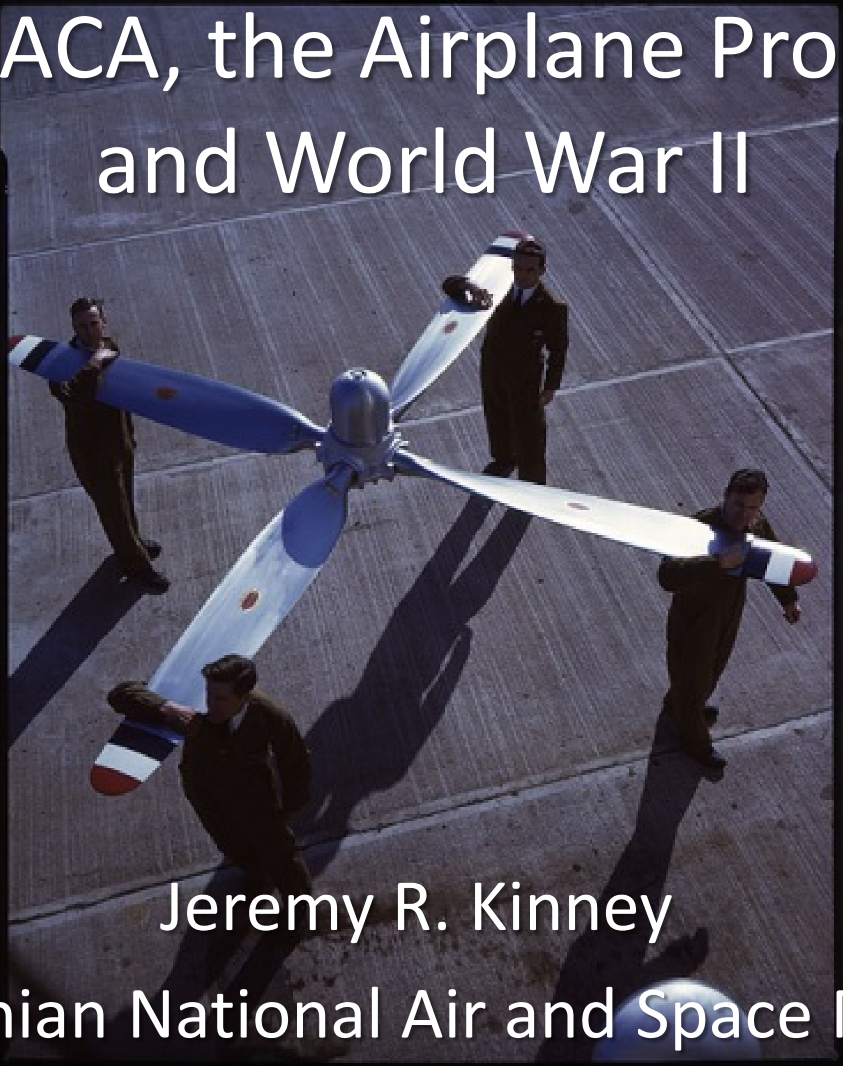
The NACA, the Airplane Propeller, and World War II



Jeremy R. Kinney

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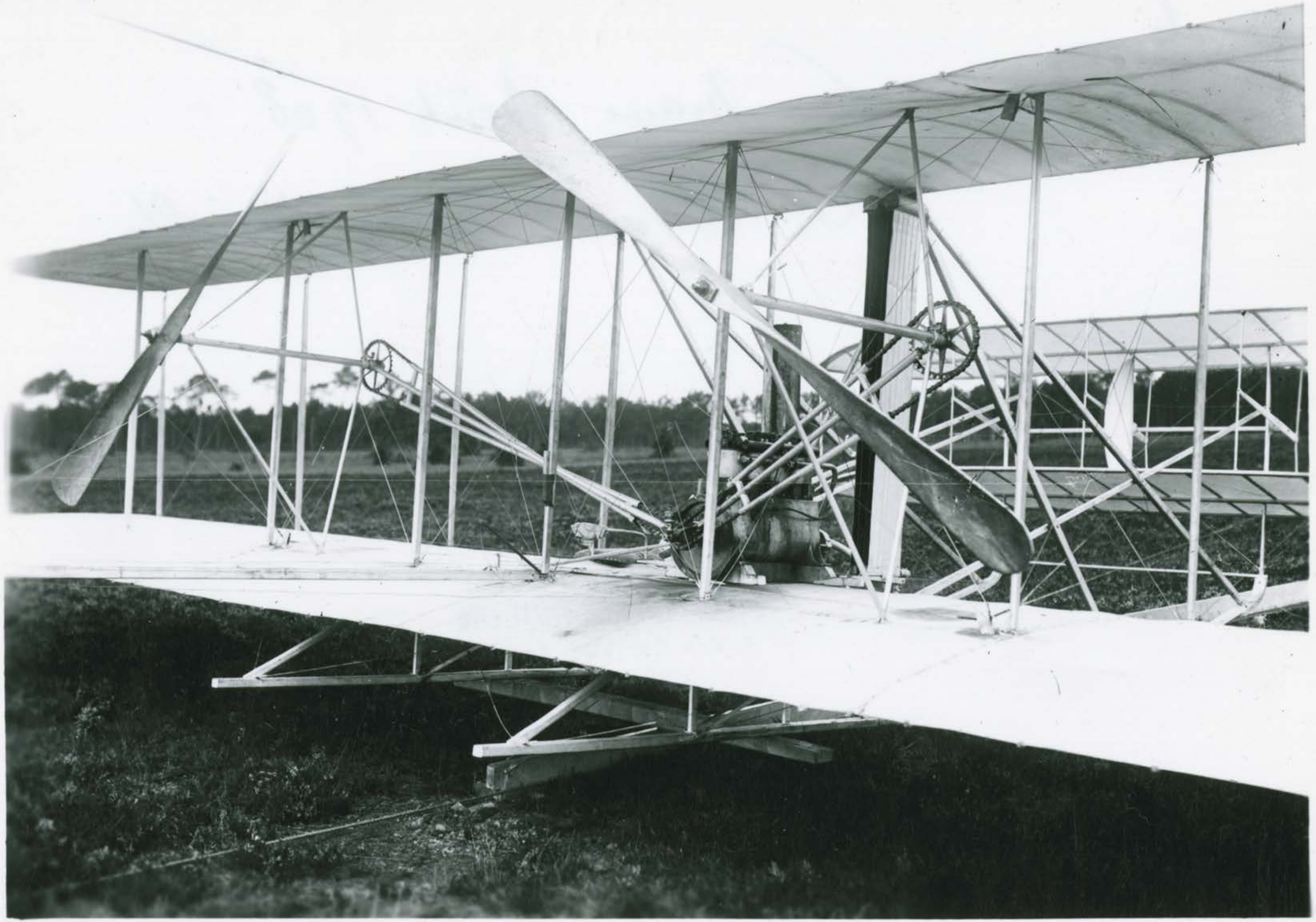


