TECHNICAL NOTES

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

No. 318

FULL SCALE INVESTIGATION OF THE DRAG OF A WING RADIATOR

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Summary

Tests were made on the left lower wing of the 1927 Williams racer in the Twenty Foot Propeller Research Tunnel, in order to determine the effect of the wing radiator on the airfoil characteristics. It was found that the radiator doubled the minimum drag of the portion of the wing which it covered, and also reduced the lift somewhat.

T e s t s

At the request of the Bureau of Aeronautics, Navy Department, an investigation was made of the effect of a certain type of wing radiator on the high-speed aerodynamic characteristics of a wing. The left lower wing of the Williams racer was furnished by the Bureau for this purpose, and the tests on it were made in the 20-foot air stream of the Propeller Research Tunnel (Reference 1).

The rounded tip of the wing was cut off so that the entire surface tested, excepting a 2-inch strip along each end, was covered by the radiator as shown in Figure 1. This left the span 75.62 inches, and with the chord of 44 inches, gave an aspect ratio of 1.718. The total wing area was 23.1 square feet, and the area covered by the radiator was 21.88 square feet, on each surface. The wing was intended to have a C-62 section under the radiator, but it was very imperfect.

Figure 2 shows in detail the wing surface formed by the radiator, which was made up of specially drawn brass tubes giving the effect of rather deeply grooved fins. A cross section through the tubes and wing surface is given in Figure 3.

With the wing mounted in the tunnel as shown in Figure 4, the lift and drag forces were measured at an air velocity of approximately 100 m.p.h., and at angles of attack varying by 1° intervals from -2° to $+4^{\circ}$. Since the effect of the radiator at the high-speed condition of flight only was desired, it was unnecessary to test the wing at higher angles of attack, and thus it was possible to use small supports with very low tare drag. (The tare drag was about 7 per cent of the minimum drag of the wing without radiator.)

After the first test the radiator was stripped off, new leading and trailing edges fitted (the radiator headers originally formed the leading and trailing edges), and minor defects and irregularities in the wing surface were filled with plasticine. The wing as ready for the second test is shown in Figure 5. The surface was very irregular and "wavy," the plywood covering apparently having swelled and buckled inward slightly, causing depressions as deep as 3/16 inch. The contour of one of the worst sections is shown in Figure 6.

Results

The results of the tests are given in Table I and Figures 7, 8 and 9. The wing with radiator had just twice the minimum drag of, and somewhat less lift than, the wing without radiator.

In computing the induced drag shown in Figure 7, the Betz formulas for rectangular wings were used. No corrections have been made for wind tunnel constraint since a few computations have shown it to be negligible for the low lifts of these tests.

The increase in drag due to the radiator can be given in the form of a coefficient C_{D_R}, where

$$C_{D_R} = \frac{\text{Increase in drag due to radiator}}{\text{(Dynamic pressure) (Area covered by radiator, both surfaces)}}.$$

The difference between the drag coefficients for the wing with and without the radiator averaged approximately .011, and since the area covered by the radiator was 2×21.88 sq.ft. while the total wing area was 23.10 sq.ft., the coefficient of increased drag due to the radiator is

$$C_{D_R} = \frac{.011 \times 23.10}{2 \times 21.88} = .00581.$$

It is interesting to note that at 300 m.p.h., covering a single smooth surface with this type of radiator increases the drag by 1.33 lb. per sq.ft., and that at the above speed, each square foot of radiator requires 1.066 thrust horsepower.

It is probable that the percentage increase in drag due to the radiator would have been even greater if the wing without radiator had been more perfect in form. A large model airfoil (3-foot chord and 12-foot span) having the C-62 section has also been tested in the Propeller Research Tunnel. The profile drag for this section is plotted against lift coefficient along with that for the Williams wing without radiator, in Figure 10, and the drag is shown to be considerably less for the more perfect model.

Conclusions

The wing radiator used on the Williams racer doubled the minimum drag of the portion of the wing which it covered, and also reduced the lift somewhat.

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Reference

1. Weick, Fred E. and Wood, Donald H. : The Twenty-Foot Propeller Research Tunnel of the National Advisory Committee for Aeronautics. N.A.C.A. Technical Report No. 300, 1928.

