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WASHINGTON, D.C. - 20007

HYDROMECHANICS

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OPEN-WATER AND CAVITATION PERFORMANCE OF THE PROPELLER FOR SARGO SS(N)583

by

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HYDROMECHANICS LABORATORY

RESEARCH AND DEVELOPMENT REPORT

February 1964 Report 1816

PRNC-TMB-648 (Rev. 3-63)

AD
434288

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NOTATION

$b_{0.7}$	Blade section length at 0.7 radius
D	Diameter of propeller
e	Propeller efficiency, $e = \dfrac{K_t \cdot J}{K_2 \cdot 2\pi}$
g	Acceleration of gravity
J	Speed Coefficient, $J = \dfrac{V_a}{n \cdot D}$
K_t	Thrust coefficient, $K_t = \dfrac{T}{\rho \cdot n^2 \cdot D^4}$
K_q	Torque coefficient, $K_q = \dfrac{Q}{\rho \cdot n^2 \cdot D^5}$
n	Revolutions per unit time
P	Pitch of propeller at 0.7 radius
p	Static pressure at centerline of propeller
p_v	Vapor pressure
Q	Torque
R	Propeller radius
r	Radial coordinate of propeller
R_e	Reynolds number, $R_e = \dfrac{b_{0.7}\sqrt{V_a^2 + (0.7 \cdot \pi \cdot n \cdot D)^2}}{\nu}$
T	Thrust
V	Ship speed, $V = \dfrac{V_a}{1 - w}$
V_a	Speed of advance
W	Average wake fraction
x	r/R
ν	Kinematic viscosity
ρ	Density of water
σ	Cavitation index, $\sigma = \dfrac{p - p_v}{1/2 \rho \cdot V^2}$

ABSTRACT

Test results are given for the predicted cavitation performance in uniform inflow of the propellers designed for SS(N)583. These results are shown as inception curves of face, back, and tip vortex cavitation at each design radius of the propeller. Open-water and cavitation characteristic curves are also included.

INTRODUCTION

As requested by the Bureau of Ships,[1] tests were conducted to determine the open-water and cavitation characteristics of model propellers 4012 and 4059, which were constructed of fiberglass according to the seven-bladed design (Dwg. No. SSN578-203-1757534 9A) for USS SARGO. Propellers 4032 and 4033 had been built earlier to the same design and propulsion tests had been conducted. Following the propulsion tests, however, it was found that the blades of these propellers were too thick in the vicinity of the chiseled trailing edge. It was not considered necessary to repeat the propulsion tests since these discrepancies could be accounted for in the analysis. Propellers 4012 and 4059 were constructed so that meaningful open-water and cavitation data could be obtained. Drawings and dimensional characteristics of these propellers are shown in Figure 1.

Tests were conducted to obtain the open-water characteristics of both the right- and left-hand propellers in the deep-water basin using the TMB propeller boat with 1/4-horsepower pendulum dynamometers. Each propeller was tested over a range of speed coefficient, J, with constant rotative speed of 22.2 rps, except at low values of J where rps was limited by the capacity of the dynamometer. The open-water characteristic curves are presented in Figure 2. The open-water tests were conducted at a Reynolds

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[1] References are listed on page 3.

number of about 3.0×10^5. However, tunnel tests at varying Reynolds numbers showed no measurable effect on thrust and torque at Reynolds numbers above 2.7×10^5.

The right-hand propeller only (4012) was tested in the 12-inch variable pressure water tunnel using the 4-horsepower dynamometer to determine the cavitation characteristics. The test was conducted in uniform flow and over a range of J values from 0.3 to 0.8 in increments of 0.1. In-between spots were run as necessary for fairing the curves. All J's were run with a constant angular velocity of 30 rps except for the J of 0.3 which was run at 28 rps with a corresponding decrease in water speed so as not to overload the fiberglass propellers.

The tunnel speed was adjusted so that the thrust with atmospheric pressure in the tunnel was the same as that obtained from the thrust coefficient K_t on the open-water curve for the same J. This water speed was held constant as the tunnel pressure was decreased to the minimum of approximately 3.5 feet of water. As the pressure was reduced by small increments of from 1 to 4 feet of water, the thrust, torque, and pressure were measured and recorded. Whenever cavitation was observed, photographs were taken and a sketch was made showing the type and extent of cavitation present. Sketches of cavitation at selected values of cavitation index for the speed coefficients tested are shown in Figure 3. The type of cavitation on these propellers as seen on Figure 3 indicates that some cavitation was triggered by irregularities along the leading edge.

