Federal Aviation Agency

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Change 1

SUBJECT: BACKGROUND INFORMATION ON THE AIRCRAFT PERFORMANCE CURVES FOR LARGE AIRPLANES

1. PURPOSE. This advisory circular sets forth background information in explanation of the development of performance curves for large airplanes used in airport planning and design. This circular also provides airport designers with information on aircraft performance curves for design which will assist them in an objective interpretation of the data used for runway length determination.

2. REFERENCES. The following publications provide further guidance and technical information as may be required:

   a. Federal Aviation Agency publication titled "Airport Design" dated 1961 including Supplement No. 1 dated 1962.

   b. "U. S. Standard Atmosphere", 1962, available from U. S. Government Printing Office at $3.50 per copy.

   c. AC 150/5325-1, "Aircraft Performance Nomograms", October 10, 1963.

3. PREFACE. This paper is prepared as an explanation in elementary terms of a complex technical subject. It is a compromise between lay presentation and advanced technical language. It may seem too basic to the expert and somewhat complicated to the layman. For the broad audience that it is meant to help, this advisory circular should provide background for ready understanding of aircraft performance curves.

4. HOW TO GET THIS PUBLICATION. Obtain additional copies of this circular AC 150/5325-3, "Background Information on the Aircraft Performance Curves for Large Airplanes," from the Department of Transportation, Distribution Unit, TAD-484.3, Washington, D. C. 20590.

Cole Morrow, Director
Airports Service

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CHAPTER 1. INTRODUCTION

1. APPLICATION. Prior to the development of aircraft performance curves, runway length requirements for airport development were determined by the airport service type concept. This concept divided airports in the system into categories; i.e., local, trunk, and continental; specifying a range of runway lengths for each airport type based upon certain requirements. These requirements took into account the route pattern being flown and the type of equipment which fly those routes. For example, an airport categorized "local" was defined as an airport to serve on local service routes providing service in the "Short-haul" category normally not exceeding 500 miles. With the advent of jet aircraft, this method produced excessive inaccuracies in establishing needed runway lengths and was therefore unacceptable. The aircraft performance curves are the result of an endeavor to develop a method for determining practical runway design lengths for airports in the National System and, specifically, for Federal-aid Airport Program participation.

2. SPECIAL STUDY. Local conditions may dictate the need for special considerations such that the use of Agency aircraft performance curves is not advisable. Runway length determinations made as a result of these special studies will agree with length determination made by use of the aircraft performance curves if the same basic data are applied.

CHAPTER 2. DISCUSSION OF PARAMETERS AFFECTING RUNWAY DESIGN LENGTH

3. INTRODUCTION. All of the factors that have a substantial effect on runway length are considered in the development of the takeoff and landing performance curves. All the other factors, such as relative humidity, are held at a selected standard during flight testing and require no further consideration. These other factors in reality have a variable effect on runway length, but their effects are relatively small and are therefore disregarded. The variable factors affecting takeoff runway lengths are the individual airplanes, airplane configuration, the atmosphere (pressure-altitude and temperature), wind, takeoff weight, and runway gradient. The variable factors affecting landing runway lengths are the airplanes considered, airplane configuration, the atmosphere (pressure-altitude only), wind, and landing weight.

4 THE AIRPLANE. The differences in the certification and operational requirements between types of present day airplanes demand independent consideration of the runway length required by each airplane. It is generally accepted that two different types of airplanes do not necessarily require the same length of runway, nor does a single airplane type require the same length of runway at all airports. It follows, therefore, that the critical airplane type for one airport need not necessarily be the critical type for another airport. The critical airplane type, the airplane in a family having the greatest requirement, controls the runway length needed at the airport. This runway length, therefore, will satisfy the requirements of all the airplanes that the airport is intended to serve. Both the landing and takeoff runway length requirements must be considered in order to determine which is greater.

a. Modifications. Optional modifications or equipment installations incorporated in airplanes have an effect on any specific airplane performance and may affect its runway length requirements. Flight test data and airline operational data for all probable combinations of airplane modifications must be considered in the development of the aircraft performance curves.

b. Selection of Design Aircraft. Each airport design is related to a selected aircraft.

(1) The preparation of individual aircraft performance curves for existing airplanes necessitates an analysis of the modifications mentioned above. In addition, a review is required of the numbers of these airplanes active in the civil fleet, the amount of hours flown in a given period, and the route segments flown which constitutes the activity in the civil fleet. This procedure usually identifies as

critical one airplane of a series which would require detailed computation of performance for design purposes. In some instances, it becomes necessary to combine characteristics of airplanes in a series throughout the range of factors considered to establish composite critical performance criteria.

(2) For the new turbojet airplanes, such as Boeing 707, Douglas DC-8, and Convair 880, a projected analysis is used based on the number of airplanes ordered and their anticipated modifications and operational data. The runway length requirements for airport development can then be determined by the use of one set of performance curves for a series depicting the overall critical requirements of that series.

5. AIRPLANE CONFIGURATION. Airplane configuration refers to the position of the various elements of the airplane affecting its aerodynamic characteristics.

a. Wing flaps are the most common element of the airplane which affect aerodynamics. Within the total range of the variable factors considered for landing and takeoff, the pilot may adjust the airplane's configuration within operational limits to conform to the requirements for certain conditions. In the development of performance curves, data for the configuration normally used in conjunction with other factors are applied. For example, the DC-8-40 may be taken off with the wing flaps positioned at either 25 degrees or 15 degrees. With wing flaps positioned at 25 degrees, this airplane requires less runway and has a flatter climb capability than with its wing flaps at 15 degrees.

b. It must be recognized that airplane performance varies with the combinations of conditions at the time of takeoff or landing. The DC-8-40 has a relatively short runway length requirement and a good climb capability under the ideal conditions of low pressure-altitude, low temperature, and light weight. Under these conditions, use of the 25-degree flap setting is advantageous. However, runway length requirements increase and climb capability sharply decreases under conditions of high pressure-altitude, high temperature, and maximum weight. Under these conditions, the total takeoff segment of flight is best attained using 15 degrees of flaps.

c. The performance curves developed for use in airport design incorporate both configurations over the expected range of variables. Consideration of this configuration change creates a balance in design requirements resulting in a maximum utility of the airport facilities to be provided.

