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TECHNICAL NOTES

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

No. 244

NAVY PROPELLER SECTION CHARACTERISTICS AS
USED IN PROPELLER DESIGN

By Fred E. Weick
Langley Memorial Aeronautical Laboratory

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Summary

This report contains artificial aerodynamic characteristics of a set of propeller sections to be used in designing propellers by means of the blade element theory. Characteristics computed from model propeller tests for a single section are extended to cover sections of all thicknesses by means of model wing tests on a series of Navy propeller sections at high Reynolds Number in the variable density tunnel of the National Advisory Committee for Aeronautics.

Introduction

Designing propellers by means of the blade element theory requires the knowledge of aerodynamic characteristics which truly represent the airfoil sections. Airfoil characteristics obtained from wind tunnel model wing tests are often used for lack of better information. These, however, are not directly applicable to segments of revolving propeller blades. Better results are obtained by using characteristics that have been calculated from model propeller tests. Such characteristics have

been determined for a limited number of sections (Reference 3).

They are extended to cover sections of all practicable thicknesses by means of model wing tests on a series of Navy propeller sections (Reference 1).

These tests were made in the variable density wind tunnel of the National Advisory Committee for Aeronautics. The sections were tested at two tank pressures, one atmosphere and twenty atmospheres, the Reynolds Number at the latter pressure corresponding to about the maximum found in propellers. The shapes of all the sections are derived from a standard curve (Fig. 5) in such a manner that the ratio of corresponding ordinates to the maximum ordinate remains the same. The cambers or maximum ordinates in terms of the chord of the six sections tested were, .04, .08, .10, .13, .16 and .20. These cover the range of flat faced sections usually found in propellers. A camber of .04 is slightly less than is used in the thinnest metal propellers at the present time, and .20 is about the camber usually found at half the radius in wooden propellers.

These sections, sometimes slightly modified, have been widely used in propellers in this country and abroad. This report gives their aerodynamic characteristics as propeller sections to be used in the blade element theory.

Scale Effect

Consider an 11 ft. propeller of average wooden construction revolving at 1800 revolutions per minute. The most effective sections, those from about 60 to 80 per cent of the radius, are operating at a Reynolds Number of about 3,600,000, which is the same as that of the propeller sections tested at twenty atmospheres. Near the tip of the propeller and at about half the radius the Reynolds Number drops to approximately 3,000,000.

Fig. 1 shows a set of C_L and C_D curves at 1 and 20 atmospheres for each section tested. Over the working range the curves for all but the thickest section lie quite close together, indicating that the scale effect with change of Reynolds Number is negligible. The tests on the thickest section show a large decrease in both the lift and drag coefficients at the higher Reynolds Number.

It is known that when operating in propellers, the lift and drag coefficients of airfoil sections increase as their speed relative to the air is increased, and this increase becomes greater as the velocity approaches that of sound (Reference 2). Since increasing the Reynolds Number tends to decrease these coefficients where it affects them at all, it follows that this increase in the coefficients must be due entirely to the compressibility of the air.

Propeller Section Characteristics for Use
With the Blade Element Theory

Airfoil characteristics obtained from wind tunnel model wing tests are not directly applicable to airfoil sections in a propeller, for the conditions of operation are quite different. The model airfoils are usually rectangular in plan form, the characteristics measured being the average for the whole span. Sections in propellers usually vary in chord and camber along the radius, and the airfoil characteristics as used in the blade element theory apply to an infinitely small element of the span. Furthermore, as Dr. Munk of the staff of this Committee has pointed out, the centrifugal effect on those particles of air which come in contact with the revolving blades may cause a difference in the air flow.

In order to obtain characteristics which more accurately represent sections working in a propeller, the values of C_L and L/D have been computed from propeller test data (Reference 3). The propellers tested have standard Navy sections, the C_L and L/D curves being calculated for a few sections of medium camber. These curves for the section having a camber of .12 are shown in Fig. 2. The curves obtained in the variable density wind tunnel tests at 20 atmospheres for the section having a camber of .12 are also shown in Fig. 2. It will be noticed that the lift curves are parallel, but the angle of attack for zero lift is about 1 degree lower for the curve calculated from the

propeller tests.

