A COMPARISON OF WIND-TUNNEL DATA AND IMPLIED SCALE EFFECTS

ON THE PIPER PA-30 AIRCRAFT

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## INTRODUCTION

For several years now the Langley Research Center has been engaged in studies of personal owner aircraft. These studies to date have covered wind-tunnel tests of a Piper PA-30 aircraft, a Piper PA-24, and some limited tests of a 1/6 size model of each. The tests include pitch runs, sideslip runs, control effects, power effects, and Reynolds number effects.

These tests and analyses of the data have progressed to a point where the results may be of some interest to the subcommittee. The purpose of this presentation then is to review some of the more significant findings and to discuss the ramifications thereof.

## DISCUSSION

Figure 1 gives an outline of the presentation which includes first of all a review of two-dimensional and three-dimensional Reynolds number effects, the applicability and status of calculative techniques, and finally, some of the measured sideslip characteristics will be discussed.

Figure 2 shows a photo of the PA-30 in the full-scale tunnel. This is the aircraft which was used in the stability and control program at the Flight Research Center. As noted earlier, a 1/6 size model of the PA-30 was tested. Figure 3 shows this model mounted in the Langley 7 × 10 tunnel. One function of the 1/6 size model was to allow the determination of dynamic or rotary derivative data power on, but we first had to investigate scale effects in order to assure that these dynamic data would be representative of the airplane. In addition, this model was intended to explore nacelle shape and thrust inclination effects.

Reynolds Number Effect on Lift

The influence of Reynolds number on lift at high angles has long been recognized and is well documented in the literature. Many references can be cited to illustrate this effect. In figure 4 is shown lift coefficient as a function of angle of attack for two-dimensional data on the left and data from the PA-30 tests in the center and on the right. The two-dimensional data illustrate the influence on $C_{L_{max}}$ of changing Reynolds number from $0.7 \times 10^6$ to $3.0 \times 10^6$. These data were taken from the listed references. Data from the PA-30 are compared to the 1/6 size model data in the center with propellers off, and we note the same order of discrepancy in $C_{L_{max}}$ is present for the same change in Reynolds number. We may draw two implications at this point: (1) effects of Reynolds number carry over from two- to three-dimensions and (2) the Reynolds number effects shown on the PA-30, power off, are associated with flow over the main lifting surface rather than an interference effect.

There has been speculation that the influence of power on a small model, that is, the increased slipstream velocity and increased turbulence in the slipstream, increased the effective Reynolds number over the wing and delayed the angle of attack at which flow separation started. The plot on the right shows, indeed, that the 1/6 size model inflection point has moved to $8^{\circ}$ at $T_c' = 0.44$ compared to $6^{\circ}$ shown in the center plot. The figure also shows that the airplane inflection point has moved from $10^{\circ}$ power off to $12^{\circ}$ power on, so that a Reynolds number effect on $C_{L_{max}}$ exists near the stall. Comparisons of the drag and moment data were also made, but no discrepancies other than those near $C_{L_{max}}$ were identified.

The result of these studies would seem to cast doubt on both the static and dynamic results on a small model in atmospheric tunnels near maximum lift.

## Calculative Techniques

The challenge to develop analytical procedures which allow the calculation of the loadings and maximum lift of a wing is always present. One such method, developed in the late 1940's, relied upon lifting line theory and employed Reynolds number dependent two-dimensional airfoil data to obtain loadings and the aerodynamic characteristics of wings. Some typical results of these calculations are given in figure 5 and are compared with experimental data. This figure shows the rather remarkable results obtained with this method. At the point when this work was terminated by the NACA, the inclusion of techniques to account for fuselage effects, nacelle effects, and power effects had not been accomplished.

The NASA has recently contracted to continue this work. This effort is designed to computerize the technique and to add the capability of accounting for fuselage effects. A matrix of computer runs intended to provide information satisfactory for preliminary design is also included. In addition, a university grant is in effect which will result in a bibliographic summary of all relevant experimental data accumulated by NACA during the hectic World War II period. At this point, however, it must be reported that existing analytical methods are inadequate to account for power effects and important interference effects.