RESULTS AND DISCUSSION

The cavitation inception curves are given in Figure 4. These curves were obtained by plotting the radial extent of cavitation, as determined from the visual observations, against σ for each value of J. At each J value, limiting values of σ were determined from this family of curves for increments of 0.1 of the normalized radial distance x and plotted against J in Figure 4.

These curves thus indicate the limiting value of σ for the inception of face, back, and tip vortex cavitation. That is, the area above any curve indicates that there is no visible cavitation of that type present at the radius, x, indicated on the curve. Below the curve at this radius, the intensity of cavitation increases with a decrease in σ with the exception of tip vortices which are visible explicitly only in the shaded area. At the σ represented by the lower edge, the tip vortices are indistinguishable from the back cavitation which occurs near the tip at this condition.

When Figure 4 is used, the speed coefficient and cavitation index are first computed for the desired operating conditions. The type of cavitation will be determined by J and the intensity of that type of cavitation will be determined by σ. For instance, with a J of 0.5 and σ of 4.0, back cavitation would extend from about 0.44 radius to the blade tip. There would be no visible tip vortices. It should be noted that at a J of 0.69, there would be no cavitation at σ as low as 2.3.

In addition to determining the inception of cavitation, the thrust and torque coefficients K_t and K_q were calculated and plotted against σ for each J tested. The cavitation characteristic curves were derived from these curves by plotting coefficients of K_t and K_q for discrete values of σ against J. These characteristic curves are presented in Figure 5.

When extrapolating any of these data to ship conditions, the standard pressure correction factor[2] for the 12-inch water tunnel should be applied to the ship cavitation index; that is, the ship pressure $p - p_v$ should be reduced to 85 percent of its actual value.

REFERENCES

1. BuShips letter SS(N)578/9440 Serial 644-513 of 13 July 1962 to DTMB.

2. Bowers, W. H., "The 12-Inch Variable Pressure Water Tunnel Propeller Testing Procedure," DTMB Report 505, Page 22 (Nov 1943).

PROPELLERS 4012 & 4059

NUMBER OF BLADES	7	DIAMETER	7.325 Ins.
E A R	0.610	PITCH	5.982 Ins.
M W R	0.166	ROTATION	4012-RH, 4059-LH.
B T F	0.099	DESIGNED BY	BUSHIPS
P/D	0.817	DRAWING NO.	SSN 578-203 - 1737539A

