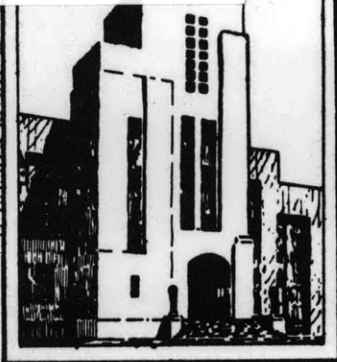


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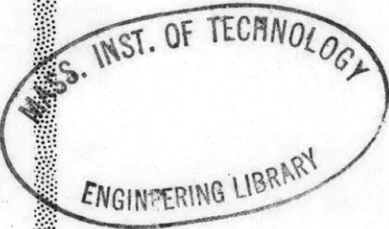
Report 1670

DEPARTMENT OF THE NAVY  
DAVID TAYLOR MODEL BASIN

HYDROMECHANICS

OPEN-WATER AND CAVITATION PERFORMANCE  
OF THE PROPELLER FOR AOE-1

AERODYNAMICS



by

W. H. Roundy

STRUCTURAL  
MECHANICS

HYDROMECHANICS LABORATORY  
TEST AND EVALUATION REPORT

APPLIED  
MATHEMATICS

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## NOTATION

|           |  |
|-----------|--|
| $b_{0.7}$ | Blade section length at 0.70 radius  |
| $D$       | Diameter of propeller  |
| $e$       | Propeller efficiency, $e = \frac{K_t \cdot J}{K_q \cdot 2\pi}$                               |
| $g$       | Acceleration of gravity  |
| $J$       | Speed coefficient, $J = \frac{V_a}{n \cdot D}$   |
| $K_t$     | Thrust coefficient, $K_t = \frac{T}{\rho \cdot n^2 \cdot D^4}$                               |
| $K_q$     | Torque coefficient, $K_q = \frac{Q}{\rho \cdot n^2 \cdot D^5}$                               |
| $n$       | Revolutions per unit time  |
| $P$       | Pitch of propeller at 0.70 radius  |
| $p$       | Static pressure at centerline of propeller   |
| $p_v$     | Vapor pressure   |
| $Q$       | Torque   |
| $R$       | Propeller radius   |
| $r$       | Radial coordinate of propeller   |
| $Re$      | Reynolds number, $Re = \frac{b_{0.7} \sqrt{V_a^2 + (0.7 \cdot \pi \cdot n \cdot D)^2}}{\nu}$ |
| $T$       | Thrust   |
| $V$       | Ship speed, $V = \frac{V_a}{1 - w}$  |
| $V_a$     | Speed of Advance   |
| $w$       | Average wake fraction  |
| $x$       | $r/R$  |
| $\nu$     | Kinematic viscosity  |
| $\rho$    | Density of water   |
| $\sigma$  | Cavitation index, $\sigma = \frac{p - p_v}{\frac{1}{2} \cdot \rho \cdot V^2}$                |

## ABSTRACT

Test results are given for the predicted cavitation performance in uniform inflow of the propeller designed for AOE-1. 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 BuShips,<sup>1</sup> a pair of model propellers (No's. 3924 and 3925) were constructed to correspond to the propellers designed for AOE-1. Drawings and dimensional characteristics of these propellers are shown in Figure 1.

Tests were conducted in the deep-water basin using the TMB propeller boat with 1/4-horsepower pendulum dynamometers to obtain the open-water characteristics of both the right and left-hand propellers. Each propeller was tested over a range of speed coefficient  $J$ , with constant rotative speed of 13.2 rps, except at low values of  $J$  where rpm was limited by the capacity of the dynamometer. The open-water characteristic curves are presented in Figure 2. The open-water test was conducted at a Reynolds number of  $3.5 \times 10^5$ . A check test conducted with the new 1-horsepower dynamometer at Reynolds numbers between  $3.5 \times 10^5$  and  $5.9 \times 10^5$  showed no measurable effect of Reynolds number on thrust and torque.

The right-hand propeller was tested in the 12-inch variable-pressure water tunnel in uniform flow using a transmission type dynamometer to determine the cavitation characteristics. The test was conducted over a range of  $J$  values from 0.4 to 1.0 in increments of 0.1 with constant angular velocity of 26.0 rps. However the test at a  $J$  of 0.4 was run at 24.0 rps with a corresponding lower water speed in order not to exceed the load capacity of the dynamometer.

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<sup>1</sup> References are listed on page 3.

The tunnel water speed was adjusted so that the thrust with atmospheric pressure in the tunnel was the same as that obtained from the thrust coefficient  $K_t$  from the open-water curves for the same  $J$ . As the tunnel pressure was decreased to the minimum (3.5 feet of water) by small increments of from one to four feet of water, the thrust, torque, and pressure were measured. When cavitation was visually 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. Sample photographs of the cavitating propeller are shown in Figures 4 and 5. The cavitation test results are shown in Figures 6 through 8.

#### RESULTS AND DISCUSSION

Cavitation inception curves are given in Figure 6. These curves were obtained by plotting the radial extent of cavitation as determined from the visual observations against  $\sigma$  for each value of  $J$ . At each  $J$  value limiting values of  $\sigma$  were determined from this family of curves for increments of 0.1 of the normalized radial distance  $x$  and plotted against  $J$  in Figure 6.

These curves thus indicate the limiting value of  $\sigma$  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 indicated on the curve. Below the curve at this radius, the intensity of cavitation increases with a decrease in  $\sigma$ . When using this curve, 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  $\sigma$ . For instance, with a  $J$  of 0.60 and  $\sigma$  of 4.0, back cavitation would extend from 0.5R to the blade tip. The tip vortices would also be visible.

In addition to determining the inception of cavitation, the thrust and torque coefficients  $K_t$  and  $K_q$  were obtained and plotted against  $\sigma$  for each  $J$  tested and are included in Figure 7. A dropping off of any of these curves from a straight line at low values of  $\sigma$  represents a loss in thrust

or torque due to cavitation. The  $\sigma$  for the point of change gives an indication of the highest operating speed without any performance loss for the  $J$  indicated. The cavitation characteristic curves were derived from these curves by plotting coefficients of  $K_t$  and  $K_q$  for discrete values of  $\sigma$  against  $J$ . These curves are presented in Figure 8.