## Lateral-Directional Characteristics

As mentioned earlier, results exist on both PA-24 and PA-30. It is well known that the PA-30 was an outgrowth of the PA-24 models, having two engines instead of one. In all other important respects, however, the PA-30 aircraft are identical. Let us put ourselves in the position of a manufacturer for the moment and trace the results of wind-tunnel tests on PA-24 in the development of the PA-30. Figure 6 shows a plot of $C_{l_\beta}$ and $C_{n_\beta}$ versus angle of attack for PA-30 and PA-24 models shown in the sketches. With wind-tunnel tests of the PA-24 available at small scale (1/6 size model), we should have been interested in verifying these results. When aircraft flight test data or tests at larger scale became available, we should, indeed, have seen good agreement with the 1/6 size model even though discrepancies exist in $C_{L_{max}}$

(compare dotted curve with connected crosses). In the process of product improvement, it was decided to explore the twin configuration, and the dashed line represents data obtained at 1/6 size on the PA-30. $C_{n_\beta}$ and $C_{l_\beta}$ would both tell us that the influence of nacelles was minimal. Since data on the PA-24 should have already consolidated our faith in the small scale results, we should have proceeded to the prototype stage. When results of the aircraft became available, shown in figure 7, we would have discovered we were completely misled by the $C_{l_\beta}$ trands even though $C_{n_\beta}$ agreed acceptably. The results shown here will be explored further to determine possible implications relative to the Langley spin program on the PA-30.

Tunnel Measurement Techniques

With the large discrepancies shown in both lift and the lateral-directional data, it is prudent to review measurement techniques. While no detailed accuracy assessment has been undertaken, figure 8 shows a comparison of data on the 1/6 size model tested in the full-scale tunnel and the 7 × 10 tunnel at Langley. While minor differences exist near maximum lift, these are small compared to those associated with scale.

## CONCLUSIONS

While not all the effects shown are understood, figure 9 summarizes the conclusions to date.

(1) Reynolds number has sizable effects on this class of aircraft power off as well as power on.

(2) Techniques are not presently available to calculate all the measured effects, nor do these techniques allow us to correct data from low Reynolds to full scale when Reynolds number discrepancy flow separation is present.

(3) The Langley research program on general aviation aircraft has been reoriented and will concentrate on obtaining data at higher Reynolds number. For example, the effects of nacelle shape and thrust inclination, originally intended for study with the 1/6 size model, will be undertaken with a modified version of the PA-24 hull.

# COMPARISON OF WIND TUNNEL DATA AND IMPLIED SCALE EFFECTS ON PA-30

- 2-DIMENSIONAL AND 3-DIMENSIONAL REYNOLDS NUMBER EFFECTS
- ABLICABILITY OF CALCULATIVE TECHNIQUES
- SIDESLIP CHARACTERISTICS

