THE CORRELATION OF AIRCRAFT TAKE-OFF AND LANDING CHARACTERISTICS WITH AIRPORT SIZE

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PREFACE

The following report represents one approach to an extremely complex problem the solution of which involves economic and topographic limitations as well as technical considerations The statements and conclusions contained herein are not intended to have any regulatory significance nor do they express the general airport policy of the Civil Aeronautics Administration The report does present factual data and a suggested use of that data for correlating airport dimensions with the performance characteristics of the airplanes

This investigation was undertaken by the Technical Development Division early in 1936, and continued until late in 1940 when the report was completed This was originally intended to aid the Administration in connection with its airport planning and regulatory activities However, continued requests from the industry have indicated the desirability of its general distribution

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THE CORRELATION OF AIRCRAFT TAKE-OFF AND LANDING CHARACTERISTICS WITH AIRPORT SIZE

SUMMARY

The purpose of this study is to establish a fundamental basis for the determination of airport dimensions that will accomodate safely the operation of aircraft The study involves the obtainment of adequate and pertinent factual data and the interpretation of these data in the form of recommended dimensional requirements for airports These requirements should remain within reasonable topographic and economic limits, and should be determined so that no increase in dimensions will be necessary for many years to come It is believed important that these dimensions be founded, as far as possible, upon data that indicate how airplanes actually perform under ordinary conditions rather than upon an assumed standard of performance Accordingly, this study is based mainly upon photographic records of day-in and day-out operations of a number of representative airplanes, obtained at various altitudes and at various airports

In addition to these performance data, this study includes a large number of accident records and meteorological observations through which the photographic records are translated into airport dimensions Thus, a study of the accident records has aided in the establishment of general standards to which may be applied the performance characteristics of any airplane to obtain airport dimension requirements for that airplane, also, through a study of the meteorological observations, allowances were made for unfavorable temperature and barometric conditions that are often encountered

The study of accident records has led to the establishment of the following general standards or criteria

(a) Runways should be long enough to permit aircraft to roll safely to a stop in the event of an engine failure during the take-off at the point where the wheels are just leaving the ground

(b) The cleared areas on either side of the runways should be wide enough to provide reasonably smooth surfaces on which aircraft can come to rest, should some unforeseen contingency cause them to swerve from their original take-off or landing directions

(c) Obstacles should not project up into the flight paths

Note Runway lengths as determined solely from flight path characteristics against obstacle clearance requirements are in close agreement with runway lengths as determined through the application of criterion (a) above

A study of meteorological observations has led to general conclusions concerning possible airport temperature and barometric pressure conditions that will be encountered in actual operation Accordingly, it appears that at any airport, allowances should be made for a density altitude several thousand feet greater than the geographical altitude of that airport All observed data are corrected to zero wind velocity and to specification gross weight

These studies have resulted in the attainment of two broad objectives

(a) The establishment and application of a basic and practical method for correlating the take-off and landing characteristics of any airplane with any airport at any altitude so as to insure safe operating accomodations

(b) The determination of definite dimensional requirements for four classes of airports at any altitude based upon such a correlation

The grouping of airport requirements into four classifications, as mentioned above, is based upon the types of airplane that can be accomodated safely These are as follows

Class I	Lowest powered private owner type
Class II	Medium powered private owner type
Class III:	Higher powered private owner type and smaller airline type
Class IV	The largest of airline aircraft

The application of the basic correlation method may be seen in table 14

Conclusions concerning dimensional requirements for the four classes of airports under zero wind conditions are presented in two sets of curves The first (fig 22) shows runway length requirements for each class of airport at any altitude up to 10,000 feet. The second (fig 23) shows obstacle zoning ratio requirements for each class of airport, and at any altitude up to 10,000 feet The obstacle zoning ratio is obtained by dividing the distance from the obstacle to the near end of the runway by the height of the obstacle above the runway elevation

Data from which the widths of the landing strip areas may be determined are far from adequate In a purely arbitrary manner, however, it is suggested that,

(a) Between the center lines of any two parallel landing strips,

(b) From the center line of any landing strip to the boundary of the airport,

(c) From the center line of any landing strip to any obstruction or to any area which may be occupied by aircraft, automobiles, etc ,

the following minimum distances well might be provided

Class I	150 ft
Class II	300 ft
Class III	450 ft
Class IV	600 ft

As indicated from this study, runway length and obstacle zoning ratio requirements at SEA LEVEL and for zero wind velocity conditions are as follows

Airport Class	Runway Length	Obstacle Zoning Ratio
I	1,800 ft.	13
II	2,800 ft	18
III	3,800 ft	23
IV	4,800 ft	28

At any airport at any altitude, an obstacle zoning ratio of 43* is recommended where radio instrument landing systems are installed

The actual take-off and landing paths of the airplanes involved in this study are shown in figure 21

Appendix #3, of this report, involves the consideration of the effect of wind in reducing the dimensional requirements of airports having runways lying in more than one direction Runway lengths and obstacle zoning ratios may be reduced safely if at least one runway together with its corresponding obstacle zoning ratio safely provides for flying operations during dead calm conditions The determination of such reductions is independent of prevailing wind velocities, since they are based upon low wind velocities rather than upon high velocities

Definite lengths are suggested for airports, Class I to IV, having one, two, three, or four runways These data are presented as curves showing the recommended length and ratio requirements for each of the four classes of airports and for altitudes up to 10,000 feet An illustrative sketch of an eight-direction Class IV airport located at sea level also is presented In this sketch the runway lengths have been shortened to allow for winds

Appendix #3 involves the consideration of partially paved runways In this connection it appears that the length of paving may be reduced appreciably if adequate lengths of smooth turf

* This ratio results from flight test data which involve only the radio instrument landing system at Oakland, California

are provided at both ends of the paved portion This requires 40 percent additional total length but permits a 40 percent reduction in the required length of paving

Concerning future requirements, it appears that advances in designing technique are resulting in aircraft which will require no larger airports than are required by existing aircraft It is believed, therefore, that no increase in airport dimension requirements will be necessary for many years to come

INTRODUCTION

The problem of airport size has long been a troublesome one Government and private agencies have been faced with it continuously since the beginning of the rapid growth of aviation activities at the end of the World War The problem has become increasingly acute as military, commercial, and private flying activities have increased and as the size and speed of aircraft have increased

The problem is a complex one as it involves both safety and economics It can be argued that the safest airport would be one of tremenduous size having a surrounding territory free from obstructions to flight Such an airport is beyond the bounds of economic possibility and, in a number of cases, is beyond the bounds of topographic possibility The problem resolves itself into that of combining safety with economic and topographic possibilities

The solution of the problem is not a simple matter Absolute safety is, of course, impossible of attainment Reasonable safety is very difficult to define Consequently, the solution of any problem involving reasonable safety is a very difficult task

The Civil Aeronautics Administration is faced with the necessity of determining airport size in the performance of its functions under several of the provisions of the Civil Aeronautics Act of 1938 Its procedure to date, so far as air carrier operations are concerned, has been to accept the recommendations of its Air Carrier Inspection personnel as to whether or not airports are of sufficient size to accomodate, with reasonable safety, the types of aircraft which the air carriers propose to operate So far as development planning and certification are concerned, its procedure to date has been to accept the recommendations of its Airports Service personnel as to airport size

These recommendations of the Administration's personnel have been based upon a knowledge of what a new airplane in the hands of an expert test pilot can do when undergoing tests for certification as to its airworthiness, together with a knowledge, gained through long experience, of what that airplane, in actual service, does in the hands of an average airline pilot

Because of the long experience of the personnel involved, the Administration has been fully justified in accepting the recommendations. However, because personal opinion, personal judgment, and individual definitions of reasonable safety are involved in each case, there has been a lack of uniformity in the recommendations The Administration fully realizes this and is endeavoring to remedy the situation

The first remedial step appeared to be the obtainment of data showing the actual take-off and landing performance of airplanes under normal day-by-day service conditions The Administration then could use these factual data as one basis for the determination of airport size in lieu of accepting, with their attendant disadvantages, the recommendations of its personnel in each case

ANALYSIS OF THE PROBLEM

The objective of this study is the establishment of one practical and fundamental basis for the determination of airport dimensions that will accomodate safely the operation of aircraft This involves the acquisition of adequate and pertinent data, and the translation of these data into performance characteristics and airport dimensions

This objective breaks down into two parts

(1) The establishment and application of a basic and practical method for correlating the take-off and landing characteristics of any airplane with the dimensions of any airport so as to insure reasonably safe operating accomodations

(2) The establishment of a basis for determining definite dimensions for four classes of airports to accomodate safely the four following types of airplanes

Class I	Lowest powered private owner type
Class II	Medium powered private owner type.
Class III	Higher powered private owner type and smaller airline type
Class IV	The largest of airline aircraft

In the attainment of the objective, it must be kept in mind that the airport dimensions as finally determined should remain within reasonable economic and topographic limits, and preferably, should not be subject to change for many years to come As far as possible these dimensions should be founded upon factual data that involve normal operating performance rather than upon an assumed standard performance, and should be determined in a simple and straightforward manner

The problem, then, is to determine what data shall be obtained, how they shall be obtained, and how they shall be employed in attaining the desired objective

If this objective is to be attained, two general considerations must be kept in mind.

(a) Any material that does not lead to this objective by the shortest possible route must be excluded
(b) Every correction and theoretical manipulation that is applied to the original observed data will reduce the general acceptability and effectiveness of the final results. Thus, the degree of refinement should be no more than adequate

A study of take-off and landing accident records will aid in the elimination of non-pertinent performance data through the establishment of general performance criteria A study of meteorological observations obtained at various airports will aid in the intelligent translation of the performance data into reasonably safe airport dimensions

The method used for obtaining performance data should provide accurate and permanent records of initial climbs and approaches as well as of the ground roll characteristics The recording equipment should be automatic in its operation, and the translation of the resulting records into actual performance characteristics should involve as little work as possible Other desirable recording equipment characteristics are mobility and lack of restriction upon the piloting of the aircraft involved

Deciding upon the type of piloting technique to be included in this study is most important, in that it determines the performance characteristics through which airport dimensions are determined These dimensions obviously should not be based upon ultimate performance characteristics, since these never are attained except under controlled conditions which are not often realized in normal service operation Two major considerations appear to be involved

(a) The normal functioning of the aircraft
(b) Possible emergencies

If all aircraft were designed so as to eliminate the more vicious stalling characteristics, or if engines never failed, or if the brakes always functioned perfectly, airport dimensions could be determined safely from something very close to the ultimate performance characteristics Although it cannot be said that perfect aircraft never will be produced, the existing models will be in operation for some time to come, and it is necessary therefore to provide enough airport to accomodate performance characteristics which result when aircraft are operated so as to realize an optimum of safety with respect to emergencies This obtains when take-off speeds are great enough to preclude the possibility of stall after take-offs, when speeds during the initial climb are sufficient to favor controlled flight in the event of an engine failure, and when landing approach speeds are well above the stalling speed Engine failures during the take-off run and brake failures during the landing run also must be considered in determining airport dimensions

In order to be sure of the inclusion of such performance in this study, records of normal day-in and day-out operations should be obtained at the larger airports The piloting technique should not be restricted As a corollary, data involving special flight tests should be excluded, except that all landing ground roll data should involve the full use of the brakes This exception is necessary because of the fact that in daily operation, power often is used to prolong the ground roll in cases where the loading ramp is located at the far side of the airport Data involving instrument landings with the pilot "under the hood", and data involving the climbing characteristics of multiengine aircraft with one or more engines cut out, also should be included in this study

Performance results obtained from data involving daily operations as described above, of course, will be divergent Some values will approach the ultimate characteristics while others will lie too far on the conservative side This indicates the necessity of a large number of records for each airplane so that an adequate determination of the normal operating characteristics may be realized Conversely, the time and cost involved in the obtainment and employment of these records make it necessary to limit the number required to a minimum Records of at least 30 take-offs and 30 landings should be obtained at any one altitude, and at least three different altitudes should be included Thus, 180 records are necessary to determine adequately the normal safe operating characteristics of any one airplane over a reasonable range of altitudes Additional tests may be necessary to obtain instrument landing and braked landing data Moreover, since the reliability and the degree of permanence of the final results depend upon the inclusion of a reasonable number and variety of airplanes, it will be seen that the total number of records required is exceedingly large, particularly when this number is visualized in terms of actual take-offs and landings

Meteorological data, including at least two seasonal cycles, should be obtained at several airports and at several altitudes These should consist of temperature and barometric pressure observations at each airport of such a nature that they can be used to determine the fluctuations of density altitude and pressure altitude over a period of approximately two years These data, in turn, can be used:

(a) to determine the least favorable meteorological conditions which are likely to be encountered at the airport in question, and
(b) to establish general assumptions concerning temperature and barometric pressure characteristics to be considered at any airport

The accident data should include as many types of airplanes as possible and should be arranged so as to facilitate the determination of just which performance characteristics should be used to obtain airport dimensions Thus, runway length requirements may be determined from the take-off characteristics, or from the landing characteristics, or from a combination of both Obstacle zoning ratio requirements may be based upon either take-off or landing requirements Data concerning accidents due to engine failures during the take-off and overshooting while landing should be emphasized Data concerning hazards which may be reduced effectively by the elimination of the basic causes, rather than by providing larger airports, should be identified so that they may be excluded immediately from consideration in airport size determination Accidents involving uncontrolled swerving of the airplane from its original take-off or landing direction should receive particular attention, since these may lead to the determination of adequate widths of runway areas

PROCEDURE

1 Development of Equipment for Obtaining Records of Take-Off and Landing Characteristics

In connection with the equipment or method to be used for obtaining so large a number of records of day-in and day-out operations, the requirements discussed in the "Analysis of the Problem" were considered most carefully The use of photographic equipment obviously is indicated because it obtains a permanent record and because its automatic operation practically eliminates the human element Moreover, photographs also record pertinent surrounding conditions such as flight attitude, flap setting, runway characteristics, and other noteworthy details

It developed that none of the existing types of photographic equipment were completely satisfactory Methods involving a camera set-up located at some fixed distance from the side of the runway, so that the airplane is flown across the field of vision, are lacking in range as concerns the flight path Methods that involve microscopic measurements on the film of some known dimension of the airplane, such as the wing span, require considerable work in reducing the basic records to pertinent distances, speeds, flight paths, and are subject to errors due to the yawing of the aircraft which are difficult to evaluate

It was considered necessary, therefore, that the Administration develop its own equipment This development was accomplished through the efforts of the personnel of the Airport Section of the Technical Development Division in conjunction with the Research Development Department of the Eastman Kodak Company The equipment has proved to be most satisfactory

This equipment operates on the range finder principle and consists essentially of two widely separated motion picture cameras having carefully matched lenses These are located at one end of the runway and are equipped with electrically timed shutters so that simultaneous photographs, at the rate of four per second, are taken of the airplane while it is taking off or landing Vertical and horizontal markers, precisely located in front of the cameras, constitute references which permit direct measurements of horizontal and vertical distances from the cameras to the airplane through the projection, side by side, of each pair of simultaneous pictures on a ground glass screen Both the airplane and the marker must be included in each of the photographs

Through careful calibration the scales on the projector are graduated to indicate the actual distances in feet, thus permitting a reasonably quick obtainment of space-time records of each take-off and landing maneuver

Actually, two pairs of cameras and markers are used which permit a distance range of 12,000 feet, and a height range of 650 feet at that distance. The accuracy of these measurements is within plus or minus one percent

A complete report covering this equipment is now being prepared for publication

2 The Obtainment and Presentation of Records of Take-Off and Landing Characteristics

The original program for this study included the obtainment and study of some 1,300 records involving three private-owner type and four airline type aircraft This included normal operating conditions, "blind" weather conditions, and in the case of multiengine aircraft, flight with one engine inoperative About one year would have been required to complete this program

The actual obtainment of these records was well under way when, early in September, 1938, the need for at least an indication concerning airport dimension requirements became so urgent that it was necessary to abandon the original program and to complete the study as quickly as possible with such data as already were available As a result of that contingency, this study includes only some 560 records These are distributed in such a manner that complete characteristics of one model and sea level characteristics of four other models are determined from observed data in a reasonably adequate manner. Since it was found desirable to include a total of eight models in this study, it has been necessary to determine the normal day-by-day operating characteristics of the three remaining models through the use of "spread coefficients" which are applied to the computed ultimate characteristics of these models. These spread coefficients are determined as a ratio of the observed normal to the computed ultimate characteristics for the models on which actual photographic records have been obtained. A uniform and, therefore, comparable basis of performance computation was used for all eight models This was evolved through a study of the methods of computation developed in Report #103 prepared by the Aircraft Engineering Division These computations result in figures that check very closely with actual flight test results

It is evident that the number of records available for inclusion in a study of this nature should be increased However, it is felt that the 560 records obtained are so disposed with respect to the types or models of aircraft considered as to provide a reasonable evaluation of their airport requirements The acquisition of those records would not have been possible without the complete cooperation of the aircraft manufacturers, the air carriers, the municipalities, and the personnel of the various airports

The following table I lists the number of take-off and landing records obtained for each airplane included in this study and the airports where these records were obtained The runway lengths and the geographical altitudes of the airports are also listed

It will be noted in Table 1 that models A, B, and C are private owner type aircraft while models D, E, F, G, and H, are airline type aircraft It also will be seen that the normal take-off and landing characteristics of airplanes A, C, and G must be obtained through the application of the spread coefficients to the computed ultimate characteristics of those airplanes

No photographic records have been obtained to date of the flying characteristics of multiengine aircraft with one engine inoperative However, other data involving flight tests under such conditions are available These indicate that when the existing two-engine aircraft of the airline type are operated on one engine only, the resulting flight path varies tremendously Test results indicate that the rate of climb may vary from 150 feet per minute to zero, or that the airplane actually may lose altitude

In view of this, the consideration of positive climbing characteristics under such conditions has been eliminated so far as this study is concerned, except in the matter of obstacle zoning, which should be such as to provide reasonable clearance to permit an airplane to circle the airport and land in the event that controlled flight is possible after an engine failure during the take-off

It is possible, of course, to extract a wealth of useful and interesting information from the recorded performance data As previously discussed, however, the effectiveness of this study depends largely upon the exclusion of all but the most pertinent material. Thus, the basis for the determination of airport dimensions can be attained through analysis of the distances travelled by the airplanes in taking off and landing, including the distances required to clear obstacles. This analysis, however, requires a knowledge of unstick and landing speeds. It was found possible to exclude all but the following performance characteristics:

NUMBER OF TAKE-OFF AND LANDING RECORDS OBTAINED FOR EACH AIRPLANE
AND THE AIRPORTS WHERE THESE RECORDS WERE OBTAINED

TABLE 1

Airport	Geog Alt (ft)	Runway Lengths (Ft)				Number of Take-Off and Landing Records, Airplanes (A) to (H) inclusive																	
						PRIVATE OWNER TYPE						AIRLINE TYPE											
						A		B		C		D		E		F		G		H		H(Blind)	
		N/S	E/W	NW/SE	NE/SW	T O	L	T O	L	T O	L	T O	L	T O	L	T O	L	T O	L	T O	L	T O	L
Oakland (Blind Landings)	5	5000	5000		3500																		31
L A Municipal (Mines Field)	93		5280		3500			21	22			20	70					6	11				
Chicago Municipal	614	2250	4700	3200	3200									22		16				35	3		
Fort Worth	690	3400	3200	3800	3300											13				4	10		
Burbank	695	3600	3550	3650	3650									20	23	5				13	41		
Salt Lake City	4220	5550	4350	5550				27	25			7		16						15	6		
Cheyenne	6145	3816	6500	5100	3024															35	46		
Totals (Take-offs and Landings) per Airplane								48	47			27	** 70	58	23	34		6	11	102	106		31
Total Number of Records per Airplane						0 *		95		0 *		97		81		34		17 *		208		31	
Total Number of Records: 563																							

* Normal Performance characteristics of these airplanes are determined through use of spread coefficients as described on Page 18 of this report

** Five of these records involved special flight tests For these five, only the ground roll characteristics were considered (See table 40)

NOTE

Airplane (A) is a low powered private owner type
Airplane (B) is a medium powered private owner type
Airplane (C) is a high powered private owner type
Airplanes (D, E, and F) are the smaller airline type
Airplane (G) is one of the largest and latest of transport aircraft
Airplane (H) is one of the larger modern airline type

TAKE-OFF

Unstick Distance
Unstick Speed
Distance to attain 50 and 100 feet heights (from start)

LANDING

Distance from 50 and 100 feet heights to contact
Contact Speed
Ground Roll Distance (with use of brakes)

In the determination of the foregoing performance characteristics, the speeds and distances as recorded during each take-off and landing must be reduced to a comparable basis, necessitating the application of a certain number of corrections On the other hand, as has been mentioned previously, the general acceptability of the final conclusions will be lessened in proportion to the number of manipulations which are applied to the original observed data In view of this, only two corrections are applied Distances and speeds first are corrected to zero wind velocity, and second, to specification gross weight

Since information concerning the effect of altitude upon performance is necessary for the determination of the dimensions of airports located at various elevations, the observed data were not corrected to sea level Instead, the effective altitude for each take-off and landing was determined through analysis of observed temperatures and barometric pressures, so that eventually curves of performance characteristics against altitude might be plotted

It is realized that a number of additional corrections could have been applied to the original data These might have involved corrections to standard horsepower for each model, depending upon the particular type of engine and propeller installed in the individual airplanes, or corrections for cross wind effect, for runway grade, for flap setting, and so forth It was felt, however, that such refinements could be eliminated in view of the fact that their effect easily could be negated by any one of a number of indeterminate items* such as

Throttle manipulation
Mechanical condition of the engines
Engine temperatures
Manipulation of intake-air-heat controls
Quality of fuel
Condition of airport surface
Air turbulence and gusts
Piloting technique

The combined effect of the above items is responsible for the divergence among the corrected performance data for any one model The final determination, for that model, of the performance characteristics which may be used for the determination of its airport requirements cannot be made adequately except through the study of a large amount of take-off and landing data As previously indicated, these data should involve different individual airplanes of each model included in the study, different pilots, different airports at different elevations, and should be obtained at the larger airports so as to insure safe piloting technique These data then may be spotted on coordinate paper and curves may be drawn so as to include the less favorable points, but in such manner as to exclude the ultra-conservative results

For each airplane, take-off speeds, contact speeds and take-off distances, including the initial climb, are plotted against altitude Approach paths are not affected by altitude Data involving approach distances, therefore, are not plotted, but are presented in a graphical manner so as to facilitate the final determination of these distances for each airplane Landing ground roll distances are affected by contact speed rather than by altitude These data, therefore, have been plotted against contact speed

3 <u>The Obtainment and Presentation of Accident Records</u>

A total of 452 records of take-off and landing accidents was obtained from the Accident Analysis Section of the Safety Bureau These involve both private owner type and airline type aircraft In addition to these, a total of 28 records of mechanical interruptions involving

*Note An accurate determination of the effect of any of the above items, even under carefully controlled flight test conditions, appears doubtful Where records of day-by-day flight operations are being obtained, such determination is practically impossible airline type aircraft was obtained from the Aircraft Engineering Division of the Safety Regulation Service A brief account of each accident is presented in a tabular form These accounts have been further condensed in a second set of tables in such a manner as to facilitate the study of the accident data as they affect the determination of airport dimension requirements. All of the take-off and landing accidents and mechanical interruptions for the period of time considered were included in these tables so as to present a complete picture of the situation

4 <u>The Obtainment and Presentation of Meteorological Data</u>

The meteorological data included in this study were obtained from the United States Weather Bureau These data were in the form of thermograph and barograph records involving two seasonal cycles, and included the airports at Burbank, California (altitude 695 feet), Salt Lake City, Utah (altitude 4,220 feet), and Cheyenne, Wyoming (altitude 6,145 feet) These data are presented in the form of curves which show the fluctuations in density altitude and pressure altitude

DISCUSSION OF FACTUAL DATA

1 <u>Accident Records</u>

Brief accounts of 452 accidents and 28 mechanical interruptions are presented in tables 23 to 27 inclusive (appendix #4) All accidents and interruptions involving take-offs and landings which occurred during the period of time considered are included These data have been grouped so that each table includes the following types of accidents

Table 23 - Take-Off, Airline Aircraft
Table 24 - Landing, Airline Aircraft
Table 25 - Take-Off, Private Owner Aircraft
Table 26 - Landing, Private Owner Aircraft
Table 27 - Take-Off and Landing Interruptions, Airline

Because of their quantity, the above data have been placed in an appendix to this report They have been condensed, however, in the following tables 2 to 6 inclusive, which list the primary causes of those accidents which are pertinent to the consideration of airport dimensions

TABLE 2

PRIMARY CAUSES			
TAKE-OFF ACCIDENTS INVOLVING AIRLINE TYPE AIRCRAFT			
Item No	Cause of Accident	Accident Numbers as Listed in Table 23	Total No of Accidents
1	Ice or snow on wings	8 - 10 - 11 - 18 - 20	5
2	Carburetor Ice	2 - 3 - 22	3
3	Failure of Fuel Supply	1 - 6 - 12	3
4	Insufficient Width of Runway Area	9 - 17 - 22	3
5	Obstacles in Flight Path	7 - 19	2
6	Uncontrolled Swerving Out of Runway Area	1 - 2 - 3 - 4 - 5 - 12 13 - 14 - 15 - 16 - 22	11
7	Engine Failure	1 - 2 - 3 - 4 - 6* - 12 14 - 15 - 16 - 22	10*

*All accidents due to engine failure, with the exception of #6 involved uncontrolled swerving from the original flight path.

<u>NOTE</u> 1 Only the accident data which are pertinent to the consideration of airport dimension requirements are included in this table

2 This table is a condensation of the data listed in table 23 which involves a total of 22 accidents, which in turn involved a total of 157 people Of these, 5 were injured fatally, 13 seriously, 6 sustained minor injuries and 133 were uninjured

TABLE 3

PRIMARY CAUSES			
LANDING ACCIDENTS INVOLVING AIRLINE TYPE AIRCRAFT			
Item No	Cause of Accident	Accident Numbers as Listed in Table 24	Total No of Accidents
1	Overshooting	4 - 8 - 19 - 22 - 30 - 32 35 - 48 - 53 - 56 - 57 - 64 72	13
2	Brake Malfunctioning	12 - 19 - 23 - 30 - 35 - 38 55 - 63 - 65 - 72 - 53	11
3	Uncontrolled Swerving Out of Runway Area	12 - 27 - 42 - 54 - 55 - 65	6
4	Insufficient Width of Runway Area	55	1

NOTE: 1 Only the accident data which are pertinent to the consideration of airport dimension requirements are included in this table

2 This table is a condensation of the data listed in table 24 which involves a total of 72 accidents, which, in turn, involved a total of 539 people Of these 3 were seriously injured and 536 were uninjured

TABLE 4

PRIMARY CAUSES			
TAKE-OFF ACCIDENTS INVOLVING PRIVATE OWNER TYPE AIRCRAFT			
Item No	Cause of Accident	Accident Numbers as Listed in Table 25	Total No of Accidents
1	Over-running	3 - 22 - 33 - 48 - 51 - 61 63 - 66 - 67 - 80 - 82 90 - 99 - 102	14
2	Engine Failure	5 - 7 - 9 - 11 - 12 - 14 18 - 23 - 24 - 27 - 29 - 30 31 - 32 - 34 - 39 - 43 - 44 52 - 70 - 72 - 77 - 78 - 87 88 - 89 - 94 - 96 - 97 - 100 104	31
3	Obstacles in Flight Path	16 - 17 - 22 - 25 - 31 - 33 38 - 42 - 56 - 60 - 61 - 63 66 - 67 - 68 - 75 - 84 - 90 93 - 102	20
4	Failure of Fuel Supply	18 - 24 - 88	3
5	Uncontrolled Swerving Out of Runway Area	37 - 49 - 53 - 58 - 83 - 103	6

NOTE 1 Only the accident data which are pertinent to the consideration of airport dimension requirements are included in this table

2 This table is a condensation of table 25 which involves a total of 104 accidents, which in turn involved a total of 211 people Of these, 2 were injured fatally, 9 seriously, 12 sustained minor injuries and 188 were uninjured

TABLE 5

PRIMARY CAUSES			
LANDING ACCIDENTS INVOLVING PRIVATE OWNER TYPE AIRCRAFT			
Item No	Cause of Accident	Accident Numbers as Listed in Table 26	Total No of Accidents
1	Overshooting	7 - 23 - 24 - 41 - 45 - 129 147 - 160 - 174 - 221 - 235	11
2	Brake Malfunctioning	34 - 35 - 168	3
3	Uncontrolled Swerving Out of Runway Area	8 - 12 - 14 - 17 - 22 - 24 26 - 29 - 31 - 34 - 35 - 39 47 - 56 - 58 - 63 - 64 - 75 - 82 93 - 96 - 107 - 127 - 132 - 135 136 - 140 - 141 - 142 - 155 - 162 168 - 169 - 170 - 197 - 215	36
4	Obstacles in Flight Path	9 - 49 - 67 - 70 - 86 - 108 - 110 - 148 - 161 - 189	10
5	Insufficient Width of Runway Area	17 - 56 - 58 - 75 - 96 - 162 170	7

NOTE 1 Only the accident data which are pertinent to the consideration of airport dimension requirements are included in this table

2 This table is a condensation of the data listed in table 26 which involves a total of 472 accidents, which, in turn, involved a total of 472 people Of these, 6 were injured fatally, 5 seriously, 38 sustained minor injuries and 423 were uninjured

TABLE 6

PRIMARY CAUSES			
MECHANICAL INTERRUPTIONS INVOLVING AIRLINE TYPE AIRCRAFT			
Item No	Cause of Interruption	Interruption Nos as Listed in Table 27	Total No of Interruptions
1	Engine Failures	19 - 20 - 21 - 22 - 23 - 24 25 - 26 - 27* - 28	10 *
2	Brake Malfunctioning	6 - 7 - 8 - 10 - 13 - 14 - 15 - 16 - 17 - 18	10

* All of these interruptions with the exception of #27 involved the failure of one outboard engine Controlled flight was maintained

NOTE Only the interruption data which are pertinent to the consideration of airport dimension requirements are included in this table

From inspection of the tabulated records, it will be noted that there were a number of accidents in which the airplanes travelled beyond the boundaries of the airport, but which, it is believed, would not have been avoided even though the airport had been larger Thus, the formation of ice or snow on the wings either prior to or during the take-off often results in the following sequence of events the airplane apparently is functioning in a normal manner during the ground run, but refuses to leave the ground at the usual speed The pilot does not realize that the aerodynamic characteristics of the wings have been impaired and persists in his attempt to take off until he suddenly realizes that he is approaching the boundary of the airport

At this point he closes the throttle, but continues beyond the boundary In view of the above, and in view of the fact that sea level runways as long as 4,500 feet have been involved, (accident #11, table 23), it appears that dispatching practice rather than runway length is the critical factor Nevertheless, both take-offs and landings continually will be attempted under such conditions It is important, therefore, that airport dimensions be of sufficient magnitude to minimize the hazards involved

There also have been a number of accidents, the primary causes of which have been eliminated or which are subject to elimination Again, it is felt that in such cases airports need not be enlarged to accomodate the resulting maneuvers of the aircraft One such cause is the formation of ice in the engine induction systems

The removal of this hazard through the application of means to prevent engine icing reduces the possibility of engine failures due to such causes The presence of water in the fuel has caused a number of engine failures Proper fuel handling practices together with the use of adequate storage equipment is proving effective in the elimination of this hazard

Many accidents have been due to the pilot's failure to take off within a reasonable distance, or have resulted from overshooting in attempting to land. Obviously, these would have been avoided if the airport had been larger It also is obvious that poor piloting technique can result in accidents of this type regardless of runway length This is evidenced by the fact that runways as long as 3,650 feet have been overrun in attempted take-offs of medium powered private owner type aircraft, (accident #63, table 25), and that 4,000 foot runways have been overshot in attempted landings of airline aircraft, (accident #8, table 24) In view of the above, it appears impractical to consider the determination of runway lengths directly from accident records, particularly since observed performance data are now available, as listed in this report

The necessity for adequate width of cleared areas on either side of the runway is evidenced by a number of accidents listed in the tabulated data Thus, accidents have been caused by piles of snow which were left on either side of the runway when the runway itself was cleared There also have been accidents which involved an uncontrolled and sudden swerving of the airplane from its original take-off or landing direction In such cases, airplanes have travelled as far as 600 feet from the center of the runway before coming to rest (accident #3, table 23) While it is true that damage to the airplane usually will result from such maneuvers, even though cleared areas are available, it also is true that adequate width of such areas will minimize the possibility of injuries to passengers and crew and, therefore, should be provided These records include so little specific information concerning actual distances that they cannot be used as a basis for precise determination of this important dimension Consideration of the aircraft performance characteristics in this connection also is of little value, since these do not involve such maneuvers However, if the 600 foot distance mentioned above were to be accepted as a criterion, it would follow that on large airports a minimum distance of 600 feet should be provided between the center lines of any two parallel runways, from the center line of any runway to the boundary of the airport, and from the center line of any runway to any obstruction It appears reasonable, however, to reduce this dimension in the case of smaller airports

In considering runway length requirements with a view to minimizing the hazards resulting from engine failure during take-off, it would be desirable to determine

(a) The point along the take-off where such failure is likely to occur
(b) The probable sequence of events following the engine failure

Table 2 lists ten accidents due to such engine failures involving five different types of multiengine airline aircraft These accidents include engine failures at various points along the take-off They have occurred at the start, during the ground run, and after take-off, at heights up to 60 feet above the ground In every case, except one, the airplane did not continue in a straight line but swerved to one side out of control, and crashed at some distance from the runway On the other hand, table 6 lists nine interruptions due to failure of one outboard engine in which the pilot was able to maintain control after the engine had failed This table also includes five types of aircraft. Single engine aircraft have been involved in 31 accidents (table 4) which were caused by engine failures during the ground run, and after take-off, at heights up to 700 feet above the ground

The above data indicate that it is not possible to determine the point along the take-off where engine failures are likely to occur However, they do give some indications concerning the probable sequence of events following such failures, particularly as to multiengine airline aircraft in current operation It appears that the loss of an outboard engine need not result in loss of control On the contrary, it would seem that correct pilot reaction can result in controlled flight regardless of the air speed at the time of the engine failure, and in spite of the fact that such failures come as a complete surprise to the pilot at the time when he is occupied with the extremely delicate task of getting his passengers safely into the air This would appear to explode the idea that, for any particular model, there is a critical speed above which control may be maintained and below which a crash is certain However, it undoubtedly is true that high speeds favor controlled flight in such emergencies

From the standpoint of safety, it seems reasonable that runways should be long enough to permit airplanes to roll safely to a stop in the event of an engine failure during the take-off In view of the foregoing discussion there is no clearcut basis for a general determination of the point at which the engine failure will occur, except that high speeds at the time of engine failure will favor controlled flight

As an example, it might be assumed from consideration of accident #1, table 23 , that runways should be long enough to permit an airline aircraft to take off, climb to 60 feet, lose an engine, land, and roll safely to a stop On this basis actual lengths can be obtained through a study of the normal take-off and landing flight paths as shown in figure 21 These curves indicate that airline aircraft will travel between 4,000 and 5,600 feet to attain a height of 60 feet, and that an additional 3,500 feet to 4,200 feet will be required to permit them to land and roll to a stop Accomodations for such maneuvers would result in runways from 7,500 feet to 9,800 feet long, depending on the type of airplane It cannot be established from the accident records that even these lengths would provide absolute safety under such conditions In view of the accident data, however, safety in the event of an engine failure during the take-off would seem to depend upon correct pilot reaction It is believed that this will be less likely if the pilot finds that he is nearing the boundary of the airport when his engine fails On the other hand, if runways were at least long enough to permit the airplane to come safely to a stop in the event of a partial loss of power during the take-off at the speed at which level flight power requirements were a minimum, the pilot could come to a stop or, if he so elected, his chances of successfully going around for a landing would be favorable

It would seem that runway lengths determined on the basis outlined above should favor correct pilot reaction, and therefore should provide reasonably well for the safe operation of both single and multiengine aircraft

The speeds for minimum power, level flight, under standard sea level conditions are listed on line 19 of table 7, for the eight airplanes included in this study The unstick speeds as realized in normal day-by-day flying operations involving unfavorable temperature and barometric conditions (T =100°F, H_p= 500 ft) are listed on line 5, table 8 When the speeds listed in table 7 are corrected to the temperature and barometric conditions which are involved in table 8, it will be seen that under similar conditions the speeds for minimum power closely approximate the operating unstick speeds

In view of the above, it is felt that a reasonable degree of safety will be realized if runways are long enough to permit aircraft to roll safely to a stop in the event of an engine failure during the take-off at the point where the wheels are just leaving the ground, as determined from performance characteristics realized during normal day-by-day operations

2 <u>Performance Data</u>

(a) <u>Basis for Correction</u>: When the photographic records of each take-off or landing were obtained, as previously discussed in this report, notations were made of the accompanying wind direction, wind speed, temperature, barometric pressure, and of the gross weight of the airplane The distances, heights, and speeds, as determined through the viewing of the films on the projector, then were corrected to zero wind velocity and to specification gross weight in the conventional manner A detailed discussion of these corrections may be found in appendix #1 Since it is necessary to determine the variation of these performance characteristics with altitude, they were not corrected to sea level Instead, the particular altitude at which each record was obtained is listed so that curves of performance against altitude can be plotted for each airplane involved When this has been accomplished, it is necessary only to determine the altitude of any airport so that the performance characteristics of that airplane on that airport also may be determined

The altitude that is listed, either with respect to the recorded flight characteristics or with respect to any airport, must be expressed in terms of the atmospheric conditions that affect the particular performance characteristic in question Thus, speeds are affected only by the density of the air, since only aerodynamic characteristics are involved Landing ground roll distances also are affected by density in that they depend upon the speeds at contact Take-off distances and climb path ratios, on the other hand, are affected both by density and by pressure, since both the aerodynamic and the engine power characteristics are involved Approach path ratios are not affected by altitude, since they depend only upon the angle of attack or flying attitude of the airplane

In order to express density and pressure in terms of altitude, it is necessary to consider the standard relationship of these characteristics to altitude Meteorological observations from all over the world and covering a period of many years have led to the general adoption of a "Standard Atmosphere" Thus, for any altitude, there is a standard temperature, a standard pressure, and a standard density When the density has been determined from the observed temperature and pressure, a corresponding altitude may be determined from standard atmosphere tables This is designated as the "density altitude" In a similar manner the altitude corresponding to any observed pressure is termed "pressure altitude" Figure 1 is a nomogram, or chart, which may be used to determine the density altitude from any combination of observed temperature and pressure, or which may be used to determine the pressure altitude when the barometric pressure is known To increase its utility, additional scales are included on this nomogram which permit the conversion of density altitude to the square root of the density ratio (ratio of observed density to standard sea level density)

The determination of altitudes corresponding to the combinations of density and pressure, which affect take-off distances and climb path ratios, is difficult because of the complicating effect of engine supercharging However, an altitude coefficient (K_{DP}) has been determined, and these characteristics have been plotted against (K_{DP}) This, in effect, is a multiplying coefficient which may be used to reduce these performance characteristics to sea level conditions A second nomogram (figure 2) is used to determine (K_{DP}) from known values of density altitude (H_D) and effective pressure altitude (Δ Hp) The use of this nomogram, including the determination of (Δ Hp), is explained on the nomogram itself The values resulting from the use of figure 2 are in close agreement with the curve shown in figure 218, page 442, on the revised edition of Diehl's Engineering Aerodynamics

Thus, when the temperature and barometric pressure corresponding to any photographic record are known, the nomograms (figures 1 and 2) may be used to determine the pressure altitude, the density altitude, and the altitude coefficient (K_{DP}) which existed during that flight

(b) Presentation of Performance Data for each Airplane

The normal performance characteristics involving take-offs and landings as listed in table 1, and corrected as previously discussed, are presented in tables 28 to 40 , and in figures 3 to 19 inclusive As far as possible, these data are grouped according to the model involved

Take-off distances from start to unstick, to 50 feet height, and to 100 feet height, as well as unstick speeds and landing speeds are tabulated and plotted against altitude

The tabulation and graphical presentation of landing approach data include distances from 100 feet height to contact and from 100 feet height to 50 feet height Since these characteristics are not affected by altitude, as previously discussed, they are not plotted against altitude but are represented on figure 18, by straight horizontal lines which are drawn to scale from a common datum line so that the length of each line corresponds to the observed glide path ratio for each landing The glide path ratio is the ratio of distance to height

The presentation of the landing ground roll data as curves of distance against contact speed (figure 19) involves four separate models It appears that the size of the airplane does not influence the definition of such curves, but that certain design characteristics will have an appreciable effect Thus, two closely related curves are drawn The first curve involves normal airplanes, while the second involves airplanes equipped with tricycle landing gears or with low hanging Fowler flaps Only data involving the full use of brakes are included

A careful study of the graphical presentation of these data will clarify and facilitate the consideration of airport size determination In this connection, it again is emphasized that these data were photographically obtained, and that no restrictions were imposed upon the pilots with respect to flying technique They are records of how the airplanes perform under normal operating conditions rather than how they might perform under ideal conditions The result of each recorded flight is shown These flights involve flying technique that has been evolved through years of experience, not all of which has been pleasant, as it includes a number of fatal accidents These accidents, however, have resulted in increased safety, since their analyses have made it possible to eliminate unsafe flying practices It is felt, therefore, that the observed performance data included in this study involve a reasonable balance of practicability and safety

It might well be expected that, by this time, the flying technique for each airplane would have become more or less standardized, and that this would be reflected in reasonably consistent records of the normal performance characteristics for those airplanes On the contrary, however, the observed data for any one model are seen to be widely divergent This emphasizes the fact that piloting technique is but one of many variables, any of which can seriously affect the resulting performance characteristics, and none of which is accounted for by aerodynamic theory For example, in figure 17, it will be noted that under normal conditions and at moderate altitudes, airline aircraft (H) will require from 1,100 feet to 2,200 feet to get off the ground

The manner of divergence of these data is significant It will be noted that the majority of the data lie within reasonably definite boundaries, while a few are so widely scattered as to appear to be completely unrelated to the main group It is believed that these few could be the result of ultra-conservatism on the part of those particular pilots, or perhaps could be due to extremely unusual combinations of unfavorable circumstances

The problem in each case is to locate curves through the observed data, so that the conclusions drawn from these curves will represent reasonable safety It is believed that only the main group need be considered and the few data which lie far beyond the boundaries of this group may be ignored It might be possible to draw a curve which would be a mathematical average of the grouped points If this were done, roughly fifty percent of the observed data would fall beyond the curve However, as previously discussed, all of the observed data involve a high standard of piloting technique and were obtained under normal operating conditions If airport dimensions were determined from average curves, only about fifty percent of the flying operations would enjoy the degree of safety which the criteria previously discussed should provide It would seem desirable, therefore, that these critical curves be located so as to mark the reasonably conservative boundary of the main groups of data This latter reasoning is that used in locating the curves Furthermore, no attempt was made to shape these curves to conform to aerodynamic theory, since it is felt that the many indeterminate variables easily could negate its effect

In studying the curves of unstick and contact speeds against density altitude, it will be noted that in each case a horizontal line is drawn across the sheet at a density altitude (H_D) of 3,200 feet, and that this line is labeled "S L - High Temp & Low Barometer" The intersection of this line with the curve gives the velocity characteristic that will be realized at sea level airports on exceedingly hot days Take-off distance curves include a similar horizontal line located at K_{DP}= 867 for unsupercharged engines and at K_{DP}= 894 for supercharged engines As explained previously, the above values are based upon a large volume of meteorological observations

It appears desirable that sea level airports should be large enough to accomodate the performance indicated by the intersections of the above lines with the curves It is believed that the factual data have been interpreted in a correct and reasonable manner There follows a detailed discussion of these data with reference to each specific airplane model

Airplane A (Private Owner Type)

The characteristics of Airplane A are determined through the use of spread coefficients This will be discussed later

Airplane B (Private Owner Type)

The adequacy of the 96 available records concerning Airplane B can be determined from inspection of figures 3, 4, and 5 From these it will be seen that although the two groups of points adequately determine the actual performance characteristics of this airplane at sea level and at about 3,000 feet density altitude (K_{DP}= 70), a third group of points at an appreciably higher altitude is needed to determine more accurately the manner in which the performance of this airplane varies with altitude This need is illustrated by the extrapolation of the curve involving the contact speed and density altitude as shown in figure 4 The landing approach data are presented graphically in figure 18 The complete determination of the observed characteristics of this airplane could be realized by obtaining 60 additional records at a geographical altitude of 6,000 feet or higher These should include 30 take-offs and 30 landings

Since all of the landings of this airplane involved the use of brakes, the speeds at contact and the corresponding ground roll distances are listed in table 40 and are plotted in figure 19

Airplane C (Private Owner Type)

The characteristics of Airplane C are determined through the use of spread coefficients This will be discussed later

Airplane D (Airline Type)

The tabulated and plotted characteristics of Airplane D are the results of photographic records of controlled flight tests of this airplane, and do not include normal day-in and day-out operations, nor any approach path data Moreover, the number and the altitude distribution of these records are not completely adequate, even for the determination of sea level characteristics, as will be seen from inspection of the following figures 6, 7, and 8 except that the landing ground roll characteristics plotted in figure 19 involve the use of brakes These data are presented at this time, however, since it is felt that the inclusion of observed data on at least five airline aircraft is desirable It is believed that the majority of these results which involve contact speed characteristics represents normal operating practice The location of the curves, particularly relating to the take-off characteristics, is a matter of extrapolation These can be located fairly accurately at low altitudes (1,000 feet density altitude or K_{DP}= 97) Their extrapolation to higher altitudes, however, involves sloping them in approximately the same manner as the corresponding curves for Airplanes B, E, F, and H, which were defined by more complete data at various altitudes It is believed that the performance characteristics of Airplane D, as determined from these curves, will result in reasonably safe airport requirements for this airplane, and that unduly conservative results are not included It will be noted that the available data concerning this airplane do not include approach path characteristics These are determined through the use of spread coefficients

Although it is believed that the interpretation of the available data concerning this airplane has resulted in a reasonable determination of its actual operating performance characteristics, it would be most desirable to obtain a complete set of 180 additional records involving normal piloting technique rather than controlled flight tests

Airplane E (Airline Type)

The take-off characteristics of this model are adequately determined from observed data which involve only day-in and day-out operations for density altitudes up to 5,500 feet (K_{DP}= 82) The contact speed characteristics, however, are not determined very definitely above 2,000 feet density altitude Approach path characteristics are determined adequately as seen in figure 18 No records of braked landings are available for this airplane

A more complete determination of the observed characteristics could be realized through the obtaining of 30 additional take-off records at a geographical altitude of 6,000 feet or better, and 60 additional landing records at altitudes from 4,000 feet to 7,000 feet Records of braked landings also should be obtained for this model

Airplane F (Airline Type)

Available records concerning this model include only take-offs All of these take-offs involve normal operations, except that the records obtained at density altitudes below sea level involve controlled tests The inclusion of such data is of interest, since they appear to lie close to the curves of take-off performance against altitude, as defined by data involving normal flying These curves are defined adequately for density altitudes up to 3,200 feet (K_{DP}= 894)

The landing performance characteristics are determined through the use of spread coefficients, as will be discussed later in this report

If the take-off and landing characteristics of this airplane were to be determined completely from observed data involving day-by-day operations, it would be desirable to obtain 30 additional records of take-offs at a geographical altitude of approximately 4,000 feet and another 30 take-off records at 6,000 feet or higher It also would be desirable to obtain a complete set of 90 landing records consisting of three groups of 30 obtained at sea level, 4,000-foot, and at 6,000-foot altitudes Records of landing ground rolls involving the use of brakes would improve the definition of the curves shown in figure 19

Airplane G (Airline Type)

The available data concerning this airplane not only are inadequate from the standpoint of quantity, but involve only controlled flight tests in which efforts were made to realize the ultimate performance characteristics of this airplane It is necessary, therefore, to determine the normal take-off and landing characteristics through the use of spread coefficients The landing data, however, do include ground roll distances which involved the use of the brakes These data are incorporated in figure 19

It would be most desirable, of course, to obtain a complete set of 180 records involving day-by-day operation of this airplane

Airplane H (Airline Type)

The recorded data from which the day-by-day take-off and landing characteristics of this airplane have been determined are very complete This is most fortunate in view of the fact that the performance characteristics of Airplane H, as realized in normal operation are such that they determine the dimensions of the largest airports (Class IV), as will be seen in tables 8, 9 and 10

The radio instrument landing characteristics for this airplane, however, were determined from data which involved low density altitudes In order to determine these characteristics for sea level airports, but under unfavorable meteorological conditions, it was necessary to extrapolate the curve of contact speed from a density altitude of -500 feet to a density altitude of 3,200 feet This has been accomplished by sloping the curve in a manner similar to the slopes of other contact speed against altitude curves It is believed that the intersection of this curve with the horizontal line drawn at $H_D = 3,200$ feet gives a reasonable value of contact speed at this altitude, and that it safely may be used to determine normal ground roll distances for this airplane when landing on the radio instrument landing system and under unfavorable meteorological conditions at sea level airports

It would be most desirable to obtain photographic records of blind take-offs for this airplane, since it is believed that such conditions may induce more conservative piloting technique More radio instrument landing records at higher altitudes also should be obtained

Figures 14, 15, 16, and 17 concerning this particular airplane and also figures 18 and 19 concerning the approach paths and ground roll characteristics of this and other airplanes are included at this point

It is regretted that the number of data involving braked landing runs is not greater since the resulting curves (figure 19) are so important in determining runway lengths Eventually more should be obtained However, it is believed that the use of those curves will result in runway lengths that will provide reasonably safe stopping distances

3 Meteorological Data

As previously stated, the meteorological data observed at the Burbank, California, Salt Lake City, Utah, and Cheyenne, Wyoming airports consist of actual temperature and barometric pressure readings involving the period from June 6, 1937 to September 22, 1938 These data are listed in table 41 and are plotted in figure 20.

