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TECHNICAL NOTES

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No. 356

WALL INTERFERENCE IN CLOSED TYPE WIND TUNNELS

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Summary

A series of tests has been conducted by the National Advisory Committee for Aeronautics, in the variable density wind tunnel on several airfoils of different sizes and sections to determine the effect of tunnel wall interference and to determine a correction which can be applied to reduce the error caused thereby. The use of several empirical corrections was attempted with little success. The Prandtl theoretical correction gives the best results and its use is recommended for correcting closed wind tunnel results to conditions of free air.

Introduction

When tests are made on models in wind tunnels to determine their aerodynamic characteristics, the results obtained are not truly representative because of the limited air jet of the tunnel. The boundary of the jet, whether free or enclosed by walls, affects the flow to a considerable extent. This effect has been considered theoretically and a method devised for correcting the results from wind tunnel tests.

Experimental confirmation of this correction is extremely desirable and though such confirmation has been obtained in wind tunnels in Europe, tests for that purpose had not been made in the wind tunnels of the National Advisory Committee for Aeronautics. A series of tests was therefore authorized to be conducted by the aerodynamics staff to be made in the variable density wind tunnel at the Langley Memorial Aeronautical Laboratory, Langley Field, Virginia.

This investigation was to consist of force tests on several airfoil models of the N.A.C.A. M-6 section, having a constant chord and a varying span, from which some idea of the effect of tunnel walls could be ascertained.

Data from previous tests on the M-6 airfoil section were also available and were used in the analysis. For further confirmation, in conjunction with another investigation, tests were made on three airfoil models of the R.A.F. 19 section, each having the same aspect ratio but different areas.

The Tests

The tests on the N.A.C.A. M-6 in this investigation were conducted after the usual method employed in the variable density wind tunnel (Reference 1). The angle of attack was varied from -3° to $+21^{\circ}$. Runs were made at several densities, or Reynolds Numbers. The R.A.F. 19 series was similarly tested.

The N.A.C.A. M-6 section model was 4½ inches by 36 inches in plan. It was tested in this form, of aspect ratio 8.00, and then cut off on the ends so that the span became 32 inches, giving the airfoil an aspect ratio of 7.12. This procedure was repeated, making tests on the airfoil with aspect ratios 6.00, 5.33, and 4.44. The R.A.F. 19 models were all of aspect ratio 6.00 but had plan form dimensions of 4 inches by 24 inches, 5 inches by 30 inches, and 6 inches by 36 inches. All models were of duralumin and machined to within ±0.002 inch of the specified ordinates.

Results and Discussion

Readings of lift and drag at various angles of attack were obtained and reduced to absolute coefficients. Those obtained from the tests on airfoils of aspect ratios other than six were reduced to coefficients of that aspect ratio as noted in the figures, using the Prandtl theory of aspect ratio variation. These data were then plotted on charts of various forms to determine any effects that might possibly be attributed to the interference of the walls. Numerous empirical corrections and the Prandtl theoretical correction (References 2 and 3) were applied to find out whether better agreement in the results could be arrived at by their use.

The Prandtl correction when applied, produced the results

which were in best agreement (See Figures 1 to 10 inclusive). The corrections used were:

$$\Delta C_{D_i} = \frac{C_L^2 \; S}{2 \pi D^2} , \qquad \frac{S}{C} C_L^2$$

and

$$\Delta \alpha_i = \frac{C_L \; S}{2 \pi D^2} ,$$

where C_L = lift coefficient

C_{D_i} = induced drag coefficient

α_i = induced angle

S = area of airfoil

D = diameter of the tunnel

These amounts were added to the C_D and α, respectively.

Figures 1, 2, and 3 show the polar curves of the N.A.C.A. M-6 airfoils of various aspect ratios: Figure 1, the results in coefficient form as observed in the tunnel; Figure 2, the same, corrected to aspect ratio 6.00 of the same span in the tunnel; and Figure 3, the same, corrected also for wall interference to agree with the 4½-inch by 27-inch airfoil as tested in the tunnel, using the Prandtl formula. It can be seen that the scattering of points is less in the last of these, indicating that the application of the formula improves the agreement.

Figures 4, 5, and 6 show the lift coefficient plotted against the angle of attack for the same airfoils, before and after the two above corrections have been made.

Data from previous tests at 20 atmospheres density on the

N.A.C.A. M-6 airfoil, made on models of different sizes, aspect ratio 6.00, are compared with those of these tests in Figures 7 and 8. The polar curves show very good agreement after the correction has been added.

In Figures 9 and 10, the results of the R.A.F. 19 airfoils (Reynolds Number 530,000) are shown plotted as polar curves without and with the Prandtl correction applied. Here, likewise, the results are improved by its use.

Conclusion

Test data from closed wind tunnels on airfoils of a given section, but having various plan forms, agree better when corrected for tunnel wall interference by the Prandtl theoretical formula. Its use is recommended for correcting wind tunnel data to the conditions of free air.

References

1. Munk, Max M. and Miller, Elton W. : The Variable Density Wind Tunnel of the National Advisory Committee for Aeronautics. N.A.C.A. Technical Report No. 227, 1925.

2. Prandtl, L. : Applications of Modern Hydrodynamics to Aeronautics, Part II, Section F. N.A.C.A. Technical Report No. 116, 1921.

3. Glauert, H. : The Interference of Wind Channel Walls on the Aerodynamic Characteristics of an Airfoil. Reports and Memoranda No. 867, March, 1923. British Aeronautical Research Committee.

