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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS.

No. 158

ANALYSIS OF DR. SCHAFFRAN'S PROPELLER MODEL TESTS.

By Max M. Munk.

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Summary.

The following note, prepared for the National Advisory Committee for Aeronautics, contains an analysis of the propeller model tests of Dr. Schaffran. This analysis was made in the same way as that of Dr. Durand's tests. Only the thrust is examined. It appears that the thrust produced by three-blade and four-blade propellers follows the same laws as with two-blade propellers, and that all conclusions reached from Dr. Durand's tests can be upheld.

Reference.

Max M. Munk: Analysis of Dr. W. F. Durand's and E. P. Lesley's Propeller Tests. N.A.C.A. Report No. 175.

The following note is an extension of my analysis of Dr. Durand's propeller model tests, adding now the slip curves obtained from tests made with a different arrangement of the test and with propellers with more than two blades. The series of tests analyzed now is a very complete and systematic one. The tests are made by Dr. Karl Schaffran, Charlottenburg, Germany. It seems that they have never been published, but have only been

distributed privately by him. The copy of the report of the tests used for the preparation of this note was made available for this purpose by the courtesy of the Bureau of Aeronautics of the United States Navy Department.

The tests were made with brass models of 120 mm. (4 3/4 in.) diameter in water. At 1800 R.P.M. the models were towed through a towing basin, the axis of the propellers being one propeller diameter below the surface of the water. The velocity of motion, the thrust and the torque were measured. In the present note only the thrust, and not the torque, is used.

The tests comprise two-blade, three-blade, and four-blade propellers, each with two different blade widths (7.5% and 10% of diameter) and each again with nine different pitch ratios, giving a systematic series of fifty-four tests. The series is completed by eighteen tests with pairs of two-blade propellers rotating in opposite direction. From this latter series only five tests were analyzed for this note.

The dimensions and the shape of the propellers are shown in Fig. 1. The blade sections are the same throughout the whole series. The pitch is constant for each propeller, and its ratio to the diameter has the values .40, .50, .60, .70, .80, .90, 1.00, 1.10, 1.20. The greatest blade widths are .075 and .10 of the diameter.

In the report available the results are only given by curves without indication of the points really observed. It cannot even be seen, whether all curves inserted are really obtained from tests

with as many different models, or some of them by interpolation only. The quantities plotted are rather unusual mathematical combinations of the propeller dimensions and the quantities observed. From them, the thrust coefficient

(1) $$C_T = \frac{T}{\frac{V^2\rho}{2}\ \frac{D^2\pi}{4}}$$ where

T = thrust

V = velocity of flight

ρ = density of air

D = propeller diameter

was first computed, and from this coefficient the relative slip velocity

v/V by means of the equation

(2) $$v/V = \sqrt{1 + C_T} - 1$$

where v nominally is the velocity of the slipstream. An account for equation (2) and for the arguments which lead to this method is given in the reference. The relative slip velocity is finally plotted against the relative tip velocity U/V, where U denotes the tangential component of the tip velocity of the propeller.

I have shown in the paper referred to that this "slip curve" so obtained can be expected to be a straight line within the practical range. The tests show that it is not straight for very small thrusts, and that beyond the practical range the slip curve has ordinarily a break and then runs straight again. The slope $m = \frac{d\ v/V}{d\ U/V}$ called the slip modulus, within the useful range, is

shown in the mentioned paper to be approximately

$$(3) \qquad m = \frac{2.8\ S/D^2}{1 + 1.4\ (U/V)_0\ S/D^2}$$

where S denotes the entire blade area and $(U/V)_0$ that particular value of U/V where the slip curve intersects with the horizontal axis and hence the thrust would be zero.

Each diagram contains the slip curves of all propellers only differing by the value of the pitch. Equation (3) shows that the value of m does not vary much with the pitch, and accordingly all slip curves on one diagram are almost parallel. The table at the end of this note contains the mean value of the slip modulus for each diagram, and in the next column the value of m computed from equation (3). The third column gives the correction factor obtained by dividing the observed value by the computed value. For the propellers with wide blades this correction factor varies from .96 to 1.00 and for the narrow propellers .99 to 1.09. The variations do not indicate any systematic law. The pairs of propellers running in opposite direction have a slip modulus about 10% higher than the four-blade propellers with the same blades.

Table.