It will be noted in table 41 that each line involves a period of about one week This is due to the fact that the data were obtained from inspection of thermograph and barograph records There are four of these per month, thus, for each quarter of a month, the minimum barometric pressure and the combination of pressure and temperature for minimum density are listed From these the maximum density and pressure altitudes are determined using the nomogram (figure 1)

These tabulated altitude data are plotted for the period of 16 months in figure 20 A separate set of curves for each airport is presented Thus, for each airport there is a curve showing the fluctuations in density altitude over two seasonal cycles, and a similar curve for pressure altitudes Two horizontal lines will be noted One is marked (H_D), density altitude, while the other is marked (H_p), pressure altitude These are located so as to indicate the values of (H_D) and (H_p) that actually are experienced at those airports over considerable periods of time during the summer The values thus indicated may be used in conjunction with the nomogram (figure 2) to interpret the curves of observed performance characteristics plotted against altitude, so as to correlate the dimensions of those airports with the performance characteristics of the particular airplane in question Such a procedure will insure safe operation with full pay load, and under unfavorable meteorological conditions of observed magnitude The values indicated by these lines are listed in the lower left hand corner of each plot under the heading "Assumed Operating Conditions" Eventually, the meteorological data discussed above can be obtained for all airports just as observed performance characteristics can be photographically obtained for all aircraft

APPLICATION OF FACTUAL DATA

1 Determination of Normal Sea Level Characteristics

(a) General Considerations The determination of the normal sea level performance characteristics for the eight airplanes included in this study constitutes the first step in the final establishment of the proposed dimensional standards for the four classes of airports at all elevations up to 10,000 feet There are two major considerations involved in this application of the factual data These are

(a) Unfavorable meteorological conditions which are likely to be encountered
(b) The use of spread coefficients

Regarding the consideration of unfavorable meteorological conditions in connection with the establishment of proposed dimensional standards involving elevations up to 10,000 feet, it will be noted that the observed data (figure 20) do not extend above 6,200 feet elevation It is necessary therefore, to make a general assumption concerning temperatures and barometric pressures which will apply at all altitudes After studying the values indicated in the foregoing meteorological data, it is assumed that at any airport during the summer months, flying operations will be carried on during the heat of the day when the temperature is 100°F , and when subnormal barometric pressures indicate a pressure altitude of 500 feet above the elevation of the airport The use of the monograms (figures 1 and 2) in conjunction with the above assumption results in values of density altitude (H_D) and pertinent multiplying coefficients as listed in table 12, which in turn are involved in the determination of airport dimensional standards versus altitude as shown in figures 22 and 23

The above assumption is slightly conservative when compared with the values indicated by the plotted meteorological data in the foregoing figure 20 However, its final effect as reflected by the runway length and obstacle zoning requirements versus elevation (figures 22 and 23), checks very closely with the dimensional requirements obtained through the direct use of the observed values in figure 20

For the immediate purpose of determining the normal sea level characteristics of the eight airplanes included in this study, the temperature of 100°F and the pressure altitude of 500 feet are applied to the nomograms (figures 1 and 2) to obtain the following values

H_D (Density Altitude)	3,200 ft
K_{DP} (For Unsupercharged Engines)	867
K_{DP} (For Supercharged Engines)	894

The above values are used in conjunction with the curves of observed performance characteristics against altitude to obtain the proposed dimensional standards for sea level airports They are indicated on each curve by a horizontal line designated "S L High Temp and Low Barometer" The intersection of these horizontal lines with the performance curves gives the values that are used in the determination of dimensions for "sea level" airports

Values from observed performance data as described above can be obtained only for Models B, D, E, F, and H because of the limited amount of such data It becomes necessary to obtain the normal operating characteristics of Models A, C, and G through the use of spread coefficients As previously explained, this is accomplished through the application of a uniform method for computing the ultimate characteristics of all models (Models A to H, inclusive) When the ultimate characteristics have been determined, coefficients may be obtained for Models B, D, E, F, and H by dividing the observed normal characteristics by the computed ultimate characteristics A study of these coefficients leads to the determination of spread coefficients, which may be applied to the computed ultimate characteristics of Airplanes A, C, and G to obtain a close approximation of their normal day-in and day-out operating characteristics

The application of spread coefficients to ultimate performance characteristics always will be necessary, since it is the only method available for determining the normal day-by-day performance characteristics of projected or newly developed aircraft, and since it always will be necessary to determine the airport size requirements of such aircraft long before their use has become so general that records of day-by-day operating characteristics can be obtained The estimation of these coefficients for such aircraft will become increasingly accurate as the number of airplanes included in these photographically obtained data increases

The computations involved in obtaining the ultimate performance characteristics of Models A to H, inclusive, are accomplished through a method of tabulation (See table 7)

The application of such methods, of course, negates one of the fundamental precepts of this study, namely, that all of the performance values used in the determination of airport dimensions should be obtained from photographic records of normal day-by-day operations, rather than from the application of aerodynamic theory As previously explained, however, the urgent need for immediate results necessitated the abandonment of the original program for obtaining records It is to be hoped that more factual data eventually may be obtained In the meantime, the use of spread coefficients yields fairly reasonable results and the establishment of a method of applying such coefficients should prove useful for the obtaining of normal characteristics of new and untested airplanes

There follows an explanation of the method of tabulation

(b) Computation of Ultimate Sea Level Characteristics

The following is an explanation of the values listed in table 7 This table includes the aerodynamic computations of the following take-off and landing characteristics

(1)	Lift-Drag Ratio (gear extended)	(line 16)
(2)	Minimum Unstick Speed (Standard sea level)	(line 21)
(3)	Distance to Unstick (Sea Level t = 100° H_p - 500')	(line 27)
(4)	Distance from 50' height to 100' height (Standard sea level)	(line 32)
(5)	Distance from Unstick to 50' height (Standard sea level)	(line 33)
(6)	Contact Speed (Standard sea level)	(line 38)

In detail then, and line for line, the values listed in table 7 were obtained as follows

(THE AERODYNAMICS INVOLVED ARE DISCUSSED IN APPENDIX NO 2)

Line 1 Weight (W) - from Aircraft Specifications
Line 2 Span (B) - from Aircraft Specifications
Line 3 Area (S) - from Aircraft Specifications
Line 4 Geometric Aspect Ratio ($N = B^2/S$)
Line 5 Normal Rated Brake Horsepower per engine (BHP_N) from Aircraft Specifications
Line 6 Normal Engine Speed (RPM) from Aircraft Specifications
Line 7 Brake Horsepower for Take-Off (Total) (BHP_T) from Aircraft Specifications
Line 8 Maximum Speed (V_M) from compiled performance data
Line 9 Propeller Coefficient

$$K_S = \frac{325 V_M}{RPM} \left[\frac{V_M^3}{BHP} \right]^{\frac{1}{2}}$$

Line 10. Propeller Efficiency
$\eta = K_S/(\ 197 + 1\ 124\ K_S)$ two blade props $\eta = K_S/(\ 20 + 1\ 16 K_S)$ three blade props

Line 11 Parasite Drag Coefficient (gear retracted) $C_{DP_2} = 133000\ BHP\,\eta / S V_M^3$

Line 12 Parasite Drag Coefficient (gear extended) $C_{DP_1} = 1\ 5\ C_{DP_2}$

Line 13 Effective Aspect Ratio (gear retracted) $R_2 = N/(1 + 2\ N C_{DP_2})$

Line 14 Effective Aspect Ratio (gear extended) $R_1 = N/(1 + 2\ N C_{DP_1})$

Line 15 Lift Drag Ratio (gear retracted) $L/D_2 = (\ 7854\ R_2 / C_{DP_2})^{\frac{1}{2}}$

Line 16 Lift Drag Ratio (gear extended) $L/D_1 = (\ 7854\ R_1 / C_{DP_1})^{\frac{1}{2}}$

Line 17 Traction Coefficient $\mu =\ 03$ (assumed)

Line 18 Thrust Horsepower for take-off $THP = \eta\ BHP_T$

Line 19 Velocity for minimum power

$$V_{MP} = \left[16{,}300 (W/S)^2 / R_2 C_{DP_2} \right]^{\frac{1}{4}}$$

Line 20 Speed Factor $K_u =\ 90$ (Normal wings) $K_u =\ 85$ (Plain flaps) $K_u = .80$ (Fowler flaps)

Line 21 Minimum Unstick Speed $V_u = K_u V_{MP}$

Line 22 Initial Thrust $T_1 = 375\ THP/AV_M$ A = Thrust Constant A = 3 (Controllable propellers) A = 5 (Fixed pitch propellers)

Line 23 Final Thrust $T_2 = 375\ HP/AV_M + CV_u$ C = Thrust Constant C = 6 (Controllable propellers) C = 5 (Fixed pitch propellers)

Line 24: Initial Net Force $F_1 = T_1 - \mu W$

Line 25: Final Net Force $F_2 = T_2 - \frac{W}{L/D_1}$

Line 26 Distance to Unstick $X_1 = 0167\ V_u^2 W\ (F_1 + F_2)/\ F_1\ F_2$

Line 27: Distance to Unstick ($t = 100°F$, $H_p = 500'$) X_1 / K_{DP}

K_{DP} (from nomogram figure 2)

Line 28: Thrust at Speed for Minimum Power $T_3 = 375 THP/AV_M + CV_{MP}$

Line 29: Net Force at Speed for Minimum Power $F_3 = T_3 - \frac{W}{L/D_2}$

Line 30 Distance to accelerate from V_u to V_{MP} $\Delta X = 067\ W/(V_{MP}^2 - V^2_u)F_2 + F_3$

Line 31 Distance from V_{MP} to 50' height $\Delta X_{50} = \frac{HW}{F_3} = \frac{50W}{F_3}$

Line 32: Distance from 50' height to 100' height $\Delta X_{(50\ to\ 100)} = \Delta X_{50} = \frac{50W}{F_3}$

Line 33: Distance from Unstick to 50' height $\Delta X_{50} = \Delta X + \Delta X_{50}$

Line 34 Distance from Unstick to 100' height $\Delta X_{100} = \Delta X + \Delta X_{50} + \Delta X_{(50\ to\ 100)}$

Line 35 Approach Path Ratio Proportional to L/D_1 from Line 16

Line 36. Velocity for Minimum Power V_{MP} from line 19

Line 37 Contact Speed Factor K_C = 80 (Normal wing) K_C = 70 (Plain flap)

K_C = 60 (Fowler flap)

Line 38: Contact Speed $V_C = K_C V_{MP}$

As previously discussed, the main objective in computing the optimum performance characteristics, as listed in table 7, is to provide a basis for determining the actual operating characteristics of airplanes on which no observed data have been obtained

In view of this, it will be seen that it is desirable to employ a uniform method for such computations and that this method should involve a large number of the physical characteristics of each airplane The accuracy of these computed values as compared to the characteristics that can be realized in actual flight tests is desirable but is not essential to this study, since it is necessary to provide only an adequate basis for comparison

(c) Determination of Required Runway Lengths, Sea Level

The values computed in table 7 are combined with observed values (figures 3 to 19, inclusive) in table 8, so that the required runway lengths finally are determined for Airplanes A to H, inclusive These are such as to permit the airplanes to roll safely to a stop in the event of an engine failure at the point where the wheels are just leaving the ground, and involve sea level airports under conditions of high temperature and low barometer, as previously discussed

Referring to table 8, the observed values were obtained from the figures indicated at the points where the curves intersect the horizontal lines designated as "S L -High Temp and Low Barometer", as explained previously The assumed spread coefficients listed on line 4 for Airplanes A, C, and G were determined as follows:

Since these coefficients are largely representative of the degree of pilot conservatism,

COMPUTED PERFORMANCE DATA (SEA LEVEL)

TABLE 7

These data involve standard sea level conditions unless otherwise noted

LINE NO	TYPE		PRIVATE OWNER			AIRLINE				
	AIRPLANE	SYMBOL	A	B	C	D	E	F	G	H
	TAKE-OFF									
1	Weight	W	1040	2400	3800	15500	13650	18560	60000	24400
2	Span	B	36	36 3	38	65 5	74 0	85	138 25	95
3	Area	S	146 35	174	185 5	551	836	939	2157	987
4	Aspect Ratio	N	8 86	7 55	7 80	7 8	6 56	7 7	8 86	9 15
5	Normal Brake Horsepower per Engine	BHP_N	40	145	320	800	550	690	1150	900
6	Normal Engine Speed	RPM	2540	2050	2200	2275	2200	2200	2200	2200
7	Brake Horsepower for Take-Off Total	BHP_T	40	145	350	1700	1200	1510	5600	2200
8	Maximum Speed	V_m	93	135	185	220	200	210	227	216
9	Propeller Coefficient	K_s	1 7	2 78	3 74	3 62	3 56	2 54	3,38	3 38
10	Propeller Efficiency	η	0 806	0 840	0 851	0 824	0 824	0 808	0 822	0 822
11	Parasite Drag Coefficient (Gear Retracted)	C_{DP2}				0 0299	0 018	0 0171	0 0199	0 0197
12	Parasite Drag Coefficient (Gear Extended)	C_{DP1}	0 0364	0 0376	0 0308	0 0449	0 027	0 0256	0 0299	0 0296
13	Effective Aspect Ratio (Gear Retracted)	R2				5 31	5 30	6 10	6 55	6 73
14	Effective Aspect Ratio (Gear Extended)	R1	5 38	4 82	5 25	4 59	4 85	5 52	5 80	5 92
15	Lift Drag Ratio (Gear Retracted)	L/D2				11 80	15 20	16 80	16 10	16 40
16	Lift Drag Ratio (Gear Extended)	L/D1	10 80	10 05	11 50	8 96	11 80	13 00	12 40	12 50
17	Traction Coefficient	μ	0 03	0 03	0 03	0 03	0 03	0 03	0 03	0 03
18	Thrust Horsepower	THP	32 2	122	298	1400	990	1220	4660	1810
19	Speed for Minimum Power	V_{mp}	45 5	65 0	81 0	95 0	82 5	88 5	99 5	93 5
20	Speed Factor	K_U	0 90	0 85	0 85	0 80	0 90	0 85	0 85	0 85
21	Minimum Unstick Speed	V_U	41 0	55 3	68 9	76 0	74 5	75 5	84 5	79 5
22	Initial Thrust	T_1	259	680	1210	7970	6200	7260	25200	10500
23	Final Thrust	T_2	181	480	880	4710	3550	4225	14500	6040
24	Initial Force	F_1	228	608	1096	7505	5790	6704	23400	9770
25	Final Force	F_2	85	241	550	2980	2400	2800	9650	4090
26	Distance to Unstick	X_1	473	710	820	700	745	935	1050	895
27	Distance to Unstick (Sea Level T = 100° H_p + 500')*	X_1/K_{DP}	545	817	945	785	833	1045	1173	1001
	CLIMB									
28	Thrust at Speed for Minimum Power	T_3	175	458	840	4260	3390	3950	13500	5620
29	Net Force Speed for Minimum Power	F_3	79	219	510	2950	2490	2850	9770	4130
30	Distance Required for Acceleration from V_U to V_{MP}	ΔX	165	410	436	570	235	470	572	482
31	Distance from V_{MP} to 50' Height	ΔX_{50}	660	548	373	262	274	325	307	296
32	Distance from 50' Height to 100' Height	ΔX_{100}	660	548	373	262	274	325	307	296
33	Distance from Unstick to 50' Height	X_{50}	825	958	809	832	509	795	879	778
34	Distance from Unstick to 100' Height	X_{100}	1485	1506	1182	1094	783	1120	1186	1074
	APPROACH AND LANDING									
35	Approach Path Ratio	L/D1	10 80	10 05	11 50	8 96	11 80	13 0	12 4	12 5
36	Speed for Minimum Power	V_{mp}	45 5	65 0	81 0	95 0	82 5	88 5	99 5	93 5
37	Contact Speed Factor	K_c	0 80	0 70	0 70	0 60	0 80	0 70	0 70	0 70
38	Contact Speed	V_c	36 4	45 5	56 5	57 0	66 0	62 0	69 5	65 5

*Operating Conditions at Sea Level are Assumed to Include a Temperature of 100° F and a Pressure Altitude of 500 This Results in an Assumed Density Altitude of 3200' In this Case K_{DP} for Unsupercharged Engines = 0 867 and for Supercharged Engines = 0.894

it was necessary to consider the general flying characteristics of the aircraft in estimating them In other words, it was assumed that airplanes of like flying characteristics would have nearly the same spread coefficients

In the case of Airplane A, which is of the low-powered private owner type, the only comparable airplane was Airplane E, which is of the airline type, as these are the only models in the group which are not equipped with flaps The coefficient for unstick speed for Airplane E is 1 15, which is quite low compared to the others However, since pilot conservatism was assumed to increase with airplane size, an increase in this value for Airplane A did not appear to be justified On the other hand, since Airplane E has the reputation of having reasonably safe flying characteristics at speeds near the stall, a decrease in this value for Airplane A did not appear to be justified either

In the cases of Airplanes C and G, the values of spread coefficients listed average fairly closely with the observed values for Airplanes B, D, F, and H. Special consideration was given to the estimation of the coefficient for unstick distance for Airplane G It was felt that since this airplane was equipped with a tricycle landing gear, the distance from start to unstick would be relatively shorter than for airline aircraft equipped with conventional gear A coefficient of 2 13 appears to be reasonable

In using figure 19 to determine the values listed on line 6, it is important to note that the upper curve determines ground roll distances for Airplanes D and G, while the lower curve is used to obtain these distances for Airplanes A, B, C, E, F, and H

The values listed on lines 2 and 8 were obtained from the indicated figures at the intersection of the curves with the "effective sea level" line

The assumed spread coefficients listed on line 10 for Airplanes A and C were estimated on the assumption that the degree of pilot conservatism increases with the size of the airplane

(d) Determination of Normal Take-Off and Climb Characteristics, Sea Level

The values listed in tables 7 and 8 are combined with observed values (figures 3 to 19, inclusive) in table 9 to obtain normal operating distances from start to unstick to 50 feet height and to 100 feet height The climb path ratio from 50 feet height to 100 feet height also is determined

Referring to table 9, the values listed on lines 2 and 3 again are obtained from the indicated curves for operation at effective sea level

In estimating values of spread coefficients listed on lines 8 and 12 for Airplanes A, B, and G, it again is assumed that the piloting technique will become increasingly conservative as the size of the airplane increases

(e) Determination of Normal Approach and Ground Roll Characteristics - Sea Level

The values listed in table 7 are combined with observed values (figures 3 to 19, inclusive) in table 10 to obtain normal operating distances from 100 feet height to stop, 50 feet height to stop, and from contact to stop

Referring to table 10, the spread coefficients listed on line 4 for Airplanes A, C, D, F, and G were estimated It is believed that these are reasonably consistent with the coefficients based upon observed values for Airplanes B, E, and H

The estimated spread coefficients listed on line 12, for Airplanes A, C, F, and G again are based on the assumption that the actual landing speeds will be closer to the stalling speeds where the smaller airplanes are concerned

A fair average value was assumed for the spread coefficients listed on line 17

(f) Discussion of Method for Determining Normal Sea Level Characteristics

The normal day-by-day performance characteristics finally determined and listed in tables 8, 9, and 10, involve runway lengths, take-off paths, and landing paths for Airplanes A to H, inclusive, as normally operated from airports geographically located at sea level, but involving the assumption of a temperature of 100°F together with a barometric pressure such that the pressure altitude is 500 feet above the geographical altitude

In reviewing the data listed in these tables it is important to consider the magnitudes of the various spread coefficients, as determined from observed performance characteristics As noted in the tables, the apparent magnitudes of these coefficients are exaggerated in that the

RUNWAY LENGTHS (SEA LEVEL)
(AIRCRAFT)

TABLE 8

LINE NO	TYPE	PRIVATE OWNER			AIRLINER				
	AIRPLANE	A	B	C	D	E	F	G	H
	UNSTICK SPEEDS								H
1	Computed Optimum Unstick Speed (Table 7, Line 21) (V_U)	41 0	55 3	68 9	76.0	74.5	75 5	84 5	79 5
2	Observed Normal Unstick Speed (From Curves — Figs 3, 6, 9, 12, 14)*		69 8		96 5	85 5	92 5		99 5
3	Spread Coefficients Based on Observed Actuals		1 26		1 27	1 15	1.23		1 25
4	Spread Coefficients - Assumed	1 15	1 26	1 25	1 27	1 15	1 23	1 25	1 25
5	Normal Unstick Speed Computed & Observed (V_{UN})*	47 2	69 8	86 1	96 5	85 5	92 5	105 6	99 5
	DISTANCES								
6	Distance to Stop from (V_{UA}) (From Curve Fig 19 & Line 5) (S)*	1090	1700	2200	2220	2180	2400	2490	2630
7	Computed Optimum Unstick Distance (Table 7 Line 26) (U)	473	710	820	700	745	935	1050	895
8	Observed Normal Unstick Distance (From Curves Figs 5, 8, 11, 13, 17)*		1140		1500	1620	2050		2250
9	Spread Coefficients Based on Observed Actuals		1 61		2 14	2 17	2 19		2 51
10	Spread Coefficients - Assumed	1 50	1 61	1 73	2 14	2 17	2.19	2 13	2 51
11	Normal Unstick Distance - Computed and Observed (U_N)*	710	1140	1419	1500	1620	2050	2235	2250
12	Required Runway Length (Line 6 + Line 11) (R)*	1800	2840	3619	3720	3800	4450	4725	4880

These data Involve Standard Sea Level Conditions Unless Otherwise Noted

*Operating Conditions at Sea Level are Assumed to Include a Temperature of 100° F and a Pressure Altitude of 500'
This results in an Assumed Density Altitude of 3200' In this Case K_{DP} for Unsupercharged Engines =0.867 and for Supercharged Engines =0 894

The Magnitude of the Spread Coefficients is Exaggerated due to the fact that they Involve a Comparison of Observed data Obtained at a Density Altitude of 3200' with Computed Ultimate Performance Characteristics which Involve Standard Sea Level Conditions

NORMAL TAKE-OFF AND CLIMB CHARACTERISTICS (SEA LEVEL)

TABLE 9

LINE NO	TYPF	PRIVATE OWNER			AIRLINE				
	AIRPLANE	A	B	C	D	E	F	G	H
1	Observed Normal Distance from Start to Unstick *(Table 8 Line 8)		1140		1500	1620	2050		2250
2	Observed Normal Distance from Start to 50' Height *(Figs 5, 8, 11, 13, 17)		2310		4070	3800	4800		5050
3	Observed Normal Distance from Start to 100' Height *(Figs 5, 8, 11, 13, 17)		3080		5200	5000	6200		6450
4	Observed Normal Distance from Unstick to 50' Height *(Line 2 - Line 1)		1170		2570	2180	2750		2800
5	Observed Normal Distance from 50' to 100' Height *(Line 3 - Line 2)		770		1130	1200	1400		1400
6	Computed Optimum Distance from Unstick to 50' Height (Table 7 Line 33)	8 25	958	809	832	509	795	879	778
7	Spread Coefficient Based on Observed Values		1 22		3 09	4 28	3 46		3 60
8	Spread Coefficient Assumed	1 10	1 22	2 5	3 09	4 28	3 46	3 50	3 60
9	Normal Distance from Unstick to 50' (Computed & Observed)*	907	1170	2020	2570	2180	2750	3075	2800
10	Computed Optimum Distance from 50' to 100' (Table 7 Line 32)	660	548	373	262	274	325	307	296
11	Spread Coefficient Based on Observed Values		1 41		4 31	4 38	4 32		4 75
12	Spread Coefficient Assumed	1 20	1 41	3 0	4 31	4 38	4 32	4 35	4 75
13	Normal Distance from 50' to 100' (Computed & Observed)*	791	770	1120	1130	1200	1400	1335	1400
14	Normal Distance from Start to Unstick (Table 8 Line 11)*	710	1140	1419	1500	1620	2050	2235	2250
15	Normal Distance from Start to 50' Height (Line 9 + Line 14)*	1617	2310	3439	4070	3800	4800	5310	6450
16	Normal Distance from Start to 100' Height (Line 13 + Line 15)*	2408	3080	4559	5200	5000	6200	6645	5050
17	Climb Path Ratio (50' to 100') (Line 13/50)*	15 80	15 40	22.40	22.60	24 00	28 00	26 70	28 00

These data involve standard sea level conditions unless otherwise noted

*Operating conditions at sea level are assumed to include a temperature of 100° F and a pressure altitude of 500' This results in an assumed density altitude of 3200' In this case K_{DP} for unsupercharged engines = 0.867 and for unsupercharged engines = 0 894

The magnitude of the spread coefficients is exaggerated due to the fact that they involve a comparison of observed data, obtained at a density altitude of 3200', with computed ultimate performance characteristics which involve standard sea level conditions.

NORMAL APPROACH & GROUND ROLL CHARACTERISTICS (SEA LEVEL)
AIRCRAFT

TABLE 10

LINE NO	TYPE	PRIVATE OWNER			AIRLINE					
	AIRPLANE	A	B	C	** D	E	F	** G	H	(BLIND) H
1	Minimum Computed Approach Path Ratio (L/D Max) (Table 7 Line 16)	10 8	10 05	11 50	8.96	11 8	13 0	12 4	12 5	12 5
2	Normal Approach Path Ratio (100' to Contact) Observed (Fig 18)		17 5			22 5			24 0	50 0
3	Spread Coefficient Based on Observed Values		1 74			1 90			1.92	4 0
4	Spread Coefficient (Assumed)	1 70	1 74	1 70	1.90	1 90	1 90	1 90	1 92	4 0
5	Normal Approach Path Ratio (Computed & Observed)	18 4	17 5	19 5	17 0	22 5	24 7	23 6	24 0	50 0
6	Normal Distance from 100' to Contact (Computed & Observed) (Line 5 x 100)	1840	1750	1950	1700	2250	2470	2360	2400	5000
7	Speed for Min Power (Table 7 Line 19) V_{mp}	45 5	65 0	81 0	95 0	82 5	88 5	99 5	93 5	93 5
8	Speed Factor (For Contact) (Table 7 Line 37) K_c	0 80	0 70	0 70	0 60	0 80	0 70	0 70	0 70	0 70
9	Minimum Computed Landing Speed (Line 7 x Line 8)	36 4	45 5	56 7	57 0	66 0	62 0	69 6	65 5	65 5
10	Normal Landing Speed Observed (At H_D = 3200') *(Figs 4, 7, 10, 15, 16)		62 3		83 5	82 5			94 5	110 0
11	Spread Coefficient (Based on Observed Values)		1 37		1 47	1 25			1 44	1 68
12	Spread Coefficient (Assumed)	1 25	1 37	1 40	1 47	1 25	1 45	1 45	1 44	1 68
13	Normal Landing Speed (Computed & Observed) Vcn*	45 5	62 3	79.4	83 5	82 5	90 0	101 0	94 5	110 0
14	Distance from (Vcn) to Stop (From Curve, Fig 19)*	1050	1490	1990	1850	2090	2320	2360	2460	2960
15	Observed Actual Approach Path Ratio 100' to 50' (Fig 18)		12 0			15 0			15 0	43 00
16	Spread Coefficient Based on Observed Values		1 20			1 27			1 20	3 44
17	Spread Coefficient Assumed	1 22	1 20	1 22	1 22	1 27	1 22	1 22	1 20	3 44
18	Normal Approach Path Ratio 100' to 50' (Computed & Observed)	13 2	12 0	14.0	10 9	15 0	15 9	15 1	15 0	4300
19	Normal Distance 100' to 50' (Computed & Observed) (Line 18 x 50)	660	600	700	545	750	795	755	750	2150
20	Normal Distance 100' to Stop (Line 6+Line 14)*	2890	3240	3940	3550	4340	4790	4720	4860	7960
21	Normal Distance 50' to Stop (Line 20 - Line 19)*	2230	2640	3240	3005	3590	3995	3965	4110	5810
22	Normal Distance Contact to Stop (From Line 14)*	1050	1490	1990	1850	2090	2320	2360	2460	2960

These data involve standard sea level conditions unless otherwise noted

*Operating conditions at sea level are assumed to include a temperature of 100° F and a pressure altitude of 500' This results in an assumed density altitude of 3200' In this case K_{DP} for unsupercharged engines =0 867 and for supercharged engines =0 894

** Line 14 Use upper curve of Fig 19

The magnitude of the spread coefficients is exaggerated due to the fact that they involve a comparison of observed data, obtained at a density altitude of 3200', with computed ultimate performance characteristics which involve standard sea level conditions computed data involve values that would be realized under standard sea level conditions, whereas the observed values were realized at a density altitude of 3,200 feet which results at sea level when a temperature of 100°F together with a barometric altitude of 500 feet are assumed Lines 7 and 11 of table 9 indicate that during the initial climb to 100 feet height and under adverse conditions, these aircraft actually travel more than four times the distance that would be required to attain this height if the airplanes were operated so as to realize their optimum performance at standard sea level Lines 3, 11, and 16 of table 10 indicate that the landing characteristics are nearly as conservative as the take-off characteristics

As discussed previously in this report, an appreciable divergence is to be expected between the optimum performance characteristics and the performance characteristics realized in regularly scheduled flying The magnitude of this divergence, however, is rather startling and indicates a possibility of safely realizing more favorable performance characteristics under normal operating conditions Thus, improved stalling characteristics and improved directional stability characteristics, with one engine inoperative, would undoubtedly result in better operating performance without any sacrifice in safety It is possible also that, even for existing aircraft, better performance safely could be realized It is believed, however, that the actual characteristics listed in tables 8, 9, and 10 constitute a fair indication of existing conditions, and that they should be used in the determination of airport dimensions until it can be established that improved performance is being realized safely in daily operation of these aircraft

(g) Normal Flight Paths - Sea Level

The determination of flight path characteristics for the eight airplanes included in this study, as realized in normal flying operations at sea level airports, is accomplished by the application of the data listed in the foregoing tables 9 and 10 These are presented in the following figure 21 which shows curves of distance against height including the distances from start to unstick to 100 feet height, and from 100 feet height to contact to stop Thus, lines 14, 15, and 16 of table 9 include the data from which the take-off characteristics are plotted, while lines 20, 21, and 22 of table 10 list the values which were employed in the plotting of the landing characteristics

As previously noted, the data involving take-offs include only the distances from start to unstick, to 50 feet height, and to 100 feet height The landing data include only distances to stop from 100 feet height, from 50 feet height, and from contact Curves plotted from such data can show only a general picture of the performance to be expected, and cannot show every variation in flight path Such refinement, however, is not believed to be warranted in view of the many indeterminate variables which affect the day-by-day operating characteristics In plotting these curves, it is assumed that the flare will be completed below 50 feet and that above this height the flight path will be straight

The plotting of the take-off and landing flight paths for any airplane immediately provides a basis which may be used to determine its "full-power" runway length requirements and its obstacle zoning requirements Thus, if the take-off is the more critical condition rather than the landing, a straight line may be drawn which has the same slope as the straight portion of the take-off flight path but which is located at a reasonable distance below the flight path Obstacles, of course, should not project above this line It follows that the obstacle zoning ratio for this airplane is equal to the slope of this line, and that the "full-power" runway length for this airplane may be taken as the distance from the start of the take-off to the point where this line intersects the ground The expression "full-power runway length" means that such lengths do not involve the consideration of a possible loss of power during the take-off Paving considerations are discussed in part (e) of appendix #3

2 Determination of Dimensional Standards for Airports

(a) Sea Level: The solid lines in the foregoing figure 21 show the flight paths for each of the eight airplanes included in this study. Four obstacle boundary lines are presented to indicate the obstacle zoning requirements for each of the four classes of airports and are shown dotted In locating these lines, it is assumed that airports may be grouped in four general classes according to the type of aircraft that safely can be accomodated

Since Airplane A is one of the lowest powered private owner types of aircraft, its performance characteristics as listed in tables 8, 9, and 10, and as shown in figure 21, are used for determining the safe runway length and obstacle zoning requirements of Class I airports On a similar basis, the characteristics of Airplanes G and H are employed to determine the dimensions for Class IV airports Runway lengths and obstacle zoning ratios for Class II and III airports are determined arbitrarily in such a manner as to result in equal increments in the requirements for the four classes of airports

In determining the dimensional requirements for Class I and Class IV airports, one pertinent fact is particularly outstanding:

For both of these classes, obstacle boundary lines which provide reasonable clearances below the flight paths of the critical airplanes, intersect the ground at a point such that the resulting "full-power" runway length requirements are exactly equal to the runway lengths as determined on line 12 of table 8, which in turn were determined through the application of the criterion that runways should be long enough to permit aircraft to roll safely to a stop in the event of an engine failure during the take-off at the point where the wheels are just leaving the ground

This is most important since it indicates that for any class of airport the application of either of the two independent and fundamental methods result in identical runway length requirements

With reference to line 12 of table 8, the runway length for Class I airports, as determined by the requirements for Airplane A, is 1,800 feet The requirements for Airplanes G and H indicate that Class IV airports should have runways 4,800 feet long Equal division of the difference between 4,800 feet and 1,800 feet results in a runway length for Class II airports of 2,800 feet and for Class III airports of 3,800 feet These distances are indicated on figure 21 by the positions of the Roman numerals and are the starting points for the obstacle zoning lines for each class of airport As previously discussed, the slope of each of these lines is determined through consideration of the slopes of the climb and approach paths of Airplanes A to H, inclusive Again, the characteristics of Airplane A are critical for Class I airports and the characteristics of Airplanes G and H determine the requirements for Class IV airports It appears also from figure 21 that, in general, the climbing characteristics are more critical than the approach characteristics The climbing path ratios for each airplane are listed on line 17 of table 9 Thus, Airplane A has a climbing ratio of 15 80 and Airplanes G and H have ratios of 26 70 and 28 00 respectively The dotted line which indicates the limits of obstacle heights for Class I airports has a slope of 13 00 The corresponding line for Class IV airports has a slope of 28 00 The intermediate lines have slopes of 18 00 for Class II airports and 23 00 for Class III airports Where radio instrument landing systems are used, an obstacle zoning ratio of 43 00 is indicated by the flight path

It will be noted that the obstacle zoning lines for Class IV airports will limit obstacle heights so as to provide adequate clearances for Airplanes F, G, and H, that the zoning line for Class III airports will provide for the safe operation of Airplanes C, E, and D, and that Class II airports are adequate for the safe operation of Airplane B The zoning line for Class I airports, if extended, will intersect the climb path of Airplane A at a height of 350 feet and at a distance of 6,300 feet from the start of the take-off In terms of actual flying technique, the above indicates that a pilot taking off in an airplane having the characteristics of Airplane A would be obliged to change his direction within a distance of 1-1/5 miles from the start if obstacle heights were limited by the zoning line for Class I airports This does not seem unreasonable in view of the fact that Class I airports should not be required to provide for "blind" weather conditions Such reasoning has not been applied to airline aircraft, since "blind" take-offs and landings of these airplanes are not uncommon

The obstacle boundary lines for Class I and Class IV airports which intersect the ground at the 1,800 and 4,800 feet runway lengths are at a reasonable distance below the flight paths of the critical airplanes A, G, and H In normal operation these airplanes will clear safely any obstacles, the heights of which are limited by those lines It is believed that the indicated clearance is no more than adequate In other words, runway lengths, as determined on line 12 of table 8, which involve the consideration of possible engine failure during the take-off, are no greater than runway lengths as determined through analysis of the normal flight paths of these airplanes which does not involve any consideration of possible engine failure or loss of power

Sea level runway lengths and obstacle zoning ratio requirements, as shown on figure 21, are summarized in the following table 11

TABLE 11

RUNWAY LENGTHS AND OBSTACLE ZONING RATIOS FOR AIRPORTS GEOGRAPHICALLY LOCATED AT SEA LEVEL

Class of Airport	Runway Length	Obstacle Zoning Ratio
Class I	1,800	13
Class II	2,800	18
Class III	3,800	23
Class IV	4,800	28
For Radio Instrument Landing Systems		43

The determination of adequate widths of cleared areas on either side of the runways has been discussed in detail on page 12 of this report As concluded in that discussion, there are very little data available from which an adequate determination of this important dimension can be realized, except that on large airports a minimum distance of 600 feet should be provided between the center lines of any two parallel runways, from the center line of any runway to the boundary of the airport, and from the center line of any runway to any obstacle that might aggravate the damage or injuries sustained in an accident resulting from an uncontrolled swerving from the take-off or landing path It also would seem reasonable that this dimension should be reduced in the case of smaller airports In a purely arbitrary manner, the following dimensions are suggested.

For Class I Airports	-	150 feet	For Class III Airports	-	450 feet
For Class II Airports	-	300 feet	For Class IV Airports	-	600 feet

The maneuvers necessitating such dimensions are unaffected by altitude

The use of any class of airport by aircraft which normally would operate out of a higher class airport would seem to be necessary under emergency conditions The flight paths shown in figure 21 involve both normal operating technique and unfavorable meteorological conditions

Since, in an emergency, any of the airplanes included in this study can be operated so as to realize performance characteristics that are better than are indicated by the curves shown in figure 21, it will be seen that a Class II airplane (Airplane B) could get in or out of a Class I airport, that Class III airplanes (Airplanes C, E, and D) could, in an emergency, use a Class II airport, and finally that Class IV airplanes could use a Class III airport

(b) Effect of Altitude Runway lengths and obstacle zoning ratios which are adequate for the safe operation of aircraft at airports geographically located at sea level are listed in the foregoing Table 11 for Class I, II, III, and IV airports These have been determined from observed data The effect of altitude on these dimensions is determined through the application of aerodynamic theory in the following manner

(1) Runway Lengths

The effect of altitude on runway lengths will be considered first It will be noted that runway lengths are determined as the sum of two distances: first, the distance (U) required for the airplane to attain unstick speed (V_U), and second, the distance (S) required for the airplane to roll to a stop after having attained this speed Considering each of these distances separately then,

$$U_H = U_o \times \frac{1}{K_{DP}} \qquad (1)$$

Where U_H = Unstick Distance at Altitude (H)

U_O = Unstick Distance at Sea Level

K_{DP} is determined from Figure 2

Also since the ground roll varies as the square of the contact speed, the following expression for distance from (V_U) to stop may be written:

$$S_H = S_o \times \left(\frac{V_{UH}}{V_{Uo}}\right)^2 \qquad (2)$$

Where S_H = Stopping Distance at Altitude (H)

S_o = Stopping Distance at Sea Level

V_{UH} = Unstick Speed at Altitude (H)

V_{UO} = Unstick Speed at Sea Level

Note As indicated by the criterion for runway lengths, the unstick and contact speeds in this case are identical

$$\text{But } V_{UH} = \frac{V_{Uo}}{\sqrt{\frac{\rho}{\rho_o}}} \qquad (3)$$

Where $\sqrt{\frac{\rho}{\rho_o}}$ is obtained from Figure 1

Therefore $S_H = \dfrac{S_o}{\rho/\rho_o}$ (4)

As noted above, the runway length = $R_H = U_H + S_H$ (5)

Substituting from equations (1) and (4) into equation (5)

$$R_H = \frac{U_o}{K_{DP}} + \frac{S_o}{\rho/\rho_o} \,. \qquad (6)$$

From inspection of table 8 (lines 6, 11, and 12) it will be noted that, as an average for all eight airplanes, the unstick distance is approximately 4 of the runway length, and that the stopping distance is 6 of the runway length,

$$\text{or,} \quad U_o = 4\,R_o \quad \text{and} \quad S_o = .6\,R_o$$

Substituting into equation (6),

$$R_H = \frac{4R_o}{K_{DP}} + \frac{6R_o}{\rho/\rho_o} \,. \qquad (7)$$

$$\text{or,} \quad R_H = R_o \left(\frac{.4}{K_{DP}} + \frac{6}{\rho/\rho_o} \right) \qquad (8)$$

For convenience, the expression $\left(\dfrac{4}{K_{DP}} + \dfrac{6}{\rho/\rho_o} \right)$

may be designated as F_a (9)

Accordingly, $R_H = R_o\, F_a$ (10)

(2) Obstacle Zoning Ratios

The effect of altitude on obstacle zoning ratios is determined as follows:

$$\text{Obstacle Zoning Ratio} = \frac{\text{Distance}}{\text{Height}}$$

$$\text{or,} \quad Z = \frac{X}{Y} \qquad (11)$$

$$\text{now,} \quad X_H = \frac{X_o}{K_{DP}} \qquad (12)$$

$$\text{and,} \quad Y_H = Y_o \qquad (13)$$

where Z = Obstacle zoning ratio

X_H = Distance at altitude (H)

X_o = Distance at sea level

Y_H = Corresponding height at altitude (H)

Y_o = Corresponding height at sea level

$$\text{now,} \quad Z_H = \frac{X_H}{Y_H} \qquad (14)$$

Substituting equations (12) and (13) into equation (14):

$$Z_H = \frac{X_o}{Y_o} \times \frac{1}{K_{DP}}$$

$$\text{But,} \quad \frac{X_o}{Y_o} = Z_o$$

Therefore, $Z_H = \frac{Z_o}{K_{DP}}$ . . . . (15)

Equations (9), (10), and (15) may be applied to determine the variation in runway lengths and obstacle zoning ratios due to changes in geographical altitude. This is accomplished in tables 12 and 13 as follows:

Table 12 includes computations for determining F_a (Corrected) and $1/K_{DP}$ (Corrected) at geographical altitudes from sea level to 10,000 feet Two values of each of these multiplying factors are listed for each altitude The first involves aircraft equipped with unsupercharged engines, while the second involves supercharging It again is assumed that at each geographical altitude the temperature may be 100°F , and the barometric pressure may be such that the pressure altitude is 500 feet above the geographical altitude Complete explanations are included on the same sheet with table 12.

The multiplying factors listed in columns 14 to 17, inclusive, of table 12 are applied in table 13 to sea level values of runway lengths and obstacle zoning ratios of Class I, II, III, and IV airports to determine the effect of changes in geographical altitude of these dimensions. Explanations also are included on the same sheet with table 13

The runway lengths listed in columns 6, 7, 8, and 9 of table 13 are plotted on figure 22 The obstacle zoning ratio data listed in columns 10, 11, 12, and 13, are plotted on figure 23 In examining figures 22 and 23, it will be noted that the curves involving the dimensions of Class IV airports are not continued above the altitudes where they intersect the curves for Class III airports. Above these altitudes, the dimensions of both Class III and Class IV airports are determined from the curves for Class III airports This is because unsupercharged airplanes, having performance characteristics which permit them to operate out of Class III airports, may be expected to operate out of Class IV airports, regardless of altitude It is necessary, therefore, to provide dimensions adequate for the safe operation of these airplanes at both Class III and Class IV airports With particular reference to figure 23, it will be noted that the obstacle zoning ratios which safely will permit instrument landings are represented by a vertical line, since instrument landing approach path ratios are unaffected by altitude, as has been discussed previously in this report Obstacle zoning ratios are determined entirely from the climb path characteristics, except in the case of instrument landings, as may be seen from inspection of figure 20

3. Correlation of the Performance Characteristics of any Airplane with Any Airport

An analysis of the data previously discussed indicates that there are two possible methods for correlating the performance characteristics of any airplane with any airport These are.

Method (a) Through direct analysis of the observed data involving normal operating characteristics

Method (b) Through application of spread coefficients to the ultimate performance characteristics to obtain normal operating characteristics The ultimate characteristics may be determined by a standard method of computation or obtained from carefully controlled flight tests

The above methods are discussed further and are illustrated as follows:

Method (a) The correlation of the performance characteristics of any airplane with the size of any airport preferably should be attained entirely through the use of factual data Thus, observed performance data involving take-offs and landings at various altitudes should involve the "effective" altitude of the airport in question, and the meteorological data obtained at that airport should be adequate to establish this "effective" altitude, as previously discussed

Had it been possible to complete the original program for this project, the effect of altitude on runway lengths and obstacle zoning requirements for the eight airplanes included in this study would have been determined completely from factual data To illustrate the application of Method (a), however, such data as are available are used to obtain correlations of observed performance characteristics with airport dimensions for three actual airports where meteorological data have been obtained for a period of two seasonal cycles

Table 41 (appendix #4) includes meteorological data involving the airports at Burbank, California, at Cheyenne, Wyoming, and at Salt Lake City, Utah These are plotted on figure 20. The horizontal lines indicate the maximum density altitudes and the corresponding maximum pressure altitudes which must be considered in correlating performance characteristics of aircraft with the dimensions of these airports.

Thus, through the use of these values for (H_D) and (H_p) together with the nomogram on

MULTIPLYING FACTORS

FOR DETERMINING THE EFFECT OF GEOGRAPHICAL ALTITUDE ON RUNWAY LENGTH AND OBSTACLE ZONING RATIOS

TABLE 12

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
GEOG ALTITUDE H	PRESS ALTITUDE H_P	DENSITY ALTITUDE H_D	ρ/ρ_o	$\frac{6}{\rho/\rho_o}$	K_{DP}		$4/K_{DP}$		F_a		$1/K_{DP}$		F_a (Corr.)		$1/K_{DP}$ (Corr.)	
					Unsup	Sup	Unsup	Sup	Unsup	Sup	Unsup	Sup	Unsup	Sup	Unsup	Sup
0	500	3200	0.910	0.659	0.866	0.893	0.401	0.448	[illegible]	1.107	1.154	1.120	1.000	1.000	1.000	1.000
1000	1500	4400	0.877	0.684	0.785	0.859	0.469	[illegible]	1.193	1.150	1.274	1.164	1.064	1.039	1.104	1.039
2000	2500	5600	0.846	0.710	0.710	0.823	0.564	0.486	1.274	1.196	1.408	1.215	1.136	1.080	1.220	1.085
3000	3500	6800	0.816	0.735	0.641	0.791	0.624	0.506	1.359	1.241	1.560	1.265	1.212	1.121	1.352	1.129
4000	4500	8100	0.784	0.765	0.578	0.760	0.692	0.526	1.457	1.291	1.730	1.316	1.300	1.166	1.499	1.175
5000	5500	9250	0.756	0.794	0.522	0.729	0.766	0.548	1.560	1.342	1.915	1.371	1.392	1.212	1.659	1.224
6000	6500	10450	0.728	0.824	0.472	0.700	0.847	0.571	1.671	1.395	2.119	1.429	1.491	1.260	1.836	1.276
7000	7500	11650	0.701	0.856	0.423	0.671	0.946	0.596	1.802	1.452	2.364	1.490	1.607	1.312	2.049	1.330
8000	8500	12850	0.674	0.890	0.380	0.645	[illegible]	0.620	1.943	1.510	2.631	1.550	1.733	1.364	2.280	1.384
9000	9500	14000	0.650	0.923	0.340	0.618	1.176	0.647	2.099	1.570	2.941	1.618	1.872	1.418	2.549	1.445
10000	10500	15250	0.624	0.962	0.303	0.593	1.320	0.675	2.282	1.637	3.300	1.686	2.036	1.479	2.860	1.505

NOTE

Column 2 It is assumed that low barometric pressure can exist at an airport such that the pressure altitude is 500 feet higher than the geographical altitude

Column 3 Density altitude is obtained through use of the nomogram (Fig 1) using values of (H_P) listed in Column 2 and assuming that a temperature of 100° F can exist at an airport

Column 4 The density ratio is obtained from the values of (H_D) listed in Column 3 through use of tables of standard atmospheric characteristics or from Fig 1

Column 6 & 7 K_{DP} is obtained through use of the nomogram (Fig), involving both unsupercharged and supercharged engines

Column 10 & 11, $F_a = 4/K_{DP} + \frac{6}{\rho/\rho_o}$

Column 14, 15, 16, & 17 The values listed in these columns are obtained from the corresponding value listed in Columns 10 to 13, inclusive, by dividing each of those values by the value listed for zero geographical altitude

Runway length at altitude = (Sea level runway length) x F_a

Obstacle zoning ratio at altitude = (Sea level obstacle zoning ratio) x $1/K_{DP}$

AIRPORT RUNWAY LENGTHS AND OBSTACLE ZONING RATIOS VS GEOGRAPHICAL ALTITUDE

TABLE 13

1	2	3	4	5	6	7	8	9	10	11	12	13
GEOG ALTITUDE	F_a (Corr)		$1/K_{DP}$ (Corr)		Runway Lengths (R)				Obstacle Zoning Ratios (Z)			
	Unsup	Sup	Unsup	Sup	Class I Unsup	Class II Unsup	Class III Unsup	Class IV Sup	Class I Unsup	Class II Unsup	Class III Unsup	Class IV Sup
0	1 000	1 000	1 000	1 000	1800	2800	3800	4800	13 00	18 00	23 00	28 00
1000	1 064	1 039	1 104	1 039	1915	2979	4043	4987	14 35	19 87	25 39	29 09
2000	1 136	1 080	1 220	1 085	2045	3181	4317	5184	15 86	21 96	28 06	30 38
3000	1 212	1 121	1 352	1 129	2182	3394	4606	5381	17 58	24 34	31 10	31 61
4000	1 300	1 166	1 499	1 175	2340	3640	4940	5597	19 49	27 00	34 48	32 90 *
5000	1 392	1 212	1 659	1 224	2506	3898	5290	5818	21 57	29 87	38 16	34 27 *
6000	1 491	1 260	1 836	1 276	2684	4175	5666	6048	23 87	33 05	42 23	35 73 *
7000	1 607	1 312	2 049	1 330	2893	4500	6107	6298	26 64	36 88	47 13	37 24
8000	1 733	1 364	2 280	1 384	3119	4852	6585	6547 *	29 64	41 04	52 44	38 75 *
9000	1 872	1 418	2 549	1 445	3370	5242	7114	6806 *	33 14	45 88	58 63	40 46 *
10000	2 036	1 479	2 860	1 505	3665	5701	7737	7099 *	37 18	51 48	65 78	42 14 *

NOTE

Columns 2, 3, 4, and 5 are duplicates of Columns 14, 15, 16, and 17 as listed in Table 12

The sea level values listed in Columns 6, 7, 8, and 9 were obtained from Table 11

The sea level values listed in Columns 10, 11, 12, and 13 were obtained from Table 11

The remaining values listed in Columns 6 to 13, inclusive, were obtained by multiplying the sea level values by the multiplying factors listed in Columns 2, 3, 4, and 5

Runway length at altitude = (Sea level runway length) x F_a

Obstacle Zoning Ratio at altitude = (Sea level obstacle zoning Ratio) x $1/K_{DP}$

Since approach path characteristics are not affected by altitude, only obstacle zoning ratios which are governed by the climb path characteristics need be compensated for change in altitude as listed above

* Less than for Class III (See Page 30)

figure 2 and the curves shown on figures 3 to 19 inclusive, the performance characteristics of Airplanes B, D, E, F, and H are correlated with the dimensions of the airports at Burbank, California, Salt Lake City, Utah, and Cheyenne, Wyoming, insofar as the observed data permit This is accomplished on table 14

Method (b) The necessity for developing Method (b) arises from the fact that Method (a) cannot be employed until a large number of performance data involving day-by-day operations at various airports and at various altitudes have been obtained This in turn limits the application of Method (a) to aircraft that have passed through the development stage, and which are in regular operation To permit the determination of the airport size requirements of projected or newly developed aircraft, Method (b) is discussed and illustrated as follows:

(1) Runway Lengths

Runway Length (R) $= (X_1 C_1 + D_2) F_a$

X_1 = The shortest distance required to travel from start to unstick under standard sea level conditions This may be determined through computation as illustrated on line 26, table 7, for Method (b), or may be determined by actual flight tests

C_1 = Spread coefficient applied to (X_1)

This may be determined as shown on line 10, table 8, and as discussed on page 18

D_2 = Distance from unstick to stop as realized in normal day-by-day operation at sea level airports on hot summer days This may be determined from figure 19, when the normal unstick speed (V_{un}) has been determined

$V_{un} = V_u C_2$

V_u = Minimum unstick speed under standard sea level conditions This may be determined through computation as illustrated on line 21, table 7, or may be determined by actual flight test

C_2 = Spread coefficient applied to (V_u) This may be determined as shown on line 4, table 8, and as discussed on page 18

F_a = Altitude Factor This may be determined from columns 14 and 15, table 12, when the geographical altitude of the airport is known

(2) Obstacle Zoning Ratios

Obstacle Zoning Ratio (Z) $= \left(\frac{\Delta X \times C_3}{50}\right) \frac{1}{K_{DP}}$

ΔX = Shortest distance required to climb from 50 feet to 100 feet heights under standard sea level conditions This may be determined as illustrated on line 32, table 7, or may be determined by actual flight tests

C_3 = Spread coefficient applied to (ΔX)

This may be determined as shown on line 12, table 9, and as discussed on page 18

$1/K_{DP}$ = Altitude Factor This may be determined from columns 16 and 17, table 12, when the geographical altitude of the airport is known

The application of Method (b) to the determination of airport size requirements from computed performance characteristics of Airplane A when operated at Salt Lake City, Utah, is presented as follows:

Runway Length

X_1	(Airplane A) (Unsupercharged)	473 ft	(line 26, table 7)
C_1	"	1 50	(line 10, table 8)
V_u	"	41 0 mph	(line 21, table 7)

CORRELATION OF NORMAL AIRCRAFT PERFORMANCE CHARACTERISTICS WITH SIZE
OF EXISTING AIRPORTS LOCATED AT VARIOUS ALTITUDES, AS DETERMINED ENTIRELY FROM OBSERVED DATA

TABLE 14

LINE NO	PERFORMANCE CHARACTERISTIC		REQUIRED RUNWAY LENGTH					CLIMB PATH				
			PRIVATE	AIRLINE				PRIVATE	AIRLINE			
	AIRPLANE		B	D	E	F	H	B	D	E	F	H
	Burbank, California - Geographical Altitude - 695 Feet											
1	Density Altitude (From Curves, Fig 20)	H_D	2900	2900	2900	2900	2900	2900	2900	2900	2900	2900
2	Pressure Altitude (From Curves, Fig 20)	H_p	900	900	900	900	900	900	900	900	900	900
3	Altitude Coefficient (From Nomogram, Fig 2)	K_{DP}	0.857	0.904	0.904	0.904	0.904	0.857	0.904	0.904	0.904	0.904
4	Unstick Speed (Observed) (Figs 3, 6, 9, 12, 14)	V_{UN}	[illegible]	[illegible]	84.7	[illegible]	98.7					
5	Distance from (V_{UN}) to Stop (From Line 4 & Fig 19)	S	1690	2190*	[illegible]	2400	[illegible]					
6	Normal Unstick Distance (Observed) (Figs 5, 8, 11, 13, 17)	U_N	1160	1450	1560	2040	2140					
7	Required Runway Length (Line 5 + Line 6)	R	2850	3640	3720	4440	4730					
8	Distance from 50' to 100' (Observed) (Figs 5, 8, 11, 13, 17)							[illegible]	1050	1180	1290	1400
9	Climb Path Ratio (Line 8/50) = Obstacle Zoning Ratio							16.4	21.0	23.6	25.8	28.0
	Salt Lake City, Utah - Geographical Altitude - 4330 Feet											
10	Density Altitude (From Curves, Fig 20)	H_D	7300	7300	7300	7300	7300	7300	7300	7300	7300	7300
11	Pressure Altitude (From Curves, Fig 20)	H_p	4400	4400	4400	4400	4400	4400	4400	4400	4400	4400
12	Altitude Coefficient (From Nomogram, Fig 2)	K_{DP}	0.597	0.778	0.778	0.778	0.778	0.597	0.778	0.778	0.778	0.778
13	Unstick Speed (Observed) (Figs 3, 6, 9, 12, 14)	V_{UN}			93.2		107.3					
14	Distance from (V_{UN}) to Stop (From Line 13 & Fig 19)	S			2420		[illegible]					
15	Normal Unstick Distance (Observed) (Figs 5, 8, 11, 13, 17)	U_N			2030		[illegible]					
16	Required Runway Length (Line 14 + Line 15)	R			4450		5710					
17	Distance from 50' to 100' (Observed) (Figs 5, 8, 11, 13, 17)							1100		1240		1650
18	Climb Path Ratio (Line 17/50) = Obstacle Zoning Ratio							22.0		24.8		33.0
	Cheyenne, Wyoming - Geographical Altitude - 6145 Feet											
19	Density Altitude (From Curves, Fig 20)	H_D	9200	9200	9200	9200	9200	9200	9200	9200	9200	9200
20	Pressure Altitude (From Curves, Fig 20)	H_p	6200	6200	6200	6200	6200	6200	6200	6200	6200	6200
21	Altitude Coefficient (From Nomogram, Fig 2)	K_{DP}	0.502	0.729	0.729	0.729	0.729	0.502	0.729	0.729	0.729	0.729
22	Unstick Speed (Observed) (Figs 3, 6, 9, 12, 14)	V_{UN}					110.3					
23	Distance from (V_{UN}) to Stop (From Line 22 & Fig 19)	S					2990					
24	Normal Unstick Distance (Observed) (Figs 5, 8, 11, 13, 17)	U_N					2950					
25	Required Runway Length (Line 23 + Line 24)	R					5940					
26	Distance from 50' to 100' (Observed) (Figs 5, 8, 11, 13, 17)											1760
27	Climb Path Ratio (Line 26/50) = Obstacle Zoning Ratio											35.2

*This airplane is equipped with Fowler Flaps Use upper curve in Fig 19

NOTE Landing characteristics are not included in this table, since they are not critical, either as regards runway lengths, or obstacle zoning ratios This will be seen from Fig 21 Moreover, altitude has no effect on approach path ratios

C_2 (Airplane A) (Unsupercharged) 1 15 (line 4, table 8)

Geographical altitude (Salt Lake City) 4,220 ft (table (41)

F_a 1 320 (col 14, table 12)

$V_{un} = V_u C_2$ 47 2 mph

D_2 (Normal airplane) 1,080 ft (fig 19)

X_1C_1 710 ft

Runway Length (R) $= (X_1C_1 + D_2) F_a$ 2,360 ft

Obstacle Zoning Ratio

ΔX (Airplane A) (Unsupercharged) 660 ft (line 32, table 7)

C_3 " 1 20 (line 12, table 9)

Geographical altitude (Salt Lake City) 4,220 ft

$1/K_{DP}$ 1 534 (col 16, table 12)

Obstacle Zoning Ratio (Z) $= \left(\frac{\Delta X \quad C_3}{50}\right) \frac{1}{K_{DP}} = 24$

Note The method outlined above may be applied to the ultimate performance characteristics as determined from controlled flight tests

4 Comparison of Airport Dimension Requirements as Obtained by Method (a) with those Indicated on figures 22 and 23

On page 18 of this report the assumption is made that, at any airport during the summer months, flying operations will be carried on during the heat of the day when the temperature is 100°F and when the sub-normal barometric pressures indicate a pressure altitude 500 feet above the elevation of the airport It then is stated that the final effect of the above assumption, as reflected by the runway length and obstacle zoning requirements versus elevation (figs 22 and 23) checks very closely with the dimensional requirements obtained through the direct use of the observed temperature and pressure data shown on figure 20 This now is substantiated in the following table 15 which compares airport dimension requirements for Airplane H as obtained by Method (a) with Class IV airport requirements indicated on figures 22 and 23 This comparison appears justified because of the fact that the airport requirements of Airplane H at sea level closely approximate the requirements for a Class IV airport at sea level.

Table 15

AIRPORT DIMENSION REQUIREMENTS - AIRPLANE (H)				
Line No	Airport	Burbank	Salt Lake City	Cheyenne
1	Geographical Altitude	695	4,220	6,145
2	Runway Length (Observed Data, table 14)	4,730	5,710	5,940
3	Runway Length (fig 22)	4,930	5,680	6,100
4	Percentage Difference	4 3%	-0 6%	2 9%
5	Obstacle Zoning Ratio (Observed Data, table 14)	28 0	33 0	35 2
6	Obstacle Zoning Ratio (fig 23)	28 8	33 2	36 0
7	Percentage Difference	2 9%	0 6%	2 3%

Table 15 indicates that the effect of geographical altitude on airport size as determined through direct application of observed data, Method (a) is in reasonable agreement with data obtained through the application of aerodynamic theory, (figs 22 and 23), up to 6,145 feet elevation This result indicates that the assumption involving unfavorable meteorological conditions as discussed on page 17 is justified

It is important to state that, if a plotting of the data listed on lines 2 and 5 of the above table is superimposed on figures 22 and 23, it will be noted that the variation of airport dimensions with elevation as determined by Method (a) for Airplane H does not follow the theoretical trend which is reflected in the curves for the four classes of airports This variation again results from the application of the fundamental principle involved in interpreting the observed data

CONCLUSIONS

As stated in the beginning, the purpose of this study is to establish a fundamental basis for the determination of airport dimensions that will accommodate safely the operation of aircraft It is believed that this has been accomplished Thus, certain pertinent factual data have been obtained These include:

1 Take-off and landing characteristics of several types of aircraft as realized at various altitudes in normal day-by-day operation
2 A large volume of accident data involving both private owner and airline type aircraft
3 A large number of meteorological observations involving these airports at widely different altitudes and covering two seasonal cycles

These data in themselves are a record of facts They involve no assumptions and no personal opinions The performance data were obtained photographically and were corrected to zero wind and to specification gross weight only Thus, as presented, they involve a minimum of theoretical manipulations The accident data are a record of what actually happened, and the meteorological data are a listing of the original observations

The interpretation of these data to obtain airport dimension requirements, however, is subject to considerable controversy because of the multiplicity of important, and in many cases, indeterminate elements which can influence the final results In addition to the many variables that affect the performance characteristics, there are many economic and practical considerations which are difficult to evaluate The degree of safety that can be obtained practically is a highly contentious subject

In order that this study may be of maximum aid in the final determination of reasonable requirements, an interpretation of the observed data has been made This has resulted in the attainment of two major objectives which are

(1) Two methods have been established for correlating the performance characteristics of any airplane with the dimensions of any airport at any altitude
(2) Dimensional standards have been suggested for four classes of airports, involving any elevation up to 10,000 feet The grouping of such standards into classifications is based upon the types of airplanes that can be accommodated safely These are

Class I	Lowest powered private owner type
Class II	Medium powered private owner type
Class III	Higher powered private owner type and smaller airline type
Class IV	The largest of airline aircraft

The determination of numerical values involved in the attainment of the above objectives was made through the application of three general requirements or criteria, which are as follows

(a) Runways should be long enough to permit aircraft to roll safely to a stop in the event of an engine failure during the take-off at the point where the wheels are just leaving the ground
(b) The cleared areas on either side of the runways should be wide enough to provide reasonably smooth surfaces on which the aircraft can come to rest should some unforeseen contingency cause them to swerve from their original take-off or landing directions
(c) Obstacles should not project up into the flight paths

It would seem that criteria (b) and (c) above are fundamental The acceptability of criterion (a) is somewhat controversial, in spite of the fact that it has resulted from a careful analysis of a large amount of accident data As discussed in detail on page 25 and as shown in figure 21, its application results in runway lengths that are identical with the lengths obtained through the practical application of criterion (c), which involves no consideration of possible engine failure during the take-off This is significant in that such agreement should add to the acceptability of the final results

Criteria (a), (b) and (c) have been applied in the interpretation of the factual data to obtain numerical values involved in the attainment of the two major objectives of this study The results are:

(a) Recommended runway lengths and obstacle zoning requirements as obtained through the correlation of observed performance data with the meteorological conditions actually existent at several airports are listed in table 14

(b) Recommended dimensional standards for airports, Classes I to IV inclusive, and for elevations up to 10,000 feet, are presented in figures 22 and 23 Figure 22 shows curves of runway length versus altitude Figure 23 shows curves of obstacle zoning requirements against altitude

(c) Data from which the widths of landing strip areas may be determined are far from adequate In a purely arbitrary manner, however, it is suggested that,

(1) between the center lines of any two parallel landing strips,
(2) from the center line of any landing strip to the boundary of the airport,
(3) from the center line of any landing strip to any obstruction or to any area which may be occupied by aircraft, automobiles, etc ,

the following minimum distances well might be provided

Class I	150 ft	Class II	300 ft
Class III	450 ft	Class IV	600 ft

It is believed that no increases in the requirements suggested in this report will be necessary for many years to come This statement is based upon the indicated advance in designing technique involving future aircraft This advance is being reflected in improved stalling characteristics, and improved climb and directional control characteristics of multiengine aircraft with one engine inoperative, which in turn promises to result in a reduction in spread coefficients In other words, it appears that future airplanes may be operated safely so as to realize performance characteristics that are closer to the ultimate than are realized by currently existing airplanes These factors should tend to compensate for any increase in landing speeds.

