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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS
WASHINGTON, DC

FEB 1946

NACA-WRL-23

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

WARTIME REPORT

ORIGINALLY ISSUED

February 1946 as
Confidential Bulletin L5F28

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By Alfred A. Adler

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VARIATION WITH MACH NUMBER OF STATIC AND TOTAL PRESSURES THROUGH VARIOUS SCREENS

By Alfred A. Adler

SUMMARY

Tests were conducted in the Langley 24-inch high-speed tunnel to ascertain the static-pressure and total-pressure losses through screens ranging in mesh from 3 to 12 wires per inch and in wire diameter from 0.023 to 0.041 inch. Data were obtained from a Mach number of approximately 0.20 up to the maximum (choking) Mach number obtainable for each screen.

The results of this investigation indicate that the pressure losses increase with increasing Mach number until the choking Mach number, which can be computed, is reached. Since choking imposes a restriction on the mass rate of flow and maximum losses are incurred at this condition, great care must be taken in selecting the screen mesh and wire diameter for an installation so that the choking Mach number is not approached at the maximum operating velocity.

INTRODUCTION

In the design of ducts for aircraft it has become necessary to know the losses in static and total pressure through screens installed within these ducts. Data on the losses through screens at low speeds have long been available, but for current aircraft ducting problems data on the losses through screens at high speeds are necessary. Tests were therefore conducted in the Langley 24-inch high-speed tunnel to ascertain the static-pressure and total-pressure losses through screens ranging in mesh from 3 to 12 wires per inch and in wire diameter from 0.023 to 0.041 inch, at Mach numbers from approximately 0.20 to the maximum (choking) Mach number obtainable for each screen.

SYMBOLS

M	Mach number ahead of screen
M_{choke}	choking Mach number, also known as limiting Mach number, the Mach number ahead of screen at which a Mach number of 1 is obtained completely across openings in screen
ΔH	total-pressure loss through screen
Δp	static-pressure drop through screen
q	dynamic pressure ahead of screen
c_d	section drag coefficient $\left(\frac{\text{Drag/Unit area}}{q}\right)$
m	mesh, wires per inch
d	wire diameter, inch
S	screen solidity, ratio of blocked area to original free area $\left(2md - m^2d^2\right)$
ρ_1	density ahead of screen
u_1	velocity ahead of screen
u_2	velocity downstream from screen

APPARATUS AND METHODS

The Langley 24-inch high-speed tunnel, in which these tests were run, is a nonreturn, induction-type tunnel with the induction nozzle placed downstream from the test section (reference 1). The total pressure throughout the test section is therefore equal to atmospheric pressure, except for a negligible loss through the entrance screens.

Each screen was supported for tests within a 16-inch length of seamless steel tubing having an inside diameter of $5\frac{1}{2}$ inches (fig. 1), which was mounted

longitudinally in the test section of the tunnel by means of $\frac{1}{16}$-inch-diameter steel cables.

The Mach number was determined from the static pressure ahead of the screen, which was measured by means of two diametrically opposed static-pressure orifices located in the walls of the supporting tube 3 inches ahead of the screen. The static pressure behind the screen was measured by means of two additional static-pressure orifices located at a distance of 4 inches behind the screen. The total-pressure loss through the screen was taken as the difference between atmospheric pressure and the total pressure as indicated by two tubes placed behind the screen with the noses in the same plane as the static-pressure orifices. The tube-entrance losses were assumed to be negligible.

RESULTS AND DISCUSSION

The data for all the screens tested are presented in figures 2 and 3, which show the static-pressure drop and total-pressure loss, respectively, plotted against Mach number. The data show, mainly, that both static-pressure drop and total-pressure loss, in percent of dynamic pressure, increase with increasing Mach number until the highest obtainable test Mach number is reached. This Mach number is known to correspond to the choked condition, since further increase in tunnel speed did not increase the Mach number ahead of the screen.

The data of figures 2 and 3, plotted in terms of screen solidity rather than mesh and wire diameter, are presented in figures 4 and 5. From these figures it can be seen that the pressure losses are dependent only on screen solidity and Mach number within the range of this investigation.

Figure 6 shows drag coefficient c_d plotted against Mach number. These values of drag coefficient were obtained from the equation

$$c_d = \frac{\Delta p}{q} - \frac{\rho_1 u_1 (u_2 - u_1)}{q}$$

This equation was derived on the assumption that conditions were uniform across the wake. As was expected, the data show that the drag coefficient increases with increase in Mach number.

Since choking of the flow through a tube occurs when a Mach number of 1 is reached at the cross section of minimum area, choking of the flow would be expected to occur when a Mach number of 1 is obtained completely across the openings in the screen. This choking fixes a limit to the Mach number that can be obtained in the flow ahead of the screen. There are now two possibilities. If the total pressure ahead of the screen is maintained constant, no further increase in mass rate of flow is possible. Any decreases in back pressure will only increase the losses through the screen. If, however, the total pressure ahead of the screen is increased - as is possible in flight - the mass rate of flow can be increased. This increase in mass rate of flow will be accompanied by large losses and will progress at a far lesser rate than for speeds below choking. It is highly desirable therefore that care be taken in the selection of screen mesh and wire diameter so that the choking Mach number is not approached at the maximum operating velocity. The following equation, derived from the continuity equation, the adiabatic law, and Bernoulli's equation for compressible flow, relates the speed at which this choking occurs to the screen variables:

$$1 - 2md + m^2d^2 = \frac{M_{choke}}{0.579\left(1 + 0.2M_{choke}^2\right)^3}$$

This relation, presented graphically in figure 7 in terms of the screen variables and in figure 8 in terms of screen solidity, shows good agreement with the experimentally determined choking Mach numbers.

CONCLUDING REMARKS

Tests in the Langley 24-inch high-speed tunnel to ascertain the static- and total-pressure losses through screens indicate that the losses increase with increasing

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Mach number until the choking Mach number, which can be computed, is reached. Because choking imposes a restriction on the mass rate of flow and because maximum losses are incurred at this condition, great care must be taken in selecting the screen mesh and wire diameter for an installation so that the choking Mach number is not approached at the maximum operating velocity.

Langley Memorial Aeronautical Laboratory
National Advisory Committee for Aeronautics
Langley Field, Va.

REFERENCE

1. Stack, John, Lindsey, W. F., and Littell, Robert E.: The Compressibility Burble and the Effect of Compressibility on Pressures and Forces Acting on an Airfoil. NACA Rep. No. 646, 1938.