6. THE ATMOSPHERE. The atmosphere plays a very important part in runway length design. The atmosphere is a related combination of the variable factors of pressure, temperature, and density.

a. Variations in Pressure and Temperature. It is a matter of common knowledge that both atmospheric pressure and temperature at sea level vary from time to time at any given place as well as from place to place at a given time. In numerous locations in the United States, the pressure may vary over a range of 70 or more pounds per square foot and the temperature may vary over 100 or more degrees Fahrenheit during the course of a year. Both pressure and temperature changes occur with changes in altitude. For example, with an increase in altitude the rate of temperature change may vary from an increase of one or two degrees Fahrenheit to a decrease of five or six degrees Fahrenheit per thousand feet of altitude change. Finally, it is difficult to predict or forecast what these values of pressure and temperature will be for more than a few hours in advance of the time of making the forecast.

b. The Standard Atmosphere. Practical considerations of the atmosphere for many purposes, such as the design and testing of aircraft, need to be represented in average definite terms which can be used as a basis of reference. Such a representation is termed a standard atmosphere; it aims at specifying the average variation of temperature with elevation from which the corresponding variations of pressure and density can also be given. To prescribe a standard atmosphere which simulates the average distribution in the middle latitudes from sea level up to the middle stratosphere, it is necessary to resort to an approximation which may be considered invariable. The approximation by common agreement, almost universally used, is called "The Standard Atmosphere".

(1) The standard atmosphere is defined in terms of an ideal air assumed to be devoid of moisture and dust and obeying the perfect gas law. It is based upon accepted standard values of the sea-level air temperature and pressure. These values are 14.7 pounds per square inch pressure and 59 degrees Fahrenheit temperature. In this standard atmosphere, temperature is considered to decrease uniformly with altitude at the rate of 3.566 degrees Fahrenheit per thousand feet of altitude up to 36,000 feet.

(2) The standard atmosphere is ordinarily presented in the form of a table showing for various altitudes the corresponding pressure, temperature, and density. This table is found in "U. S. Standard Atmosphere", 1962. Also included with this table is background information including a brief historical statement and basis for the tables as well as the basic assumptions, formulas, and derived quantities.

c. Altitude. Generally, as height above sea level increases, the air pressure and density become less. The consequence of these factors upon airplane operations is a loss of lift for a given true airspeed, a loss of horsepower for unsupercharged engines, and a reduction of propeller efficiency. The combined result of these losses is that it takes longer to obtain the forward speed necessary to produce the required lift--thus, the takeoff runway for a given aircraft becomes progressively longer as it is operated from airports of higher and higher elevations. Similarly, at higher altitudes, landing speeds are greater, and less dense air reduces the drag available to assist in reducing the landing roll. Allowances must be made for these longer takeoff and landing distances in designing runway lengths. To make these allowances, a relationship of the altitude at an airport to a sea level elevation is necessary. This is done by determining one of two altitudes, pressure altitude or density altitude, along with the temperature.

(1) Pressure altitude is that altitude above sea level at which a given pressure occurs in the standard atmosphere. At any given location it is the height indicated on an altimeter when the instrument is set to read 29.92 inches of mercury.

(2) Density altitude is that altitude in the standard atmosphere to which the actual density corresponds. It can be approximated by correcting pressure altitude for nonstandard temperatures which may exist.

Of these two, pressure altitude is the one of concern to airport designers since it is used by pilots when referring to aircraft performance curves to compute takeoff and landing distances. These curves are plotted using varying pressure altitudes and varying temperatures. This same material is presented in the nomograms contained in the Airport Design manual. However, since mean maximum pressure altitude information is not usually available for a particular locale, a one to one conversion factor is considered to exist between an airport's pressure altitude and elevation, and the pressure lines on the nomograms are labeled as airport elevation. This substitution is warranted since the likelihood of simultaneous occurence of both maximum pressure altitude and mean maximum temperature is very slight, the application of both maximums to the curves would result in runway length determinations in excess of actual requirements, and temperature accountability is provided in the nomograms.

d. Temperature. The performance of an airplane depends on several factors among which temperature is important. At a given pressure, high temperature results in lower density and so has an adverse effect on both piston-engined and jet aircraft; this effect is usually greatest when taking off especially for jet aircraft, but it should also be considered at other stages of operation. The efficiency of a jet engine depends in part on the difference between the outside air temperature and the maximum temperature attainable in the combustion chamber. As outside temperature increases above a certain value depending on the altitude, both engine efficiency and aircraft true air speed are decreased (other things being equal) and, therefore, the aircraft's performance is reduced.

7. WIND. The airport must be designed to accommodate airplane operations under most normal wind conditions.

a. A tailwind on one runway is a headwind on a runway with a reciprocal heading. Runway lengths increase with tailwind, so when using the bidirectional runway concept; i.e., theoretically utilizing a headwind for all conditions in establishing runway length, the zero-wind condition is critical for landing. This requires, however, a change in operational direction on that runway each time the wind changes direction and does not provide adequate length for the preferential runway concept in use at many busy airports where tailwind operations are conducted. The problem is further compounded by the fact that winds up to five knots are reported as "calm". For these reasons, landing aircraft performance curves are based on a five-knot tailwind to recognize the flexibility required in airplane landing operations.

b. The takeoff aircraft performance curves, however, are developed for zero wind. The critical wind condition for takeoff is dependent upon the other factors affecting the runway length requirements for takeoff (see Paragraph 9). To establish the relation between a critical wind and the other factors would have necessitated a procedure too complex for the introduction of aircraft performance curves in planning and design. It was therefore deemed appropriate to hold this variable at a constant zero velocity.