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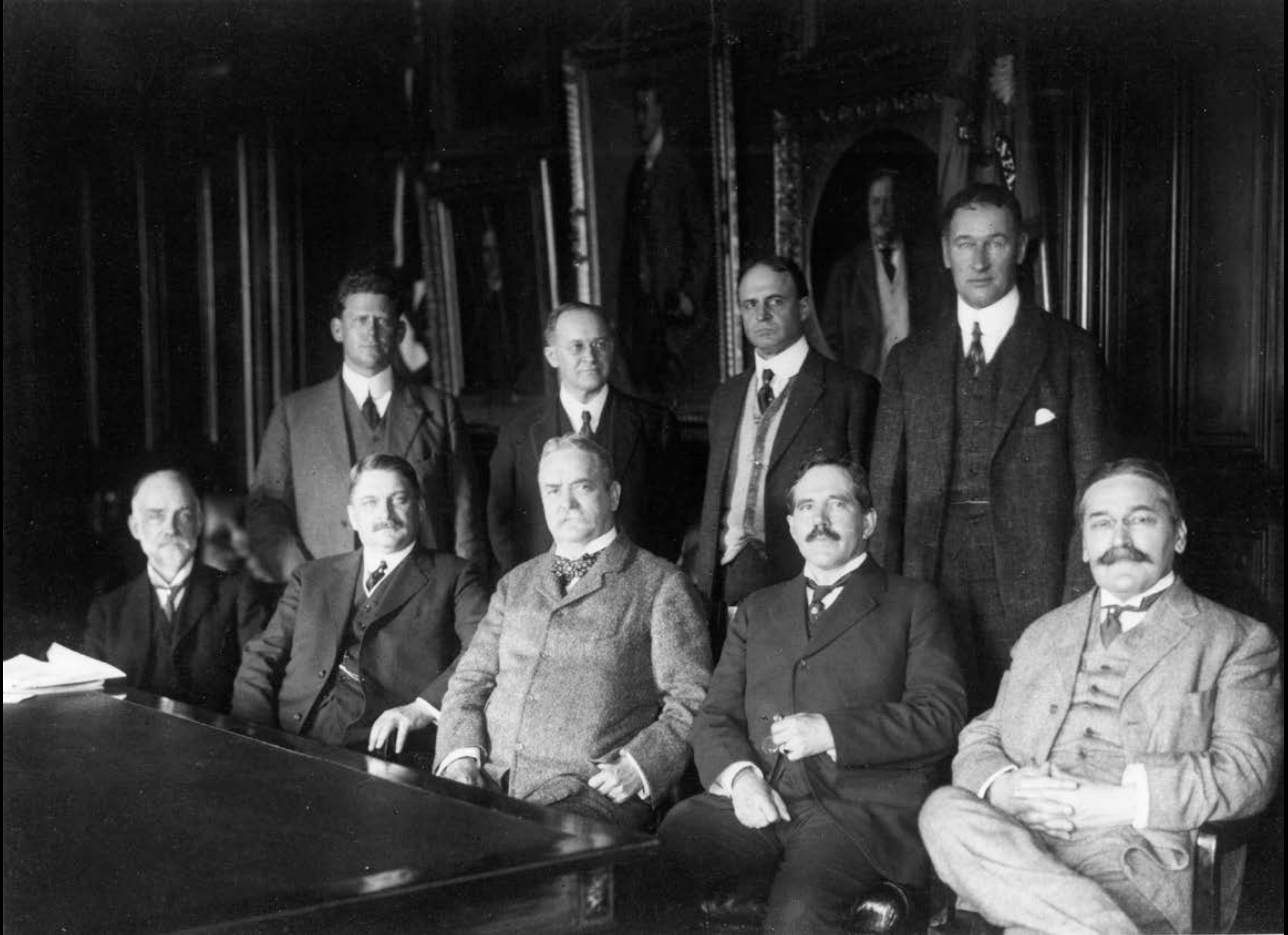