Fig 1

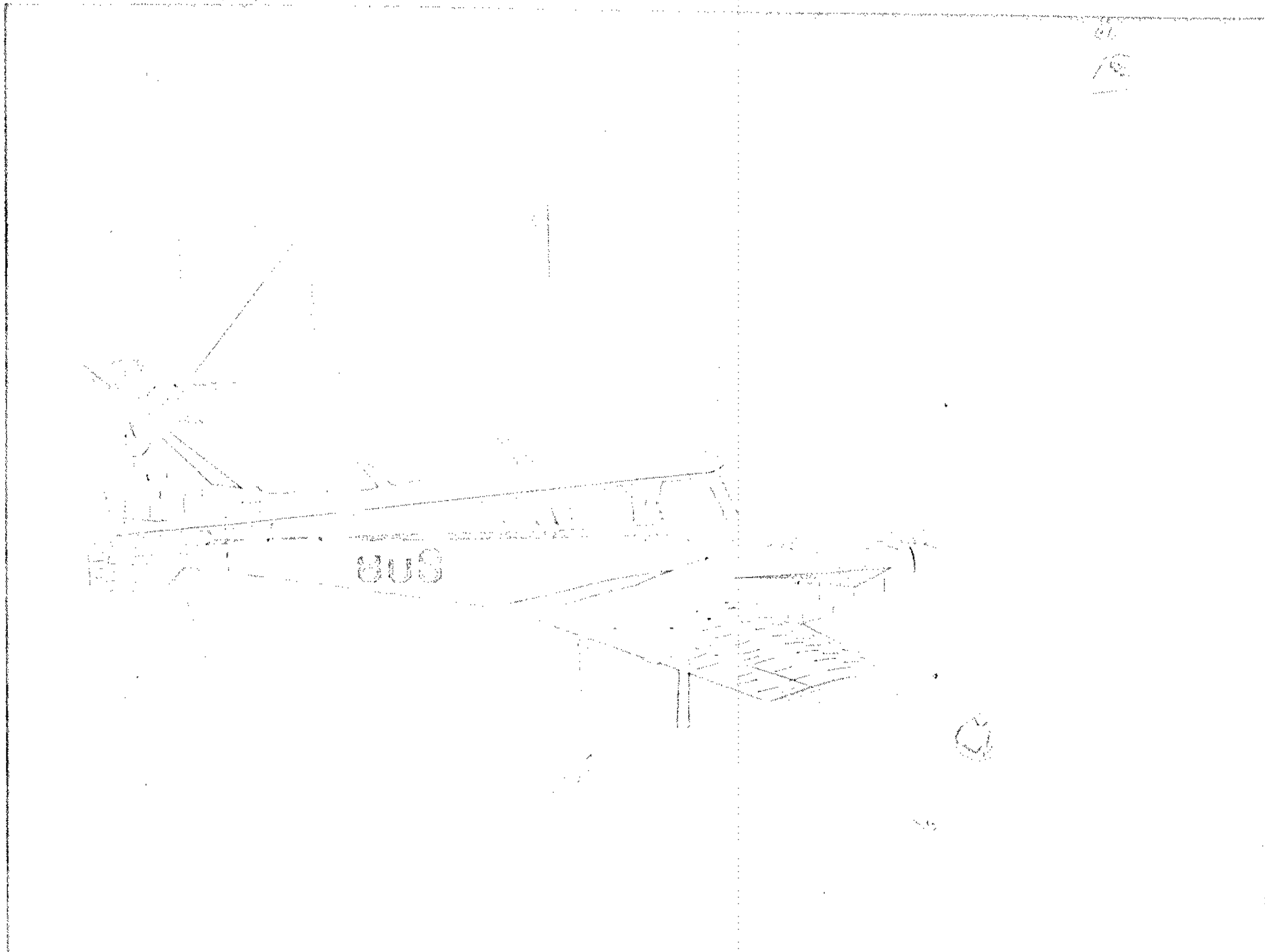


Figure 2. - Photograph ofthe airplane mounted in the full scale tunnel.