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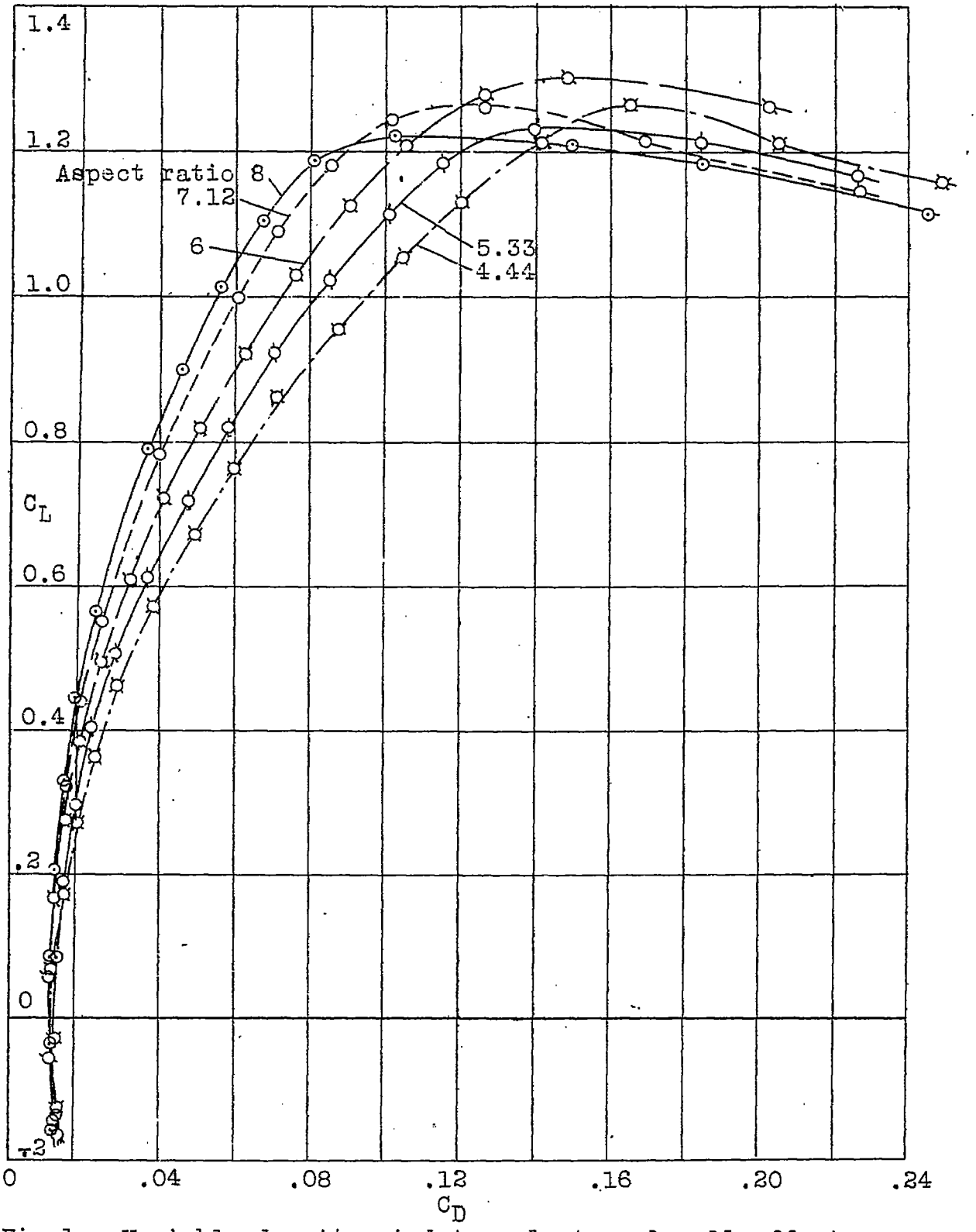

Fig.1 Variable density wind tunnel, tunnel wall effect. N.A.C.A. M-6 airfoils of various aspect ratios, as observed in tunnel. Average Reynolds No.3,150,000