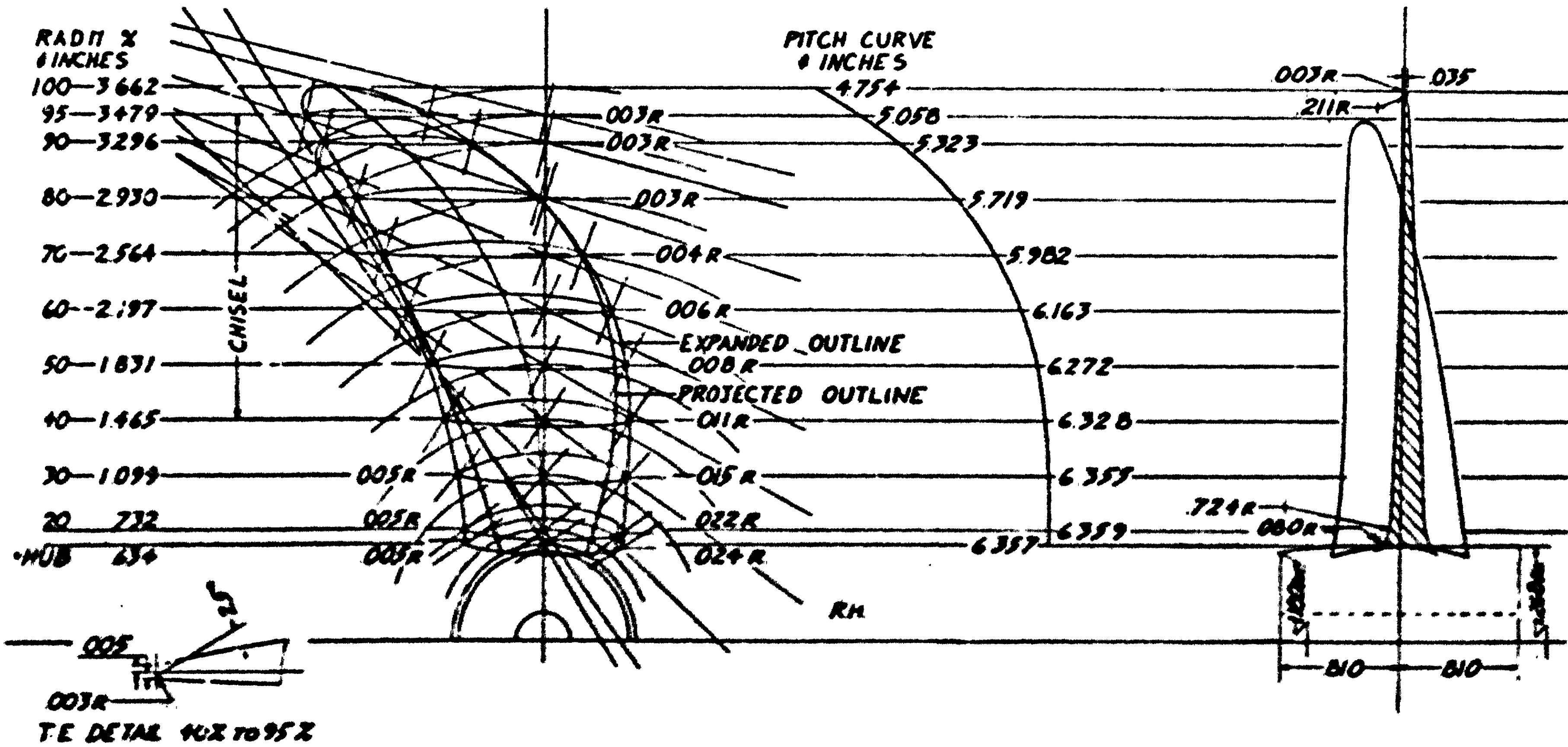

Figure 1 - Drawing of Model Propellers 4012 and 4059

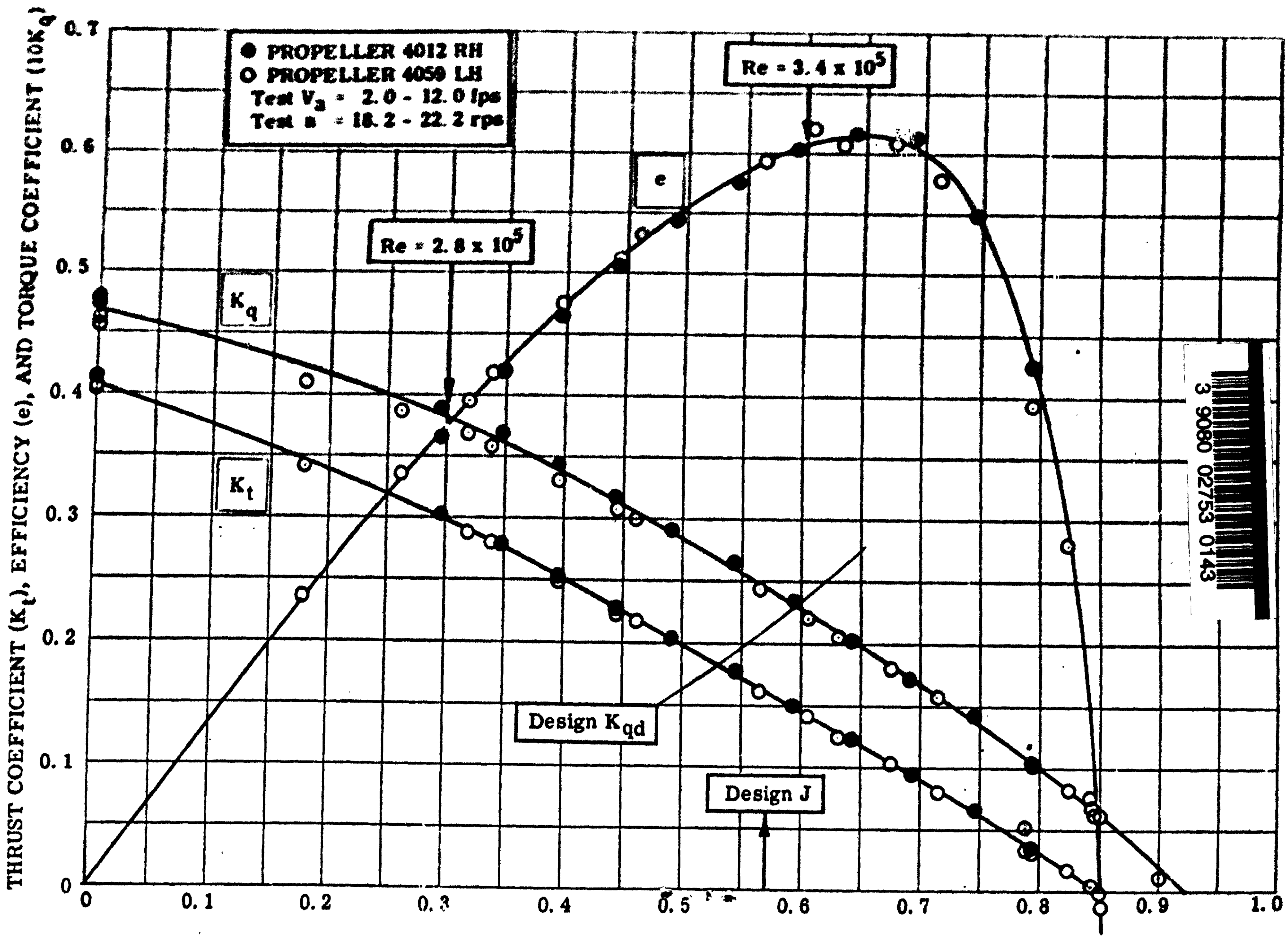

