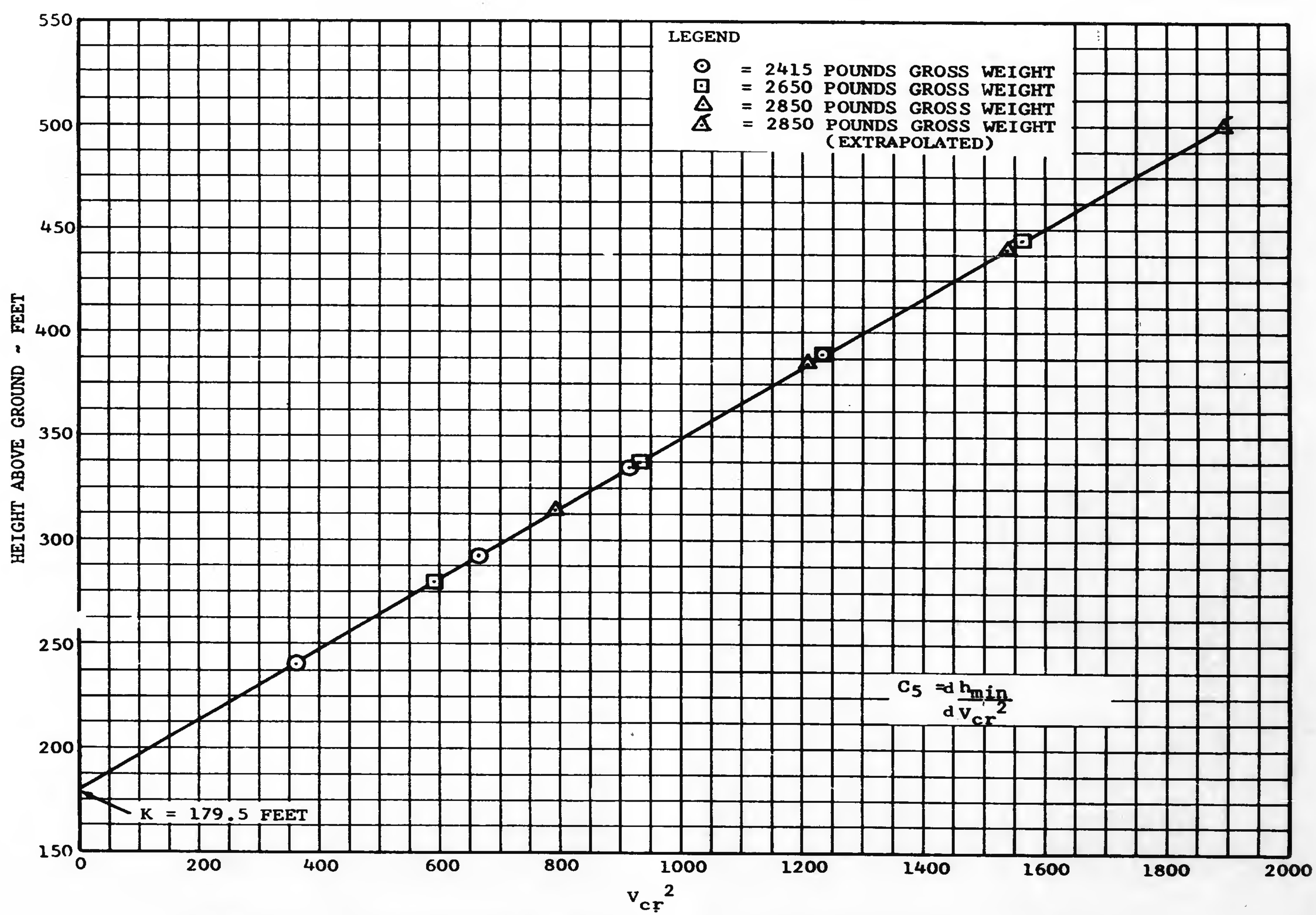
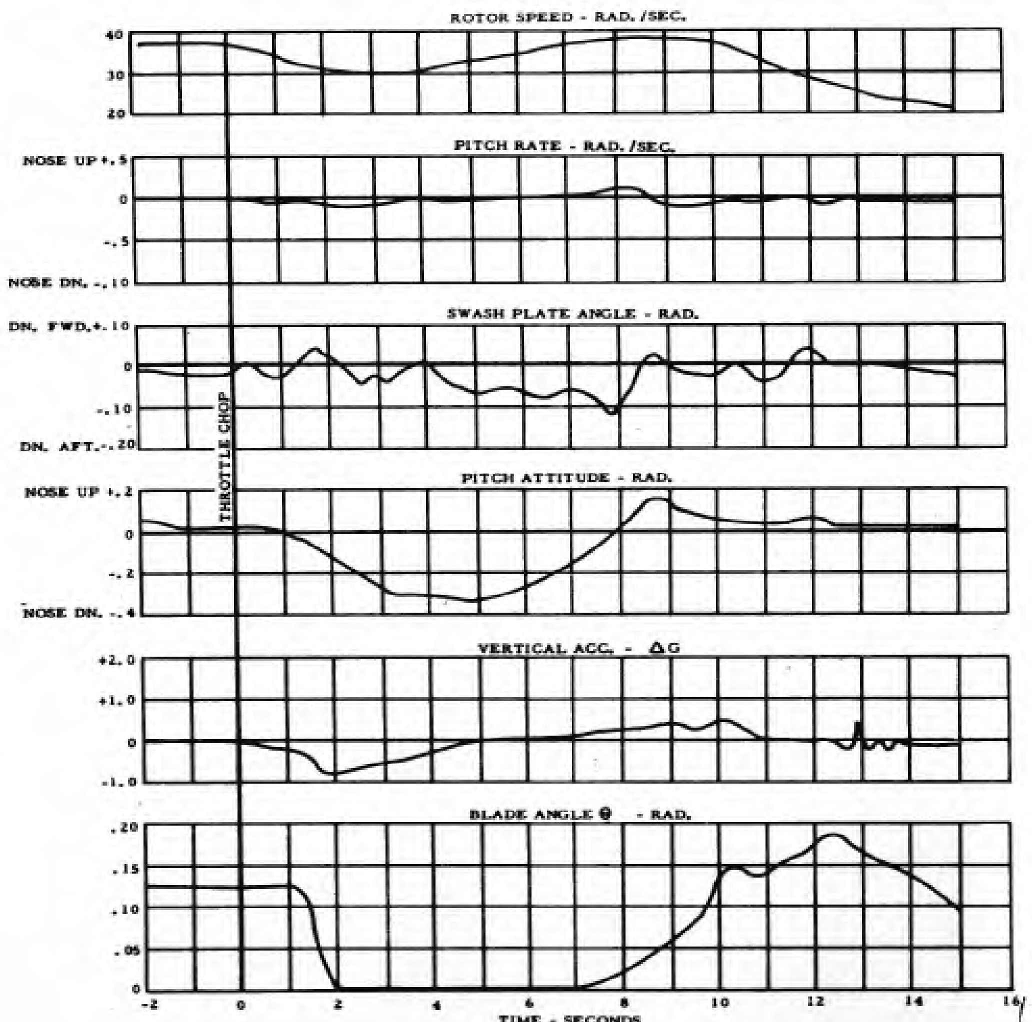