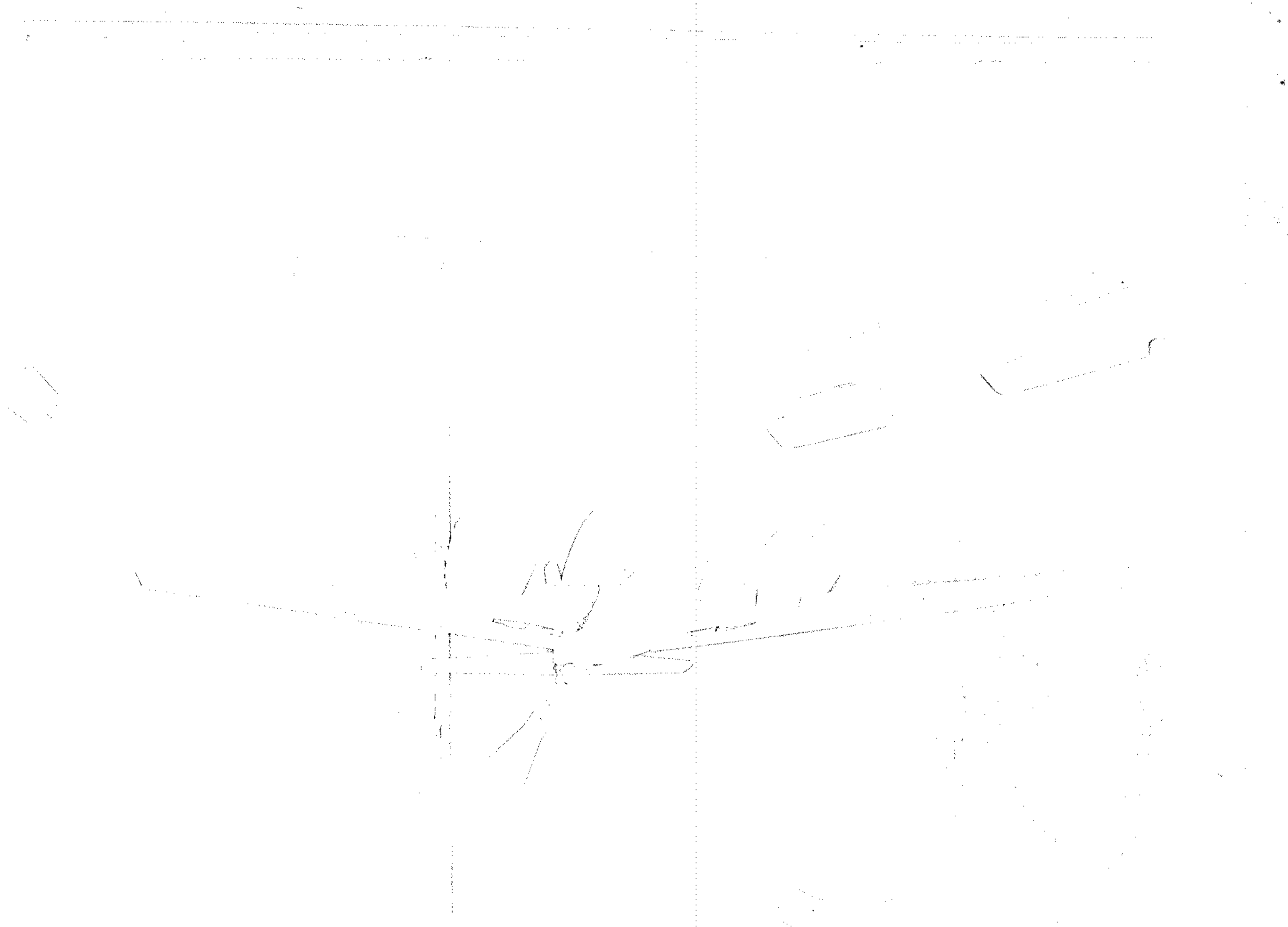
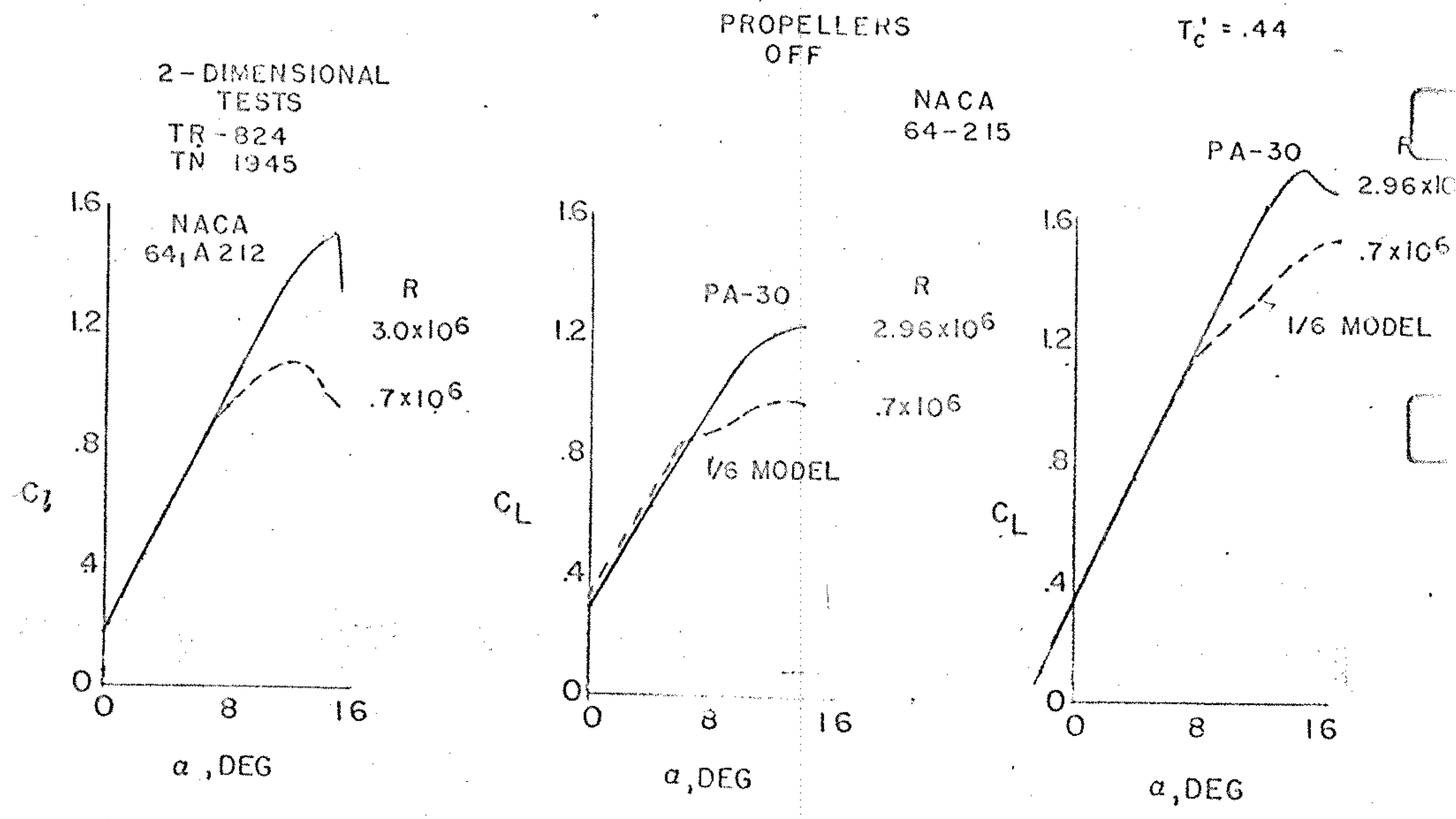


