UNITED STATES DEPARTMENT OF COMMERCE
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Technical Development Report No 32

INSTRUMENT APPROACH PERFORMANCE CHARACTERISTICS ON RADIO INSTRUMENT LANDING SYSTEMS

Part I—UAL-Bendix System

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JUNE 1943

UNITED STATES GOVERNMENT PRINTING OFFICE
WASHINGTON 1943

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INSTRUMENT APPROACH PERFORMANCE CHARACTERISTICS ON RADIO INSTRUMENT LANDING SYSTEMS

SUMMARY

Photographic space-time records of the approach paths followed by a DC-3 airplane in making 25 instrument landings with the pilot under the hood, were obtained at the Oakland, Calif., municipal airport. The Bendix type radio instrument landing equipment (equi-signal localizer and constant intensity glide path) was used in all these landings.

The results are presented as curves showing the vertical and horizontal projection of the flight paths, air speeds, and sinking speeds from 100 feet above the ground to and through contact, including the first few hundred feet of ground roll. Curves involving each individual approach, as well as envelopes of all the approaches, are presented. Because of the lack of positive information, the path of the radio beam is not shown and the sensitivities of the localizer and glide path are not listed. The photographic records indicate that:

1. Contacts were made at distances of 3,300 to 4,600 feet from the transmitter, and at lateral distances from the centerline of the runway up to 175 feet.
2. Height variation during approach was approximately 30 feet, as indicated by the envelope of approach paths.
3. The lower boundary of the approach path envelope indicates a distance to height ratio of 43:1 down to a height of 50 feet, below which the landing "flare" is accomplished.
4. Lateral deviations of approach paths with respect to the centerline of the airplane were within a lane 350 feet wide and symmetrical about the centerline of the runway.
5. Air speeds at contact varied from 75 to 105 miles per hour. At a height of 100 feet, air speeds varied from 105 miles per hour to 135 miles per hour. The air speed variation during these approaches was approximately 30 miles per hour.
6. Sinking speeds during approach did not exceed nine feet per second.

Figure 1. Photographic equipment field set-up.

INTRODUCTION

The results presented in this report involve data that were obtained originally in connection with a study of aircraft take-off and landing characteristics conducted during the latter part of 1938 and the correlation of those characteristics with airport size. Since those data involve instrument approaches using a radio instrument landing system and with the pilot under the hood, it is felt that the interpretation as presented in this report might prove helpful in the consideration of further developments and installations of similar systems. It also is believed that this report illustrates one feasible method for correlating flight characteristics with existing installations of radio instrument landing systems, and provides an indication as to desirable separation of parallel runways involving instrument landings.

A similar study of instrument approach performance characteristics on the CAA-RTCA radio instrument landing system is planned and will be described in a subsequent report.

EQUIPMENT

Instrument Landing System

The instrument landing system at Oakland, Calif., was of the Bendix type, involving the use of an equi-signal localizer and a constant intensity glide path. In shape, the beam path was substantially parabolic. The availability of this radio landing system, together with the DC-3 airplane and thoroughly experienced