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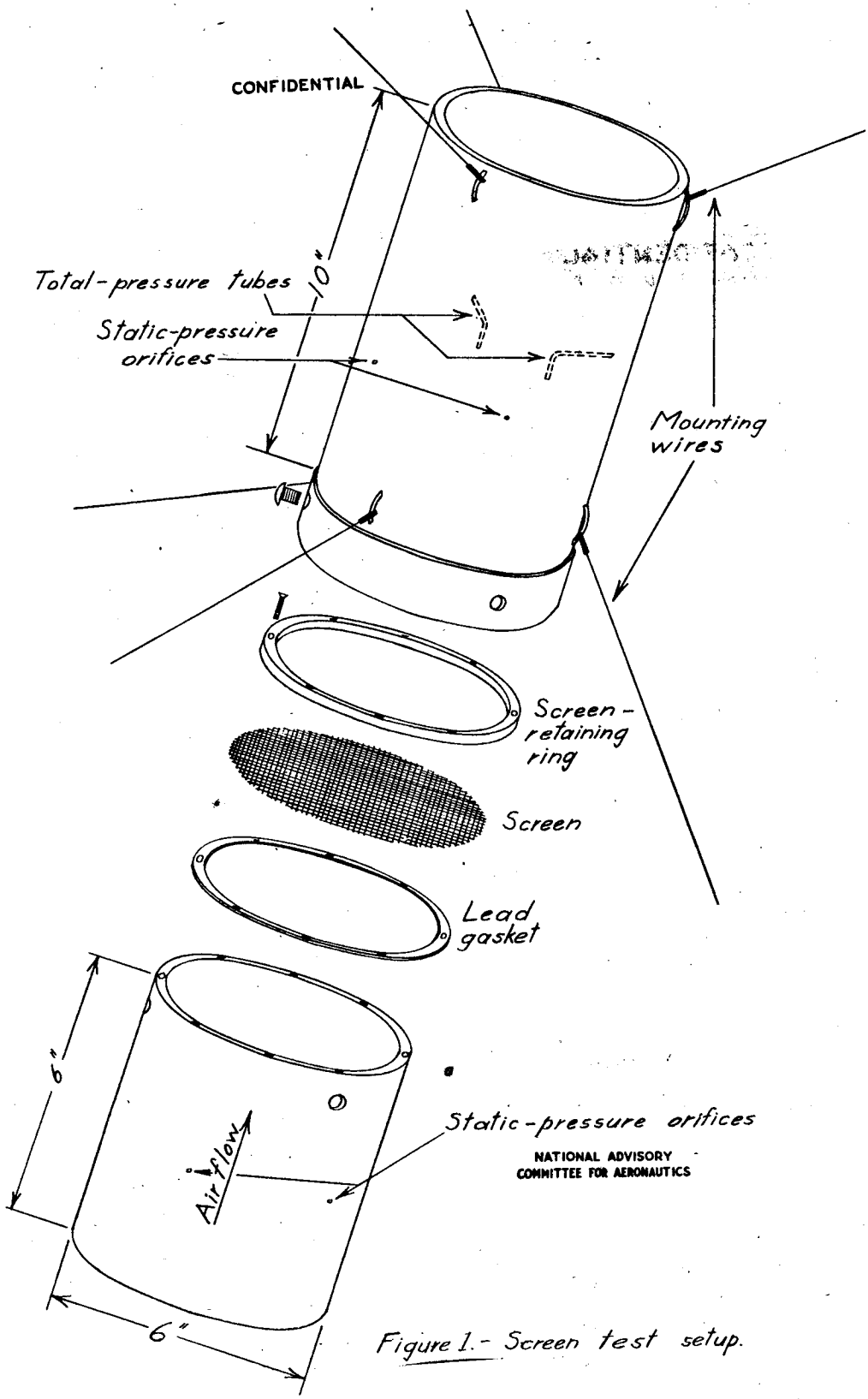


Figure 1.- Screen test setup.

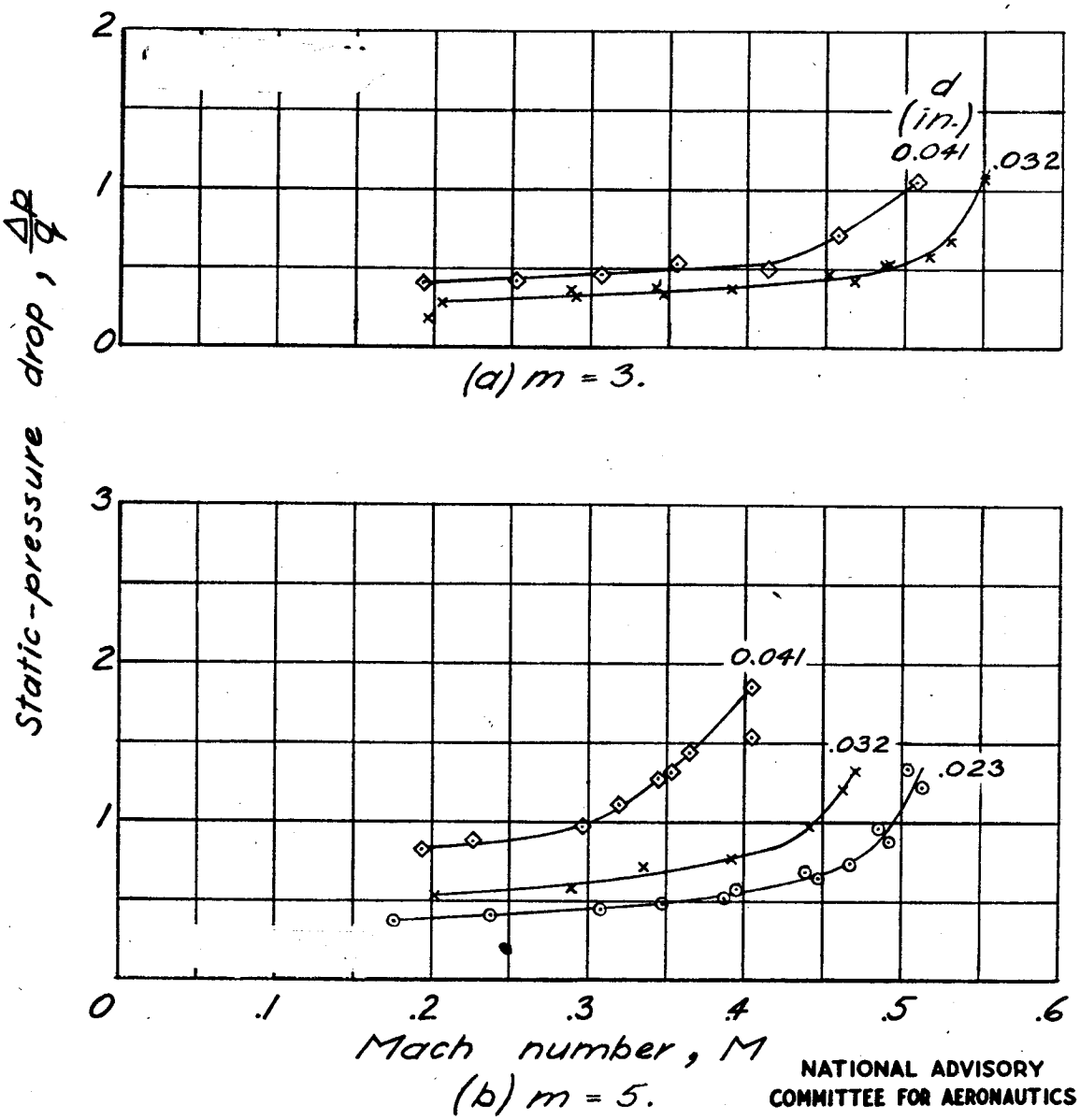


Figure 2.- Variation of static-pressure drop through screens with Mach number.