	Blade width .10 D			Blade width .075 D			
	2 blades	3 blades	4 blades	2 blades	3 blades	4 blades	2 x 2 blades
m observed	.168	.225	.248	.142	.203	.246	.270
m computed	.175	.224	.258	.144	.190	.225	
Correction	.96	.100	.96	.99	.106	.109	-

Fig. 1

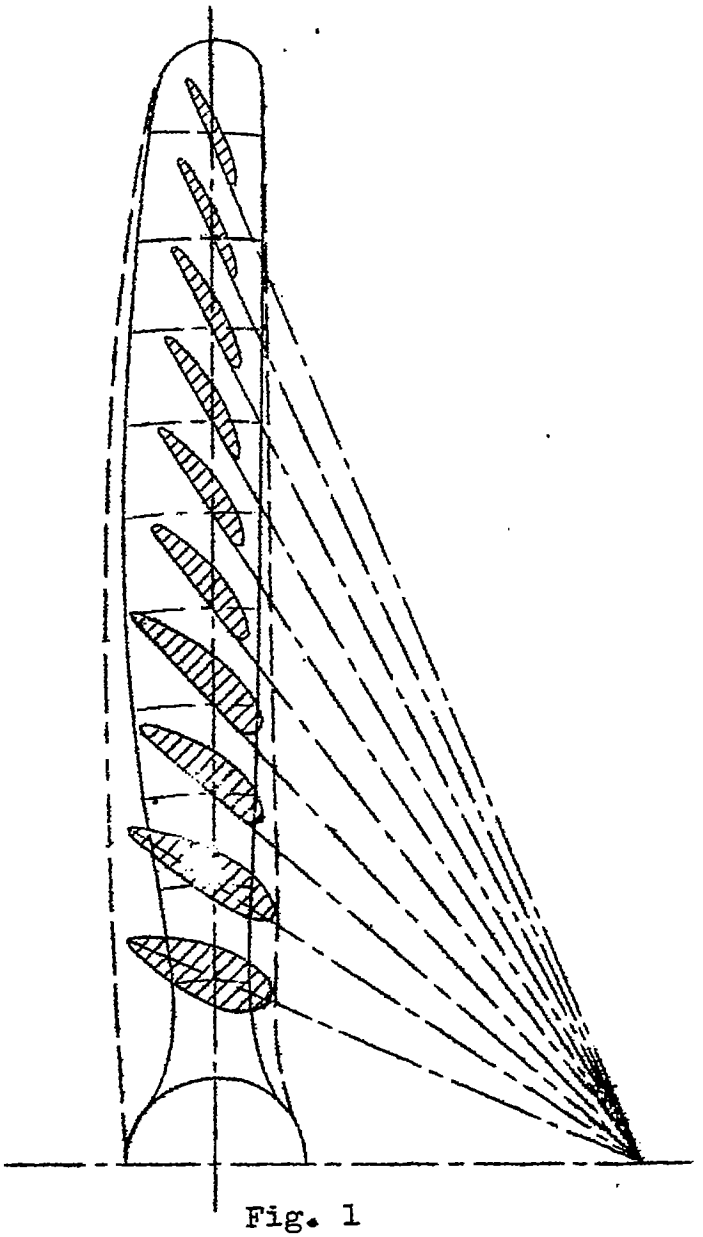

Fig. 1

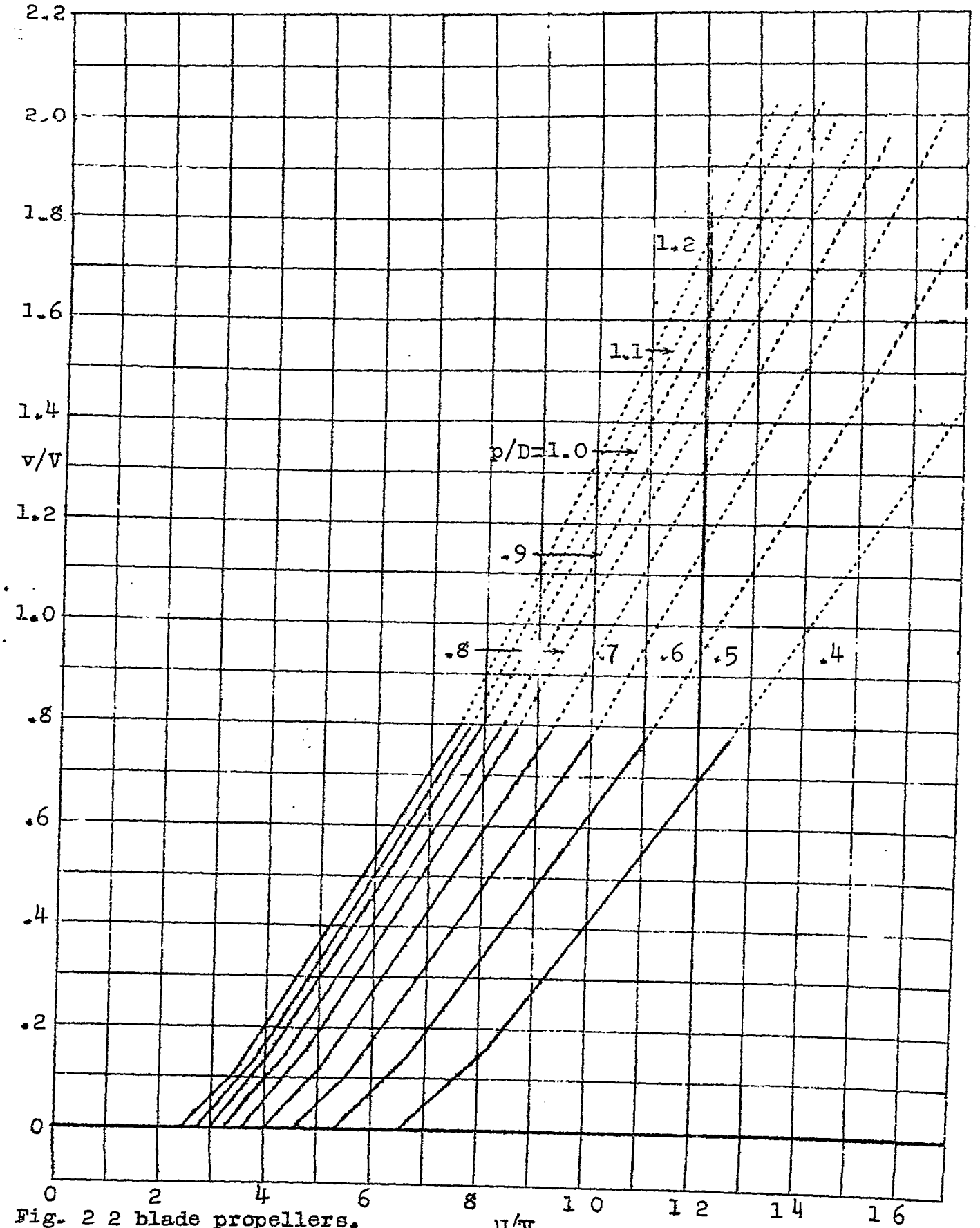

Fig. 2 2 blade propellers.
Blade width .10D