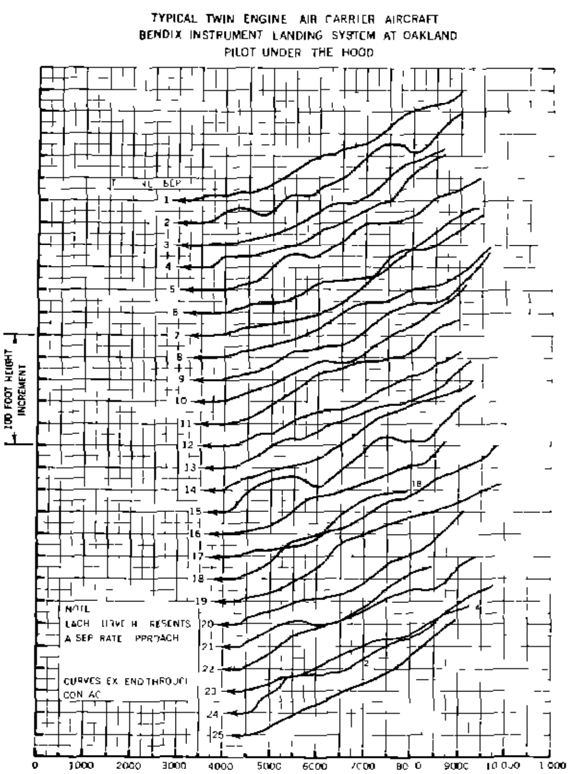


Figure 2 Instrument approach flight paths (Curves 2 and 17 are also shown on figure 9)