As previously explained, it has been impossible to determine airport dimension requirements entirely from observed data The inclusion of a certain amount of computed performance data has been unavoidable Such data have been reduced to a minimum, however, and it is believed that the numerical values obtained will be supported, if and when more complete factual data have been obtained The following table 16 lists in detail the performance data that still are needed, so that the airport dimension requirements of all eight airplanes included in this study may be determined entirely from observed data

Table 16

ADDITIONAL PHOTOGRAPHIC RECORDS DESIRABLE FOR COMPLETE DETERMINATION OF PERFORMANCE VERSUS ALTITUDE FROM OBSERVED DATA AIRPLANES A TO H, INCLUSIVE

Geographical Altitude	S L -1000		3000-4000		6000-7000		
Type of Record*	T O	L	T O	L	T O	L	Totals
Airplane A	30	30	30	30	30	30	180
Airplane B					30	30	60
Airplane C	30	30	30	30	30	30	180
Airplane D	30	30	30	30	30	30	180
Airplane E				30	30	30	90
Airplane F		30	30	30	30	30	150
Airplane G	30	30	30	30	30	30	180
Airplane H (Blind)					30		30
Totals	120	150	150	180	240	210	1050

* All records should involve actual day-in and day-out operations rather than controlled flight tests, except that a number of the landing ground rolls for each model should involve the use of maximum braking

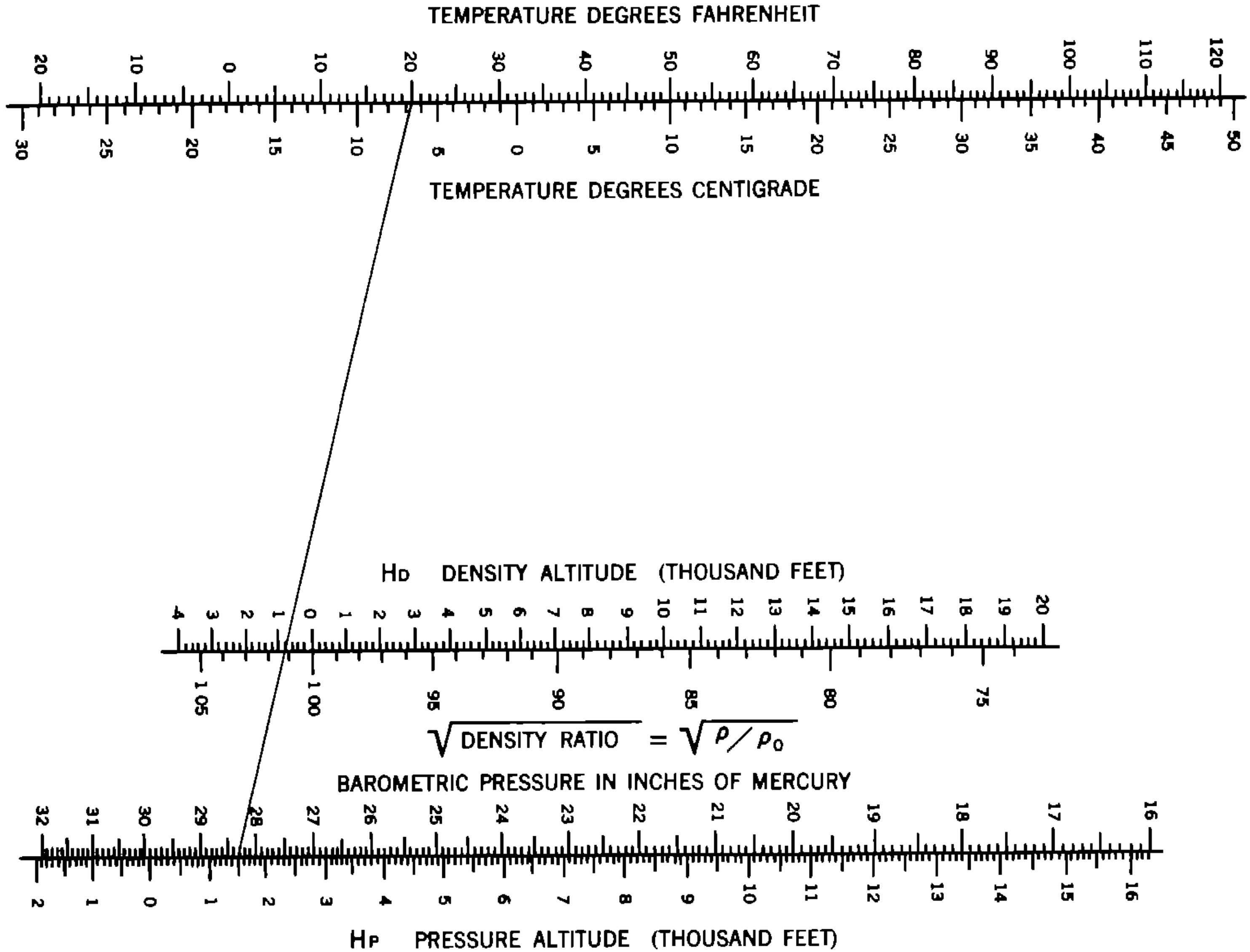


Figure 1 Nomogram for Determining Standard Atmospheric Conditions

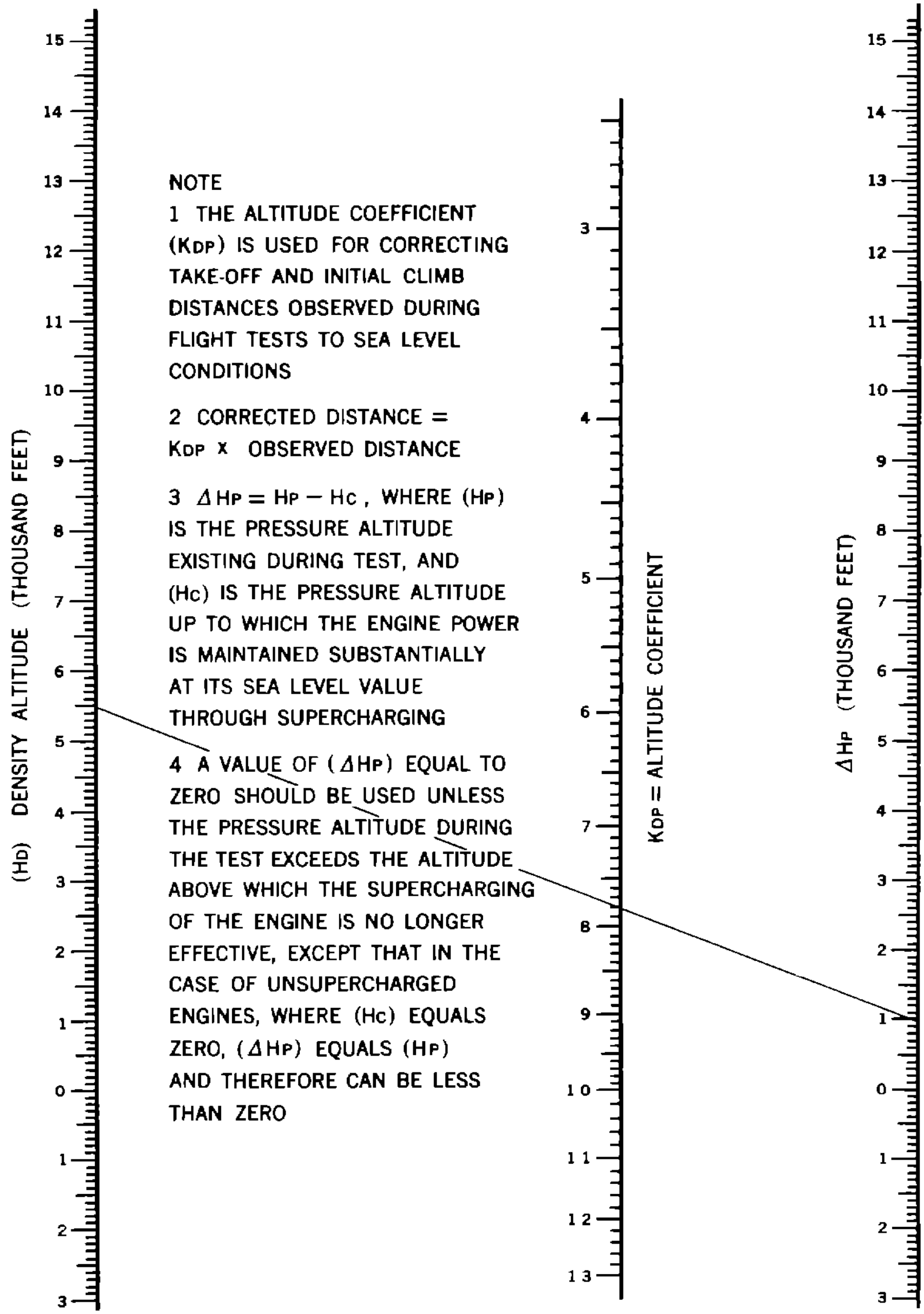


Figure 2 Nomogram for Determining Altitude Coefficient

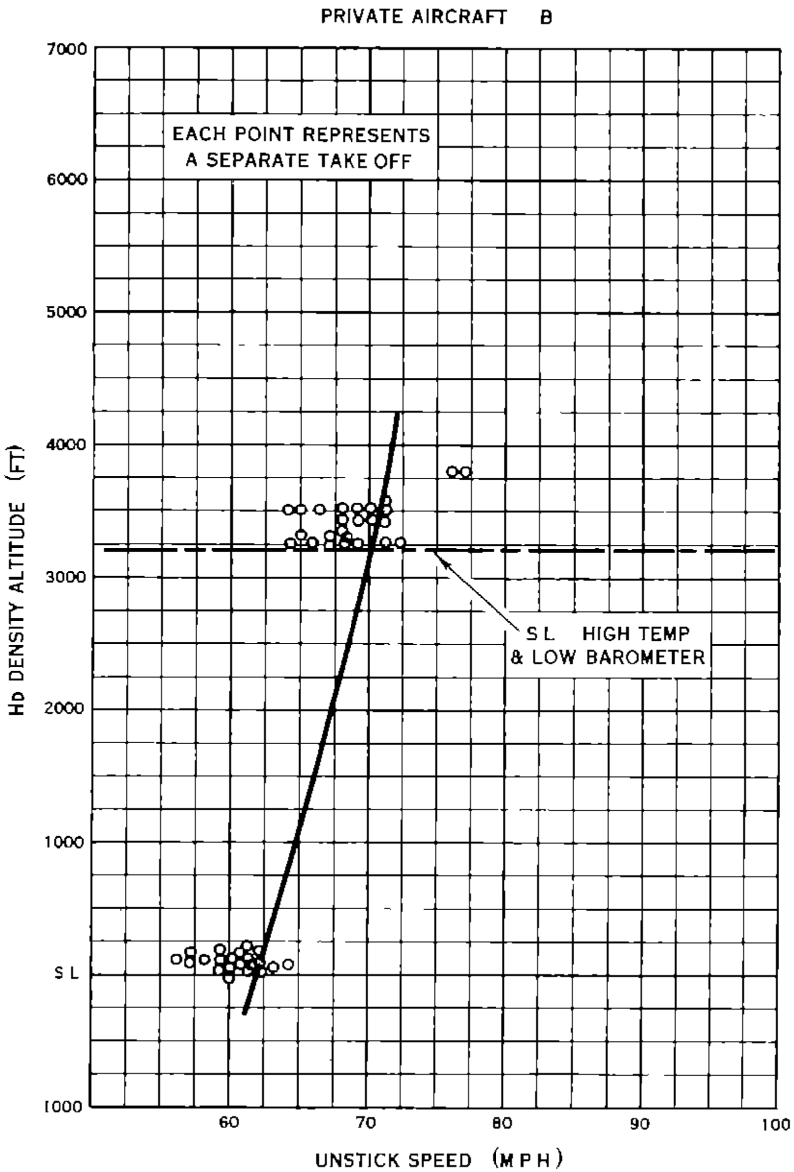


Figure 3 Unstick Speed Characteristics

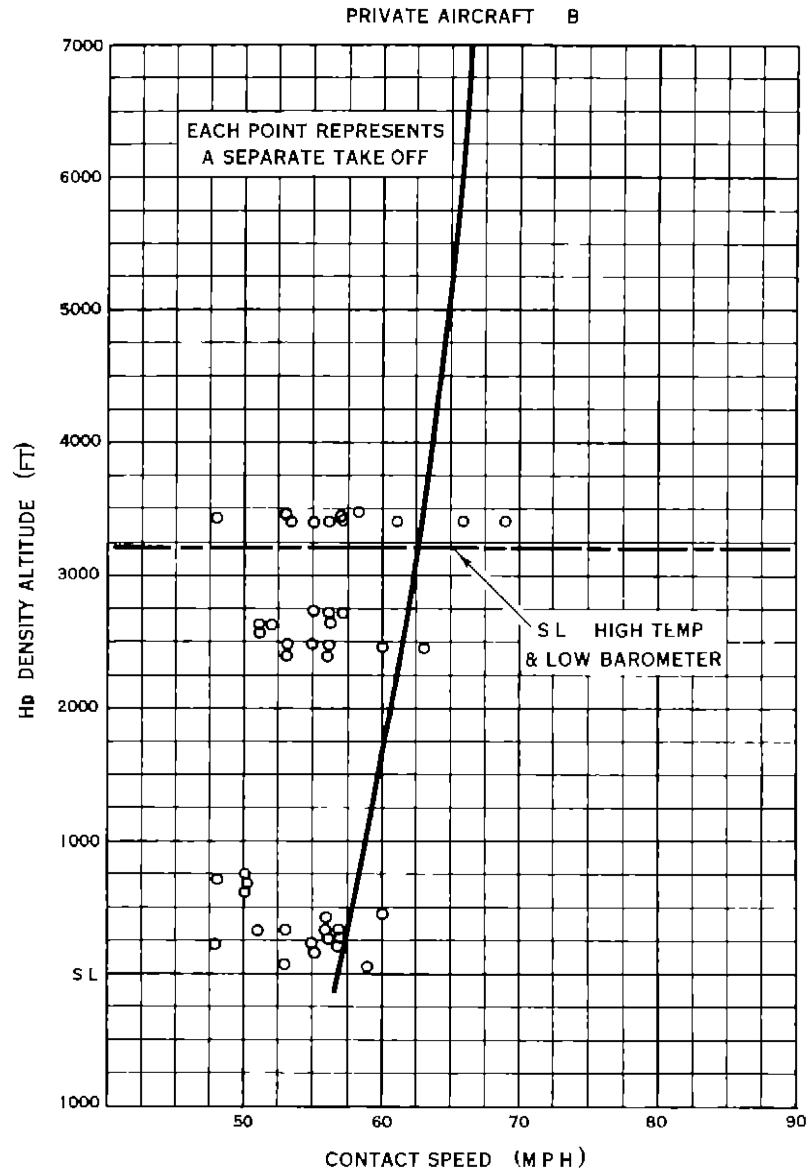


Figure 4 Contact Speed Characteristics

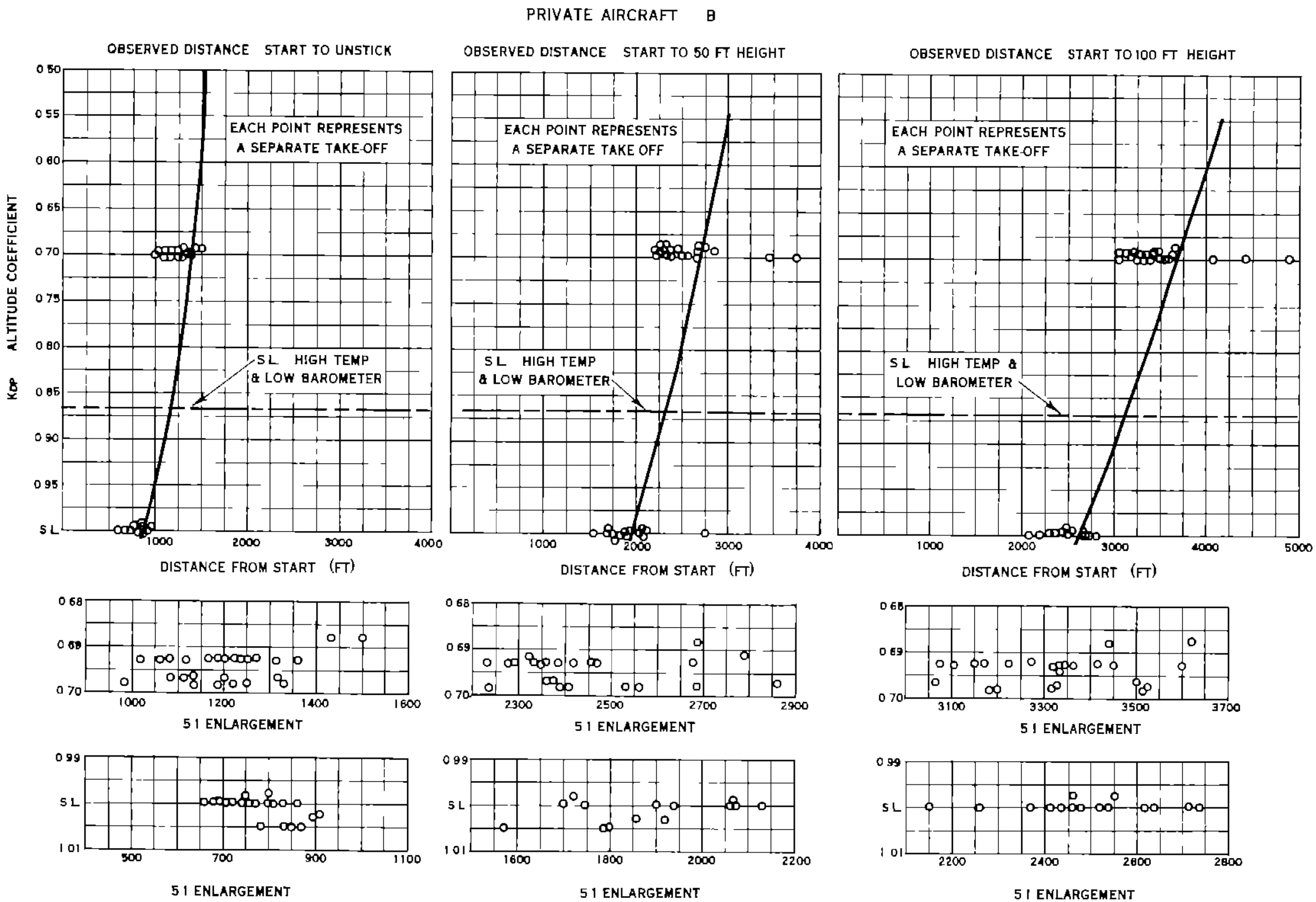


Figure 5 Take-Off Characteristics

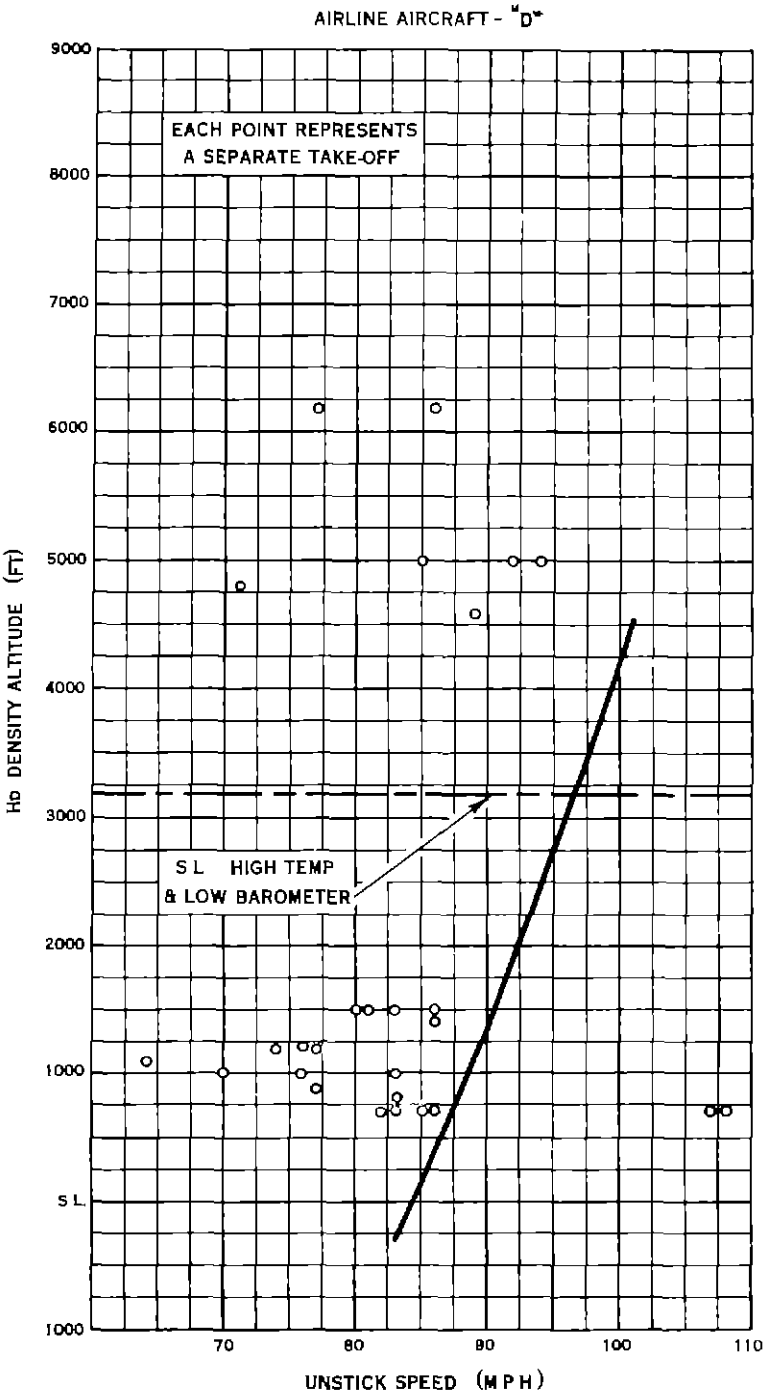


Figure 6 Unstick Speed Characteristics

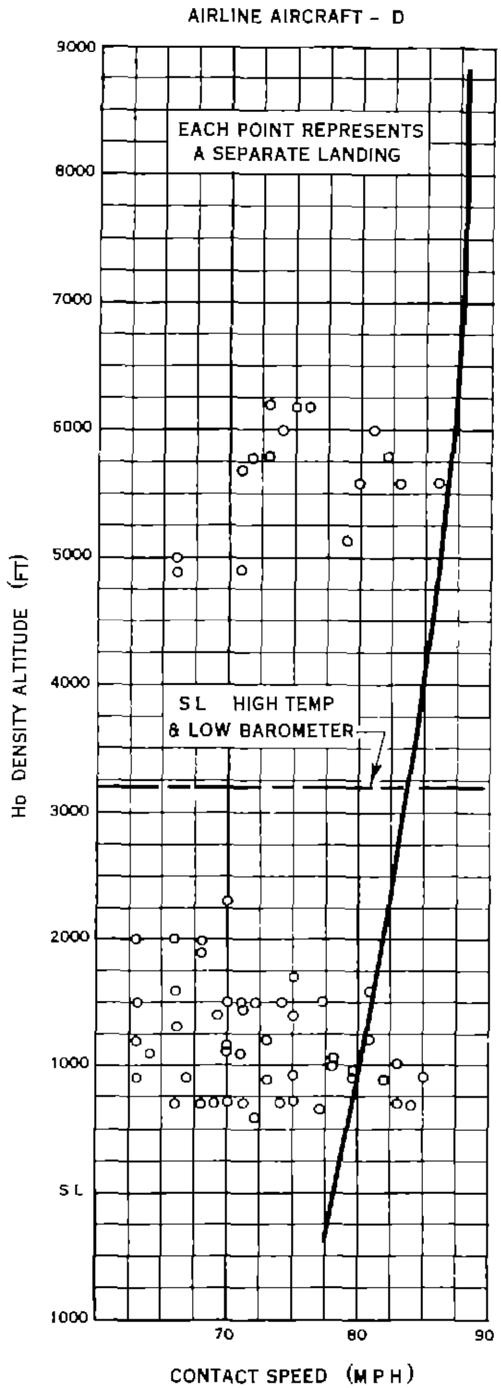


Figure 7 Contact Speed Characteristics

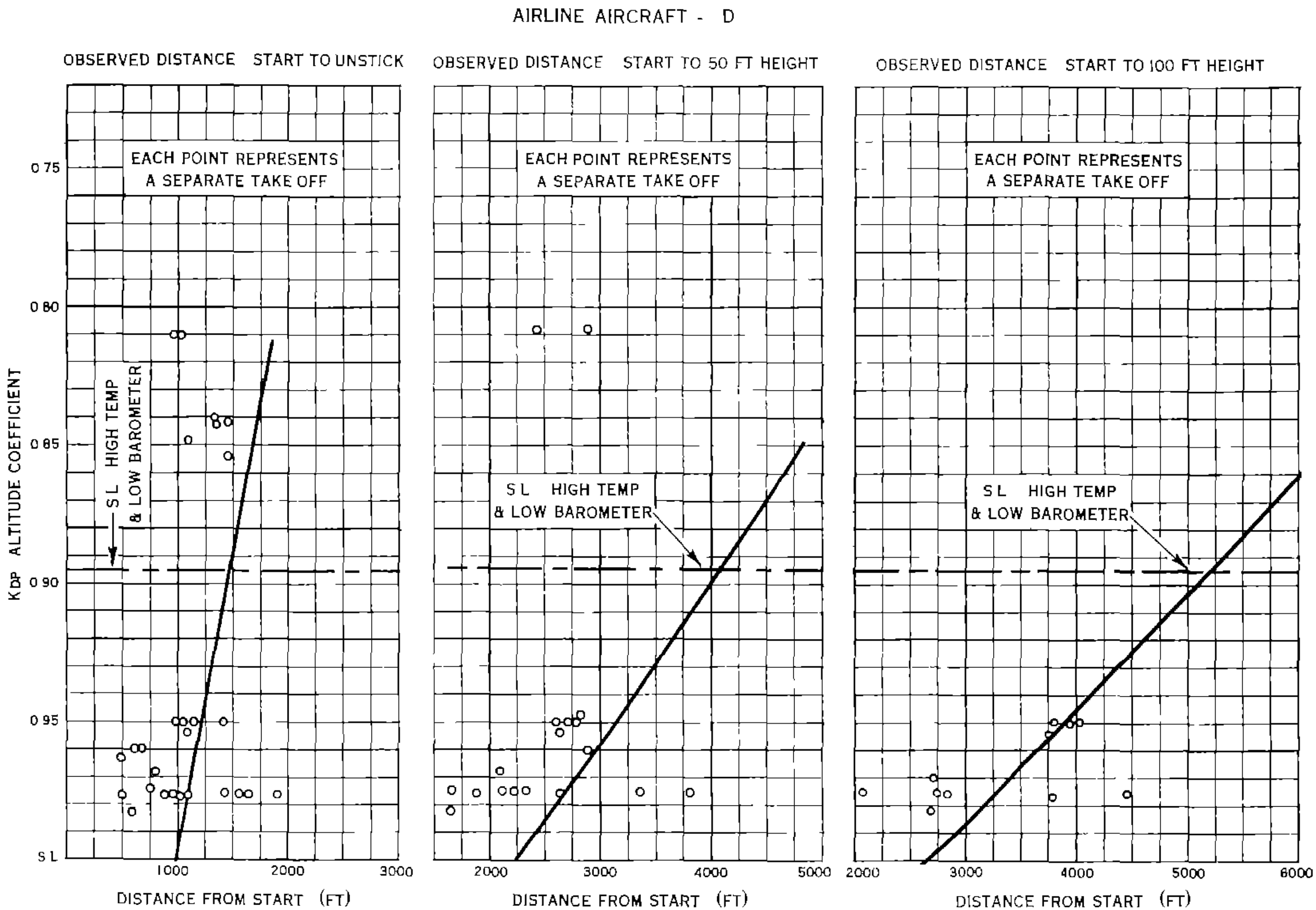


Figure 8 Take-Off Characteristics

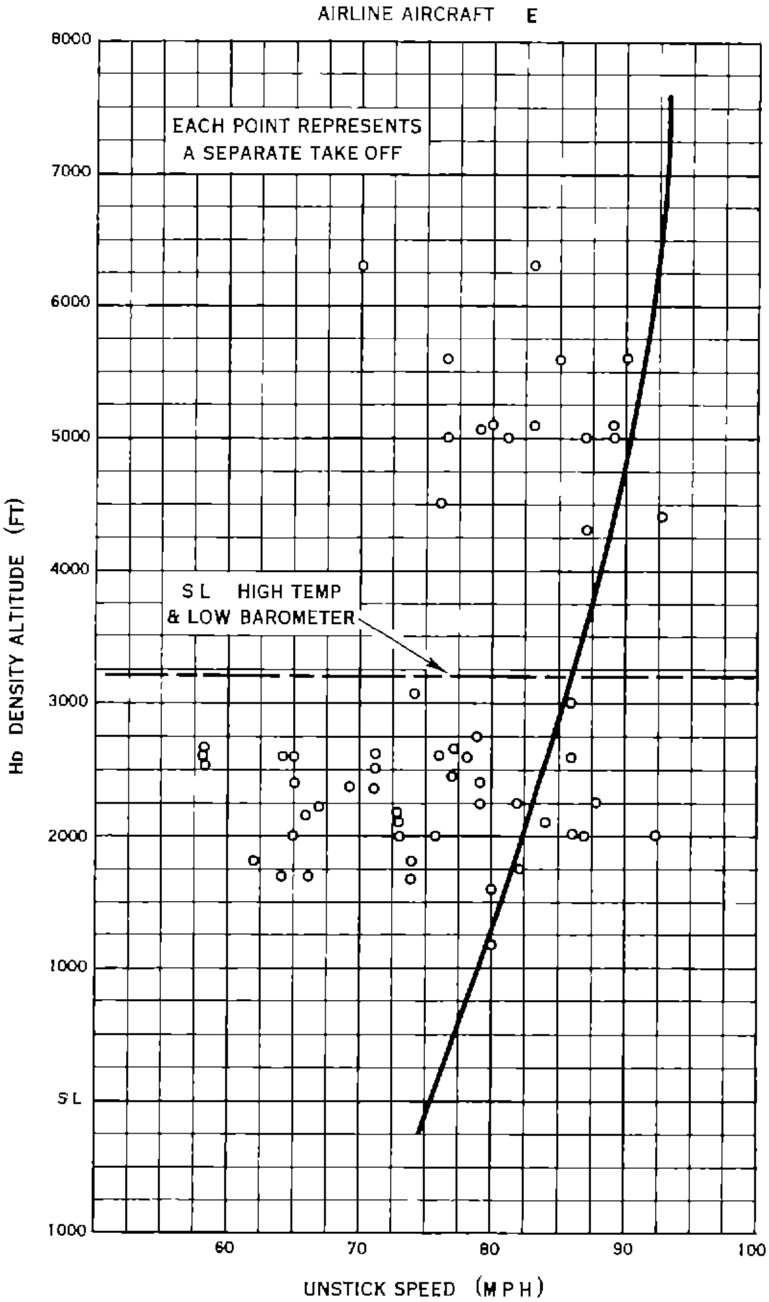


Figure 9 Unstick Speed Characteristics

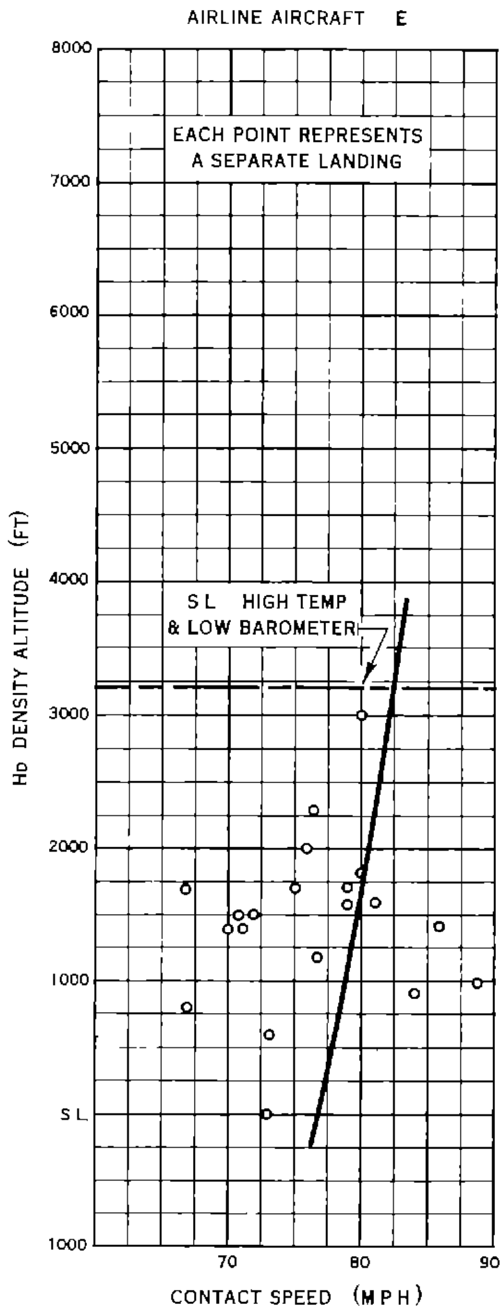


Figure 10 Contact Speed Characteristics

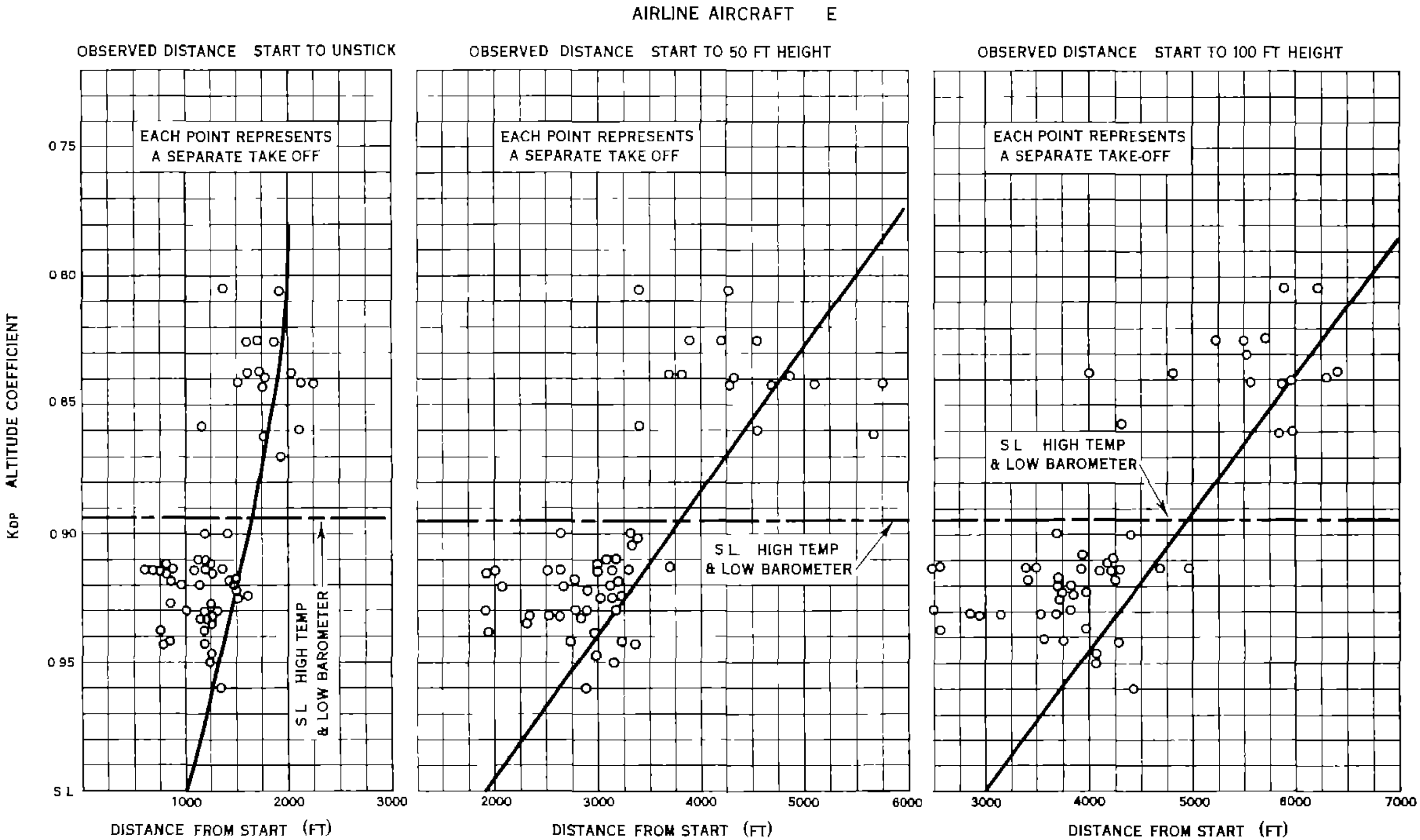


Figure 11 Take-Off Characteristics

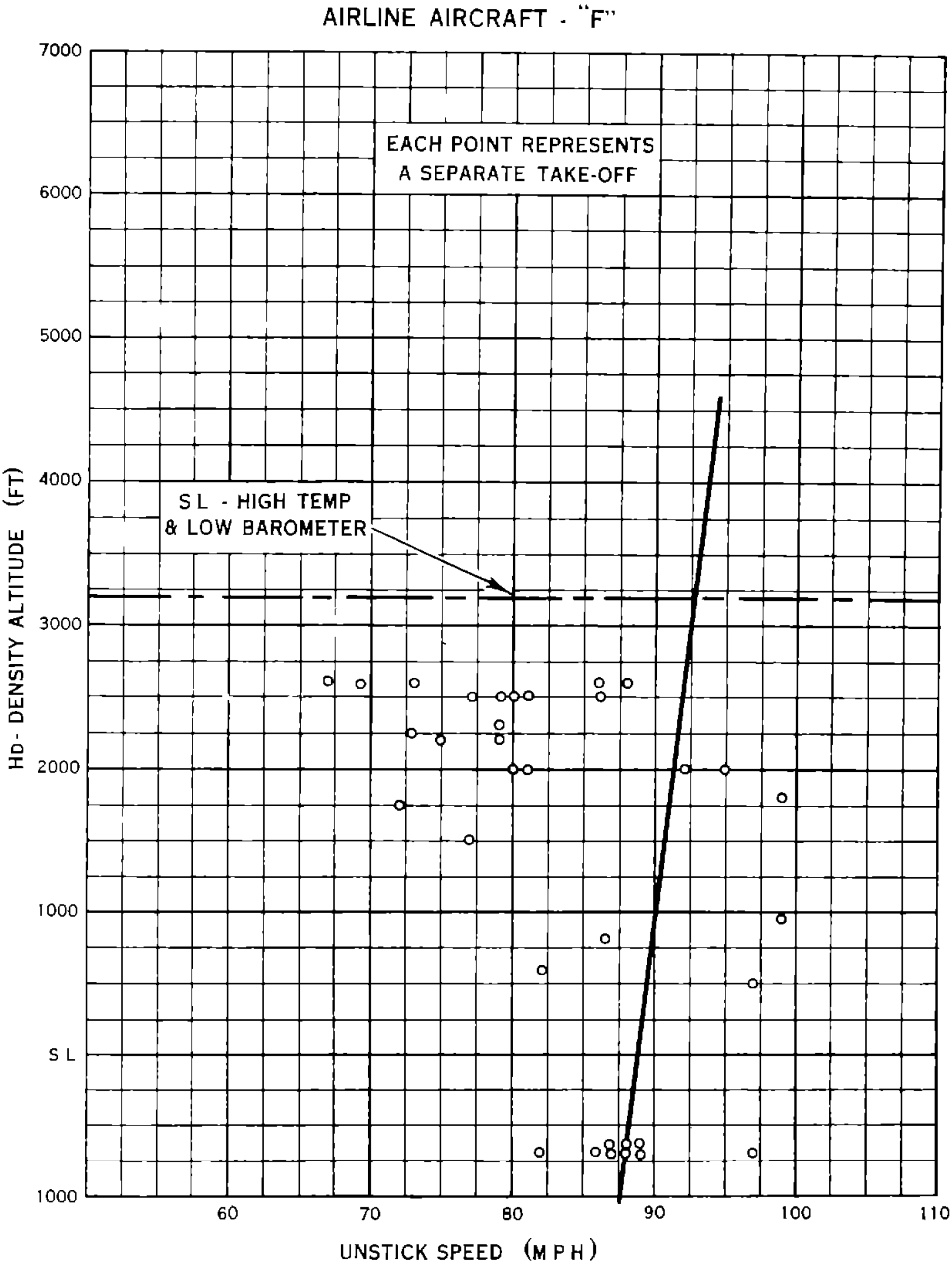


Figure 12 Unstick Speed Characteristics

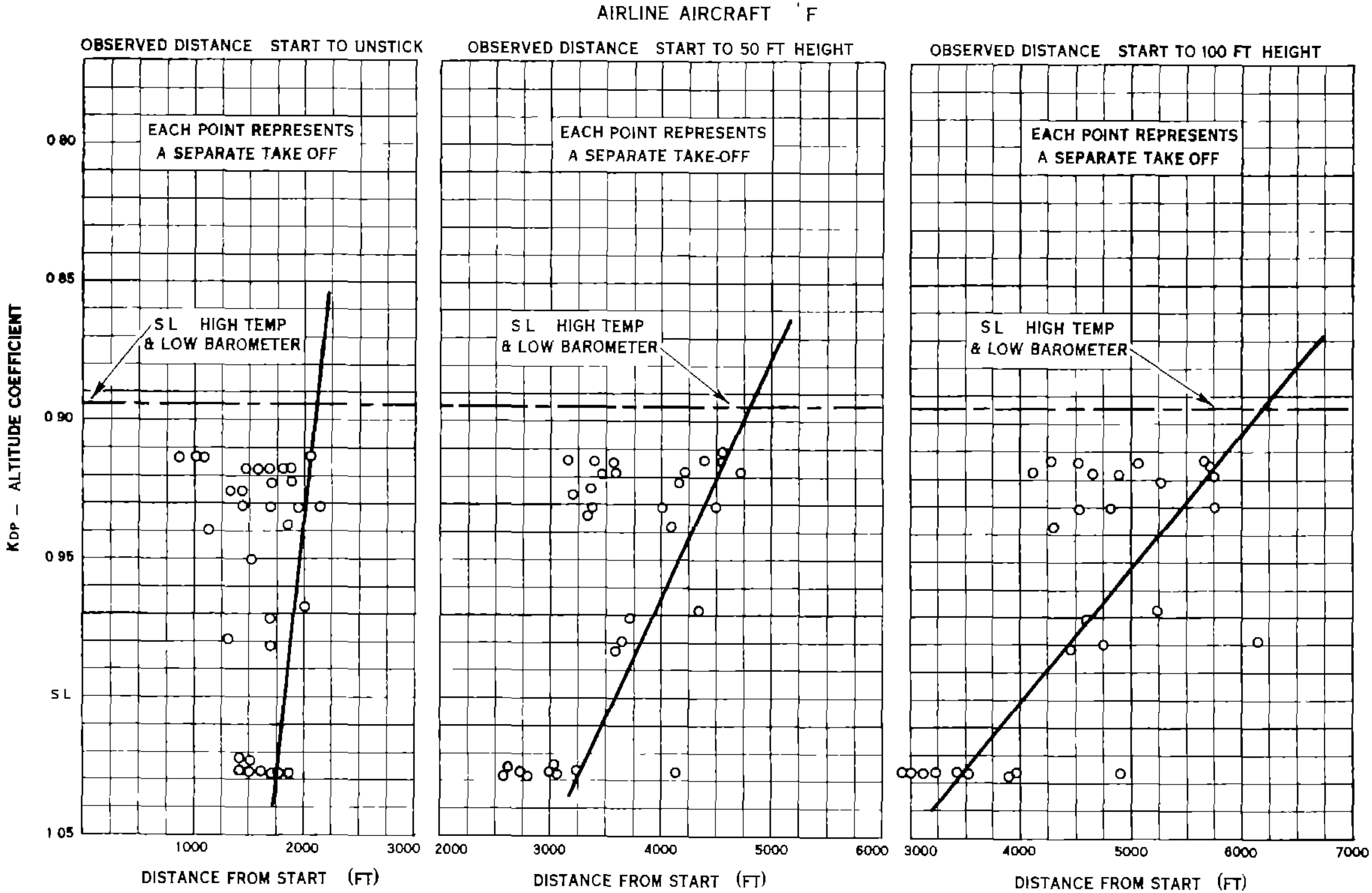


Figure 13 Take-Off Characteristics

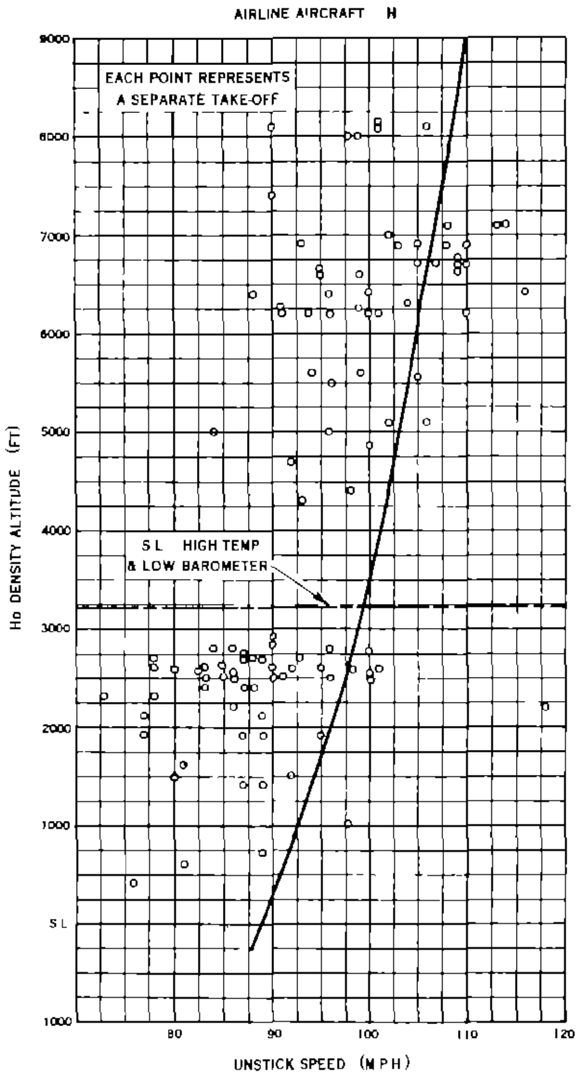


Figure 14 Unstick Speed Characteristics

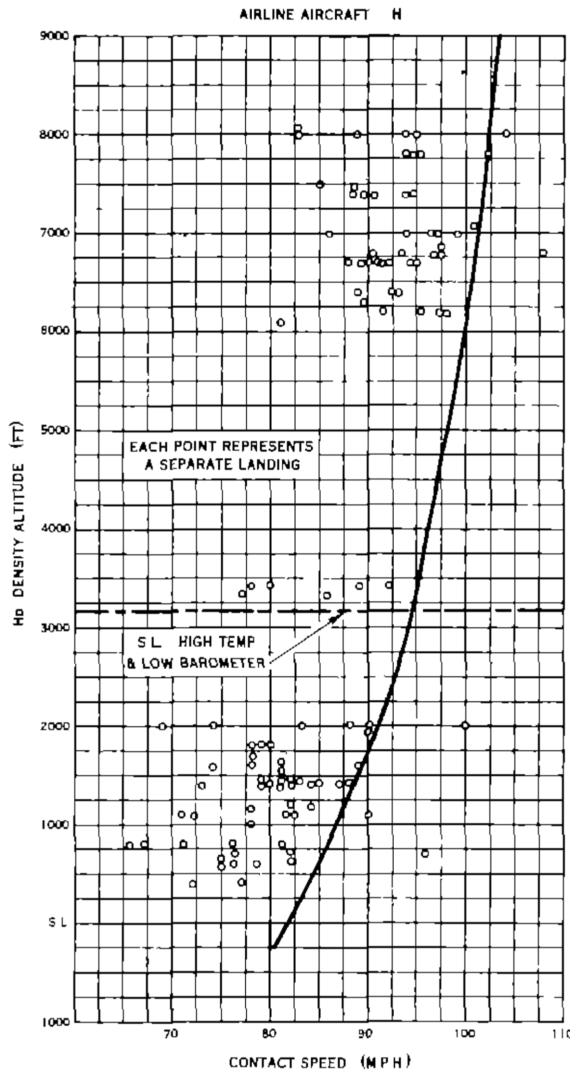


Figure 15 Contact Speed Characteristics

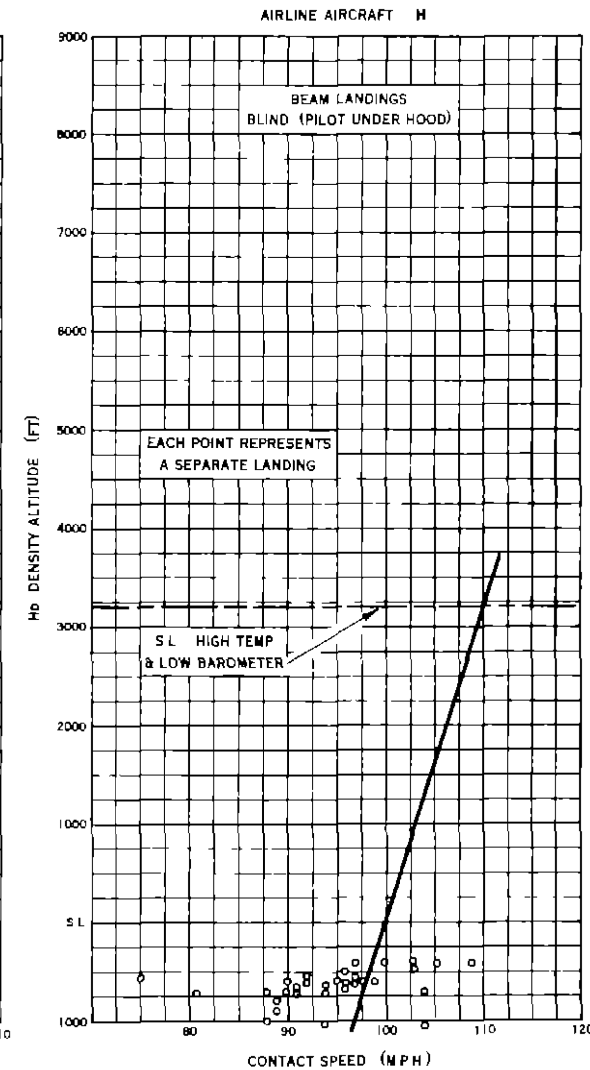


Figure 16 Contact Speed Characteristics

AIRLINE AIRCRAFT H

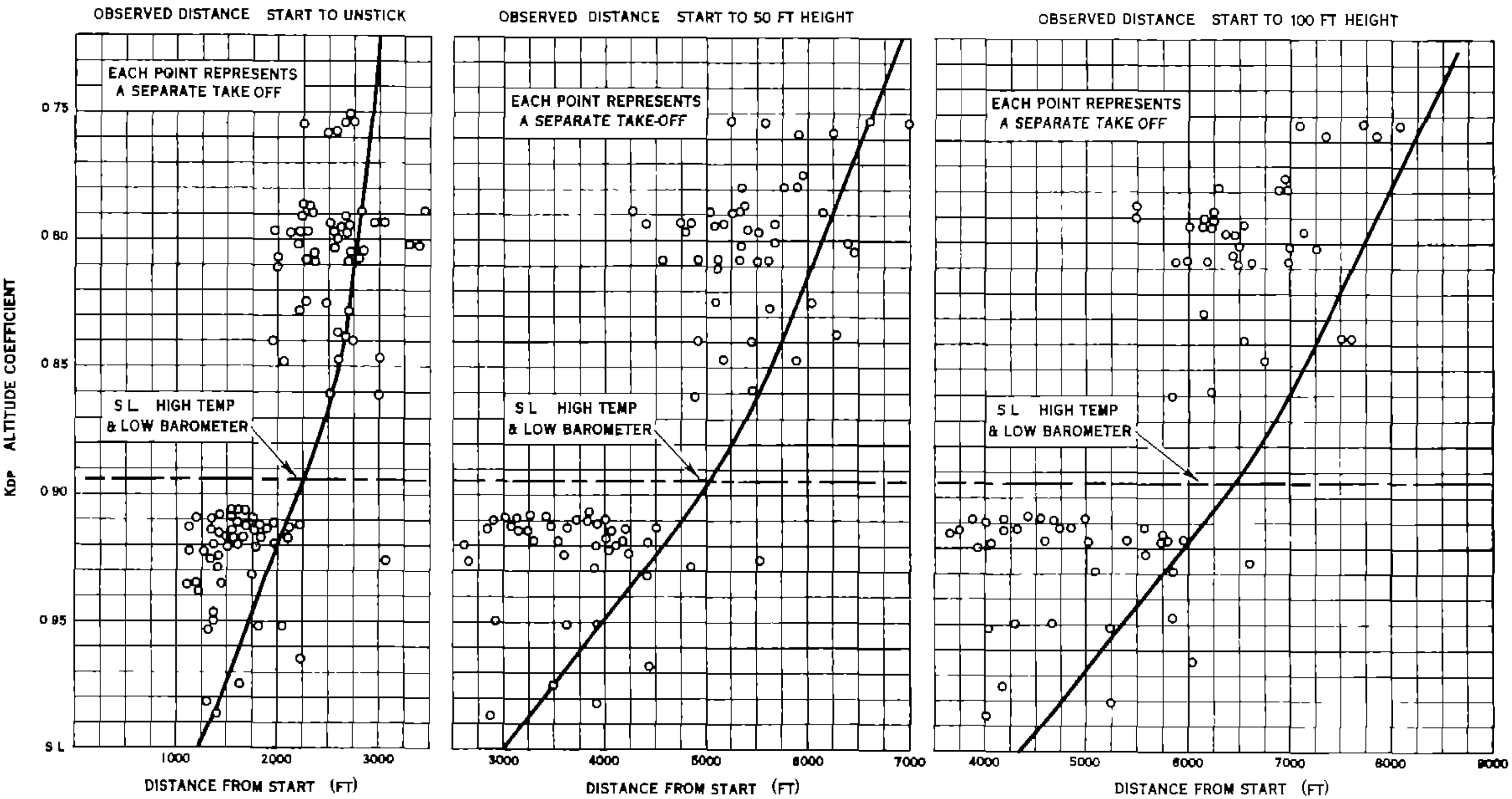
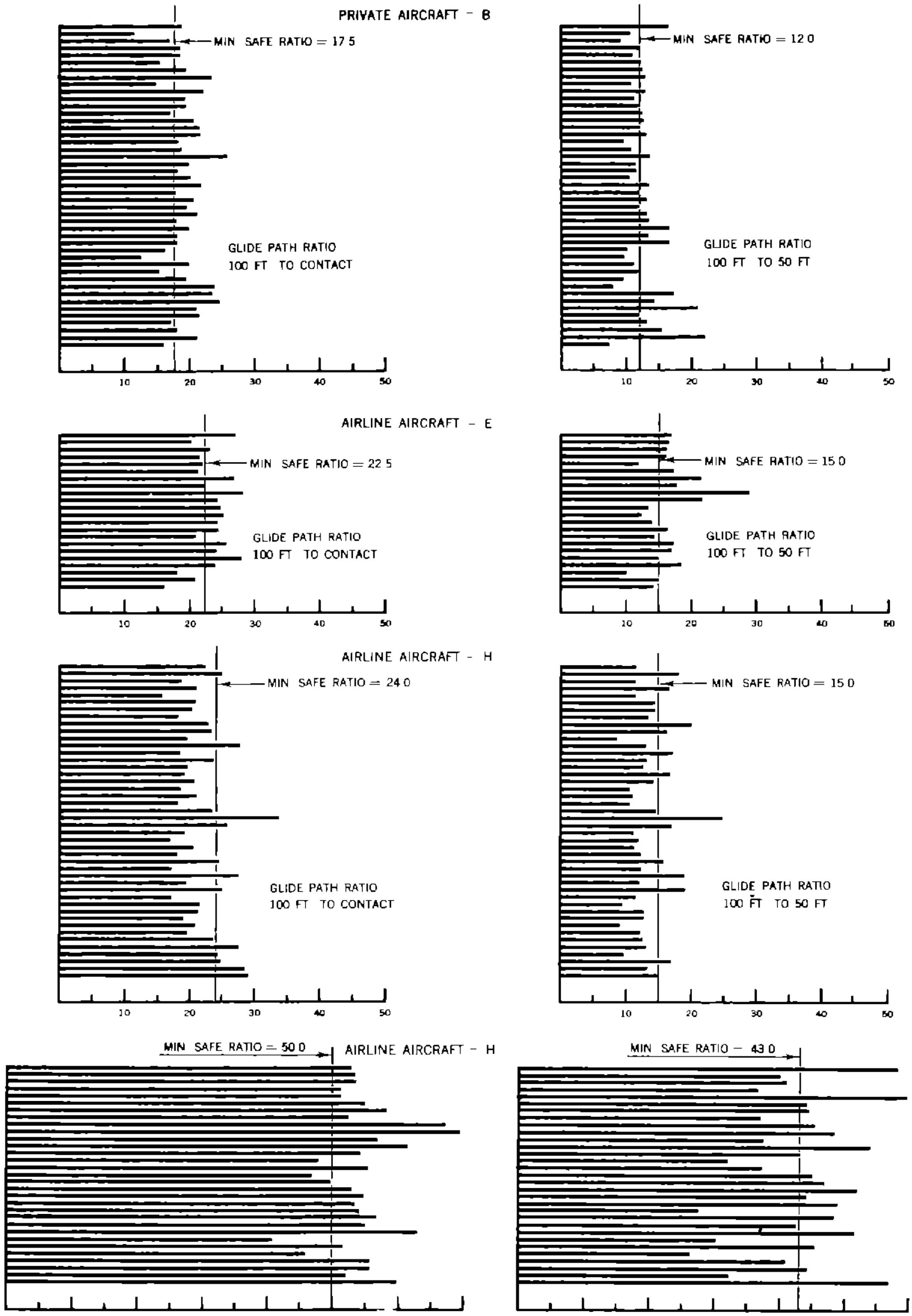