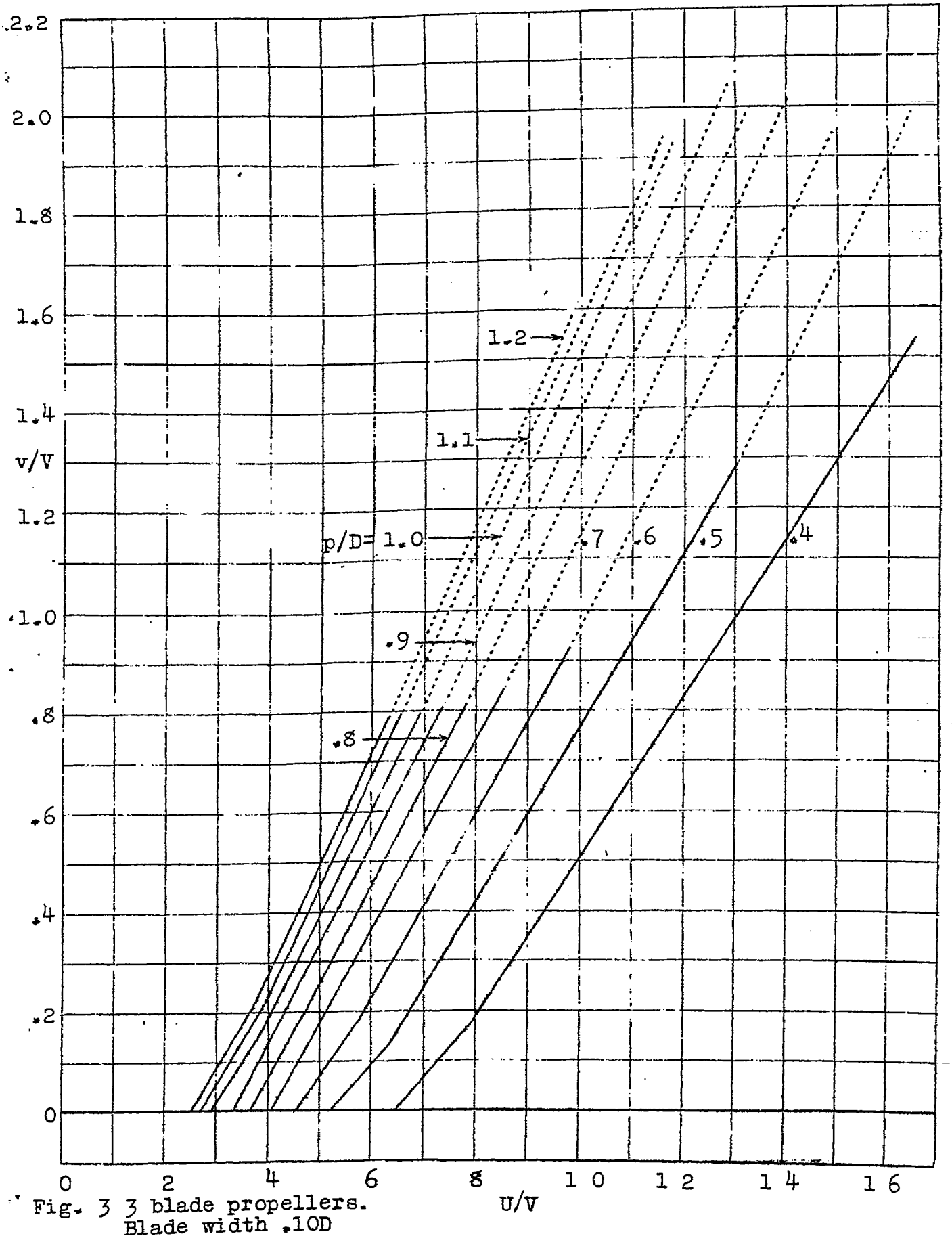

Fig. 3 3 blade propellers.
Blade width .10D

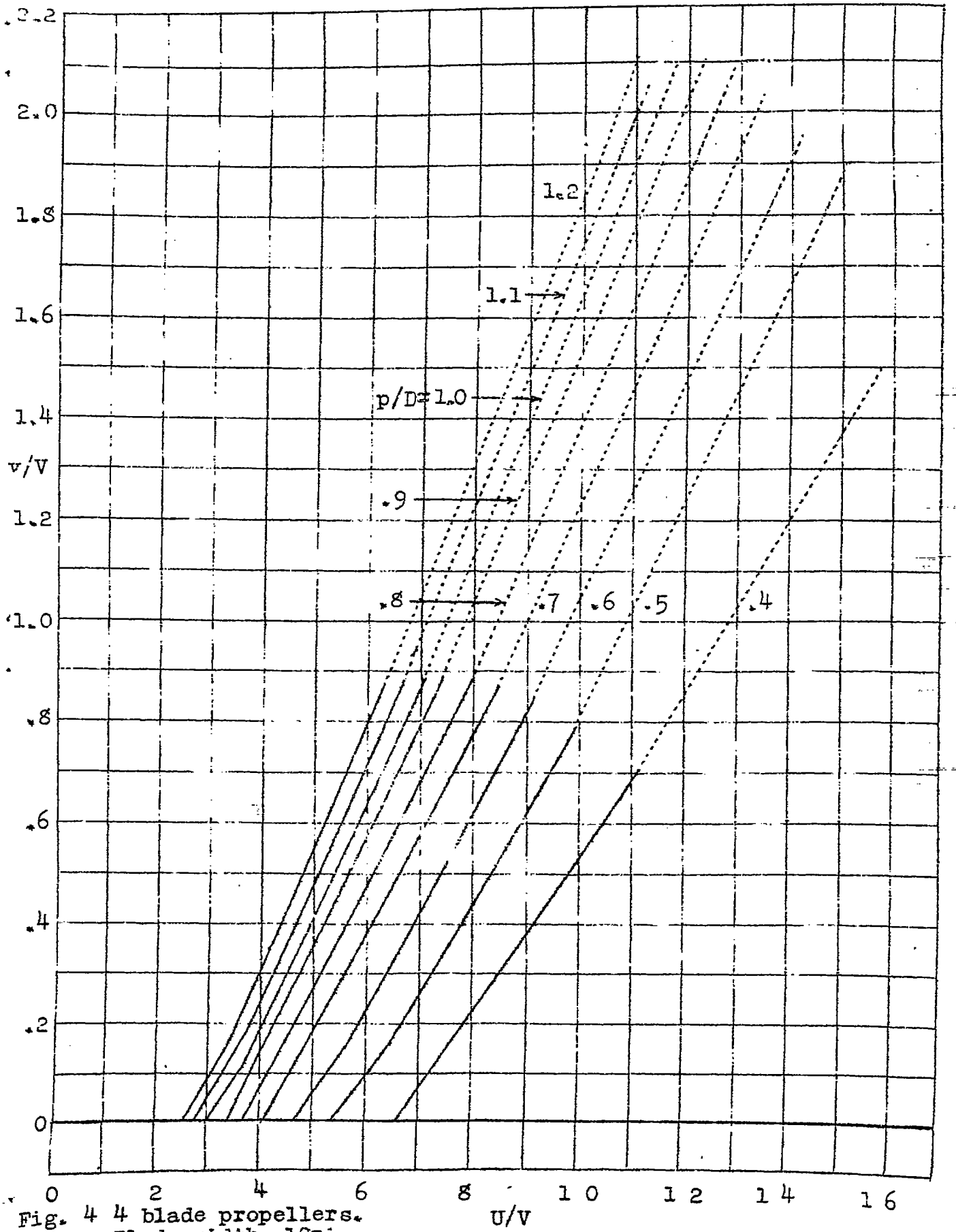