It seems reasonable to assume that the variation of lift and drag with section thickness is the same for wing sections and propeller sections. Therefore, for propeller work, a set of characteristics for these sections covering the full range of thickness might be based on the curves calculated from the propeller tests for a camber of .12 and the variation for other cambers obtained from the airfoil section tests in the variable density tunnel. Fig. 3 shows a set of such curves which have been faired and cross faired. The lift coefficient at 20 atmospheres for each section tested has been obtained in relation to that for the section of camber .12 at each angle of attack. The faired curves for this relation $\left(\frac{C_L}{C_L \text{ for camber } .12} \right)$ plotted against camber are shown in Fig. 4. The values of the lift coefficients for all cambers excepting .12 shown in Fig. 3 have been obtained through Fig. 4. The values of L/D in Fig. 3 have been obtained in like manner.

This provides a set of propeller section characteristics to be used with any accurate form of the blade element theory which takes into account the inflow and the blade interference (Reference 4). For all excepting the thickest sections they may be used for any Reynolds Number, but compressibility of the air at speeds approaching that of sound is not taken into account.

Comparison of Navy Propeller Sections with Other Airfoil Sections
Tested at Full Scale Reynolds Number

In Fig. 6 the maximum L/D found in the variable density tunnel at 20 atmospheres for each of the Navy propeller sections is plotted against section camber. It will be noticed that except for the thinnest section they all plot close to a straight line. It was necessary to use a different method of supporting the section having a camber of .04 in the test due to its extreme thinness, so the high L/D found for it is probably due to an error in the drag reading. It is possible, however, that the sections show rapid improvement as the camber is reduced from .08 to .04.

The maximum values of L/D of some other sections which have been tested under the same conditions in the variable density tunnel are also plotted in Fig. 6. Each of the values is higher than that of the propeller section having the same camber, indicating that for full scale Reynolds Number, better propeller sections could be designed for all cambers with the possible exception of the extremely low ones. More complete investigation has shown that this holds true over the entire working range of the sections and not merely for the point of maximum L/D . The use of propeller sections similar to the Clark Y or the U.S.A. 35-B should result in an increase in propeller efficiency of from 2 to 3 per cent over Navy propeller sections. If this is

confirmed in propeller tests, full scale tests on a family of improved propeller sections would be a help to propeller designers.

Conclusions

1. Scale effect with change of Reynolds Number is negligible for all excepting very thick Navy propeller sections.

2. A set of Navy propeller section characteristics is given to be used in connection with the blade element theory.

3. There seems to be a possibility of increasing propeller efficiencies from 2 to 3 per cent by the use of better sections.

References

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(To be published later.)
2. Douglas, G. P. : The Effects of Tip Speed on Airscrew
and Performance. Brit. Adv. Com. for
Wood, R. McKinnon : Aeron. R&M No. 834 - 1924.
3. Weick, Fred E. : Propeller Design-II: Extension of Test Data on a Family of Model Propellers by Means of the Modified Blade Element Theory. N.A.C.A. Technical Note No. 236 -1926. Fig.5-6.
4. Weick, Fred E. : Propeller Design-I: Practical Application of the Blade Element Theory. N.A.C.A. Technical Note No. 235 - 1926.

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PROPELLER SECTION CHARACTERISTICS AT ONE AND 20 ATMOSPHERES.