TABLE I.

Aerodynamic Characteristics

Values from faired curves

Wing with radiator

Angle of attack	C_L	C_D
-2°	-.0250	.0221
-1°	+.0125	.0217
0°	.0520	.0217
+1°	.0950	.0225
2°	.1385	.0246
3°	.1785	.0278
4°	.2135	.0317

Wing without radiator

Angle of attack	C_L	C_D
-2°	-.0100	.0112
-1°	+.0305	.0107
0°	.0705	.0112
+1°	.1140	.0125
2°	.1575	.0148
3°	.2000	.0177
4°	.2425	.0216

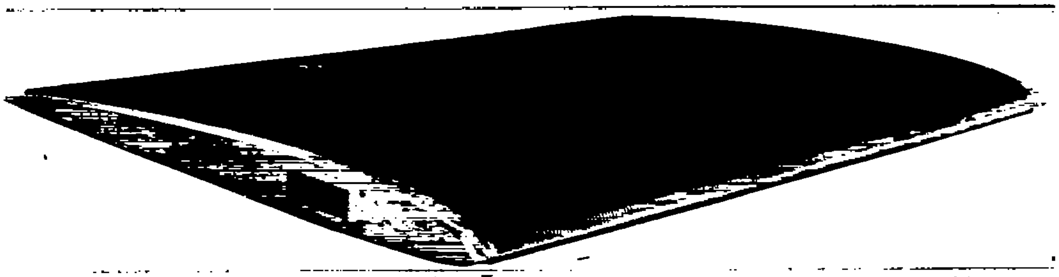

Fig.1 Williams Racer Wing with radiator ready for test