8. WEIGHT. The heavier the airplane's weight, the longer are its runway length requirements. When the weight of an airplane is increased, the wing load and power required will have to be increased. This may be accomplished by either a larger angle of attack or, if the same angle of attack is maintained, by an increase in speed. At any one angle of attack, velocity (V) varies as the square root of the weight and the required power as the cube of the square root of the weight. Also, the maximum lift coefficient and wing area remain constant in today's fixed wing aircraft, and the landing speeds vary as the square root of the

weight. Landing speeds increase with high wing loading, so do takeoff speeds; therefore, according to the laws of acceleration/deceleration, the length of run or roll needed to attain such speeds or diminish to zero is increased.

a. Landing Weights. Airplanes are landed with weights up to the maximum landing weights which fall into one of three types.

(1) Structural. Maximum landing weights based on structural limitations are constant regardless of pressure-altitude, temperature, runway length, and wind.

(2) Climb. Maximum landing weights based on climb limitations vary with:

(a) Pressure-altitude for nonturbine-powered airplanes.

(b) Pressure-altitude and temperature for turbine-powered airplanes. An increase in pressure-altitude and/or temperature decreases the maximum landing weight.

(3) Runway Length. Maximum landing weight based on a runway length limitation results from a previous design for runways developed to accommodate airplanes with lesser takeoff and landing length requirements. The need to use a lighter weight than the maximum structural or climb landing weight shown on the curves to fit the existing runway length will automatically produce a limitation on the new critical airplane.

b. Takeoff Weights. Airplanes are taken off at weights up to the maximum takeoff weight which falls into one of six types.

(1) Structural. Maximum takeoff weights based on structural limitations are constant regardless of pressure-altitude, temperature, wind, runway length, and runway gradient.

(2) Climb. Maximum takeoff weights based on climb limitations vary with:

(a) Pressure-altitude for nonturbine-powered airplanes.

(b) Pressure-altitude and airport temperature for turbine-powered airplanes. An increase in pressure-altitude and/or temperature decreases takeoff weight.

(3) Tire Speed. Maximum takeoff weights based on tire speed limitations vary with pressure-altitude, temperature, and tailwind. An increase in any of these factors or in combination decreases maximum takeoff weight.

(4) Maximum Landing Weight. Maximum takeoff weights based on maximum landing weight plus fuel consumed to get to the airport of destination vary with the sum of these weights. In the development of the curves, only the maximum structural landing weight was used.

(5) Obstacle Clearance. Maximum takeoff weights based on obstacle clearance limitations are dependent on the location and height of obstacles in the vicinity of runway ends. In the development of the curves, it was assumed that all obstacles that were adverse to airplane operations would not exist or would be removed.

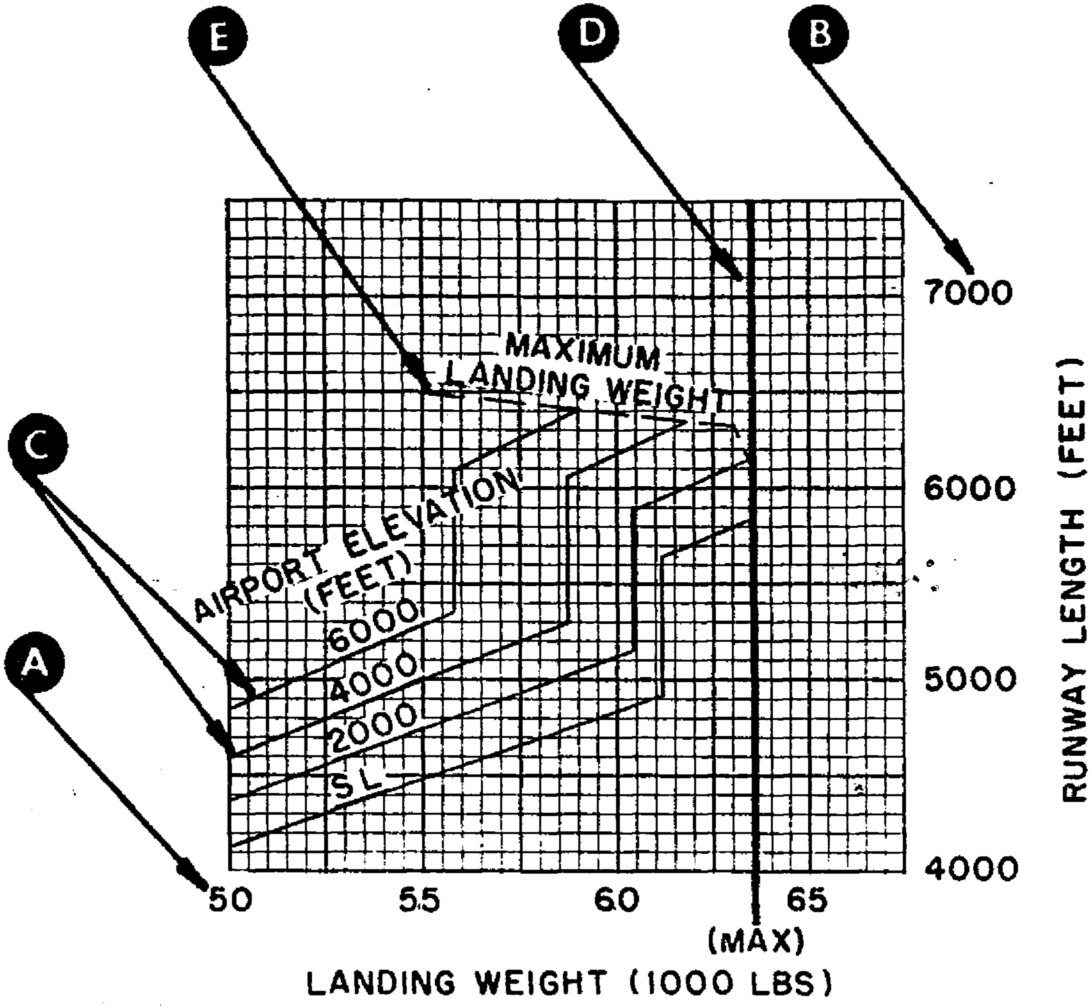
(6) Runway Length. Maximum takeoff weights based on runway length limitations are a result of operating airplanes from runways that were developed to accommodate airplanes with lesser runway length requirements or where the runway length was built on the basis of takeoff weights for the airplane in question equal to the sum of the following:

(a) Aircraft's zero fuel weight.