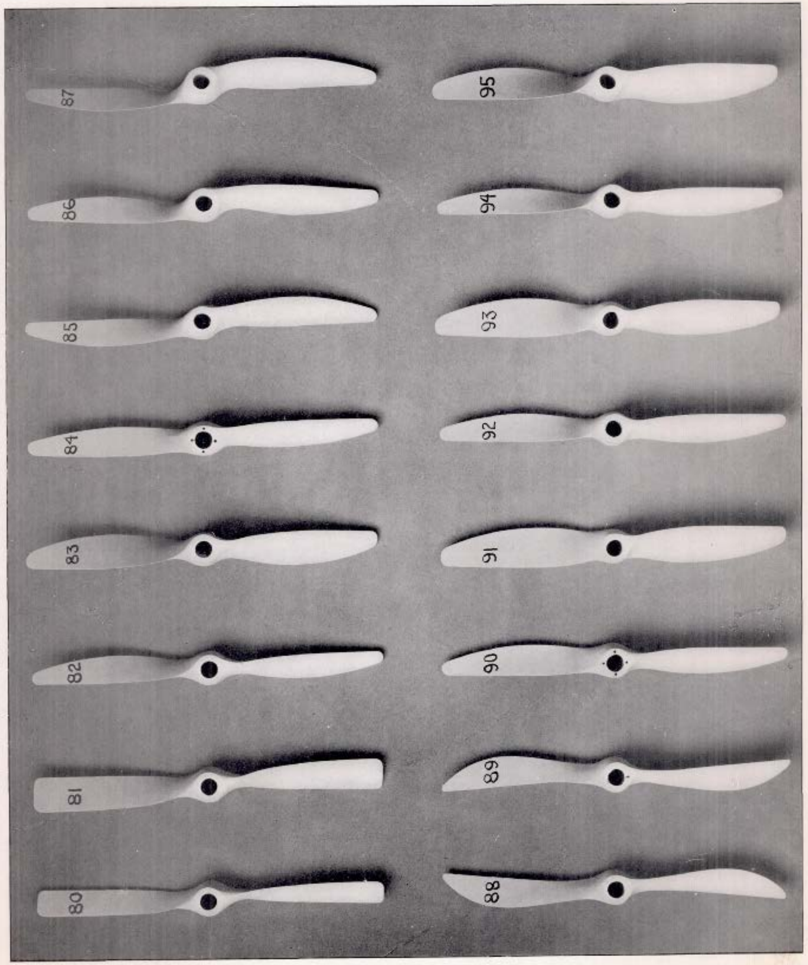
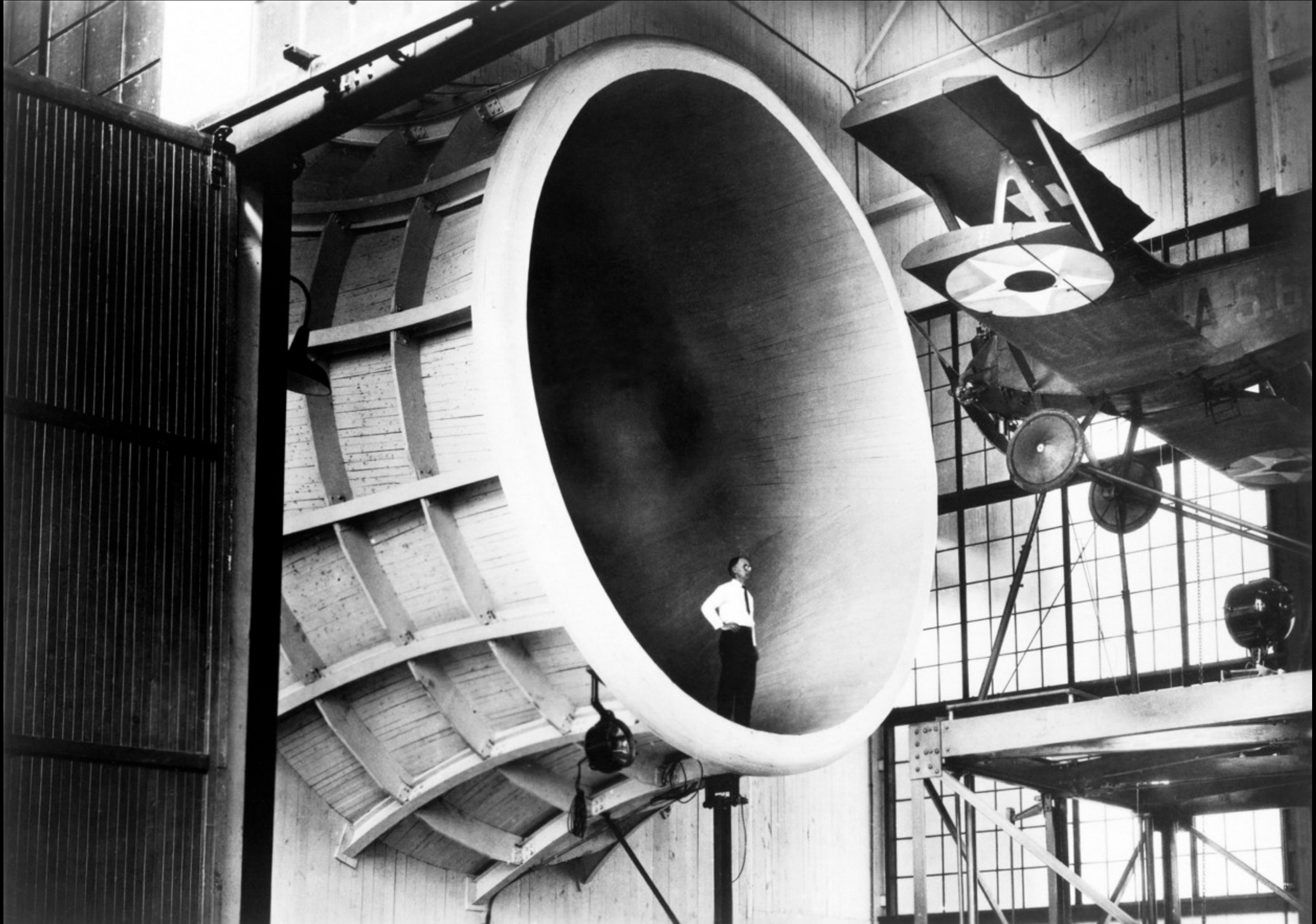