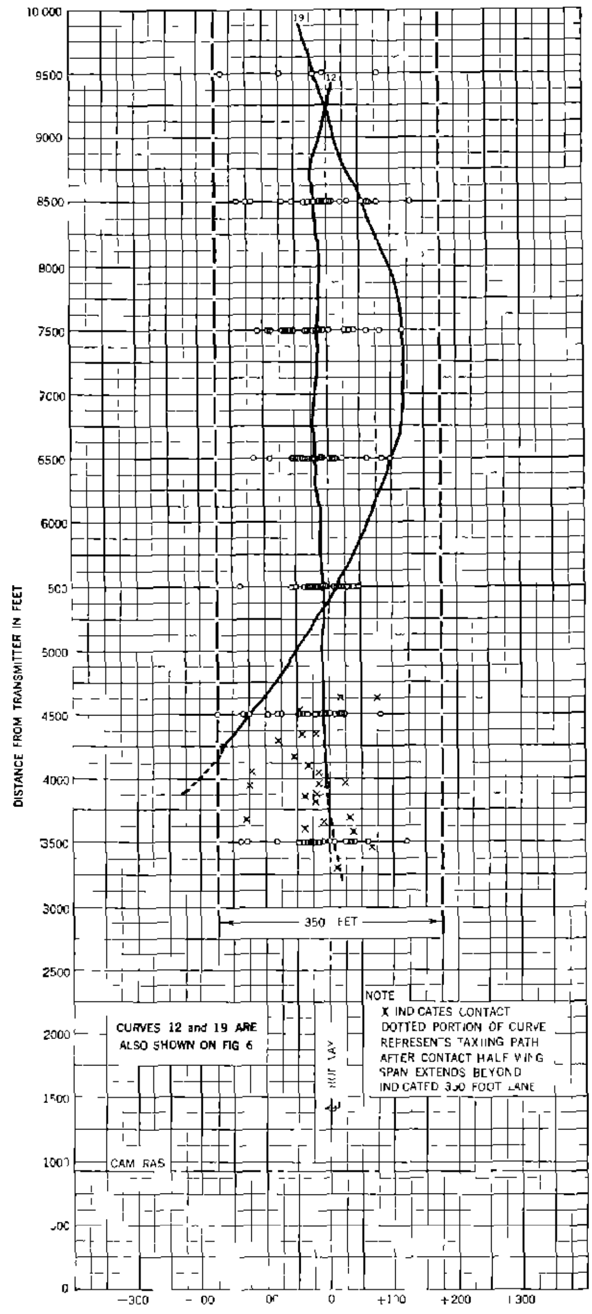


Figure 3 Probable instrument approach lateral deviations of flight paths

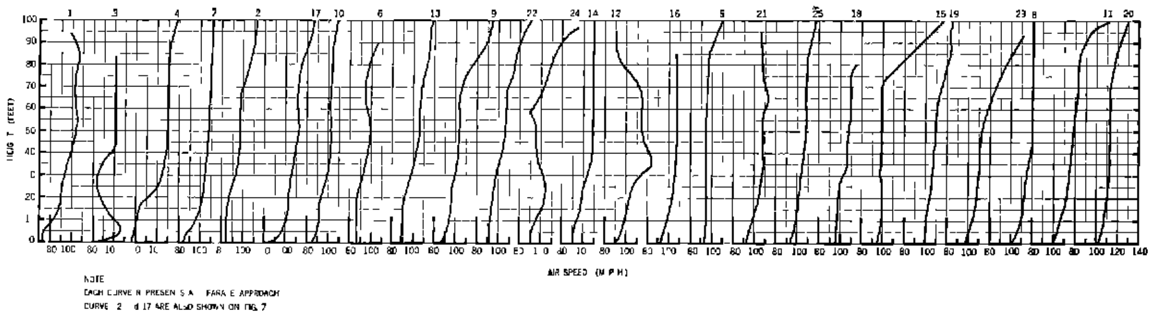


Figure 4 Instrument approach air speeds

pilots, was made possible through the co-operation of the United Air Lines Transport Corporation

Photographic Recording Equipment

The photographic recording equipment obtains space-time records of aircraft in flight It operates on the range-finder principle and includes a field set-up which consists fundamentally of a widely but specifically separated pair of motion picture cameras, together with their reference markers These are located symmetrically with respect to the centerline of the runway and precisely with respect to one another

The cameras are not traversed as the photographs are taken, but remain fixed with their lens axes substantially parallel to the line of flight Automatic shutter timing obtains simultaneous pictures at the rate of four each second When a pair of simultaneous pictures is projected side by side, vertical and horizontal distances from the camera base line to the airplane as well as lateral deviation of the airplane from the centerline of the runway may be obtained from the image displacements in the projections

The accuracy of this equipment is within 0 5 percent at short ranges and is approximately 1 5 percent at the extreme range of 12,000 feet This equipment was developed for the Technical Development Division by the Eastman Kodak Company, and will be described in detail in a separate Technical Development Division report A photograph of a typical field set-up with reduced camera separation is shown in figure 1

USE OF DATA

In addition to the photographic records of 25 instrument approaches, data involving temperature barometric pressure, wind direction, and velocity were obtained The instruments used to obtain these meteorological data were located just off the runway near the point of contact The temperature and barometric pressure determine the density altitude which may be used to correct the flight test results to sea level conditions

Photographic projections rendered vertical and horizontal flight path projections and space-time data Air speeds and sinking speeds were obtained from the slopes of the space-time curves The length of the runway used in these tests and its location with respect to the transmitter were not shown in figure 9, since in practice the transmitter-receiver arrangement is adjusted for each individual airport to obtain the point of contact so that suitable obstacle clearances and distances for ground roll are realized

No corrections were made for density altitude, since approximately sea level conditions existed Flight path projections were not corrected for wind as a radio path was followed Wind corrections, however, were applied to flying speeds and sinking speeds In this connection the wind velocity was assumed to increase with altitude in accordance with the following expression taken from National Advisory Committee for Aeronautics Report No 626

$$V_A = V_O\left(\frac{H_A}{H_O}\right)^{\frac{1}{7}}$$

Where

V_A = Component wind velocity at any altitude (H_A)

V_O = Component wind velocity at the ground (H_O) as determined from the anemometer reading and from the wind direction

It should be noted that the wind velocity and direction will vary considerably during the approach for a landing and that a precise determination of these values along the flight path is practically impossible

RESULTS

Curves showing the vertical and horizontal projections of the approach paths from 100 feet to contact for each of the 25 blind landings are shown in figures 2 and 6 The envelopes of these paths are shown in figures 9 and 3, which