Fig. 4 4 blade propellers.
Blade width .1CD

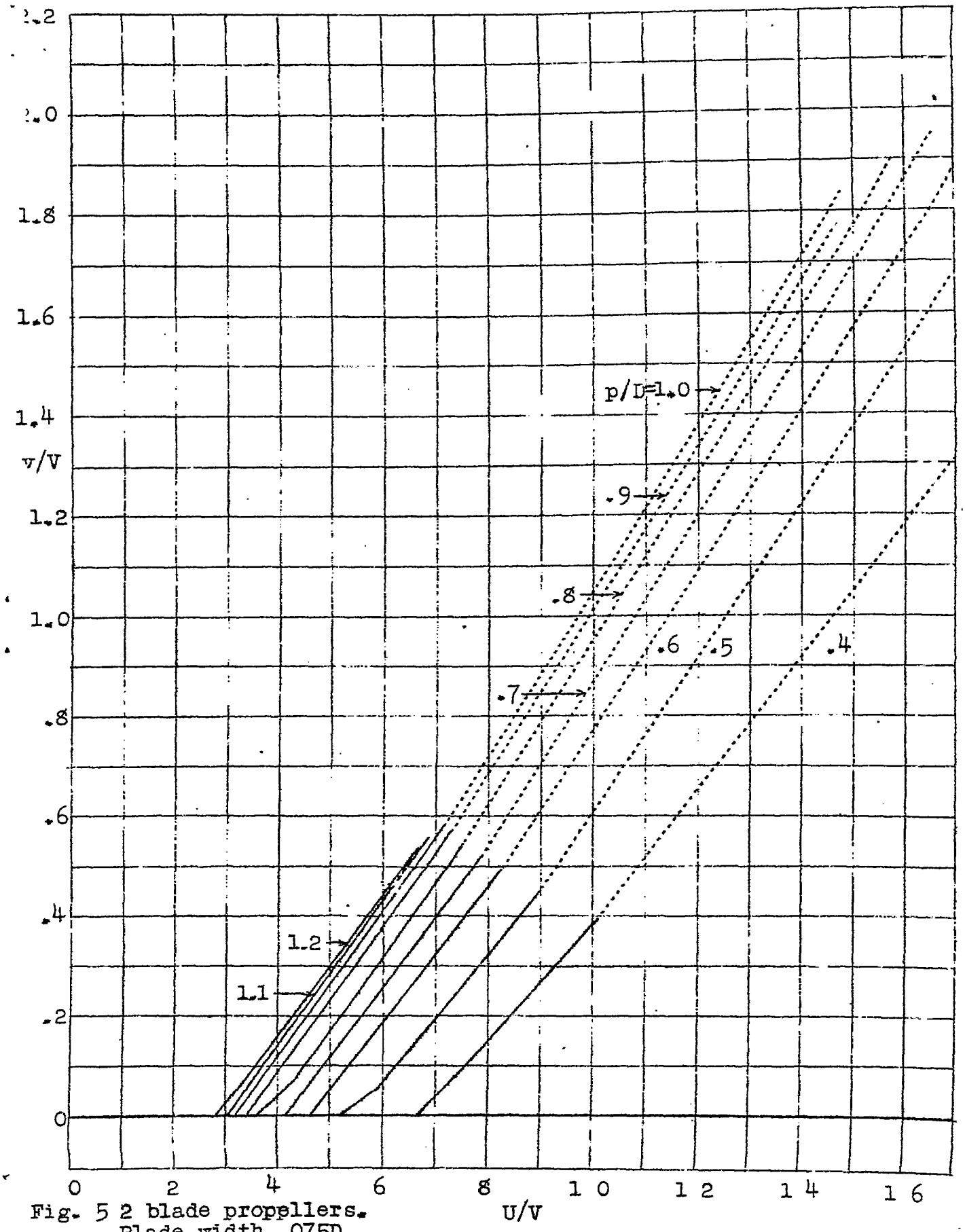

Fig. 5 2 blade propellers.
Blade width .075D