When extrapolating any of these data to ship conditions, the standard pressure correction factor<sup>2</sup> for the 12-inch water tunnel should be applied to the ship cavitation index; i.e., the ship pressure  $p-p_v$  should be reduced to 85 percent of its actual value.

#### REFERENCES

1. BuShips ltr AOE/9440 Ser 644-173 of 6 Mar 1961.
2. Bowers, W. H., "The 12-Inch Variable Pressure Water Tunnel Propeller Testing Procedure," David Taylor Model Basin Report 505, page 22, (Nov 1943).

PROPELLERS 3924 & 3925

NUMBER OF BLADES...6

DIAMETER..... 8.697 Ins.

E.A.R. .... 0.661

PITCH At 0.7R...8.821 Ins.

M.W.R. .... 0.216

ROTATION ..3924 R.H. 3925 L.H.

B.T.F. .... 0.045

DESIGNED BY BUSHIPS

$P/D$  At 0.7R ... 1.014

TESTED FOR BUSHIPS

-4-

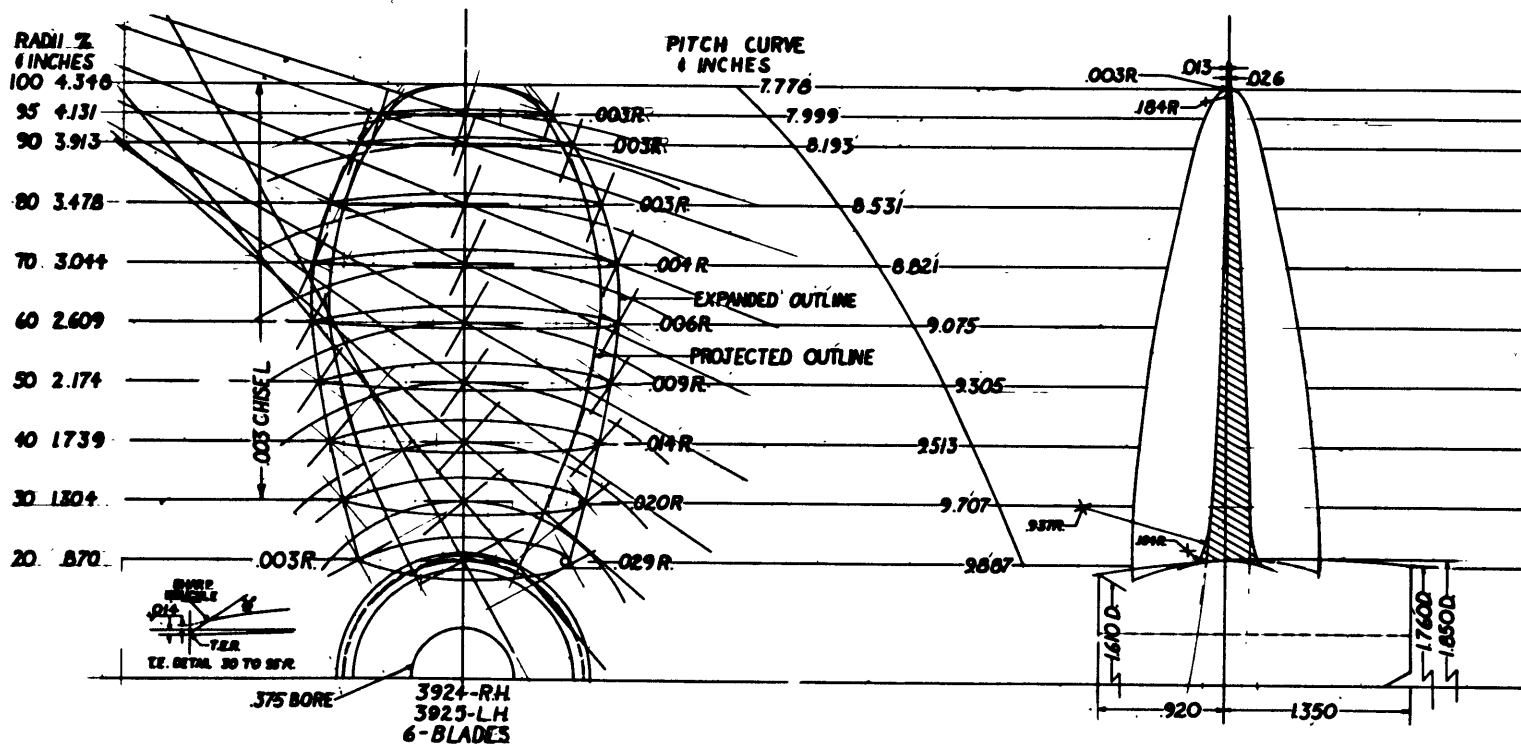


Figure 1 - Drawing of Model Propellers 3924 and 3925



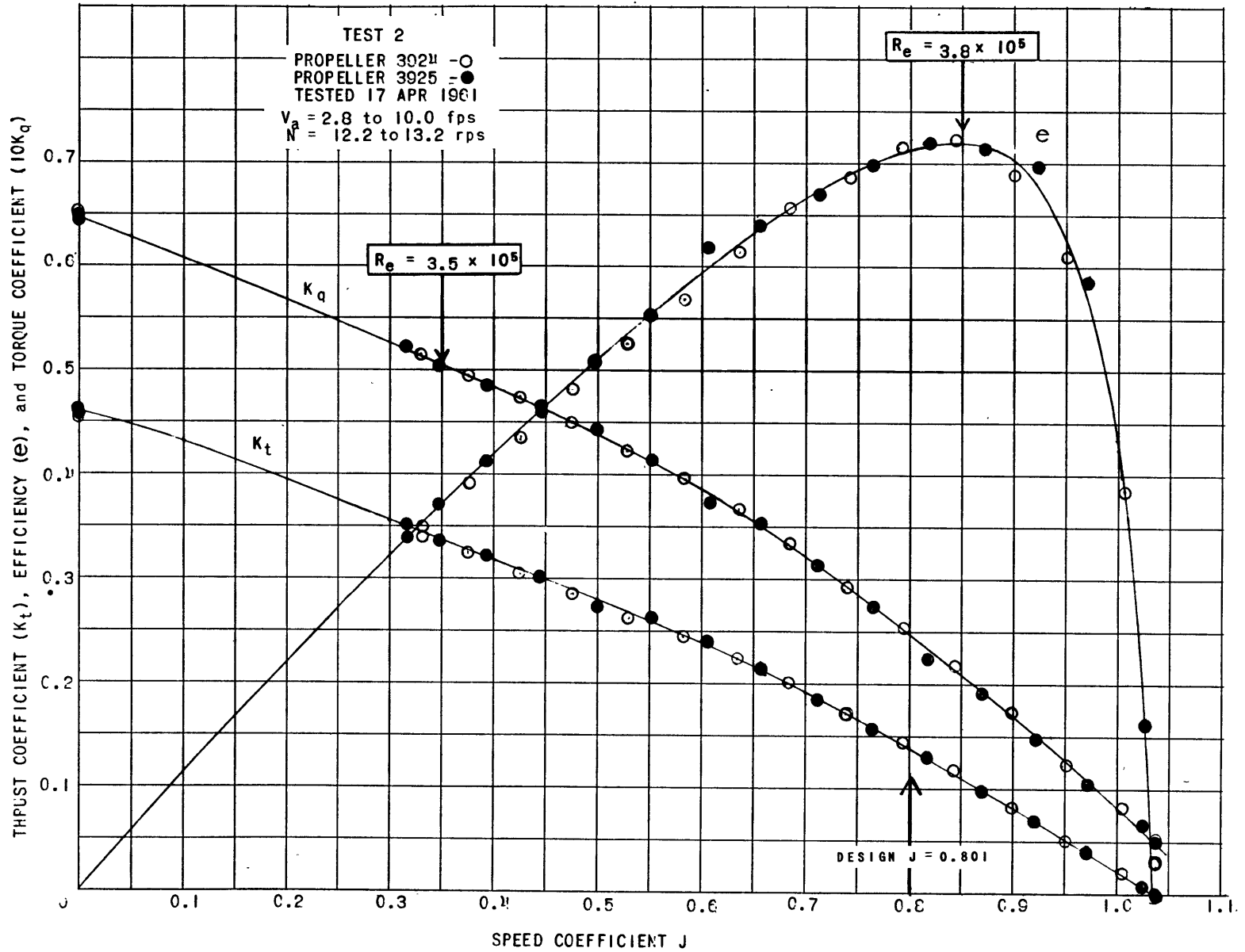


Figure 2 - Open-Water Characteristics of Model Propellers 3924 and 3925

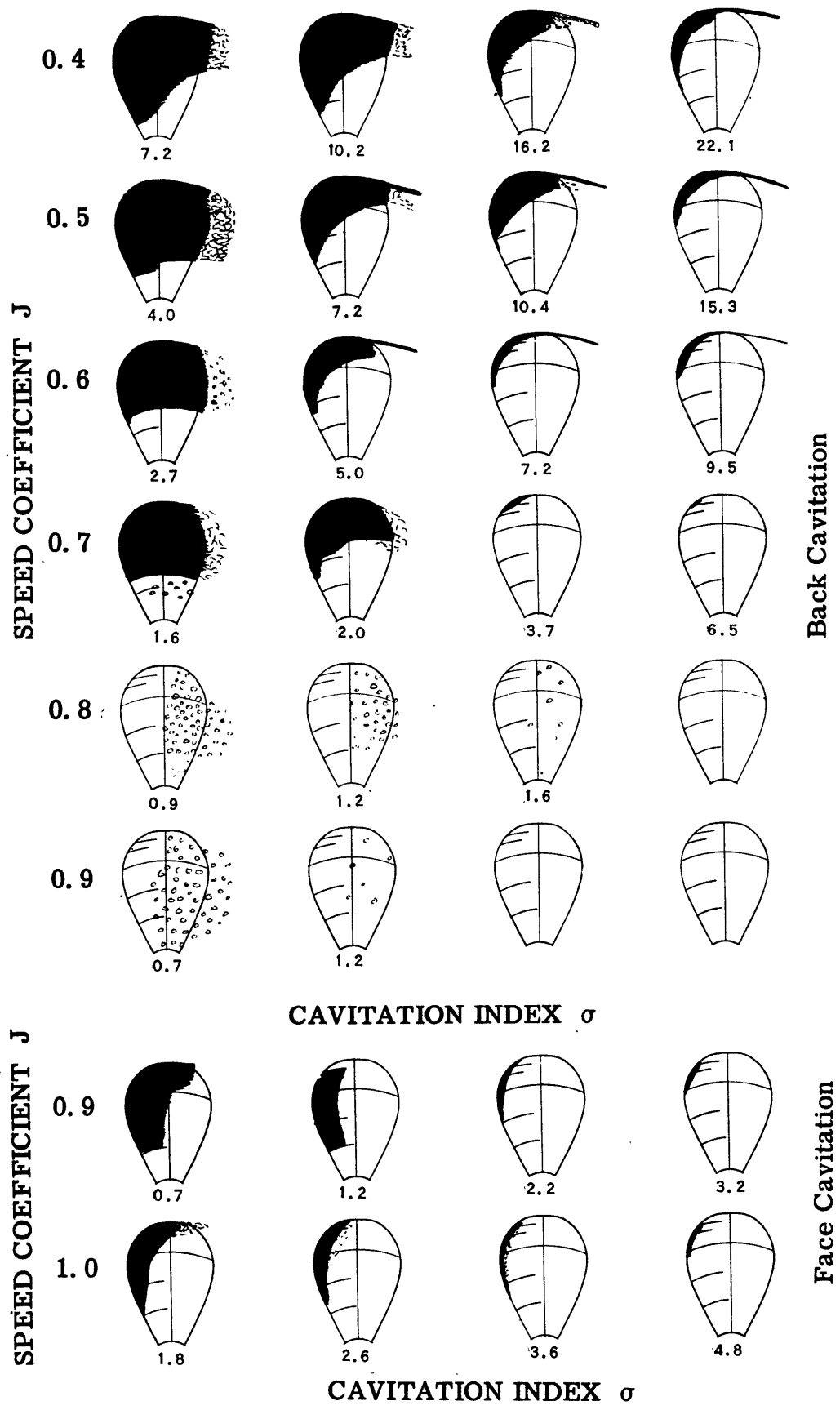
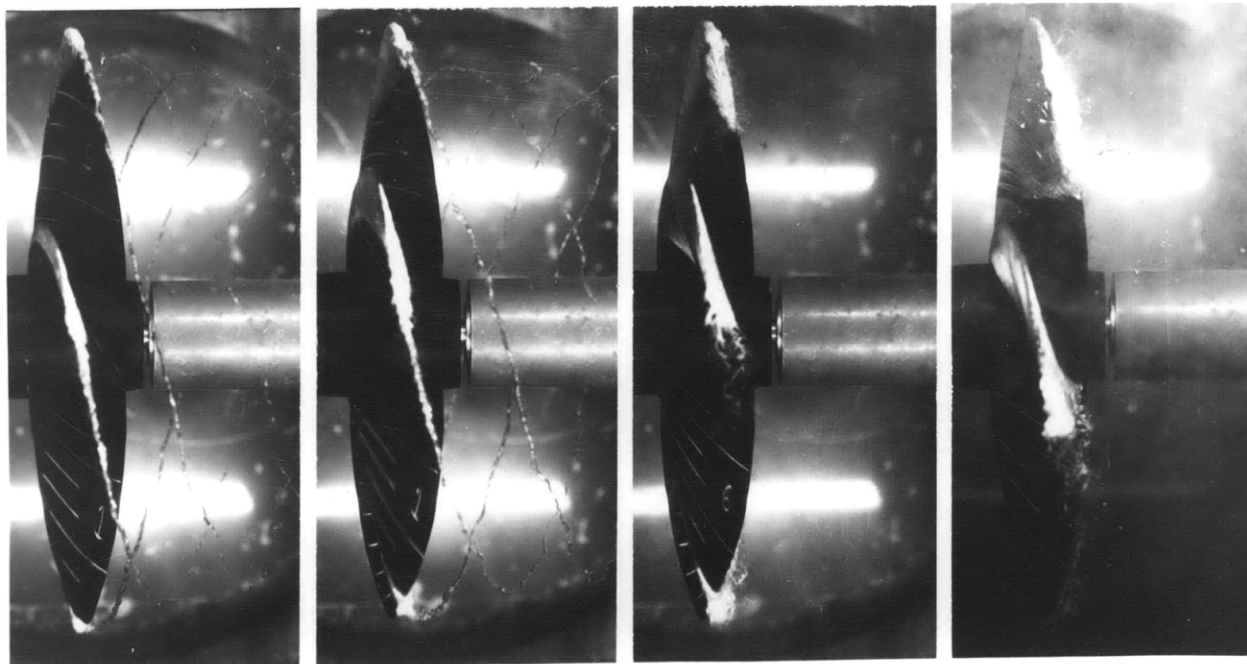