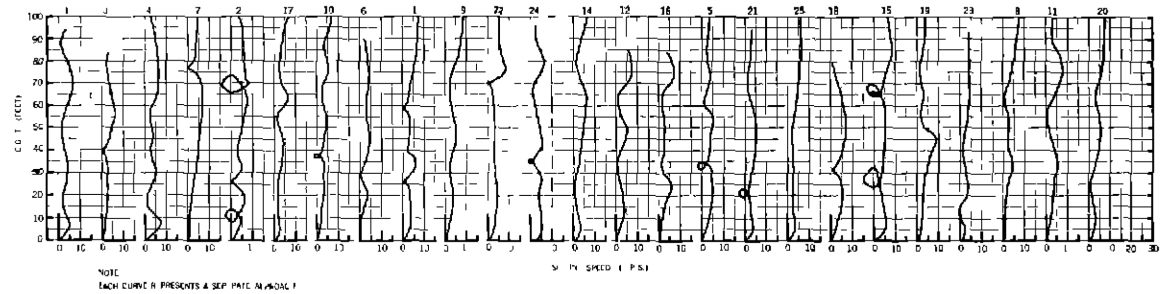


Figure 5 Instrument approach sinking speeds

also include individual flight paths numbers 17 and 2 in figure 9 and numbers 12 and 19 in figure 3 Those individual flight paths in each case represent the best and worst of the 25 approaches

The air speed and sinking speed are both plotted against height above ground in figures 4 and 5 The envelopes of the air speed and sinking speed curves are shown in figures 7 and 8

DISCUSSION OF RESULTS

An inspection of all figures will reveal that the height scales are exaggerated with respect to the distance scales This scale ratio serves to emphasize the "hunting" of the airplane during approaches

From figure 9 it will be noted that the variation in height during the 25 approaches was approximately 30 feet and that the lower boundary of the envelope indicates a distance to height ratio of 43 1 down to a height of 50 feet below which the landing "flare" is accomplished Individual flight paths numbers 17 and 2 are shown here as being the best and worst of the 25 approach paths

From figure 3 it will be noted that the lateral deviations of the airplane during the 25 approaches were within a lane 350 feet wide and approximately symmetrical to the runway centerline, while contacts varied from 3 300 to 4 600 feet from the location of the transmitter

With reference to figure 6, it is apparent that the previously used best and worst flight paths (numbers 17 and 2) do not represent the best and worst lateral deviation approach paths Instead, individual flight paths numbers 12 and 19 are incorporated on figure 3

In order to determine the distance between parallel runways using radio instrument landing equipment, an airplane having a wing span of 200 feet may be considered The minimum distance between the two runway centerlines, therefore, is the width of the lane plus the wing span, or