(b) Weight of fuel required to fly to airport of destination.

(c) Weight of fuel reserve required for one hour and 15 minutes of flying time.

9. RUNWAY GRADIENT. Runway gradient is normally referred to as runway slope and for purposes of aircraft performance should not be confused with effective runway gradient, which is the maximum difference in runway centerline elevation divided by the runway length. Runway slope is for all practical purposes equal to the difference in the runway end elevations divided by the length of runway. An uphill slope increases the length of runway required for takeoff. This factor is held constant at zero gradient in the aircraft performance nomograms and accountability for runway gradients other than zero was provided for by the established effective runway gradient procedure. The existing procedure has been retained for simplicity of application and understanding. A change to this procedure was unjustified because of the insignificant discrepancies in the end result of runway length increase.



Note:
Except for reference letters keyed to text this example aircraft performance curve is identical in format to existing aircraft performance curves.

FIGURE 1 AIRCRAFT PERFORMANCE CURVE, LANDING (EXAMPLE)

CHAPTER 3. TECHNIQUE OF DEVELOPMENT OF LANDING PERFORMANCE CURVES

10. INTRODUCTION. Runway length requirements based on Federal Aviation Regulations were incorporated in the aircraft performance curves. Much of the data used in the development of the landing performance curves is from airplane flight manuals. These curves (see Figure 1) are composed of one graph for each representative airplane.

11. THE GRAPH.

a. Abscissa axis (see Figure 1, reference "A") represents the landing weight scale.

b. Ordinate axis (see Figure 1, reference "B") represents the runway length scale.

c. The lines marked with airport elevation (see Figure 1, reference "C") present the relationship of runway length to landing weight for the airplane configuration selected, five knot tailwind, and the pressure-altitude equal to the airport elevation depicted. Any vertical break in these lines is due to a change in airplane configuration under conditions where such a change is normal.

d. The heavy vertical line over (MAX) (see Figure 1, reference "D") represents the maximum structural landing weight.

e. Dashed limitation lines marked with maximum landing weight (see Figure 1, reference "E") represent the maximum weight for missed approach climb at standard temperature for nonturbine-powered airplanes and an arbitrary lower temperature for turbine-powered airplanes. This lower temperature eliminated the landing runway length limitation for greater spans of temperature down to the limits used. It also reduced the amount of restriction imposed by this limit for temperature below that selected.