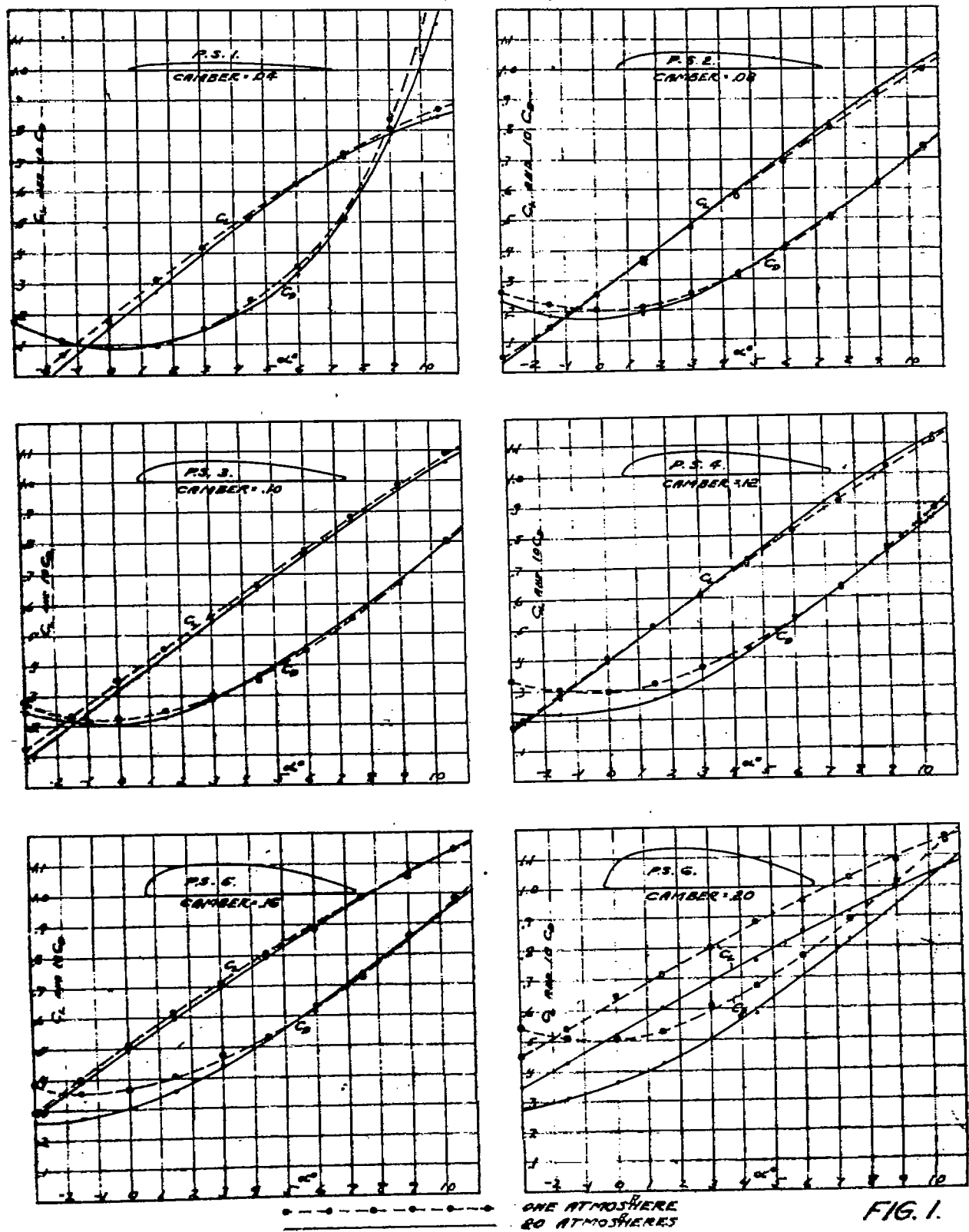


FIG. 1.