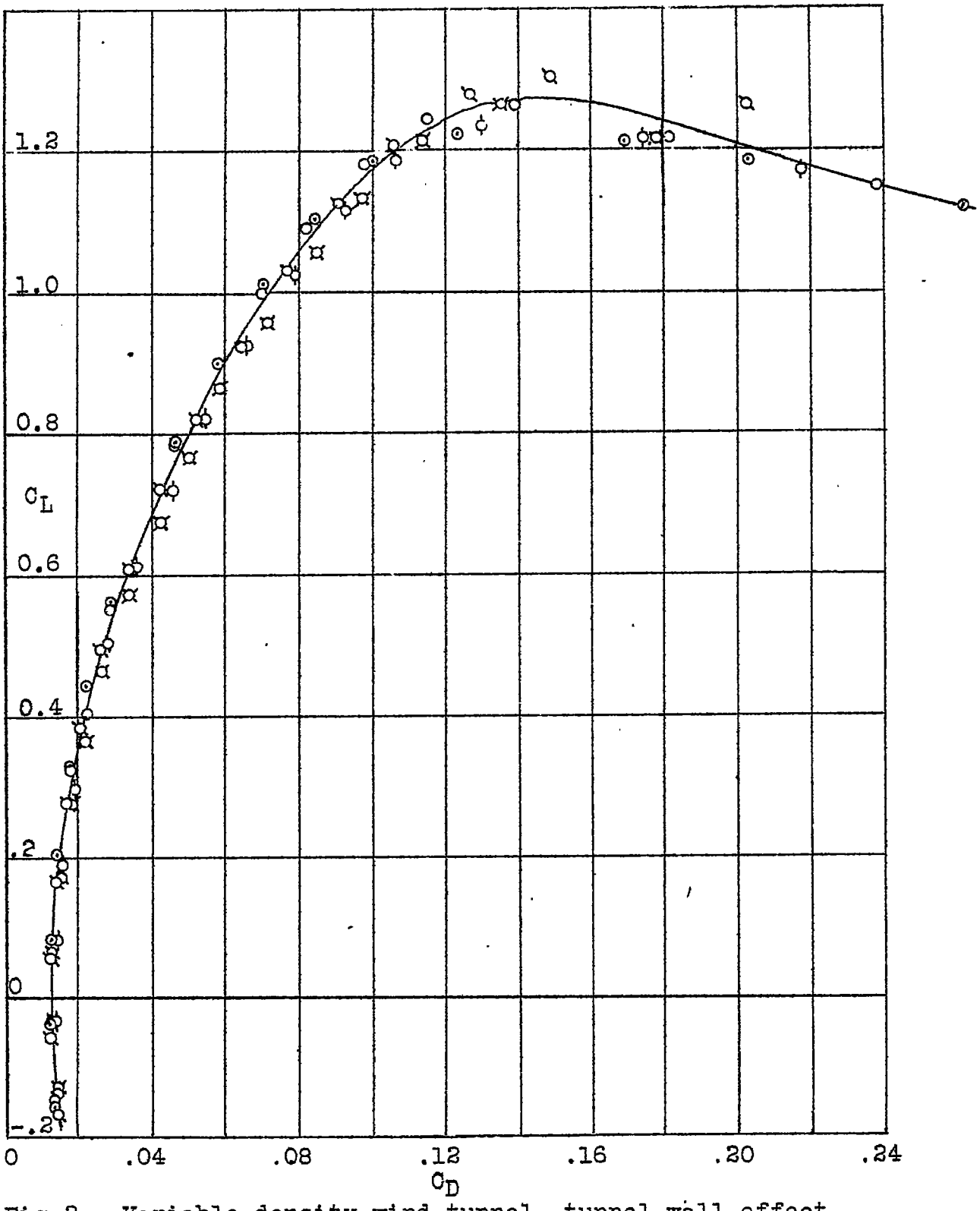

Fig.2 Variable density wind tunnel, tunnel wall effect. N.A.C.A. M-6 airfoil of various aspect ratios, corrected to aspect ratio 6. in tunnel. Average Reynolds No. 3,150,000.

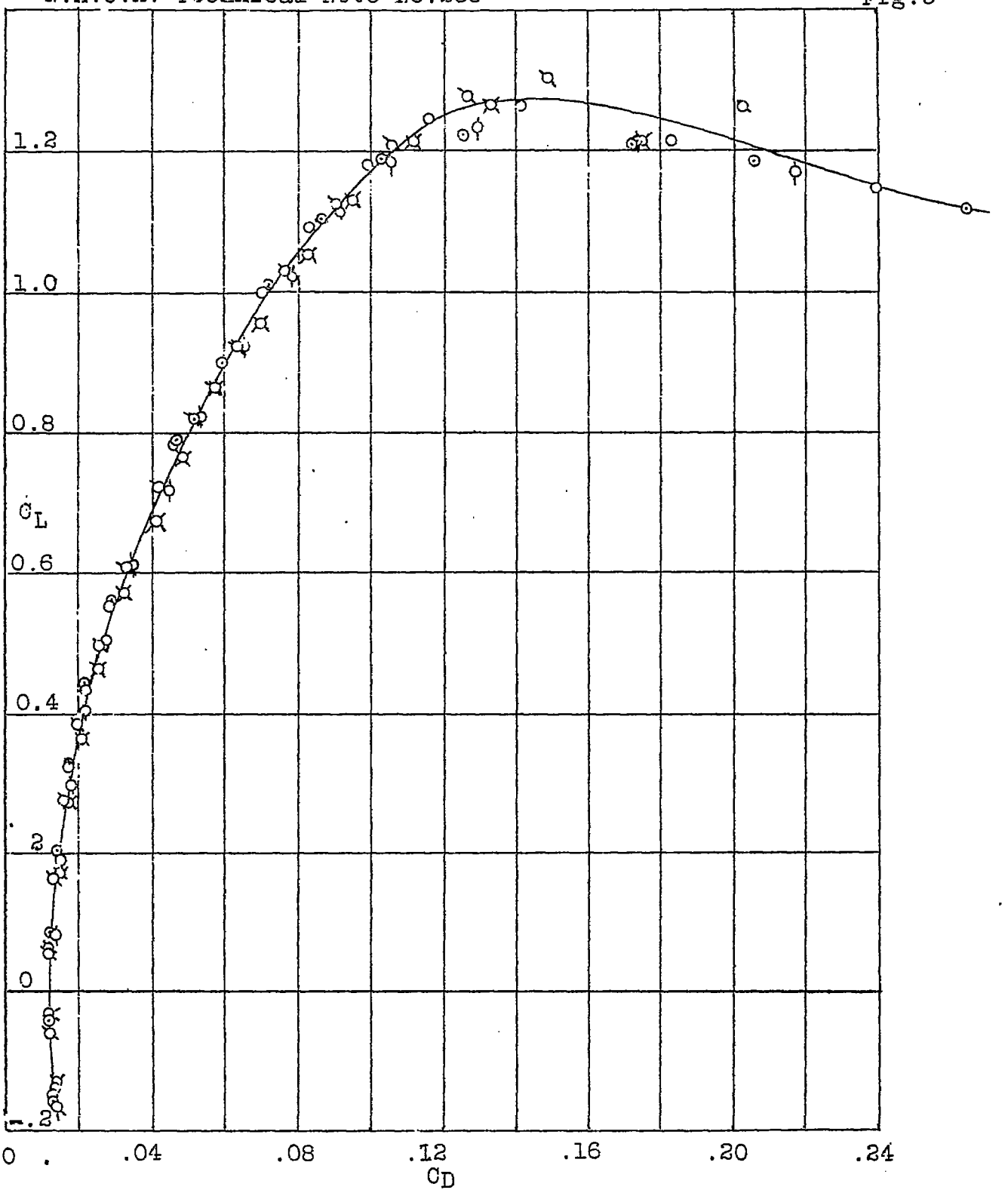

Fig.3 Variable density wind tunnel, tunnel wall effect. N.A.C.A. M-6 airfoil of various aspect ratios, corrected for wall interference, aspect ratio 6, in tunnel. Average Reynolds No. 3,150,000.