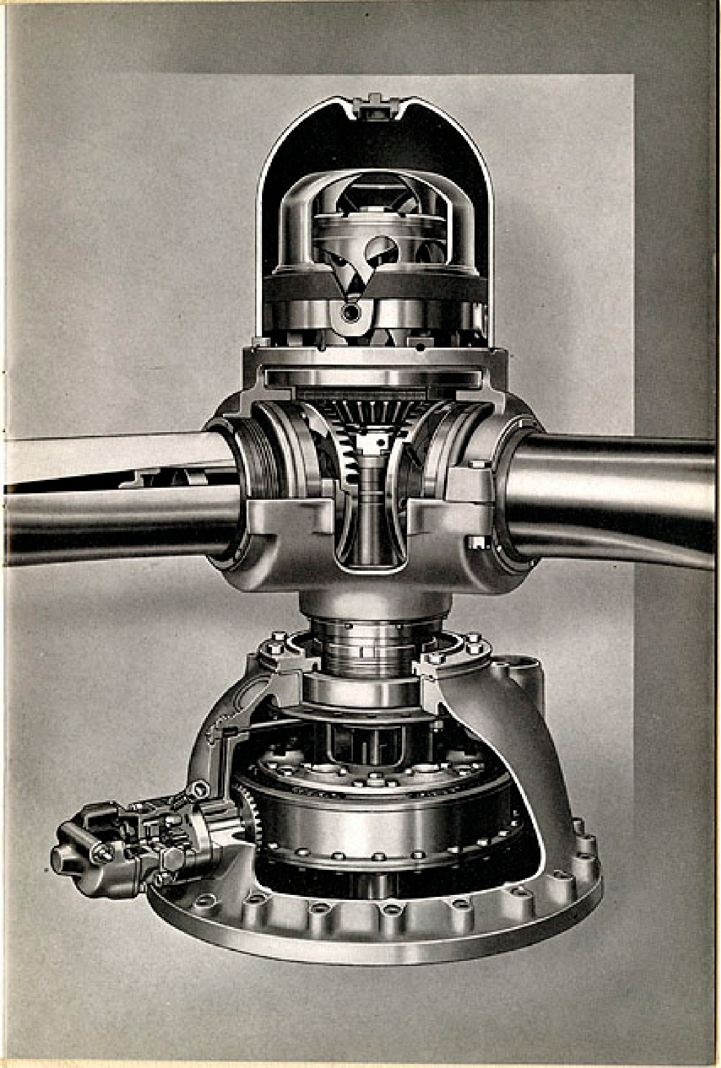