Figure 3 - Visual Observations of Cavitation on Propeller 3924



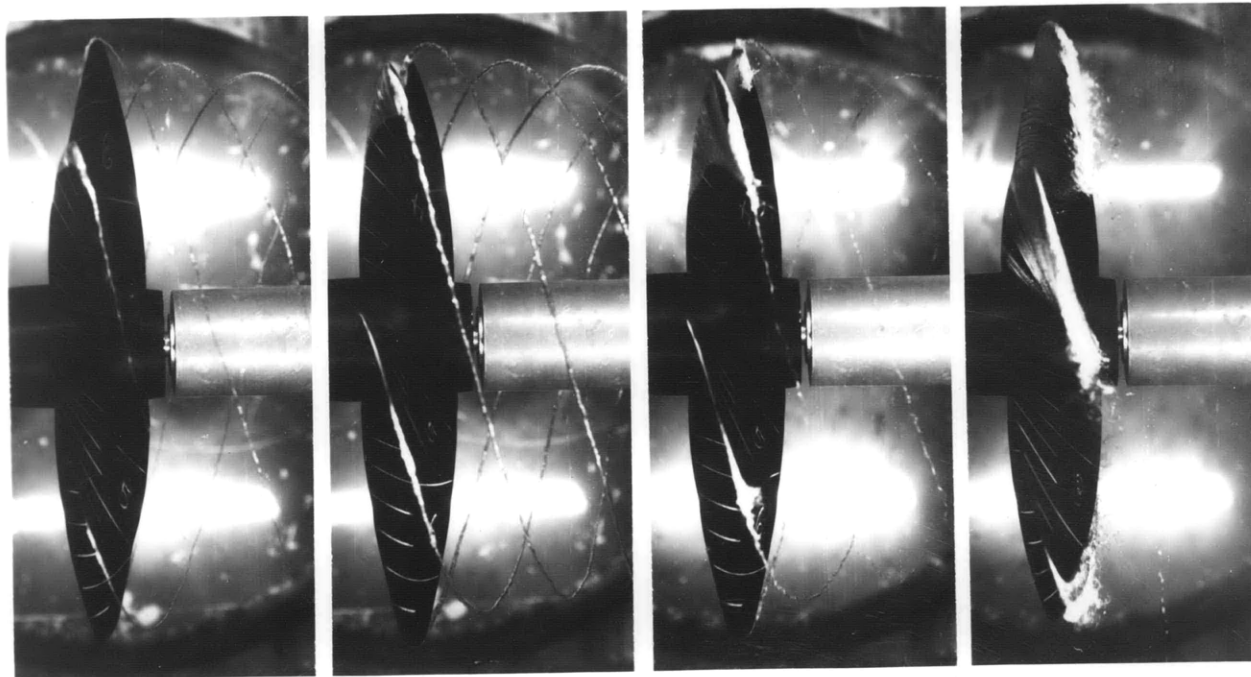
$\sigma = 22.1$

$\sigma = 16.2$

$\sigma = 10.2$

$\sigma = 7.2$

**J = 0.4**



$\sigma = 15.3$

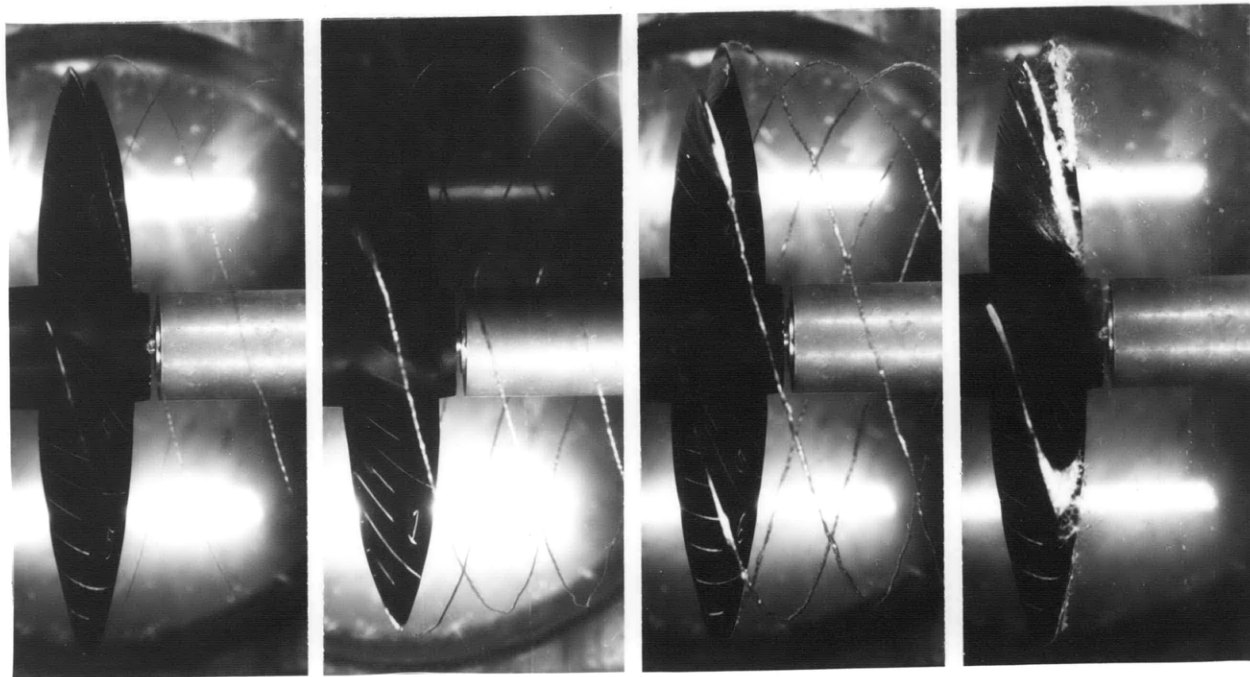
$\sigma = 10.4$

$\sigma = 7.2$

$\sigma = 4.0$