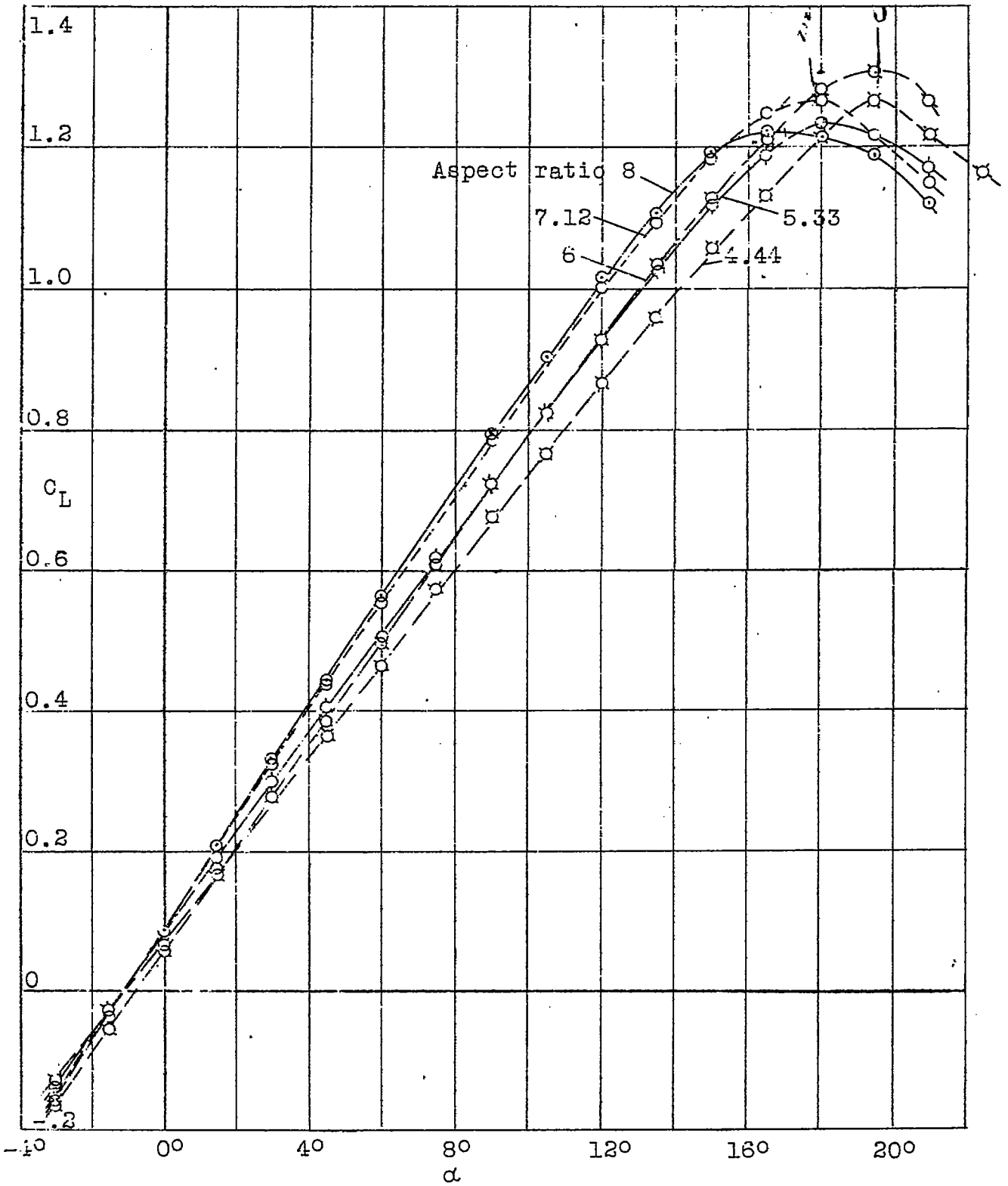

Fig.4 Variable density wind tunnel, tunnel wall effect. N.A.C.A. M-6 airfoils of various aspect ratios, as observed in tunnel. Average Reynolds No.3,150,000.