FIG. 1.





REPORT No. 763

TESTS OF AIRFOILS DESIGNED TO DELAY THE COMPRESSIBILITY BURBLE

By John Stack

SUMMARY

Fundamental investigations of compressibility phenomena for airfoils have shown that serious adverse changes of aerodynamic characteristics occur as the local speed over the surface exceeds the local speed of sound. These adverse changes have been delayed to higher free-stream speeds by development of suitable airfoil shapes. The method of deriving such airfoil shapes is described, and aerodynamic data for a wide range of Mach numbers obtained from tests of these airfoils in the Langley 24-inch high-speed tunnel are presented. These airfoils, designated the NACA 16-series, have increased critical Mach number. The same methods by which these airfoils have been developed are applicable to other airplane components.

INTRODUCTION

Development of airfoil sections suitable for high-speed applications has generally been difficult because little was known of the flow phenomenon that occurs at high speeds. A definite critical speed has been found at which serious detrimental flow changes occur that lead to serious losses in lift and large increases in drag. This flow phenomenon, called the compressibility burble, was originally a propeller problem but, with the development of high-speed aircraft, serious consideration has to be given to other parts of the airplane. It is important to realize, however, that the propeller will continue to offer the most serious compressibility problems for two reasons: First, because propeller-section speeds are higher than the speed of the airplane and, second, because structural requirements lead to thick sections near the root.

Fundamental investigations of high-speed air-flow phenomena recently completed (references 1 to 3) have provided much new information. From practical considerations an important conclusion of these investigations has been the determination of the critical speed, that is, the speed at which the compressibility burble occurs. The critical speed was shown to be the translational velocity at which the sum of the translational velocity and the maximum local induced velocity at the surface of the airfoil or other body equals the local speed of sound. Obviously, then, higher critical speeds can be attained through the development of airfoils that have minimum induced velocity for any given value of the lift coefficient.

Presumably, the highest critical speed will be attained by an airfoil that has uniform chordwise distribution of induced velocity or, in other words, a flat pressure-distribution curve. All conventional airfoils tend to have high negative pressures and correspondingly high induced velocities near the nose, which gradually taper off to the air-stream conditions at the rear of the airfoil. If the same lift coefficient can be obtained by decreasing the induced velocity near the nose and increasing the induced velocity over the rear portion of the airfoil, the critical speed will be increased by an amount proportional to the decrease obtained in the maximum induced velocity. The ideal airfoil for any given high-speed application is, then, that shape which at its operating lift coefficient has uniform chordwise distribution of induced velocity. Accordingly, an analytical search for such airfoils has been conducted by members of the staff of the Langley Memorial Aeronautical Laboratory and these airfoils have been investigated experimentally in the Langley 24-inch high-speed tunnel.

The first airfoils investigated showed marked improvement over those shapes already available; not only was the critical speed increased but also the drag at low speeds was decreased considerably. Because of the marked improvement achieved, it was considered desirable to extend the thickness and the lift-coefficient ranges for which the original airfoils had been designed to obtain data of immediate practical value before further extending the investigation of the fundamental aspects of the problem.

SYMBOLS

x	abscissa of camber line
y_c	ordinate of camber line
t	thickness, percent of chord
c	airfoil chord
θ	defined by $\frac{x}{c}=\frac{1}{2}(1-\cos\theta)$
C_L	lift coefficient
C_D	drag coefficient
$C_{D_{min}}$	minimum drag coefficient
$C_{m_{c/4}}$	pitching-moment coefficient about quarter-chord point
P	pressure coefficient
M	Mach number
M_{cr}	critical Mach number
R	Reynolds number
α	angle of attack, degrees