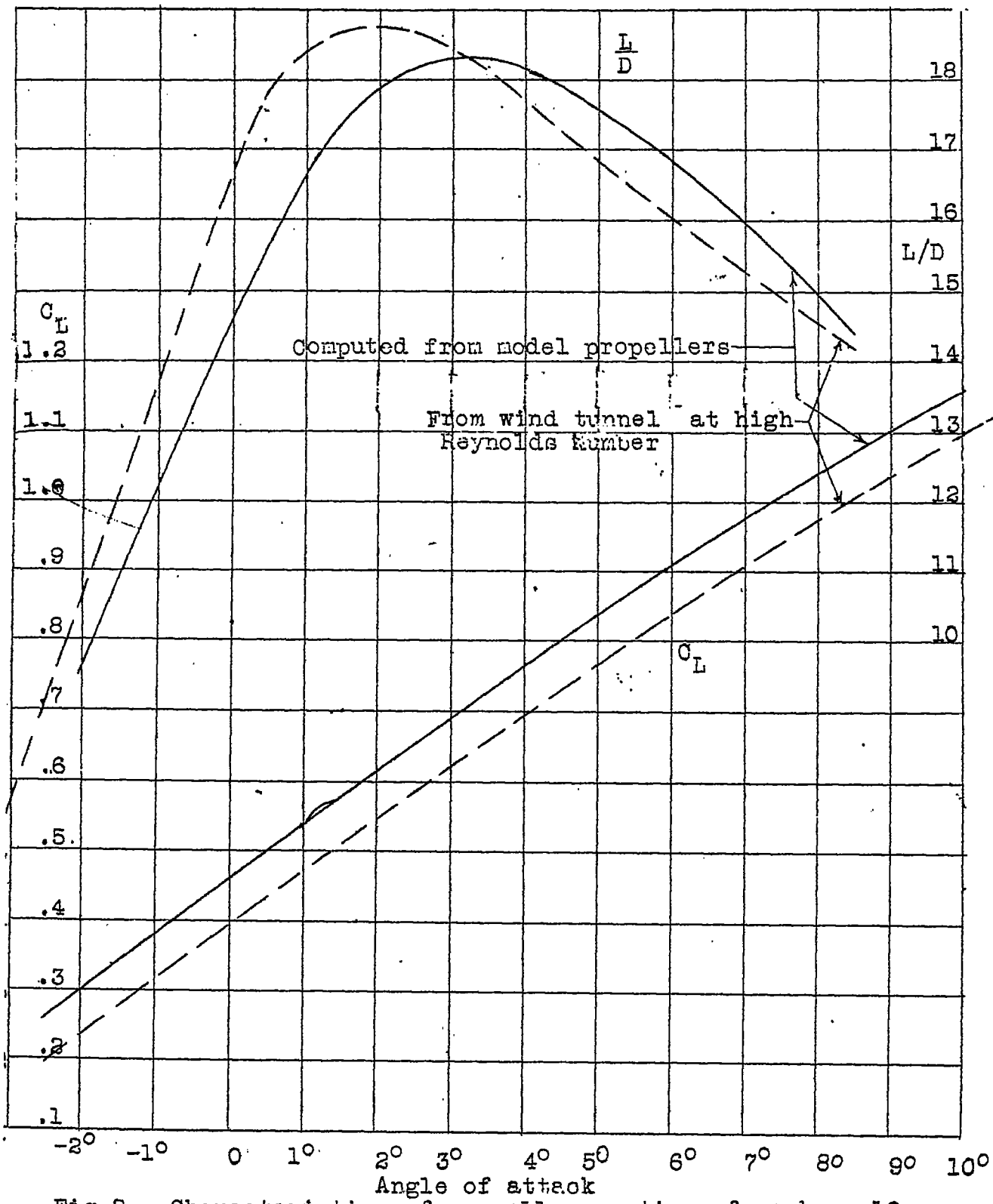


Fig.2 Characteristics of propeller section of camber .12