Figure 2 - Open-Water Characteristics of Model Propellers 4012 and 4059

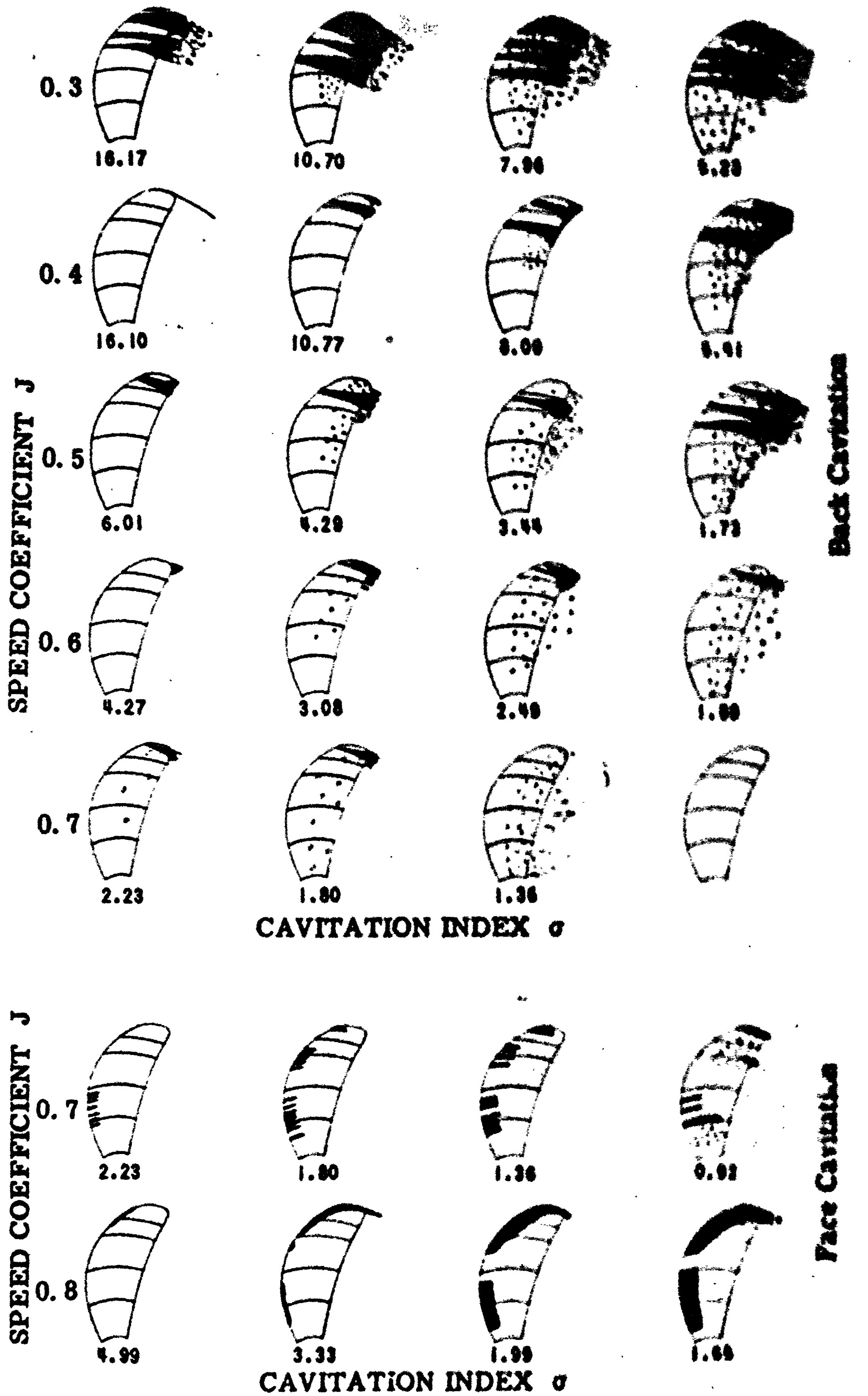