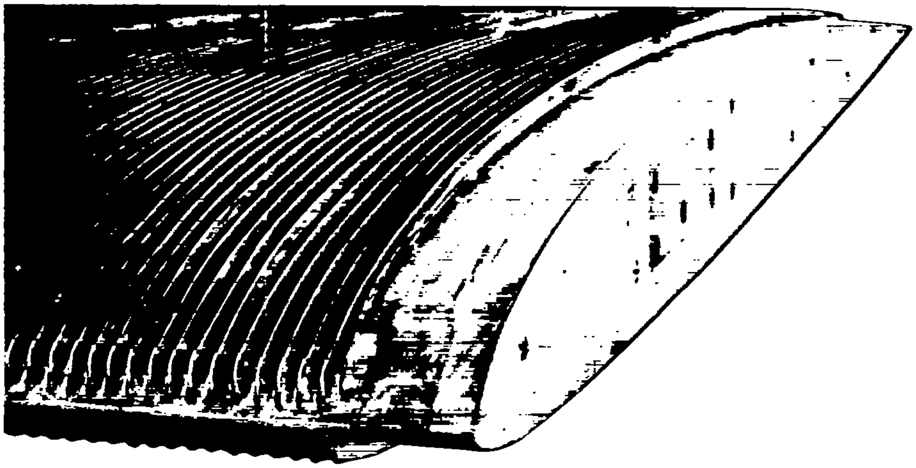

Fig.2 Details of wing radiator

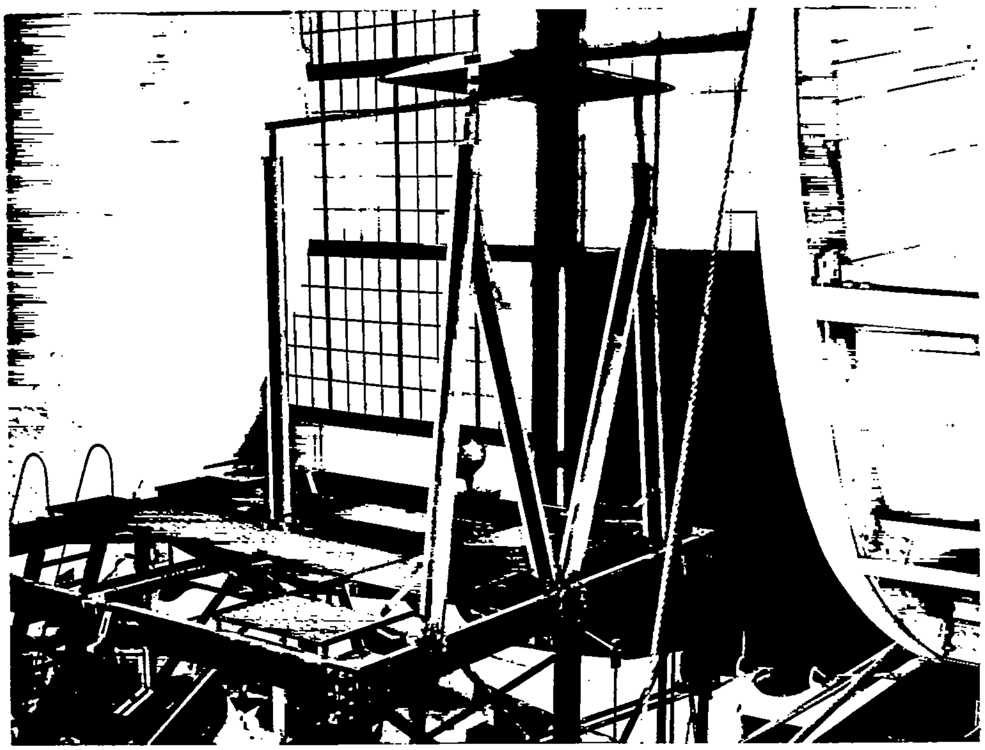

Fig.4 Wing with radiator mounted on balance

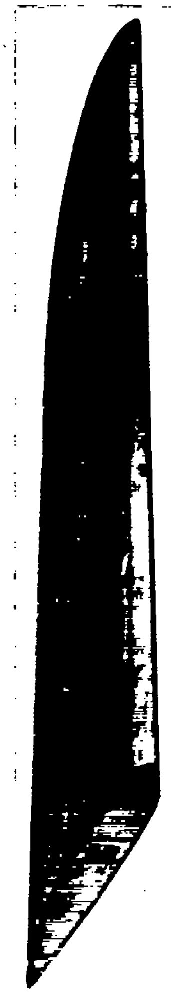

Fig.5 Williams racer wing with radiator off ready for test