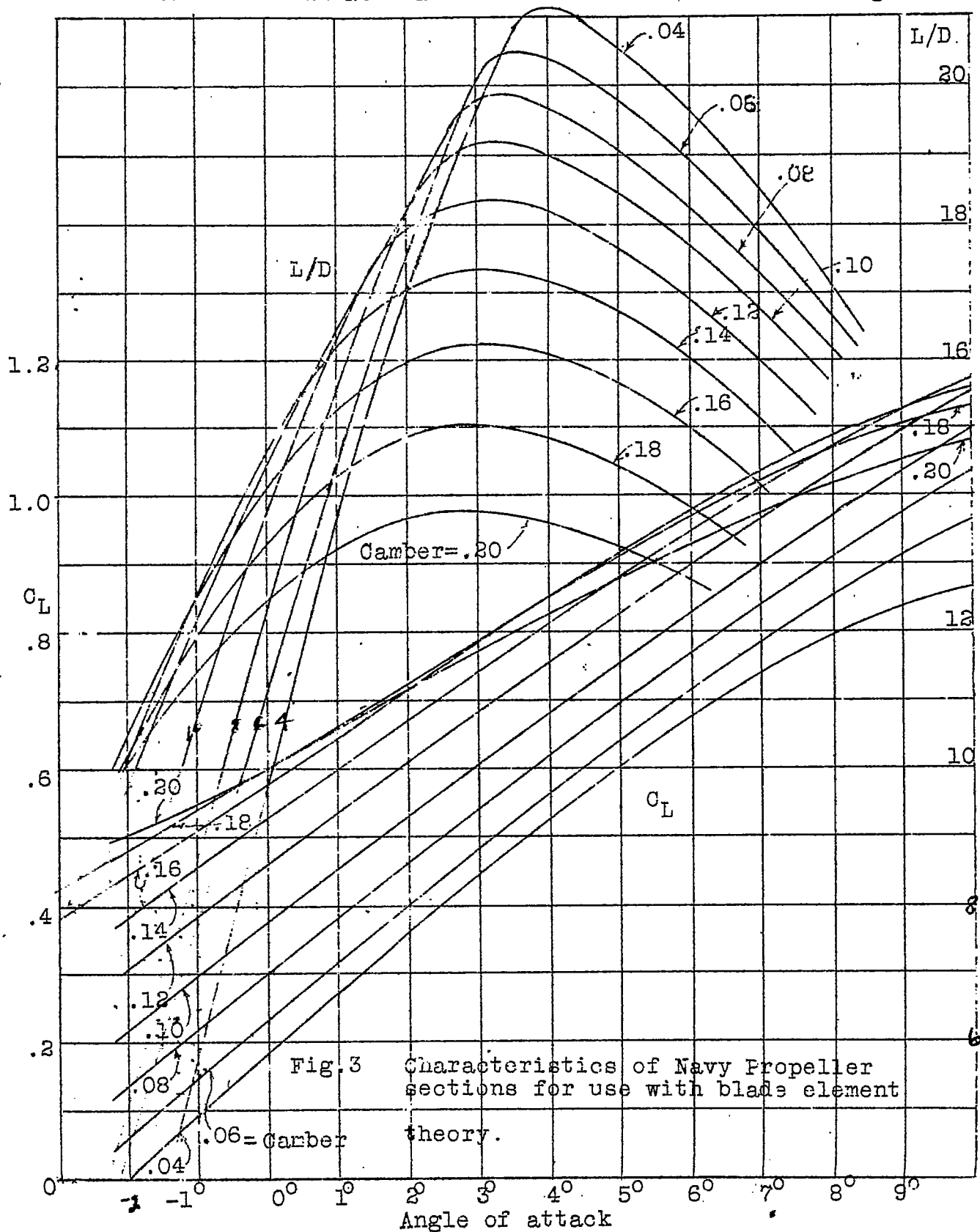


Fig.3 Characteristics of Navy Propeller sections for use with blade element theory.