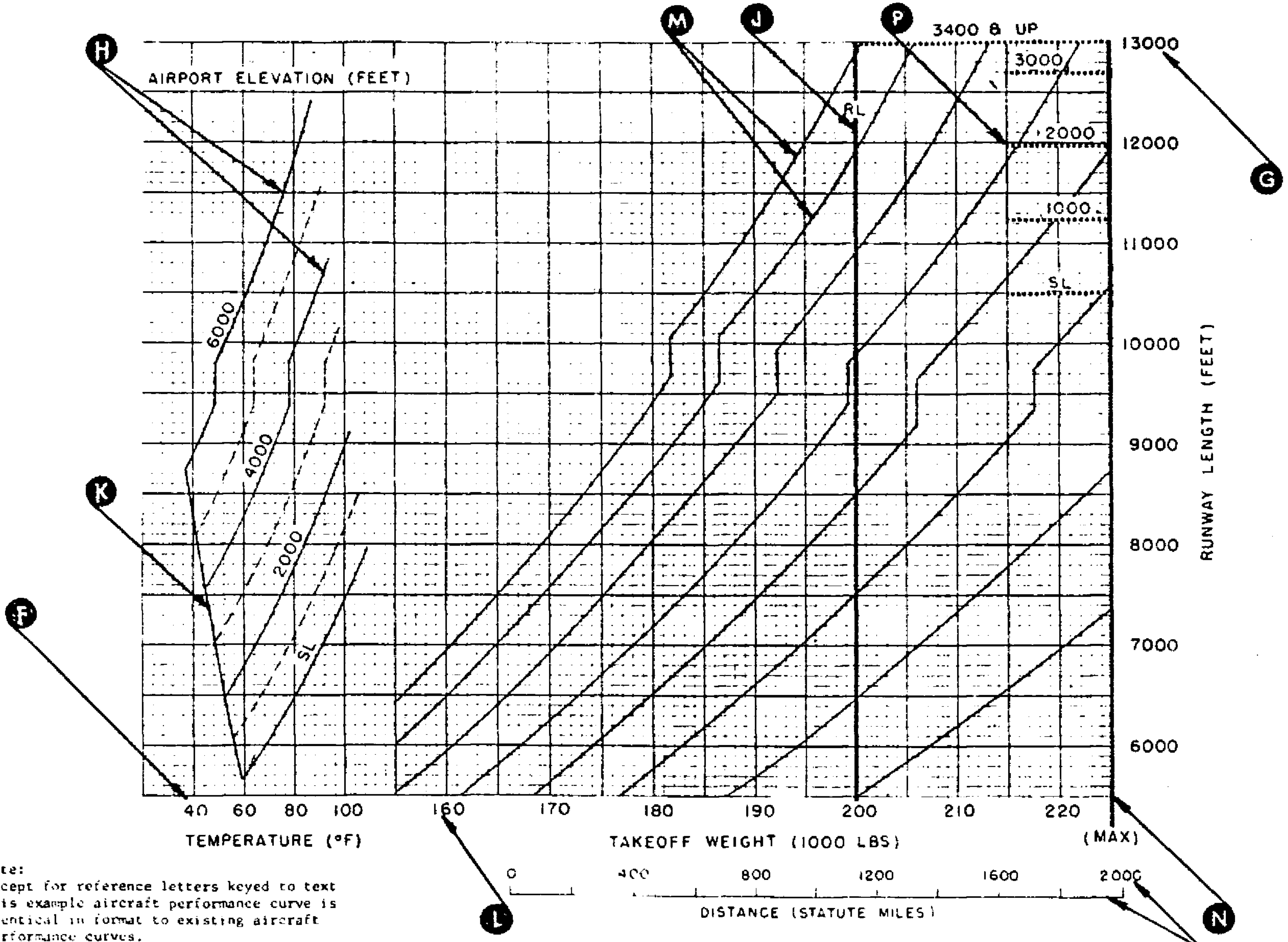


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FIGURE 2 AIRCRAFT PERFORMANCE CURVE, TAKEOFF (EXAMPLE)

CHAPTER 4. TECHNIQUE OF DEVELOPMENT OF TAKEOFF PERFORMANCE CURVES

12. INTRODUCTION. Runway length requirements based on Federal Aviation Regulations were incorporated in the aircraft performance curves. The data used in the development of the takeoff performance curves come from airplane flight manuals and from Schedule T-3, "Quarterly Statement of Aircraft Operating Statistics", which are on file at the Civil Aeronautics Board. These curves (see Figure 2) are composed of two graphs and one bar chart for each airplane.

13. LEFT GRAPH.

a. Abscissa axis (see Figure 2, reference "F") represents the airport temperature scale.

b. Ordinate axis (see Figure 2, reference "G") represents the runway length scale.

c. The lines marked with airport elevation, pressure-altitude equal to the airport elevation depicted, (see Figure 2, reference "H") present the relationship of runway length to airport temperature for the airplane configuration selected, zero wind, zero runway gradient, and the takeoff weight represented by the heavy vertical RL line shown on the right-hand graph (see Figure 2, reference "J"). The break in this curve is due to a change in airplane configuration.

d. The unmarked line on this graph (see Figure 2, reference "K") is the standard altitude line which depicts the standard temperature for each altitude. The information furnished by this line is not required for the determination of runway length.

14. RIGHT GRAPH.

a. Abscissa axis (see Figure 2, reference "L") represents the takeoff weight scale.

b. Ordinate axis (see Figure 2, reference "G") represents the runway length scale.

c. The unmarked lines (see Figure 2, reference "M") represent the relationship of runway length to takeoff weight for a constant airport temperature and pressure-altitude, airplane configuration, zero wind, and zero runway gradient. Note: To find the infinite number of combinations of constant airport temperature and pressure-altitude represented by these lines, take the runway length represented by the intersection of these lines with the heavy vertical RL line (see Figure 2, reference "J") and find the temperature and pressure-altitude combinations from the graph on the left that will give this runway length. The break in these lines is due to a change in airplane takeoff configuration.

d. The heavy vertical line over (MAX) (see Figure 2, reference "N") represents the maximum structural takeoff weight.

e. The dashed limitation lines marked with airport elevation (see Figure 2, reference "P") represent the lesser of the following:

(1) TSO-N6b limitation for Intercontinental Air Carrier Service (10,500-foot runway length increased for airport elevation above mean sea level at the rate of seven percent for each one thousand feet).

(2) Maximum takeoff weight due to climb limitations.

(3) Maximum takeoff weight due to tire speed limitations.

15. <u>BAR CHART</u>.

a. Scale reference "Q", Figure 2, represents the distance (length of haul).

b. Scale reference "L", Figure 2, represents the takeoff weight that corresponds to the lesser of (1) or (2).

(1) The aircraft's zero fuel weight, plus the weight of fuel required to fly to the airport of destination, plus the weight of fuel reserve required for one hour 15 minutes of flying time.

(2) The airplane's maximum structural landing weight plus the weight of fuel required to fly to the airport of destination. The airplane's fuel consumption is based on an average representative consumption rate obtained from data on Schedule T-3, "Quarterly Statement of Aircraft Operating Statistics".

16. <u>EFFECTIVE RUNWAY GRADIENT</u>. The runway length obtained from the graph on the right must be, in the event of runway gradient, increased at the rate of twenty percent for each one percent of effective runway gradient to obtain the required length for takeoff.

Federal Aviation Agency **AC NO: AC 150/5325-3**

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BACKGROUND INFORMATION

ON THE

AIRCRAFT PERFORMANCE CURVES

FOR

LARGE AIRPLANES

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Chester G. Bowers
for Cole Morrow, Director
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(1) Pressure altitude is that altitude above sea level at which a given pressure occurs in the standard atmosphere. At any given location it is the height indicated on an altimeter when the instrument is set to read 29.92 inches of mercury.

(2) Density altitude is that altitude in the standard atmosphere to which the actual density corresponds. It can be approximated by correcting pressure altitude for nonstandard temperatures which may exist.

Of these two, pressure altitude is the one of concern to airport designers since it is used by pilots when referring to aircraft performance curves to compute takeoff and landing distances. These curves are plotted using varying pressure altitudes and varying temperatures. This same material is presented in the nomograms contained in the Airport Design manual. However, since mean maximum pressure altitude information is not usually available for a particular locale, a one to one conversion factor is considered to exist between an airport's pressure altitude and elevation,and the pressure lines on the nomograms are labeled as airport elevation. This substitution is warranted since the likelihood of simultaneous occurence of both maximum pressure altitude and mean maximum temperature is very slight, the application of both maximums to the curves would result in runway length determinations in excess ot actual requirements, and temperature accountability is provided in the nomograms.

d. Temperature. The performance of an airplane depends on several factors among which temperature is important. At a given pressure, high temperature results in lower density and so has an adverse effect on both piston-engined and jet aircraft; this effect is usually greatest when taking off especially for jet aircraft, but it should also be considered at other stages of operation. The efficiency of a jet engine depends in part on the difference between the outside air temperature and the maximum temperature attainable in the combustion chamber. As outside temperature increases above a certain value depending on the altitude, both engine efficiency and aircraft true air speed are decreased (other things being equal) and, therefore, the aircraft's performance is reduced.