Figure 17 Take-Off Characteristics



GLIDE PATH RATIO
100 FT TO CONTACT

BLIND LANDINGS ON THE OAKLAND BEAM

GLIDE PATH RATIO
100 FT TO 50 FT

NOTE

1 GLIDE PATH RATIO = $\frac{\text{DISTANCE}}{\text{HEIGHT}}$

2 EACH LINE REPRESENTS A SEPARATE TEST

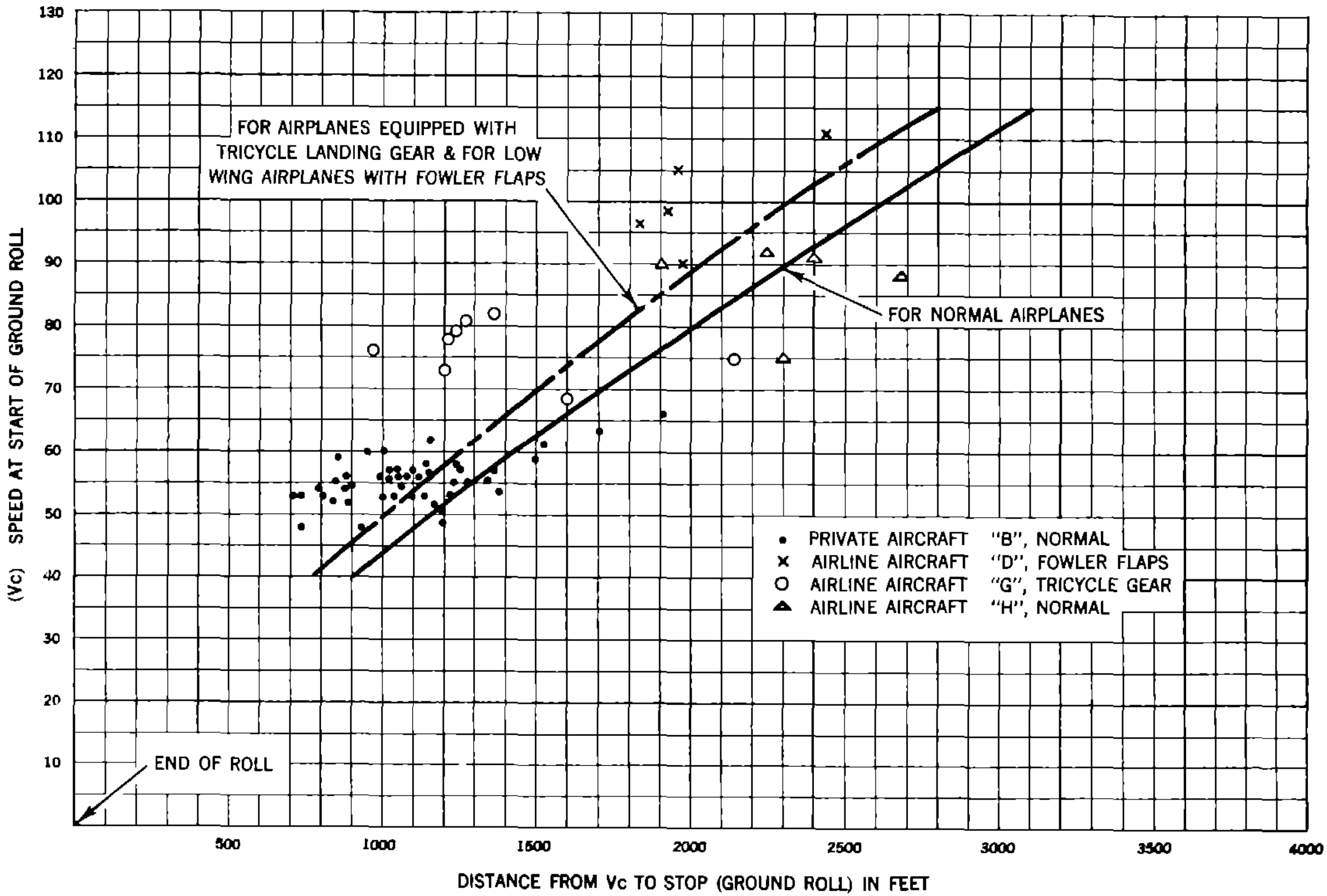


Figure 19 Ground Roll Characteristics - All Altitudes

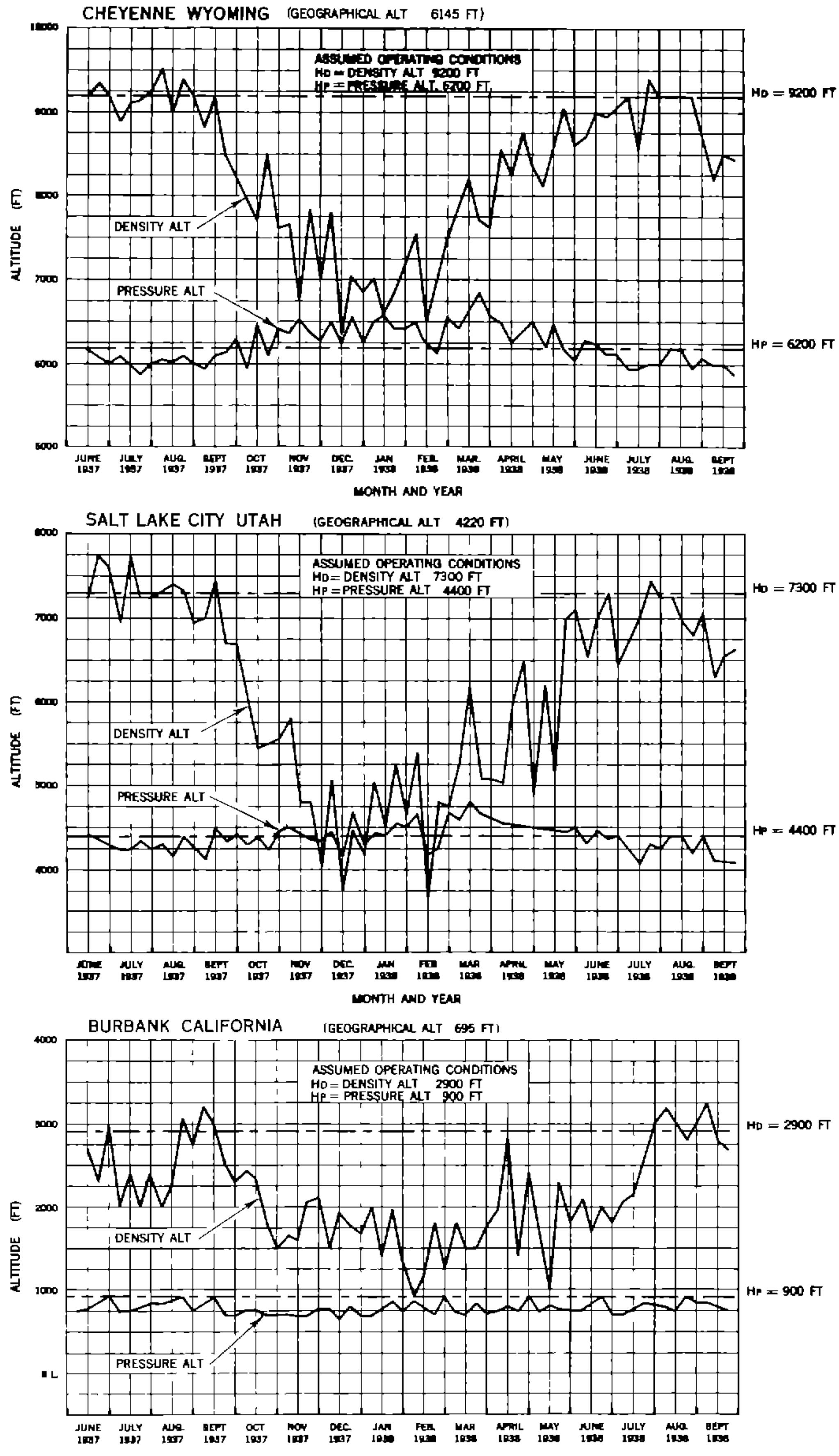


Figure 20 Seasonal Variations in Pressure and Density Altitudes

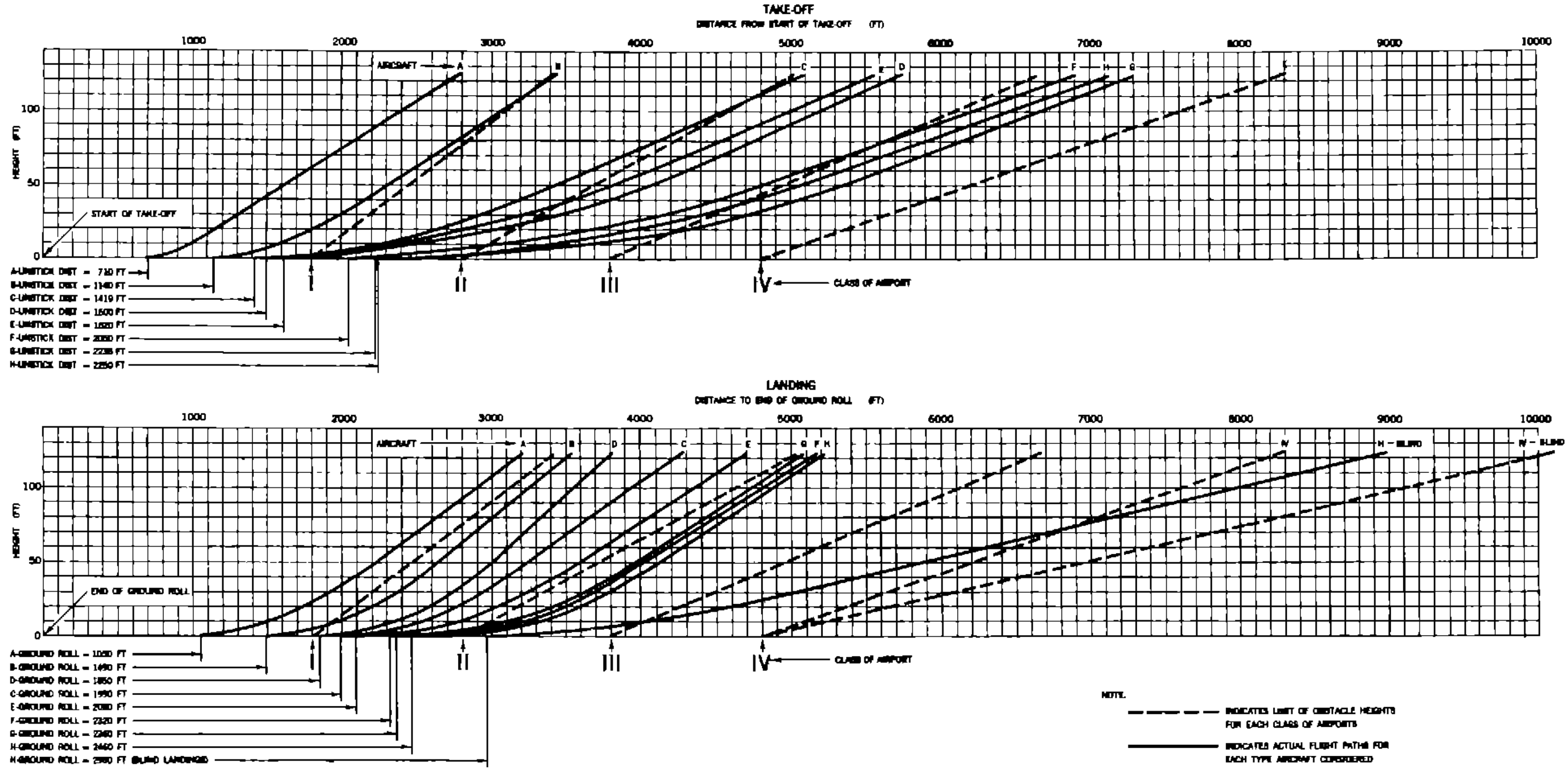


Figure 21 Take-Off and Landing - Airplane Characteristics and Airport Maximum Allowable Obstacle Heights - (Sea Level)

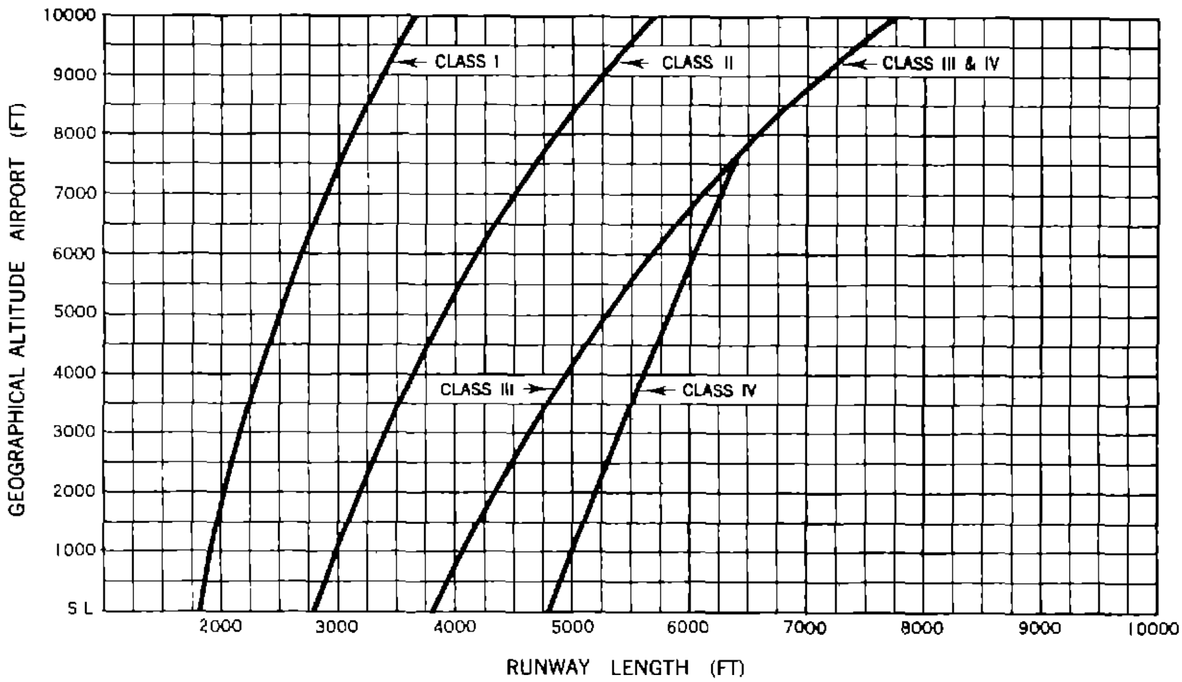


Figure 22 Runway Lengths Versus Altitude of Airport.

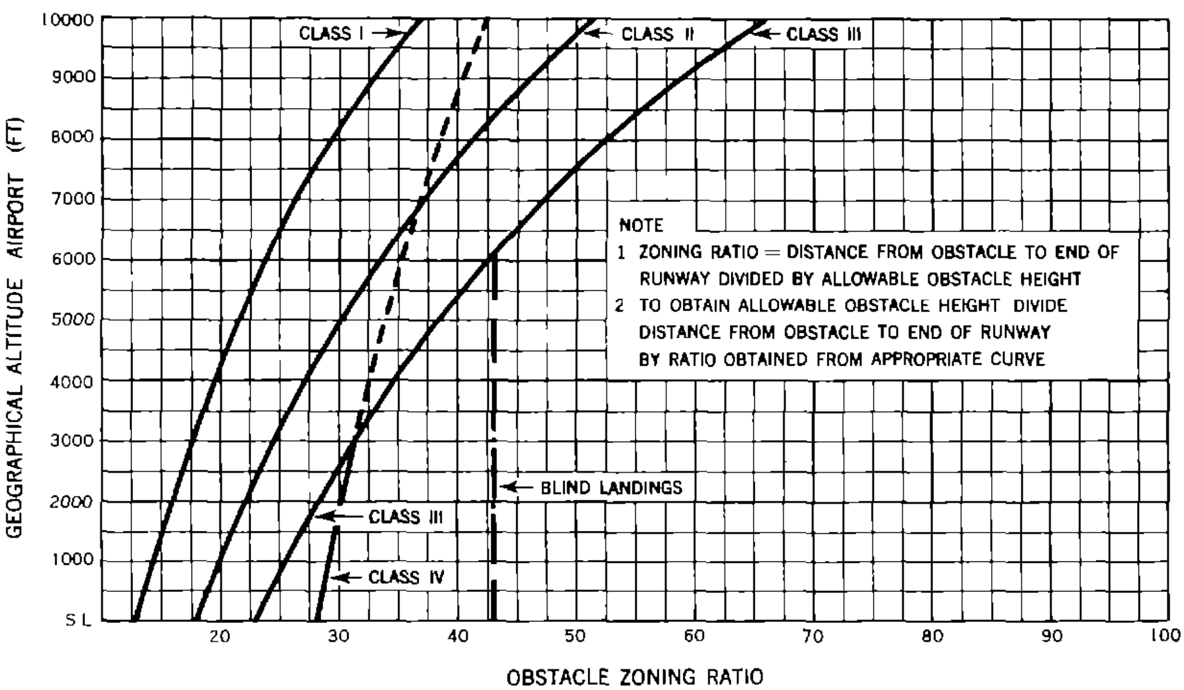


Figure 23 Obstacle Zoning Ratio Versus Altitude of Airport.

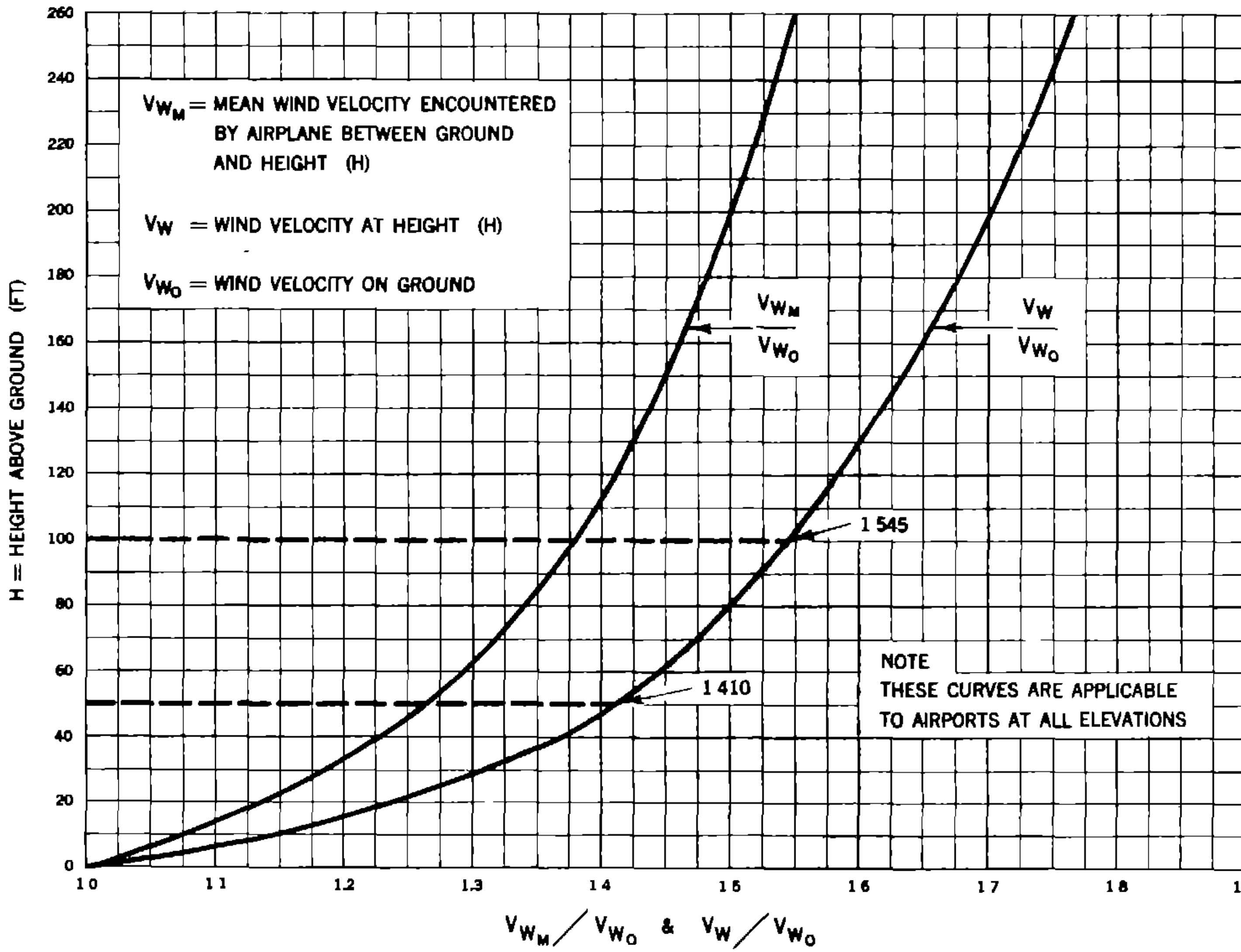


Figure 24 Wind Velocity Characteristics Versus Height Above Surface of Airport

$$R_W = R_O \times K_R$$

R_W = RUNWAY LENGTH FOR ANY WIND VELOCITY

R_O = RUNWAY LENGTH FOR ZERO WIND VELOCITY

K_R = RUNWAY LENGTH REDUCTION COEFFICIENT AS OBTAINED FROM CURVE

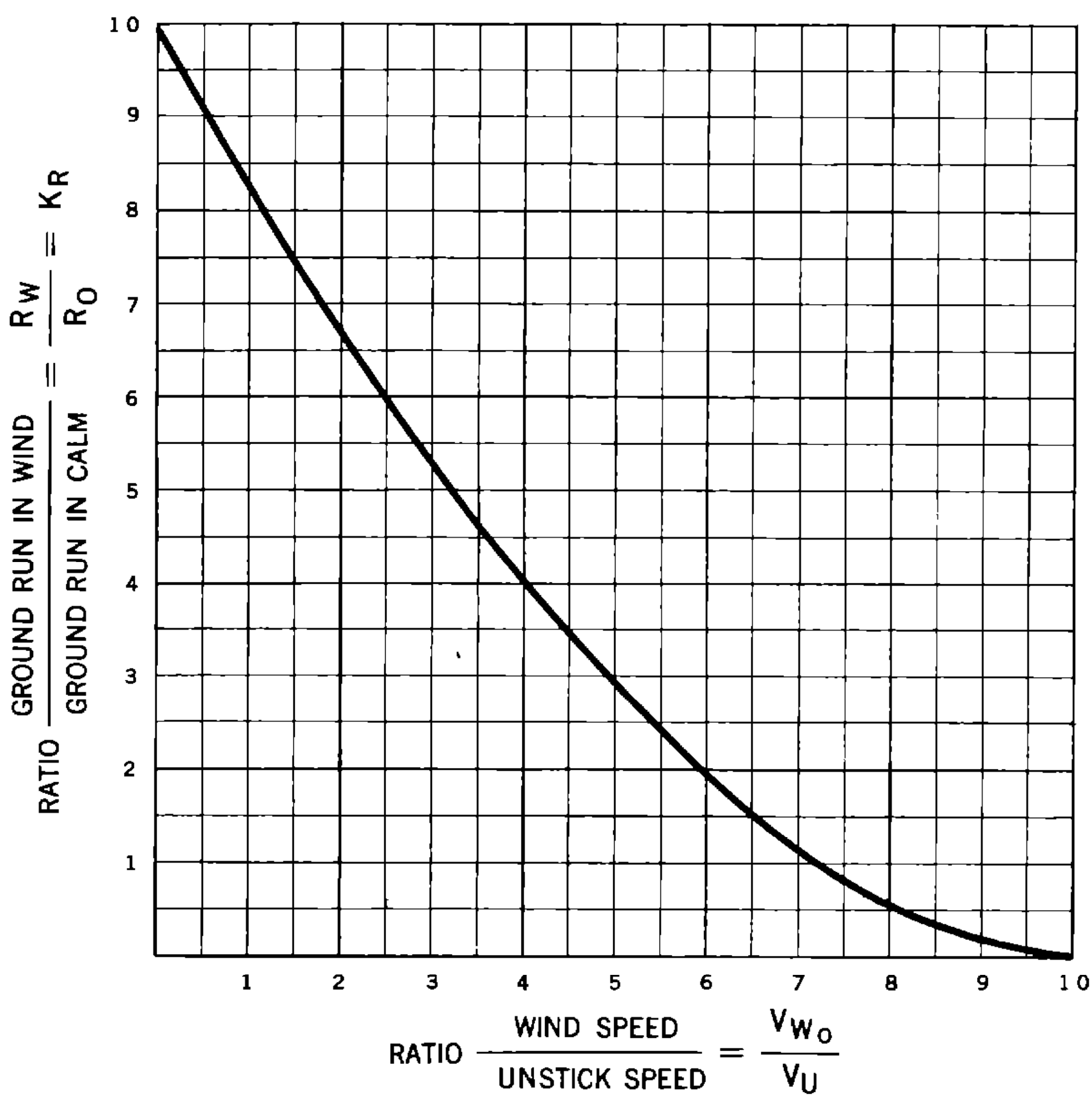


Figure 25 Effect of Wind on Take-Off Run and Runway Length

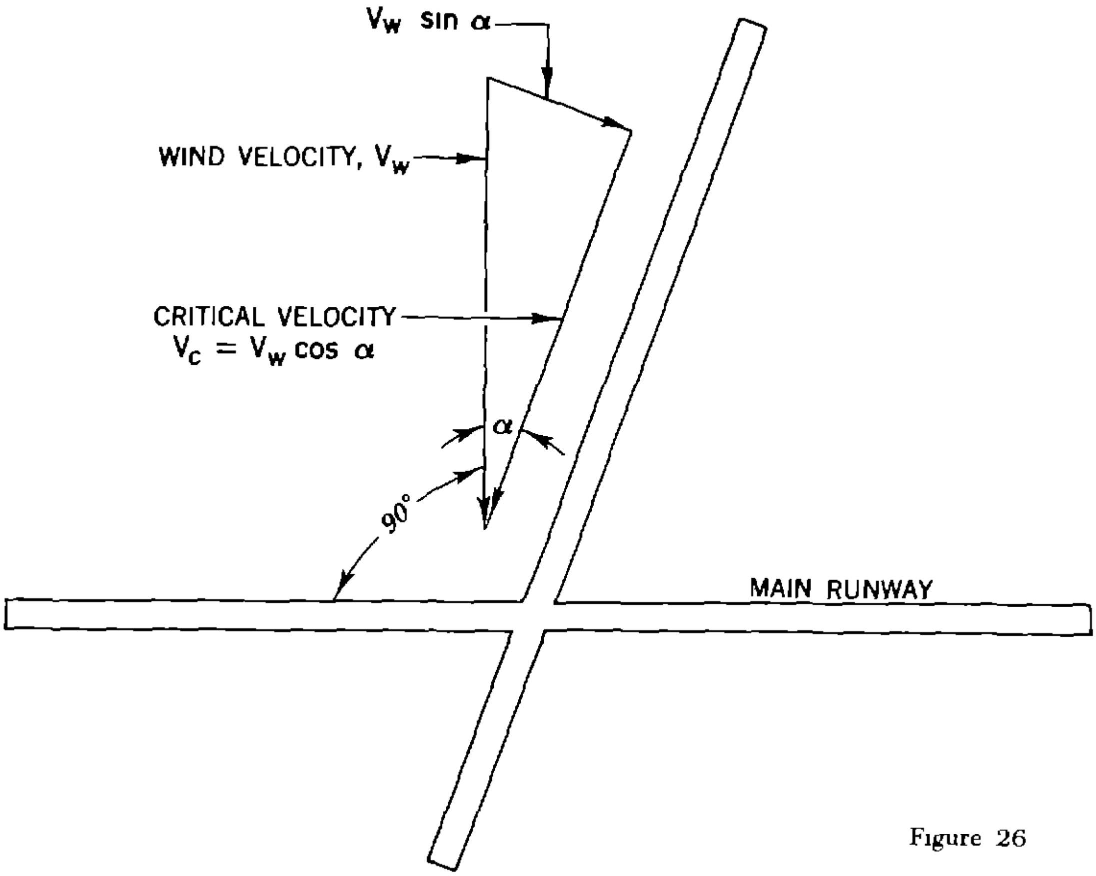


Figure 26

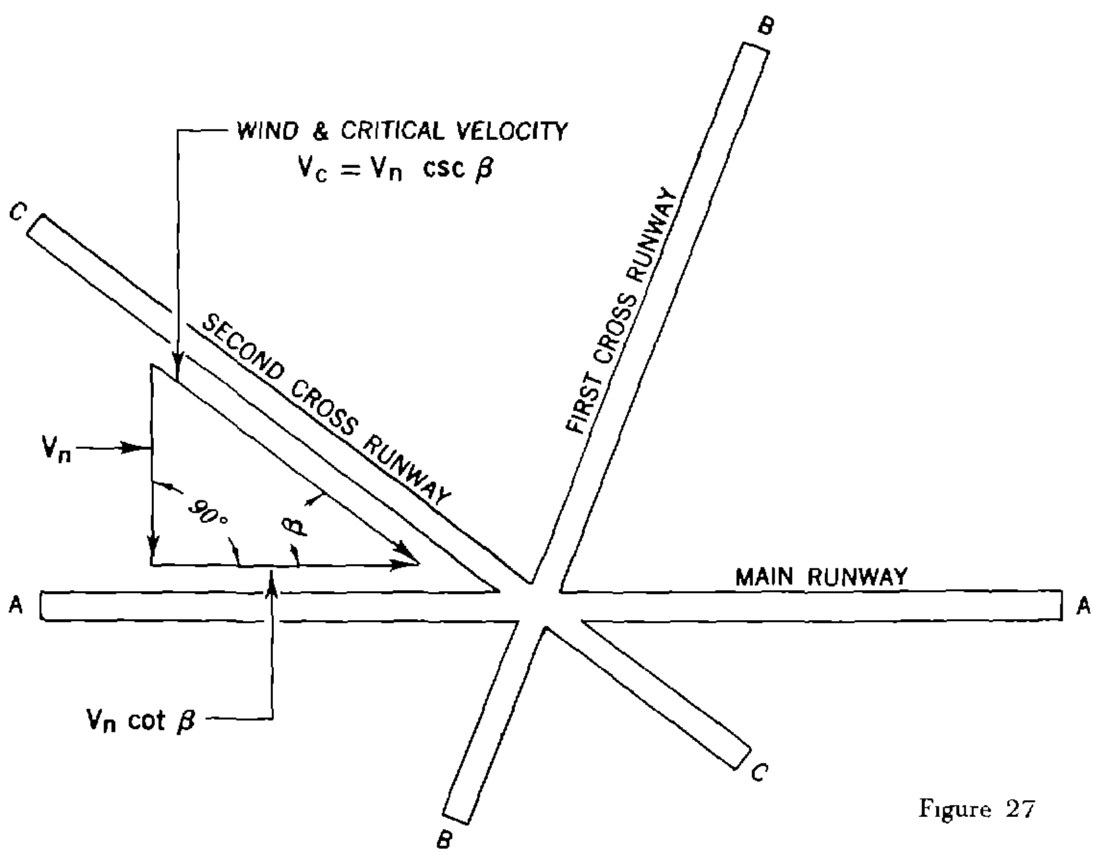
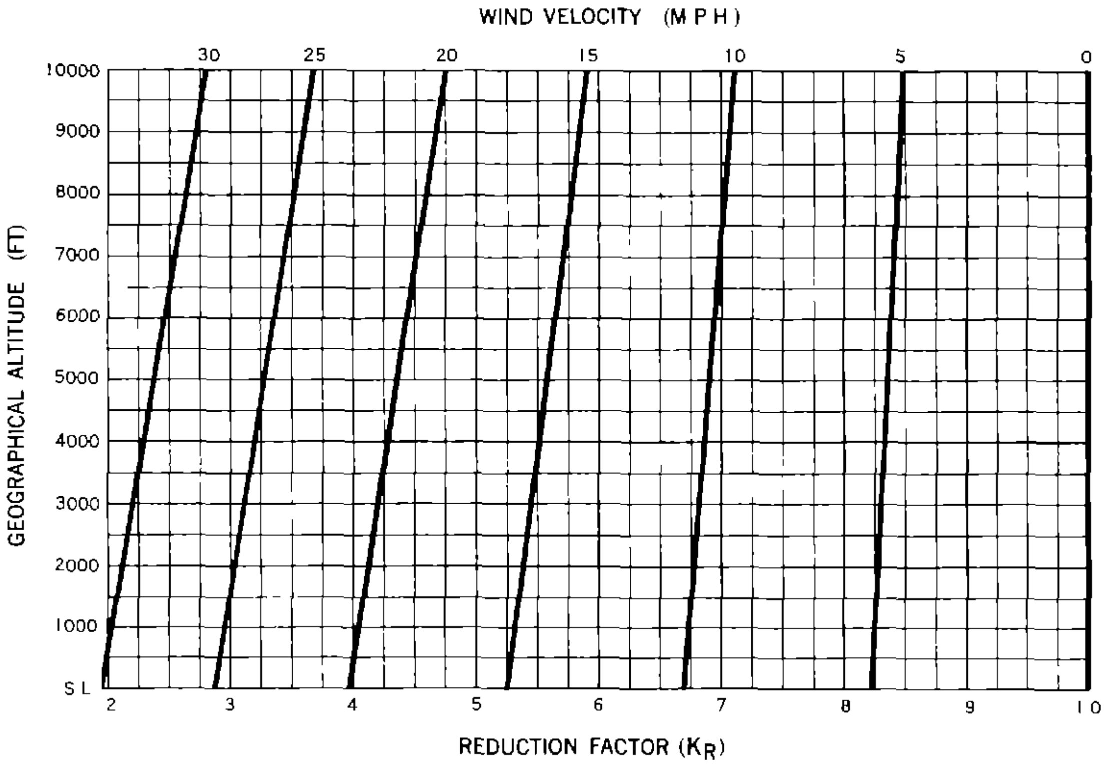
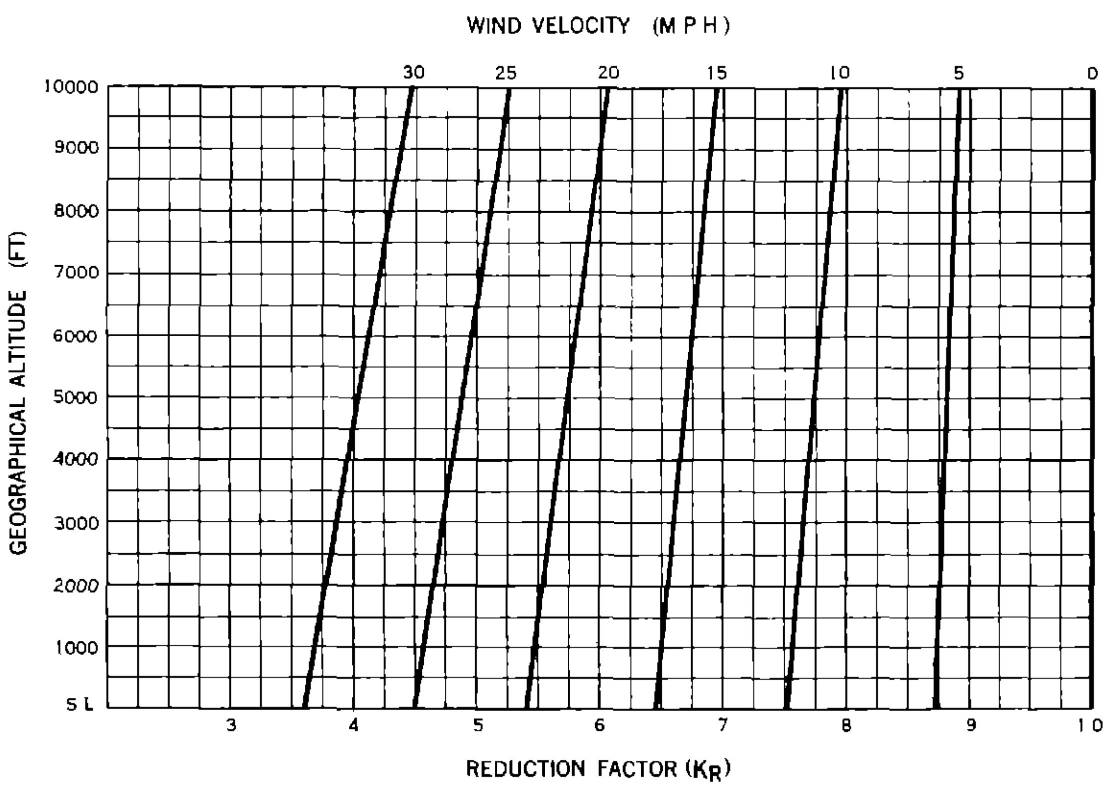


Figure 27



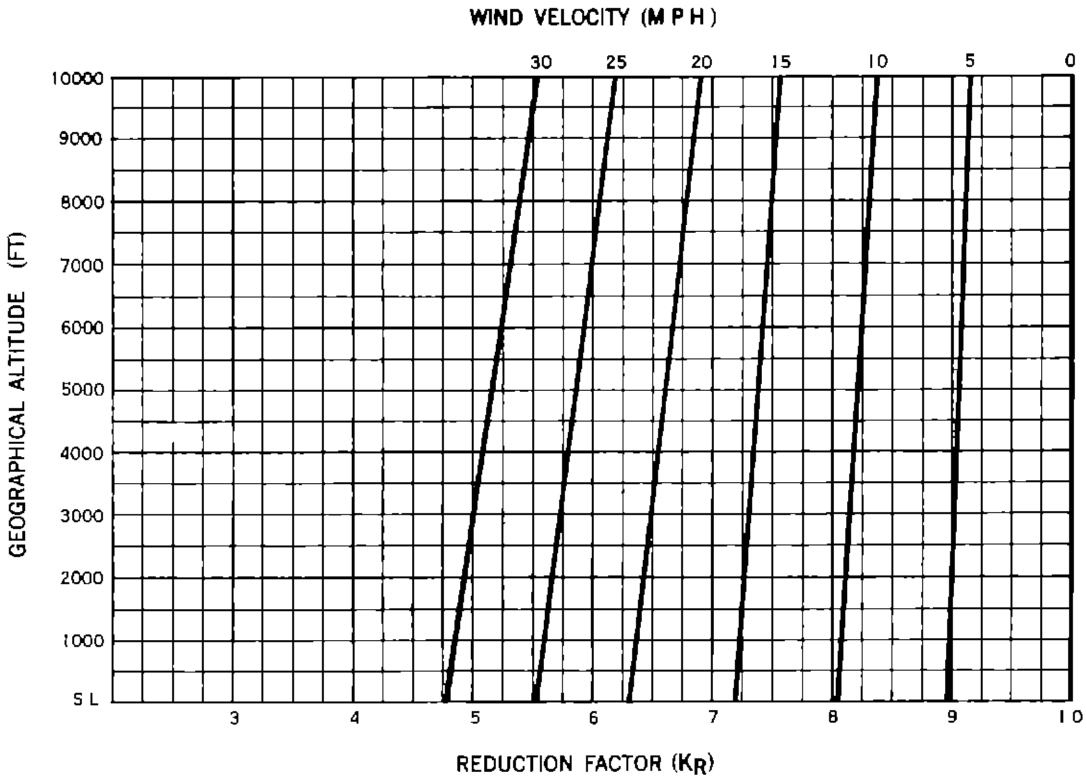
CLASS I

Figure 28 Runwav Length Reduction Factor Versus Altitude for Various Wind Velocities



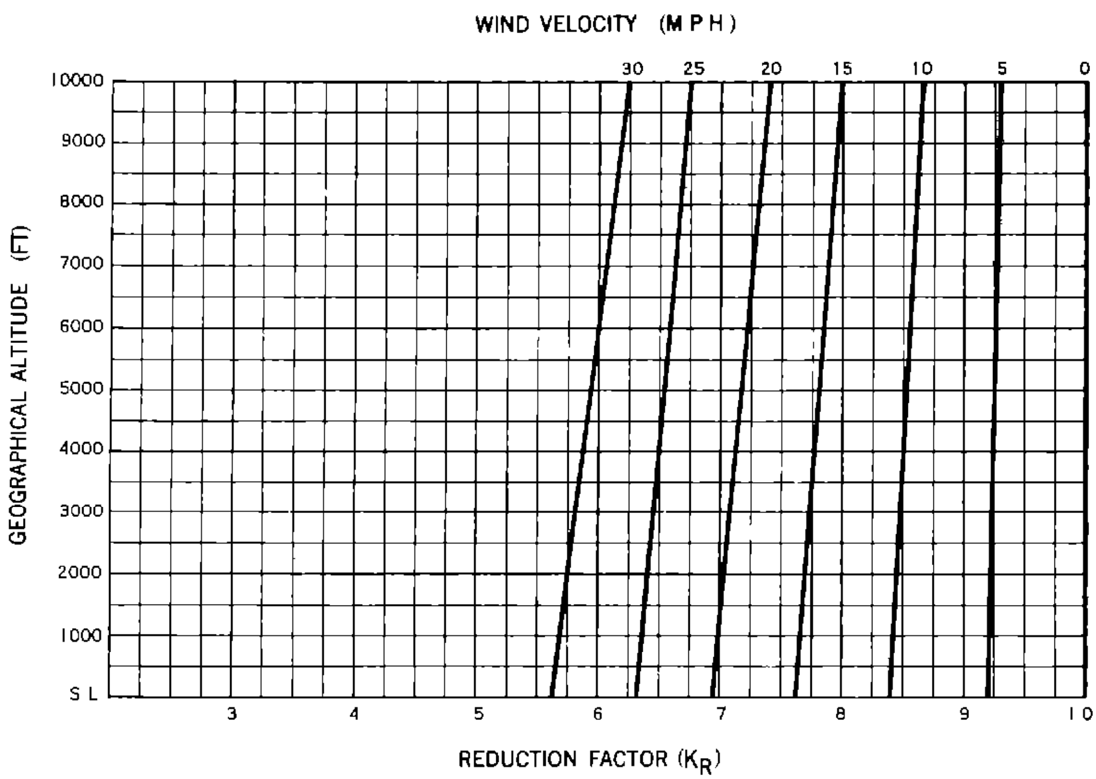
CLASS II

Figure 29 Runway Length Reduction Factor Versus Altitude for Various Wind Velocities



CLASS III

Figure 30 Runway Length Reduction Factor Versus Altitude for Various Wind Velocities



CLASS IV

Figure 31 Runway Length Reduction Factor Versus Altitude for Various Wind Velocities

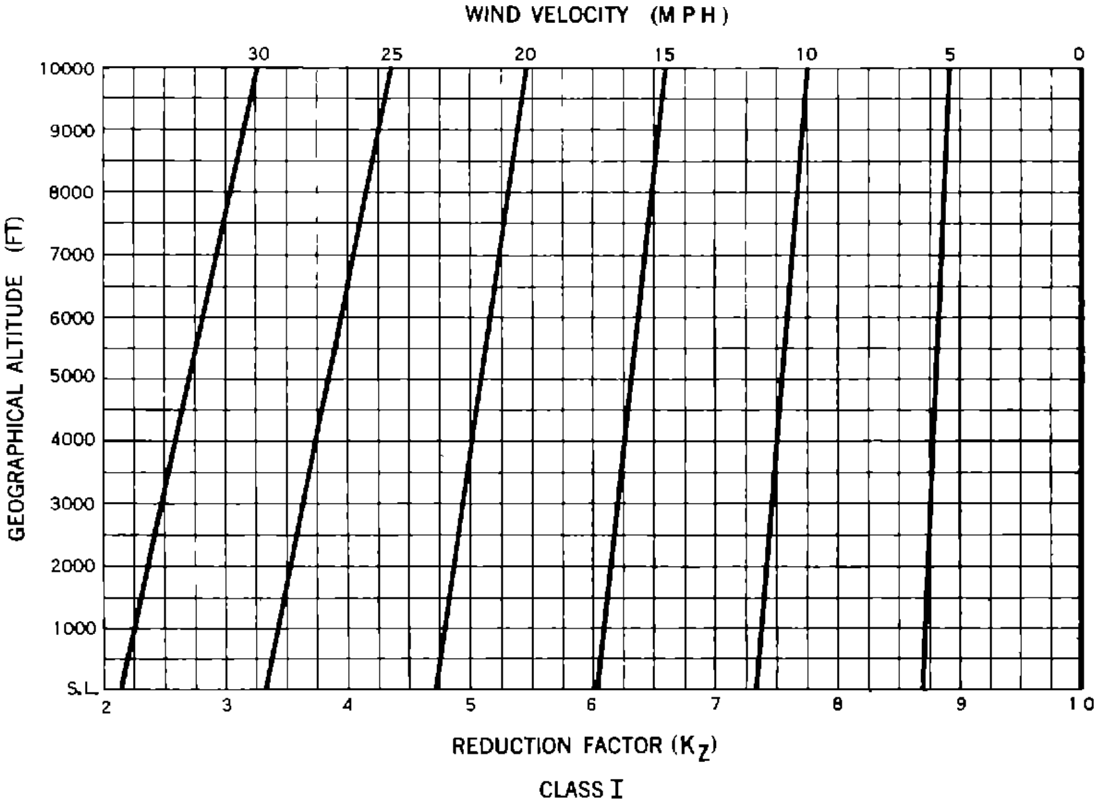


Figure 32 Obstacle Zoning Ratio Reduction Factor Versus Altitude for Various Wind Velocities

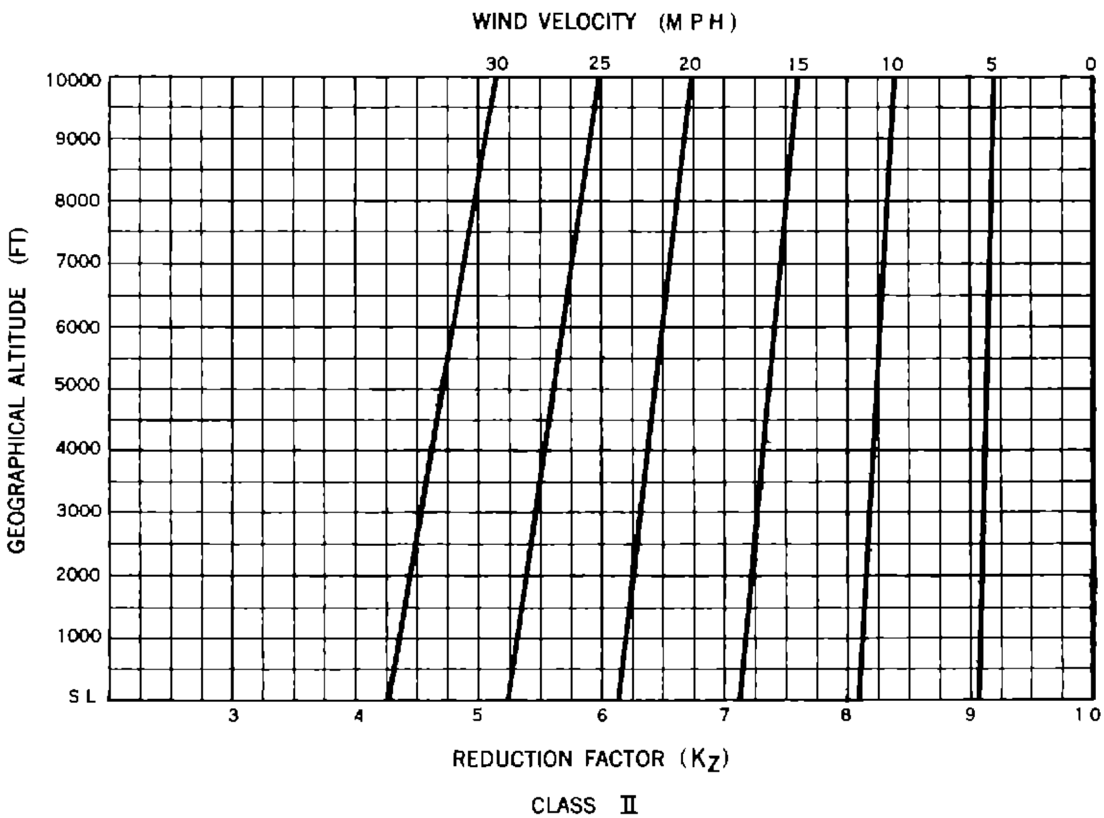
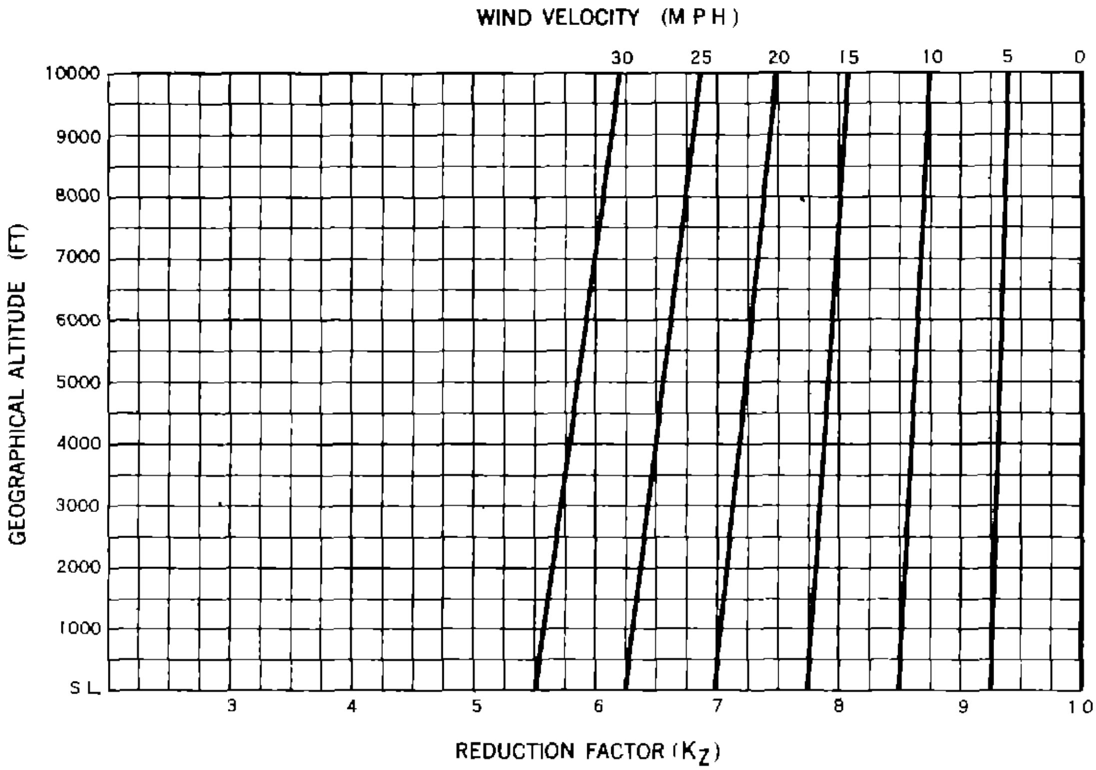
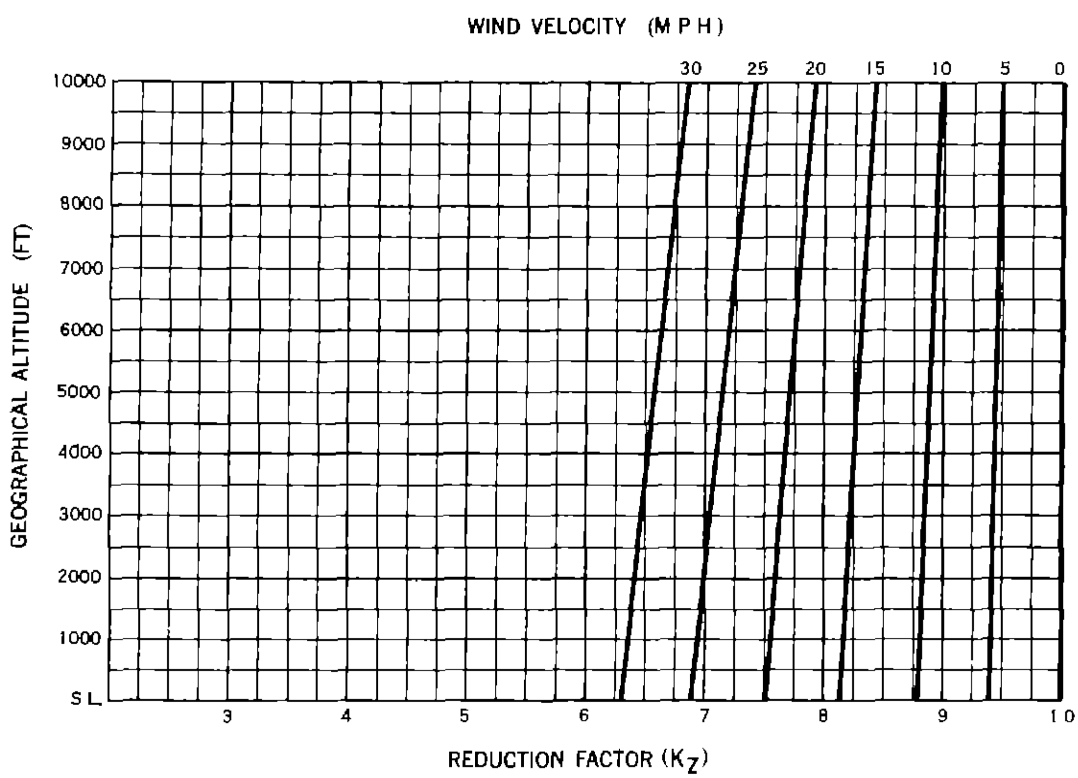