FIG. 24 HIGH HOVER HEIGHT (h_{min}) VERSUS SQUARE OF CRITICAL VELOCITY (V_{cr}^2)



HEIGHT - VELOCITY TEST

FLIGHT NO. 9 RUN NO. 5 COUNTER NO. 764

GROSS WEIGHT 2816 LBS. DENSITY ALTITUDE 4,450 FEET

WIND COMPONENT VELOCITY +2.9 MPH

SKID HEIGHT 358.5 FEET
CALIBRATED AIRSPEED 2.7 MPH } AT THROTTLE CHOP

CALIBRATED AIRSPEED 20.4 MPH
Δ ACCELERATION 0.4 G's } AT LANDING

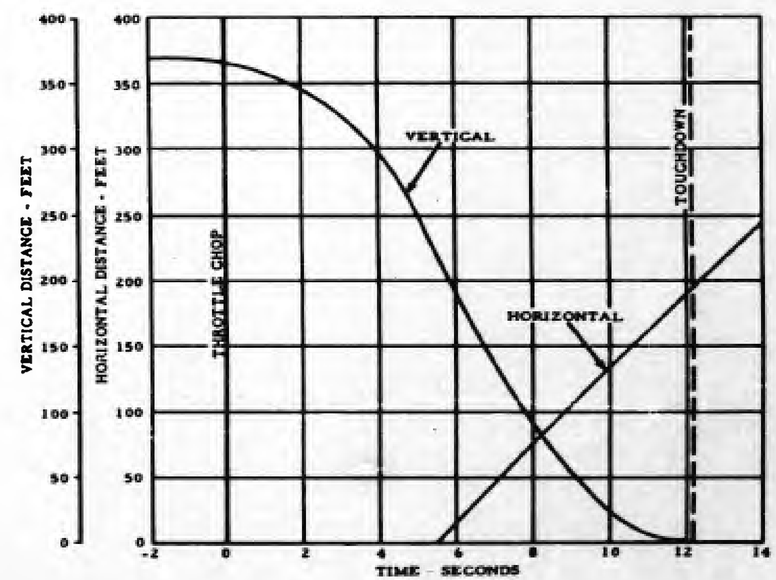


FIG. 25 TYPICAL TIME-HISTORY PLOT
HIGH HOVER AREA AT MAXIMUM GROSS WEIGHT

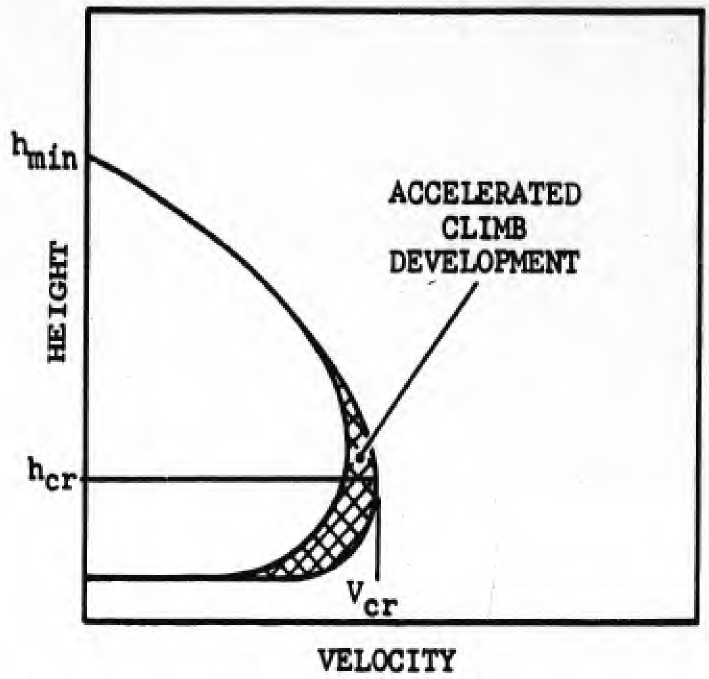


FIG. 26 ACCELERATED CLIMB INFLUENCE ON THE HEIGHT-VELOCITY DIAGRAM

UNCLASSIFIED

UNCLASSIFIED