13150 A.S.

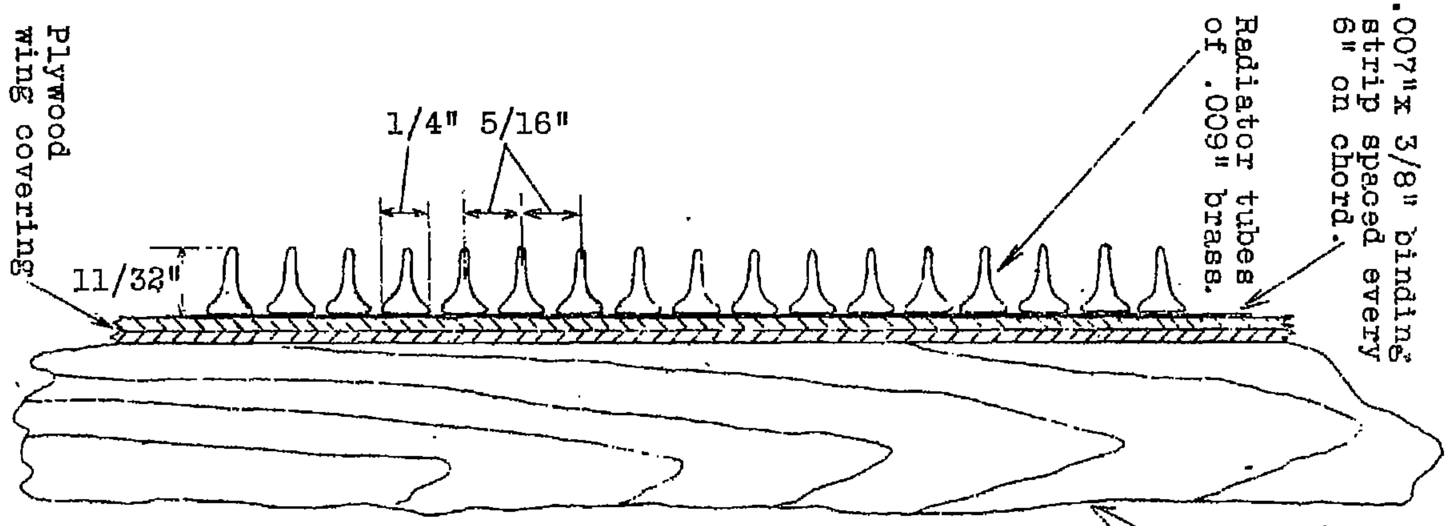

Fig. 3 Cross-section through radiator tubes

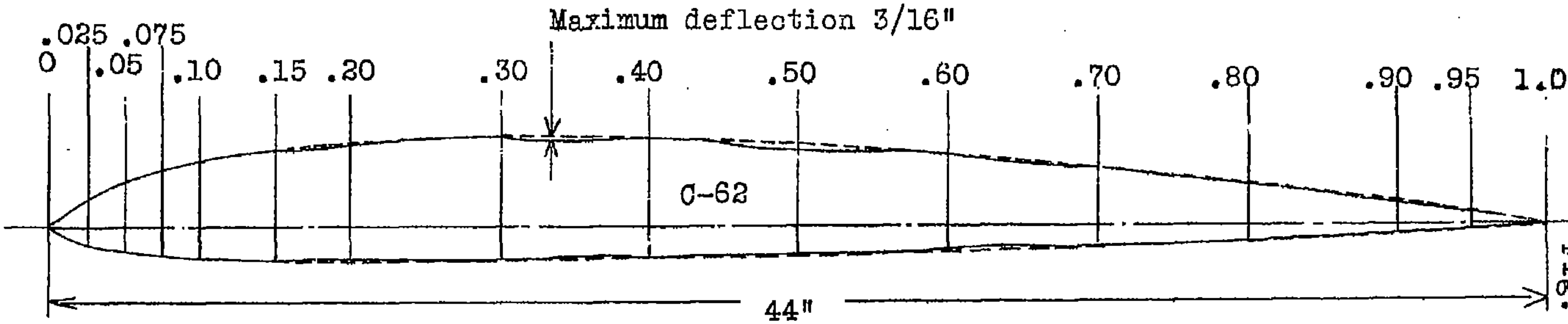

Fig. 6

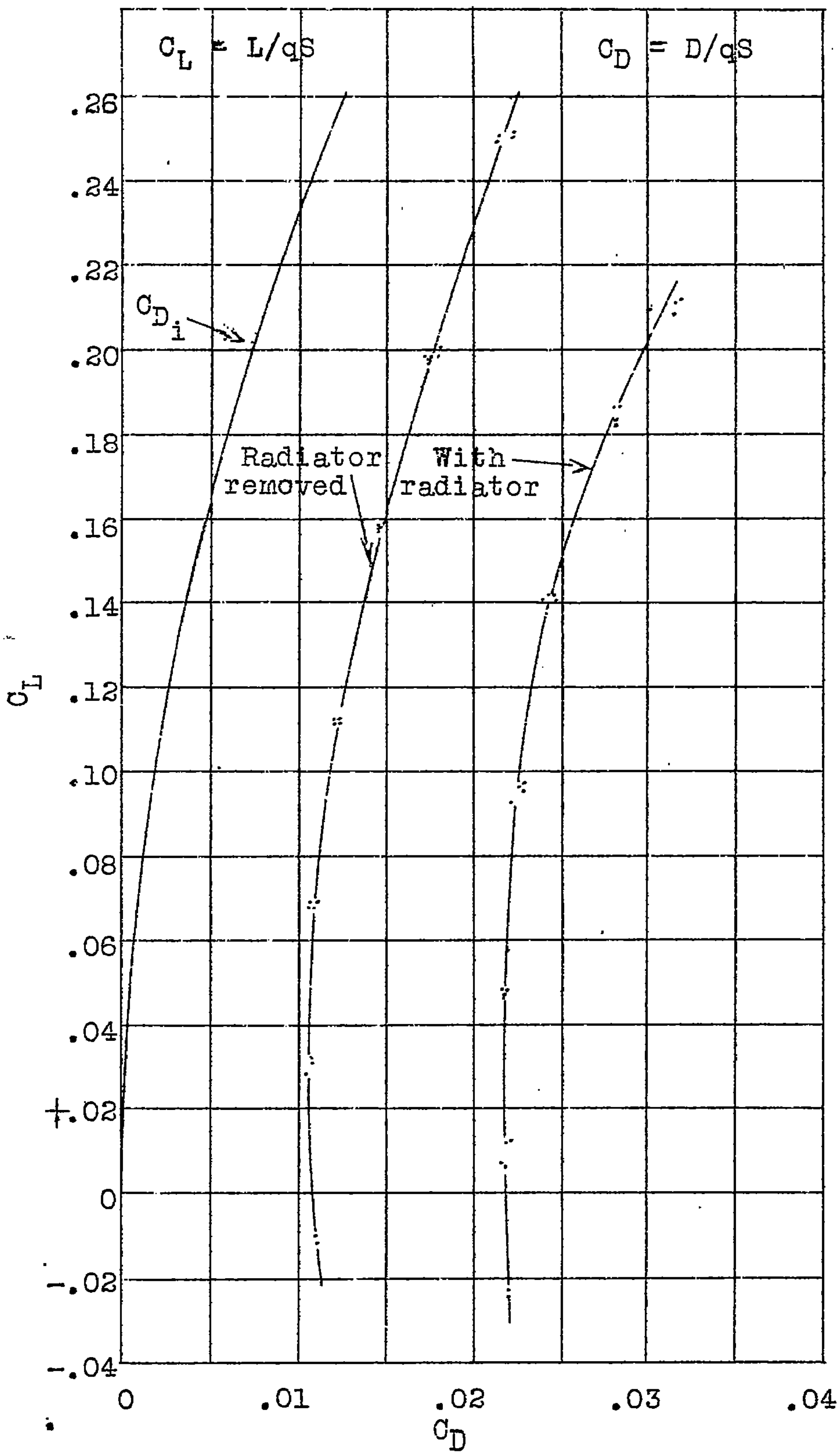

Fig. 7 Velocity 100 m.p.h., A.R.=1.718