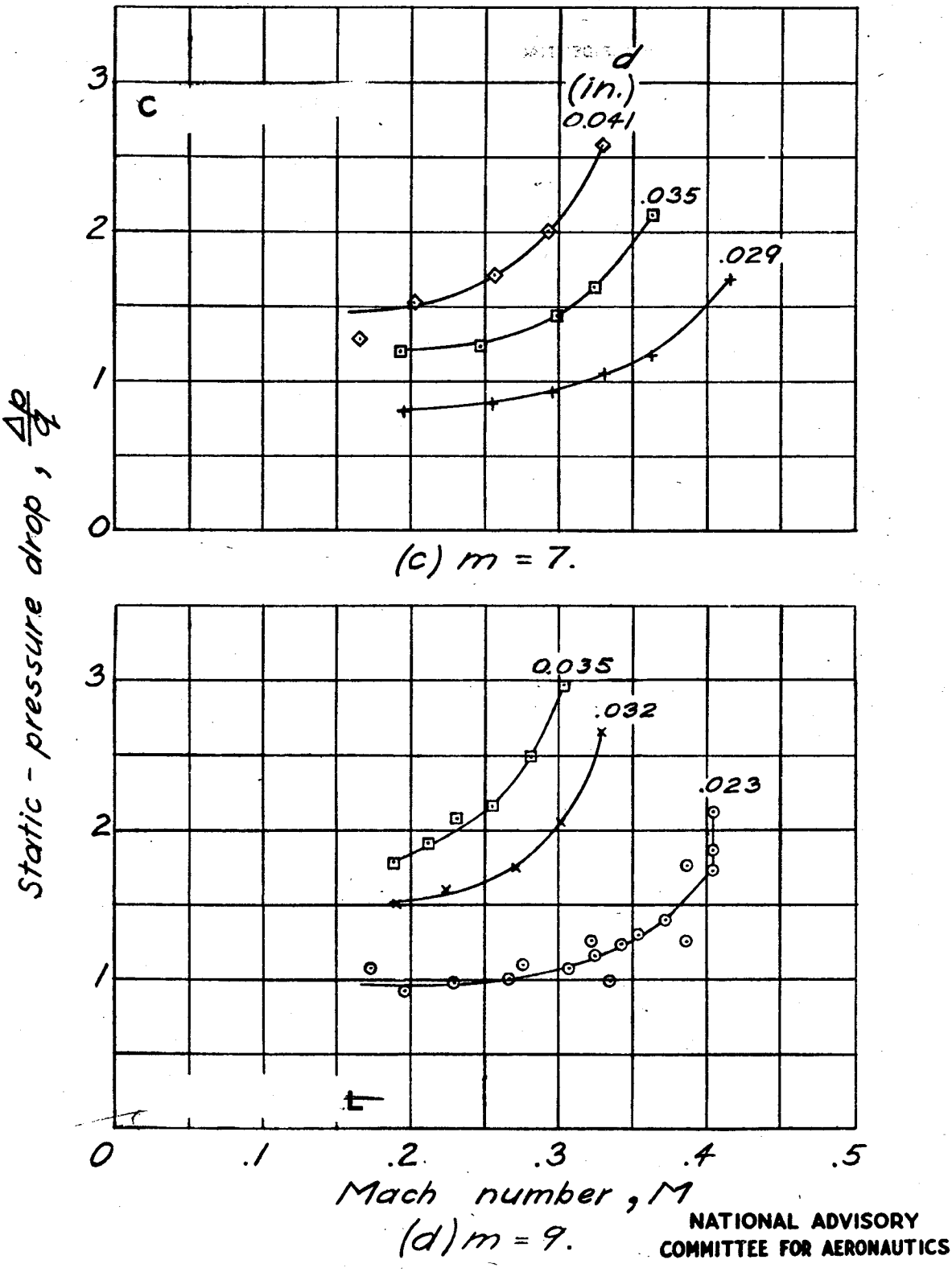
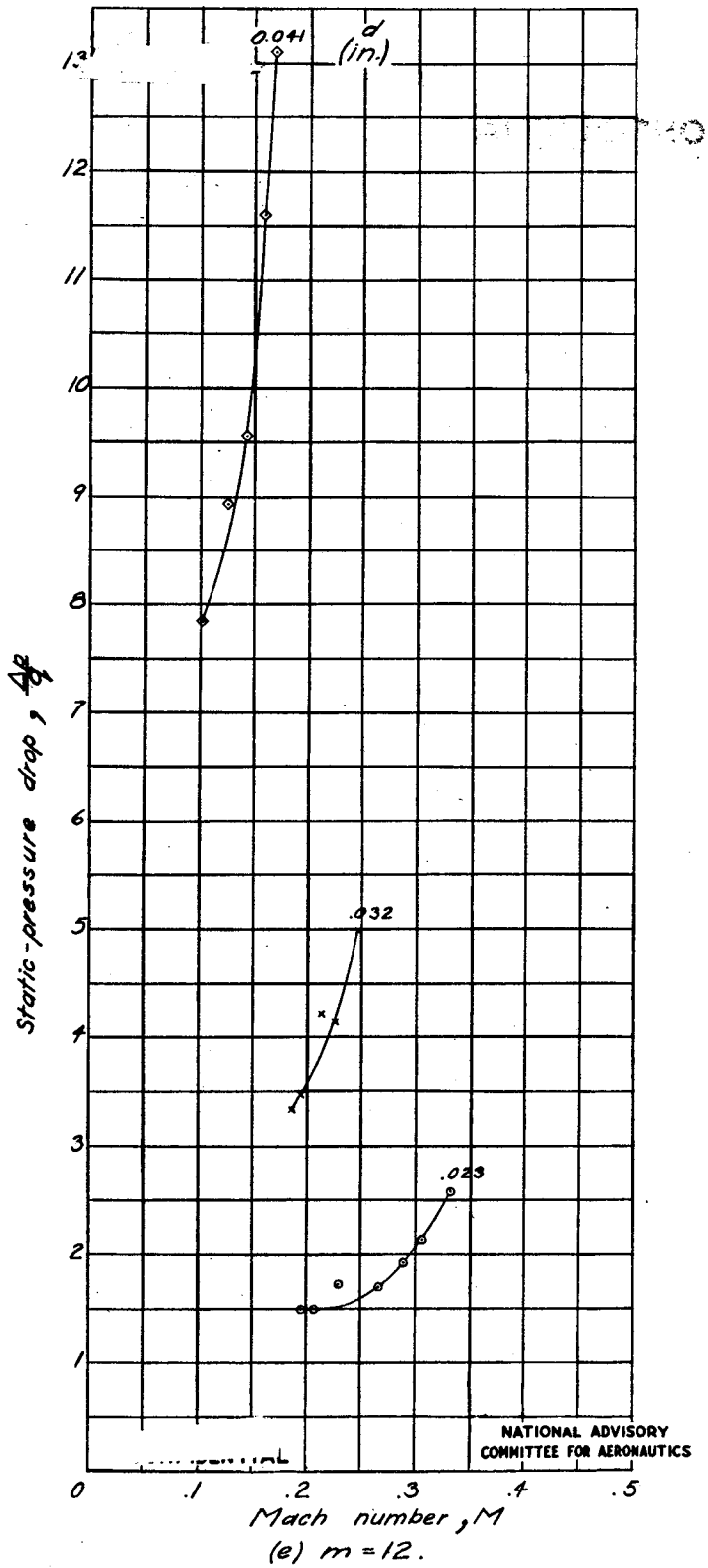


Figure 2. - Continued.



(e) $m = 12$.

Figure 2.- Concluded.

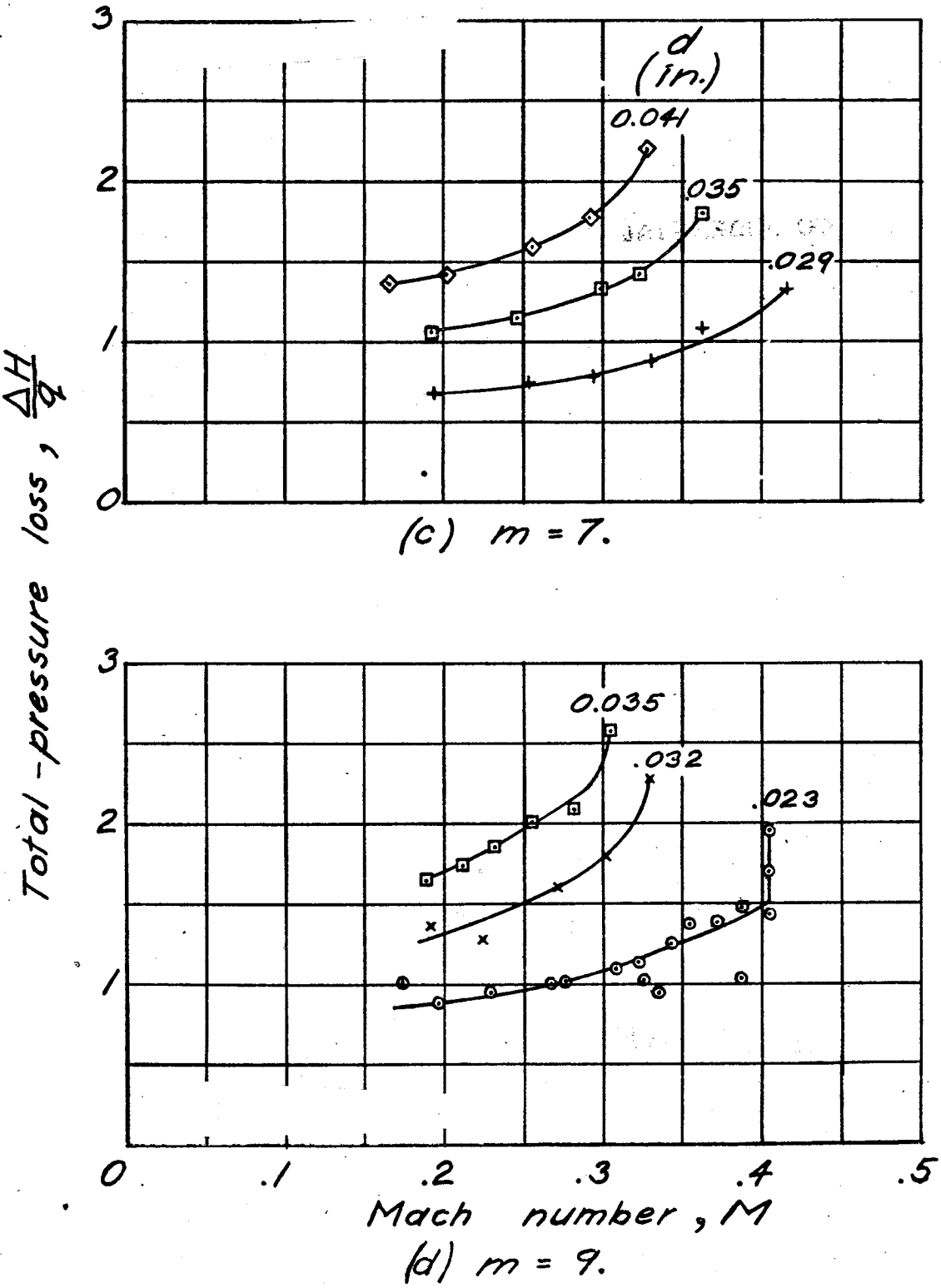


Figure 3.- Continued.