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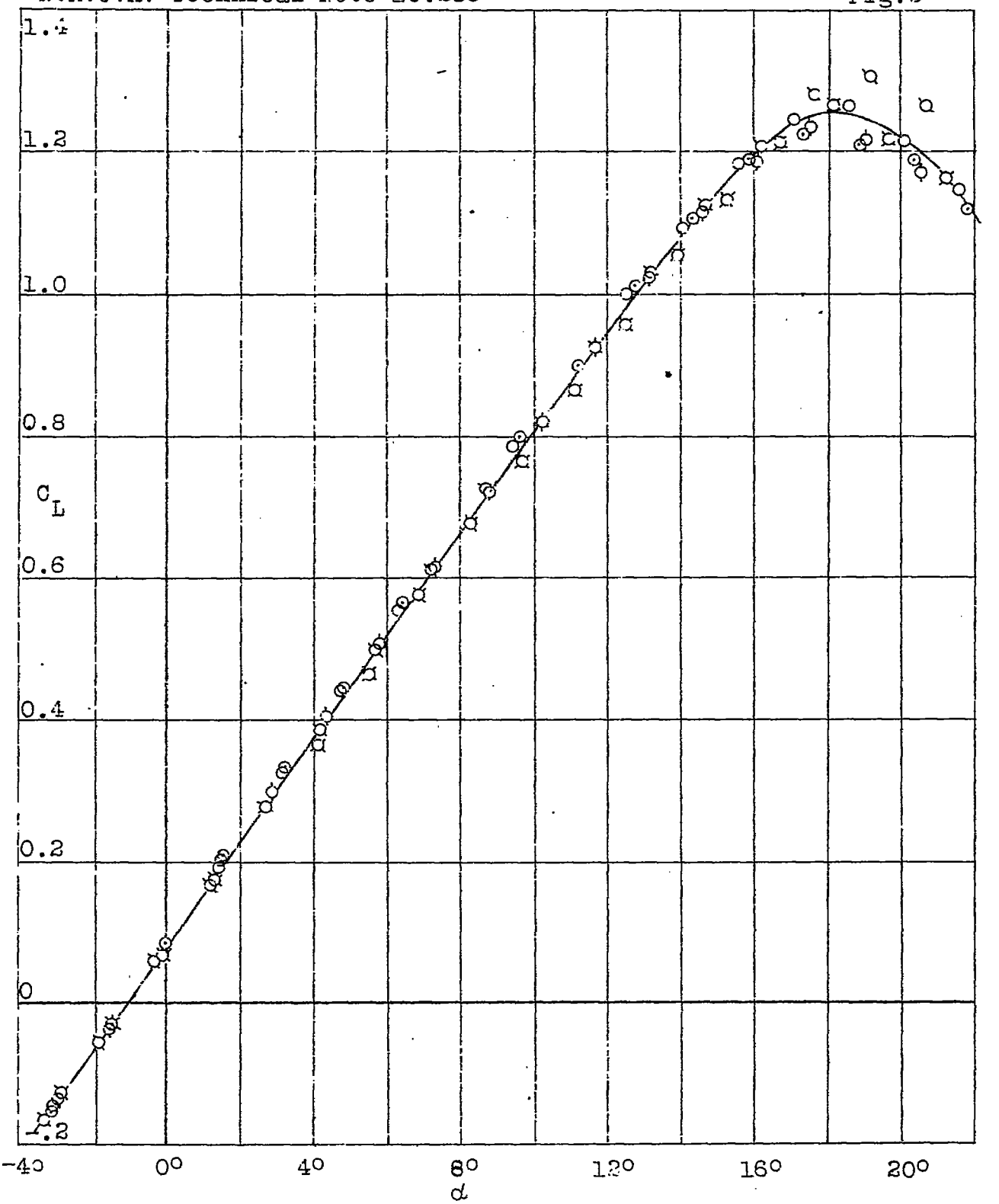

Fig.5 Variable density wind tunnel, tunnel wall effect. N.A.C.A. M-6 airfoil of various aspect ratios, corrected to aspect ratio 6, in tunnel. Average Reynolds No.3,150,000.