FIGURE 3 1/6 SIZE MODEL IN 7X10 TUNNEL

# EFFECTS OF REYNOLDS NUMBER ON NACA AIRFOIL SECTIONS



CALCULATION OF WING CHARACTERISTICS
NACA TR 865
AR=10.05

SECTIONS:
TIP 4412
ROOT 4420

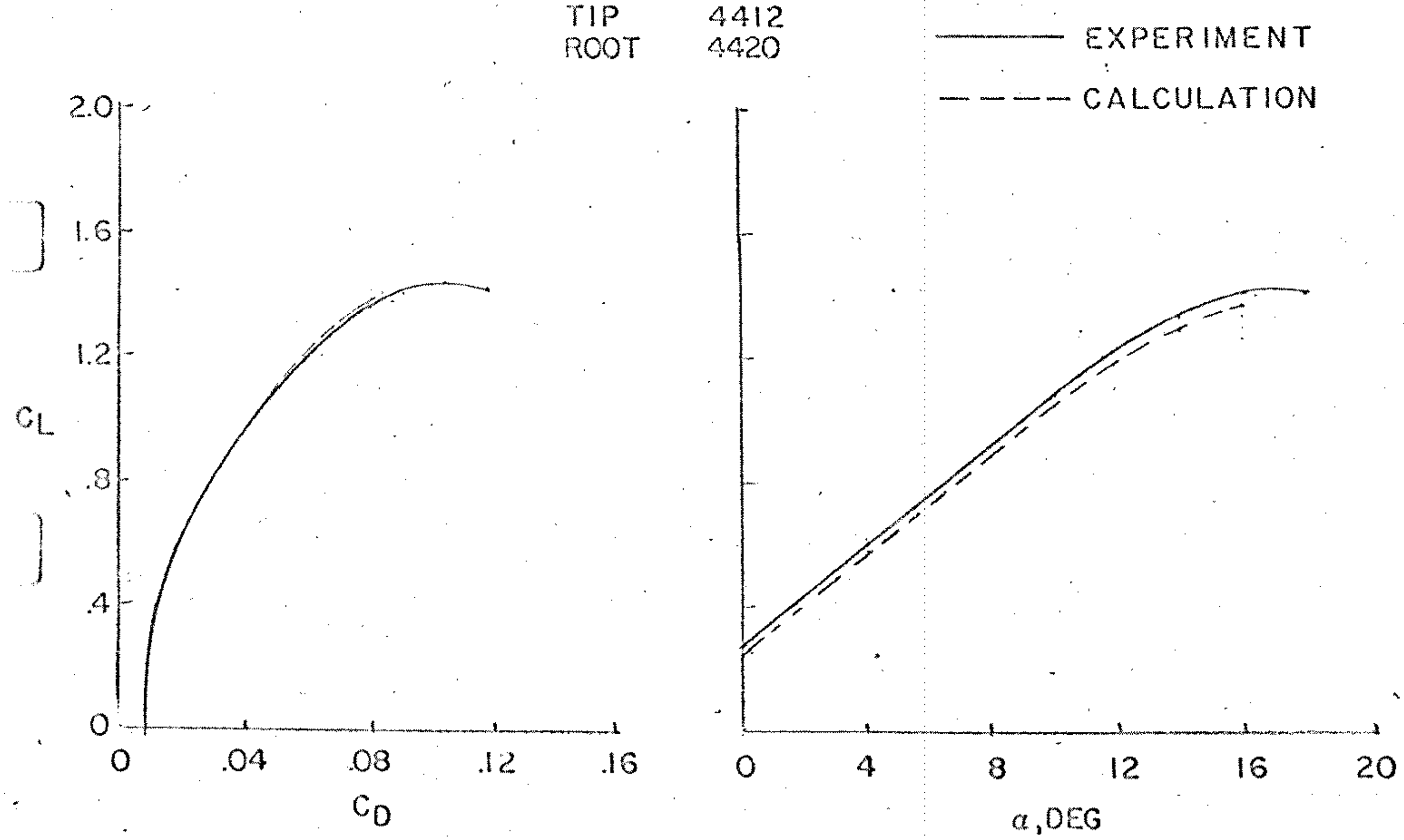



FIGURE 5

COMPARISON OF LATERAL-DIRECTIONAL AERODYNAMIC CHARACTERISTICS (FULL SCALE TUNNEL DATA)