Figure 33 Obstacle Zoning Ratio Reduction Factor Versus Altitude for Various Wind Velocities



CLASS III

Figure 34 Obstacle Zoning Ratio Reduction Factor Versus Altitude for Various Wind Velocities



CLASS IV

Figure 35 Obstacle Zoning Ratio Reduction Factor Versus Altitude for Various Wind Velocities

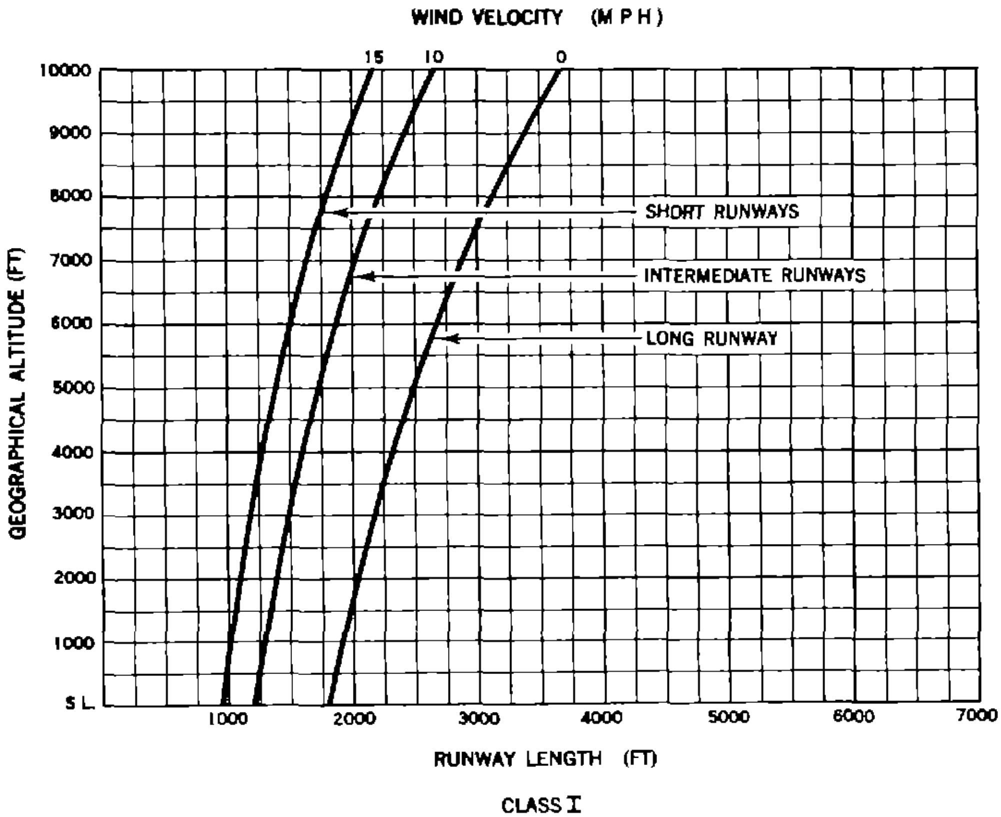


Figure 36 Runway Lengths Versus Altitude

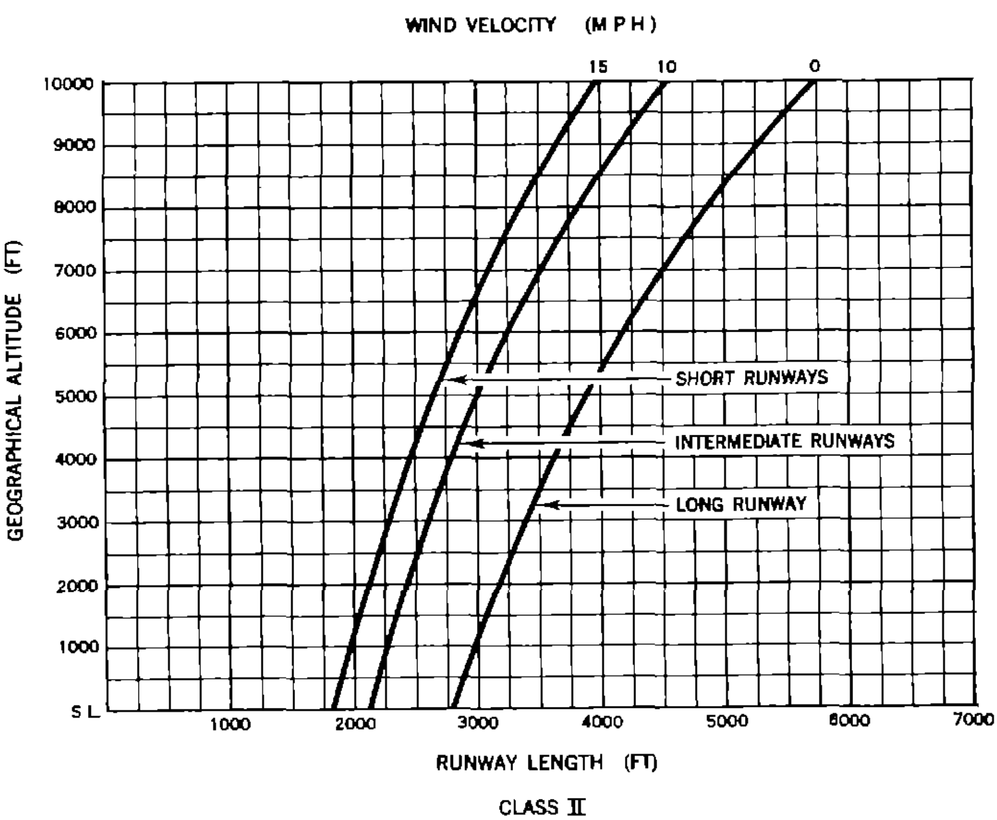
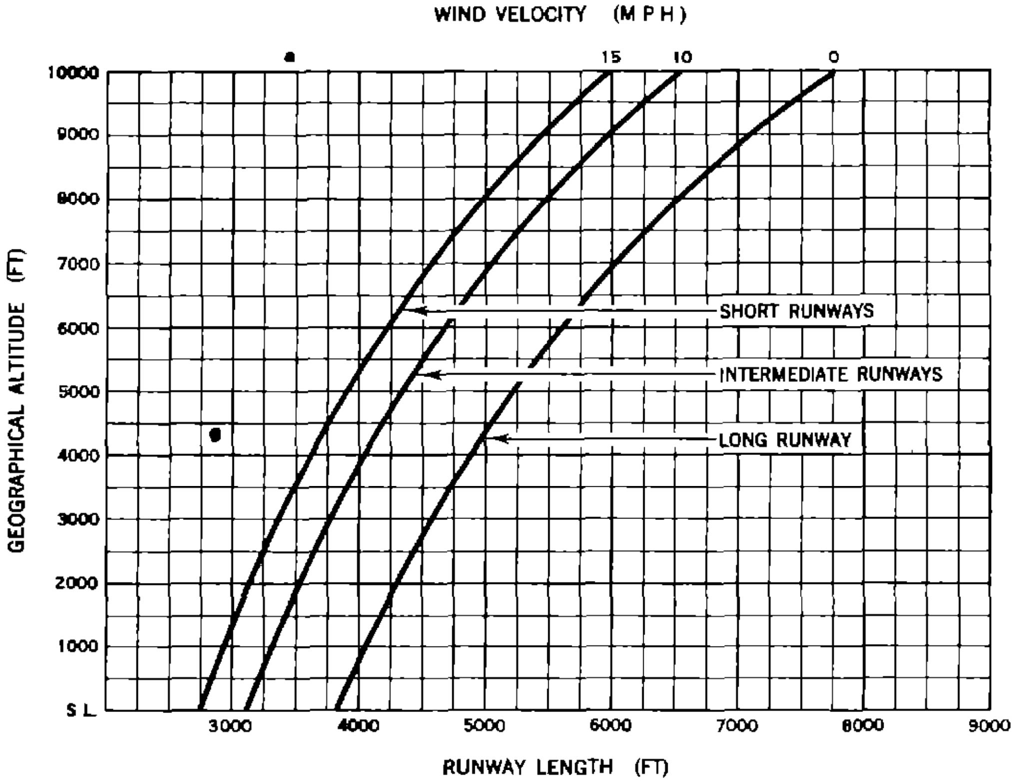
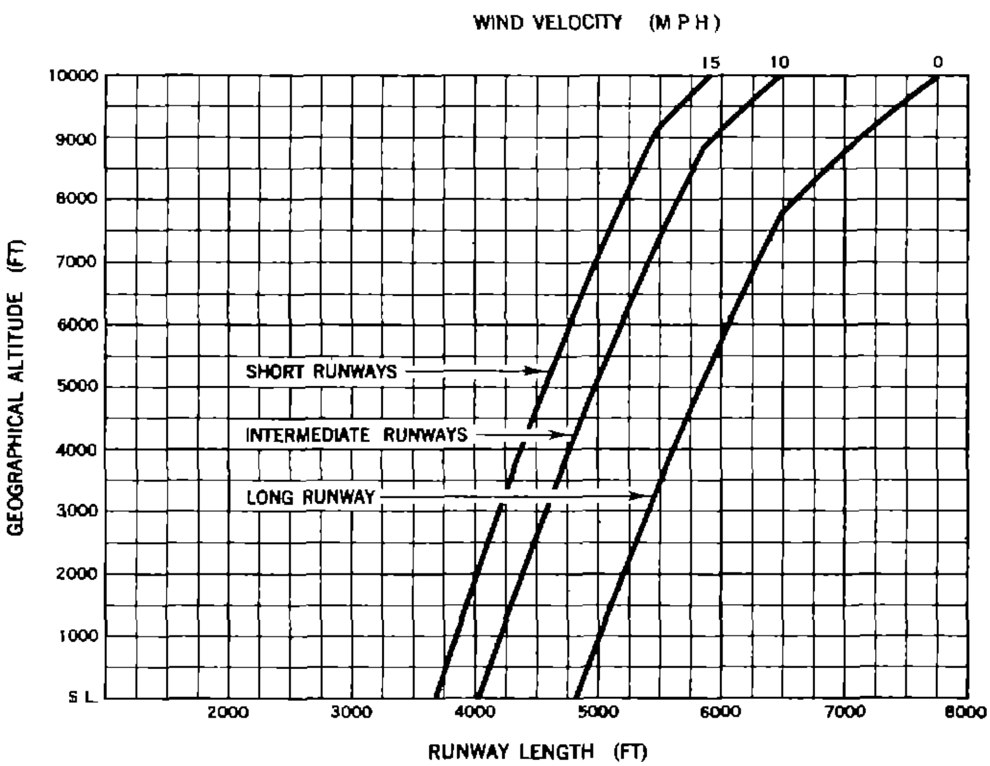


Figure 37 Runway Lengths Versus Altitude



CLASS III

Figure 38 Runway Lengths Versus Altitude



CLASS IV

Figure 39 Runway Lengths Versus Altitude

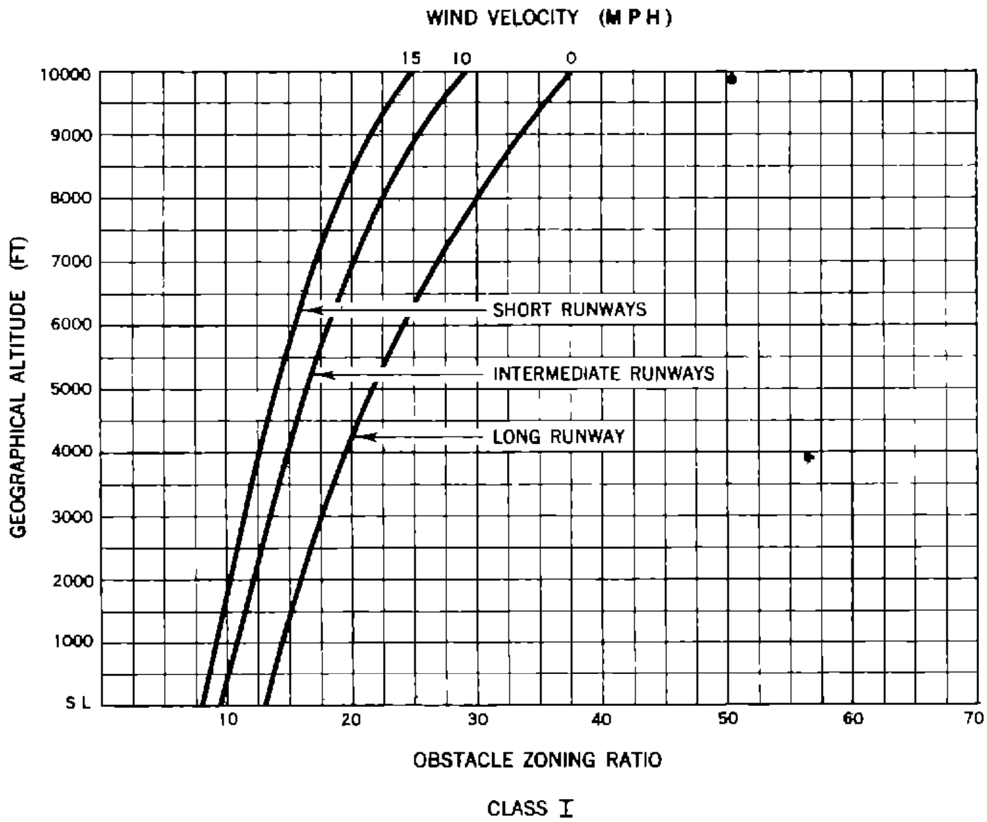


Figure 40 Obstacle Zoning Ratios Versus Altitude

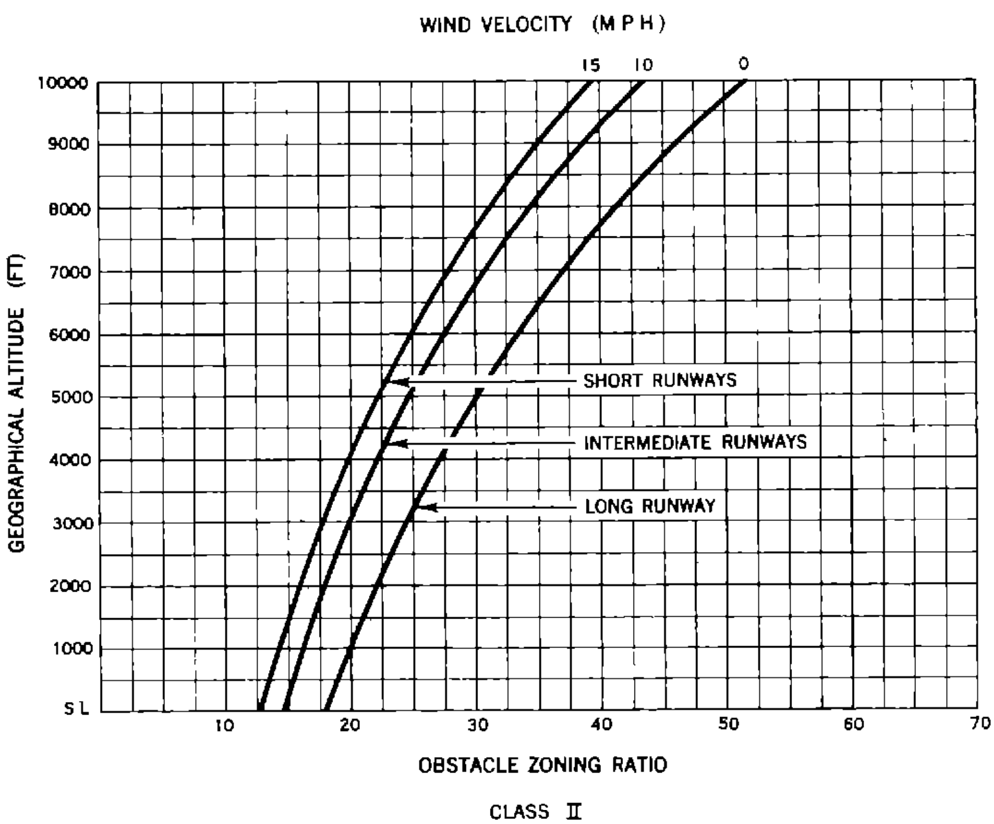
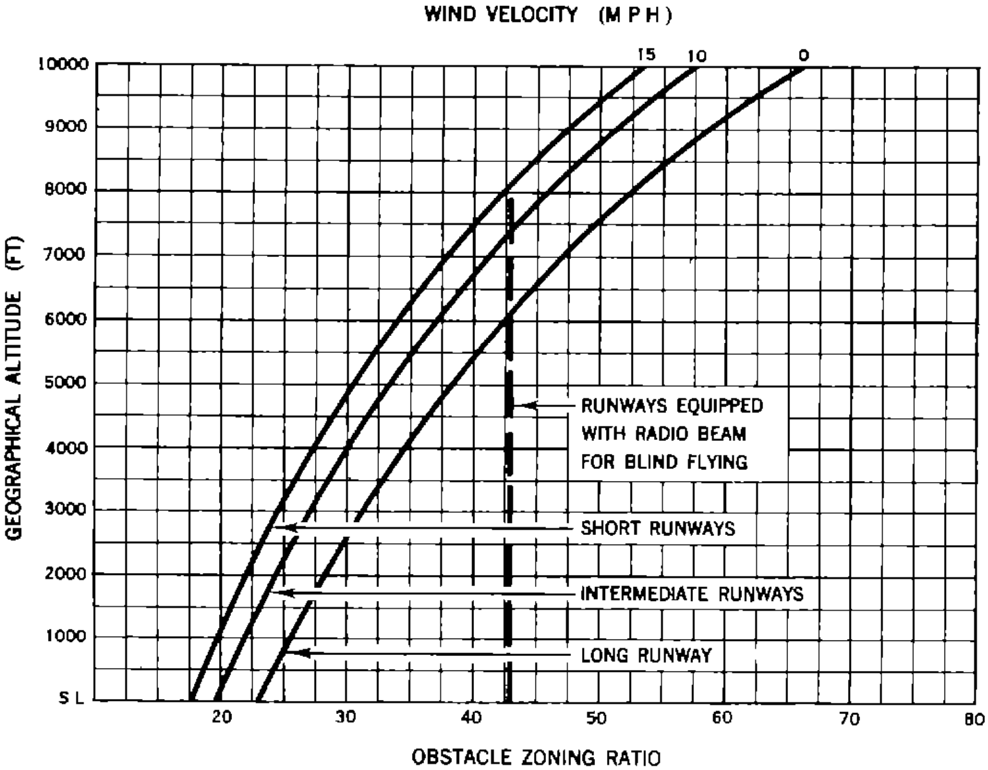
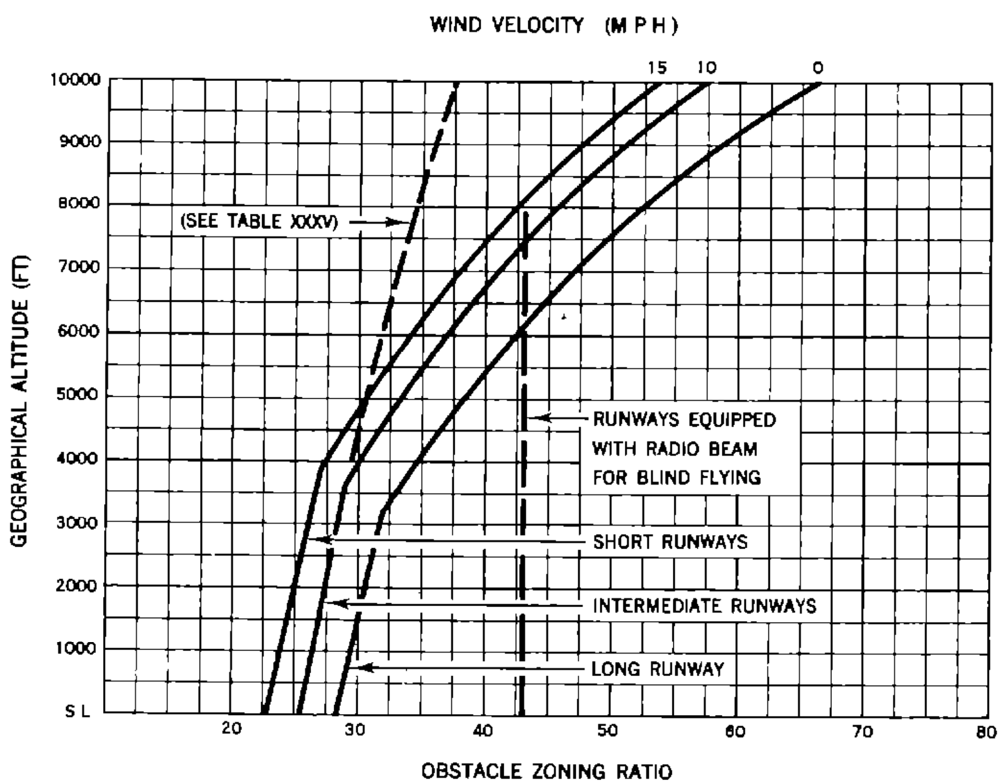


Figure 41 Obstacle Zoning Ratios Versus Altitude



CLASS III

Figure 42 Obstacle Zoning Ratios Versus Altitude



CLASS IV

Figure 43 Obstacle Zoning Ratios Versus Altitude

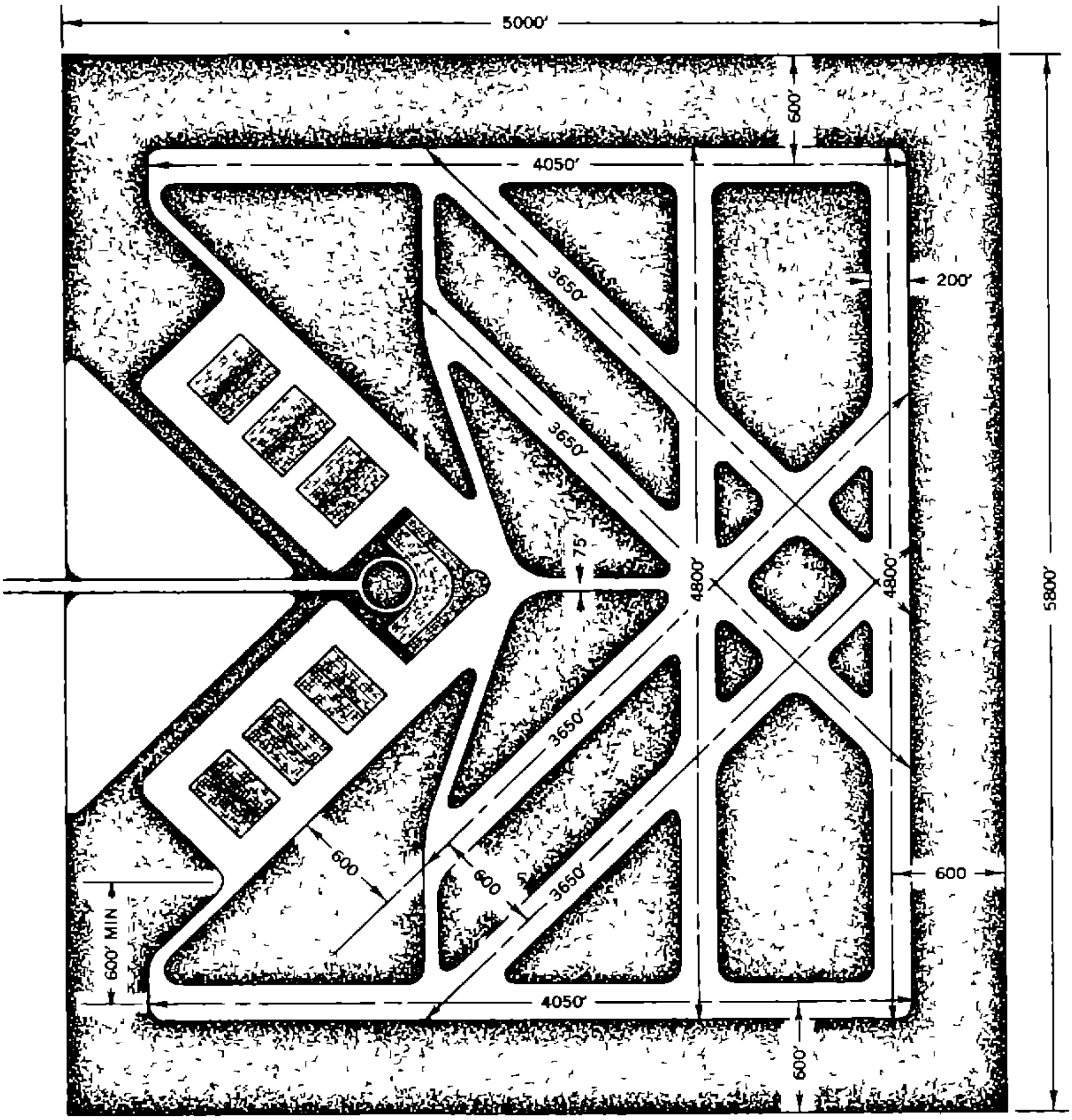


Figure 44 Illustration of Possible Arrangement of a Class IV Airport at Sea Level, With Runway Lengths Modified by Considerations of Wind Speeds

APPENDIX NO 1

DISCUSSION OF CORRECTIONS TO THE OBSERVED PERFORMANCE DATA

Discussion of Corrections Applied to the Observed Performance Data

The photographic records of each take-off and landing have been corrected to zero wind velocity and to specification gross weight. These corrections have been applied to speeds and distances traveled both on the ground and in the air

An accurate determination of the wind velocity actually encountered by the airplanes while taking off or landing is practically impossible because of gusty and shifting wind conditions The wind velocity data included in this study were obtained through the use of an anemometer set at one side of the runway near the take-off and landing points

Since there was no reasonable method for obtaining actual data concerning increases in velocity with height, it was necessary to refer to N A C A Report No 626, "The Transition Phase in the Take-Off of an Airplane" This report includes experimental data obtained at Langley Field, Virginia, which indicate that the variation of wind velocity with the height above the ground may be determined from the following expressions

$$\frac{V_W}{V_{WO}} = \left(\frac{H}{H_O}\right)^{\frac{1}{7}}$$

where

V_W = Wind speed at any height (H)

V_{WO} = Wind speed close to the ground or at a height (H_O)

H = Height at which (V_W) is realized

H_O = Height of anemometer

From the above it was possible to plot a curve of (V_W / V_{WO}) against height (H) This is shown on figure 24, and gives the wind velocity at any height up to 260 feet when the wind velocity at the ground is known The use of this curve in conjunction with the anemometer readings described above results in only rough approximations of the actual conditions It is reasonably adequate, however, and is applicable to all airports at all elevations Using the curve of (V_W / V_{WO}) as a basis, it was possible to obtain a second curve which is designated in figure 24 as (V_{WM} / V_{WO}) For any height (H) this curve may be used to obtain the mean wind velocity that was encountered by the airplane in climbing to that height or in gliding down from that height

The two curves shown in figure 24, together with the anemometer readings, are used to correct observed air-borne distances to zero wind velocity The following observed characteristics may be corrected through application of the anemometer readings:

Distance from start to unstick
Unstick speed
Contact speed
Landing ground roll distance

The effect of wind on unstick and landing ground roll distances is determined through the use of the curve shown on page 440 of the revised edition of "Engineering Aerodynamics" by Commander Walter S Diehl This curve has been redrawn in figure 25, and shows the variations of (R_W / R_O) with (V_{WO} / V_U), where (R_W / R_O) is the ratio of the ground run in wind velocity (V_{WO}) to the ground run in a calm, and (V_{WO} / V_U) is the ratio of the wind velocity (as determined from the anemometer reading) to the air speed of the airplane at unstick For landings, the contact speed is used instead of the unstick speed

The corrections of the pertinent take-off and landing characteristics to zero wind velocity finally are accomplished as follows:

(a) Air speed at unstick (V_U)

The air speed at unstick is the sum of the airplane speed obtained through analysis of the camera records plus the component of the wind speed parallel to the flight direction

(b) Air speed at contact (V_c)
Determined same as unstick speed
(c) Distance from start to unstick
Obtained through use of figure 25, as previously explained
(d) Distance from contact to stop
Obtained through use of figure 25, as previously explained.
(e) Air-borne distances

The observed air-borne distances, both in take-offs and landings are corrected to zero wind velocity by the addition of a distance (ΔD), which is obtained by multiplying the mean wind velocity encountered by the airplane (V_{wm}) by the air-borne time (t) as determined from the photographic space-time records

Thus, $D_o = D_w + V_{wm} \times t$

Where,
D_o = air-borne distance in a calm
D_w = air-borne distance in wind
V_{wm} = mean wind speed encountered by the airplane
t = air-borne time

Correction to specification gross weight will be considered next In the take-off, both the unstick distance and the air-borne distance are corrected to specification gross weight in accordance with equation No 328 (p 439) of Commander Diehl's "Engineering Aerodynamics" This equation is as follows:

$$\frac{S_1}{S_2} = F\left(\frac{W_1}{W_2}\right)^2$$

where,
S_1 = Distance at Gross Weight No 1
S_2 = Distance at Gross Weight No 2
W_1 = Gross Weight No 1
W_2 = Gross Weight No 2
F = Multiplying Factor = 1

As suggested on page 440 of Commander Diehl's book, (F) is assumed equal to unity when the difference between (W_1) and (W_2) is not too great.

In the approach for a landing no correction is made to the air-borne distance for weight This is because the flight path depends only upon the flying attitude or angle of attack of the airplane

In correcting landing ground roll distances to specification gross weight, the assumption is made that the ground roll varies as the square of the contact speed Since the square of the contact speed varies directly with the gross weight of the airplane, the ratios of observed to specification gross weight were applied directly as multiplying factors in the observed ground roll distances to correct them to specification gross weight. Speeds will vary as the square root of the weight ratio.

The specification gross weight for each airplane included in this study is listed on line 1 of table 7

APPENDIX NO 2

DISCUSSION OF COMPUTED PERFORMANCE DATA

Discussion of Computed Performance Data

This section is devoted to the derivation and justification of the methods employed in the computation of the values listed in table 7 of this report

Distance from Start to Unstick

A method for the precise determination of the distance required to attain any velocity on the ground may be derived from the fundamental relationship:

where,

$$s = \frac{v^2}{2a} = v^2\left(\frac{1}{2a}\right)$$

where,

s = Distance in feet
v = Velocity in feet per second
a = Acceleration in feet per second per second

The computation may be facilitated considerably by the assumption that the acceleration is inversely proportional to the square of the velocity. The validity of this assumption has been established by flight test data Such substantiation permits an average value of the reciprocal of the acceleration to be expressed by,

$$\frac{1}{a} = \frac{W}{Fg} = \frac{W}{2g}\left(\frac{F_1 + F_2}{F_1 F_2}\right)$$

where,

$\frac{W}{g}$ = Mass = $\frac{\text{Gross Weight}}{32.2}$
F_1 = Initial accelerating force
F_2 = Final accelerating force

Substitution of this average value in the basic expression obtains:

$$S = \frac{v^2}{2a} = \frac{V^2 W}{4g}\left(\frac{F_1 + F_2}{F_1 F_2}\right)$$

which may be more conveniently expressed in engineering units by,

$$X_1 = .0167\, V_u^2\, W \left(\frac{F_1 + F_2}{F_1 F_2}\right)$$

where,

X_1 = Unstick distance in feet
V_u = Unstick speed in m.p h.
W = Gross weight in pounds
F_1 = Initial net force
F_2 = Final net force

The accelerating forces (F_1) and (F_2) are obtained on the following assumptions: When the airplane is at rest it may be assumed that the only resistance to forward motion is due to the weight of the airplane and the texture of the surface on which it rests. Hence, the accelerating force at the instantaneous origin of motion must equal the difference between the initial or static thrust and the rolling traction This is mathematically expressed as follows:

$$F_1 = T_1 - \mu W$$

where,

F_1 = Initial net force
T_1 = Initial or static thrust
μ = Traction coefficient = .03 assumed
W = Gross Weight

By comparative reasoning it is clear that the rolling traction becomes zero and the aerodynamic drag furnishes the entire resistance to forward motion at the instant of unstick This being the case, the net accelerating force at unstick must equal the difference between thrust and drag This is analytically defined as

$$F_2 = T_2 - \frac{W}{L/D}$$

where

F_2 = Final net force
T_2 = Final thrust
L/D = Ratio of lift to drag

The thrust is computed as follows:

<u>Computation of Thrust</u>

The variation of thrust with velocity throughout the normal range of velocities for take-off and climb is expressed by an empirical equation which is in good agreement with figure 2-II of the Aircraft Engineering Report No 103, and figure 154 of Diehl's "Engineering Aerodynamics" (revised edition) The expression is as follows:

$$T = \frac{375\ THP}{AV_m + CV} = \text{Thrust in lbs}$$

The application of this formula requires a knowledge of the following data

THP = Maximum Thrust Horsepower available for take-off
BHP_t = Maximum Brake Horsepower available for take-off.
η = Propeller efficiency
V_m = Maximum velocity
V = Any velocity
A = .3 for controllable propellers
A = .5 for fixed pitch propellers
C = .6 for controllable propellers
C = 5 for fixed pitch propellers

Since (V) is zero for the initial or static condition and equal to unstick speed at the instant of unstick it follows that,

$$T_1 = \frac{375 \; THP}{A \; V_m}$$

and

$$T_2 = \frac{375 \; THP}{AV_m + CV_u}$$

The evaluation of thrust involves the propeller efficiency which may be obtained as follows:

Propeller Efficiency

An analysis of the existing N.A C A propeller data yields the following general formulas for the computation of maximum propeller efficiency:

$$\eta = K_S / (.197 + 1\;124 \; K_S)$$

for propellers with two blades, and

$$\eta = K_S / (20 + 1\;16 \; K_S)$$

for three-bladed propellers.
In these equations the propeller constant,

$$K_S = \frac{325 \; V_m}{RPM} \left(\frac{V_m^{\;3}}{BHP}\right)^{\frac{1}{2}}$$

Efficiencies thus obtained are in general agreement with those recommended by Commander Walter S Diehl in figures 148 and 151 of his "Engineering Aerodynamics" (revised).

In the application of the above expression for propeller efficiency, a knowledge of the maximum speed of the airplane is required In general, this must be obtained by reference to standard compilations of performance data While it is generally conceded that such data are unreliable, they nevertheless are sufficiently accurate for the purpose of computations relative to take-off and climb characteristics In the subsequent calculation of parasite drag, for example, it can be demonstrated that a positive error of ten percent in the estimation of maximum speed, while resulting in a considerably optimistic value of parasite drag coefficient, also will produce a reduction in the horsepower available at velocities in the proximity of take-off and climb The net error in the computation of these two latter quantities, other things being equal, will not exceed five percent It should be noted that this represents an extreme case In general, it is believed that the computed values are within three percent of accuracy.

The computation of parasite drag coefficient proceeds as follows:

Parasite Drag Coefficient

In the computation of the minimum parasite (including profile) drag coefficient, the simplifying assumption that induced drag is a constant percentage of parasite drag at maximum velocity is resorted to This permits the following process of derivation:

$$\text{Drag} = D = 00256 \; (C_{D_i} + C_{D_p}) \; SV^2$$

where C_{D_i} = Induced drag coefficient

C_{D_p} = Parasite drag coefficient

$C_{D_i} = KC_{D_p}$ at V_{max}

hence, $D = .00256(KC_{D_p} + C_{D_p})SV^2$

or

then,

since

$$D = KC_{D_P} SV^2$$

$$BHP\,\eta = \frac{DV}{375} = KC_{D_P} SV_m^3$$

$$C_{D_P} = \frac{K\,BHP\,\eta}{SV_m^3}$$

Empirical evaluation of the constant (K) by application of known performance indicates good accuracy when the above formula is expressed as,

$$C_{D_P} = \frac{133000\ BHP\,\eta}{SV_m^3}$$

This is in substantial agreement with equation 3:2 of N A.C A Report No 408 and equation (28) of N A.C A Technical Memorandum No. 456

It is believed to be sufficiently accurate for the purpose of this discussion to assume that the parasite drag coefficient with chassis extended is of the following order:

$$C_{D_{P_1}} = 1\ 5\ C_{D_P} = C_{D_P} \text{ with gear extended.}$$

$$C_{D_{P_2}} = \frac{133000\ BHP\,\eta}{SV_m^3} = C_{D_P} \text{ with gear retracted.}$$

The foregoing assumption may be substantiated by reference to Manual 04, Civil Aeronautics Administration, February 1, 1941, figure 6 The variation of parasite drag with angle of attack is expressed as a function of the square of the lift coefficient by application of Diehl's conception of an effective aspect ratio defined as:

$$R = \frac{N}{1 + 2NC_{D_P}}$$

where

R = Effective aspect ratio

N = Geometric aspect ratio = B^2 / S

B = Span

S = Wing area

C_{D_P} = Parasite drag coefficient

The effective aspect ratio is used in the following computation of lift drag ratio:

Maximum Ratio of Lift to Drag

The proximity of the ground during take-off generally is conceded to result in a marked reduction in induced drag The magnitude of such reduction is incapable of exact analytical expression, but may be closely approximated by the assumption that the maximum ratio of lift to drag obtains at unstick

Obviously this ratio will be a maximum when its reciprocal is a minimum and expressed as follows:

$$\frac{C_D}{C_L} = \frac{C_{D_P}}{C_L} + \frac{C_L}{\pi R}$$

where C_D = Total drag coefficient.

If the derivative of C_D / C_L with respect to C_L is equated to zero as follows:

$$\frac{d\,(C_D / C_L)}{d\,C_L} = \frac{1}{\pi R} - \frac{C_{D_P}}{C_L^2} = 0$$

it then is obvious that the ratio C_D / C_L will be a minimum when:

$$C_L = \sqrt{\pi R C_{D_P}}$$

$$\text{and when} \quad C_{D_P} = \frac{C_L^2}{\pi R}$$

Hence the maximum ratio of lift to drag is realized when:

$$\frac{L}{D} = \frac{C_L}{C_D} = \sqrt{\frac{\pi R C_{D_P}}{4 C_{D_P}^2}} = \sqrt{\frac{.7854R}{C_{D_P}}}$$

After unstick and during initial climb, the proximity of the ground becomes increasingly less effective in the reduction of induced drag as height is attained. On the other hand, for a rigorous analysis, the increase in velocity after unstick should be accompanied by an increase in effective aspect ratio, and a consequent reduction in induced drag. Hence, it would appear that this combination of factors contributes toward an approximately constant value of lift-drag ratio throughout the extremely limited range of velocities here involved. It is believed that further refinement would but complicate the solution and render the method less applicable to comparative performance studies.

The maximum ratio of lift to drag is the controlling factor in the establishment of approach path ratios since it is conservatively assumed that flaps and similar lift increasing devices might be rendered inoperative. In addition to the possibility of flap failure the possibility of landings under power due to ice formations or other factors must be considered.

Unstick and Contact Speed

The apparent discrepancy between computed and actual landing speeds, in general, is attributed to a combination of ground effect, wing fuselage interference, and so forth. In our effort to derive a method whereby substantial agreement with observed landing speeds might be obtained, recourse was had to the fact that airplanes do land consistently at a reasonably constant percentage of their theoretical velocity for minimum power requirement, (V_{MP}). (V_{MP}) may be derived from the following fundamental expression for drag at any velocity:

$$D = \frac{C_{D_P} S V^2}{391} + \frac{125 W^2}{R S V^2}$$

from which it follows that the power required at any velocity will be:

$$HP = \frac{DV}{371} = \frac{C_{D_P} S V^3}{391 \times 375} + \frac{125\ W^2}{375\ RSV}$$

Differentiating this quantity with respect to velocity and equating it to zero gives:

$$\frac{d\ HP}{d\ V} = \frac{3 C_{D_P}\ SV^2}{391 \times 375} - \frac{125\ W^2}{375\ RSV^2} = 0$$

which may be reduced to:

$$V_{MP} = \left(\frac{16300\ (W/S)^2}{R C_{D_P}}\right)^{\frac{1}{4}}$$

This permits the expression of contact and unstick speeds as functions of V_{MP} as follows:

$$V_c = K_c V_{MP} = \text{Contact speed}$$
$$V_u = K_u V_{MP} = \text{Unstick speed}$$

Empirically derived constants based on the known landing speeds of some fifty airplanes indicate an average conservative relationship between (V_c) and (V_{MP}) expressed as follows:

$$V_c = K_c V_{MP}$$

where K_c = .80 for normal wings
K_c = .70 for plain flaps
K_c = .60 for Fowler flaps

In the application of this method to the computation of minimum unstick speed, it was believed advisable to increase the constants by an appropriate safety factor approximating ten per cent in the case of the normal wing and twenty and thirty percent respectively when ordinary and Fowler flaps are employed The employment of the greater correction in the latter instance is in agreement with observed unstick speeds and indicates that full flap deflections are of limited utility in normal take-off technique The average conservative relationship between (V_u) and (V_{MP}) is then:

$$V_u = K_u V_{MP}$$

$$K_u = 90 \text{ for normal wings}$$
$$K_u = 85 \text{ for plain or split flaps}$$
$$K_u = 80 \text{ for Fowler flaps}$$

Climb Path Characteristics

The complete take-off of an airplane is assumed to include the following three phases distance to unstick, distance for acceleration from unstick speed to climbing speed, and distance from climbing speed to any specified height

The distance required for an airplane to accelerate from unstick speed to a safe climbing speed may be computed with reasonable accuracy by the fundamental formula

$$s = \frac{V_2^2 - V_1^2}{2a}$$

where s = Distance in feet
a = Acceleration in feet per second per second
V_1 = Initial Velocity
V_2 = Final Velocity

Since height attainment with a minimum of required horizontal distance is the controlling factor in take-off technique, it is desirable that climb be initiated at the velocity for minimum power requirement This justifies the following substitutions in the original expression,

$$s = \frac{V_2^2 - V_1^2}{2a} = \frac{V_{MP}^2 - V_u^2}{2a}$$

where $2a = \frac{32\ 2}{W}(F_2 + F_3)$

and $F_3 = T_3 - \frac{W}{L/D}$

The formula may be expressed in engineering units as follows:

$$\Delta X = \frac{067\left(V_{MP}^2 - V_u^2\right)W}{F_2 + F_3}$$

where ΔX = Distance from V_u to V_{MP}

The procedure involved in the evaluation of the net accelerating force (F_3) is analogous to that employed in the determination of (F_2) It is accomplished as follows:

$$F_3 = T_3 - \frac{W}{L/D}$$

$$T_3 = \frac{375\ THP}{AV_M + CV_{MP}}$$

Distance from V_{MP} to Height

The ratio of distance to height is obviously proportional to the corresponding ratio of horizontal velocity to vertical velocity It follows then that,

$$\frac{X_2}{H} = \frac{\text{Velocity}}{\text{Rate of Climb}} = \frac{88V}{RC}\left(\frac{\text{Miles per hour}}{\text{Feet per minute}}\right)$$

$$X_2 = \frac{88VH}{RC} = \text{Distance from } V_{MP} \text{ to } H$$

Then, since

$$RC = \frac{88VF_3}{W}$$

$$X_2 = \frac{HW}{F_3} \text{ as noted}$$

APPENDIX NO 3

RUNWAY LENGTH AND OBSTACLE ZONING REQUIREMENTS AS AFFECTED BY WINDS

Runway Length and Obstacle Zoning Requirements as Affected by Winds

Runway length and obstacle zoning requirements, as listed in the conclusions of this report, involve no consideration of the effect of winds They are based upon dead calm conditions Doctor Edward P Warner has suggested that, in the case of airports having runways in more than one direction, it appears unnecessary to provide for zero wind conditions on all runways In fact, zero wind dimensions need involve but one runway direction, while the dimensional requirements of the remaining cross runways may be reduced to allow for the effect of winds

The following investigation has as its objectives:

- (a) The determination of wind velocities to be used in reducing the dimensional requirements of the cross runways
- (b) Determination of multiplying factors, which may be applied to the main runway dimensions to obtain the reduced values of runway lengths and obstacle zoning ratios for the cross runways
- (c) Application of the foregoing data to actual airport dimensions
- (d) Correlation of observed characteristics with airport dimensions in relation to wind effect
- (e) Consideration of runways having only part of their lengths paved

(a) The Determination of Wind Velocities to be Used in Reducing the Dimensional Requirements of the Cross Runways as Compared with the Zero Wind Runway

The criteria for the safe use of a cross runway, the dimensions of which have been reduced to allow for general wind conditions, involve both the magnitude and direction of the wind velocity as translated into components along and across that cross runway Thus, a given runway should not be used if the longitudinal component is less than the critical wind velocity that was employed in determining its dimensions, nor if the cross component is great enough to seriously affect take-off and landing maneuvers

The first step in establishing these criteria is to decide upon a safe maximum value for the cross wind component The critical velocities then may be determined solely through consideration of the number of runways and the angles that they make with one another

It is felt generally that flight operations tend to become hazardous when the cross wind component exceeds 10 miles per hour If a value of approximately this magnitude is established as maximum, critical wind velocities may be determined as follows:

Regardless of the total number of runways provided, the critical velocity for the cross runway, which is roughly at right angles to the main runway, is determined on the basis that operations will be transferred from the main runway to that cross runway whenever a wind, the direction of which is at 90 to the main runway, attains a velocity in excess of 10 miles per hour The critical velocity for that cross runway, then, may be obtained from the expression,

$$V_c = V_w \times \cos \alpha$$

where

V_c = The critical velocity (component)
V_w = The velocity of the wind across the main runway
α = The angle between the cross runway and the wind direction

This method of analysis is illustrated in figure 26

If V_c = 10 mph and (α) varies between +30° and −30°, (V_w) will vary between 11 6 mph and 10 mph Since a cross wind of 11 6 mph is not excessive, it is believed to be both safe and practical to so dimension the cross runway in question that it may be used whenever its longitudinal wind velocity component is equal to or greater than 10 mph, except that the component across that runway should not greatly exceed 10 miles per hour This assumes that the angle between that cross runway and the main runway is not less than 60°

The method outlined above may be applied to the dimensioning of a two-runway airport. It also applies to the dimensioning of a three-runway airport, with respect to one of the cross runways, again providing that the angle between that cross runway and the main runway is not less than 60° The critical velocity for the second cross runway, however, is determined on a slightly different basis In this case, the critical velocity for the second cross runway is determined on the basis that operations will be transferred from the second cross runway to the nearer of the other two runways whenever a wind, the direction of which is in line with the second cross runway, fails to attain a velocity equal to the critical velocity for the second cross runway (See fig 27) However, the longitudinal and cross components of the wind, with respect to the runway to which operations are to be transferred, must be such that the use of that runway is not hazardous Thus, the longitudinal component at least should be equal to the critical velocity and the cross component should not greatly exceed 10 mph The critical velocity for the second cross runway may be obtained from the expression,

$$V_c = V_n \times \csc \beta \text{ and } V_n = V_c \sin \beta$$

where

V_c = The critical velocity (actual wind velocity)
V_n = Component of (V_c) across runway to which operations are to be transferred (approximately 10 mph)
β = Angle between second cross runway and runway to which operations are to be transferred.

In the case of a three-runway airport a minimum angle between any two runways of 50° could result in a maximum angle of 80° between any two runways Consequently a 20 mile per hour wind which bisected the 80° angle would result in a cross component of 12 9 mph If the bisecting wind never greatly exceeds 20 miles per hour, a minimum angle of 50° would not result in serious cross wind components On the bases outlined above the angle between the second cross runway and the nearest adjacent runway may vary between 50° and 60° An assumed critical velocity of 10 mph for the second cross runway can result in a cross component (V_n) which will vary between 7.7 mph and 8 7 mph Since these values approach 10 mph, it is believed practical to dimension the second cross runway for a critical velocity of 10 mph Thus, for a three-runway airport, both cross runways are dimensioned for a 10 mph critical velocity The angle between the main runway and the first cross runway should not be less than 60° , and the angle between any two runways should not be less than 50°

A four-runway airport can be said to comprise the main runway, the first cross runway (roughly at 90° to the main runway) and a second and third cross runway In this case the method for obtaining the critical velocity for the first cross runway is the same as for a two-runway airport, and the basis for obtaining the critical velocity for either the second or third cross runway is the same as for a three-runway airport In a four-runway airport, a minimum angle between any two runways of 35° could result in a maximum angle of 75° , and a bisecting wind of 20 mph could result in a cross component of 12 2 mph A minimum angle of 35° , therefore is recommended. Such an arrangement limits the angle between the main runway and the first cross runway to a 70° minimum The latter therefore can be dimensioned for a 10 mph critical velocity as previously discussed Using figure 27 as a reference, the critical velocities for the second and third cross runways may be obtained from the expression:

also from figure 27

$$V_c = V_n \times \csc \beta$$
$$V_n = V_c \sin \beta$$

The angle (β) can vary between 35° and 55° so that an assumed critical velocity (V_c) of 15 mph for the second and third cross runways can result in a cross component (V_n) which will vary between 8 6 mph and 12 3 mph Since these values approximate 10 mph, it is believed practical to dimension the second and third cross runways for a critical velocity (V_c) of 15 mph.

Summarizing, the suggested critical velocities for cross runways for all classes of airports are as follows:

For a two-runway airport: one cross runway; critical velocity = 10 mph, minimum angle between cross runway and main runway = 60°

For a three-runway airport: critical velocity for both cross runways = 10 mph, minimum angle between main runway and one of the cross runways = 60°; minimum angle between any two runways = 50°

For a four-runway airport, critical velocity for one cross runway = 10 mph; minimum angle between that runway and the main runway = 70°; critical velocity for remaining two cross runways = 15 mph; minimum angle between any two runways = 35°

It will be noted that in the preceding discussion the meteorological data involving prevailing wind velocities are not considered in determining critical velocities In the case of a four-runway airport it is believed that the prevailing wind direction may be ignored and that the directional orientation of the runways may be arranged best to suit the topography of the airport and surrounding areas, provided of course, that the mutual angularity between runways is in accordance with the suggested minimums. Where less than four runways are provided it would seem advisable to arrange the runways so that at least one cross runway lines up with the prevailing wind direction

It is believed that the foregoing constitutes a practical and safe establishment of critical wind velocities to be used in reducing the dimensional requirements of cross runways so as to realize a maximum saving in total paving length

From consideration of these critical wind velocities multiplying or reduction factors may be determined which can be applied to the dimensions of the main runway to obtain reduced values for the dimensions of the cross runways This is accomplished as follows:

(b) Determination of Reduction Factors

In considering the effect of critical wind velocities upon airport dimensions, it appears desirable to present numerical data in the form of coefficients which may be applied to the requirements for dead calm conditions to obtain the reduced requirements Two factors are involved: (1) runway lengths, and (2) obstacle zoning ratios Reduction factors involving these factors are determined as follows

(1) Runway Lengths As discussed previously in this report, the runway length is the sum of the take-off distance plus the distance required for the airplane to roll to a stop should an engine failure occur at the point of take-off

Both the take-off distance and the landing ground roll distance are corrected for wind in accordance with the curve shown in figure 25 To use this curve for determining the effect of wind upon unstick distances, it first is necessary to determine the ratio of the wind speed to unstick speed, (V_{WO} / V_u) When this value has been obtained, figure 25 may be used to obtain a correction factor which may be applied to the distance required to take off in a dead calm

When using this curve to determine the effect of wind on landing ground roll distance, the ratio of wind speed to contact air speed is the determining factor According to the basic criterion for runway lengths the airplane is brought to rest after having attained unstick speed In effect, this involves a take-off followed by a landing in which the unstick and contact speeds are one and the same Therefore, figure 25 may be used to obtain runway length reduction factors (K_r) when the ratios of wind speeds to unstick speeds have been determined

(2) Obstacle Zoning Ratios As previously discussed in this report, obstacle zoning requirements are expressed as the ratio of horizontal distance from the end of the runway to the obstacle divided by the height of the obstacle above the elevation of the runway Specifically, they are determined from the flight path ratios involving the climb after take-off from 50 to 100 feet height, as expressed by the horizontal distance traveled by the airplane while climbing from 50 to 100 feet divided by 50 Therefore, any reduction in this horizontal distance will result in a proportional reduction in climb path ratio. If this is expressed as a reduction coefficient, it may be applied directly to zero wind obstacle zoning requirements for determining the effect of wind This is accomplished as follows

Obstacle zoning reduction coefficients (K_z) may be determined by evaluating the ratio (D_W / D_O) where (D_W) is the distance traveled while heading into a wind, and (D_O) is the distance traveled in a dead calm Now,

$$D_W = D_O - \Delta D \quad \quad (1)$$

Where (ΔD) is the distance that the airplane in effect was blown back by the wind

$$D = V_{wa} \times t \quad \quad (2)$$

Where (V_{wa}) = the average wind velocity encountered by the airplane in climbing from 50 to 100 feet and (t) is the time required to climb that distance

(Note The use of an average rather than a mean value in this case is believed to be sufficiently accurate)

$$V_{wa} = V_{wo} \times \frac{V_{wa}}{V_{wo}} \qquad (3)$$

Where (V_{wo}) is the wind speed on the ground, such as might be measured with an anemometer

Now,

$$\frac{V_{wa}}{V_{wo}} = \frac{\frac{V_{w50}}{V_{wo}} + \frac{V_{w100}}{V_{wo}}}{2} \qquad (4)$$

Where $\frac{V_{w50}}{V_{wo}}$ is the ratio of the wind speed at 50 feet height to the wind speed on the ground,

And $\frac{V_{w100}}{V_{wo}}$ is the ratio of the wind speed at 100 feet height to the wind speed on the ground

As obtained from the curve in figure 24

$$\frac{V_{w50}}{V_{wo}} = 1\ 410 \text{ and } \frac{V_{w100}}{V_{wo}} = 1\ 545$$

From equation #4 then,

$$\frac{V_{wa}}{V_{wo}} = \frac{1{,}410 + 1\ 545}{2} = 1\ 478$$

And $V_{wa} = V_{wo} \times 1\ 478$ (at the airport elevation) . (5)

The climbing time (t) is not affected by wind and

$$t = \frac{D_o}{V_u \times 1\ 10} \qquad (6)$$

(V_u) is the air speed at the unstick point It is assumed that the average speed between 50 and 100 feet height is 10 percent greater than the unstick speed This assumption is supported by actual records

Numerical Determination of Reduction Factors

In applying the foregoing principles, unstick air speed data are necessary for the numerical determination of runway length and obstacle zoning reduction factors For the purpose of this investigation, these speeds will involve the four classes of airports as defined in the summary of this report, and may be considered as the characteristics of four airplanes, each of which is marginal as concerns the size of the airport in question From line 5 of table 8, it will be seen that for the eight airplanes considered in this study (V_u), at sea level, varies from 47 2 mph to 105 8 mph For each class of airport, the following values of (V_u) will be used to determine the reduction factors:

Class of Airport	V_u *
I	50
II	70
III	90
IV	110

* Sea Level Values

In the above table a high value of (V_u) was assumed in each case so that the resulting values of reduction factors will be slightly on the conservative side

The effect of altitude on (V_u) is determined in the following table 17 In this table the values of (ρ/ρ_o) are obtained from table 12, and a multiplying factor (K_v) is determined Sea level values of (V_u) may be multiplied by (K_v) to obtain (V_u) at various altitudes

By combining the assumed values of (V_u) with the values of (K_v) listed in table 17, and through the use of figure 25, it is possible to determine values for runway length reduction coefficients (K_r) for each class of airport at various altitudes and at various wind velocities This is accomplished in the following table 18, the results of which are plotted in figures 28, 29, 30 and 31

TABLE 17

AIR SPEED vs ALTITUDE FACTOR			
Geog. Altitude H	ρ/ρ_o	$\sqrt{\rho_o/\rho}$	K_v *
0	0 910	1.058	1.000
1,000	0 877	1 061	1.003
2,000	0 846	1 088	1.027
3,000	0.816	1 107	1.056
4,000	0.784	1 129	1.065
5,000	0 756	1 150	1.086
6,000	0 728	1 173	1.109
7,000	0.701	1 195	1.129
8,000	0 674	1 218	1 151
9,000	0.650	1 240	1 172
10,000	0.624	1.265	1 195

* (K_v) is determined as the ratio of $\sqrt{\rho_o/\rho}$ at any geographical altitude to its value at sea level

In the following determination of reduction factors, values are presented for a wide range of wind velocities, rather than for only the 10 mph and 15 mph velocities previously discussed It is felt that this will improve the general utility of the report

By interpolating between curves, figures 28 to 31 inclusive may be used to obtain runway length reduction factors for each class of airport for any altitude up to 10,000 feet and for any wind up to 30 mph.