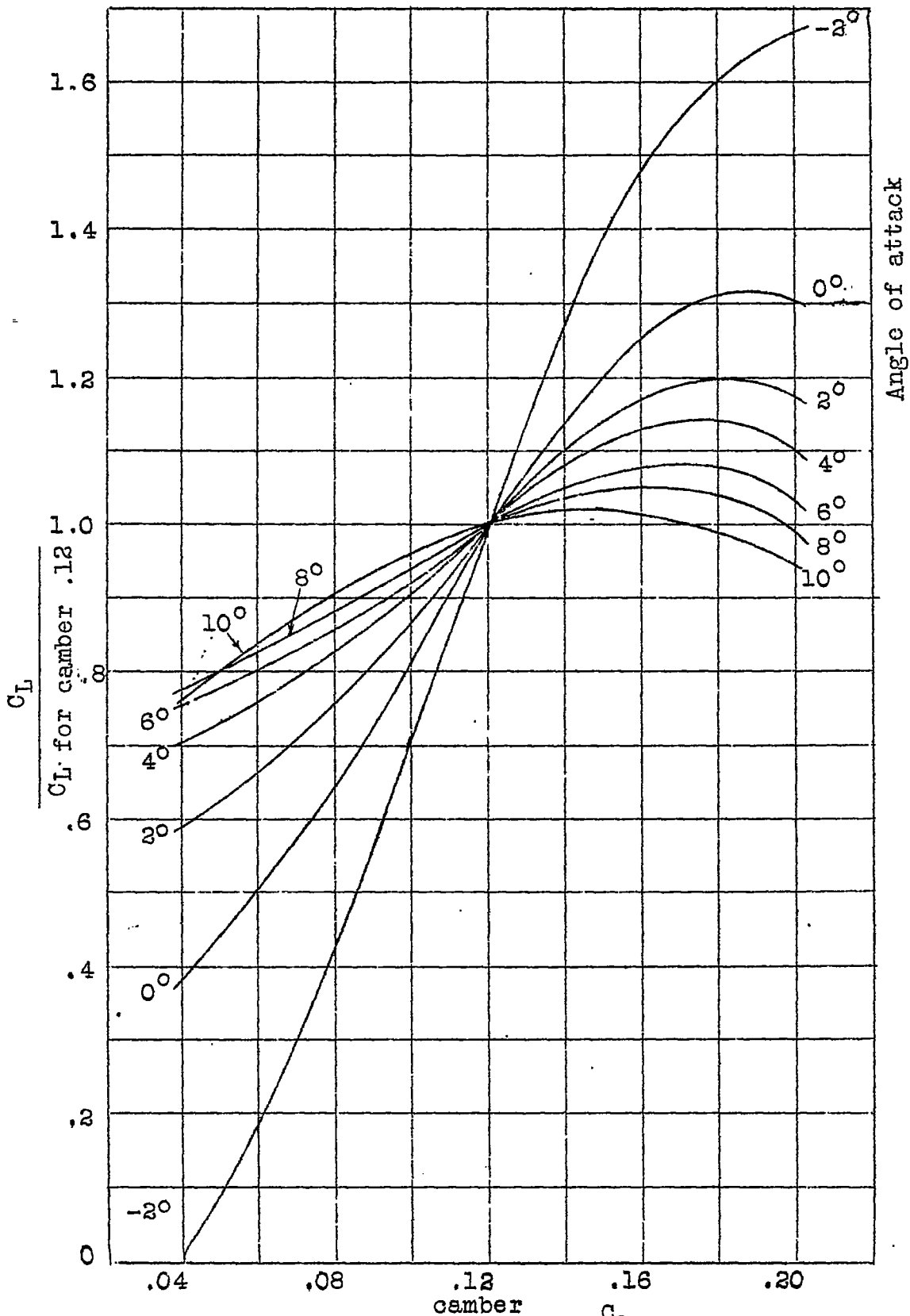
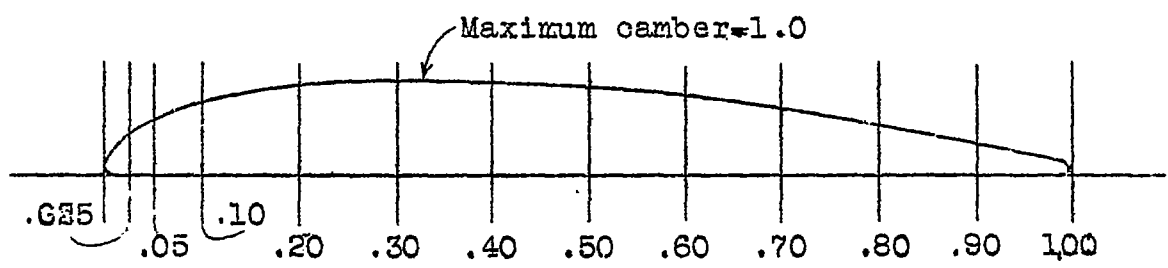


Fig.4 Curves of the ratio $\frac{C_L \text{ for camber } .12}{C_L \text{ for camber .12}}$



Fraction of chord	L.E. rad.	.025	.05	.10	.20	.300	.40	.50	.60	.70	.80	.90	T.E. rad.	
Ordinate		.100	.41	.59	.79	.95	.998	.99	.95	.87	.74	.56	.35	.077

Fig.5 Navy propeller section curve. Ordinates in terms of maximum ordinate.