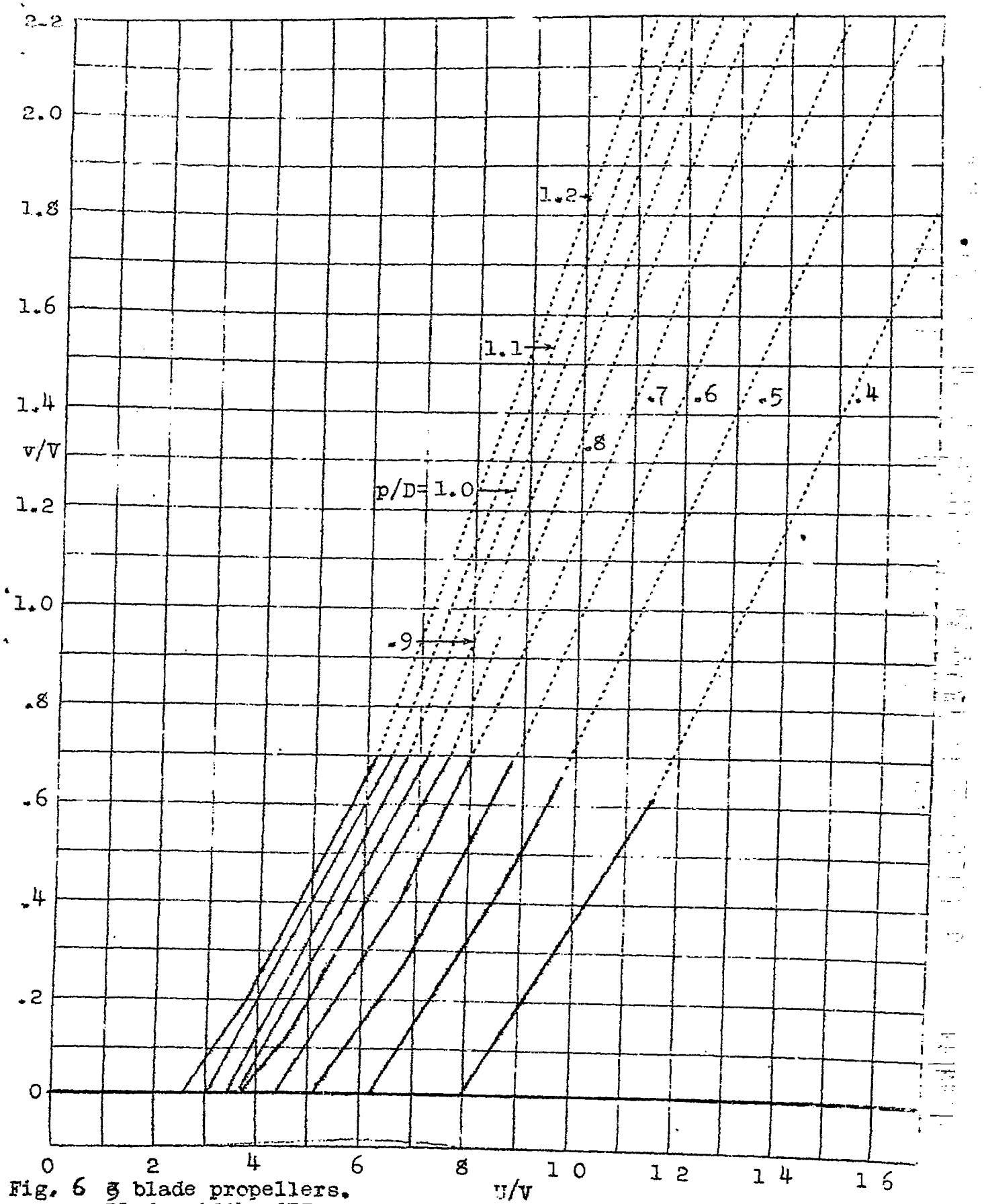

Fig. 6 3 blade propellers.
Blade width .075D

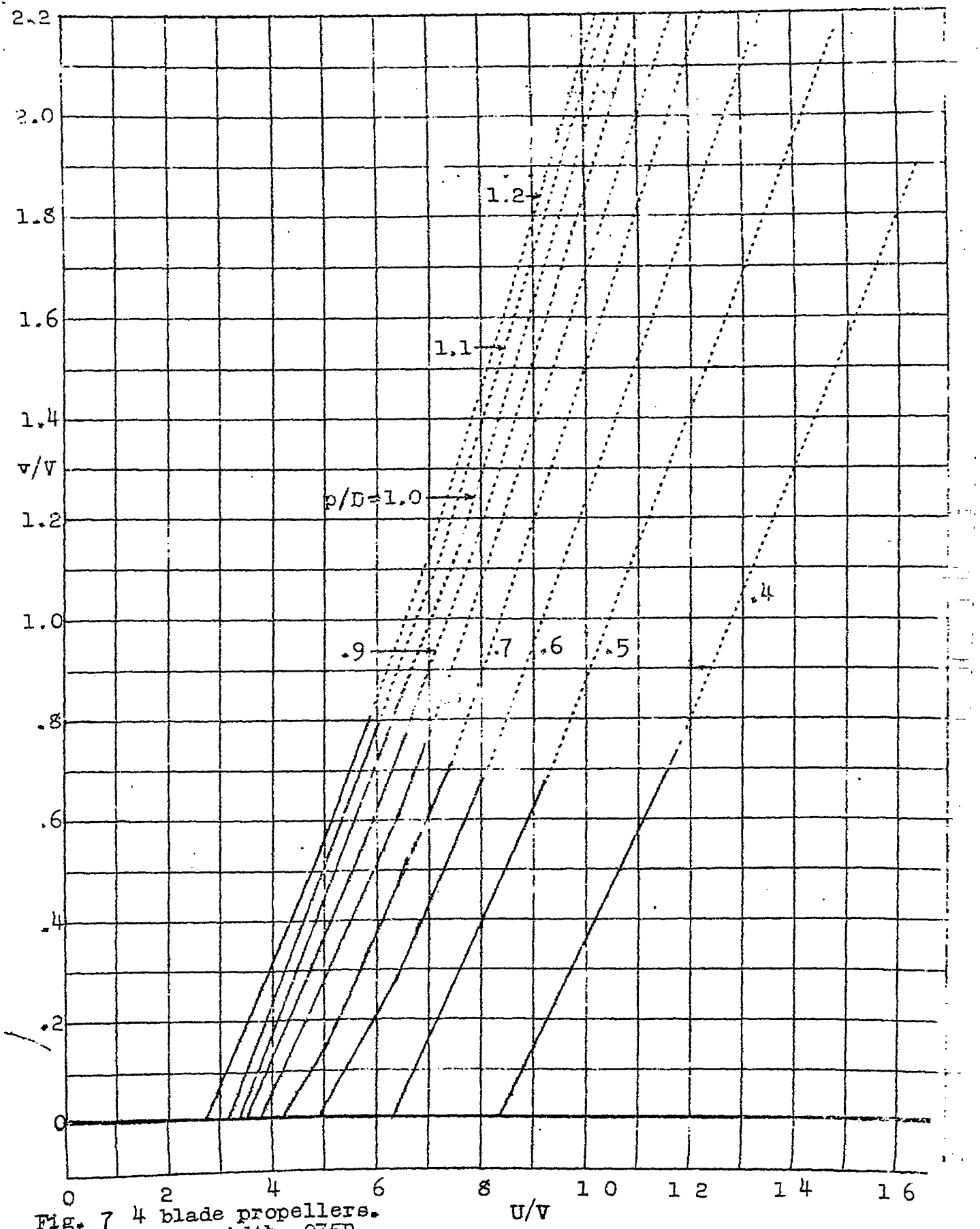