The determination of obstacle zoning ratio reduction factors (K_z) first involves the determination of the time required (t) to climb from 50 to 100 feet height. This has been accomplished in table 19 in accordance with the principles previously discussed In this table, (V_u), column 2, was obtained from table 18. (Z_o), column 5, was obtained from table 13

Having determined (t) in table 19, (K_z) is determined in table 20 in accordance with the principles previously discussed

The values of (K_z) as listed in table 20 are plotted on figures 32, 33, 34, and 35

The precise plotting of the data listed in the above tables will result in lines having a slight curvature It was considered adequate, however, to plot these as straight lines It will be noted that the airport dimensions resulting from the straight line plots, in general, are slightly conservative as compared to values which would have resulted from a precise plotting

These curves may be used to obtain obstacle zoning ratio reduction factors (K_z) for each class of airport, for any altitude up to 10,000 feet, and for any wind up to 30 miles per hour As previously noted, the values of (K_r) and (K_z) shown in figures 28 to 35 inclusive may be applied to such zero wind requirements as eventually may be determined, even though these may differ from the values recommended in this report

(c) Application of Foregoing Data to Actual Airport Dimensions

In applying the foregoing data involving critical wind velocities and reduction factors to the obtainment of actual airport dimensions, the four classes of airports again will be considered Thus, in the following table 21, critical wind velocities of 0 mph, 10 mph, and 15 mph are included, and for various elevations up to 10,000 feet, the following items are determined

Runway length reduction factor	K_r	Obstacle zoning ratio reduction factor	K_z
Actual runway lengths	R	Actual obstacle zoning ratios	Z

The values of (R) listed in table 21 are plotted in figures 36 to 39 inclusive, and the values of (Z) are plotted in figures 40 to 43 inclusive The use of these curves will give the length of any runway and its obstacle zoning ratio for all four classes of airports and for any elevation up to 10,000 feet

As in figures 22 and 23, the curves of runway lengths versus altitude and of obstacle zoning ratios versus altitude are drawn so that the curves for Class III airports become critical above altitudes where the dimensional requirements for Class III airports become more restrictive than those for Class IV airports As in figure 23, the flight paths involving an instrument landing system are unaffected either by wind velocity or altitude and a ratio of 43 is indicated

VARIATION OF RUNWAY WIND REDUCTION FACTOR (K_r) WITH GEOGRAPHICAL ALTITUDE, WITH WIND VELOCITY AND FOR AIRPORTS CLASS I TO IV INCLUSIVE

TABLE 18

GEOG ALT FT	K_v	FOR CLASS I AIRPORTS							FOR CLASS II AIRPORTS						
		V_u	V_{wo}/V_u and K_r						V_u	V_{wo}/V_u and K_r					
			V_{wo} = 5	= 10	= 15	= 20	= 25	= 30		V_{wo} = 5	= 10	= 15	= 20	= 25	= 30
S L	1.000	50.0	0.100 0.825	0.200 0.667	0.300 0.524	0.400 0.395	0.500 0.284	0.600 0.194	70.0	0.071 0.872	0.143 0.751	0.214 0.644	0.286 0.540	0.357 0.448	0.429 0.361
3000	1.056	52.8	0.095 0.834	0.189 0.681	0.284 0.544	0.378 0.420	0.474 0.311	0.568 0.222	73.9	0.068 0.880	0.135 0.765	0.203 0.660	0.271 0.562	0.338 0.470	0.406 0.388
5000	1.086	54.3	0.092 0.838	0.184 0.691	0.276 0.555	0.368 0.435	0.460 0.325	0.552 0.235	76.0	0.066 0.883	0.132 0.770	0.198 0.672	0.263 0.571	0.329 0.487	0.395 0.400
7000	1.129	56.4	0.089 0.842	0.177 0.701	0.266 0.568	0.354 0.452	0.443 0.347	0.532 0.255	78.9	0.063 0.887	0.127 0.780	0.190 0.680	0.253 0.587	0.317 0.498	0.380 0.417
10,000	1.195	59.7	0.084 0.851	0.168 0.715	0.251 0.590	0.335 0.475	0.419 0.372	0.503 0.282	83.6	0.060 0.892	0.120 0.795	0.180 0.696	0.239 0.609	0.299 0.525	0.359 0.445
		FOR CLASS III AIRPORTS							FOR CLASS IV AIRPORTS						
S L	1.000	90.0	0.056 0.900	0.111 0.805	0.167 0.720	0.222 0.634	0.278 0.552	0.334 0.476	110.0	0.045 0.919	0.091 0.839	0.136 0.763	0.182 0.693	0.227 0.628	0.273 0.561
3000	1.056	95.0	0.053 0.902	0.105 0.815	0.158 0.731	0.211 0.650	0.263 0.572	0.316 0.500	116.2	0.043 0.920	0.086 0.850	0.129 0.775	0.172 0.708	0.215 0.642	0.258 0.581
5000	1.086	97.6	0.051 0.907	0.103 0.820	0.154 0.739	0.205 0.658	0.256 0.583	0.308 0.515	119.4	0.042 0.921	0.084 0.854	0.127 0.780	0.168 0.717	0.209 0.652	0.251 0.591
7000	1.129	101.4	0.049 0.910	0.099 0.829	0.148 0.746	0.197 0.671	0.247 0.599	0.296 0.530	124.1	0.040 0.923	0.081 0.858	0.121 0.790	0.161 0.725	0.201 0.665	0.242 0.604
10,000	1.195	107.5	0.046 0.914	0.093 0.837	0.140 0.756	0.186 0.690	0.233 0.619	0.279 0.553	131.5	0.038 0.928	0.076 0.866	0.114 0.800	0.152 0.740	0.190 0.680	0.288 0.625

NOTE:

(K_v) was obtained from Table 17 (Page 78)
(V_u) at sea level was obtained from page 77
(K_r) was obtained from Fig 25 (Page 56)

TABLE 19

DETERMINATION OF TIME (t) TO CLIMB FROM 50' TO 100'							
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Class of Airport	V_u M P H	V_u F P S (2) x 1.467	V_u between 50' x 100' (3) x 1.10	Z_o (Zoning Ratio at Zero Wind)	D_o (Zero Wind 50' to 100') (5) x 50	t (6)/(4)	t Assumed
ALTITUDE - SEA LEVEL							
I	50	73.3	80.6	13.0	650	8.0	8.0
II	70	102.6	112.9	18.0	900	8.0	
III	90	132.0	145.0	23.0	1150	7.9	
IV	110	161.2	177.3	28.0	1400	7.9	
ALTITUDE - 3000 Feet							
I	52.8	77.4	85.0	17.6	880	10.3	10.0
II	73.9	108.3	119.2	24.3	1215	10.2	
III	95.0	139.2	153.0	31.1	1555	10.2	
IV	116.2	170.6	187.5	31.6 *	1580 *	8.4 *	8.5 *
ALTITUDE - 5000 Feet							
I	54.3	79.6	87.7	21.6	1080	12.3	12.0
II	76.0	111.5	122.5	29.9	1495	12.2	
III	97.6	143.3	157.8	38.2	1910	12.1	
IV	119.4	175.0	192.2	34.3 *	1715 *	8.9 *	8.5 *
ALTITUDE - 7000 Feet							
I	56.4	82.7	90.9	26.6	1330	14.5	14.5
II	78.9	115.5	127.0	36.9	1845	14.5	
III	101.4	149.0	163.9	47.1	2355	14.4	
IV	124.1	182.0	200.0	37.2 *	1860 *	9.3 *	9.0 *
ALTITUDE - 10,000 Feet							
I	59.7	87.5	96.3	37.2	1860	19.3	19.0
II	83.6	122.5	135.0	51.5	2575	19.1	
III	107.5	157.8	173.5	65.8	3290	18.9	
IV	131.5	192.9	212.0 *	42.1 *	2105 *	10.0 *	10.0 *

* Involves assumption that airplanes using Class IV airports are supercharged

Values of V_u were obtained from Table 18 (Page 79)

Values of Z_o were obtained from Table 13 (Page 32)

At 10,000 feet elevation - $1/K_{DP}$ = (Unsupercharged 2.860; (Supercharged 1.505

DETERMINATION OF OBSTACLE ZONING RATIO REDUCTION FACTORS

TABLE 20

V_{WO} (M P H)	0	5	10	15	20	25	30
(F P S) $V_{WA} = V_{WO}$ x 1 467 x 1 478*	0	10 9	21 8	32 7	43 7	54 5	65 5
Alt & Time**	Alt = S L t(I-IV) = 8 0						
V_{WA} x t = Δ D (I-III)	0	87	174	262	350	436	523
V_{WA} x t = Δ D (IV)	0	87	174	262	350	436	523
D_W (Class I)	650	563	476	388	300	214	127
D_W (Class II)	900	813	726	638	550	464	377
D_W (Class III)	1150	1063	976	888	800	714	627
D_W (Class IV)	1400	1313	1226	1138	1050	964	877
K_Z (Class I)	1 000	0 867	0 733	0 597	0 462	0 329	0 195
K_Z (Class II)	1 000	0 905	0 807	0 708	0 611	0 516	0 418
K_Z (Class III)	1 000	0 925	0 848	0 771	0 695	0 620	0 545
K_Z (Class IV)	1 000	0 938	0 877	0 813	0 750	0 688	0 627
Alt & Time	Alt = 3000 Ft t(I-III) = 10 0 t(IV) = 8 5						
V_{WA} x t = Δ D (I-III)	0	109	218	327	437	545	655
V_{WA} x t = Δ D (IV)	0	93	185	278	371	462	555
D_W (Class I)	880	771	662	553	443	335	225
D_W (Class II)	1215	1106	997	888	778	670	560
D_W (Class III)	1555	1446	1337	1228	1118	1010	900
D_W (Class IV)	1580	1487	1395	1302	1209	1118	1025
K_Z (Class I)	1 000	0 876	0 751	0 627	0 502	0 380	0 255
K_Z (Class II)	1 000	0 910	0 819	0 729	0 639	0 550	0 460
K_Z (Class III)	1 000	0 929	0 860	0 789	0 718	0 650	0 578
K_Z (Class IV)	1 000	0 940	0 882	0 825	0 764	0 707	0 649

V_{WO} (M P H)	0	5	10	15	20	25	30
(F P S) $V_{WA} = V_{WO}$ x 1 467 x 1 478*	0	10 9	21 8	32 7	43 7	54 5	65 5
Alt & Time**	Alt = 5000 Ft t(I-III) = 12 0 t(IV) = 9 0						
V_{WA} x t = Δ D (I-III)	0	131	262	392	525	655	787
V_{WA} x t = Δ D (IV)	0	98	196	294	393	490	590
D_W (Class I)	1080	949	818	688	555	425	293
D_W (Class II)	1495	1364	1233	1103	970	840	708
D_W (Class III)	1910	1779	1648	1518	1385	1255	1123
D_W (Class IV)	1725	1627	1529	1431	1332	1235	1135
K_Z (Class I)	1 000	0 878	0 758	0 636	0 514	0 394	0 271
K_Z (Class II)	1 000	0 913	0 825	0 739	0 649	0 561	0 474
K_Z (Class III)	1 000	0 931	0 861	0 793	0 725	0 656	0 588
K_Z (Class IV)	1 000	0 943	0 885	0 830	0 772	0 715	0 658
Alt & Time	Alt = 7000 Ft t(I-III) = 14 5 t(IV) = 9 5						
V_{WA} x t = Δ D (I-III)	0	158	316	474	634	790	950
V_{WA} x t = Δ D (IV)	0	104	207	311	415	517	622
D_W (Class I)	1330	1172	1014	856	696	540	380
D_W (Class II)	1845	1687	1529	1371	1211	1055	895
D_W (Class III)	2355	2197	2039	1881	1721	1565	1405
D_W (Class IV)	1860	1756	1653	1549	1445	1343	1238
K_Z (Class I)	1 000	0 881	0 761	0 643	0 523	0 405	0 287
K_Z (Class II)	1 000	0 915	0 827	0 744	0 657	0 571	0 485
K_Z (Class III)	1 000	0 934	0 866	0 799	0 730	0 664	0 596
K_Z (Class IV)	1 000	0 944	0 889	0 831	0 776	0 723	0 665

V_{WO} (M P H)	0	5	10	15	20	25	30
(F P S) $V_{WA} = V_{WO}$ x 1 467 x 1 478*	0	10 9	21 8	32 7	43 7	54 5	65 5
Alt & Time**	Alt = 10,000 Ft t(I-III) = 19 0 t(IV) = 10 0						
V_{WA} x t = Δ D (I-III)	0	207	415	621	831	1035	1245
V_{WA} x t = Δ D (IV)	0	109	218	327	437	545	655
D_W (Class I)	1860	1653	1445	1239	1029	825	615
D_W (Class II)	2575	2368	2160	1954	1744	1540	1330
D_W (Class III)	3290	3083	2875	2669	2459	2255	2045
D_W (Class IV)	2105	1996	1887	1778	1668	1560	1450
K_Z (Class I)	1 000	0 890	0 775	0 664	0 551	0 442	0 330
K_Z (Class II)	1 000	0 921	0 839	0 760	0 678	0 598	0 516
K_Z (Class III)	1 000	0 937	0 873	0 811	0 748	0 685	0 622
K_Z (Class IV)	1 000	0 947	0 895	0 842	0 791	0 740	0 688

* See Page 77
** See Table 19

(D_W) at wind speeds is determined by subtracting (Δ D) from (D_W) at zero wind speed

(K_Z) is determined by dividing (D_W) at each wind speed by (D_W) at zero wind speed wherever radio instrument landing systems are involved, except that the ratio indicated by the curves should be provided if it exceeds the ratio of 43 mentioned above

To illustrate further the application of the foregoing data, figure 44 is a sketch of a hypothetical Class IV airport located at sea level and having four pairs of dual runways at 45° to one another The dimensions noted on this sketch are obtained from figure 39 Thus, the zero wind runway is 4,800 feet long The boundaries of the airport are moved out so that the fence is 600 feet away from the center lines of the runways and a distance of 600 feet between the center lines of the runways is shown This is in accordance with the suggestions set forth under conclusions Obstacle zoning ratios, which start from the ends of the runways, should be obtained from figure 43 These would be 28 0, 25 5, and 23 0 respectively

The total paving length as indicated by figure 44 is as follows

$$4{,}800 \times 2 + 3{,}650 \times 4 + 4{,}050 \times 2 = 32{,}300 \text{ feet}$$

If no account were taken of the possible reduction of runway lengths due to winds, the total paving length would be

$$4{,}800 \times 8 = 38{,}400 \text{ feet}$$

Assuming no change in the length of the taxi strips and assuming a runway paving width of 200 feet and a paving cost of $1 50 per square yard, the consideration of the effect of wind on runway lengths would result in a saving of

$$(38{,}400 - 32{,}300) \times \frac{200}{9} \times \$1\ 50 = \$203{,}300$$

(d) Correlation of Observed Characteristics with Airport Dimensions in relation to Wind Effect

It is possible to correlate the observed performance characteristics of any airplane with any airport relative to the effect of wind upon runway length and obstacle zoning ratio requirements, provided adequate data are available

An example of such correlation is presented in table 22 involving Airplane (H), the airports at Burbank, California, Salt Lake City, Utah, and Cheyenne, Wyoming, and involving a critical wind speed (V_{WO}) = 10 mph Table 22 also shows a comparison of the values of runway lengths (R) and obstacle zoning ratios (Z) as obtained for Airplane (H) through correlation of observed characteristics with actual airports, as against values obtained for Class IV airports in figure 39 and figure 42 Airplane (H) has characteristics that are nearly marginal as concerns Class IV airports The percentage differences (lines 15 and 18) indicate that the method used to determine requirements for all four classes of airports, considering the effect of wind, is reasonable and that the results so obtained are in fair agreement with results obtained by a correlation of observed performance data with actual airports

(e) Consideration of Runways Having Only Part of Their Lengths Paved

As previously discussed, the general standard or criterion for the length of any runway involves the distance from start to unstick plus a reserve length to permit the airplane to roll safely to a stop in the event of an engine failure during the take-off at the point where the wheels are just leaving the ground

In view of this, it would appear unnecessary to provide more than enough paved runway to accommodate the airplane while it is rolling on the ground, so long as the surface of the reserve portion is not so rough as to cause the airplane to nose over before it comes to a stop.

With such an arrangement, the take-off would be started from one end of the paved portion and the airplane would normally leave the ground before running off of the pavement The unpaved portion would not be used except in an emergency due to engine failure.

This arrangement would result in an appreciable saving in paving costs, but would necessitate the provision of an emergency strip at both ends of the pavement, since take-offs would be made in both directions; and this in turn would result in a total length greater than that indicated by the basic length criterion and would be practical only when plenty of suitable land was available

Where runway lengths cannot be extended beyond the minimum criterion values because of geographical or other limitations, full length paving must be provided to accommodate take-offs in both directions

The partial pavement arrangement may offer distinct advantages in some localities

DETERMINATION OF RUNWAY LENGTHS (R) AND OBSTACLE ZONING RATIOS (Z),
AS AFFECTED BY WIND AND ALTITUDE, AIRPORTS-CLASSES I TO IV INCLUSIVE

TABLE 21

GEOG ALTITUDE FEET	ITEM	K_R = Runway Reduction Coefficient, K_Z = Obstacle Zoning Ratio Reduction Coefficient											
		CLASS I			CLASS II			CLASS III			CLASS IV		
	K_R	V_{WO} = 0	V_{WO} = 10	V_{WO} = 15	V_{WO} = 0	V_{WO} = 10	V_{WO} = 15	V_{WO} = 0	V_{WO} = 10	V_{WO} = 15	V_{WO} = 0	V_{WO} = 10	V_{WO} = 15
S L	K_R	1 000	0 667	0 524	1 000	0 751	0 644	1 000	0 805	0 720	1 000	0 839	0 763
	K_Z	1 000	0 733	0 597	1 000	0 807	0 708	1 000	0 848	0 771	1 000	0 877	0 813
	R	1800	1200	943	2800	2104	1800	3800	3060	2735	4800	4020	3660
	Z	13 0	9 5	7 8	18 0	14 5	12 7	23 0	19 5	17 7	28 0	25 6	22 7
3000	K_R	1 000	0 681	0 544	1.000	0 765	0 660	1 000	0 815	0 731	1 000	0 850	0 775
	K_Z	1 000	0 751	0 627	1 000	0 819	0 729	1 000	0 860	0 789	1 000	0 882	0 825
	R	2182	1486	1186	3394	2600	2240	4606	3755	3370	5381	4570	4170
	Z	17 6	13 2	11 2	24 3	19 9	17 7	31 1	26 8	24 5	31 6	27 9	26 0
5000	K_R	1 000	0 691	0 555	1 000	0 770	0 672	1 000	0 820	0 739	1 000	0 854	0 780
	K_Z	1 000	0 758	0 636	1 000	0 825	0 739	1 000	0 861	0 793	1 000	0 885	0 830
	R	2506	1733	1391	3898	3000	2620	5290	4330	3910	5818	4970	4535
	Z	21 6	16 4	13 8	29 9	24 6	22 0	38 2	33 8	31 0	34 3*	30.4*	28 5*
7000	K_R	1 000	0 701	0 568	1 000	0 780	0 680	1 000	0 829	0 746	1 000	0 858	0 790
	K_Z	1 000	0 761	0 643	1 000	0 827	0 744	1 000	0 866	0 799	1 000	0 899	0 831
	R	2893	2028	1643	4500	3510	3060	6107	5065	4560	6298	5400	4975
	Z	26 6	20 2	17 1	36 9	30 5	27 4	47 1	40 8	37 6	37 2*	33 0*	31 0*
10,000	K_R	1 000	0 715	0 590	1 000	0 795	0 696	1 000	0 837	0 756	1 000	0 866	0 800
	K_Z	1 000	0 775	0 664	1 000	0 839	0 760	1 000	0 873	0 811	1 000	0 895	0 842
	R	3665	2625	2165	5701	4530	3970	7737	6470	5850	7099*	6150*	5675*
	Z	37 2	28 8	24 7	51 5	43 1	39 2	65 8	57 5	53 4	42 1*	37.7*	35 4*

NOTE

Values for (K_R) are obtained from Figs 28 to 31 inclusive

Values for (K_Z) are obtained from Figs 32 to 35 inclusive

Values of (R) and (Z) for zero wind velocity were obtained from Table 13

*Runway length and obstacle zoning requirements for Classes I, II, & III airports are based upon the use of unsupercharged engines while for Class IV airports the use of supercharged engines is assumed

CORRELATION OF OBSERVED NORMAL PERFORMANCE CHARACTERISTICS WITH AIRPORT SIZE INVOLVING AIRPLANE (H) AND A 10 M P H WIND VELOCITY

TABLE 22

V_{wo} = 10 M P H
V_{wa} = 10 x 1 467 x 1 478 = 21 7 F P S (See Page 77)

LINE NO	GEOGRAPHICAL ALTITUDE (Fig 20)	695	4220	6145
1	(V_u) Unstick Speed (M P H)	98 7	107 3	110 3
2	(R_o) = Required Runway Length (Zero-Wind)	4730	5710	5940
3	(Z_o) = Obst Zoning Ratio (Zero-Wind)	28 0	33 0	35 2
4	(D_o) Dist While Climbing From 50' to 100'	1400	1650	1760
5	V_{wo}/V_u = 10/Line #1	0 102	0 093	0 090
6	K_R (From Fig 25)	0 82	0 83	0 84
7	Runway Length, (R_{10}) = (Line #2) x (Line #6)	3880	4750	4980
8	V_u x 1 10 x 1 467 (F P S)	159	173	178
9	(t) = (Line #4)/(Line #8)	8 8	9 5	9 9
10	(ΔD) = 21 7 x t	191	206	215
11	D_{10} = D_o - Δ D	1209	1444	1545
12	Z_{10} = $D_{10}/50$	24 2	28 9	30 9
	COMPARING VALUES FOR AIRPLANE (H) WITH VALUES FOR CLASS IV AIRPORTS (See Figs 38 and 42)			
13	R_{10} (Class IV) (Fig 39)	4150	4810	5200
14	Difference = (Line #13) - (Line #7)	270	60	220
15	Percentage Diff = (Line #14 /)/(Line #7)	7 0	1 3%	4 4%
16	Z_{10} (Class IV) (Fig 43)	26 0	29 6*	32 0*
17	Difference = (Line #16)-(Line #12)	1 8	0 7	1 1
18	Percentage Diff = (Line #17)/(Line #12)	7 5%	2 3%	3 6%

NOTE:

*From dotted extension of 10 M P H wind curve (Fig 43) (Airplane (H) is supercharged)

The values listed in lines #1 to #4 inclusive were obtained from Table 14.

The airports and elevations involved in this correlation are Burbank, California, at 695 ft , Salt Lake City, Utah, at 4220 ft ; and Cheyenne, Wyoming, at 6145 ft

Quantitative values of such length requirements, therefore, are determined as follows

It is believed that the pavement should accommodate landing ground rolls as well as take-off runs From inspection of figure 21, it will be seen that for blind landings the ground roll requires approximately 60 percent of the basic runway length Take-off distances are less critical If it is assumed that only 60 percent of the basic criterion runway length need be paved, it will be necessary to provide emergency strips at both ends of the pavement, the lengths of which are 40 percent of the criterion length Thus, the total of the pavement length plus the lengths of the two emergency strips becomes 140 percent of the criterion length

Obstacle zoning would start at the ends of the emergency strips

APPENDIX NO 4

Tabulations of:

ACCIDENT DATA
PERFORMANCE DATA
METEOROLOGICAL DATA

SUMMARY OF TAKE-OFF ACCIDENTS INVOLVING AIRLINE AIRPLANES

TABLE 23

No.	Place and Year	Aircraft Type	No Eng & Total H P (Take Off)	Damage to Airplane	Remarks	Injuries * A	B	C	D
1	Milwaukee, Wisconsin 1934	12 PCLM	2 - 900	Washout	This night take off accident was caused by the misfunctioning of the fuel gage which indicated that the L H tank was one-half full The pilot took off with the selector valve on the L H tank. After attaining a height of about 30 ft and after having switched off the landing lights the L H engine stopped Just after the selector valve had been turned to "BOTH ON" the airplane contacted the ground. At this time the L H engine started again and the airplane took off At a height of 60 feet the R H engine stopped The airplane swerved to the right, dropped the right wing, and became uncontrollable Inspection after the crash indicated that the L H tank had been practically empty		7	2	
2	Columbus, Ohio 1935	16-18PCLM	2-1750	Major	This day take off accident was due to carburetor ice which caused the R H engine to rev-down just off the ground The airplane swerved to the right, dropped the right wing and became uncontrollable The right wing struck the ground Distance from start to stop was 2300 ft Runway length 3500 feet				6

* A - Fatal, B - Serious, C - Minor, D - Uninjured

TABLE 23 (Cont'd 2)

No	Place and Year	Aircraft Type	No. Eng & Total H P (Take-Off)	Damage to Airplane	Remarks	Injuries * A B C D
3	Detroit, Mich (City Airport) 1935	16-18PCLM	2 - 1750	Overhaul	This night take-off accident was due to carburetor ice which caused the L H engine to rev-down at a height of 18 ft The airplane swerved to the left, dropped the left wing and became uncontrollable The airplane crashed to the left, 600 ft out of the runway area and off the airport Weather conditions included a freezing mist Distance from start to stop was 3900 ft Runway length 5400 ft	3 5
4	Buffalo, N Y 1935	16-18PCLM	2 - 1750	Major	The cause of this day take-off accident was not determined When just off the ground and at an airspeed of about 80 m p h the L H engine reved down The airplane swerved to the left and the left wing dropped It was impossible to maintain control until the R H engine was throttled The airplane then landed off the runway with the landing gear partially retracted Distance from start to stop was 2000 ft Runway length 2800 ft Rain and haze Vis 3 mi	16
5	East St Louis, Illinois 1935	11 PCLB	3 - 780	Major	This day take-off accident was caused by carelessness and negligence in that a take-off was attempted with the ailerons locked The pilot cut the throttle but was too late to avoid a ground loop	1
6	Pittsburgh, Pa. 1935	10 PCLM	3 - 780	Overhaul	This night take off accident was caused by water in the fuel All engines stopped at a height of 50 ft The pilot landed straight ahead with wheels retracted but slid off the end of the airport Distance from start to stop was 4000 ft 3500 ft available	2
7	San Francisco, California 1935	13 PCLM	2 - 1100	Major	This day take off accident was caused by fog on the airport about 30 ft deep The airplane took off blind and after traveling about 3000 ft from the start, hit a dike about 5 ft high This damaged the landing gear so that the airplane sustained additional damage on landing	13

TABLE 23 (Cont'd 3)

No	Place and Year	Aircraft Type	No Eng & Total H P (Take-Off)	Damage to Airplane	Remarks	Injuries * A	B	C	D
8	St Paul, Minn 1936	12 PCLM	2 - 900	Overhaul	This day take off accident was caused by carelessness and negligence in that the snow, which had accumulated on the wings was not cleaned off before attempting to take off. The airplane struck a snow bank and settled off the airport There was a light fog and medium snow was falling Gross weight (actual) 7308 lbs				7
9	Albany, N Y 1936	11 PCLB	3 - 700	Washout	The cause of this day take-off accident is believed to have been 75% due to the shifting of the wind and 25% due to slow response to controls The airplane struck a snow drift on the side of the runway and ground looped Visibility clear and unlimited	1			
10	Louisville, Ky 1936	16-18PCLM	2-1750	Overhaul	This night take off accident is believed to have been caused 50% by carelessness and negligence and 50% by ice on the wings Ice accumulated on the wings while the airplane was being refueled and loaded A take off was attempted with this ice on the wings At a height of 25 ft the left wing dropped, the airplane settled to the ground and ground looped The distance from start to stop was 4000 ft A five mile per hour wind was blowing and there was a light freezing rain				16
11	Washington, D C 1936	16-18PCLM	2-1750	Major	This day take off accident is believed to have been caused 70% by carelessness and negligence and 30% by icing conditions In spite of these conditions combined with slush and snow on the field, a take off was attempted Although the airplane bounced off the ground several times, it never was able to maintain flight After using 3000 out of an available 4500 ft the throttles were cut The airplane continued through the fence A 7 m p h tail wind was blowing				13

* A - Fatal, B - Serious, C - Minor, D - Uninjured

TABLE 23 (Cont'd 4)

No	Place and Year	Aircraft Type	No Eng & Total H P (Take-Off)	Damage to Airplane	Remarks	Injuries * A	B	C	D
12	Lansing, Mich 1936	17 PCLM	3 - 1290	Minor	This day take off accident is believed to have been caused 50% by carelessness and negligence and 50% by poor design of the fuel system It was decided after the accident that the co-pilot had accidentally partially closed the fuel valve to the R H engine while entering his seat The engine stopped after the airplane had run 500 feet but while it was still on the ground The airplane immediately went out of control and swerved to the right of the runway This type of airplane is no longer used Modern designs locate fuel valves in safe visible position				1
13	Miami, Fla 1936	12 PCLM	2 - 900	Overhaul	This day take off accident was caused by carelessness and negligence in that a take off was attempted with the rudder locked The airplane swerved from its course, went up on its nose and dropped back				1
14	Cheyenne, Wyo 1936	13 PCLM	2 - 1100	Overhaul	The cause of this night take off accident was not determined The R H engine stopped at a height of 30 ft after the airplane had traveled about 3000 ft The airplane swerved to the right, dropped the right wing and became uncontrollable The airplane struck the ground with the landing gear partially retracted Distance from start to stop was 5100 ft Runway length 4370 ft				1
15	Burlington, Vt 1936	11 PCLM	3 - 645	Washout	This day take off accident was caused by poor judgment on the part of the pilot who attempted a take off with only two of the three engines operating, namely, the center and L H engine As the airplane took off it turned to the right and the right wing was low The nose was pulled up to clear some trees about 250 ft to the side of the runway and about 30 ft high This resulted in a complete stall The airplane swung sharply 180 to the right and crashed	1		1	

* A - Fatal, B - Serious, C - Minor, D - Uninjured

TABLE 23 (Cont'd 5)

No	Place and Year	Aircraft Type	No Eng & Total H P (Take-Off)	Damage to Airplane	Remarks	Injuries * A	B	C	D
16	Columbus, Ohio 1936	16-18PCLM	2 - 1750	Overhaul	The cause of this night take off accident was not determined At an air speed of about 65 m p h , but while the airplane still was on the ground, the L H engine reved down The airplane swerved to the left off the runway and ground looped in soft mud				14
17	Fairbanks, Alaska 1937	12 PCLM	2 - 900	Overhaul	This day take off accident was caused by some soft snow on the R H side of the runway The airplane was equipped with wheels instead of skis when the R H wheel ran into the soft snow, the airplane turned to the right When both wheels ran into deep snow, the airplane nosed over				7
18	Cheyenne, Wyo 1937	24 PCLM	2 - 2000	Overhaul	This night take off accident was due to lack of appreciation of the effect of snow on the wings A moderate wet snow was falling when the take off was attempted The start was normal but the airplane would not leave the ground. The propeller pitch was reduced still further which permitted the engines to speed up Since the pilot expected the airplane to get off, he continued outside of the airport boundary before cutting his engines The airplane finally came to rest 1500 ft beyond the boundary of the airport Runway length 4000 ft				12
19	Daytona, Fla 1937	16-18PCLM	2 - 1750	Washout	It is believed that this night take off accident was due to carelessness and negligence in that a row of electric power line poles had been installed the day before the accident happened and as yet were unlighted The airplane arrived at 4 30 A M and left at 4.35 A M The pilot had not left the cockpit and evidently knew nothing of the poles The engines functioned perfectly and the airplane was about 20 ft high when it struck the pole after having traveled about 2509 ft The runway was 2371 ft long	4	5		

* A - Fatal, B - Serious, C - Minor, D - Uninjured

TABLE 23 (Cont'd 6)

No	Place and Year	Aircraft Type	No Eng & Total H P (Take-Off)	Damage to Airplane	Remarks	Injuries * A B C D
20	Newark, N J 1938	25 PCLM	2 - 2000	Minor	This night take off accident was caused by lack of complete understanding as to the seriousness of ice and snow on the wings Although an effort was made to clean off the snow that had accumulated on the wings, a coating of rough ice with some snow remained, and a take off was attempted The engines functioned properly and a take off speed of 82 m p h was attained. The airplane would not climb after getting off but mushed back into the ground and continued beyond the boundaries of the airport Runway length 2200 ft there was $1\frac{1}{2}$" to 2" of snow on the ground and snow was falling	14
21	Akiak, Alaska 1938	10 PCLM	1 - 575	Minor	This day take off accident was caused by the mechanical failure of the ski stand which evidently broke on the take off, but which was not discovered until the airplane was about 50 ft in the air The pilot then cut the switches and landed on the R H ski and L H axle	2
22	Concord, N H 1938	12 PCLM	2 - 900	Major	It is believed that this day take off accident was caused primarily by carburetor ice which caused the R H engine to lose power shortly after starting Gusty cross winds may have contributed to this accident After traveling about 400 ft the airplane swerved to the right and struck a 6 ft snow bank These snow banks were piled along the entire length of both runways when they were cleared of snow Distance from start to stop was 400 ft Cleared runway area length was about 3500 ft The turning tendency could not be controlled	9
22	Totals					5 13 6 133
					Total number of persons involved in these accidents	157

* A - Fatal, B - Serious, C - Minor, D - Uninjured

SUMMARY OF LANDING ACCIDENTS INVOLVING AIRLINE AIRPLANES

TABLE 24

No	Place and Year	Aircraft Type	No Eng & Total H P (Take-Off)	Damage to Airplane	Remarks	Injuries * A B C D
1	Boston, Mass 1934	10-12PCLB	3 - 780	Overhaul	This night landing accident appears to have been caused 50% by carelessness and negligence and 50% by bad weather Icing conditions caused the windshield to become frosted This combined with darkness was a contributing factor The right wheel struck a 5 ft pile of rocks about 30 ft outside of the boundary lights	7
2	Cleveland, Ohio 1934	17-18PCLB	2 - 1440	Minor	This day landing accident was caused by the misfunctioning of the tail wheel which started to shimmy after stricking a knoll It finally broke loose	?
3	Kansas City, Missouri 1934	13 PCLM	2 - 1100	Minor	This day landing accident was believed to have been caused 80% by carelessness and negligence and 20% by mechanical failure The pilot failed to lower the landing gear and the warning signals failed to function	1
4	Cheyenne, Wyo 1934	13 PCLM	2 - 1100	Minor	This day landing accident appears to have been caused entirely by poor judgment The pilot came in high and fast, overshot the field and clipped a fence with the wheels and stabilizers He then circled the field and landed (3900 ft runway)	?
5	St Paul, Minnesota 1934	12 PCLM	2 - 900	Minor	This night landing accident was due to the mechanical failure of the drive shaft of the landing gear retracting mechanism The pilot was unable to extend the left wheel and was forced to land with gear retracted	6
6	Agawam, Mass 1934	17-19PCLB	2 - 1440	Minor	This day landing accident was caused by the mechanical failure of the tail wheel which broke after a normal landing and a 300 ft ground roll	14

* A - Fatal, B - Serious, C - Minor, D - Uninjured

TABLE 24 (Cont'd 2)

No	Place and Year	Aircraft Type	No Eng & Total H P (Take-Off)	Damage to Airplane	Remarks	Injuries * A B C D
7	Arkadelphia, Arkansas 1934	17-18PCLB	2 - 1440	Minor	This day landing accident was caused by the landing gear The co-pilot lowered the gear as the approach was made Signal light showed green, but after a short roll the gear retracted and airplane nosed up	11
8	Little Rock, Arkansas 1934	17-18PCLB	2 - 1440	Major	This night landing accident was believed to have been caused 50% by poor judgment and 50% by weather The pilot overshot the field which was wet so that the wheels skidded when the brakes were applied and the airplane crashed into a fence. A four mile wind was blowing at 45° to the runway and the visibility was 6 mi The runway was 4000 ft long	6
9	Camden, N J 1934	17-18PCLB	2 - 1440	Major	This night landing accident appears to have been caused 60% by poor piloting technique and 40% by a mechanical failure of the landing gear A hard landing was made causing the airplane to bounce After a short roll the gear collapsed	6
10	Columbia, S C 1934	16-18PCLM	2 - 1750	Major	Fog conditions were largely the cause of this night accident The pilot saw two green lights and thought that they marked the beginning of the runway The airplane struck an embankment, which folded up the landing gear, and skidded to a stop The ceiling was 700 ft and there was mist and rain	10
11	Charlotte, N C 1934	17-18PCLB	2 - 1440	Major	The mechanical failure of the landing gear was the cause of this night landing accident A normal landing was made, but after a short roll the landing gear collapsed	12
12	Scranton, Pa 1935	10-12PCLB	3 - 780	Overhaul	This day landing accident is believed to have been caused 20% by carelessness and negligence and 80% by mechanical misfunctioning The left brake became packed with snow during a previous take off so that it failed to hold The airplane struck a hangar	4

* A - Fatal, B - Serious, C - Minor, D - Uninjured

TABLE 24 (Cont'd 3)

No	Place and Year	Aircraft Type	No Eng & Total H P (Take-Off)	Damage to Airplane	Remarks	Injuries * A B C D
13	Pittsburgh, Pa 1935	16-18PCLM	2 - 1750	Minor	This night landing accident was caused mainly by a gusty 12 m.p h wind blowing about 20° to the runway This lifted the left wing causing the right wing to scrape the ground	5
14	Washington, D C 1935	17-18PCLB	2 - 1440	Major	This night landing accident was caused by the mechanical failure of the left landing gear which folded up after rolling a short distance in a normal landing	16
15	Fort Worth, Texas 1935	17-18PCLB	2 - 1440	Minor	This day landing accident was caused by the mechanical misfunctioning of the landing gear which locked 2/3 of the way down Landing was made with gear in this position	2
16	Newark, N J 1935	16-18PCLM	2 - 1750	Minor	This night landing accident was caused largely by weather and to a small extent by lack of supervision After a normal landing the airplane rolled through a deep puddle of water, the force of the water damaged the right flap	15
17	Buffalo, N Y	16-18PCLM	2 - 1750	Overhaul	This night landing accident was caused by fog conditions with poor piloting technique as a contributing factor Landing was made in thick fog scraping left wing on ground	11
18	Buffalo, N Y 1935	16-18PCLM	2 - 1750	Overhaul	This day landing accident was caused mainly by lack of supervision on the part of the airport management Pilot came in low with power Right landing gear struck an unmarked pile of cinders which broke the wheel (3000 ft runway)	6
19	Ogden, Utah 1935	13 PCLM	2 - 1100	Minor	It appears that this day landing accident was caused 60% by poor piloting technique and 40% by the mechanical misfunctioning of the brakes After using about 1980 ft of a 3130 ft runway there were only about 1150 ft in which to stop after contact The brakes failed to hold when applied, a right turn was made and the left wheel dropped into a 3 ft ditch outside of the boundary of the airport (Altitude of Airport 4725 ft)	8

* A - Fatal, B - Serious, C - Minor, D - Uninjured

TABLE 24 (Cont'd 4)

No	Place and Year	Aircraft Type	No Eng & Total H P (Take-Off)	Damage to Airplane	Remarks	Injuries * A B C D
20	Washington, D C 1935	16-18PCLM	2 - 1750	Minor	This day landing accident was caused by the mechanical failure of the tail wheel which collapsed when it struck a rough spot after a normal landing	6
21	Newark, N J 1935	16-18PCLM	2 - 1750	Minor	This day landing accident was caused by the mechanical failure of the tail post frame which broke after landing and while rolling on the ground	10
22	Murfreesboro, Tennessee 1935	17-18PCLB	2 - 1440	Washout	This night landing accident is believed to have been caused 20% by fog and 80% by an error of the co-pilot The ground fog was about 75 ft thick Three approaches were made, overshooting the field In climbing out after the third approach co-pilot pulled the wheel back The airplane stalled and crashed outside of airport	3 11
23	Santa Monica, California 1935	16PCLM	3 - 1260	Overhaul	This day landing accident was caused by the mechanical misfunctioning of the brakes after a normal landing This caused the tires to skid and the airplane nosed up	2
24	Pittsburgh, Pa 1935	16-18PCLM	2 - 1750	Minor	This day landing accident was caused by the mechanical failure of the tail wheel which collapsed after a normal landing	11
25	Columbus, Ohio 1935	16-18PCLM	2 - 1750	Minor	This day landing accident was caused by the mechanical failure of the tail wheel which collapsed after rolling 300 ft on a smooth landing	10
26	Phoenix, Ariz 1935	17-18PCLB	2 - 1440	Major	This night landing accident was caused by the mechanical failure of the left landing gear which buckled after rolling 1500 ft following a normal landing	8
27	Oakland, Calif 1935	13 PCLM	2 - 1100	Minor	This night landing accident is believed to have been caused 70% by combined fog and darkness and 30% by poor piloting technique After landing through fog and rolling about 200 ft the pilot made a gradual turn to the left and then continued straight ahead This resulted in the airplanes crashing through a fence	5

* A - Fatal, B - Serious, C - Minor, D - Uninjured

TABLE 24 (Cont'd 5)

No	Place and Year	Aircraft Type	No Eng & Total H P (Take-Off)	Damage to Airplane	Remarks	Injuries * A	B	C	D
28	Detroit, Mich 1935	16-18PCLM	2 - 1750	Minor	The cause of this day landing accident was attributed to turbulent wind conditions, which caused the left wing to drop and scrape the ground while the airplane was still 8 ft above the ground during a normal approach The pilot circled the field and made a normal landing The presence of a gas tank on the field is believed to have been responsible for the turbulence				7
29	Murfreesboro, Tennessee 1935	16-18PCLM	2 - 1750	Minor	This night landing accident was due to mechanical misfunctioning In preparing to land the pilot could not get green signal light, although the landing gear seemed to be extended Made landing and came to practically a dead stop Gear gave way when pilot started to taxi to ramp				10
30	Chattanooga, Tennessee 1935	12 PCLM	2 - 900	Overhaul	This night landing accident was caused 50% by bad weather, 30% by poor judgment, and 20% by poor pilot technique Pilot overshot the field, with about 1250 ft left, he applied the brakes and skidded into an embankment (Wet paved runway 4000 ft)				8
31	El Paso, Texas 1936	17-18PCLB	2 - 1440	Overhaul	This night landing accident was caused 20% by bad weather and 80% by mechanical damage to the landing gear The pilot made a rough landing, due to gusty wind, and damaged the gear When the warning bell commenced to ring, the pilot took off again and landed on the nacelle and nose				7
32	Louisville, Ky 1936	17-18PCLB	2 - 1440	Minor	This night landing accident was caused by co-pilot overshooting the field in making a fast landing Pilot tried to gun the motors but they were cold He ground-looped, hit a ridge and collapsed the gear (4000 ft runway)				6

* A - Fatal, B - Serious, C - Minor, D - Uninjured

TABLE 24 (Cont'd 6)

No	Place and Year	Aircraft Type	No Eng & Total H P (Take-Off)	Damage to Airplane	Remarks	Injuries * A B C D
33	Chicago, Ill 1936	16-18PCLM	2 - 1750	Minor	This night landing accident was due to mechanical failure Pilot taxied over rough part of field at Pittsburgh and in landing at Chicago found the tail wheel retaining structure had failed	13
34	Detroit, Mich 1936	16-18PCLM	2 - 1750	Minor	This night landing accident was due to weather conditions After landing a gust of wind lifted the left wing which caused the right wing to scrape the ground	8
35	Newark, N J 1936	16-18PCLM	2 - 1750	Overhaul	This night landing accident was due to poor judgment on the part of the pilot In attempting to land the pilot overshot the field and was unable to stop plane with brakes Plane ran off the field into soft ground and right gear pushed strut through nacelle. (3000 ft runway)	9
36	Winslow, Ariz 1936	16-18PCLM	2 - 1750	Minor	This night landing accident was due mainly to weather conditions Pilot made a normal landing but after a short roll a gust of wind lifted the left wing causing the right wing to drag along the ground	13
37	Cleveland, Ohio 1936	17-18PCLB	2 - 1440	Minor	This day landing accident was caused by mechanical failure After making a normal landing, the tire blew out and caused a mild ground loop	15
38	Chicago, Ill. 1936	16-18PCLM	2 - 1750	Overhaul	This day landing accident was caused by the mechanical misfunctioning of the brakes After landing cross wind, the pilot applied brakes which caused the plane to ground loop and damaged the tail	6
39	Atlanta, Ga. 1936	12 PCLM	2 - 900	Minor	This night landing accident was due to error on the part of the pilot After landing the landing gear started to retract, which caused the aircraft to nose up Apparently the pilot became confused and mistook the landing gear switch for the flap switch	2

* A - Fatal, B - Serious, C - Minor, D - Uninjured

TABLE 24 (Cont'd 7)

No.	Place and Year	Aircraft Type	No Eng & Total H P (Take-Off)	Damage to Airplane	Remarks	Injuries * A B C D
40	Boston, Mass 1936	17-18PCLB	2 - 1440	Minor	This day landing accident was due to error on the part of the pilot, who came in for a landing with the gear up	2
41	Mobile, Ala 1936	12 PCLM	2 - 900	Minor	This day landing accident was due to mechanical misfunctioning. Because no warning lights or horn sounded the pilot landed with a partially extended gear A fuse was blown in the landing gear circuit	3
42	Elkins, W Va 1936	10 PCLM	3 - 645	Minor	This day landing accident was caused by shifting wind in which pilot landed and ground looped to avoid ditch All means of straightening out ship failed	8
43	Washington, D C 1936	16-18PCLM	2 - 1750	Minor	This night landing accident was due to pilot error In turning ship in order to taxi to loading ramp, the empennage hit a field boundary light	15
44	Minneapolis, Minnesota 1936	12 PCLM	2 - 900	Minor	This day landing accident was caused by an error on the part of the co-pilot Ship nosed up when co-pilot pulled landing gear switch instead of wing flap switch	2
45	Detroit, Mich 1936	13 PCLM	2 - 1100	Overhaul	This night landing accident appears to have been caused by mechanical failure and poor maintenance Upon landing the airplane bounced slightly, causing the left oleo strut to separate, and allowing the left wheel to fold back into the wheel well, letting the airplane down on the ground on the left wing tip.	2
46	Atlanta, Ga 1936	10 PCLM	3 - 645	Washout	This unexplained day landing accident occurred after the take off at 100 ft altitude when the right wing dropped and the airplane went out of control In attempting to land, the ship tore through three small trees and landed on a barbed wire fence (4000 ft runway)	2
47	Idaho Falls, Idaho 1936	13 PCLM	2 - 1100	Minor	This day landing accident was mainly caused by carelessness and negligence In taxying down the apron, the right wheel dropped into a pit approximately 4 ft deep	8

* A - Fatal, B - Serious, C - Minor, D - Uninjured

TABLE 24 (Cont'd 8)

No	Place and Year	Aircraft Type	No Eng & Total H P (Take-Off)	Damage to Airplane	Remarks	Injuries * A B C D
48	Miramar, Calif 1936	13 PCLM	2 - 1100	Minor	This day landing accident was due to bad weather In attempting to land through fog, the pilot overshot the field slightly, rolling through a fence	6
49	Kansas City, Mo 1936	12 PCLM	2 - 900	Overhaul	This night landing accident was due to mechanical mis-functioning Landing was made with the wheels up due to the fact landing gear mechanism would not function	2
50	Robertson, (St Louis,) Mo 1936	17-18PCLB	2 - 1440	Minor	This day landing accident was caused by the mechanical failure of the landing gear, which gave way as contact was made with the ground	3
51	Washington, D C 1936	10 PCLM	3 - 645	Minor	This night landing accident was caused by fog After landing the pilot ran into a boundary light with a high standard	4
52	Newark, N J 1936	13 PCLM	2 - 1100	Washout	This night landing accident was due 25% to bad weather and 75% pilot error In executing a precision instrument approach for a landing, pilot drifted slightly to right of NE leg of the range and due to poor visibility landed short of field in a swamp	6
53	Charleston, S C 1937	16-18PCLM	2 - 1750	Minor	This day landing accident was mainly due to mechanical misfunctioning of the brakes, but was partly due to poor judgment on the part of the pilot Pilot landed approximately in center of field and even though the brakes were applied, the plane would not lose speed and ran 1440 ft into a ditch Brakes apparently were defective Wind N-9 N S runway 3000 ft long	13
54	Jackson, Miss 1937	12 PCLM	2 - 900	Minor	This day landing accident was caused by bad weather and poor piloting technique Due to the fact that the field was very slick, the plane rolled through west side of runway and into a fence Wind N-5 N S runway 3000 ft long	3

* A - Fatal, B - Serious, C - Minor, D - Uninjured

TABLE 24 (Cont'd 9)

No	Place and Year	Aircraft Type	No Eng & Total H P (Take-Off)	Damage to Airplane	Remarks	Injuries * A B C D
55	Portland, Ore 1937	12 PCLM	2 - 800	Major	This day landing accident was due to mechanical mis-functioning of the brakes Left brake would not hold causing the plane to turn steadily to the right, striking a pile of frozen dirt	7
56	Atlanta, Ga 1937	16-18PCLM	2 - 1750	Washout	The cause of this night landing accident was not determined While cruising at 3000 ft , ship suddenly started to climb at the rate of 2000 ft per minute at which time the pilot decided to land Flying fast, pilot overshot field and ground looped to avoid a building Wind S-5 N S runway 3000 ft long	7
57	Camden, N J 1937	16-18PCLM	2 - 1750	Minor	This night landing accident was caused by poor piloting technique Pilot came in high and used too much runway before the wheels actually touched the ground, leaving about 750 ft on which to stop plane Pilot ground looped to avoid hitting fence 2500 ft runway	2
58	Columbus, Ohio 1937	16-18PCLM	2 - 1750	Minor	This night landing accident was due to bad weather After landing on the S W runway and rolling a short distance, a strong gust of wind lifted the right wing causing the left wing tip to drag on the ground	2
59	Springfield, Illinois 1937	16-18PCLM	2 - 1750	Minor	This day landing accident was due to the mechanical failure of the Decier boot on the right wing, which tore loose during flight Upon landing the right wing suddenly lost lift and scraped the ground	5
60	Denver, Colo 1937	24 PCLM	2 - 2200	Minor	This day landing accident was due to weather conditions A sudden dust squall covered the field with a layer of blowing dust about 10 ft thick as the plane was about to land, causing the pilot to level off too high, losing flying speed and dropping right wing tip	14
61	Pittsburgh, Pa 1937	13 PCLM	2 - 1100	Major	This day landing accident was caused by mechanical failure The tail wheel assembly collapsed as plane landed and ship ground looped into an automobile	12

A - Fatal, B - Serious, C - Minor, D - Uninjured

TABLE 24 (Cont'd 10)

No	Place and Year	Aircraft Type	No Eng & Total H P (Take-Off)	Damage to Airplane	Remarks	Injuries * A B C D
62	Kylertown, Pa 1937	13 PCLM	2 - 1100	Minor	This day landing accident was caused by poor weather and poor piloting technique Pilot landed with 1500 ft of runway still available, applied brakes, skidded and then nosed up (Wet grass surface) Runway length 3000 ft	8
63	Cleveland, Ohio 1937	24 PCLM	2 - 2200	Minor	This day landing accident was due to mechanical misfunctioning The brakes grabbed after the ship rolled 350 ft and caused ship to nose up	21
64	Chicago, Ill 1937	24 PCLM	2 - 2200	Minor	This day landing accident was caused by poor judgment on the part of the pilot, who came in high and fast Realizing he would overshoot the field, the pilot gunned the motors but they would not take Plane continued down and landed on a golf course a short distance away	16
65	Chicago, Ill 1937	24 PCLM	2 - 2200	Minor	This day landing accident was caused by mechanical misfunctioning of the brakes The pilot landed to the S E (cross wind) and after rolling a short distance, plane turned to the left and crashed into a concrete junction box	13
66	Louisville, Ky 1937	16-18PCLM	2 - 1750	Minor	This day landing accident was due to weather conditions Pilot landed into a W S W -25 wind After the plane rolled for about 300 ft the wind shifted to N W -40 and tipped it up on the left wing Pilot opened throttle and took off again	10
67	Flat, Alaska 1937	12 PCLM	2 - 900	Minor	This day landing accident was due to poor field maintenance A sharp rock frozen in the runway cut a 2-1/2 inch hole in the right tire causing the tail to raise high enough to allow both propellers to hit the ground	7

* A - Fatal, B - Serious, C - Minor, D - Uninjured

TABLE 24 (Cont'd 11)

No	Place and Year	Aircraft Type	No Eng & Total H P (Take-Off)	Damage to Airplane	Remarks	Injuries * A B C D
68	Detroit, Mich 1937	24 PCLM	2 - 2200	Minor	This night landing accident was due to weather conditions Pilot landed into S W with a S S W -15 gust wind After completing over half of landing roll, a gust of wind raised the left wing - causing the right wing to drag	?
69	Tanana, Ala 1937	10 PCLM	1 - 575	Overhaul	This day landing accident was caused by mechanical failure of the tail ski post which broke due to rough ice	1
70	Buffalo, N Y 1937	25 PCLM	2 - 2000	Minor	This night landing accident was caused by the mechanical misfunctioning of the lateral control system On a normal approach, lateral instability was noted at about 60 ft height Full throttle was used to straighten the airplane out but left wing tip and aileron scraped ground upon landing	17
71	Undeveloped Field near Richlands, N C 1938	31 PCLM	2 - 2200	Major	This night landing accident was caused 30% by poor visibility and 70% by the misfunctioning of the radio facilities The pilot was forced to land in a small undeveloped field with the wheels raised	10
72	Camden, N J 1938	16-18PCLM	2 - 1750	Major	This day landing accident was caused 30% by low ceiling and 70% by poor piloting technique After breaking through the overcast at 400 ft height the pilot landed towards the N NE but not on the NE runway With 2400 ft of airport available three contacts were made After the final contact only 630 ft of airport remained Braking proved ineffective due to the gravel surface of the field, and the aircraft ran through the fence and across a highway	6
72	Totals					0 3 0 537
					Total Persons Involved in These Accidents	540