7. WIND. The airport must be designed to accommodate airplane operations under most normal wind conditions.

a. A tailwind on one runway is a headwind on a runway with a reciprocal heading. Runway lengths increase with tailwind, so when using the bidirectional runway concept; i.e., theoretically utilizing a headwind for all conditions in establishing runway length, the zero-wind condition is critical for landing. This requires, however, a change in operational direction on that runway each time the wind changes direction and does not provide adequate length for the preferential runway concept in use at many busy airports where tailwind operations are conducted. The problem is further compounded by the fact that winds up to five knots are reported as "calm". For these reasons, landing aircraft performance curves are based on a five-knot tailwind to recognize the flexibility required in airplane landing operations.

b. The takeoff aircraft performance curves, however, are developed for zero wind. The critical wind condition for takeoff is dependent upon the other factors affecting the runway length requirements for takeoff (see Paragraph 9). To establish the relation between a critical wind and the other factors would have necessitated a procedure too complex for the introduction of aircraft performance curves in planning and design. It was therefore deemed appropriate to hold this variable at a constant zero velocity.

8. WEIGHT. The heavier the airplane's weight, the longer are its runway length requirements. When the weight of an airplane is increased, the wing load and power required will have to be increased. This may be accomplished by either a larger angle of attack or, if the same angle of attack is maintained, by an increase in speed. At any one angle of attack, velocity (V) varies as the square root of the weight and the required power as the cube of the square root of the weight. Also, the maximum lift coefficient and wing area remain constant in today's fixed wing aircraft, and the landing speeds vary as the square root of the

weight. Landing speeds increase with high wing loading, so do takeoff speeds; therefore, according to the laws ot acceleration/deceleration, the length of run or roll needed to attain such speeds or diminish to zero is increased.

a. Landing Weights. Airplanes are landed with weights up to the maximum landing weights which fall into one of three types.

(1) Structural. Maximum landing weights based on structural limitations are constant regardless of pressure-altitude, temperature, runway length, and wind.

(2) Climb. Maximum landing weights based on climb limitations vary with:

(a) Pressure-altitude for nonturbine-powered airplanes.

(b) Pressure-altitude and temperature for turbine-powered airplanes. An increase in pressure-altitude and/or temperature decreases the maximum landing weight.

(3) Runway Length. Maximum landing weight based on a runway length limitation results from a previous design for runways developed to accommodate airplanes with lesser takeoff and landing length requirements. The need to use a lighter weight than the maximum structural or climb landing weight shown on the curves to fit the existing runway length will automatically produce a limitation on the new critical airplane.

b. Takeoff Weights. Airplanes are taken off at weights up to the maximum takeoff weight which falls into one of six types.

(1) Structural. Maximum takeoff weights based on structural limitations are constant regardless of pressure-altitude, temperature, wind, runway length, and runway gradient.

(2) Climb. Maximum takeoff weights based on climb limitations vary with:

(a) Pressure-altitude for nonturbine-powered airplanes.

(b) Pressure-altitude and airport temperature for turbine-powered airplanes. An increase in pressure-altitude and/or temperature decreases takeoff weight.

(3) Tire Speed. Maximum takeoff weights based on tire speed limitations vary with pressure-altitude, temperature, and tailwind. An increase in any of these factors or in combination decreases maximum takeoff weight.

(4) Maximum Landing Weight. Maximum takeoff weights based on maximum landing weight plus fuel consumed to get to the airport of destination vary with the sum of these weights. In the development of the curves, only the maximum structural landing weight was used.

(5) Obstacle Clearance. Maximum takeoff weights based on obstacle clearance limitations are dependent on the location and height of obstacles in the vicinity of runway ends. In the development of the curves, it was assumed that all obstacles that were adverse to airplane operations would not exist or would be removed.