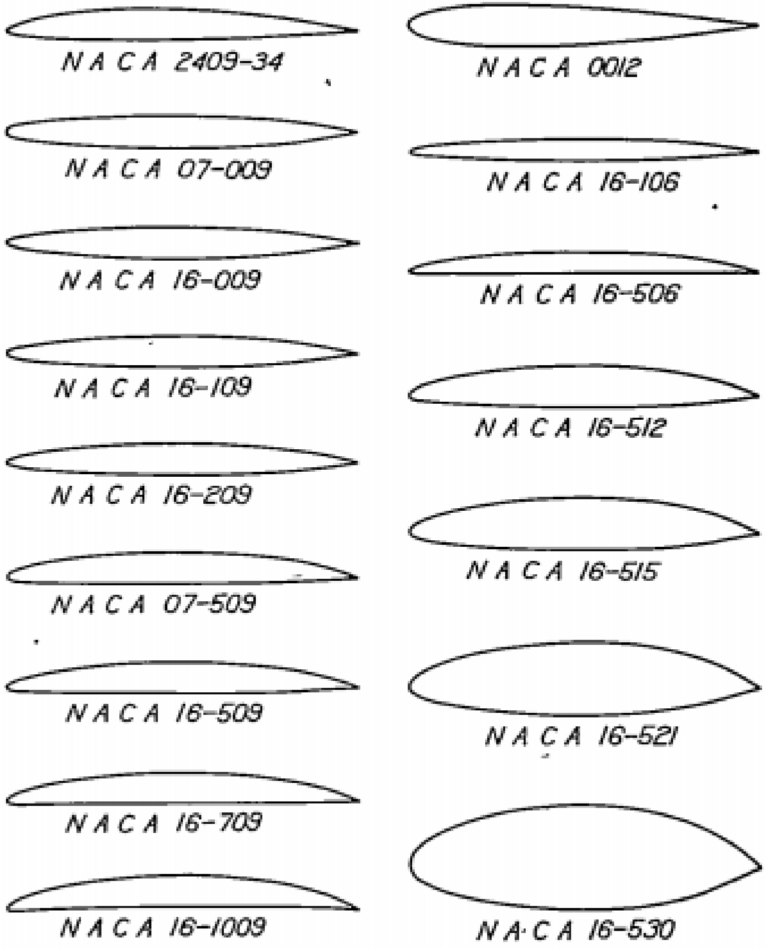


Figure 2.—Profiles for airfoils having high critical speeds.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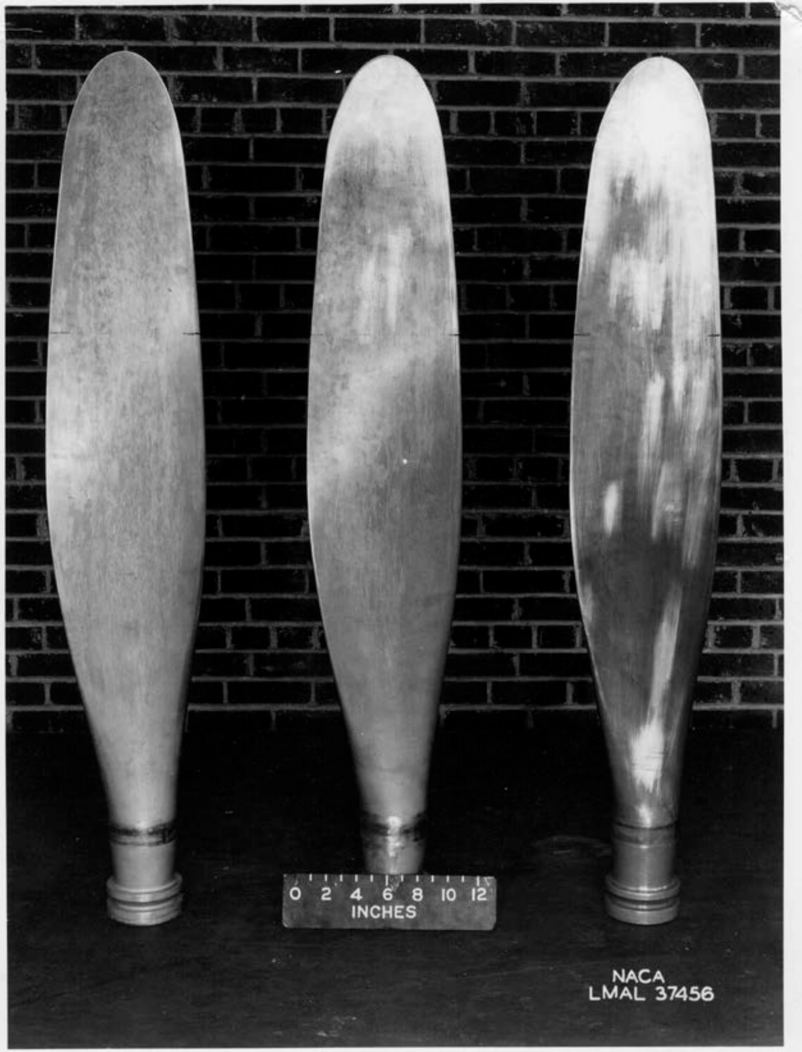