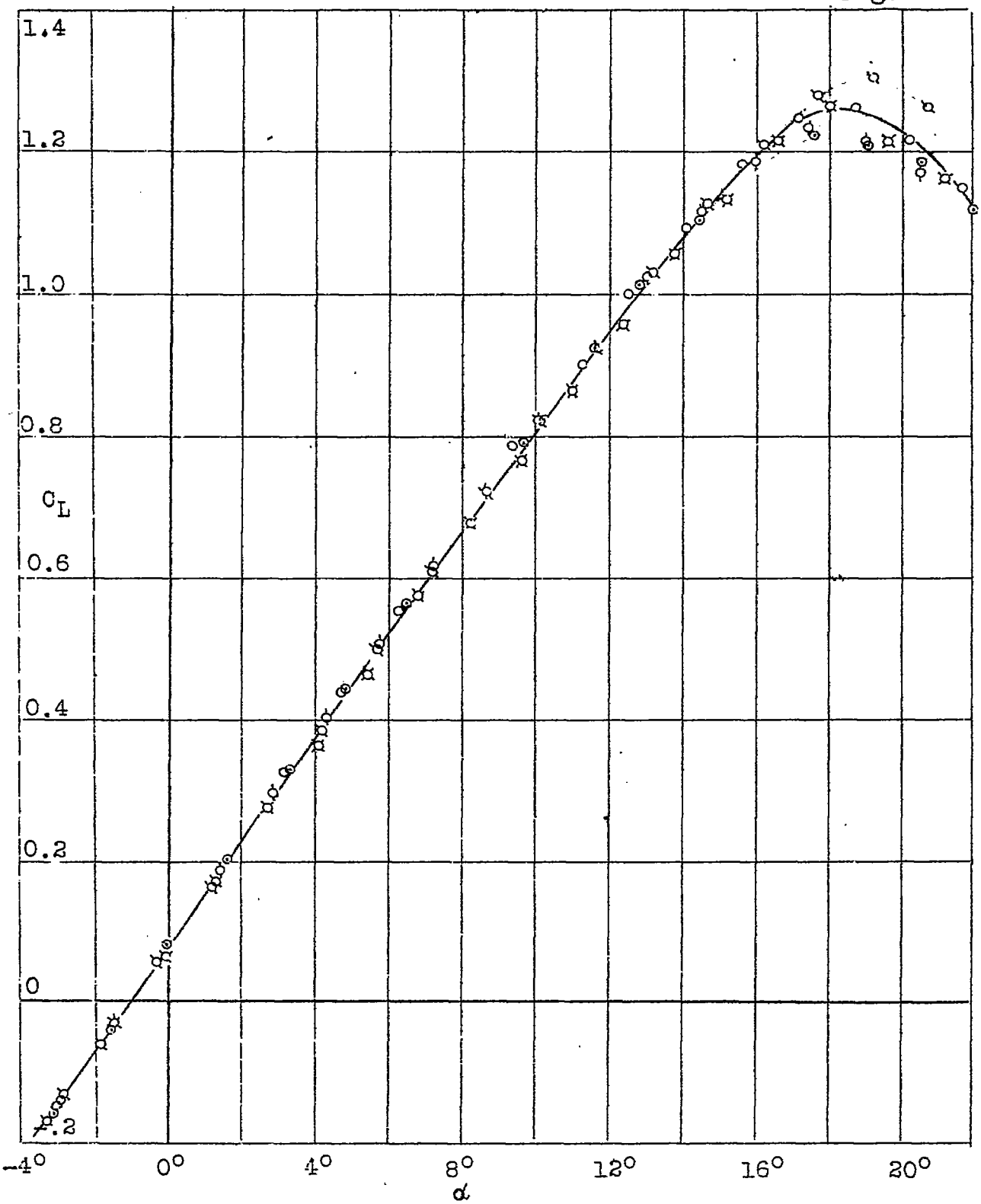

Fig.6 Variable density wind tunnel, tunnel wall effect. N.A.C.A. M-6 airfoil of various aspect ratios, corrected for wall interference aspect ratio 6, in tunnel. Average Reynolds No. 3,150,000.

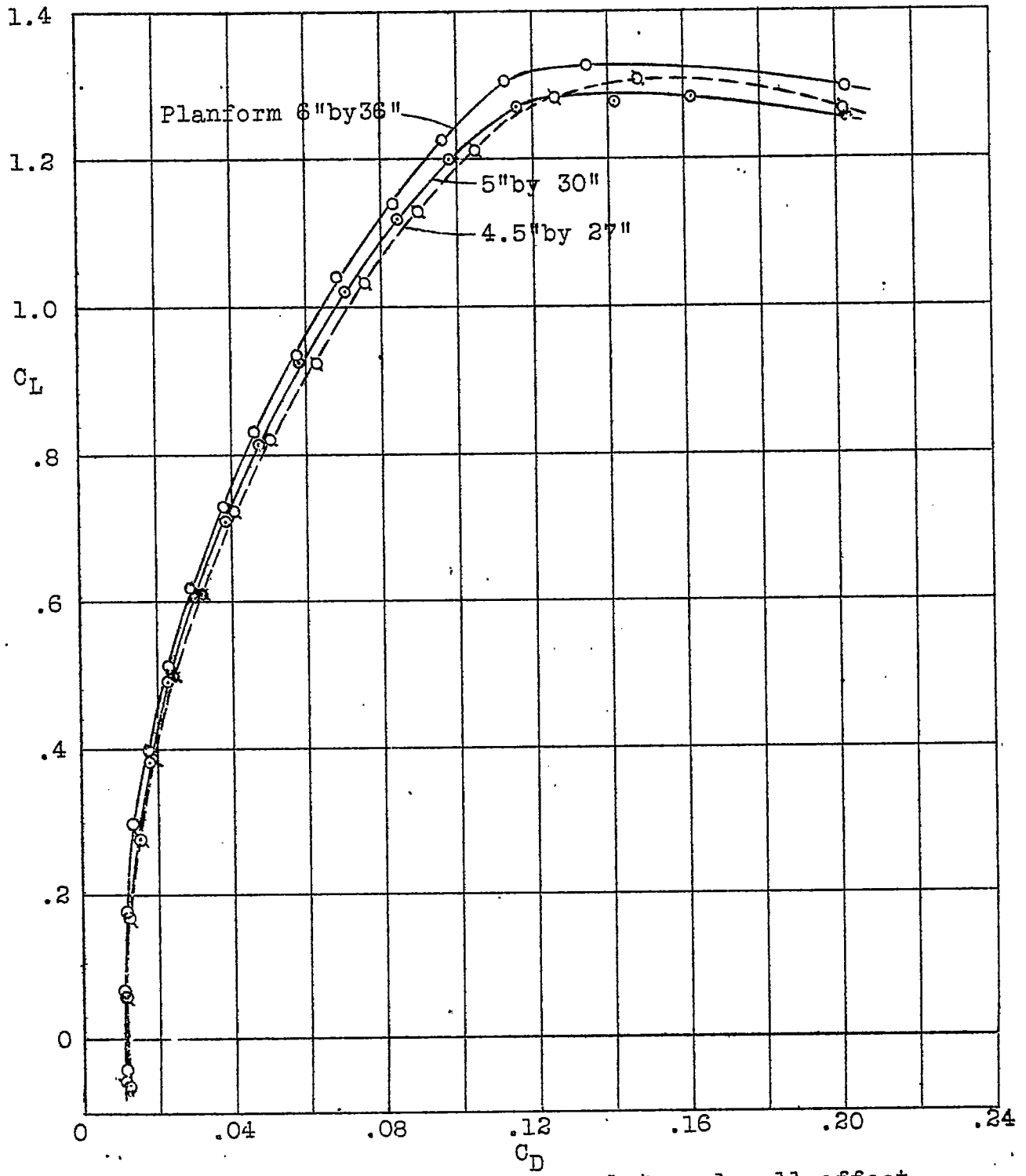

Fig.7 Variable density wind tunnel, tunnel wall effect. N.A.C.A. M-6 airfoils of various sizes, as observed in tunnel. 20 atmospheres density.