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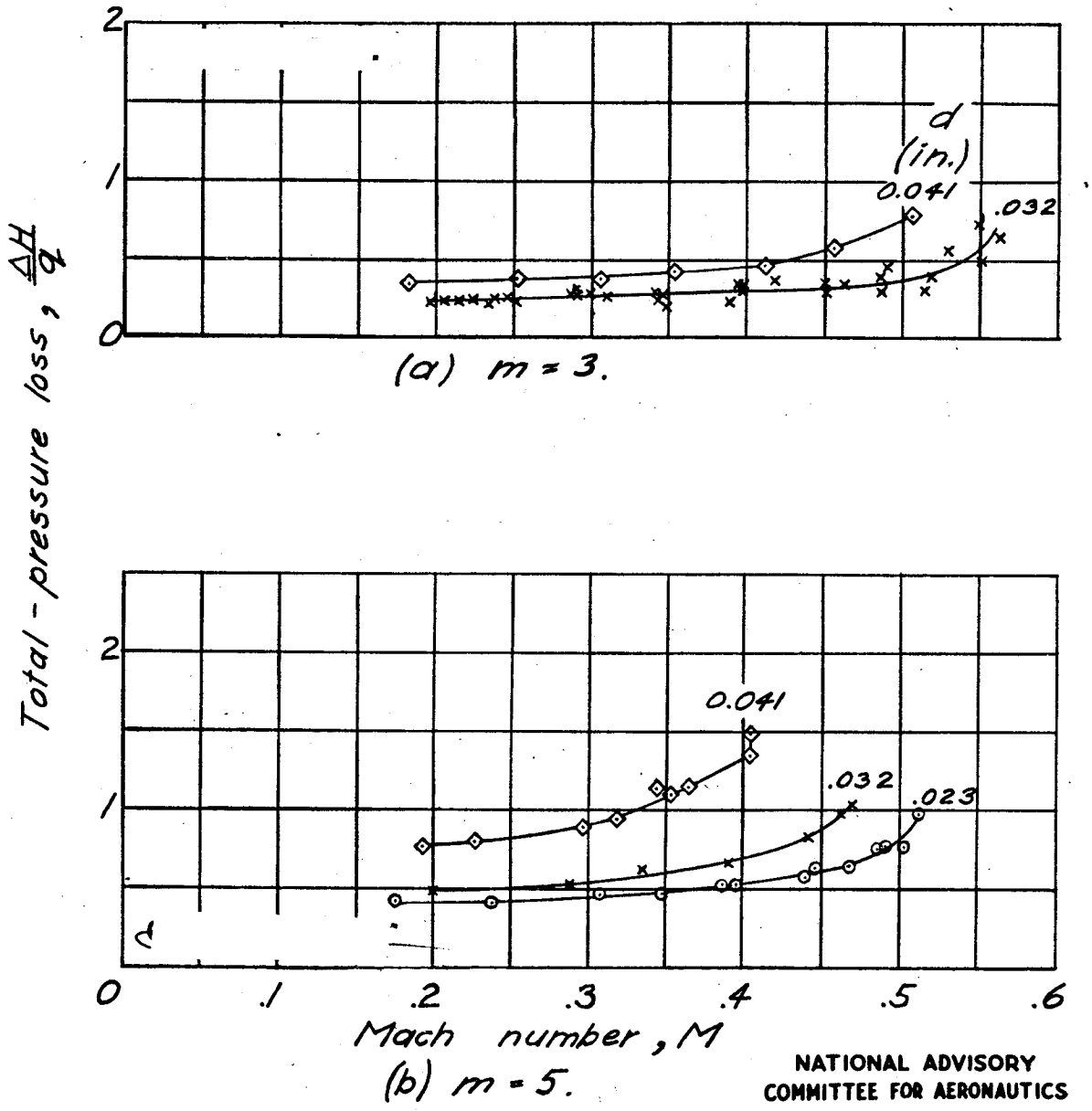

Figure 3.- Variation of total-pressure loss through screens with Mach number.

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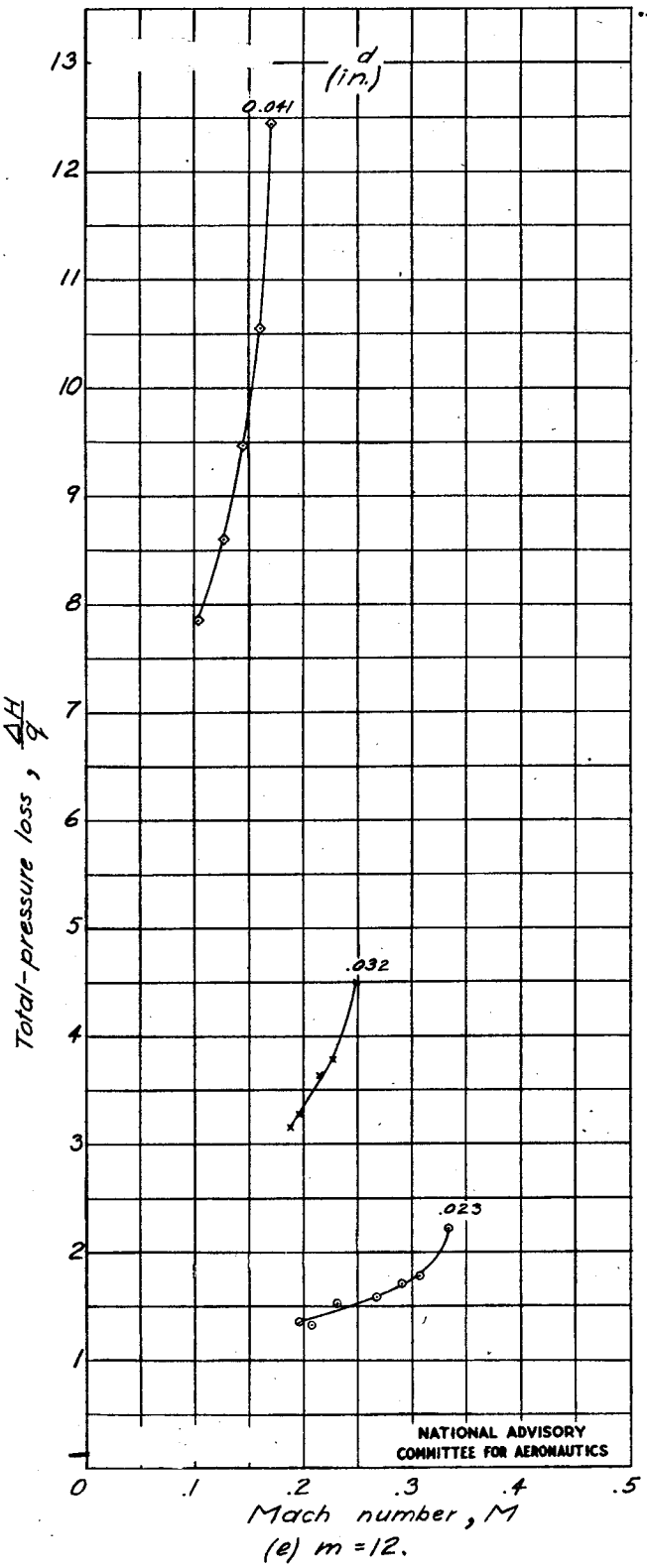


(e) m = 12.