Figure 3 - Visual Observations of Cavitation on Propeller 4012

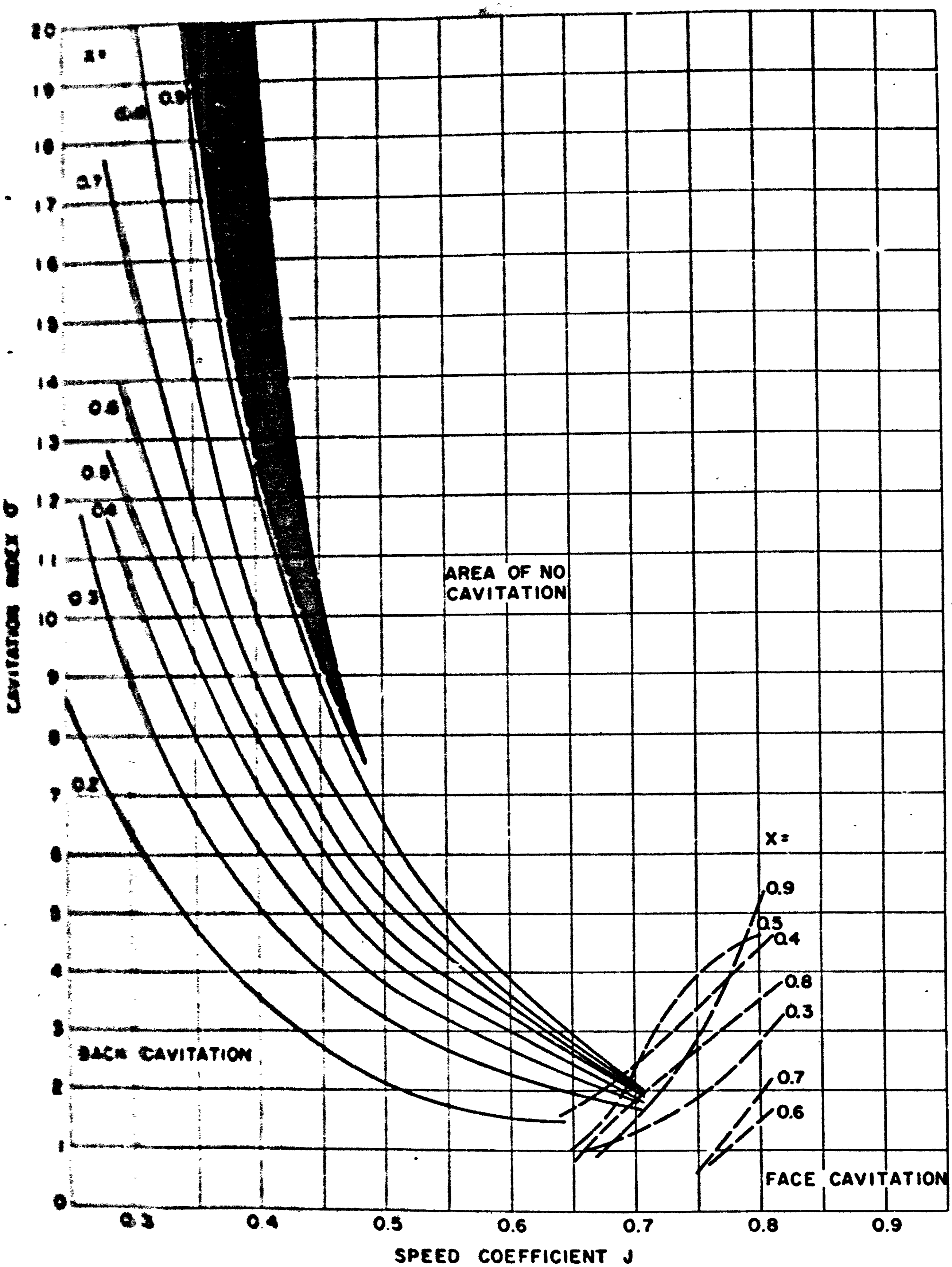

Figure 4 - Inception Curves of Visible