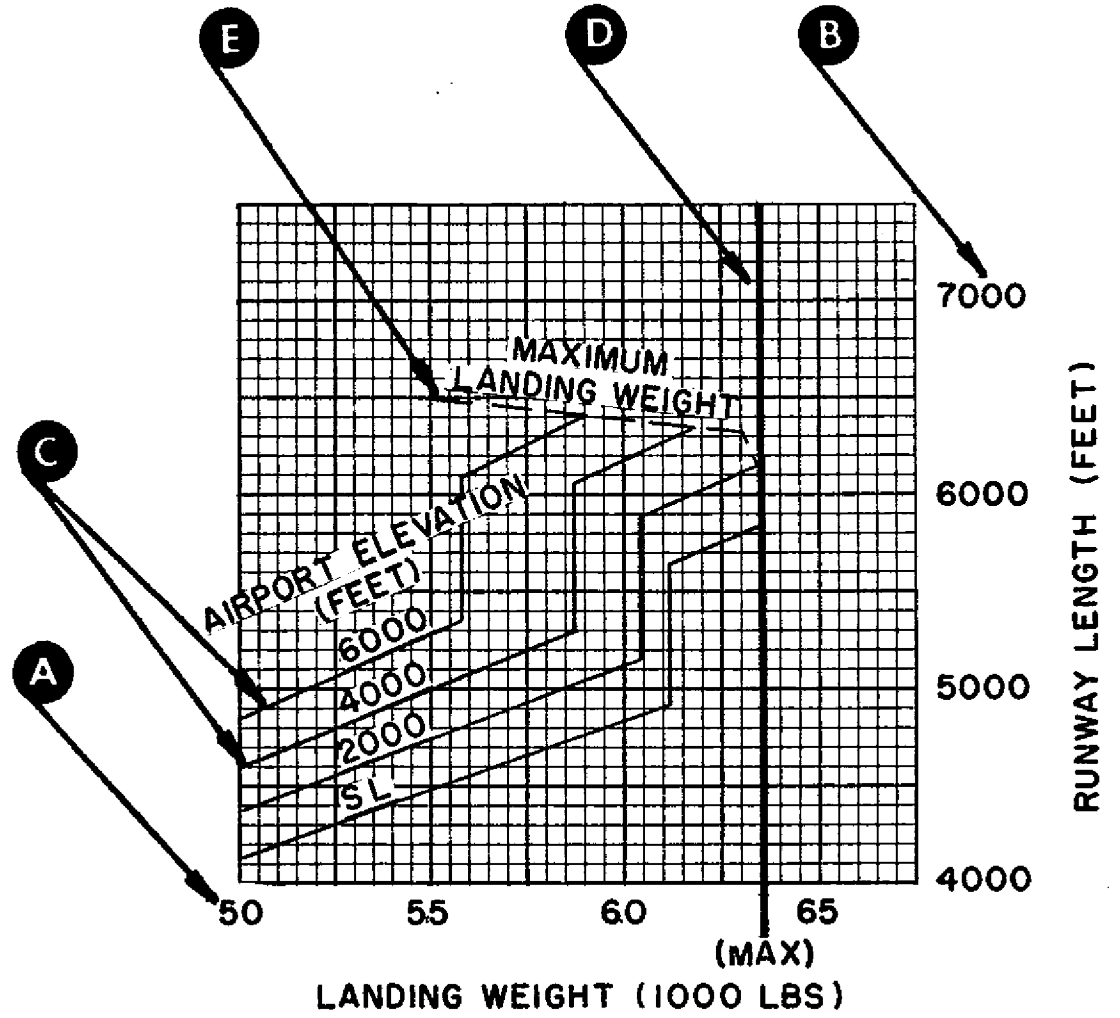
(6) Runway Length. Maximum takeoff weights based on runway length limitations are a result of operating airplanes from runways that were developed to accommodate airplanes with lesser runway length requirements or where the runway length was built on the basis of takeoff weights for the airplane in question equal to the sum of the following:

(a) Aircraft's zero fuel weight.

(b) Weight of fuel required to fly to airport of destination.

(c) Weight of fuel reserve required for one hour and 15 minutes of flying time.

9. RUNWAY GRADIENT. Runway gradient is normally referred to as runway slope and for purposes of aircraft performance should not be confused with effective runway gradient, which is the maximum difference in runway centerline elevation divided by the runway length. Runway slope is for all practical purposes equal to the difference in the runway end elevations divided by the length of runway. An uphill slope increases the length of runway required for takeoff. This factor is held constant at zero gradient in the aircraft performance nomograms and accountability for runway gradients other than zero was provided for by the established effective runway gradient procedure. The existing procedure has been retained for simplicity of application and understanding. A change to this procedure was unjustified because of the insignificant discrepancies in the end result of runway length increase.



Note:
Except for reference letters keyed to text this example aircraft performance curve is identical in format to existing aircraft performance curves.

FIGURE I AIRCRAFT PERFORMANCE CURVE, LANDING (EXAMPLE)

CHAPTER 3. TECHNIQUE OF DEVELOPMENT OF LANDING PERFORMANCE CURVES

10. INTRODUCTION. Runway length requirements based on Federal Aviation Regulations were incorporated in the aircraft performance curves. Much of the data used in the development of the landing performance curves is from airplane flight manuals. These curves (see Figure 1) are composed of one graph for each representative airplane.

11. THE GRAPH.

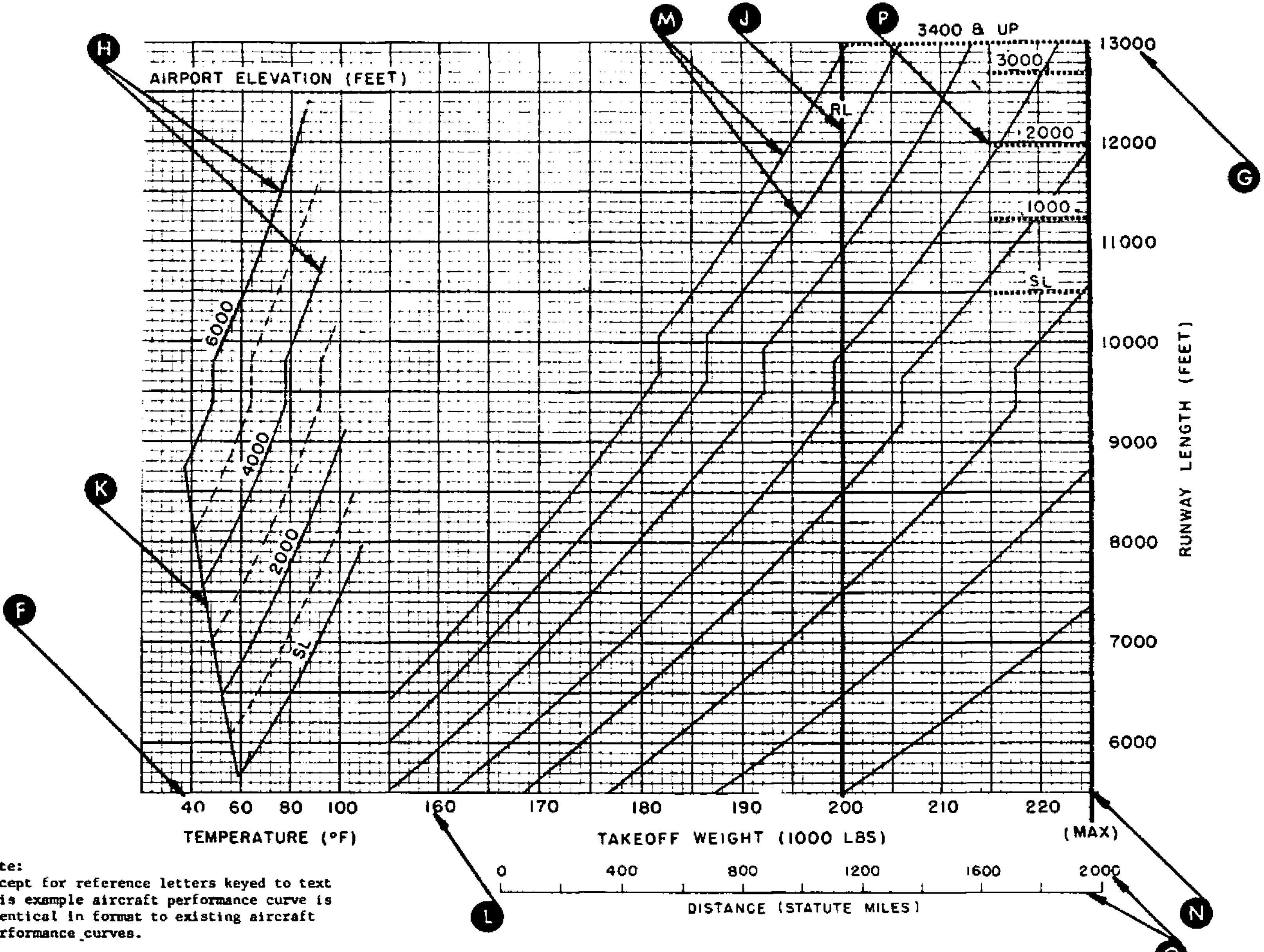
a. Abscissa axis (see Figure 1, reference "A") represents the landing weight scale.