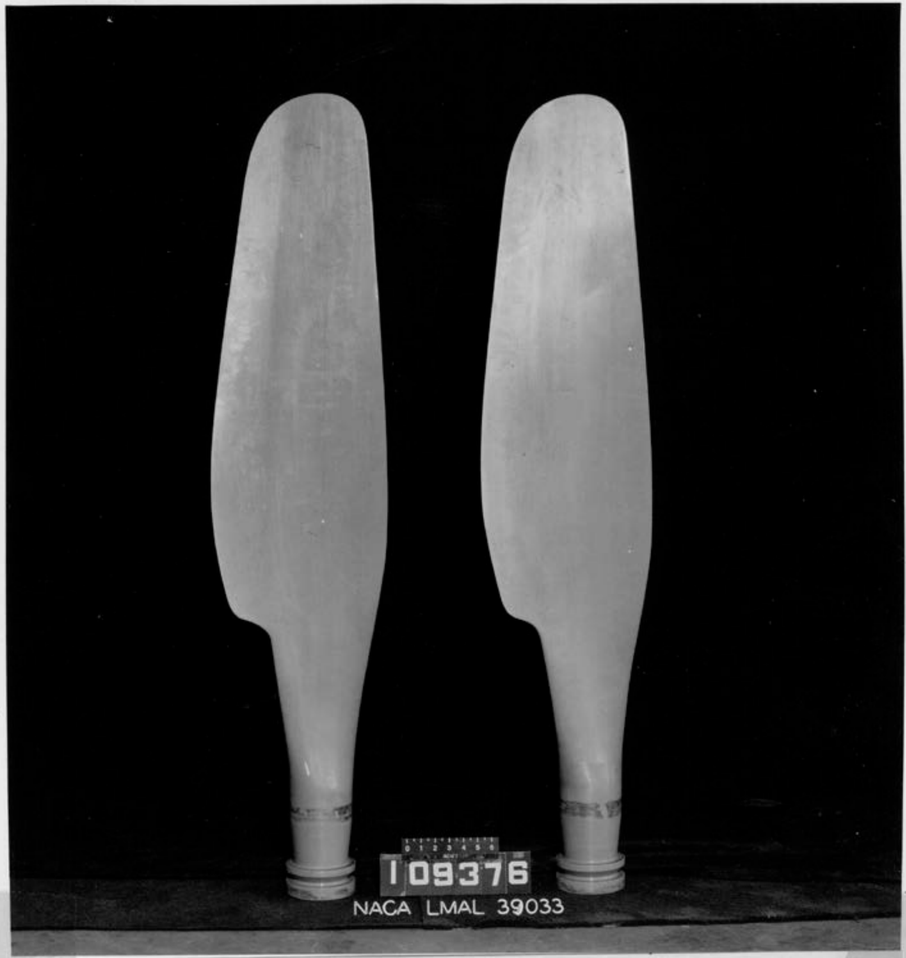

Figure 5.- Propeller blades 109376 (40 percent trailing-edge extension) - thrust face (lower surface).


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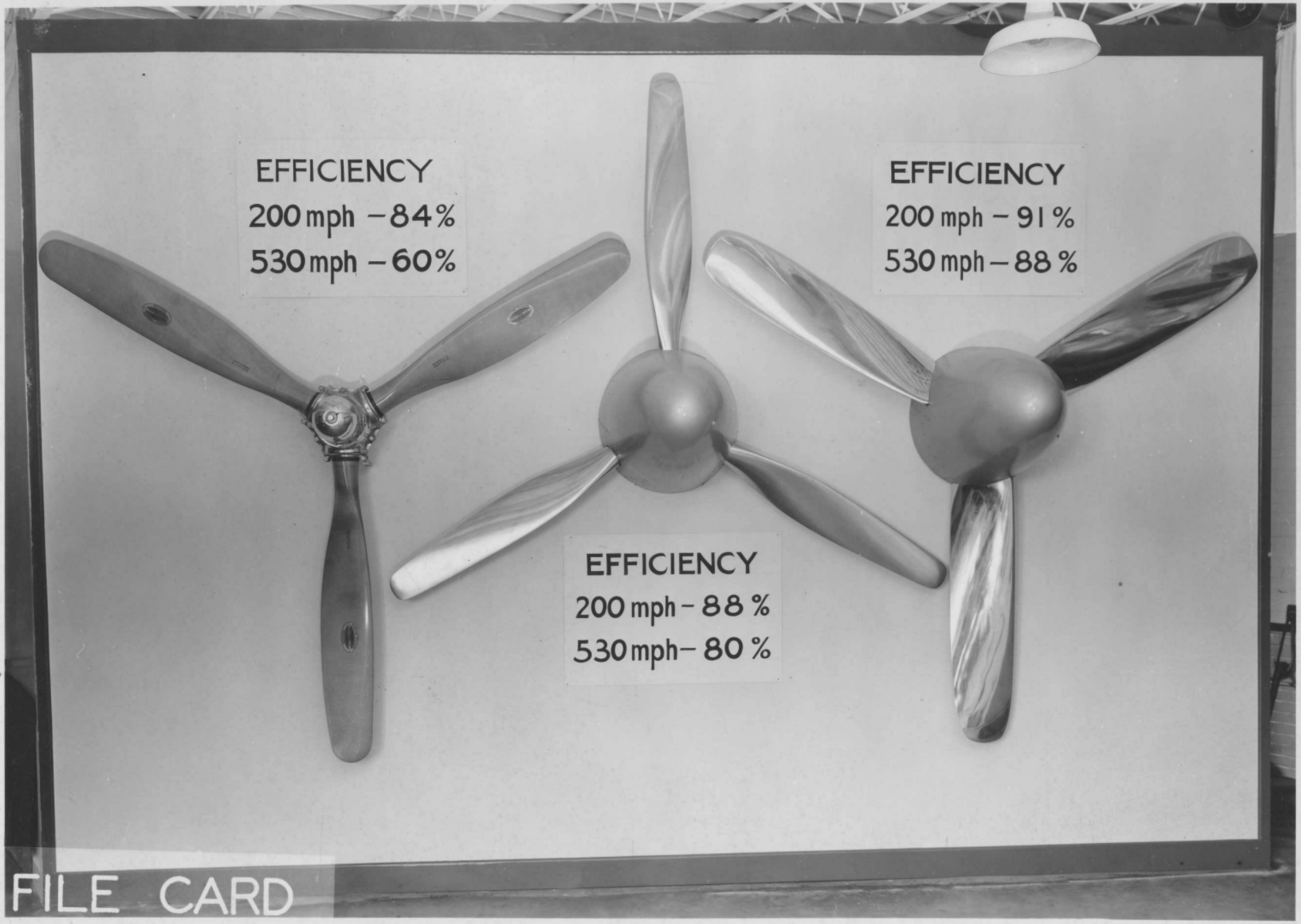