PROPELLERS OFF

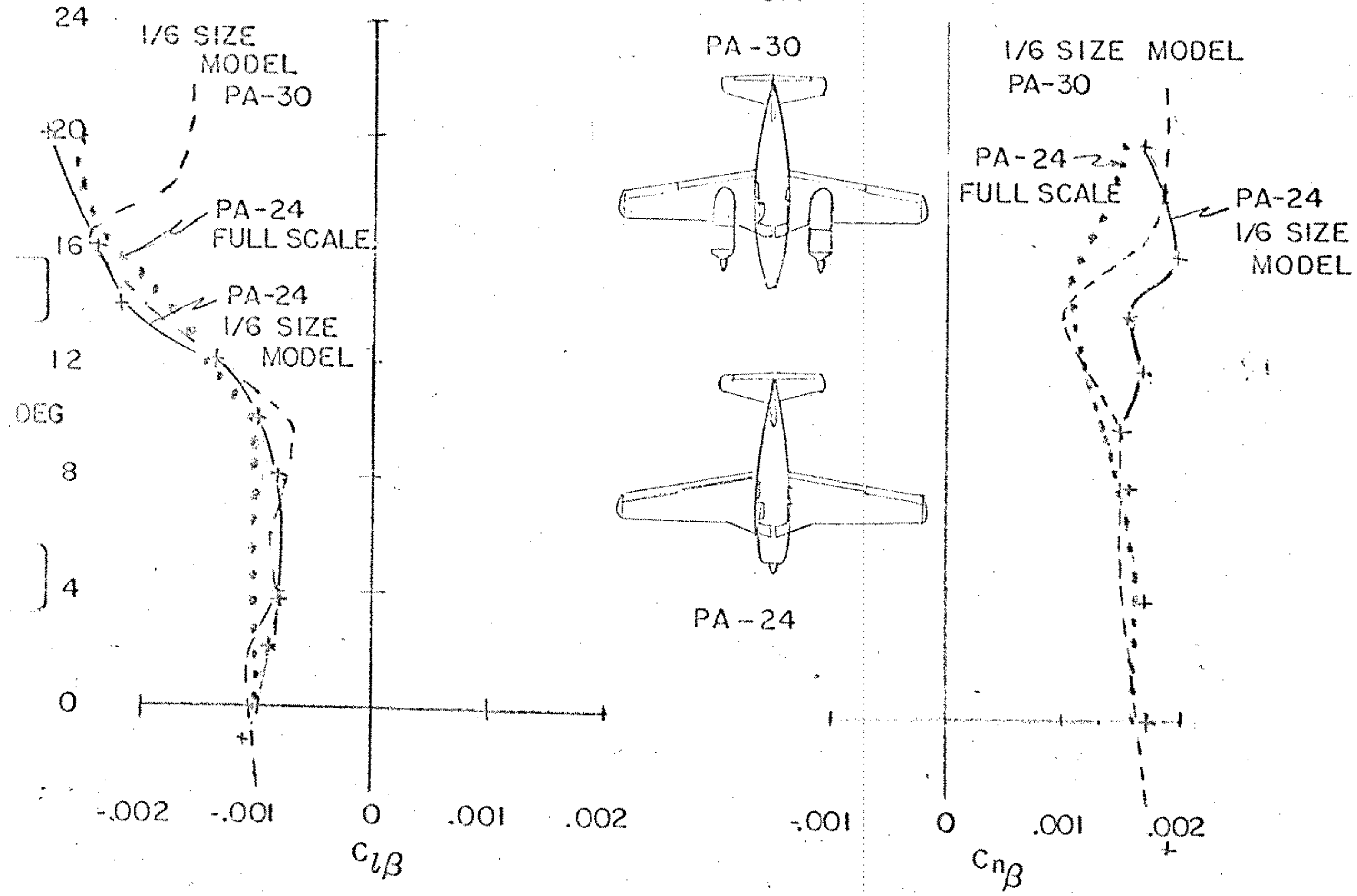



FIGURE 6

COMPARISON OF LATERAL-DIRECTIONAL AERODYNAMIC CHARACTERISTICS (FULL SCALE TUNNEL DATA)