**J = 0.5**

Figure 4a - Photographs of Back Cavitation on Propeller 3924



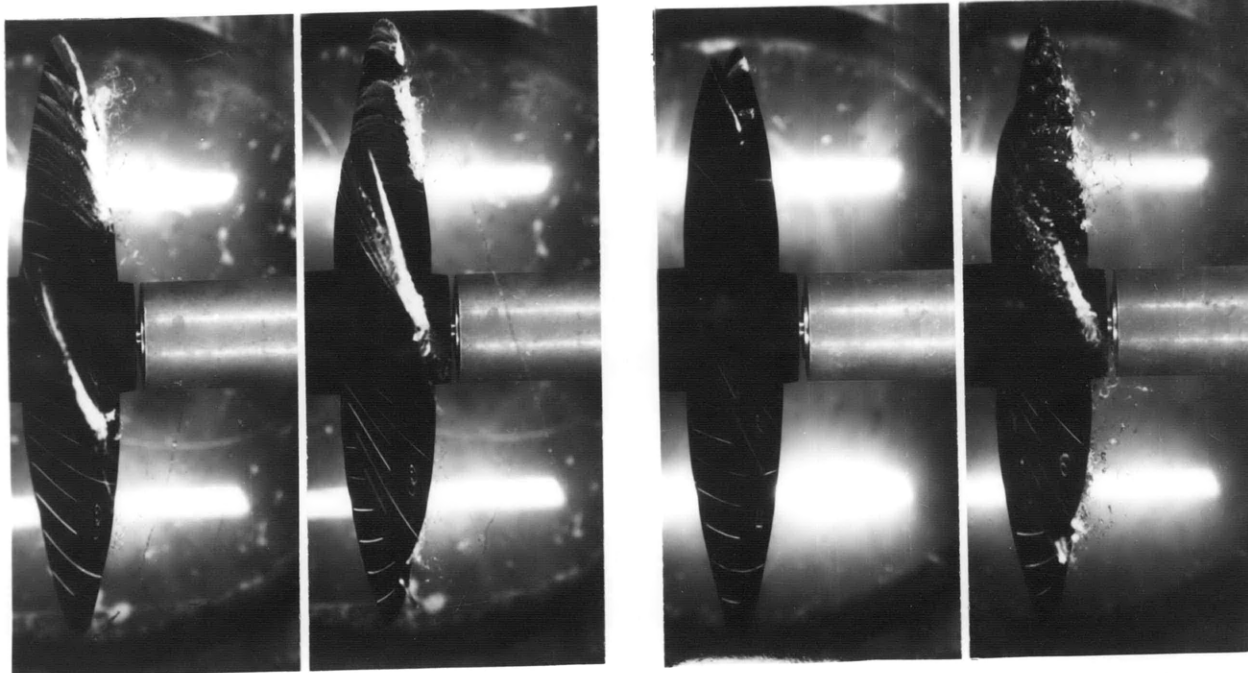
$\sigma = 9.5$

$\sigma = 7.2$

$\sigma = 5.0$

$\sigma = 2.7$

$J = 0.6$



$\sigma = 2.0$

$\sigma = 1.6$

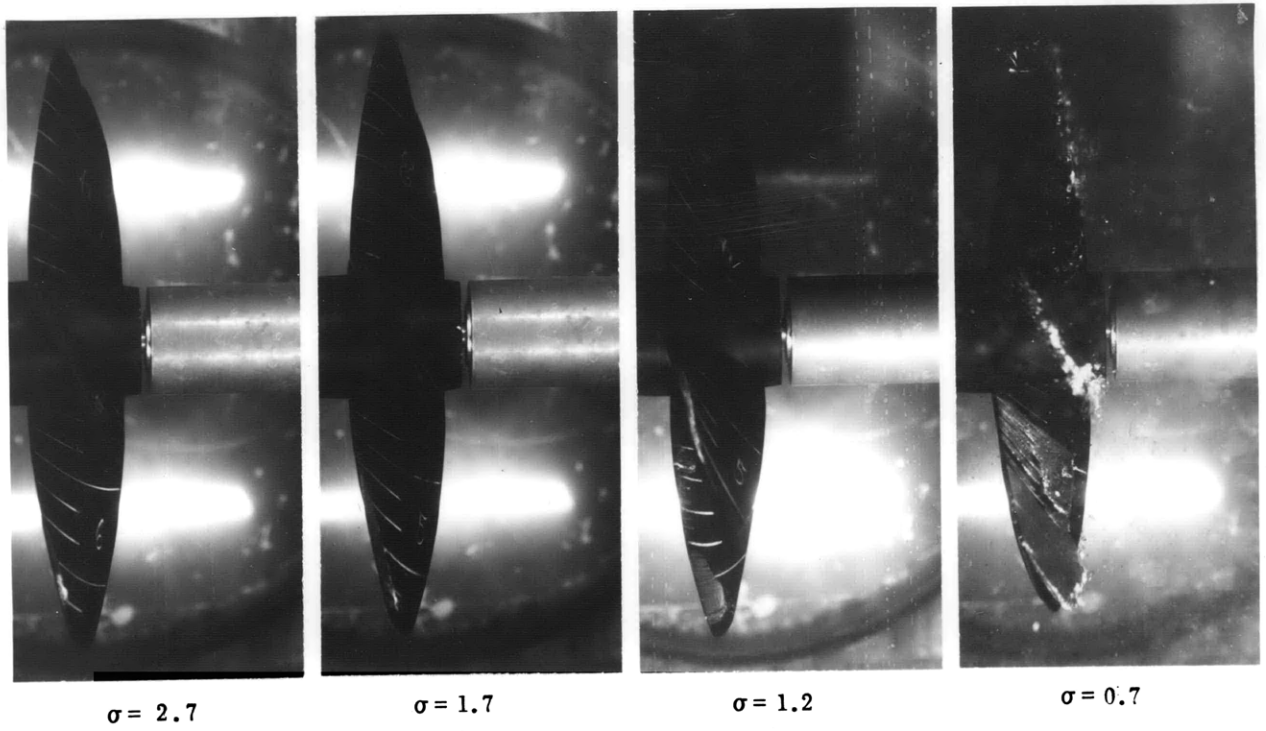
$\sigma = 1.6$

$\sigma = 0.9$