b. Ordinate axis (see Figure 1, reference "B") represents the runway length scale.

c. The lines marked with airport elevation (see Figure 1, reference "C") present the relationship of runway length to landing weight for the airplane configuration selected, five knot tailwind, and the pressure-altitude equal to the airport elevation depicted. Any vertical break in these lines is due to a change in airplane configuration under conditions where such a change is normal.

d. The heavy vertical line over (MAX) (see Figure 1, reference "D") represents the maximum structural landing weight.

e. Dashed limitation lines marked with maximum landing weight (see Figure 1, reference "E") represent the maximum weight for missed approach climb at standard temperature for nonturbine-powered airplanes and an arbitrary lower temperature for turbine-powered airplanes. This lower temperature eliminated the landing runway length limitation for greater spans of temperature down to the limits used. It also reduced the amount of restriction imposed by this limit for temperature below that selected.



Note:
Except for reference letters keyed to text this example aircraft performance curve is identical in format to existing aircraft performance curves.

FIGURE 2 AIRCRAFT PERFORMANCE CURVE, TAKEOFF (EXAMPLE)

CHAPTER 4. TECHNIQUE OF DEVELOPMENT OF TAKEOFF PERFORMANCE CURVES

12. INTRODUCTION. Runway length requirements based on Federal Aviation Regulations were incorporated in the aircraft performance curves. The data used in the development of the takeoff performance curves come from airplane flight manuals and from Schedule T-3, "Quarterly Statement of Aircraft Operating Statistics", which are on file at the Civil Aeronautics Board. These curves (see Figure 2) are composed of two graphs and one bar chart for each airplane.

13. LEFT GRAPH.

a. Abscissa axis (see Figure 2, reference "F") represents the airport temperature scale.

b. Ordinate axis (see Figure 2, reference "G") represents the runway length scale.

c. The lines marked with airport elevation, pressure-altitude equal to the airport elevation depicted, (see Figure 2, reference "H") present the relationship of runway length to airport temperature for the airplane configuration selected, zero wind, zero runway gradient, and the takeoff weight represented by the heavy vertical RL line shown on the right-hand graph (see Figure 2, reference "J"). The break in this curve is due to a change in airplane configuration.

d. The unmarked line on this graph (see Figure 2, reference "K") is the standard altitude line which depicts the standard temperature for each altitude. The information furnished by this line is not required for the determination of runway length.

14. RIGHT GRAPH.

a. Abscissa axis (see Figure 2, reference "L") represents the takeoff weight scale.

b. Ordinate axis (see Figure 2, reference "G") represents the runway length scale.

c. The unmarked lines (see Figure 2, reference "M") represent the relationship of runway length to takeoff weight for a constant airport temperature and pressure-altitude, airplane configuration, zero wind, and zero runway gradient. Note: To find the infinite number of combinations of constant airport temperature and pressure-altitude represented by these lines, take the runway length represented by the intersection of these lines with the heavy vertical RL line (see Figure 2, reference "J") and find the temperature and pressure-altitude combinations from the graph on the left that will give this runway length. The break in these lines is due to a change in airplane takeoff configuration.

d. The heavy vertical line over (MAX) (see Figure 2, reference "N") represents the maximum structural takeoff weight.

e. The dashed limitation lines marked with airport elevation (see Figure 2, reference "P") represent the lesser of the following:

(1) TSO-N6b limitation for Intercontinental Air Carrier Service (10,500-foot runway length increased for airport elevation above mean sea level at the rate of seven percent for each one thousand feet).

(2) Maximum takeoff weight due to climb limitations.

(3) Maximum takeoff weight due to tire speed limitations.

15. BAR CHART.

a. Scale reference "Q", Figure 2, represents the distance (length of haul).

b. Scale reference "L", Figure 2, represents the takeoff weight that corresponds to the lesser of (1) or (2).

(1) The aircraft's zero fuel weight, plus the weight of fuel required to fly to the airport of destination, plus the weight of fuel reserve required for one hour 15 minutes of flying time.

(2) The airplane's maximum structural landing weight plus the weight of fuel required to fly to the airport of destination. The airplane's fuel consumption is based on an average representative consumption rate obtained from data on Schedule T-3, "Quarterly Statement of Aircraft Operating Statistics".

16. EFFECTIVE RUNWAY GRADIENT. The runway length obtained from the graph on the right must be, in the event of runway gradient, increased at the rate of twenty percent for each one percent of effective runway gradient to obtain the required length for takeoff.