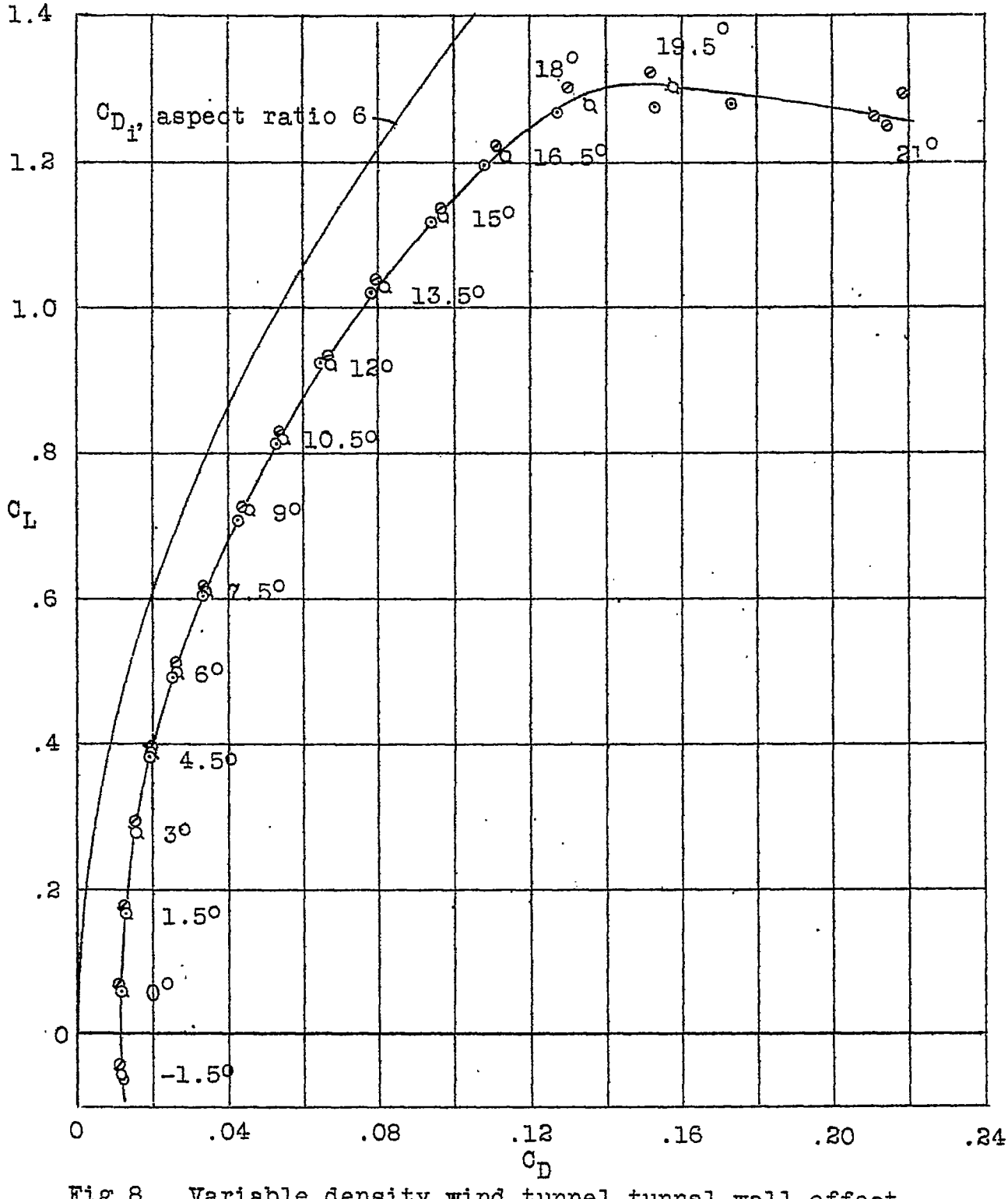

Fig.8 Variable density wind tunnel, tunnel wall effect. N.A.C.A. M-6 airfoils of various sizes, corrected for wall interference, aspect ratio 6 in free air. 20 atmospheres.