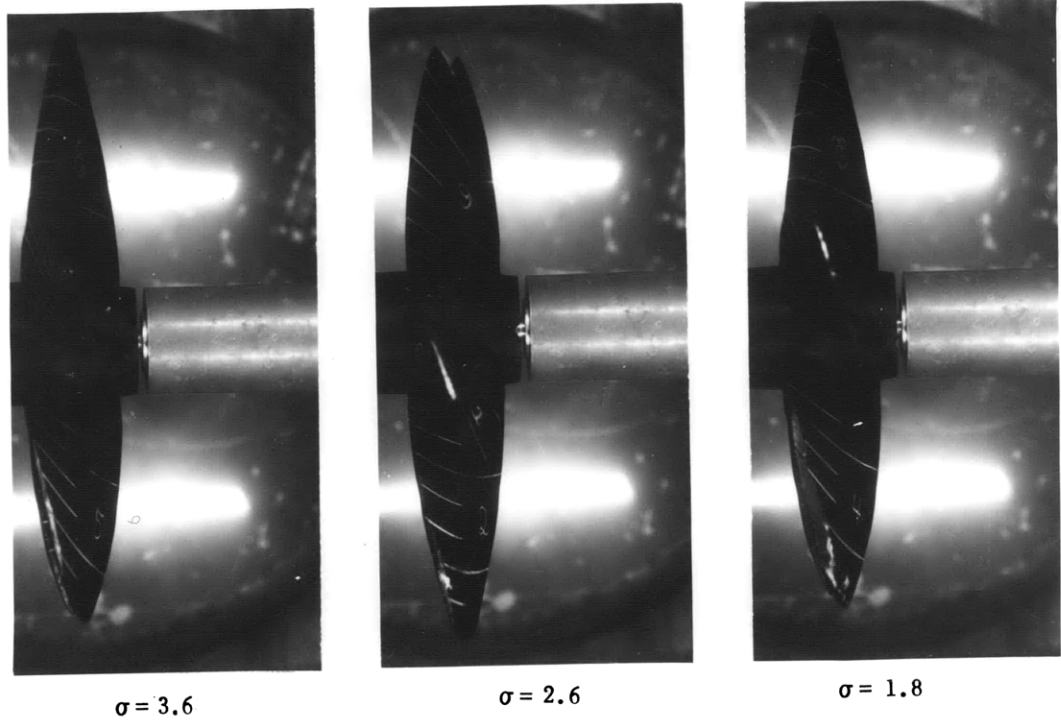
$J = 0.7$

$J = 0.81$

Figure 4b - Photographs of Back Cavitation on Propeller 3924



$J = 0.9$



$J = 1.0$

Figure 5 - Photographs of Face Cavitation on Propeller 3924

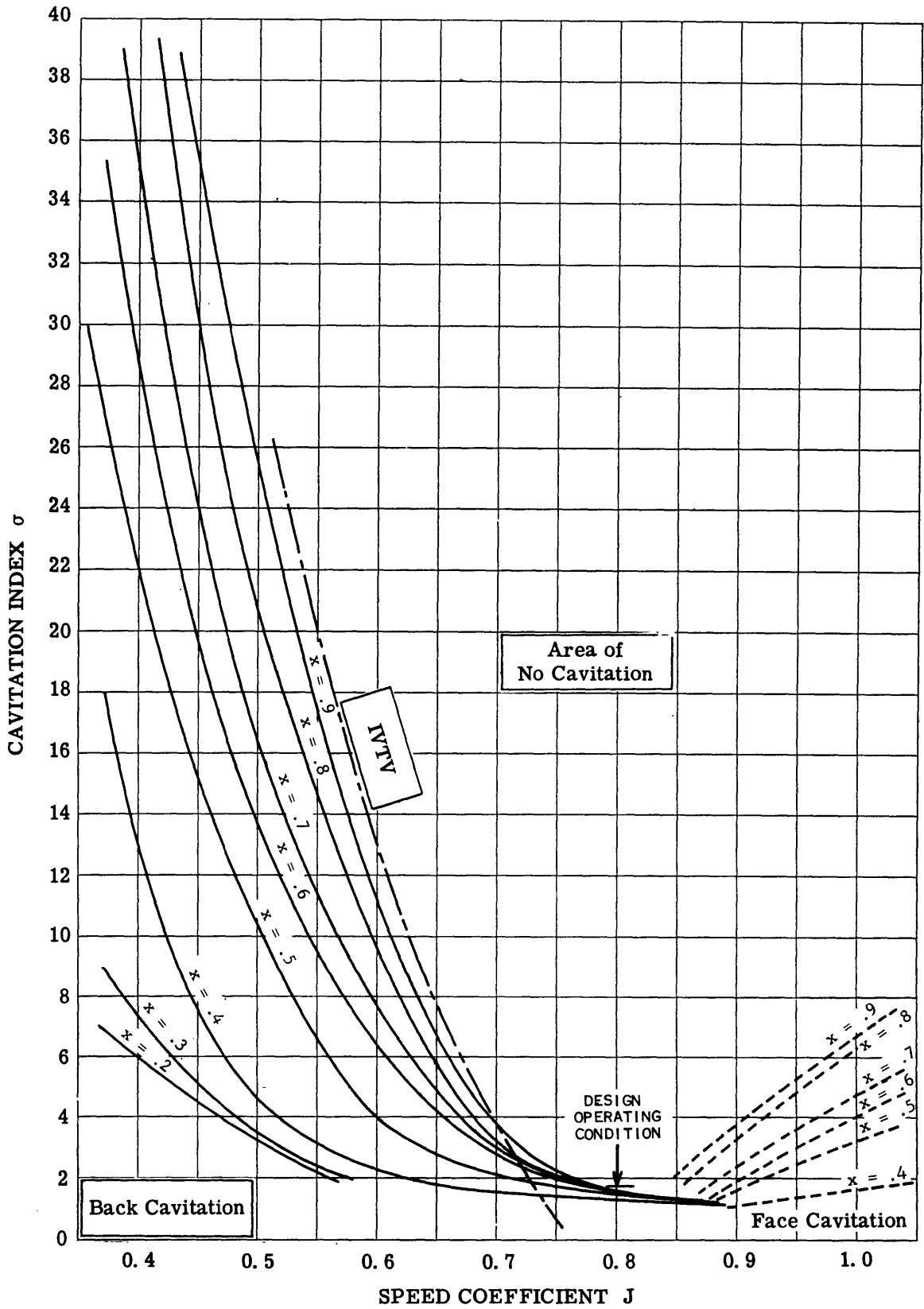


Figure 6 - Inception Curves of Visible Cavitation on Propeller 3924