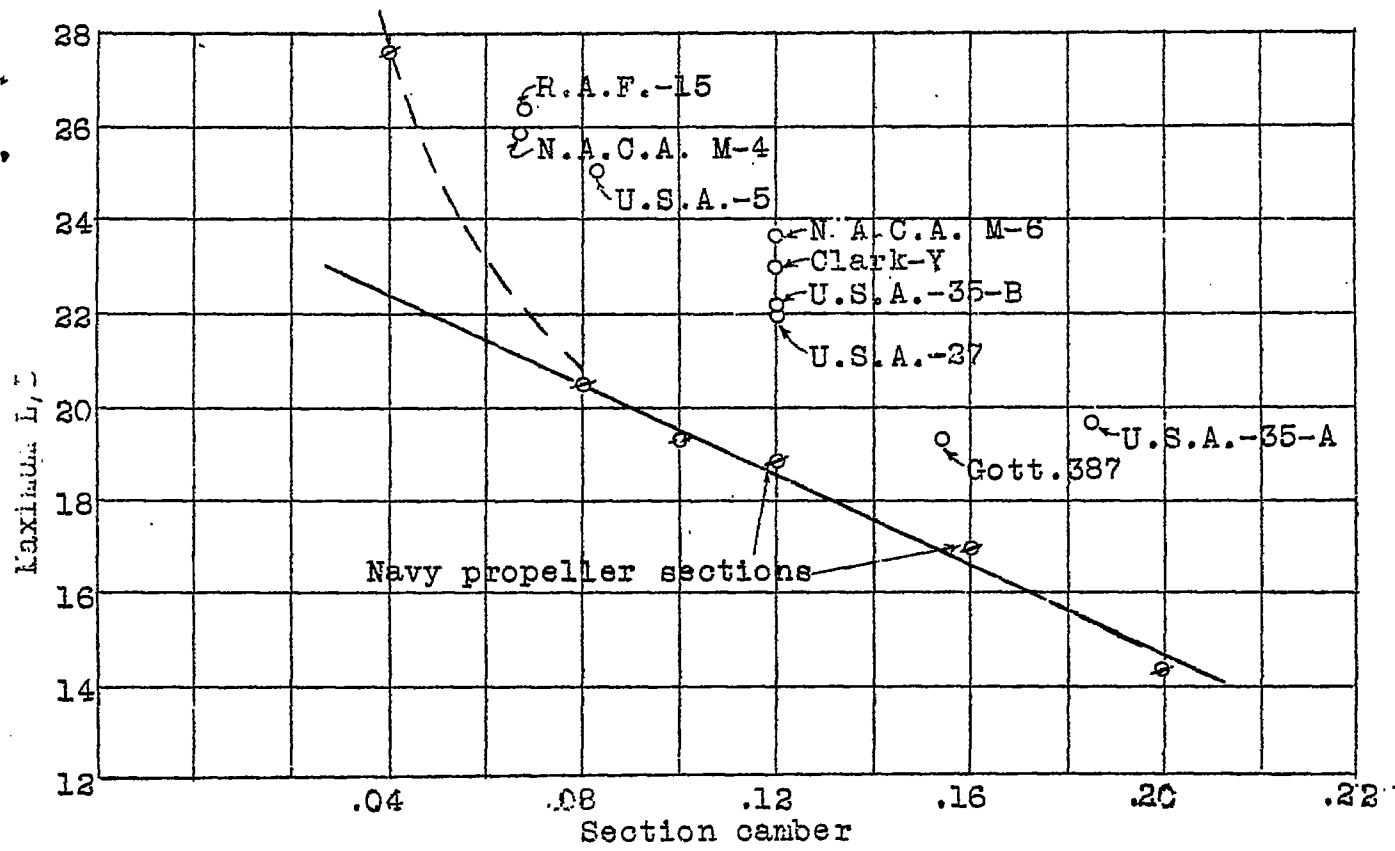


Fig.6 Chart of maximum $\frac{L}{D}$ against camber.