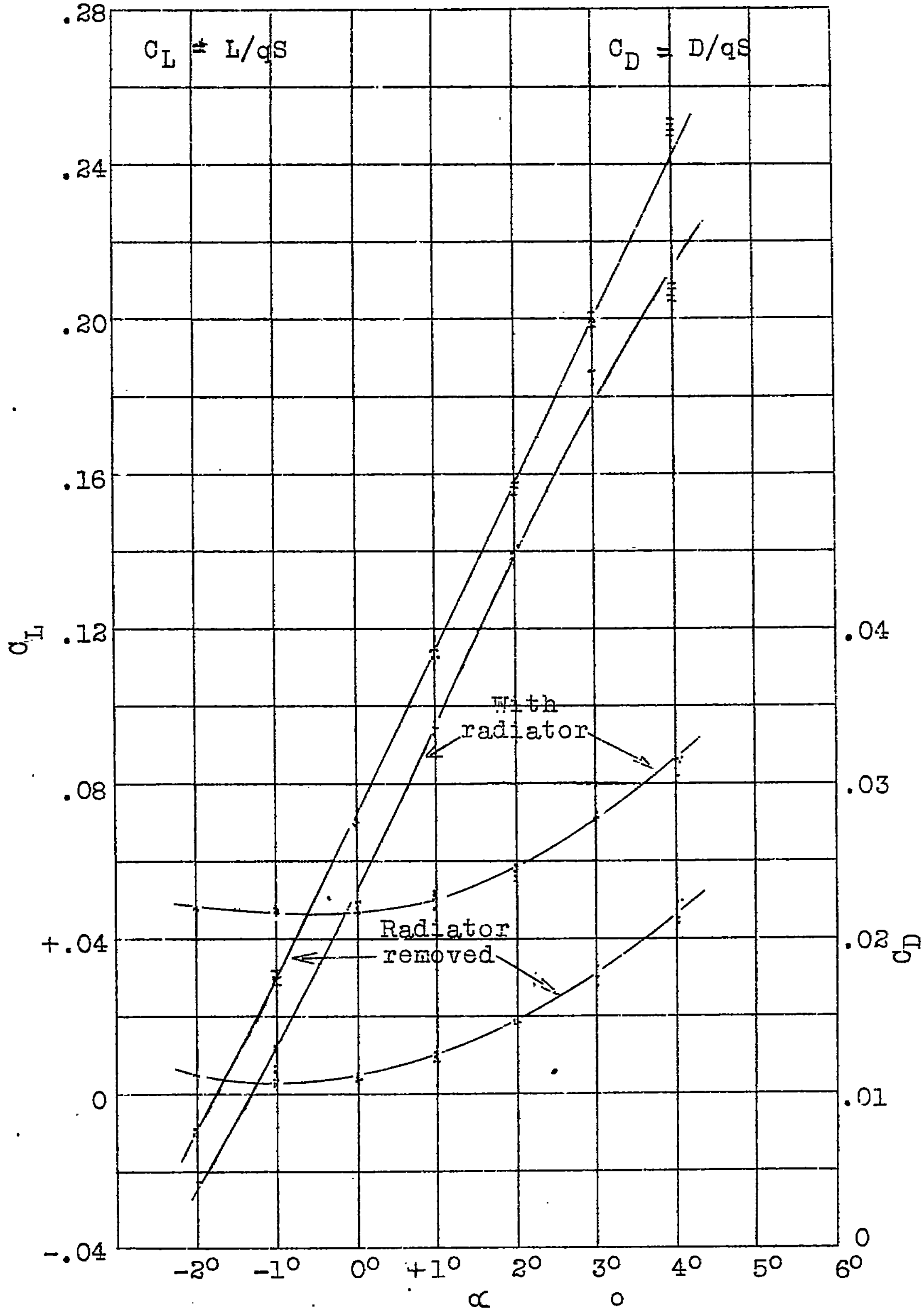

Fig. 8 Velocity 100 m.p.h.,A.R.=1.718

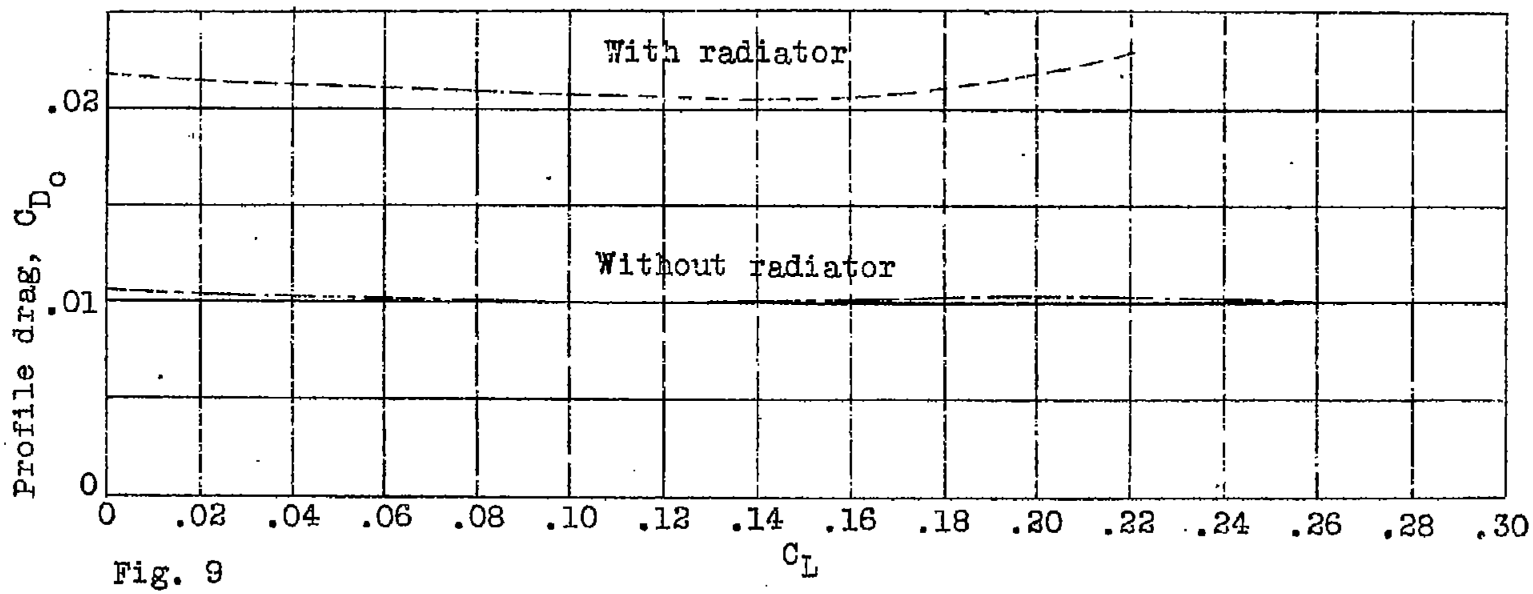
With radiator
Without radiator
Profile drag, C_{D_o}
.02
.01
0
0 .02 .04 .06 .08 .10 .12 .14 .16 .18 .20 .22 .24 .26 .28 .30
C_L