Figure 3. - Concluded.

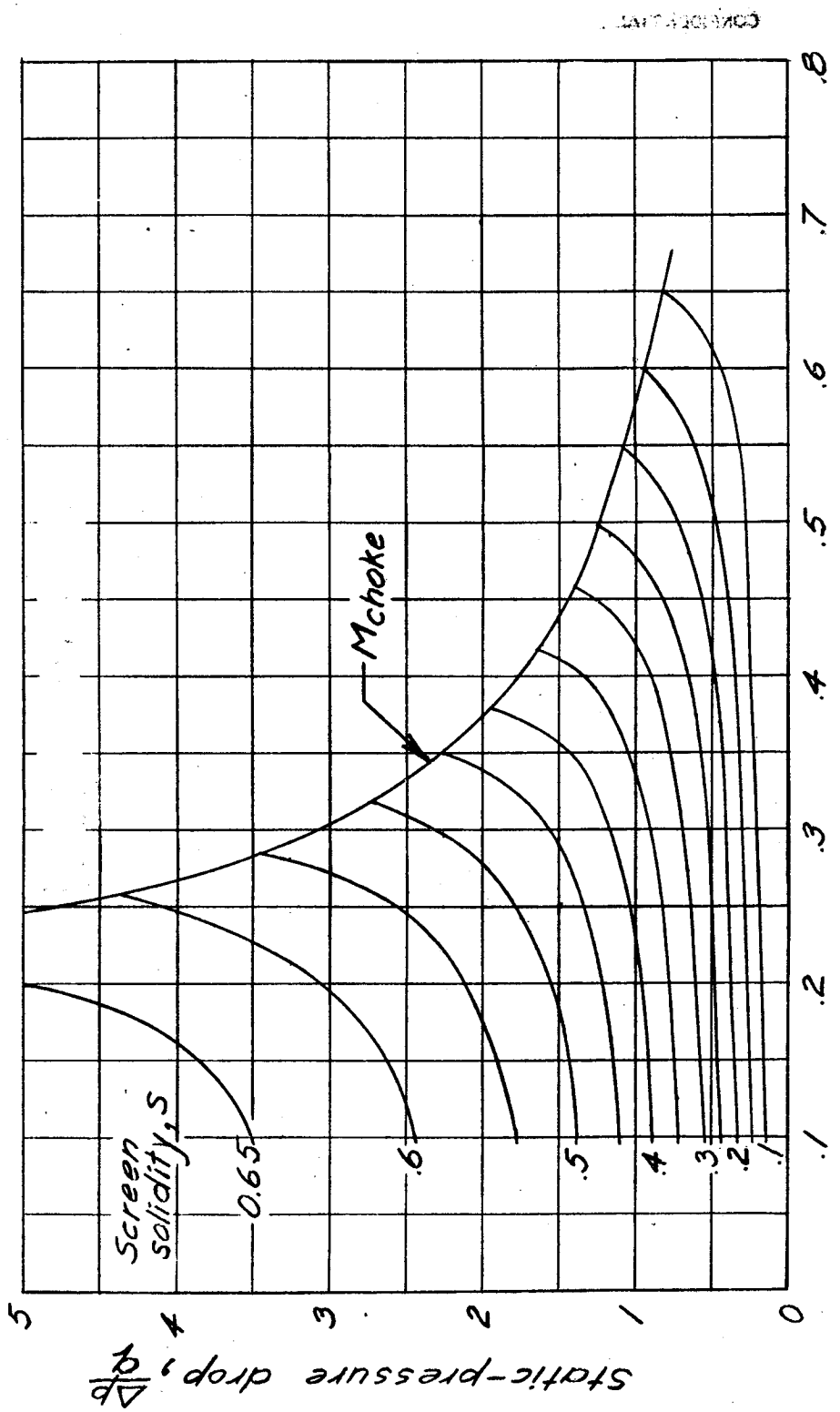


Figure 4. - Effect of compressibility on the static-pressure drop through screens of various solidities.