$$350+200=550 \text{ feet}$$

Any desired amount of clearance between

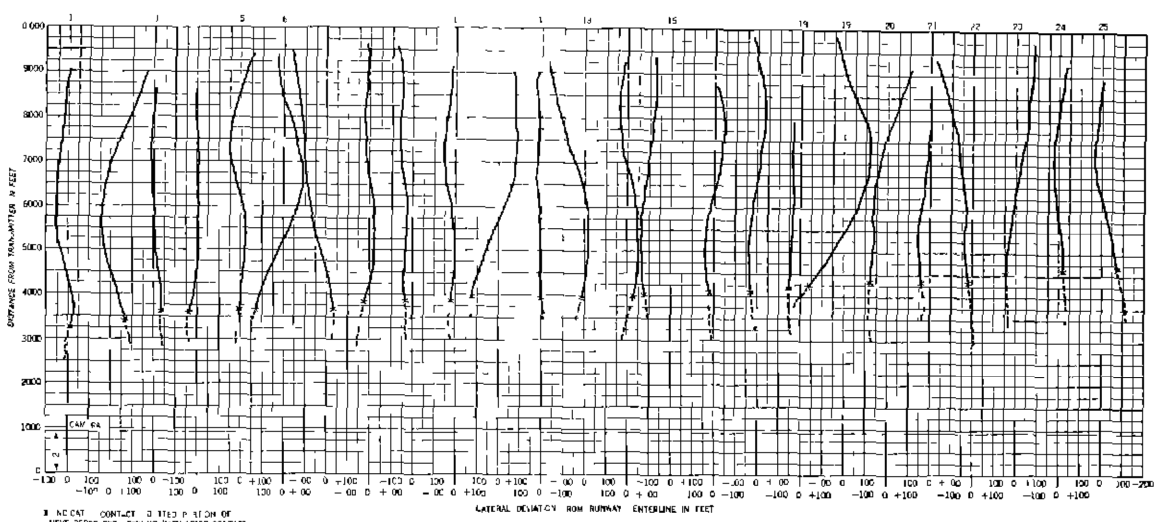
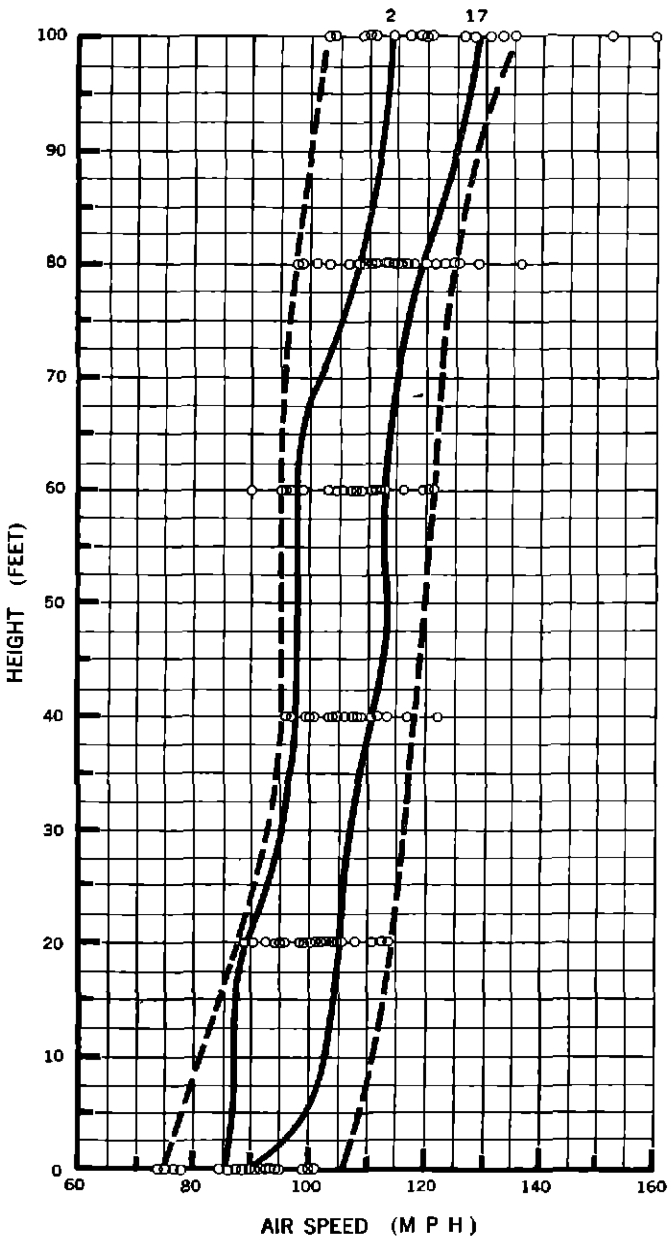
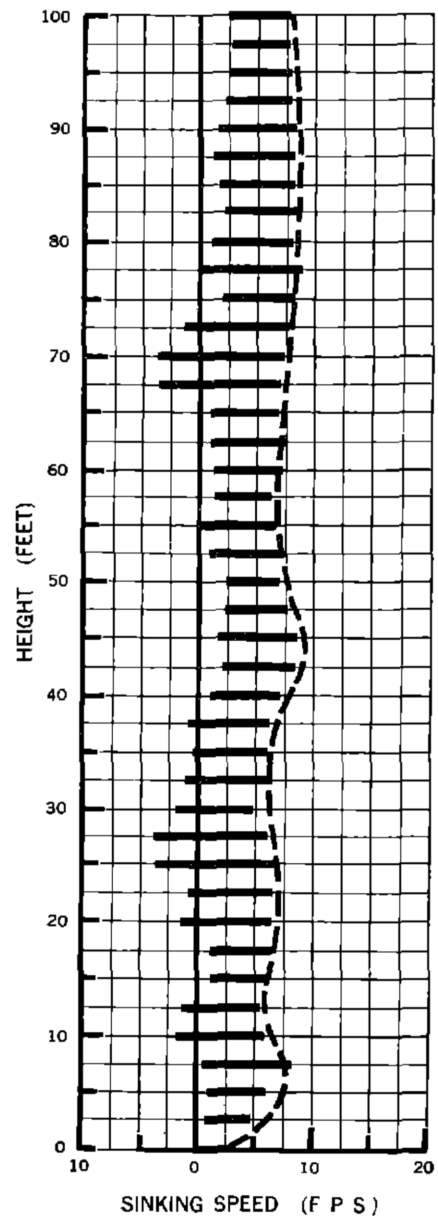