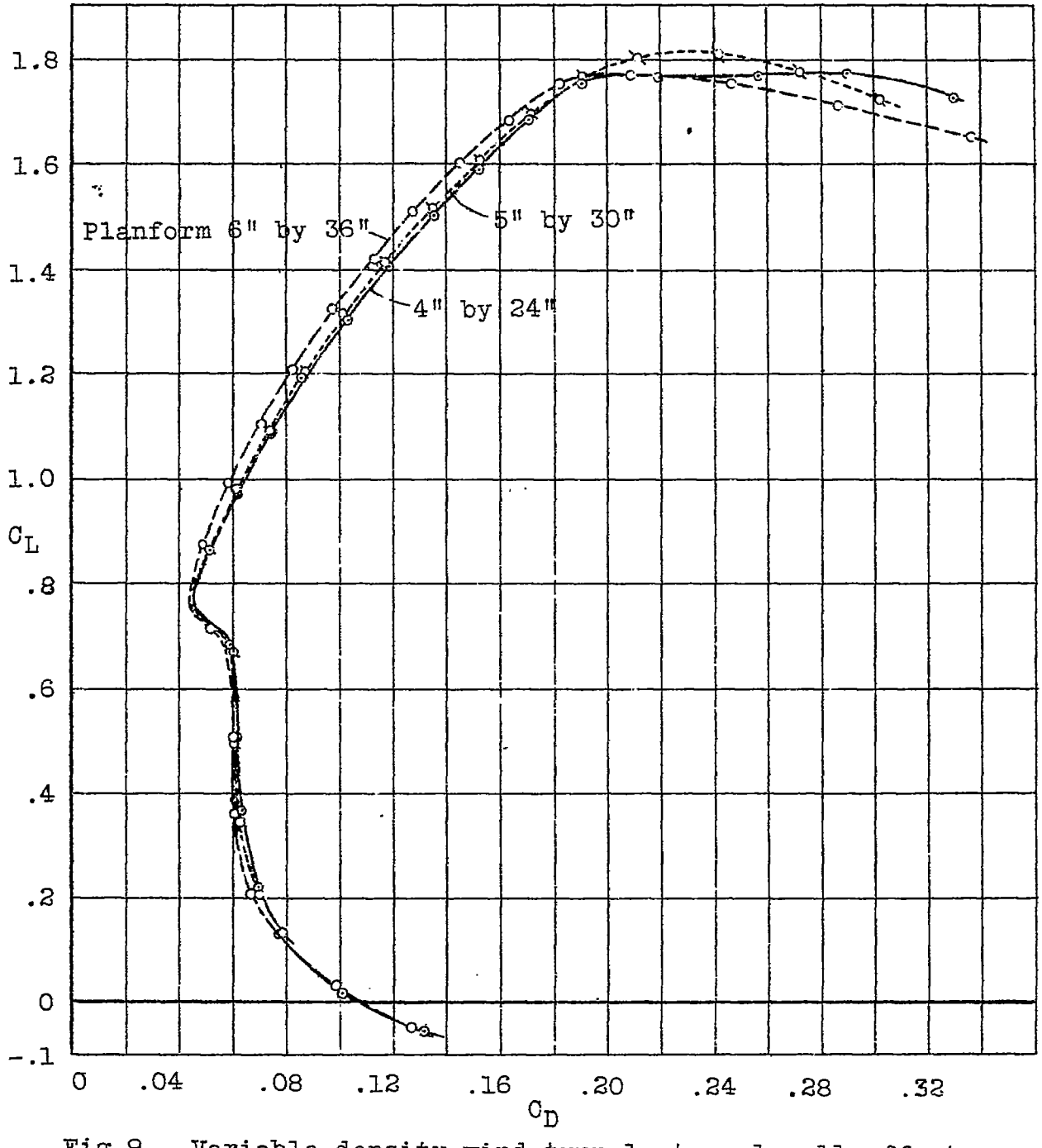

Fig.9 Variable density wind tunnel, tunnel wall effect. R.A.F. 19 airfoils of various sizes, as observed in tunnel. Average Reynolds No.530,000

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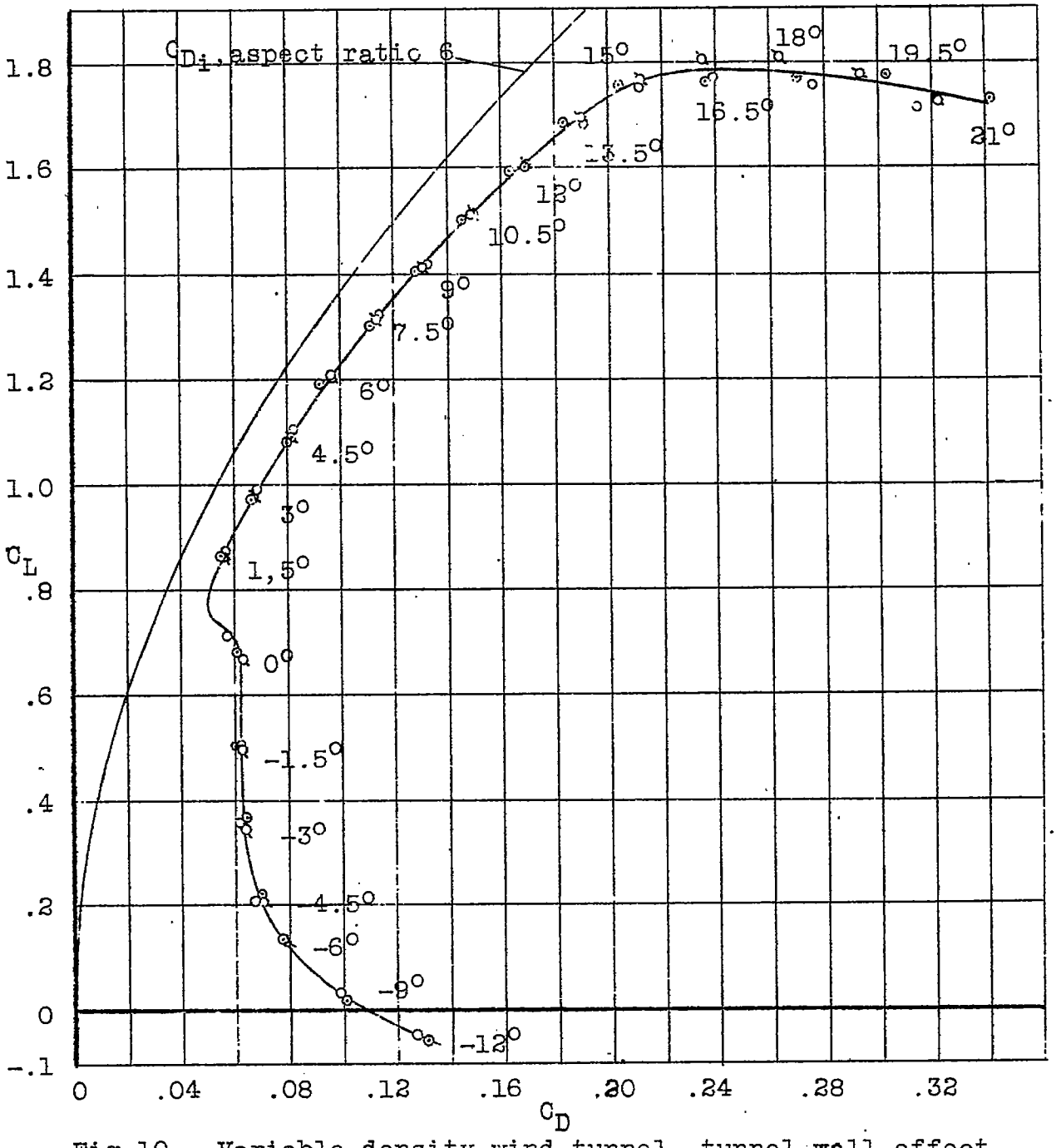

Fig.10 Variable density wind tunnel, tunnel wall effect. R.A.F. 19 airfoils of various sizes, corrected for wall interference, to aspect ratio 6 in free air. Average Reynolds No.530,000