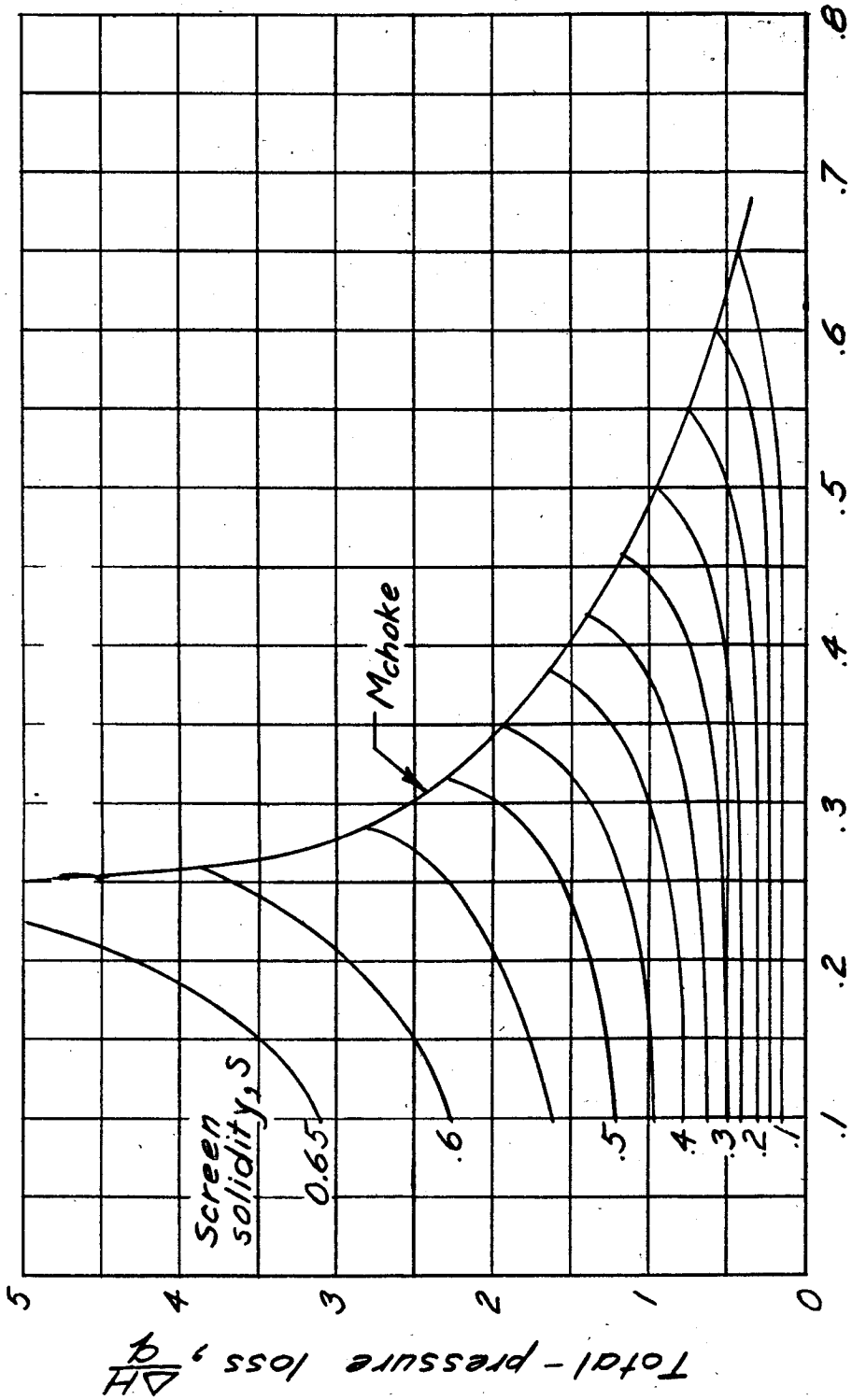
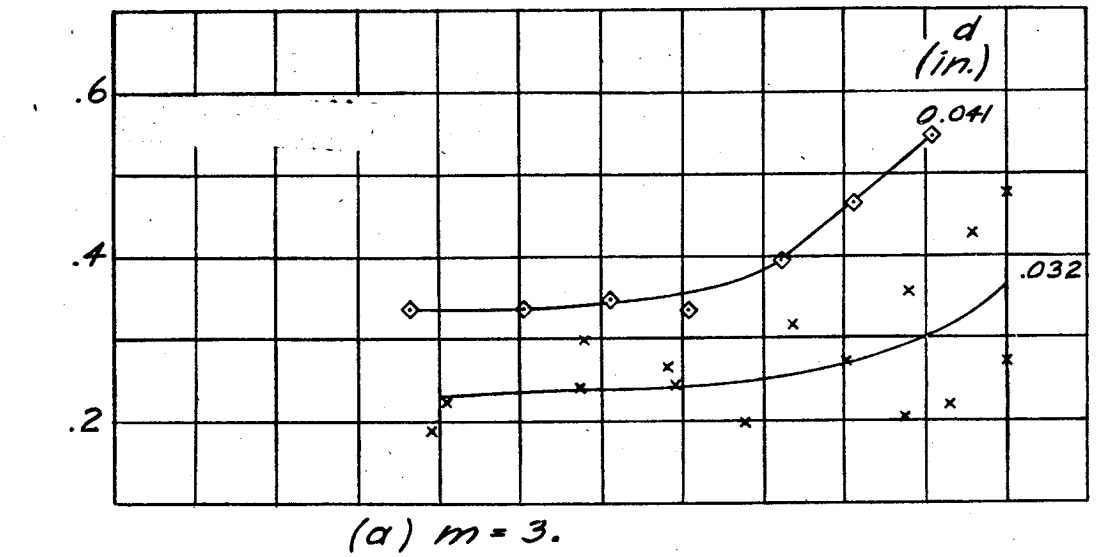
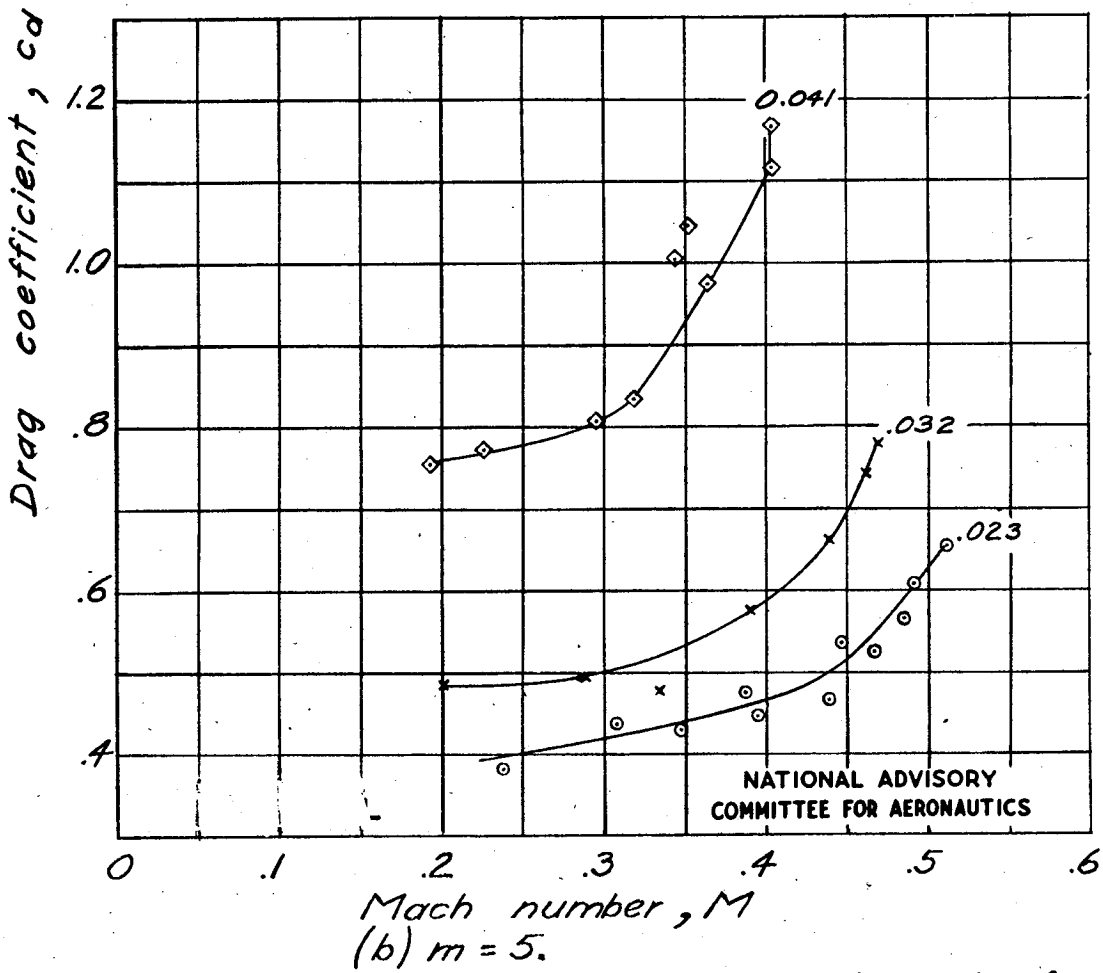


Figure 5.- Effect of compressibility on the total-pressure loss through screens of various solidities.



(a) m = 3.



(b) m = 5.

Figure 6.- Variation of drag coefficient of screens with Mach number.

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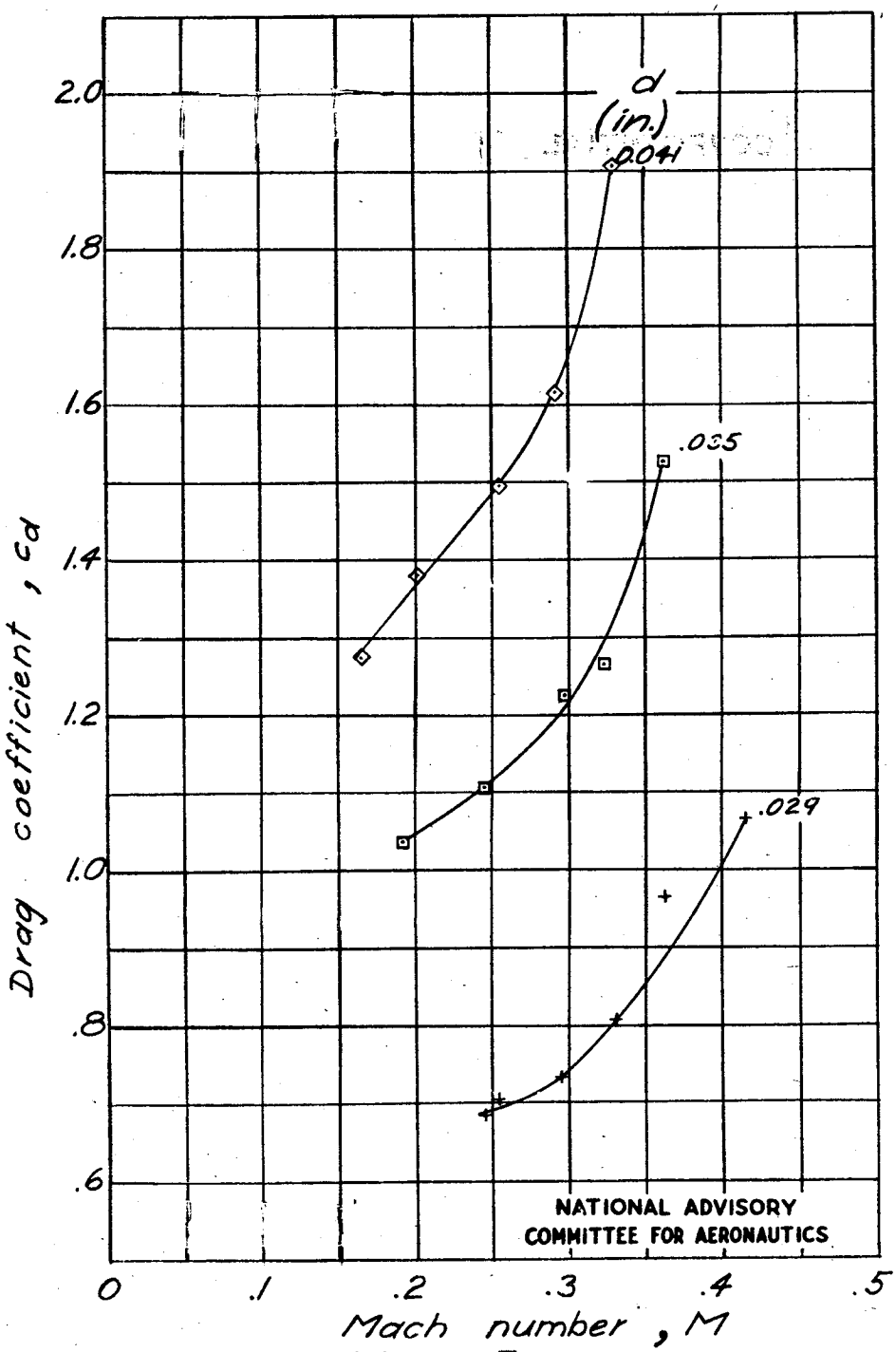

(c) m = 7.