* A - Fatal, B - Serious, C - Minor, D - Uninjured

SUMMARY OF TAKE-OFF ACCIDENTS INVOLVING PRIVATE OWNER TYPE AIRPLANES

TABLE 25

Ref No	Place	Aircraft Type	No Eng & Total H P	Damage to Ship	Remarks	Injuries * A	B	C	D
1	Fairbanks, Alaska	4PCLM	1 - 260	Overhaul	Axle broke just as ship left ground	0	0	0	2
2	Fairbanks, Alaska	10PCLM	1 - 525	Major	Hit ditch in snow while taking off	0	0	0	7
3	Fairbanks, Alaska	5PCLB	1 - 285	Major	Ship overran field About 1400 ft was usable	0	0	0	1
4	Nome, Alaska	4PCLM	1 - 245	Overhaul	Emergency flight, ship ran over a bare gravel spot	0	0	0	3
5	Texarkana, Ark	3POLB	1 - 220	Washout	Engine quit at 75 ft altitude, fell into a spin	0	0	0	3
6	Stockton, Cal	2PCLM	1 - 37	Overhaul	Prospective student stepped on right rudder when ship was 10 ft up	0	0	0	2
7	Daytona Beach, Fla	3POLB	1 - 330	Washout	Motor quit at approximately 400 ft altitude	0	0	0	1
8	Fayetteville, Ga	3POLB	1 - 220	Major	Pilot hit small girl with wing tip while taking off	0	0	0	1
9	Harvey, Ill	3POLB	1 - 90	Major	Left bank on engine cut out at 50 ft altitude	0	0	0	3
10	Lexington, Ky	2PCLM	1 - 70	Overhaul	High grass prevented ship gaining ground enough to fly, when throttle was closed, ship nosed over	0	0	0	2
11	Portland, Me	3POLB	1 - 220	Overhaul	Motor failure at approximately 200 ft altitude	0	0	0	1
12	Illfeld, N Mex	2PCLM	1 - 40	Overhaul	Motor quit when 40 or 50 ft high Water in gas	0	0	0	2
13	Waverly, N Y	5POLB	1 - 220	Overhaul	Plane ground looped when oleo block failed due to flaws	0	0	0	3
14	Rochester, N Y	2PCLM	1 - 145	Major	Engine quit when 50 ft up	0	0	0	2
15	Bellaire, Ohio	2PCLM	1 - 90	Overhaul	Motor failed at about 700 ft	0	0	0	2
16	Cleveland, Ohio	2PCLM	1 - 40	Overhaul	Took off in dead air - brushed trees with wing tip	0	0	0	2
17	West Union, Ohio	3POLB	1 - 90	Major	Tail skid caught in telephone wire 20 ft high and located 100 ft from end of runway	0	0	0	3
18	Lawton, Okla	3POLB	1 - 175	Major	Ran out of gas when approximately 50 ft up	0	0	0	3
19	Oklahoma City, Okla	3PCLM	1 - 145	Washout	Plane towing a banner stalled when banner trained through grass exerting a drag	0	0	0	1
20	Hugo, Okla	2PCLM	1 - 70	Overhaul	Wheels hit ditch covered by grass	0	0	0	2
21	Silver Lake, Ore	2PCLM	1 - 145	Overhaul	Wheels hit sandy wave, bounced and nosed over	0	0	0	1
22	Newport, R I	5PCLB	1 - 225	Overhaul	Plane took off up hill and into a 10 mile wind, unable to get off and ran into a low stone wall Rough surface	0	0	0	4
23	Shell Creek, Tenn	3POLB	1 - 220	Overhaul	Engine stopped when plane was 100 ft off the ground	0	0	0	3
24	Paducah, Texas	7PCLM	1 - 420	Washout	Ran out of gas when 25 ft up	0	0	0	4
25	San Antonio, Texas	3POLB	1 - 90	Washout	When at about 20 ft altitude, a down draft caused plane to hit a bush and nose over	0	0	0	3
26	Austin, Texas	4PCLM	1 - 225	Overhaul	Ship fell in from a stalled condition of flight immediately after a stalled take-off	0	0	1	0
27	Albany, Texas	2PCLM	1 - 40	Overhaul	Motor lost power when 50 ft in the air	0	0	0	1
28	Houston, Texas	7PCLM	2 - 800	Major	Tire went flat on take-off, damage done on landing	0	0	0	6

*A - Fatal, B - Serious, C - Minor, D - Uninjured

TABLE 25 (Cont'd 2)

Ref No	Place	Aircraft Type	No Eng & Total H P	Damage to Ship	Remarks	Injuries * A	B	C	D
29	Wisconsin Rapids, Wisc.	2PCLM	1 - 70	Overhaul	Motor failed when 100 ft up	0	0	0	2
30	Three Lakes, Wisc	2POLB	1 - 85	Major	When 10 ft up hard knock developed in engine causing severe vibration and engine started to loose revolutions Plane pancaked in	0	0	0	1
31	Brown Deer, Wisc	2PCLM	1 - 40	Overhaul	Motor lost revolutions immediately after take-off Hit fence	0	0	0	2
32	Cheyenne, Wyo	4PCLM	1 - 250	Washout	At approximately 100 ft motor quit	0	0	3	0
33	Gadsden, Ala	5PCLM	1 - 245	Major	Pilot caught his stabilizer in a coiled cable which was on a hedge 2 ft high and 100 ft from the end of the runway Private field 1200 ft long with ditch across center	0	0	0	1
34	Phoenix, Ariz	3POLB	1 - 100	Overhaul	Motor quit, pilot tried to turn plane but stalled about 10 ft above the ground	0	0	0	3
35	Inglewood, Cal	2POLB	1 - 100	Major	Mud from wheels struck and broke propeller, vibration broke engine mounting ring	0	0	0	2
36	Los Angeles, Cal	3POLB	1 - 115	Overhaul	Control stick came out when 15 ft above the ground, plane stalled and then fell in on the wing, then over on its back				
37	Garnet, Cal	2PCLM	1 - 40	Overhaul	Pilot drifted from a clearing on the desert into sagebrush	0	0	0	1
38	Pomona, Cal	2PCLM	1 - 40	Overhaul	Pilot took off from alfalfa field 1200 ft long, had to kick plane sideways to avoid trees 50 ft high at end of field, plane stalled and fell	0	0	0	2
39	Lincoln, Cal	3POLB	1 - 90	Washout	Powerplant failure when 100 ft off ground, plane landed in orchard	0	0	0	1
40	San Carlo, Cal	2PCLM	1 - 70	Major	Tail skid hit hole while plane was turning	0	0	0	1
41	Pueblo, Colo	2PCLM	1 - 36	Overhaul	Student attempted take off cross wind on closed portion of field, struck bank o" oil sand and went on his back	0	0	0	2
42	Boulder, Colo	3PCLM	1 - 145	Overhaul	Pilot took off from a golf course and stalled ship in trying to avoid high tension wires 25 ft high, plane struck a tree 1200 ft available	0	0	0	3
43	Pueblo, Colo	3POLB	1 - 220	Overhaul	Power plant failure at about 300 ft Pilot turned to land on airport and gusty wind came from behind and caused ship to settle in fast	0	1	0	0
44	Danbury, Conn	2POLB	1 - 100	Washout	With about 150 ft altitude engine quit, pilot attempted a left turn in a stalled position, fell off and spun in	1	1	0	0
45	St Petersburg, Fla	2PCLM	1 - 70	Overhaul	Attempted to take-off down wind, could not clear field, throttled down, ran off runway into rough part of field, applied brakes, nosed over	0	0	0	2

*A - Fatal, B - Serious, C - Minor, D - Uninjured

TABLE 25 (Cont'd 3)

Ref No	Place	Aircraft Type	No Eng & Total H P	Damage to Ship	Remarks	Injuries * A	B	C	D
46	Ft Meyers, Fla	2PCLM	1 - 125	Overhaul	Obstruction in wheel fairing locked wheel, plane ground looped and nosed over	0	0	0	1
47	Orlando, Fla	2POLB	1 - 100	Major	Landing gear fitting failed on take-off	0	0	0	1
48	Chicago, Ill	2PCLM	1 - 37	Overhaul	In taking off from private field into a very little wind plane ran off runway into water 6 or 8 inches deep and turned over	0	0	0	2
49	Gillespie, Ill	2PCLM	1 - 40	Major	Wind changed before plane got off the ground, hit a four strand barbed wire fence	0	0	0	1
50	Oak Lawn, Ill	2PCLM	1 - 37	Major	Pilot did not use all of field available and pulled the ship off the ground before sufficient flying speed was reached	0	0	0	2
51	Alton, Ill	2PCLM	1 - 65	Major	Plane hit ditch on take-off	0	0	0	1
52	West Chicago, Ill	2POLM	1 - 65	Major	Engine lost revolutions on take-off, necessitating landing in soft ground	0	0	0	1
53	Washington, Ind	2PCLM	1 - 70	Major	Plane skidded into a fence due to icy condition of field	0	0	0	2
54	Leon, Iowa	4PCLM	1 - 125	Major	Struck ditch collapsing landing gear	0	0	1	0
55	Paducah, Ky	4PCLM	1 - 245	Overhaul	Ship broke through crust of snow and wheel fairing caught on ice causing nose-over	0	0	0	2
56	Centertown, Ky	3POLB	1 - 90	Washout	While taking off from a pasture, wheels caught on bushes about 20 ft high	0	0	1	0
57	Louisville, Ky	4PCLM	1 - 225	Major	When about 75 ft high, pilot cut throttle for theoretical forced landing, ship slipped into ground	0	0	0	2
58	Monroe, La	3POLB	1 - 90	Major	In taking off on slippery field, Pilot skidded plane into sign board	0	0	0	3
59	Scarboro, Me	2POLB	1 - 35	Washout	Plane stalled on take-off at about 200 ft and spun in just outside of field	0	2	0	0
60	Ellsworth, Me	3POLB	1 - 128	Washout	Plane wouldn't climb, pilot mushed into trees	0	0	0	2
61	Caribou, Me	2PCLM	1 - 40	Overhaul	Pilot used a 2000 ft runway but stalled plane because of a steep climb in attempting to clear a fence Plane fell to ground from about 100 ft	0	1	0	0
62	Rockville, Md	3PCLM	1 - 175	Washout	In order to avoid incoming plane, pilot made a vertical turn right off the ground to the left with no speed and plane went in nose first	0	2	0	0
63	East Taunton, Mass	3POLB	1 - 90	Overhaul	Plane unable to gain altitude due to dead air and struck trees. 3650 ft available	0	0	0	3
64	Norton, Mass	3POLB	1 - 175	Overhaul	Pilot being unfamiliar with the ship, landed in a field too small to take-off in, plane unable to clear trees, struck tree with wing, fell, out of control	0	0	1	1

*A - Fatal, B - Serious, C - Minor, D - Uninjured

TABLE 25 (Cont'd 4)

Ref No	Place	Aircraft Type	No Eng & Total H P	Damage to Ship	Remarks	Injuries * A	B	C	D
65	Hingham, Mass	2POLB	1 - 85	Overhaul	Broke axle on take-off, caused damage on subsequent landing	0	0	0	2
66	West Branch, Mich	3POLB	1 - 90	Overhaul	While taking off from a private field in calm air, plane was unable to gain altitude and hit fence Runway 1800 ft	0	0	0	3
67	Detroit, Mich	2POLM	1 - 37	Overhaul	Plane took off about 580 ft from the fence and lifted after a 75 ft run It appeared to hit an "air pocket" and crashed into the fence Farm pasture	0	0	0	1
68	Detroit, Mich	5PCLM	1 - 220	Washout	Landing gear struck a truck directly in path of ship	0	0	2	2
69	Roseville, Mich	2POLM	1 - 145	Overhaul	Stalled on take-off and cartwheeled	0	1	0	1
70	Little Falls, Minn	2POLM	1 - 100	Overhaul	After gaining 200 ft altitude, motor lost revolutions	0	0	0	2
71	Robertson, Mo	2PCLM	1 - 90	Major	Gusty wind (26 to 35 m p h) put plane on back while waiting to take off	0	0	0	2
72	St Louis, Mo	2PCLM	1 - 70	Major	Motor lost revolutions just after take-off	0	0	0	2
73	Boulder City, Nev	4PCLM	1 - 145	Overhaul	Took off cross wind, drifted, ground looped in attempting to straighten out	0	0	0	3
74	Reno, Nev	5PCLB	1 - 285	Overhaul	Struck a boundary light approximately 5 ft off the ground	0	0	0	4
75	North Walpole, N H	2POLM	1 - 65	Washout	Plane made an emergency landing on a snow covered field, ship unable to clear trees and crashed in taking off	1	0	0	0
76	Jackson Heights, N Y	3POLB	1 - 125	Overhaul	Plane struck concrete boundary light when just off the ground	0	0	0	2
77	Jackson Heights, N Y	2PCLM	1 - 37	Overhaul	Motor lost revolutions when about 25 ft off the ground	0	0	0	2
78	Mt Pleasant, N Y	2PCLM	1 - 36	Washout	When at an altitude of 300 ft , motor quit	0	1	0	0
79	Johnstown, N.Y	1POLM	1 - 25	Overhaul	Plane hit rut and nosed over	0	0	0	1
80	Long Lake, N Y	4PCLB	1 - 210	Overhaul	Ship ran into soft sand, wouldn't lift off the field, ran into lake	0	0	0	2
81	Elmira, N Y	4PCLM	1 - 145	Washout	Pilot lost horizon, because of darkness, when approximately 100 ft up, ship spun in	0	0	2	0
82	Nunda, N.Y	2POLM	1 - 37	Major	Ship ran into swamp 500 ft from edge of field Wheat field	0	0	0	2
83	Greensboro, N Car	2POLB	1 - 85	Overhaul	Plane drifted, due to shifting wind, ground looped as bank was approached	0	0	0	2
84	Fostoria, Ohio	2POLM	1 - 36	Major	Landing gear struck fence post in taking off from small private field 1300 ft	0	0	0	2
85	Hillsboro, Ore	2POLM	1 - 90	Overhaul	Motor sputtered when 300 ft up, pilot turned back, ground looped	0	0	0	2
86	Murraysville, Pa	2PCLM	1 - 90	Overhaul	When 6 ft up a cross wind caught plane and threw it on its back	0	0	0	2
87	Brookville, Pa	2PCLM	1 - 37	Overhaul	Motor lost revolutions forcing a landing outside of airport	0	0	0	1

*A - Fatal, B - Serious, C - Minor - D, Uninjured.

TABLE 25 (Cont'd 5)

Ref. No	Place	Aircraft Type	No Eng & Total H P	Damage to Ship	Remarks	Injuries * A	B	C	D
88	Somerset, Pa.	3POLB	1 - 220	Overhaul	Ran out of gas just after take-off	0	0	0	3
89	Madville, Pa	4PCLM	1 - 215	Overhaul	Motor slowed down when plane was 30 ft up	0	0	0	4
90	Harrisburg, Pa	2PCLM	1 - 37	Overhaul	Plane attempting to take-off on 1900 ft runway was unable to avoid fence at end of field	0	0	0	2
91	Westfield, Pa	2PCLM	1 - 37	Overhaul	Plane hit stump while attempting to take-off of a 750 ft runway on a private field	0	0	0	1
92	Smithfield, R I	3POLB	1 - 90	Overhaul	Propeller hit ground loosening motor mount and forcing ship down	0	0	1	0
93	Brookings, S Dak	3POLM	1 - 115	Overhaul	While taking off from a small field, tail hit fence	0	0	0	1
94	Spearfish, S Dak	3POLB	1 - 90	Overhaul	While taking off, motor stopped and ship fell in from 50 ft	0	0	0	2
95	Knoxville, Tenn	4PCLM	1 - 125	Major	Shock cord broke when long run over rough field was made due to heavily loaded ship and dead air	0	0	0	3
96	Ft Worth, Tex	3POLB	1 - 175	Overhaul	Motor lost revolutions when about 30 ft off the ground	0	0	0	2
97	Waxahachie, Tex	2PCLM	1 - 37	Overhaul	While taking off from a golf course, the engine quit and the plane hit the trees	0	0	0	2
98	Goose Creek, Tex	3PCLM	1 - 90	Overhaul	Landing gear bolt sheared off on take-off, damage done in landing	0	0	0	1
99	Belfair, Wash	2PCLM	1 - 40	Overhaul	While attempting to take-off on a 700 ft. runway, plane wouldn't gain altitude and rolled into the brush	0	0	0	2
100	Chapmansville, W Va	3POLB	1 - 175	Washout	Powerplant failure, ship nosed over	0	0	0	1
101	Kenosha, Wisc	2PCLM	1 - 70	Major	Pilot attempted to take-off from a soft field, plane left ground on crest of small rise, fell to ground from 15 ft altitude due to lack of flying speed	0	0	0	1
102	Medford, Wisc	3POLB	1 - 220	Major	Plane hit pole on take-off Pilot did not realize that he had used up so much of the runway because of impaired vision	0	0	0	2
103	Madison, Wisc	2PCLM	1 - 90	Overhaul	In taking off from tall grass, wheel became locked and swung ship around	0	0	0	2
104	Waterford, Wisc	3POLB	1 - 175	Overhaul	Motor cut out at 50 ft , plane stalled and fell in on landing gear	0	0	0	2
104	Totals					2	9	12	188
					Total Persons Involved in These Accidents	211			

*A - Fatal, B - Serious, C - Minor, D - Uninjured

SUMMARY OF LANDING ACCIDENTS INVOLVING PRIVATE OWNER TYPE AIRPLANES

TABLE 26

Ref. No	Place	Aircraft Type	No Eng & Total H P	Damage to Ship	Remarks	Injuries * A	B	C	D
1	Prescott, Ariz	3PCLM	1 - 150	Overhaul	Wheels broke through snow crust nosing plane over	0	0	0	3
2	Winkleman, Ariz	2PCLM	1 - 70	Overhaul	Brakes applied too quickly causing nose-over	0	0	0	2
3	Newark, Ark	3PCLM	1 - 145	Washout	Lost flying speed, fell in on a down-wind turn	3	0	0	0
4	Scott, Ark	2PCLB	1 - 170	Minor	Cross wind landing, ground struck while drifting sideways	0	0	0	2
5	San Mateo, Cal	2PCLM	1 - 145	Overhaul	Brakes applied too quickly causing nose-up	0	0	0	1
6	Inglewood, Cal	5PCLB	1 - 285	Overhaul	Struck ditch one wheel at a time causing ground loop	0	0	0	5
7	Santa Barbara, Cal.	4PCLB	1 - 285	Washout	Overshot field and landed on rocks 15 ft below the field	0	0	0	1
8	Burbank, Cal	3POLB	1 - 250	Overhaul	Slow ground loop, causing wing to scrape ground	0	0	0	2
9	Visalia, Cal	3PCLM	1 - 90	Washout	Landed into the sun, struck 30 ft unmarked pole at end of runway, plane pan-caked in	0	0	1	1
10	San Diego, Cal	5PCLB	1 - 285	Overhaul	In order to avoid another plane, pilot ran into a ridge and mud-hole 300 ft wide, causing plane to nose-over	0	0	0	5
11	Palms, Cal	4PCLM	1 - 145	Major	Landed into sun, struck a plow on side of runway	0	0	0	1
12	Glendale, Cal.	5PCLB	1 - 225	Overhaul	Plane ground looped during landing	0	0	0	4
13	N Muroc, Cal	2PCLM	1 - 65	Overhaul	Plane nosed over after hitting 18 inch ridge	0	0	0	2
14	Alhambra, Cal	2POLB	1 - 100	Major	Ground looped due to cross-wind	0	0	0	2
15	Hollywood, Cal	2POLB	1 - 100	Major	Nosed over when wheels rolled into ditch	0	0	0	1
16	Dorris, Cal	5 PCLB	1 - 225	Overhaul	Stalled and fell off to the left, struck on left wing tip and wheel	0	0	0	3
17	Palo Alto, Cal	3POLB	1 - 450	Major	Ran off runway, wheels struck drainage ditch damaging landing gear	0	0	0	1
18	Monrovia, Cal	2PCLM	1 - 37	Overhaul	Motor cut-out on glide to the field, attempted turn too close to the ground causing wing to strike the ground	0	0	2	0
19	Sacramento, Cal	3POLB	1 - 125	Overhaul	Plane nosed over when wheels hit a hole	0	0	0	2
20	Pomona, Cal	3POLB	1 - 180	Overhaul	Undershot field and struck ditch tearing off landing gear, pulled up and attempted stall landing, turned ship over	0	0	1	1
21	Orville, Cal	2POLM	1 - 125	Major	Right wing struck automobile parked on field, dust cloud obscurred vision	0	0	0	1
22	San Francisco, Cal	2POLB	1 - 100	Overhaul	Ground looped due to cross-wind landing	0	0	0	2
23	Sacramento, Cal	3POLB	1 - 115	Overhaul	Rolled into wind sock and tree due to fast landing 100% pilot error	0	0	0	3
24	Sacramento, Cal.	2POLB	1 - 125	Overhaul	Ground looped, unable to use brakes because of speed 3500 ft runway	0	0	0	2
25	Glendale, Cal	2PCLM	1 - 40	Major	Right landing gear gave way on account of hard landing	0	0	0	2
26	Danbury, Cal	2POLB	1 - 100	Major	Ground looped as cross wind hit plane after striking rut	0	0	0	1
27	Tanington, Conn	3PCLM	1 - 145	Overhaul	Nosed over when wheels hit soft ground	0	0	0	2
28	Tildenville, Fla	3POLB	1 - 100	Overhaul	Nosed up on striking ditch	0	0	1	0

*A - Fatal, B - Serious, C - Minor, D - Uninjured

TABLE 26 (Cont'd 2)

Ref No	Place	Aircraft Type	No Eng & Total H P.	Damage to Ship	Remarks	Injuries * A	B	C	D
29	Orlando, Fla	2PCLM	1 - 145	Major	Ground loop caused by cross-wind landing breaking landing gear wire	0	0	0	2
30	Jessup, Ga	4PCLB	1 - 285	Overhaul	Nosed over on account of soft field	0	0	0	3
31	Waycross, Ga	2PCLM	1 - 145	Major	Ground looped due to flat tire	0	0	0	2
32	Waycross, Ga	2PCLM	1 - 90	Overhaul	Nosed over due to soft field	0	0	0	2
33	Duluth, Ga	4PCLM	1 - 225	Overhaul	Left landing gear sheared off as it rolled into a hole	0	0	0	2
34	Lavonia, Ga	3POLB	1 - 165	Overhaul	Ground looped due to improper functioning of brakes	0	0	0	3
35	Atlanta, Ga	5PCLB	1 - 225	Major	Ground looped due to improper functioning of brakes	0	0	0	2
36	Atlanta, Ga	2PCLM	1 - 70	Major	Landing gear gave way on account of soft ground	0	0	1	1
37	Elmhurst, Ill	3PCLM	1 - 185	Overhaul	Landing gear damaged due to hard landing	0	0	0	2
38	Elmhurst, Ill	2PCLM	1 - 100	Major	Landing strut buckled due to hitting hole	0	0	0	2
39	Joliet, Ill	2PCLM	1 - 65	Major	Ground looped due to cross-wind	0	0	0	2
40	Glenview, Ill	4PCLM	1 - 225	Overhaul	Brakes were applied too quickly causing nose over	0	0	0	1
41	Chicago, Ill	2PCLM	1 - 70	Overhaul	Nosed over due to overshooting runway and rolling into soft mud	0	0	0	1
42	St Charles, Ill	2POLM	1 - 90	Major	Landing off runway, struck soft mud, causing plane to nose over	0	0	0	2
43	St Charles, Ill	3PCLM	1 - 145	Overhaul	Struck mud hole causing nose over	0	0	0	2
44	East Alton, Ill	3POLB	1 - 90	Washout	Plane suddenly dropped "nose-in" due to down draft	0	1	1	0
45	Marion, Ind	4PCLB	1 - 225	Overhaul	Overshot field and ran into fence and trees Runway lengths -N/S 2700 ft E/W 1990 ft NE/SW 2390 ft	0	0	2	0
46	N Judson, Ind	4PCLM	1 - 215	Overhaul	Soft field caused nose over	0	0	0	2
47	Burlington, Iowa	2PCLM	1 - 90	Major	Ground loop caused by wind	0	0	0	2
48	Louisville, Ky	2PCLM	1 - 40	Overhaul	While practicing forced landings, pilot cut throttle, on approach to field, throttle was opened to go up again, but motor cut out Left wing, then nose hit ground, plane settled on right wing				
49	New Orleans, La	2PCLM	1 - 65	Overhaul	Hit sea wall at boundary of airport tearing off landing gear Undershot field	0	0	0	2
50	Shreveport, La	2PCLM	1 - 37	Minor	Stalled at 15 ft altitude, dropped to ground	0	0	0	1
51	S Leesville, La	5PCLM	1 - 245	Overhaul	Nosed over after striking soft spot caused by sand drift	0	0	0	3
52	Portland, Me	2PCLB	1 - 210	Overhaul	Wind blew plane over	0	0	0	1
53	Wilton, Me	4PCLB	1 - 210	Overhaul	Snow and slush on runway caused nose over	0	0	0	2
54	Auburn, Me	2PCLM	1 - 40	Overhaul	Struck ditch at beginning of runway and nosed up because of down draft	0	0	1	1
55	Great Mills, Md	2PCLM	1 - 125	Overhaul	Struck soft ground, nosed over	0	0	0	1
56	Brockton, Mass	3PCLM	1 - 185	Major	Rolled off runway striking soft spot and nosing over	0	0	0	2
57	Northampton, Mass	2PCLM	1 - 65	Major	Landing gear bent due to structural failure	0	0	0	2
58	Northampton, Mass	4PCLB	1 - 210	Overhaul	Rolled off of airport into road two feet below, tearing off landing gear and nosing ship up Landed off airport	0	0	0	4

*A - Fatal, B - Serious, C - Minor, D - Uninjured

TABLE 26 (Cont'd 3)

Ref No	Place	Aircraft Type	No Eng & Total H P	Damage to Ship	Remarks	Injuries * A	B	C	D
59	Fraser, Mich	2PCLM	1 - 37	Overhaul	Stall landing	0	0	0	2
60	Detroit, Mich	4PCLB	1 - 225	Overhaul	Brakes were applied too quickly causing nose up	0	0	0	2
61	Fraser, Mich	2POLM	1 - 37	Overhaul	Undershot field striking frozen ridge and ice at edge of runway and nosing up	0	0	0	1
62	Escanaba, Mich	2POLB	1 - 85	Overhaul	Landing gear bolt broke due to structural failure	0	0	0	1
63	Detroit, Mich	5POLB	1 - 285	Major	Ground loop caused by cross-wind	0	0	0	1
64	Detroit, Mich	3POLB	1 - 90	Major	Ground looped into hangar door	0	0	0	1
65	Mayville, Mich	3POLB	1 - 90	Overhaul	Wheel dropped into hidden hole, causing nose-up	0	0	0	1
66	Carsonville, Mich	3POLB	1 - 90	Overhaul	Landing gear strut buckled due to structural failure	0	0	0	1
67	Wayne County, Mich	3POLB	1 - 90	Washout	Struck extension on top of telephone pole at edge of field	0	0	1	0
68	Hastings, Minn	2PCLM	1 - 40	Overhaul	Ski broke due to structural failure	0	0	0	1
69	Minneapolis, Minn	3POLB	1 - 220	Major	Broke left landing gear and ground looped due to landing too hard on left side	0	0	0	1
70	Ashland, Mo	4PCLM	1 - 215	Overhaul	While landing in field, ran into fence that was not noticed	0	0	0	1
71	Robertson, Mo	5PCLB	1 - 225	Overhaul	Landing gear retracted, due to not being locked in down position	0	0	0	4
72	Kansas City, Mo	2PCLM	1 - 40	Major	Landed in tall wheat nosing ship over	0	0	0	1
73	Helena, Mont	3PCLM	1 - 145	Overhaul	Brakes applied too quickly causing nose-over	0	0	0	2
74	Reno, Nev	2PCLM	1 - 90	Major	Soft sand and gravel caused nose-over	0	0	0	1
75	Keene, N H	4PCLM	1 - 215	Overhaul	Ran off runway into soft dirt causing nose-over	0	0	0	4
76	Peterboro, N H	4PCLM	1 - 215	Overhaul	Struck grass covered mudhole causing nose-over	0	0	0	1
77	Trenton, N J	3POLB	1 - 220	Overhaul	Landing gear collapsed due to striking pile of frozen dirt	0	0	0	2
78	Summitt, N J	2PCLM	1 - 37	Washout	Stalled at about 200 ft, and wind blew ship into trees	0	0	2	0
79	Newark, N J	3PCLM	1 - 90	Overhaul	Landing gear gave way when it struck a hidden stump	0	0	0	1
80	Carlsbad, N Mex	3PCLM	1 - 145	Overhaul	Oleo strut collapsed due to structural failure	0	0	0	1
81	Livingston Manor, N Y	4PCLM	1 - 245	Overhaul	Soft ground caused ground loop into wire fence	0	0	0	2
82	Roosevelt Field, N Y	3POLB	1 - 220	Major	Ground looped	0	0	0	1
83	Utica, N Y	2PCLM	1 - 125	Overhaul	Plane stalled in due to lack of speed	0	0	0	2
84	Roosevelt Field, N Y	5PCLM	1 - 220	Washout	Struck tree and bunkers on golf course next to airport due to strong winds	0	0	0	4
85	Rochester, N Y	3POLB	1 - 100	Overhaul	Engine cut-out causing hard landing and damaging landing gear	0	0	1	0
86	Sloatsburg, N Y	2PCLM	1 - 40	Overhaul	Struck a 10 ft post in landing intentionally on playground	0	0	0	1
87	Elmira, N Y	2POLM	1 - 37	Overhaul	Landing gear broke due to hard landing	0	0	0	1
88	Elizabeth City, N Car	2PCLM	1 - 36	Overhaul	Nosed up when landing gear broke due to structural failure	0	0	0	2

*A - Fatal, B - Serious, C - Minor, D - Uninjured

TABLE 26 (Cont'd 4)

Ref No	Place	Aircraft Type	No Eng & Total H P	Damage to Ship	Remarks	Injuries * A	B	C	D
89	Pine Bench, N Car	2PCLM	1 - 37	Major	Landing gear washed out when plane hit ditch due to undershooting field	0	0	0	1
90	Sandusky, Ohio	4PCLM	1 - 215	Major	Wind under right wing caused nose-over	0	0	0	1
91	Lexington, Ohio	4PCLM	1 - 215	Overhaul	Soft field caused nose-over	0	0	0	1
92	Chesapeake, Ohio	2PCLM	1 - 36	Major	Soft field caused nose-over	0	0	0	1
93	Cleveland, Ohio	3POLB	1 - 90	Major	Ground looped	0	0	0	1
94	Mansfield, Ohio	4PCLM	1 - 245	Overhaul	Brakes applied on wet muddy field, struck gravel while skidding, nosed over	0	0	0	1
95	Warren, Ohio	3POLB	1 - 210	Overhaul	Tail wheel caught in plank on runway causing ground loop	0	0	0	1
96	Hunting Vallen Village, Ohio	3PCLM	1 - 320	Overhaul	Ground looped and struck tree	0	0	0	1
97	Warren, Ohio	4PCLB	1 - 285	Overhaul	Tail wheel deflected by rail causing ground loop	0	0	0	1
98	Willoughby, Ohio	5PCLM	1 - 245	Overhaul	Levelled off too high, landing hard on right wheel in cross wind, landing gear collapsed	0	0	0	4
99	Bellevue, Ohio	2PCLM	1 - 37	Major	Landing gear spread out due to hard landing causing nose-over	0	0	1	0
100	Youngstown, Ohio	3POLB	1 - 125	Overhaul	Turn attempted without enough altitude or flying speed, wing hit ground	0	0	0	1
101	Ponca City, Okla	4PCLM	1 - 245	Overhaul	Wind nosed plane over	0	0	0	1
102	Sweetwater, Okla	3POLB	1 - 150	Washout	Landing gear spread out and plane nosed over due to shock cord breaking	0	0	0	3
103	Hodges, Okla	3PCLM	1 - 145	Major	Landing gear broke off due to hitting hidden tree stump	0	0	0	2
104	Oklahoma City, Okla	5PCLB	1 - 285	Major	Landing gear collapsed due to structural failure	0	0	0	4
105	Eastside, Oregon	2PCLM	1 - 40	Overhaul	Plane blown into ground by strong down draft	0	0	1	0
106	Beyerstown, Pa	3PCLM	1 - 145	Overhaul	Soft field caused nose-over	0	0	0	1
107	Philadelphia, Pa	3POLB	1 - 175	Overhaul	Ground looped due to ruts in field	0	0	0	1
108	York, Pa	4PCLB	1 - 225	Major	Stalled in over wires at edge of field, struck soft ground, nosed up	0	0	1	2
109	Warren, Pa	4PCLM	1 - 215	Overhaul	Stalled in to prevent hitting row of buildings Engine failure, Landed short of airport	0	0	0	1
110	Greeville, Pa	2PCLM	1 - 37	Overhaul	Caught landing gear in top of tree, nosed into ground	0	0	0	2
111	Harrisburg, Pa	2POLM	1 - 50	Overhaul	Pancaked	0	0	0	1
112	Philadelphia, Pa	2PCLM	1 - 40	Major	Levelled off too high, fell in on one wheel	0	0	0	2
113	Vandergrift, Pa	3POLB	1 - 220	Major	Brakes applied too quickly causing nose over	0	0	0	1
114	Reading, Pa	2PCLM	1 - 36	Major	Struck by down draft and fell in	0	0	0	2
115	Charleston, S C	4PCLB	1 - 285	Major	Retractable landing gear mechanism failed, landed on fuselage	0	0	0	2
116	Ripley, Tenn	3POLB	1 - 220	Major	Ship nosed over when axle broke due to structural failure	0	0	0	2

*A - Fatal, B - Serious, C - Minor, D - Uninjured

TABLE 26 (Cont'd 5)

Ref No	Place	Aircraft Type	No Eng & Total H P	Damage to Ship	Remarks	Injuries * A	B	C	D
117	Galveston, Tex	5PCLB	1 - 225	Overhaul	Brakes applied too quickly causing nose over	0	0	0	1
118	Corpus Christi, Tex	3POLM	1 - 80	Washout	Attempted bank too low to ground, fell in	3	0	0	0
119	San Antonio, Tex	4PCLB	1 - 250	Overhaul	Brakes applied too quickly causing nose over	0	0	0	1
120	Grand Prairie, Tex	2PCLM	1 - 37	Washout	Wing hit ground when pilot lost control	0	1	0	0
121	Carrollton, Tex	2POLB	1 - 100	Overhaul	Struck stump and nosed over	0	0	0	1
122	Macoma, Tex	4PCLM	1 - 285	Overhaul	Landing gear dropped into hole	0	0	0	1
123	Richmond, Va	2POLM	1 - 90	Major	Landed hard, plane rolled into hole damaging landing gear	0	0	0	1
124	Shelton, Wash	4PCLB	1 - 210	Overhaul	Wheel fairings filled with ice and snow locking wheels and causing nose over	0	0	0	1
125	Seattle, Wash	2POLB	1 - 100	Major	Undershot field and struck border light causing nose over	0	0	0	2
126	Tacoma, Wash	3POLB	1 - 90	Major	Landed too close to edge of field, struck boundary light	0	0	0	2
127	Logan, W Va	4PCLB	1 - 170	Major	Ground looped	0	0	0	1
128	Whitewater, Wisc	4PCLM	1 - 215	Major	Landing gear hit rocks causing nose over	0	0	0	2
129	Oshkosh, Wisc	2POLM	1 - 30	Major	Overshot field and ran into fence E W runway 1666 ft N S runway 2640 ft Landed S E to N W Contacted after using up 80% of available distance due to fog Ceiling 100 ft to 200 ft	0	0	0	1
130	Tarrington, Wyo	2PCLM	1 - 37	Washout	Misunderstanding as to who was handling the controls, ran into telephone pole and wire at edge of field	0	1	1	0
131	Red Bluff, Cal	2PCLM	1 - 37	Overhaul	Wind blew ship over after landing was made	0	0	0	1
132	Van Nuys, Cal	2POLB	1 - 330	Overhaul	Ground looped	0	0	1	0
133	Santa Cruse Island, Cal	4PCLM	1 - 215	Overhaul	Sheared off undercarriage on striking soft spot	0	0	0	4
134	National City, Cal	2POLM	1 - 100	Major	Stalled	0	0	0	2
135	Shafter, Cal	4PCLM	1 - 330	Major	Ground loop caused by soft spot on field	0	0	0	4
136	Fresno, Cal	2POCLAg	1 - 160	Major	Ground loop caused by gust of wind	0	0	0	1
137	Inglewood, Cal	2POLM	1 - 125	Overhaul	Brakes applied too quickly causing nose over	0	0	0	2
138	Alhambra, Cal	7PCLM	1 - 330	Overhaul	Ran into ditch to avoid another plane, nosed up	0	0	0	3
139	Woodland, Cal	1POLB	1 - 220	Overhaul	Strong cross wind turned ship over	0	0	0	1
140	Bakersfield, Cal	1POLB	1 - 250	Overhaul	Ground looped due to cross wind	0	0	0	1
141	Sanford, Colo	3POLB	1 - 220	Major	Ground looped to avoid fence	0	0	0	2
142	Challis, Idaho	2PCLM	1 - 85	Overhaul	Ground looped	0	0	0	1
143	Oaklawn, Ill	2PCLM	1 - 70	Overhaul	Wheels went through thin ice on field, nosed over	0	0	0	2
144	Marion, Ill	5PCLM	1 - 550	Overhaul	Thick snow on field caused plane to nose over	0	0	0	1
145	Rodesha Caldo Parish, La	5PCLB	1 - 225	Overhaul	Undercarriage fitting gave way, due to structural failure, and plane nosed over	0	0	0	2
146	Pecan Island Vermilion Parish, La	3POLB	1 - 100	Overhaul	Stalled at 60 ft altitude	0	0	0	2
147	Bossier, La	3POLB	1 - 330	Overhaul	Overshot field, brakes applied too quickly, plane nosed up	0	0	0	1

*A - Fatal, B - Serious, C - Minor, D - Uninjured

TABLE 26 (Cont'd 6)

Ref No	Place	Aircraft Type	No Eng & Total H P	Damage to Ship	Remarks	Injuries * A	B	C	D
148	West Hanover, Mass	2POLB	1 - 100	Overhaul	Tail skid struck roof of car parked at edge of airport	0	0	0	2
149	Jackson, Miss	5PCLB	1 - 225	Overhaul	Wind tipped ship up and broke ski	0	0	0	4
150	West Plains, Mo	2PCLM	1 - 40	Overhaul	Landing gear demolished by hard landing	0	0	0	2
151	Omaha, Neb	1POLB	1 - 330	Overhaul	Landing gear damaged from striking ground too hard due to darkness, fog and snow-covered ground	0	0	1	0
152	Red Bank, N J	4PCLB	1 - 320	Overhaul	Soft spot caused nose-up and wind blew ship over	0	0	0	2
153	Camden, N J	5PCLB	1 - 225	Overhaul	Wind got under one wing forcing other into the ground and nosing ship up	0	0	1	1
154	Ripley, N Y.	2PCLM	1 - 40	Overhaul	Wind blew ship over on its back after it had stopped rolling	0	0	1	1
155	Syracuse, N Y.	2POLB	1 - 100	Overhaul	Plane ground looped due to cross-wind	0	0	0	1
156	Ithaca, N Y	4PCLM	1 - 260	Overhaul	Landing gear gave way due to structural failure	0	0	1	1
157	Marcy, N Y	2PCLM	1 - 125	Major	Wheel locked account ice and snow in wheel fairing	0	0	0	1
158	Binghamton, N Y.	5PCLM	1 - 285	Overhaul	Soft field, nosed over	0	0	0	3
159	Corning, N Y	5POLB	1 - 220	Overhaul	Failure of landing gear strut	0	0	0	2
160	Blue Ash, Ohio	4PCLM	1 - 245	Overhaul	Overshot field and ran into hedge fence	0	0	0	4
161	Cleveland, Ohio	4PCLM	1 - 215	Major	Hit radio antenna at edge of airport	0	0	0	3
162	Burns, Oregon	2PCLM	1 - 145	Major	Ran off snow-cleared runway causing nose-over	0	0	0	1
163	Wyoming, Pa.	2PCLM	1 - 36	Major	Landing gear damaged by hard landing due to gusty winds	0	0	0	1
164	Pittsburgh, Pa	4PCLM	1 - 250	Overhaul	Wheel fairing came off locking wheel causing nose-over	0	0	0	4
165	Dallas, Texas	4PCLB	1 - 210	Overhaul	Left landing gear strut buckled due to structural failure	0	0	0	4
166	Ft Worth, Texas	5PCLB	1 - 225	Overhaul	Landed on soft spot and nosed up due to structural failure	0	0	0	4
167	Driscoll, Texas	3POLB	1 - 125	Overhaul	Landing gear damaged due to hitting hidden ditch	0	0	0	1
168	Dallas, Texas	5PCLM	1 - 220	Major	Ground loop caused by left brake locking	0	0	0	4
169	Farmville, Va	2POCLAg	1 - 210	Major	Ground looped	0	0	0	2
170	Yelm, Wash	3POLB	1 - 220	Overhaul	Plane ground looped, one wheel rolled into hole and ship nosed over	0	0	0	3
171	Lake Minchuminca, Alaska	2PCLM	1 - 125	Major	Ski broke due to going through snow crust	0	0	0	2
172	Platinum, Alaska	5PCLB	1 - 525	Overhaul	Landing gear strut broke due to structural failure	0	0	0	1
173	Wassila, Alaska	4PCLM	1 - 330	Major	Landing gear damaged due to bouncing caused by hard snow drift	0	0	0	2
174	Gold King Creek, Alaska	5POLB	1 - 220	Major	900 ft available down hill Ran into trees at edge of short field	0	0	0	1
175	Napaimute, Alaska	6PCLSM	1 - 330	Major	Hit water hole in ice and broke ski and axle	0	0	0	1
176	Chevak, Alaska	4PCLM	1 - 245	Overhaul	Tail ski broken off in rough ice	0	0	0	4
177	Kantishna, Alaska	4PCLB	1 - 225	Overhaul	Wheels dropped through hole in ice damaging landing gear	0	0	0	1
178	Cardova, Alaska	10PCLM	1 - 575	Major	Wind blew ship over a bank	0	0	0	1

*A - Fatal, B - Serious, C - Minor, D - Uninjured

TABLE 26 (Cont'd 7)

Ref No	Place	Aircraft Type	No Eng & Total H P	Damage to Ship	Remarks	Injuries * A	B	C	D
179	Harding Lake, Alaska	6PCLM	1 - 450	Overhaul	Ski broke due to hitting frozen drift	0	0	3	3
180	Esther Island, Alaska	5PCLB	1 - 225	Overhaul	Wheels went through soft spot in ice causing nose-up	0	0	0	3
181	Woodchopper Creek Terr , Alaska	2PCLM	1 - 90	Major	Wing hit brush in landing causing nose-over	0	0	0	1
182	Moore Creek, Alaska	6PCLM	1 - 450	Major	Stones on runway damaged stabilizer	0	0	0	1
183	Sunnyvale, Cal	2PCLM	1 - 37	Overhaul	Powerplant failure, tail struck tree on edge of road when landing was attempted off airport	0	0	2	0
184	Alameda, Cal.	2PCLM	1 - 65	Overhaul	Engine failure, landing gear sheared off on striking railroad tracks	0	0	0	2
185	Bakersfield, Cal	5PCLB	1 - 285	Overhaul	Engine failure, landed in grazing land damaging landing gear and nosing ship up	0	0	0	1
186	Palmdale, Cal	3PCLM	1 - 145	Overhaul	Engine missing, landing gear damaged in landing cross wind	0	0	0	1
187	Upland, Cal	2POLM	1 - 125	Overhaul	While landing in fog, landing gear hit stump on field and nosed over	0	0	0	1
188	Capon Pass, Cal	3POLB	1 - 220	Overhaul	Down draft in canyon, could not get out, damaged landing gear	0	0	0	3
189	New Canoan, Conn	2POLB	1 - 95	Overhaul	Engine functioned improperly due to auto gas, could not clear trees at edge of field when hit by down draft	0	1	0	0
190	N Haven, Conn	3POLB	1 - 90	Overhaul	Engine failure, landed with wing low	0	0	0	3
191	Dover, Del	2POLB	1 - 100	Major	Engine failure, wings hit fence posts	0	0	0	2
192	Belle Glade, Fla	2POLM	1 - 45	Washout	Propeller flew off through fuselage cutting control wires	0	0	0	2
193	Turkey Key, Fla	2PCLM	1 - 70	Overhaul	Engine failure, landed in brush, little damage	0	0	0	1
194	Clewiston, Fla	3PCLM	1 - 145	Overhaul	Plane attempted landing on sugar cane field during heavy rain storm, wheels became locked and plane nosed over	0	0	0	2
195	Near Coco, Fla	2PCLM	1 - 70	Washout	Engine failure, flying 15 ft over water when engine cut out, landed in water	0	0	2	0
196	Midway, Ga	3PCLM	1 - 145	Overhaul	Fog, landed in soft field and nosed over	0	0	0	2
197	Savannah, Ga	2POLM	1 - 45	Major	Gas exhausted, ground looped to avoid hitting mule in cornfield	0	0	0	2
198	Cave Springs, Ga	2PCLM	1 - 70	Major	Gas exhausted, high grass caused nose-over	0	0	0	2
199	Alton, Ill	2PCLM	1 - 70	Major	Propeller assembly failure, landed on rough sand bar, damaged landing gear	0	0	0	2
200	Monon, Ind	3POLB	1 - 175	Overhaul	Engine failure, soft rolling field caused nose-over	0	0	0	3
201	New Orleans, La	2POLM	1 - 95	Overhaul	Throttle fitting broke, broke landing gear in landing on road	0	0	0	2
202	Portage Lake, Me	3POLB	1 - 220	Washout	Throttle jammed, landed on ice and went through	2	0	0	1

*A - Fatal, B - Serious, C - Minor, D - Uninjured

TABLE 26 (Cont'd 8)

Ref No	Place	Aircraft Type	No Eng & Total H P	Damage to Ship	Remarks	Injuries * A	B	C	D
203	Gardiner, Me	6PCLM	1 - 220	Major	While attempting to land during fog and on a rough plowed field, ship nosed up	0	0	0	1
204	Ashland, Mass	3POLB	1 - 225	Overhaul	Engine failure, stalled in and sheared off landing gear	0	0	1	2
205	Brainerd, Minn.	2POLB	1 - 100	Major	Low ceiling, attempted to ground loop to avoid fence, field soft causing nose-over	0	0	0	1
206	Saginaw, Minn.	3POLB	1 - 185	Overhaul	Engine failure, soft field caused nose-over	0	0	0	2
207	Eldon, Mo	2PCLM	1 - 85	Overhaul	Engine failure, soft field caused nose-over	0	0	0	2
208	Burwell, Neb	2PCLM	1 - 36	Overhaul	Engine failure, rough field caused nose-up	0	0	0	2
209	Stelton, N. J	2PCLM	1 - 145	Overhaul	Engine failure, hit ditch, sheared off landing gear and nosed up	0	0	0	1
210	Albany, N Y.	1POLM	1 - 45	Major	Engine failure, rough frozen ground, damaged landing gear	0	0	0	1
211	Otselic, N Y	3POLB	1 - 125	Overhaul	Engine failure, high grass locked wheels causing nose-over	0	0	0	2
212	Wade, N Car	2PCLM	1 - 70	Overhaul	Weather, soft field caused nose-over	0	0	0	1
213	Apple Creek, Ohio	3POLB	1 - 90	Overhaul	Darkness, unable to see ground, rolled over bank causing nose-over	0	0	0	2
214	Hamilton, Ohio	2PCLM	1 - 36	Overhaul	Propeller blade, landing without damage to the plane proper but considerable damage to the motor mount	0	0	0	2
215	Columbus, Ohio	3POLB	1 - 155	Overhaul	Engine failure, ground looped to avoid ditch	0	0	0	3
216	Dellroy, Ohio	3POLB	1 - 102	Washout	Engine failure, stalled in to avoid trees and nosed over	0	0	0	3
217	Cottage Grove, Ore	3POLB	1 - 220	Overhaul	Engine failure soft field caused nose-over	0	0	0	2
218	Portland, Ore	5PCLB	1 - 285	Overhaul	Gas exhausted, ground looped to prevent going over embankment	0	0	0	5
219	Red Lion, Pa.	2PCLM	1 - 37	Overhaul	Ice on wings necessitated fast landing, nosed up	0	0	1	0
220	Wilkes Barre, Pa	2PCLM	1 - 36	Overhaul	Gas exhausted, landed in trees	0	0	0	1
221	Austin, Texas	3PCLM	1 - 90	Major	Heavy rain, landed in small field and ran into fence Engine failure	0	0	0	1
222	Milford, Texas	3POLB	1 - 420	Overhaul	Powerplant failure, wheel broke due to structural failure, causing nose-up	0	0	0	2
223	Pampa, Texas	2PCLM	1 - 40	Overhaul	Engine reved down, down draft hit ship in turn, hit ground at 45 degree angle	0	0	1	0
224	Ft [illegible], Texas	2PCLM	1 - 90	Major	Heavy wind and rain, hard landing damaged landing gear	0	0	0	2
225	Emporia, Va	4PCLB	1 - 330	Overhaul	Weather, muddy plowed field causing nose-over	0	0	0	4
226	Shelton, Wash	2PCLM	1 - 37	Major	Engine failure, stalled in, damaged landing gear	0	0	1	1
227	Glendale, Cal.	7PCLM	1 - 420	Washout	Powerplant failure, hard landing, wheel hit slab of concrete and broke off, ground looped	0	1	2	3
228	Red Bluff, Cal.	2PCLM	1 - 145	Major	Gas exhausted, hit muddy spot in field and nosed over	0	0	0	1
229	Lakeland, Fla.	2POLM	1 - 90	Overhaul	Powerplant failure, attempted a turn without sufficient altitude or speed, wing struck ground and nosed in	0	0	2	0
230	Pahokee, Fla	5PCLM	1 - 220	Washout	Powerplant failure, engine cut out in turn at 100 ft altitude during crop dusting, crashed and burned	0	0	0	1

*A - Fatal, B - Serious, C - Minor, D - Uninjured

TABLE 26 (Cont'd 9)

Ref No	Place	Aircraft Type	No Eng & Total H P	Damage to Ship	Remarks	Injuries * A	B	C	D
231	Jackson, Ga	4PCLM	1 - 260	Overhaul	Powerplant failure, stalled in and nosed up	0	0	0	2
232	Belleville, Ill	14PCLM	3 - 660	Overhaul	Powerplant failure, right wheel struck hole and ground looped	0	0	0	2
233	Claypool, Ind	7PCLM	2 - 400	Overhaul	Mechanic accidently pulled master engine switch, landed with wheels up, slid into fence	0	0	0	5
234	Evansville, Ind	4PCLB	1 - 225	Overhaul	Powerplant failure, soft field caused nose-over	0	0	0	4
235	Groton, Mass	2POLB	1 - 115	Overhaul	Icing conditions, overshot field	0	0	0	1
236	Spring Arbor, Mich	3POLB	1 - 90	Overhaul	Powerplant failure, ran into rocks and stump, collapsed landing gear and nosed over	0	0	0	1
237	Bay City, Mich	3POLB	1 - 102	Overhaul	Powerplant failure, tried to stretch glide to clear fence, stalled	0	0	0	1
238	Scotch Plains, N J	2PCLAg	1 - 160	Overhaul	Powerplant failure, stalled into trees	0	0	0	1
239	Preakness, N J	2PCLM	1 - 40	Major	Powerplant failure, rough field damaged landing gear	0	0	0	2
240	Albany, N Y	4PCLM	1 - 245	Major	Powerplant failure, nosed up	0	0	0	2
241	Penfield, N Y	4PCLM	1 - 245	Overhaul	Powerplant failure, rough field sheared off landing gear	0	0	0	4
242	Mineola, L I , N Y	3POLB	1 - 133	Major	Powerplant failure, crankshaft broke and propeller flew off lodging between lower wing and outboard strut, landed without further damage	0	0	0	2
243	Raleigh, N Car	5PCLB	1 - 285	Overhaul	Powerplant failure, mud in wheel streamlines causing nose-over	0	0	0	2
244	Akron, Ohio	3PCLB	1 - 285	Washout	Powerplant failure, struck soft spot and nosed over	0	0	0	1
245	Cincinnati, Ohio	3POLB	1 - 115	Overhaul	Gas exhausted, soft ground caused plane to nose over	0	0	0	1
246	Cambridge, Ohio	2POLB	1 - 40	Major	Powerplant failure, crankshaft broke and propeller flew off damaging right upper wing, landed without further damage	0	0	0	2
247	Ashland City, Tenn	3POLB	1 - 90	Major	Powerplant Failure, soft field, nosed over	0	0	0	2
248	S Garrison, Texas	4PCLB	1 - 210	Washout	Plane caught fire due to short circuit, landed and burned up	0	0	0	3
249	Lynchburg, Va	4PCLM	1 - 245	Overhaul	Visibility poor, soft field caused plane to nose-over	0	0	0	1
250	Randle, Wash	2PCLM	1 - 90	Major	Darkness, became lost, deep snow caused nose-up	0	0	0	1
250	Totals				Total Persons Involved in These Accidents	6	5	38	423
						472			

* A - Fatal, B - Serious, C - Minor, D - Uninjured

SUMMARY OF MECHANICAL INTERRUPTIONS INVOLVING AIRLINE AIRPLANES

TABLE 27

Ref No	Place	Aircraft Type	Source of Interruption	Remarks
1	Tampa, Fla	10PCLM	Wheel	Right wheel began to split inside All wheels being sent to factory for reconditioning as fast as possible
2	Miami, Fla	24PCLM	Tire - 10 ply	Tires removed due to buldge developing in sidewall about three inches from the head around the entire periphery of tire Tire had made 210 landings
3	Unknown	12PCLM	Wheel	Outer flange casting cracked in lock ring groove of tail wheel Defective casting
4	Cheyenne, Wyo.	13PCLM	Tube	Tire blew out while taking off Tire blew out from a defective bead wire
5	Salt Lake City, Utah	13PCLM	Tire - 6 ply	While in the air, tire blew out near the bead Trouble probably caused by strain due to cross wind take-off from a rough field Extra heavy and ten ply tires are being placed on the airplanes in regular service
6	Buffalo, N Y	24PCLM	Outside Brake Drum	Ship arrived with brake drum broken out and brake shoe badly scored Considerable difficulty has been experienced with these brake drums and the manufacturer is furnishing new type brake drums and has given information for reworking all of these wheels
7	Washington, D C	10PCLM	Brake Discs	Left brake would not hold This type of brake has very poor heat dissipation
8	Pittsburgh, Pa	10PCLM	Brake Discs	Plane arrived with right brake not functioning properly Caused by warped brake discs Not sufficient cooling area
9	Sacramento, Cal	13PCLM	Tire	Landing gear tire blew out while plane was in flight Failure occurred in the region of the bead Since this series of tires were manufactured, a number of changes have been made to strengthen the bead
10	Cleveland, Ohio	10PCLM	Hydraulic Brake	Right brake inoperative Inspection disclosed brake was overheated
11	Pittsburgh, Pa	10PCLM	Tail Wheel Tire	Tail wheel tire flat Bigger wheel and tire on this type equipment suggested
12	Tampa, Fla	12PCLB	Tail Wheel Tire	Tail wheel tire blew out due to excessive wear from shimmying Heavier shock cord installed
13	Cleveland, Ohio	10PCLM	Tire	Tire went flat after landing Brakes too hot to immediately change tire
14	Pittsburgh, Pa	10PCLM	Brake Discs	Right brake would not hold After examination it was found that the brakes were extremely hot
15	Rochester, N Y	12PCLM	Hydraulic Brake Discs	The steel discs warped and the Laminated discs heated until fusion took place The air temperature was 105 degrees at Rochester and the brakes were used too strenuously in landing in a short field
16	Unknown	12PCLB	Brake Discs	Trouble was caused by the brake discs on the right wheel becoming seized due to warping of plates This condition was caused by heat from riding the brakes

TABLE 27 (Cont'd 2)