PROPELLERS OFF

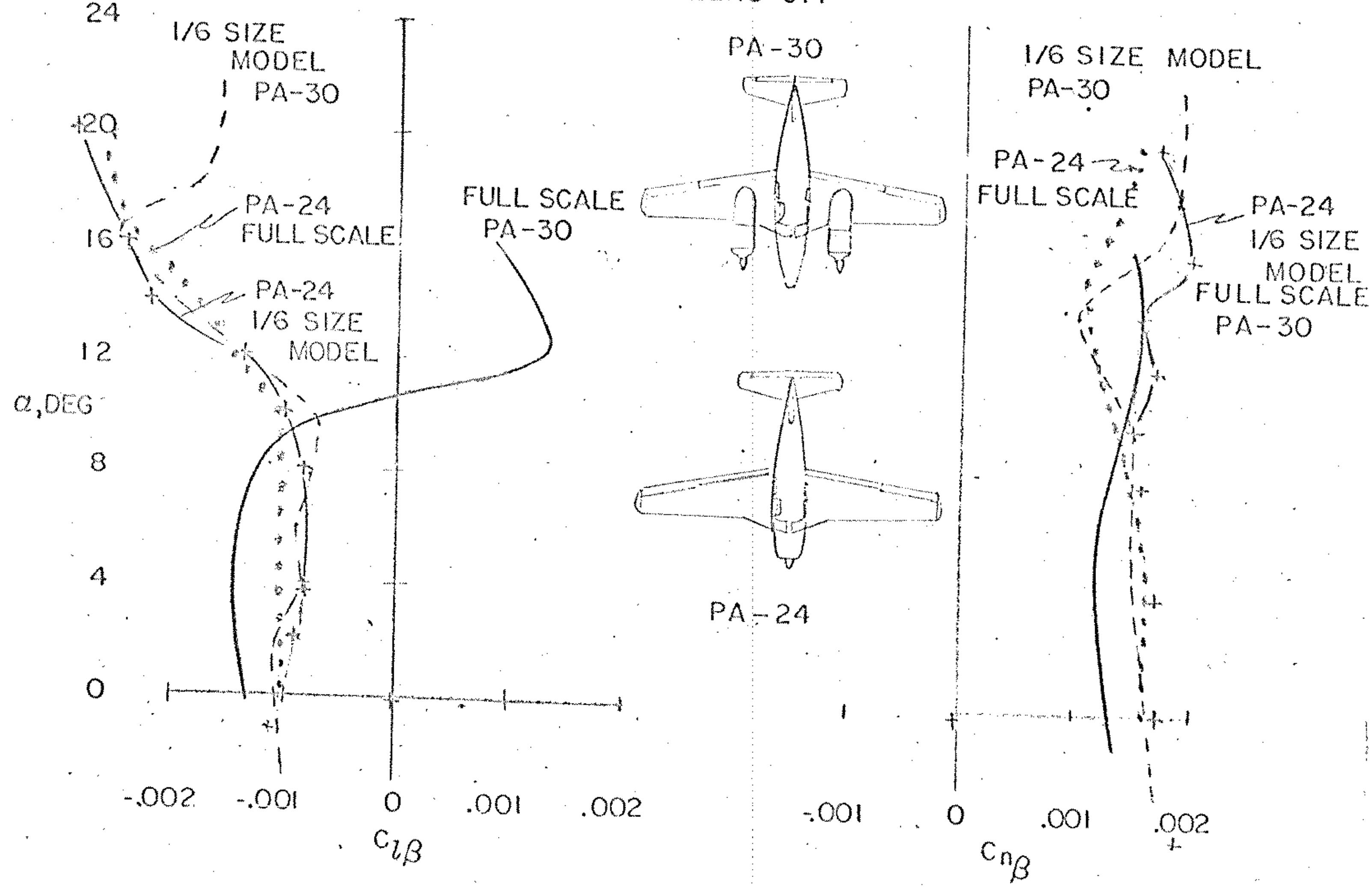



FIGURE 7

COMPARISON OF 1/6 SIZE PA-30 DATA FROM 7'x10' AND FST

$R \approx .95 \times 10^6$

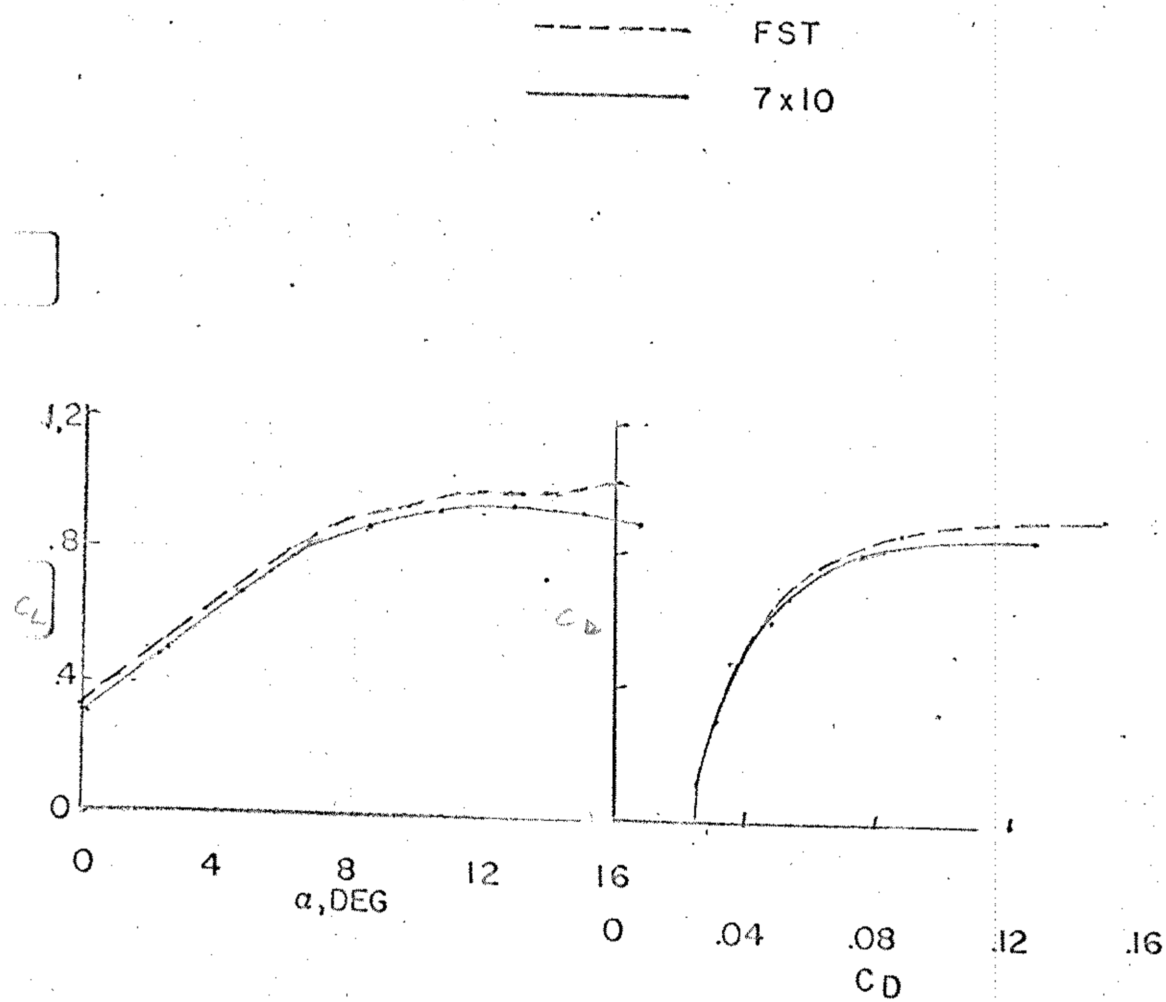



FIGURE 8

# CONCLUSIONS

- REYNOLDS NUMBER HAS SIZABLE EFFECTS ON THIS CLASS OF AIRCRAFT, POWER-OFF AND POWER-ON.
- TECHNIQUES ARE NOT PRESENTLY AVAILABLE TO CALCULATE ALL MEASURED EFFECTS NOR DO THESE TECHNIQUES ALLOW US TO CORRECT DATA FROM LOW REYNOLDS NUMBER TO FULL SCALE WHEN SEPARATION IS PRESENT.
- LANGLEY RESEARCH PROGRAM HAS BEEN REORIENTED AND WILL CONCENTRATE ON OBTAINING DATA AT HIGHER REYNOLDS NUMBER.

Figure 9