Figure 6 Instrument approach lateral deviation flight paths (curves 12 and 19 are also shown on figure 3)





NOTE
DOTTED CURVES INDICATE PROBABLE DEVIATION LIMITS
SOLID CURVES 2 and 17 ARE ALSO SHOWN ON FIG 4

Figure 7 Probable instrument approach air speed deviation

Figure 8 Probable instrument approach sinking speed deviation

wing tips of two similar airplanes passing each other becomes a constant increment to be added to the above obtained value. If a margin of safety of 150 feet is desired, the distance between centerlines of two parallel runways would thus become

$$550+150=700 \text{ feet}$$

The individual curves of sinking speed versus height as shown in figure 5 are especially interesting inasmuch as loops are found together with negative values of sinking speeds. These loops are understandable when it is seen from the corresponding flight paths that the airplane alternately sinks, climbs, and sinks again, along its approach path.

Figure 7 is the envelope of the air speed curves and shows the probable deviation during all 25 instrument approaches. Upon inspection of this figure it is apparent that contact speeds varied from 75 to 105 miles per hour, while at a height of 100 feet, air speeds varied from 105 to 135 miles per hour. This indicates a variation of 30 miles per hour during all approaches. Here, too, individual flight paths numbers 17 and 2 (best and worst tests) are plotted for the reader's comparison.

From figure 8 it will be readily seen that the sinking speeds involving all of the 25 instrument approaches did not exceed nine feet per second.

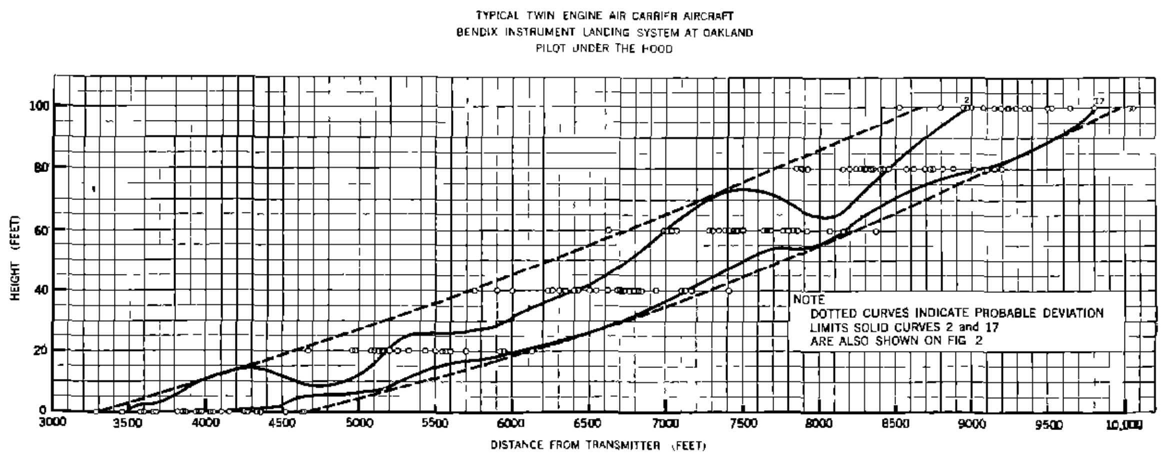


Figure 9. Probable instrument approach flight path deviation

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