Cavitation on Propeller 4012

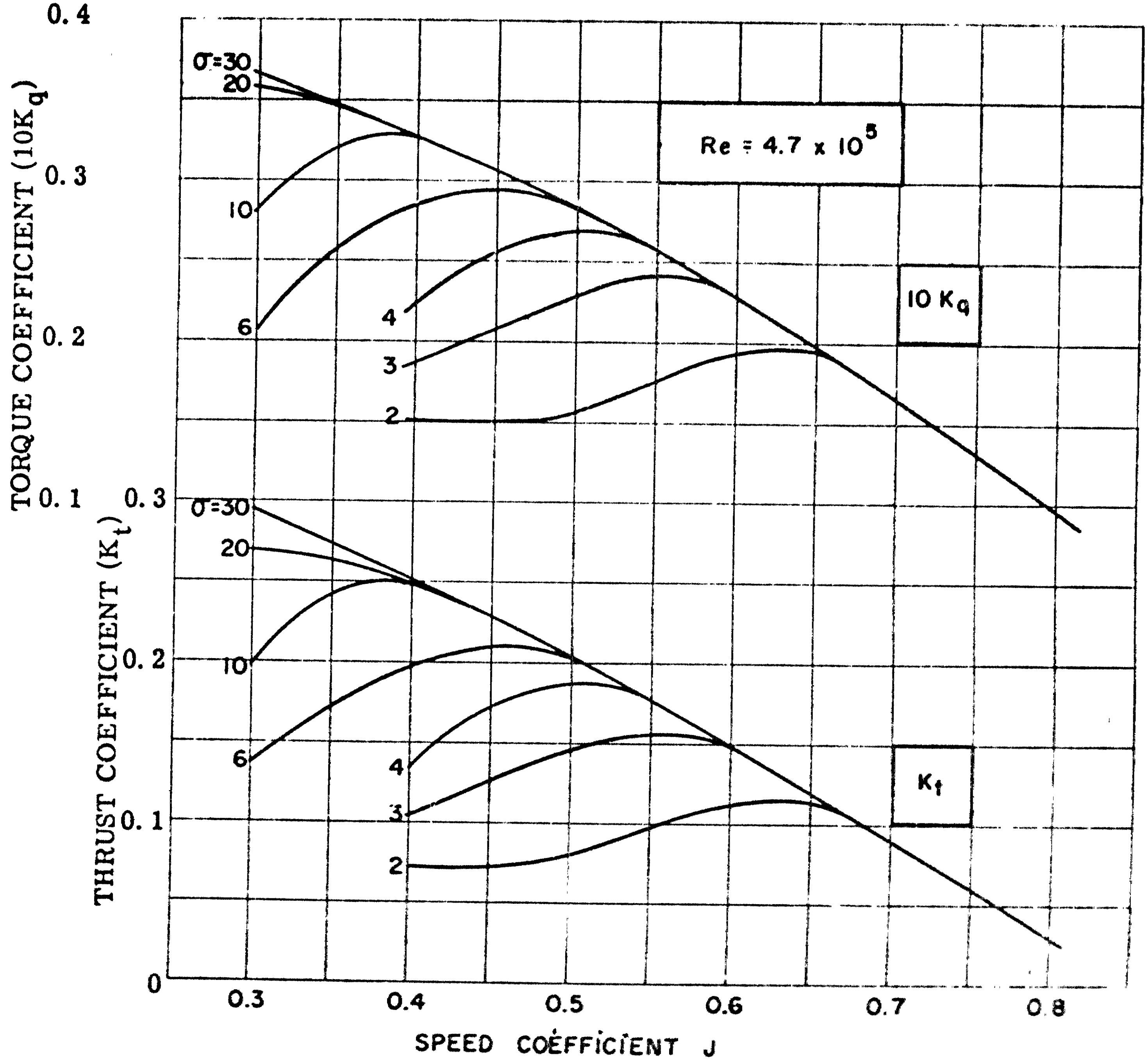

Figure 5 - Cavitation Characteristic Curves of Propeller 4012