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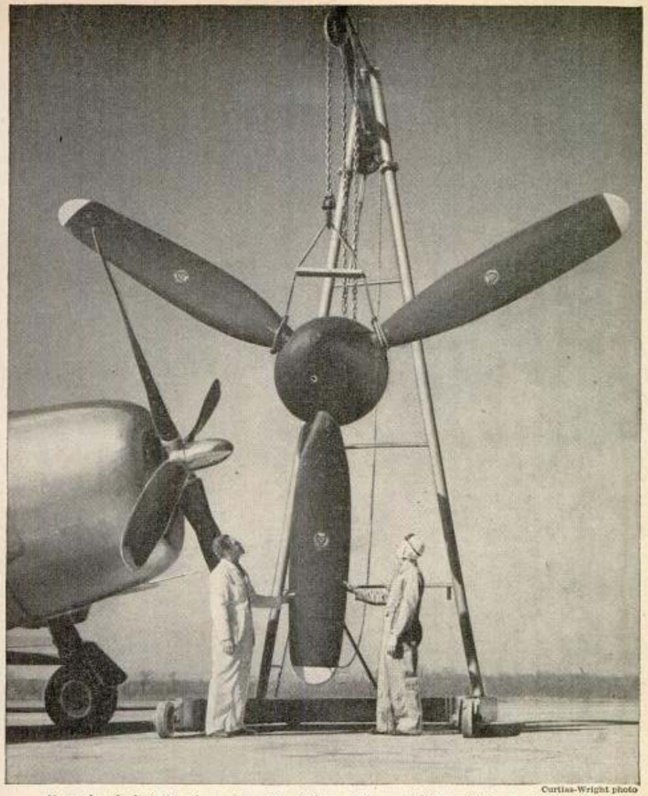


Curtiss-Wright photo

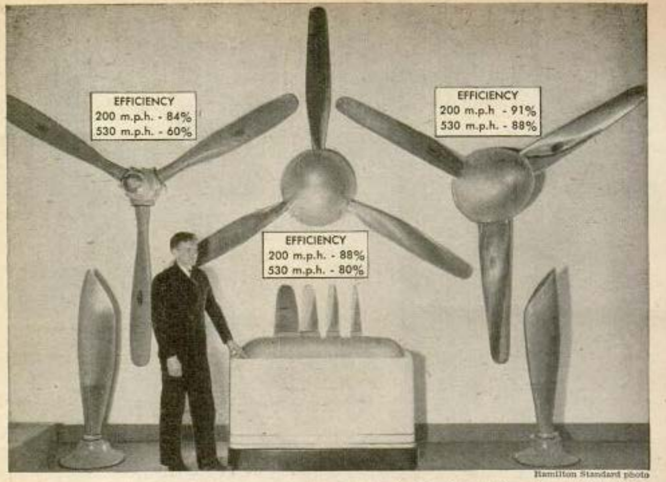
Not a last look, insists the author. Six of these 19-foot propellers pull the world's largest landplane, the XC-99, through the air. Blades' pitch can be reversed to brake landing run

Has the Propeller a Future?

By William Winter

WHEN JET PROPULSION was developed, hasty critics of old methods said the propeller was on the way out.

Yet today, engineers are readying a fantastic array of multiblade props and believe-it-or-not blade shapes that will make it possible for propeller-equipped planes to penetrate the dread transsonic region of "perpetual storm," from 600 to 700-odd miles an hour, where the spectre of split-second destruction of an airplane haunts its designers. When answers to this problem are found,



Hamilton Standard photo

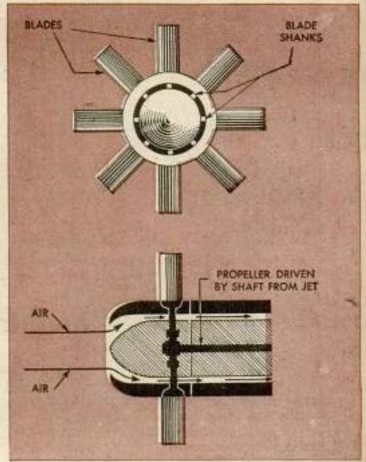
In propellers hanging on the wall, note progressive gains made by running widest section of blade into spinner. Below, drawings of an eight-bladed prop and double spinner for gas turbines of the future

the same basic airscrew device that pulled the Wright brothers' craft through the air is expected to be capable of supersonic speeds of at least 800 miles an hour.

In the propeller man's bag of tricks are future "fans" as big as 30 feet in diameter—special wind tunnels have been devised for possible propellers of 40 feet; eight and ten-bladed props that look like blowers; or props with abbreviated triangular blades. Some propellers won't even look like propellers, as we know them today.

Propellers are subject to the same high-speed teething troubles as airplanes. Fast-flying planes encounter "compressibility" effects where the air no longer streams smoothly over the surfaces of the ship, but slants off in shock waves like the waves from the prow of a motorboat. As 700-mile-an-hour speeds are approached compressibility plays gremlin tricks with the controls and will buffet any ordinary airplane to pieces. So the designers are working up strong knife-thin wing sections and wings of many strange shapes or planforms. Some are "delta" shaped like paper darts. All these difficulties were appreciated years ago by propeller engineers who necessarily must work five years or more in advance of projected airplanes.

The compressibility problem, with its abrupt changes in forces, is now believed to extend beyond the transsonic region. In

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