Figure 6. - Continued.

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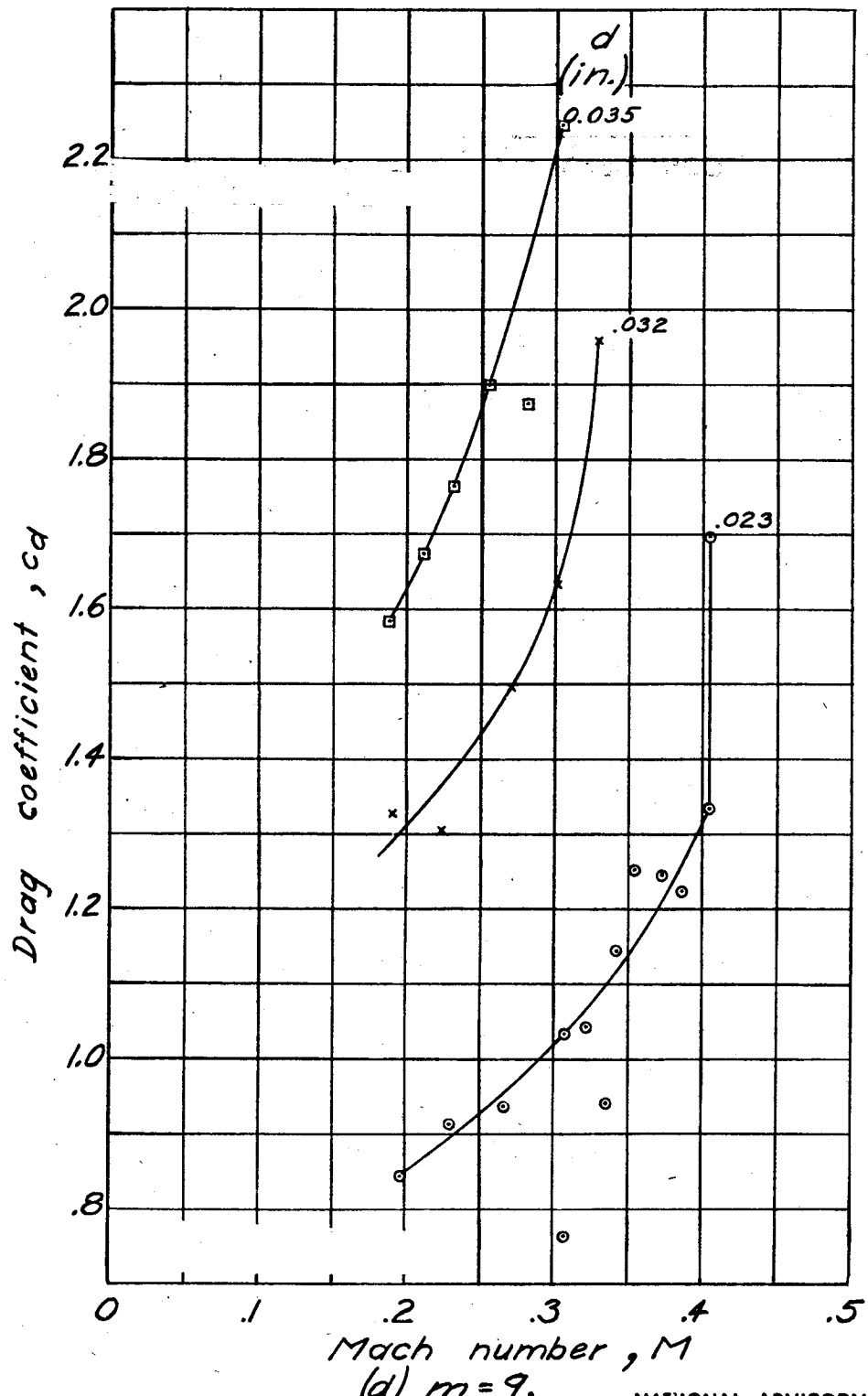

(d) m = 9.

Figure 6. - Continued.

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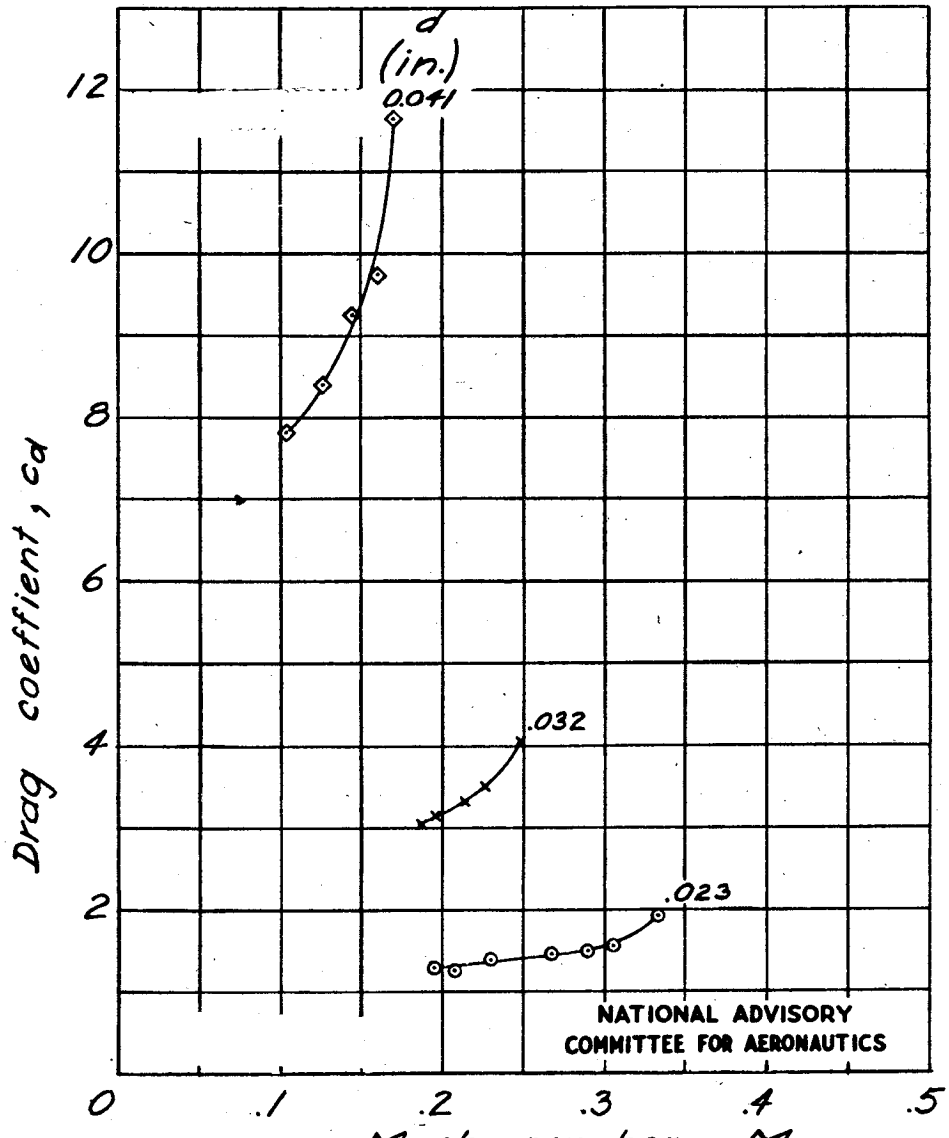

(e) m = 12.