Fig. 7 4 blade propellers.
Blade width .075D

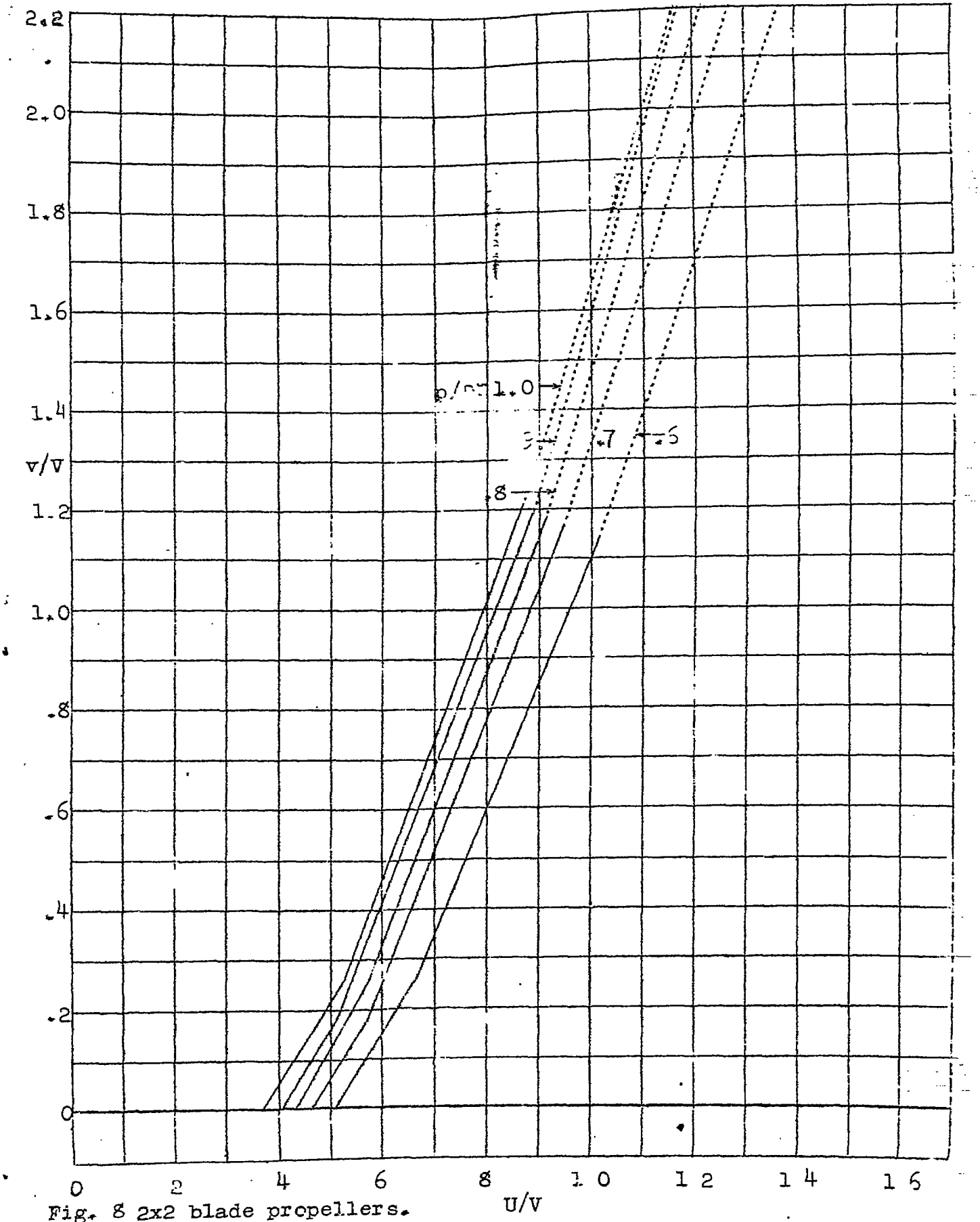

Fig. 8 2x2 blade propellers.
Blade width .075D