Fig. 9

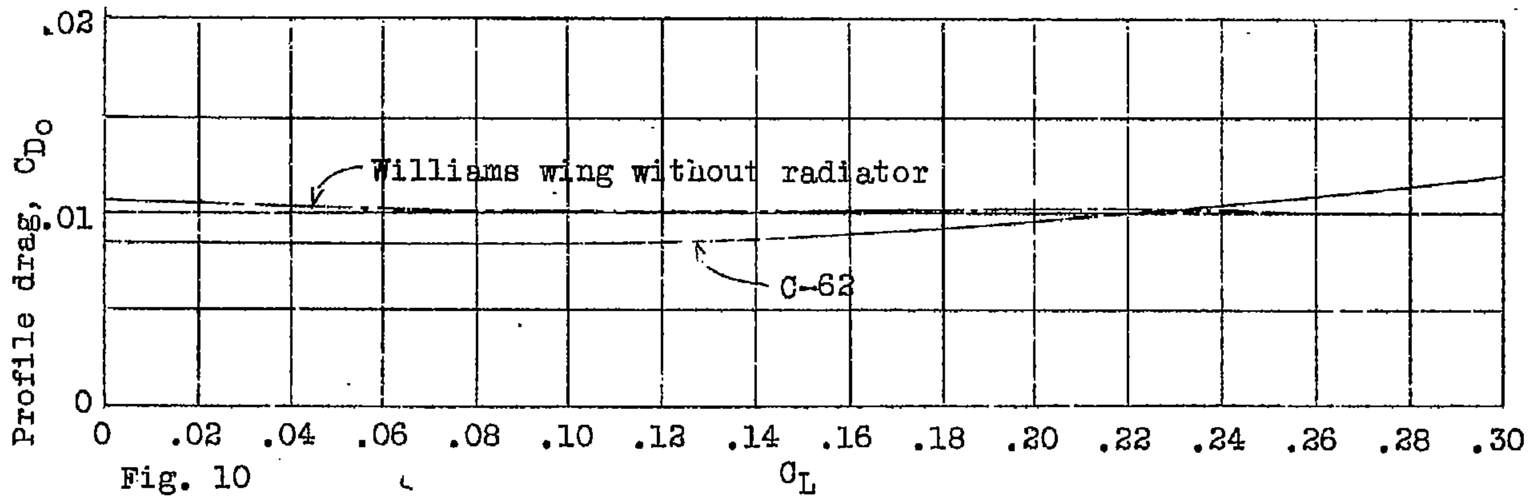
Williams wing without radiator
C-62
Profile drag, C_{D_o}
.02
.01
0
0 .02 .04 .06 .08 .10 .12 .14 .16 .18 .20 .22 .24 .26 .28 .30
C_L

Fig. 10