Figure 6.- Concluded.

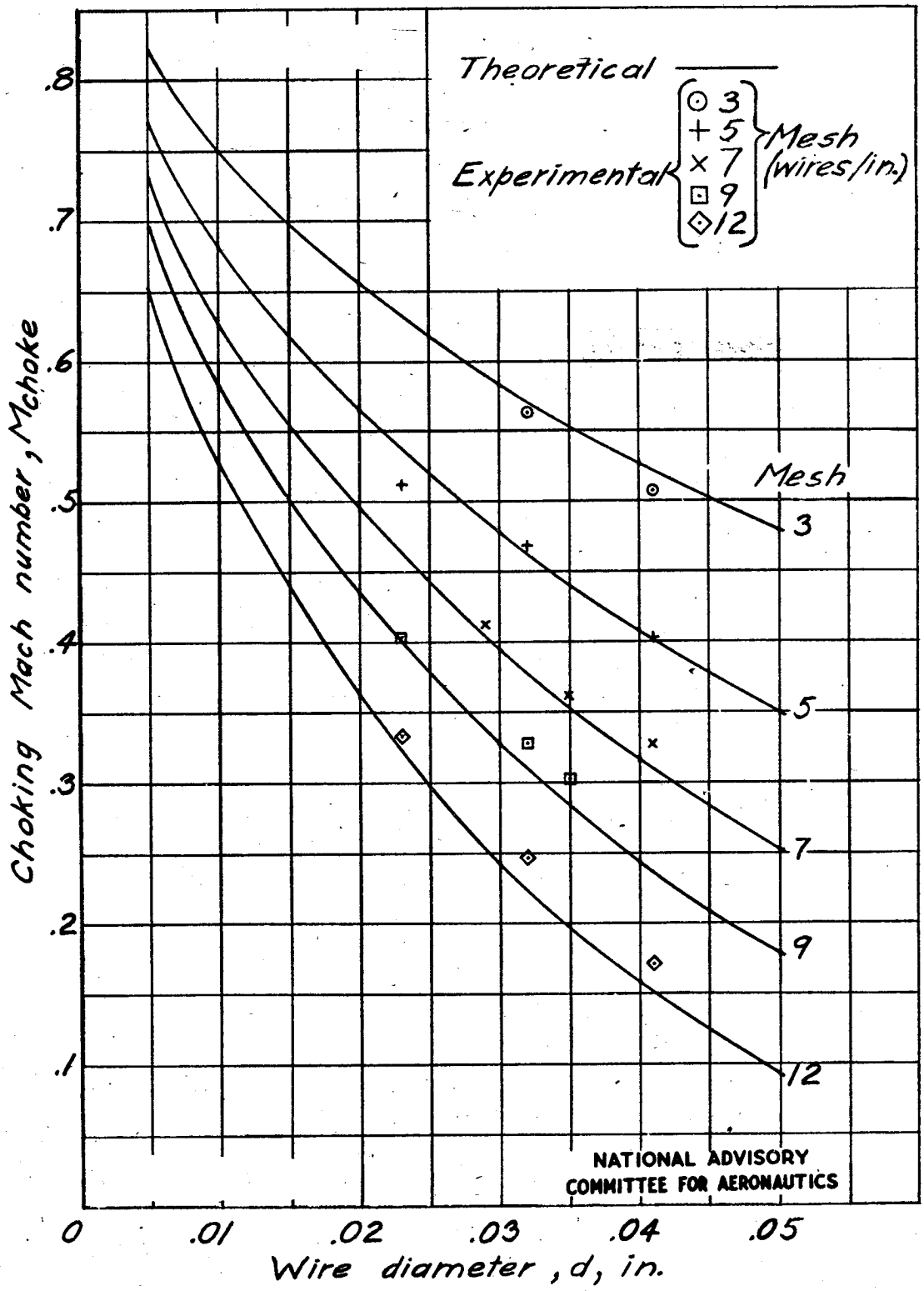

Figure 7. - Choking Mach number for screens of various meshes and wire diameters.

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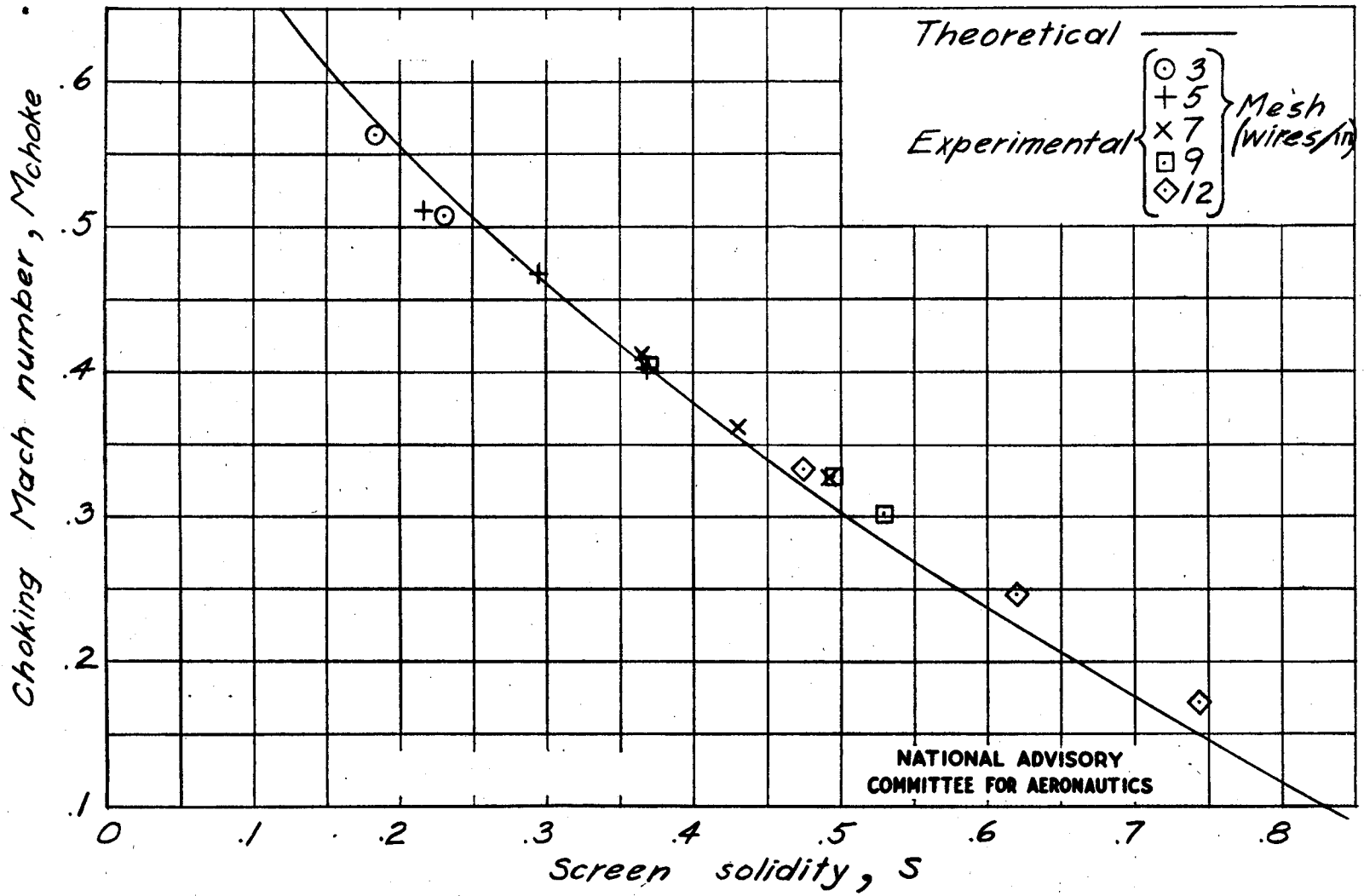

Figure 8. - Variation of choking Mach number with screen solidity.

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