Ref No	Place	Aircraft Type	Source of Interruption	Remarks
17	Unknown	24PCLM	Wheel	Brake drums cracking where bolted to wheel flanges Cracks originate at bolt holes and progress until failure is complete Where failure is complete it can be detected without removing wheel; otherwise it may be necessary to do so Eleven drums have failed so far Perhaps too light a drum and/or due to expansion on account of heat from brakes
18	Unknown	12PCLM	Wheel Flange	Outer flange casting cracked in lock ring groove of tail wheel Defective casting
			<u>Summary of Mechanical Interruptions Involving Engine Failures</u>	
19	Kansas City, Mo	24PCLM	Master Rod	Left propeller went into high pitch on take-off due to fine particles of steel and brass found in Cuno oil filter and screen resulting from master rod failure
20	Pittsburgh, Pa	24PCLM	Plugs	On the take-off, just as the landing gear had been retracted, the right engine manifold pressure dropped to 30" After sufficient altitude was reached to make the approach for a landing, the right engine was throttled down and the gear was lowered
21	Washington, D C	24PCLM	Plugs	Engine cut out on take-off due to bad plugs.
22	Newark, N J	24PCLM	Carburetor	Motor quit on take-off
23	Washington, D C	24PCLM	Detonation	Ship took off from Hoover Field and just crossed road when left engine cut out Plane landed in Washington Airport Engine cut out due to detonation brought about by high cylinder temperature caused by long run-up
24	Ft Worth, Tex	19PCLB	Overheating	Left motor overheated on take-off (Motor newly overhauled)
25	Los Angeles, Cal	13PCLM	Failure of crank case breather relief valve	R H Engine threw oil badly just as airplane left the ground and pilot landed
26	Pendleton, Ore	13PCLM	Misfunctioning of carburetor	R H Engine would not rev-up properly on take off
27	Rochester, N Y	10PCLM	Water in fuel	Center engine stopped at 75 ft height Pilot landed off the airport
28	Detroit, Mich	16-18PCLM	Mechanical failure	Cylinder head on one of the two engines blew off on the takeoff Pilot landed on airport

PRIVATE AIRCRAFT - B

TAKE OFF CHARACTERISTICS

CORRECTED TO ZERO WIND AND SPECIFICATION GROSS WEIGHT

TABLE 28

MINES FIELD, INGLEWOOD, CALIFORNIA - GEOGRAPHICAL ALTITUDE 97 FT							
Test No	Pressure Altitude Feet	Density Altitude Feet	K DP	Distance Start to Unstick	50 Ft	100 Ft	Unstick Speed
1201	-150	200	1 00	800	1892	2520	60
1203	-150	200	1 00	765	2068	2710	61
1206	-150	300	998	751	2067	2548	62
1222	-100	200	1 00	690	—	—	59
1223	-100	200	1 00	810	—	—	59
1224	-100	200	1 00	754	—	—	57
1225	-100	200	1 00	670	—	—	58
1226	-100	200	1 00	710	—	—	60
1227	-110	200	1 00	710	—	—	61
1228	-110	200	1 00	862	2729	2628	61
1229	-110	200	1 00	759	2130	2727	61
1230	-110	200	1 00	703	1936	2472	56
1231	-120	200	1 00	832	1702	2258	62
1232	-120	100	1 003	897	1855	2607	63
1233	-120	100	1 003	905	1916	2521	64
1242	-140	50	1 005	870	—	—	61
1244	-140	50	1 005	850	1785	2363	62
1246	-140	50	1 005	780	1780	2410	60
1248	-140	100	1 005	838	1566	2144	62
1250	-140	250	1 00	750	1740	2430	57
1252	-140	300	998	800	1720	2455	59
1267	4100	3300	697	—	—	—	64
1268	4100	3300	697	1110	2856	4091	67
1269	4100	3300	697	1320	3746	4878	65
1270	4100	3300	697	1200	3442	4413	68
1271	4100	3300	697	1136	2358	3497	66
1272	4100	3300	697	1078	2368	3066	67
1273	4100	3250	698	1215	2405	3322	72
1274	4100	3250	698	1246	2236	3199	68
1275	4100	3250	698	1185	2528	3322	71
1276	4100	3250	698	1325	2682	3526	69
1277	4100	3250	698	1136	2384	3188	68
1278	4100	3250	698	980	2556	3525	64
1279	4100	3500	693	1018	2332	3340	65
1280	4100	3500	693	1170	2415	3456	70
1281	4100	3500	693	1238	2329	3077	68
1282	4100	3500	693	1253	2382	3345	69
1283	4100	3500	693	1315	2674	3601	71
1284	4100	3500	693	1268	2460	3330	70
1285	4100	3500	693	1075	2345	3418	66
1286	4100	3500	693	1117	2233	3152	65
1287	4100	3500	693	1061	2281	3172	64
1288	4100	3500	693	1212	2284	3106	68
1289	4100	3550	693	1252	2349	3226	71
1290	4100	3500	693	1208	2453	3365	69
1291	4100	3500	693	1358	2330	3343	71
1292	4100	3800	688	1430	2684	3626	77
1293	4100	3800	688	1500	2722	3444	76

PRIVATE AIRCRAFT – B

LANDING CHARACTERISTICS

CORRECTED TO ZERO WIND AND SPECIFICATION GROSS WEIGHT

TABLE 29

Test No	Density Altitude Feet	Distance From 100' to Contact	Distance From 50' to Contact	Distance From 100' to 50'	Contact Speed	Glide Path Ratio 100' to Contact	Glide Path Ratio 100' to 50'
SALT LAKE CITY, UTAH – GEOGRAPHICAL ALTITUDE 4220 FT							
1295	3450	1852	1020	832	53	18 5	16 6
1296	3450	1158	627	531	58	11 6	10 6
1297	3450	1682	1221	461	57	16 8	9 2
1299	3400	1846	1261	585	57	18 5	11 7
1300	—	1819	1286	533	61	18 2	10 6
1301	3400	1519	910	609	66	15 2	12 2
1302	3400	2537	1868	669	61	25 4	13 4
1303	3400	1910	1286	624	55	19 1	12 5
1304	3400	2297	1651	646	53	23 0	12 9
1305	3400	1467	934	533	59	14 7	10 7
1306	3400	2198	1565	633	48	22 0	12 7
1307	3400	1921	1369	552	56	19 2	11 0
1308	2450	1952	1376	576	60	19 5	11 5
1309	2450	1692	1111	581	63	16 9	11 6
1310	2450	2035	1405	630	56	20 4	12 6
1311	2450	2110	1522	588	53	21 1	11 8
1312	2450	2140	1488	652	56	21 4	13 0
1313	2450	1831	1359	472	53	18 3	9 4
1314	2450	1859	1338	517	55	18 6	10 3
1315	2600	1980	1420	560	52	19 8	11 2
1316	2600	1790	1215	575	51	17 9	11 5
1317	2600	1980	1455	525	51	19 8	10 5
1318	2700	2170	1500	670	56	21 7	13 4
1319	2700	1755	1155	600	56	17 6	12 0
1320	2700	2050	1400	650	55	20 5	13 0
1321	2700	1925	1340	585	57	19 3	11 7
MINES FIELD, CALIFORNIA – GEOGRAPHICAL ALTITUDE 93 FT							
1202	200	—	—	—	48	—	—
1205	200	2056	1408	648	55	20 6	13 0
1207	200	1779	1115	664	57	17 8	13 3
1208	200	1966	1143	823	55	19 7	16 5
1209	300	1792	1147	645	53	17 9	12 9
1210	300	1783	944	839	56	17 8	16 8
1211	300	—	—	—	52	—	—
1212	300	1627	1131	496	57	16 3	9 9
1213	300	1228	748	480	57	12 3	9 6
1214	300	1968	1423	545	56	19 7	10 9
1215	400	1513	948	565	56	15 1	11 3
1216	400	1925	1455	470	60	19 3	9 4
1217	700	2360	1980	380	48	23 6	7 6
1218	700	2310	1550	860	53	23 1	17 2
1219	700	—	—	—	53	—	—
1220	700	2376	1668	708	53	23 8	14 2
1243	50	2100	1070	1030	59	21 0	20 6
1245	50	2120	1528	592	53	21 2	11 8
1247	50	1690	1050	640	53	16 9	12 8
1249	100	1803	1038	765	54	18 0	15 3
1251	300	2080	990	1090	55	20 8	21 8
1253	300	1585	1210	375	53	15 9	7 5

AIRLINE AIRCRAFT - D

TAKE-OFF CHARACTERISTICS

CORRECTED TO ZERO WIND AND SPECIFICATION GROSS WEIGHT

TABLE 30

Test No	Pressure Altitude Feet	Density Altitude Feet	K DP	Distance Start to Unstick	Distance Start to 50 Ft.	Distance Start to 100 Ft.	Unstick Speed
MINES FIELD, CALIFORNIA - GEOGRAPHICAL ALTITUDE 93 FT							
366	100	700	0.975	736	1651	2084	86
368	100	800	0 982	625	1626	2682	83
370	100	900	0 968	789	2110	2725	77
376	80	700	0 975	1675	—	—	112
378	80	700	0 975	1438	3360	4450	107
380	80	700	0 975	1915	3821	—	108
384	80	700	0 975	913	2229	2763	82
390	50	700	0 975	1101	2340	—	83
392	50	700	0 975	963	2110	2840	85
394	50	1100	0 962	500	—	—	59
396	50	1200	0 960	690	—	—	74
398	50	1200	0 960	715	2850	—	77
400	80	1000	0 976	510	1860	—	70
402	80	1000	0 976	1021	—	—	76
413	100	1000	0 976	1110	2615	3788	83
415	100	1500	0 950	1050	2750	4020	83
417	100	1500	0 950	1025	2755	3910	80
419	100	1400	0 953	1109	2626	3746	86
421	100	1500	0 950	1440	2736	3787	81
425	100	1500	0 950	1110	2593	—	86
SALT LAKE CITY, UTAH - GEOGRAPHICAL ALTITUDE 4220 FT.							
452	4300	6200	0.809	1005	2880	—	86
453	4300	6200	0.809	966	2430	—	77
460	4000	5000	0.842	1380	—	—	92
461	4000	5000	0 842	1380	—	—	94
475	3900	4800	0 848	1116	—	—	71
476	3900	4600	0 853	1450	—	—	89
477	3900	5000	0 842	1469	—	—	85

AIRLINE AIRCRAFT - D

LANDING CHARACTERISTICS

CORRECTED TO ZERO WIND AND SPECIFICATION GROSS WEIGHT

TABLE 31

Test No	Density Altitude Feet	Contact Speed (M.P H.)
MINES FIELD, CALIFORNIA - GEOGRAPHICAL ALTITUDE 93 FT		
367	700	84
369	900	82
371	1000	76
377	600	72
379	700	—
381	700	83
383	700	68
385	700	74
387	700	71
389	700	69
391	700	75
393	700	70

TABLE 31 (Cont'd 2)

MINES FIELD, CALIFORNIA - GEOGRAPHICAL ALTITUDE 93 FT		
Test No.	Density Altitude Feet	Contact Speed (M P H)
395	1100	64
397	1200	70
399	1200	63
401	1200	81
403	1200	73
405	1100	71
406	650	77
407	900	79
408	900	73
409	900	79
410	900	85
411	1000	83
412	1000	78
414	1500	77
416	1500	74
418	1400	69
420	1500	71
422	1400	75
424	1500	71
426	1500	72
427	700	66
428	900	63
429	900	75
430	900	67
431	1200	70
433	1300	66
435	1500	63
437	1500	70
438	1700	75
439	1600	66
440	1600	81
441	2000	66
442	2000	63
443	1900	68
444	2000	68
445	2300	70
462	5600	80
463	5600	86
464	5600	83
465	5800	82
466	5800	72
467	5700	71
468	6000	81
469	6000	74
470	5800	73
471	6200	76
472	6200	75
473	6200	73
481	5150	79
482	5100	93
483	4900	71
484	5000	66
485	4900	66

AIRLINE AIRCRAFT - E

TAKE-OFF CHARACTERISTICS

CORRECTED TO ZERO WIND AND SPECIFICATION GROSS WEIGHT

TABLE 32

Test No	Pressure Altitude Feet	Density Altitude Feet	K_{DP}	Distance Start to Unstick	Distance Start to 50 Ft	Distance Start to 100 Ft	Unstick Speed
CHICAGO, ILLINOIS - GEOGRAPHICAL ALTITUDE 614 FT							
11	850	2600	0 914	674	2640	3450	58
59	450	2200	0 927	850	—	—	67
83	450	2600	0 914	846	3682	4969	64
105	450	2600	0 914	638	1980	2470	58
107	450	2600	0.914	760	1920	2520	58
122	500	2000	0 932	1270	2315	2850	95
123	500	2000	0 932	1212	2587	3147	86
127	500	2000	0 932	1149	2300	2885	87
133	500	2500	0 918	1430	3189	4253	71
160	600	2600	0 914	1242	2989	3926	78
177	550	2600	0 914	1200	2517	3499	71
195	400	1600	0 947	1242	2954	4061	80
200	400	1700	0 942	790	2694	3566	64
201	400	1700	0 942	825	3206	3747	66
236	550	2300	0 922	820	2875	3740	69
284	700	2750	0 910	1200	3100	3920	82
286	700	2600	0 914	1073	3010	4100	71
287	750	2500	0 918	850	2507	3416	65
292	700	1800	0 938	1170	2980	3969	74
302	650	1800	0 938	751	1910	2560	62
305	700	2400	0 920	935	2660	3710	65
307	700	2400	0 920	1475	3100	3820	79
BURBANK, CALIFORNIA - GEOGRAPHICAL ALTITUDE 695 FT							
309	700	2100	0 930	1250	3170	3820	78
310	650	2000	0 932	1200	2800	3680	76
313	750	2600	0.914	820	3270	4690	65
314	700	2750	0 910	1148	3180	4220	79
317	750	2600	0 914	1480	3120	4260	86
320	650	2000	0 932	1250	2611	3521	73
324	700	3050	0 900	1170	2640	3710	74
326	750	3000	0 900	1410	3310	4360	86
329	650	1650	0 943	1170	3316	4268	74
331	650	2250	0 924	1490	3010	3570	88
339	750	2100	0 930	1300	2770	3790	73
340	750	2100	0 930	1240	2826	3761	84
344	850	2650	0 911	1249	3337	4189	77
345	850	2600	0 914	1360	3310	4219	76
347	850	2450	0 920	1135	2054	3196	77
349	750	1175	0.960	1344	2849	4428	80
351	750	1500	0 950	1250	3135	4066	75
354	800	2250	0 924	1585	3166	3855	82
355	800	2250	0 924	1486	3111	3956	79
357	800	2100	0 930	994	1896	2457	66
SALT LAKE CITY, UTAH - GEOGRAPHICAL ALTITUDE 4220 FT							
488	3750	5000	0 842	2014	4266	5551	77
489	750	5000	0 842	2222	4665	5880	89
490	3900	5600	0 825	1614	4546	5695	77
490 (2)	3900	5600	0 825	1845	3885	5180	85
491	4100	5600	0 825	1705	4186	5480	90
493	4100	6300	0 805	1900	3372	5896	83
496	4120	6300	0 805	1359	4274	5202	70
499	4150	5000	0 842	1526	5738	—	87
504	3800	4300	0.861	1738	5658	5824	87
505	3800	4400	0 860	2104	4539	5970	93

TABLE 32 (Cont'd 2)

SALT LAKE CITY, UTAH - GEOGRAPHICAL ALTITUDE 4220 Ft							
Test No	Pressure Altitude Feet	Density Altitude Feet	K_{DP}	Distance Start to			Unstick Speed
				Unstick	50 Ft	100 Ft	
508	3840	4500	0 858	1160	3374	4297	76
509	3950	5000	0 842	1753	5107	5970	81
511	3950	5050	0 840	1759	4298	6309	79
512	3900	5100	0.838	1710	3211	3998	89
513	3900	5100	0 838	2027	4850	6365	83
515 (B)	3900	5100	0 838	1628	3805	4800	80

AIRLINE AIRCRAFT - E

LANDING CHARACTERISTICS

CORRECTED TO ZERO WIND AND SPECIFICATION GROSS WEIGHT

TABLE 33

BURBANK, CALIFORNIA - GEOGRAPHICAL ALTITUDE 695 FT							
Test No	Density Altitude Feet	Distance From			Contact Speed	Glide Path Ratio	
		100' to Contact	50' to Contact	100' to 50'		100' to Contact	100' to 50'
727 (2)	900	—	—	—	84	—	—
741	1600	2682	1838	844	81	26 8	16 9
743	1600	1979	1156	823	79	19 8	16 4
770	600	2271	1454	817	73	22 7	16 3
779	SL	2137	1329	808	73	21 4	16 2
797	1000	2174	1590	584	89	21 7	11 7
855	1200	2122	1270	852	77	21 2	17 0
882	1500	2659	1588	1071	72	26 6	21 4
886	1700	2253	1373	880	79	22 5	17 6
890 (2)	1400	2797	1348	1499	86	28 0	29 0
897	800	2395	1329	1066	67	24 0	21 3
903	1400	2445	1785	660	71	24 5	13 2
906	1700	2457	1850	607	67	24 6	12 2
910	1400	2400	1710	690	—	24 0	13 8
911	1500	2417	1595	822	71	24 2	16 4
914	2000	2055	1345	710	76	20 6	14 2
916	2000	2547	1686	861	—	25 5	17 2
920 (2)	1400	2396	1550	846	70	24 0	16 9
923	1700	2760	2020	740	75	27 6	14 8
924	1800	2345	1432	913	—	23 5	18 3
926	1800	1756	1255	501	80	17 6	10 0
942	2300	2058	1303	755	77	20.6	15 1
947	3000	1565	863	702	80	15 7	14 0

AIRLINE AIRCRAFT - F

TAKE-OFF CHARACTERISTICS

CORRECTED TO ZERO WIND AND SPECIFICATION GROSS WEIGHT

TABLE 34

Test No	Pressure Altitude Feet	Density Altitude Feet	K_{DP}	Distance Start to Unstick	Distance Start to 50 Ft	Distance Start to 100 Ft	Unstick Speed
CHICAGO, ILLINOIS - GEOGRAPHICAL ALTITUDE 614 FT							
108	+ 480	+ 2600	0 914	1060	4571	5665	73
110	+ 480	+ 2600	0 914	853	3161	4288	67
112	+ 500	+ 2600	0 914	1050	4555	5702	69
121	+ 540	+ 2000	0 931	1462	4000	4830	81
129	+ 540	+ 2300	0 922	1870	4160	5290	79
135	+ 560	+ 2500	0 918	1480	3450	4120	79
143	+ 560	+ 2500	0 918	1870	4720	5750	81
144	+ 580	+ 2500	0 918	1827	4200	4910	77
156	+ 590	+ 2500	0 918	1675	3580	4650	80
166	+ 550	+ 2000	0 931	2140	3340	4370	95
169	+ 550	+ 2000	0 931	1710	4490	5770	80
176	+ 550	+ 2600	0 914	1917	4400	5080	88
178	+ 410	+ 2600	0 914	2040	3370	4550	86
191	+ 430	+ 2000	0 931	1940	3350	4550	92
207	+ 450	+ 2200	0.926	1455	3181	—	79
208	+ 580	+ 1800	0 938	1845	4100	—	99
FT WORTH, TEXAS - GEOGRAPHICAL ALTITUDE 680 FT							
627	+ 550	+ 600	0 979	1322	3646	4757	82
632	+ 510	+ 500	0 982	1703	3580	4460	97
647	+ 600	+ 950	0.968	2000	4330	5255	98
653	+ 600	+ 800	0.971	1700	3717	4605	87
665	+ 250	- 700	1 027	1770	4100	4900	89
666	+ 250	- 700	1.027	1576	3040	3900	88
667	+ 240	- 700	1 027	1715	3042	3528	87
668	+ 240	- 700	1.027	1618	2990	3430	86
669	+ 240	- 700	1 027	1500	2700	3240	87
670	+ 230	- 700	1 027	1790	3260	3950	97
671	+ 220	- 700	1.027	1455	2750	3142	82
672	+ 220	- 700	1 027	1445	2570	3030	88
674	+ 240	- 700	1 027	1520	2590	2980	89
BURBANK, CALIFORNIA - GEOGRAPHICAL ALTITUDE 695 FT							
278	+ 710	+ 1750	0 940	1140	—	—	72
306	+ 720	+ 2500	0 918	1570	3573	—	86
330	+ 690	+ 2200	0 926	1322	—	—	75
338	+ 770	+ 2250	0 924	1730	3360	—	73
350	+ 760	+ 1500	0 950	1525	—	—	77

AIRLINE AIRCRAFT – G

TAKE OFF CHARACTERISTICS

CORRECTED TO ZERO WIND AND SPECIFICATION GROSS WEIGHT

TABLE 35

MINES FIELD, CALIFORNIA – GEOGRAPHICAL ALTITUDE 93 FT

Test No	Pressure Altitude Feet	Density Altitude Feet	K_{DP}	Distance Start to Unstick	Distance Start to 50 Ft	Unstick Speed
1235	150	0	1 000	1070	1770	87
1236 (A)	150	200	0 993	1010	1650	83
1238	150	150	0 995	1020	1890	82
1240	150	150	0 995	930	1860	79
1260	120	300	0 990	1555	—	94
1262	120	300	0 990	1400	—	92

*NOTE: No take-off data to 100 foot height available for this airplane

AIRLINE AIRCRAFT – G

LANDING CHARACTERISTICS

CORRECTED TO ZERO WIND AND SPECIFICATION GROSS WEIGHT

TABLE 36

MINES FIELD, CALIFORNIA – GEOGRAPHICAL ALTITUDE 93 FT

Test No	Density Altitude Feet	Distance From 100' to Contact	Distance From 50' to Contact	Distance From 100' to 50'	Contact Speed	Glide Path Ratio 100' to Contact	Glide Path Ratio 100' to 50'
1188	500	—	—	—	84	—	—
1236 (1)	0	910	600	310	68	9 1	6 2
1237	200	1270	980	290	73	12 7	5 8
1239	150	1080	690	390	78	10 8	7 8
1241	150	1560	1220	340	80	15 6	6 8
1255	300	1820	1034	786	81	18 2	15 7
1257	200	1686	987	699	84	16 9	14 0
1259	300	1700	892	808	79	17 0	16 2
1261	350	1639	792	847	82	16 4	16 9
1263	300	2572	1526	1046	76	25 7	20 9

AIRLINE AIRCRAFT – H

TAKE–OFF CHARACTERISTICS

CORRECTED TO ZERO WIND AND SPECIFICATION GROSS WEIGHT

TABLE 37

CHICAGO, ILLINOIS – GEOGRAPHICAL ALTITUDE 614 FT

Test No	Pressure Altitude Feet	Density Altitude Feet	K_{DP}	Distance Start to Unstick	Distance Start to 50 Ft	Distance Start to 100 Ft	Unstick Speed
4	+ 850	+ 2800	0 909	1620	3800	4400	84
6	+ 850	+ 2700	0 910	1660	3880	4693	88
8	+ 850	+ 2600	0 913	1820	3244	3770	90
10	+ 850	+ 2700	0 910	1670	3730	4980	89
13	+ 850	+ 2700	0 910	1775	3840	4460	87

TABLE 37 (Cont'd 2)

Test No	Pressure Altitude Feet	Density Altitude Feet	K_{DP}	Distance Start to Unstick	50 Ft	100 Ft	Unstick Speed
CHICAGO, ILLINOIS - GEOGRAPHICAL ALTITUDE 614 FT							
14	+850	+2500	0.918	1660	3550	4580	88
15	+850	+2500	0.918	1430	3295	4063	85
79	+450	+2300	0.923	1260	4220	5570	78
89	+450	+2300	0.923	1150	3570	—	73
98	+450	+2600	0.913	1340	--	—	78
118	+500	+2000	0.932	1750	4420	—	96
124	+500	+2200	0.926	1365	—	—	93
130	+500	+2400	0.920	1630	—	—	87
131	+500	+2400	0.920	1800	3900	—	88
132	+500	+1900	0.936	1478	—	—	89
134	+500	+1900	0.936	1195	—	—	77
136	+500	+1900	0.936	1200	—	—	95
137	+500	+1900	0.936	1150	—	—	87
148	+550	+2600	0.913	1130	2840	3720	80
155	+550	+2600	0.913	1895	3635	4295	92
157	+600	+2500	0.918	1600	4030	5010	90
158	+600	+2500	0.918	2040	4080	5400	100
159	+600	+2500	0.918	1810	4380	5670	86
162	+600	+2500	0.918	1530	4020	5740	100
163	+600	+2500	0.918	1570	4430	5940	92
164	+600	+2500	0.918	1534	4170	4760	86
172	+550	+2200	0.926	3020	5540	6660	113
174	+550	+2600	0.913	1935	4500	5560	95
175	+550	+2600	0.913	2100	4200	—	101
182	+550	+2600	0.913	1710	3780	—	85
185	+400	+1400	0.952	1321	3940	5250	87
189	+400	+1400	0.952	2020	--	4012	89
193	+400	+1500	0.950	1814	3615	4660	80
196	+400	+1600	0.947	1380	—	5827	81
203	+450	+1500	0.950	1368	2928	4300	92
BURBANK, CALIFORNIA - GEOGRAPHICAL ALTITUDE 695 FT							
281	+700	+2800	0.909	1400	3390	4510	86
282	+700	+2750	0.910	1385	3080	—	87
289	+800	+2600	0.913	1574	3160	4725	96
290	+800	+2800	0.909	1660	3050	3670	100
294	+750	+2100	0.929	1984	4840	5830	94
295	+750	+2400	0.920	1390	2610	3915	83
298	+800	+2100	0.929	1416	3871	5091	77
299	+750	+2200	0.926	1412	2660	3353	86
318	+750	+2600	0.913	2200	3440	4165	98
328	+750	+2800	0.909	1630	3120	3420	90
337	+750	+2800	0.909	1585	3279	4165	90
342	+800	+2600	0.913	1775	4055	4830	83
343	+850	+2700	0.910	1192	2940	4000	78
SALT LAKE CITY, UTAH - GEOGRAPHICAL ALTITUDE 4220 FT							
487	4850	6300	0.805	2690	—	--	104
490-A	3900	5500	0.828	2225	5350	6130	96
492	4100	6250	0.805	2820	6450	--	99
495	4100	6400	0.802	3380	—	—	100
497	4150	4850	0.847	2580	5185	6730	100
503	3800	4300	0.861	2960	4900	5830	93
506	3825	4400	0.859	2545	5450	6230	98
507	3950	4700	0.848	2040	5870	—	92
510 (1)	4000	5000	0.840	1940	5450	—	84
510 (3)	4000	5000	0.840	2710	4930	6530	96
514	3925	5100	0.838	2645	6275	7510	102
515 (1)	3925	5100	0.838	2600	7100	7570	106
517	4000	5600	0.825	2295	5090	—	99
519	4000	5550	0.827	2710	5625	—	105
524	4000	5600	0.825	2470	6050	—	94

TABLE 37 (Cont'd 3)

Test No	Pressure Altitude Feet	Density Altitude Feet	K_{DP}	Distance Start to Unstick	Distance Start to 50 Ft	Distance Start to 100 Ft	Unstick Speed
CHEYENNE, WYOMING - GEOGRAPHICAL ALTITUDE 6145 FT							
536	+6050	+8100	0 754	2660	7020	9100	90
538	+6050	+8100	0 754	50	5250	7085	106
540	+6050	+8100	0 754	2230	5650	8060	101
544	+6050	+8100	0 754	2730	6620	7740	101
546	+6050	+8000	0 758	2545	5930	7350	98
548	+6050	+8000	0 758	2510	6280	7880	99
550	+6000	+6400	0 802	2205	6400	7250	88
552	+6000	+6400	0 802	2560	5350	6500	96
554	+6000	+6400	0 802	3270	5710	6980	116
556	+6000	+6700	0 794	2500	4400	6000	109
558	+6000	+6700	0 794	2940	5070	6180	109
560	+5960	+6700	0 794	2650	4850	6160	107
562	+5950	+6700	0 794	2640	5160	6200	105
564	+5950	+6700	0 794	2620	4730	6230	109
566	+5950	+6700	0 794	3030	5670	6510	110
568	+5950	+6900	0 789	3480	6140	—	105
570	+5950	+6900	0 789	2230	5050	6250	93
572	+5950	+6900	0 789	2340	5320	9130	103
574	+5950	+6900	0 789	2320	5250	5480	108
576	+5950	+6900	0 789	2795	4270	5480	110
580	+5950	+7000	0 787	2270	5375	6750	102
582	+5900	+6200	0 808	1976	5130	5876	91
584	+5900	+6200	0 808	1985	4560	5960	94
586	+5900	+6200	0 808	2350	5120	6450	91
588	+5900	+6200	0 808	2790	4930	6170	110
590	+5900	+6200	0 808	2664	5580	6965	101
592	+5900	+6200	0 808	2345	5340	6440	100
594	+5900	+6200	0 808	2300	5510	6600	96
596	+5900	+6600	0 797	2270	5510	6350	99
600	+5900	+6600	0 797	2110	5390	7120	95
602	+5900	+6600	0 797	1967	4700	6440	95
604	+5900	+7100	0 779	2620	5725	6930	108
606	+5900	+7100	0 779	2535	5340	6280	113
608	+5900	+7100	0 779	2560	5800	6960	114
618	+5930	+7400	0 775	1950	5960	6950	90
FORT WORTH, TEXAS - GEOGRAPHICAL ALTITUDE 680 FT							
625	600	600	0 982	1320	3912	5256	81
630	500	700	0 975	1640	3490	4150	89
649	600	1000	0 967	2245	4435	6030	98
661	400	400	0 987	1400	2884	3988	76

AIRLINE AIRCRAFT - H

LANDING CHARACTERISTICS

CORRECTED TO ZERO WIND AND SPECIFICATION GROSS WEIGHT

TABLE 38

Test No	Density Altitude Feet	Distance From 100' to Contact	Distance From 50' to Contact	Distance From 100' to 50'	Contact Speed	Glide Path Ratio 100' to Contact	Glide Path Ratio 100' to 50'
CHICAGO, ILLINOIS - GEOGRAPHICAL ALTITUDE 614 FT							
22 (2)	1100	1780	757	1023	72 3	17 8	20 46
23	1100	1073	484	589	81 5	10 7	11 78
24	1100	1545	931	614	82 5	15 5	12 28

TABLE 38 (Cont'd 2)

Test No	Density Altitude Feet	Distance From			Contact Speed	Glide Path Ratio	
		100' to Contact	50' to Contact	100' to 50'		100' to Contact	100' to 50'
BURBANK, CALIFORNIA - GEOGRAPHICAL ALTITUDE 695 FT							
732	1000	2237	1673	564	78	22.4	11.3
778	400	2492	1591	901	72	24.9	18 0
785	700	1376	795	581	77	13.8	11.6
805	700	—	904	—	96	—	—
806	400	—	920	—	77	—	—
813	700	2071	1244	827	84	20.7	16 5
814	700	1552	972	580	84	15.5	11.6
817	800	2058	1353	705	82	20.6	14 1
836	1400	2007	1293	714	81	20 1	14 3
838	1400	1833	1180	653	82	18.3	13 1
839	1400	2217	1229	988	87	22.2	19 8
840	1200	2294	1502	792	84	22.9	15 8
847	1400	1925	1505	420	73	19 3	8.4
852	2000	2748	2097	651	90	27 5	13 0
854	2000	1796	951	845	100	18 0	16 9
857	1200	2352	1704	648	82	23.5	12 9
858	1600	1939	1317	622	81	19.4	12.4
859	1600	1890	1055	835	89	18.9	16 7
860	1400	2059	1351	708	81	20 6	14 2
867	1600	1829	1308	521	78	18 3	10 4
881	1700	2099	1553	546	78	21.0	10 9
883	1400	1797	1273	524	82	18 0	10.4
884	1400	2353	1634	719	79	23.5	14 4
885	2000	3339	2103	1236	69	33 4	24 7
887	1400	2568	722	846	78	25.7	16 9
888	1400	1936	1398	538	85	19 4	10 8
891 (1)	1200	1697	1119	578	77	17 0	11 6
902	1800	2060	1521	539	78	20 6	10.8
904	1600	1795	1245	550	82	18.0	11 0
907	1800	2454	1666	788	79	24 5	15 8
908	1800	1684	1067	617	80	16.8	12.3
909	1400	2683	1745	938	80	26 8	18 8
912 (2)	1600	1923	1325	598	74	19.2	12 0
917	2000	2491	1538	953	83	24.9	19.1
918	2000	1878	1314	564	90	18.8	11 3
919	1100	2151	1693	458	90	21.5	9 2
925	2000	2134	1514	620	87	21.3	12.4
926 (2)	2000	1868	1247	621	74	18 7	12 4
927	1400	2084	1638	446	88	20 8	8 9
928	1400	1953	1340	613	83	19 5	12.2
FORT WORTH, TEXAS - GEOGRAPHICAL ALTITUDE 680 FT.							
634	600	—	—	—	75 0	—	—
636	600	—	—	—	75 0	—	—
638	600	—	—	—	76 0	—	—
640	700	—	—	—	76 0	—	—
642	600	—	—	—	79 0	—	—
646	800	—	—	—	67 0	—	—
650	800	—	—	—	76.0	—	—
652	800	—	—	—	66 0	—	—
655	800	—	—	—	72 0	—	—
659	1100	—	—	—	72.0	—	—
SALT LAKE CITY, UTAH - GEOGRAPHICAL ALTITUDE 4220 FT							
1325	3300	2353	1728	625	86	23 5	12.5
1327	3400	2729	2080	649	80	27 3	13 0
1329	3400	2407	1935	472	78	24 1	9 4
1331	3400	2462	1607	855	92	24 6	17.1
1333	3400	2869	2208	661	89	28.7	13.2
1336	3300	2890	2160	730	77	28 9	14 6

TABLE 38 (Cont'd 3)

CHEYENNE, WYOMING - GEOGRAPHICAL ALTITUDE 6145 FT							
Test No.	Density Altitude Feet	Distance From			Contact Speed	Glide Path Ratio	
		100' to Contact	50' to Contact	100' to 50'		100' to Contact	100' to 50'
527	7800	—	—	—	95 3	—	—
529	7800	—	—	—	94 2	—	—
531	7800	—	—	—	94 7	—	—
533	7800	—	—	—	102 2	—	—
535	8000	—	—	—	89 1	—	—
537	8000	—	—	—	104 0	—	—
539	8000	—	—	—	83 2	—	—
541	8000	—	—	—	83 2	—	—
543	8000	—	—	—	95 0	—	—
545	8000	—	—	—	94 0	—	—
551	6400	—	—	—	92 6	—	—
553	6400	—	—	—	92 7	—	—
555	6400	—	—	—	89 0	—	—
557	6700	—	—	—	92 0	—	—
559	6700	—	—	—	94 5	—	—
561	6700	—	—	—	91 4	—	—
563	6700	—	—	—	94 6	—	—
565	6700	—	—	—	91 0	—	—
567	6700	—	—	—	89 4	—	—
569	6800	—	—	—	93 5	—	—
571	6800	—	—	—	97 0	—	—
573	6800	—	—	—	97 2	—	—
575	6800	—	—	—	97 5	—	—
577	7000	—	—	—	97 2	—	—
579	7000	—	—	—	94 2	—	—
581	7000	—	—	—	99 3	—	—
583	6100	—	—	—	81 0	—	—
585	6300	—	—	—	89 7	—	—
587	6200	—	—	—	97 5	—	—
589	6200	—	—	—	91 5	—	—
591	6200	—	—	—	95 6	—	—
593	6200	—	—	—	95 5	—	—
595	6700	—	—	—	88 0	—	—
597	7000	—	—	—	97 0	—	—
599	6700	—	—	—	90 0	—	—
601	6700	—	—	—	90 5	—	—
603	6800	—	—	—	107 8	—	—
605	7000	—	—	—	86 0	—	—
607	7100	—	—	—	101 0	—	—
609	7400	—	—	—	94 7	—	—
611	7400	—	—	—	94 0	—	—
613	7400	—	—	—	89 5	—	—
615	7400	—	—	—	90 5	—	—
617	7400	—	—	—	88 5	—	—
619	7400	—	—	—	88 5	—	—
621	7500	—	—	—	85 0	—	—

AIRLINE AIRCRAFT - H

BLIND LANDING CHARACTERISTICS

THESE RECORDS WERE OBTAINED BY LANDING ON THE OAKLAND BEAM WITH THE PILOT UNDER THE HOOD EXCEPT AS NOTED

TABLE 39

OAKLAND, CALIFORNIA - GEOGRAPHICAL ALTITUDE 93 FT

Test No	Density Altitude Feet	Dist to Contact from 100' Ht	Dist to Contact from 50' Ht	Dist to Stop from 100'	Dist to Stop from 50'	Dist to Stop from Contact	Contact Speed (M P H)	Glide Path Ratios 100' to Cont	Glide Path Ratios 50' to Cont	Glide Path Ratios 100' to 50
1339	- 600	5285	2385	—	—	—	99	52 9:1	47.8:1	58 0 1
1340	- 500	5325	3325	—	—	—	96	53 3	66.6	40 0
1341	- 600	5350	3300	—	—	—	96	53 5	66 0	41 0
1342	- 600	5130	3290	7030	5190	1900	90	51 3	65 8	36 8
1343	- 550	5120	2150	8385	5415	3265	97	51.2	43 0	59 4
1344	- 550	5470	3270	7880	5680	2410	92	54 7	65 4	44 0
1345	- 550	5860	3630	8160	5930	2300	75	58 6	72 6	44 6
1347	- 800	5250	3400	—	—	—	89	52 5	68 0	37 0
1348*	-1050	6740	4480	—	—	—	104	67 4	89 6	45 2
1349*	-1050	6990	4560	—	—	—	94	69 9	91 2	48 6
1350*	- 900	5680	3810	—	—	—	89	56 8	76 2	37 4
1351*	-1000	6170	3490	8850	6170	2680	88	61.7	69 8	53 6
1353	- 700	5420	2370	—	—	—	104	54 2	47 4	43 0
1354	- 700	4780	3180	—	—	—	81	47 8	63 6	32 0
1355	- 700	5535	3660	—	—	—	90	55 4	73 2	37.5
1356	- 550	4660	2420	6900	4660	2240	92	46 6	48 4	44 8
1357	- 700	4970	2620	—	—	—	94	49 7	52 4	47 0
1358	- 700	5280	3090	—	—	—	91	52 8	61 8	51 8
1359	- 700	5490	3290	—	—	—	88	54.9	65 8	44 0
1360	- 700	5320	2890	—	—	—	94	53 2:1	57 8 1	48 6 1
1361	- 700	5365	3990	—	—	—	91	53 7	79 8	27 5
1362	- 650	5645	2990	—	—	—	96	56 5	59 8	53 2
1363*	- 600	5500	3390	—	—	—	97	55.0	67 8	42 3
1364*	- 600	6280	3710	—	—	—	95	62 8	74 3	51 4
1367	- 600	4050	2540	—	—	—	98	40 5	50.8	30 2
1368	- 400	5140	2870	—	—	—	103	51 4	57 4	45 4
1369	- 400	4505	3190	—	—	—	109	45 1	63 8	26 3
1370	- 400	5565	3530	—	—	—	106	55 7	70 6	40 7
1371	- 400	5580	3370	—	—	—	100	55 8	67 4	44 2
1372	- 400	5200	3590	—	—	—	103	52 0	71 8	32 2
1375	- 400	5985	3155	9550	6720	3565	97	59 9	63 1	56 6

* Visual Tests But Flying on Beam

NOTE. Distance and glide path data listed in this table are not corrected to zero wind velocity nor to specification gross weight, since these landings were made by following a radio beam, the locus of which is unaffected by either wind or weight Contact speed data, however, are corrected for both wind and weight

GROUND ROLL CHARACTERISTICS

TABLE 40

Test No	Airplane Designation	Type	Speed at Contact	Ground Roll
1202	B	Private	48	928
1205	B	Private	55	1068
1207	B	Private	57	1025
1208	B	Private	55	894
1209	B	Private	53	812
1210	B	Private	56	1058

TABLE 40 (Cont'd 2)

Test No	Airplane Designation	Type	Speed at Contact	Ground Roll
1211	B	Private	52	886
1212	B	Private	57	1053
1213	B	Private	57	1148
1214	B	Private	56	889
1215	B	Private	55	1108
1216	B	Private	60	948
1217	B	Private	48	740
1218	B	Private	53	740
1243	B	Private	59	860
1245	B	Private	53	1380
1247	B	Private	53	710
1249	B	Private	54	795
1251	B	Private	55	1280
1253	B	Private	53	1220
1295	B	Private	53	1095
1296	B	Private	58	1240
1297	B	Private	57	1152
1299	B	Private	57	1250
1300	B	Private	62	1150
1301	B	Private	66	1912
1302	B	Private	61	1532
1303	B	Private	65	1340
1304	B	Private	53	1036
1305	B	Private	59	1485
1306	B	Private	48	1188
1307	B	Private	56	1242
1308	B	Private	60	1005
1309	B	Private	63	1700
1310	B	Private	56	1090
1311	B	Private	53	1003
1312	B	Private	56	1032
1313	B	Private	53	1115
1314	B	Private	55	879
1315	B	Private	52	830
1316	B	Private	51	1180
1317	B	Private	51	1170
1318	B	Private	56	990
1319	B	Private	56	1120
1320	B	Private	55	870
1321	B	Private	57	1360
450	D	Airline	96	1835
451	D	Airline	90	1465
458	D	Airline	105	1955
459	D	Airline	111	2435
486	D	Airline	99	1922
1196	G	Airline	75	2145
1236 (1)	G	Airline	68	1600
1237	G	Airline	73	1200
1239	G	Airline	78	1210
1255	G	Airline	81	1268
1259	G	Airline	79	1230
1261	G	Airline	82	1361
1263	G	Airline	76	972
1342	H	Airline	90	1900
1344	H	Airline	92	2410
1345	H	Airline	75	2300
1351	H	Airline	88	2680
1356	H	Airline	92	2240

SEASONAL FLUCTUATIONS
IN
PRESSURE & DENSITY ALTITUDES

TABLE 41

AIRPORT: Burbank, California
Los Angeles, California

Period of Observation		Min Airport Barometer Inches Hg	Simultaneous Values of Press & Temp		Max. Density Altitude (Feet)	Max Pressure Altitude (Feet)
Beginning of Period	End of Period	(For Determining Max Pressure Altitude)	(For Max Dens Alt) Airport Barometer (In Hg)	Temp * Degrees F		
6-15-37	6-21-37	29 07	29 10	87°	2700	+780
6-22-37	6-30-37	29 01	29 10	82°	2300	+840
7-1-37	7-7-37	29 95	29 09	91°	2900	+890
7-8-37	7-14-37	29 11	29 18	78°	2000	+740
7-15-37	7-21-37	29 10	29 18	84°	2400	+750
7-22-37	7-31-37	29 08	29 14	78°	2000	+770
8-1-37	8-7-37	29 02	29 02	80°	2400	+830
8-8-37	8-14-37	29 02	29 02	77°	2000	+830
8-15-37	8-21-37	29 00	29 00	80°	2300	+850
8-22-37	8-31-37	28 98	29 15	95°	3100	+890
9-1-37	9-7-37	28 06	29 14	89°	2750	+790
9-8-37	9-14-37	29 00	29 10	95°	3200	+850
9-15-37	9-21-37	28 98	29 06	93°	3000	+890
9-22-37	9-30-37	29 12	29 17	86°	2500	+730
10-1-37	10-7-37	29 16	29 16	83°	2300	+710
10-8-37	10-14-37	29 09	29 12	85°	2450	+760
10-15-37	10-21-37	29 08	29 08	83°	2350	+770
10-22-37	10-31-37	29 12	29 14	74°	1800	+730
11-1-37	11-7-37	29 16	29 36	75°	+1500	+710
11-8-37	11-14-37	29 15	29 16	71°	1650	+720
11-15-37	11-21-37	29 17	29 28	73°	1600	+700
11-22-37	11-30-37	29 12	29 23	83°	2050	+730
12-1-37	12-7-37	29 07	29 16	80°	2100	+780
12-8-37	12-14-37	29 06	29 10	69°	1500	+790
12-15-37	12-21-37	29 20	29 24	78°	1950	+680
12-22-37	12-31-37	29 05	29 15	74°	1800	+800
1-1-37	1-7-38	29 16	29 18	73°	1700	+710
1-8-38	1-14-38	29 17	29 20	80°	2000	+700
1-15-38	1-21-38	29 06	29 10	65°	1400	+790
1-22-38	1-31-38	29 00	29 30	80°	1950	+850
2-1-38	2-7-38	29 10	29 30	69°	1400	+750
2-8-38	2-14-38	29 00	29 00	58°	900	+850
2-15-38	2-21-38	29 08	29 10	64°	1200	+770
2-22-38	2-28-38	29 16	29 22	76°	1800	+710
3-1-38	3-7-38	28 88	28 88	62°	1250	+880
3-8-38	3-14-38	29 10	29 22	77°	1800	+750
3-15-38	3-21-38	29 12	29 20	70°	1500	+730
3-22-38	3-31-38	29 02	29 05	68°	1500	+830
4-1-38	4-7-38	29 13	29 20	75°	1750	+730
4-8-38	4-14-38	29 10	29 18	77°	1950	+750
4-15-38	4-21-38	29 04	29 13	90°	+2800	+810
4-22-38	4-30-38	29 09	29 18	69°	1400	+760
5-1-38	5-7-38	28 98	29 04	80°	2400	+890
5-8-38	5-14-38	29 10	29 10	72°	1650	+750
5-15-38	5-21-38	29 04	29 10	62°	1000	+810
5-22-38	5-31-38	29 06	29 12	82°	2300	+790
6-1-38	6-7-38	29 08	29 12	74°	1800	+770
6-8-38	6-14-38	29 11	29 18	80°	2100	+770
6-15-38	6-21-38	29 04	29 08	72°	1700	+810
6-22-38	6-30-38	28 95	29 00	77°	2000	+890
7-1-38	7-7-38	29 13	29 14	74°	1800	+730
7-8-38	7-14-38	29 14	29 18	80°	2100	+725
7-15-38	7-21-38	29 10	29 10	79°	2200	+750
7-22-38	7-31-38	29 02	29.06	84°	2500	+830
8-1-38	8-7-38	29.04	29.05	94°	3000	+810

TABLE 41 (Cont'd 2)

AIRPORT: Burbank, California Los Angeles, California						
Period of Observation		Min Airport Barometer Inches Hg. (For Determining Max Pressure Altitude)	Simultaneous Values of Press & Temp. (For Max Dens Alt		Max Density Altitude (Feet)	Max. Pressure Altitude (Feet)
Beginning of Period	End of Period		Airport Barometer (In Hg)	Temp * Degrees F		
8-8-38	8-14-38	29 06	29 11	95°	3200	+790
8-15-38	8-21-38	29.10	29 22	88°	3000	+750
8-22-38	8-31-38	28 98	29 02	88°	2800	+890
9-1-38	9-7-38	29 01	29 04	81°	2250	+840
9-8-38	9-14-38	29.01	29.10	94°	3250	+840
9-15-38	9-21-38	29 06	29.16	92°	2800	+790
9-22-38	9-30-38	29 10	29 16	89°	2700	+750
AIRPORT Cheyenne, Wyoming						
6-15-37	6-21-37	23 85	24 05	90°	+9150	6150
6-22-37	6-30-37	23.92	23.95	91°	+9350	6080
7-1-37	7-8-37	24.00	24 06	91°	+9200	6000
7-8-37	7-14-37	23 93	24 00	85°	+8850	6080
7-15-37	7-21-37	24 00	24 06	92°	+9200	6000
7-22-37	7-31-37	24 10	24 10	92°	+9150	5900
8-1-37	8-7-37	24 00	24.03	93°	+9250	6000
8-8-37	8-14-37	23 97	24 00	95°	+9500	6060
8-15-37	8-21-37	23.95	24 10	89°	+9000	6050
8-22-37	8-31-37	23 90	23 93	92°	+9400	6100
9-1-37	9-7-37	24 00	24 10	83°	+9200	6000
9-8-37	9-14-37	24 03	24 04	85°	+8800	5970
9-15-37	9-21-37	23.90	23 94	88°	+9200	6100
9-22-37	9-30-37	23.84	23 90	77°	+8550	6140
10-1-37	10-7-37	23 70	24 00	74°	+8300	6280
10-8-37	10-14-37	24.05	24 06	71°	+8000	5950
10-15-37	10-21-37	23 55	23 65	59°	+7700	6500
10-22-37	10-31-37	23 92	24 00	78°	+8500	6080
11-1-37	11-7-37	23 60	23 65	57°	+7600	6410
11-8-37	11-14-37	23 66	23 80	61°	+7650	6360
11-15-37	11-21-37	23.50	23 90	48°	+6750	6530
11-22-37	11-30-37	23.62	23 70	62°	+7800	6410
12-1-37	12-7-37	23 70	23.90	52°	+7000	6280
12-8-37	12-14-37	23.55	23.70	62°	+7800	6500
12-15-37	12-21-37	23.74	23 78	39°	+6300	6250
12-22-37	12-31-37	23.44	23.80	51°	+7050	6600
1-1-38	1-7-38	23 78	23 83	48°	+6850	6260
1-8-38	1-14-38	23 55	23 92	53°	+7000	6500
1-15-38	1-21-38	23 40	23 78	43°	+6600	6600
1-22-38	1-31-38	23.60	23 82	48°	+6850	6410
2-1-38	2-7-38	23.60	23.72	53°	+7200	6410
2-8-38	2-14-38	23.58	23 59	55°	+7550	6480
2-15-38	2-21-38	23.75	23 82	42°	+6500	6250
2-22-38	2-28-38	23.90	24 30	60°	+7000	6080
3-1-38	3-7-38	23.46	23 54	51°	+7500	6600
3-8-38	3-14-38	23 60	23 67	62°	+7850	6410
3-15-38	3-21-38	23.46	23 50	63°	+8200	6600
3-22-38	3-31-38	23 22	23 66	58°	+7700	6870
4-1-38	4-7-38	23 44	23 47	53°	+7600	6600
4-8-38	4-14-38	23 58	23 58	70°	+8550	6480
4-15-38	4-21-38	23.77	23 92	72°	+8250	6260
4-22-38	4-30-38	23 67	23 68	76°	+8750	6360
5-1-38	5-7-38	23 52	23.55	67°	+8400	6510
5-8-38	5-14-38	23 78	23 86	68°	+8100	6240
5-15-38	5-21-38	23.58	23 62	70°	+8500	6480
5-22-38	5-31-38	23.86	23 88	84°	+9050	6160
6-1-38	6-7-38	23.94	23 97	80°	+8600	6050
6-8-38	6-14-38	23 70	23 72	76°	+8700	6280
6-15-38	6-21-38	23 78	23.82	84°	+9000	6240

TABLE 41 (Cont'd 3)

Period of Observation: Beginning of Period	Period of Observation: End of Period	Min. Airport Barometer Inches Hg. (For Determining Max. Pressure Altitude)	Simultaneous Values of Press. & Temp (For Max Dens. Alt): Airport Barometer (In. Hg)	Simultaneous Values of Press. & Temp (For Max Dens. Alt): Temp Degrees F	Max Density Altitude Feet	Max. Pressure Altitude Feet
Airport: Cheyenne, Wyoming						
6-22-38	6-30-38	23 88	23.91	84°	+8950	+6120
7-1-38	7-7-38	23.89	23 98	87°	+9100	+6110
7-8-38	7-14-38	24.04	24.07	91°	+9200	+5960
7-15-38	7-21-38	24 05	24.18	83°	+8550	+5950
7-22-38	7-31-38	23 98	24.05	94°	+9400	+6020
8-1-38	8-7-38	23 96	24.04	92°	+9200	+6040
8-8-38	8-14-38	23 81	23 82	87°	+9200	+6190
8-15-38	8-21-38	23.83	23 84	86°	+9200	+6170
8-22-38	8-31-38	24.04	24.14	93°	+9200	+5960
9-1-38	9-7-38	23 92	23 95	82°	+8750	+6080
9-8-38	9-14-38	24 00	24.00	73°	+8200	+6000
9-15-38	9-21-38	24.00	24 21	83°	+8500	+6000
9-22-38	9-30-38	24.10	24 14	80°	+8450	+5900
AIRPORT: Salt Lake City, Utah						
6-15-37	6-21-37	25 45	25 45	90°	7250	+4430
6-22-37	6-30-37	25.48	25 51	100°	7750	+4370
7-1-37	7-7-37	25.58	25.67	101°	7600	+4300
7-8-37	7-14-37	25.80	25 66	88°	6950	+4250
7-15-37	7-21-37	25.63	25 74	104°	7750	+4230
7-22-37	7-31-37	25.54	25 76	96°	7250	+4330
8-1-37	8-7-37	25.64	25.76	96°	7250	+4220
8-8-37	8-14-37	25.56	25.68	104°	7800	+4280
8-15-37	8-21-37	25 69	25.74	98°	7400	+4160
8-22-37	8-31-37	25.48	25 50	92°	7350	+4400
9-1-37	9-7-37	25.60	25.60	87°	6950	+4270
9-8-37	9-14-37	25 72	25 75	92°	7000	+4130
9-15-37	9-21-37	25.40	25 55	94°	7450	+4480
9-22-37	9-30-37	25 53	25.54	83°	6700	+4340
10-1-37	10-7-37	25.45	25 52	82°	6700	+4430
10-8-37	10-14-37	25 58	25 73	75°	6000	+4300
10-15-37	10-21-37	25.50	25.50	61°	5450	+4380
10-22-37	10-31-37	25 64	25.65	75°	5500	+4220
11-1-37	11-7-37	25 46	25 55	64°	5550	+4420
11-8-37	11-14-37	25 39	25.42	66°	5800	+4490
11-15-37	11-21-37	25 47	25 47	50°	4800	+4400
11-22-37	11-30-37	25 54	25 54	52°	4800	+4330
12-1-37	12-7-37	25 56	25 82	46°	4050	+4310
12-8-37	12-14-37	25 42	25 44	53°	5050	+4460
12-15-37	12-21-37	25 82	25.88	44°	3750	+4000
12-22-37	12-31-37	25 20	25 20	40°	4450	+4680
1-1-38	1-7-38	25 65	25 86	48°	4200	+4210
1-8-38	1-14-38	25 45	25 70	59°	5050	+4430
1-15-38	1-21-38	25 48	25 51	46°	4500	+4400
1-22-38	1-31-38	25 32	25 46	57°	5250	+4550
2-1-38	2-7-38	25 40	25 50	48°	4650	+4480
2-8-38	2-14-38	25 20	25 36	58°	5400	+4680
2-15-38	2-21-38	25 67	25 68	37°	3650	+4180
2-22-38	2-28-38	25 58	25 80	57°	4800	+4290
3-1-38	3-7-38	25 18	25 30	47°	4750	+4700
3-8-38	3-14-38	25 29	25.64	62°	5300	+4580
3-15-38	3-21-38	25 08	25 08	64°	6200	+4830
3-22-38	3-31-38	25 20	25 20	50°	5100	+4680
4-1-38	4-7-38	25 25	25 52	56°	5100	+4620
4-8-38	4-14-38	25 35	25 52	56°	5050	+4525
4-15-38	4-21-38	25 60	25 70	75°	6000	+4270
4-22-38	4-30-38	25 36	25 42	77°	6500	+4510
5-1-38	5-7-38	25 37	25 62	55°	+4900	+4510
5-8-38	5-14-38	25 38	25 71	78°	6200	+4500

TABLE 41 (Cont'd 4)

AIRPORT Salt Lake City, Utah

Period of Observation		Min Airport Barometer Inches Hg	Simultaneous Values of Press & Temp		Max. Density Altitude Feet	Max Pressure Altitude Feet
Beginning of Period	End of Period	(For Determining Max Pressure Altitude)	(For Max Dens Alt			
			Airport Barometer (In Hg)	Temp Degrees F		
5-15-38	5-21-38	25 42	25 70	61°	5150	+4460
5-22-38	5-31-38	25 46	25 54	86°	6950	+4440
6-1-38	6-7-38	25 38	25 70	93°	7100	+4500
6-8-38	6-14-38	25 58	25 67	84°	6550	+4290
6-15-38	6-21-38	25 41	25 46	87°	7000	+4470
6-22-38	6-30-38	25 52	25 56	92°	7300	+4360
7-1-38	7-7-38	25 50	25 80	84°	6450	+4380
7-8-38	7-14-38	25 65	25 66	86°	6750	+4210
7-15-38	7-21-38	25 74	25 77	94°	7000	+4080
7-22-38	7-31-38	25 58	25 60	96°	7450	+4300
8-1-38	8-7-38	25 61	25 62	93°	7250	+4260
8-8-38	8-14-38	25 50	25 50	90°	7250	+4380
8-15-38	8-21-38	25 52	25 55	87°	6950	+4360
8-22-38	8-31-38	25 65	25 82	92°	6800	+4210
9-1-38	9-7-38	25 51	25 56	90°	7050	+4370
9-8-38	9-14-38	25 70	25 70	78°	6300	+4150
9-15-38	9-21-38	25 72	25 74	87°	6600	+4110
9-22-38	9-30-38	25 72	25 72	86°	6650	+4110

*Temperature Data Obtained at City of Los Angeles