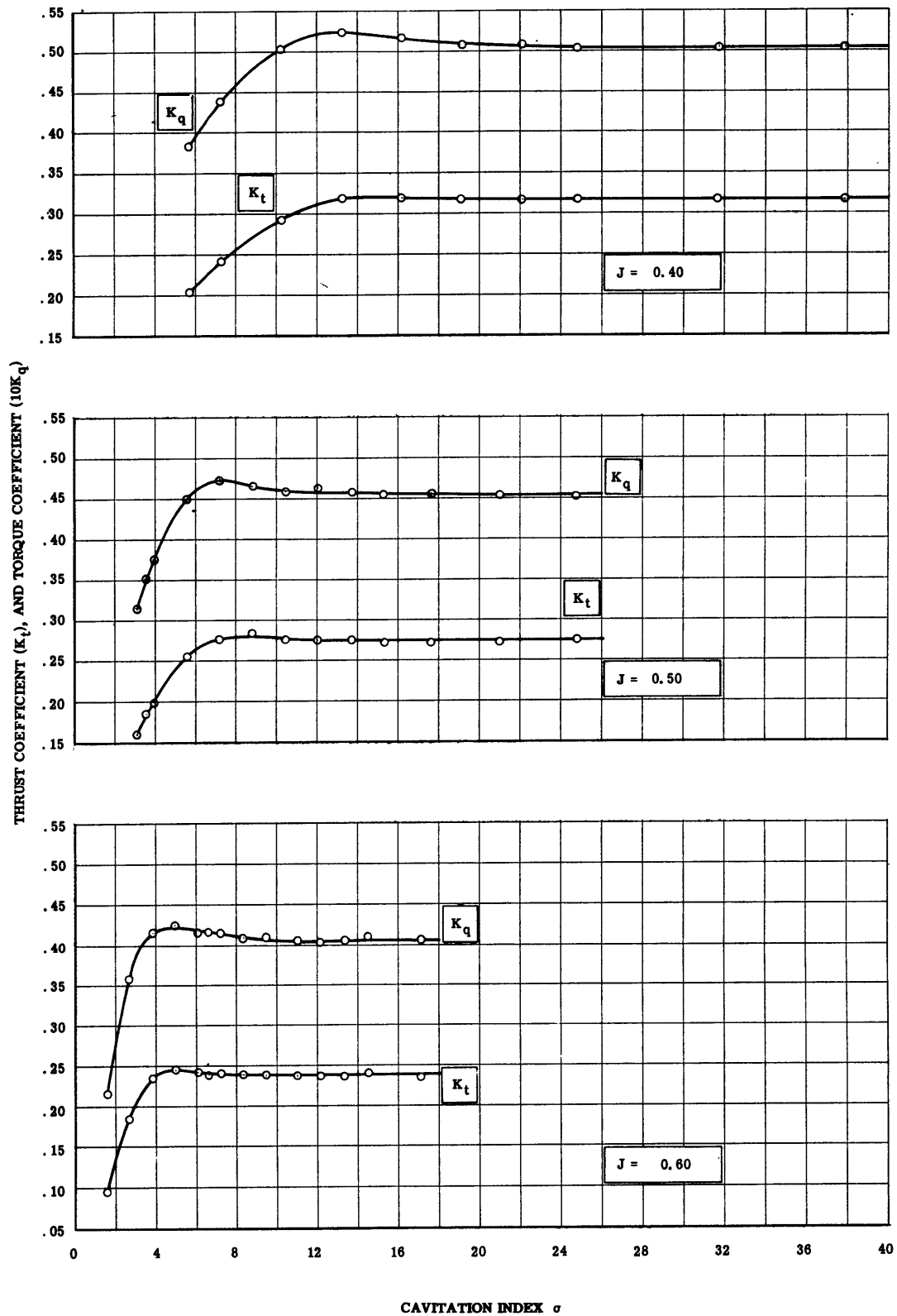


Figure 7a - Variation in Thrust and Torque Coefficients with Cavitation Index for Propeller 3924

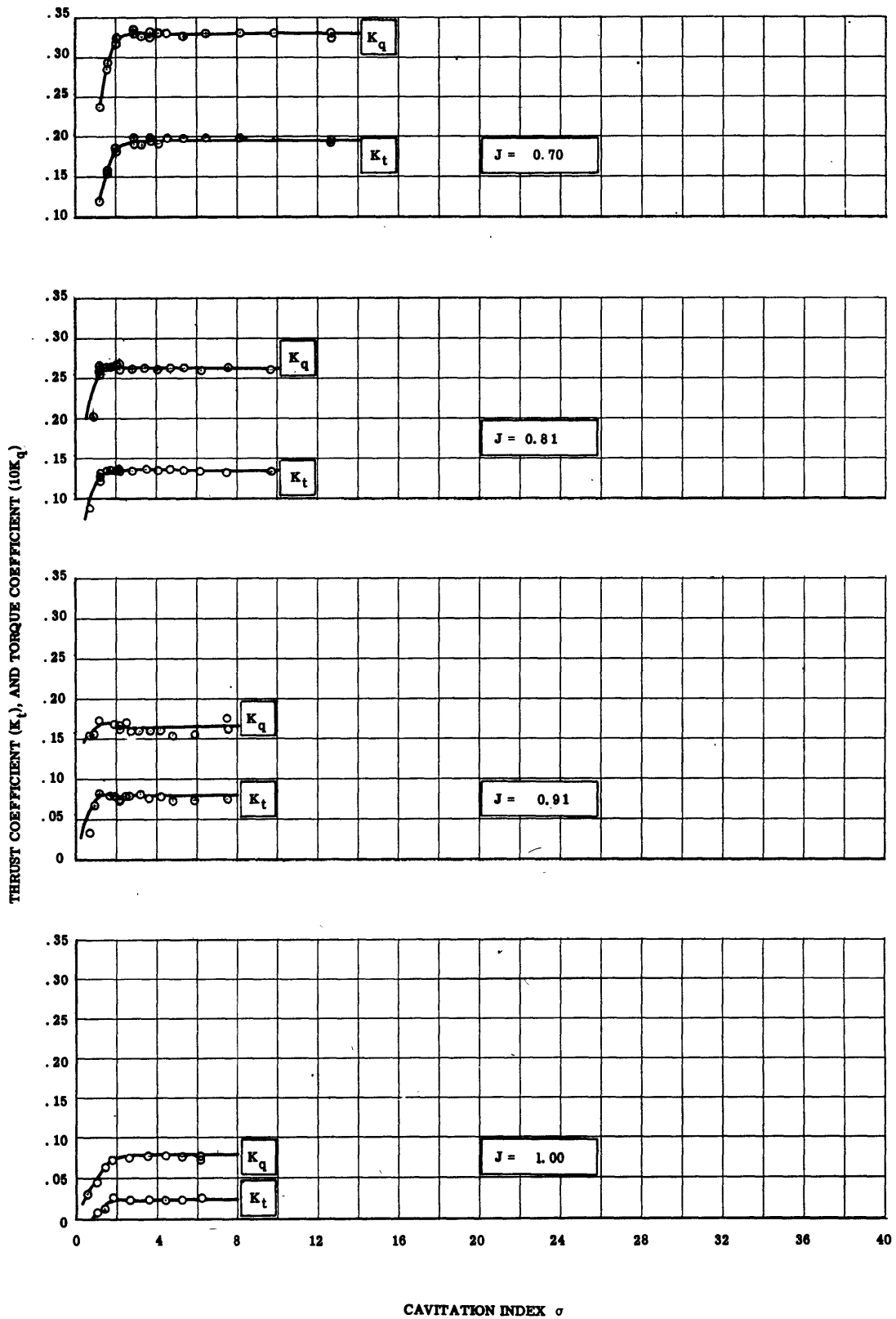


Figure 7b - Variation in Thrust and Torque Coefficients with Cavitation Index for Propeller 3924



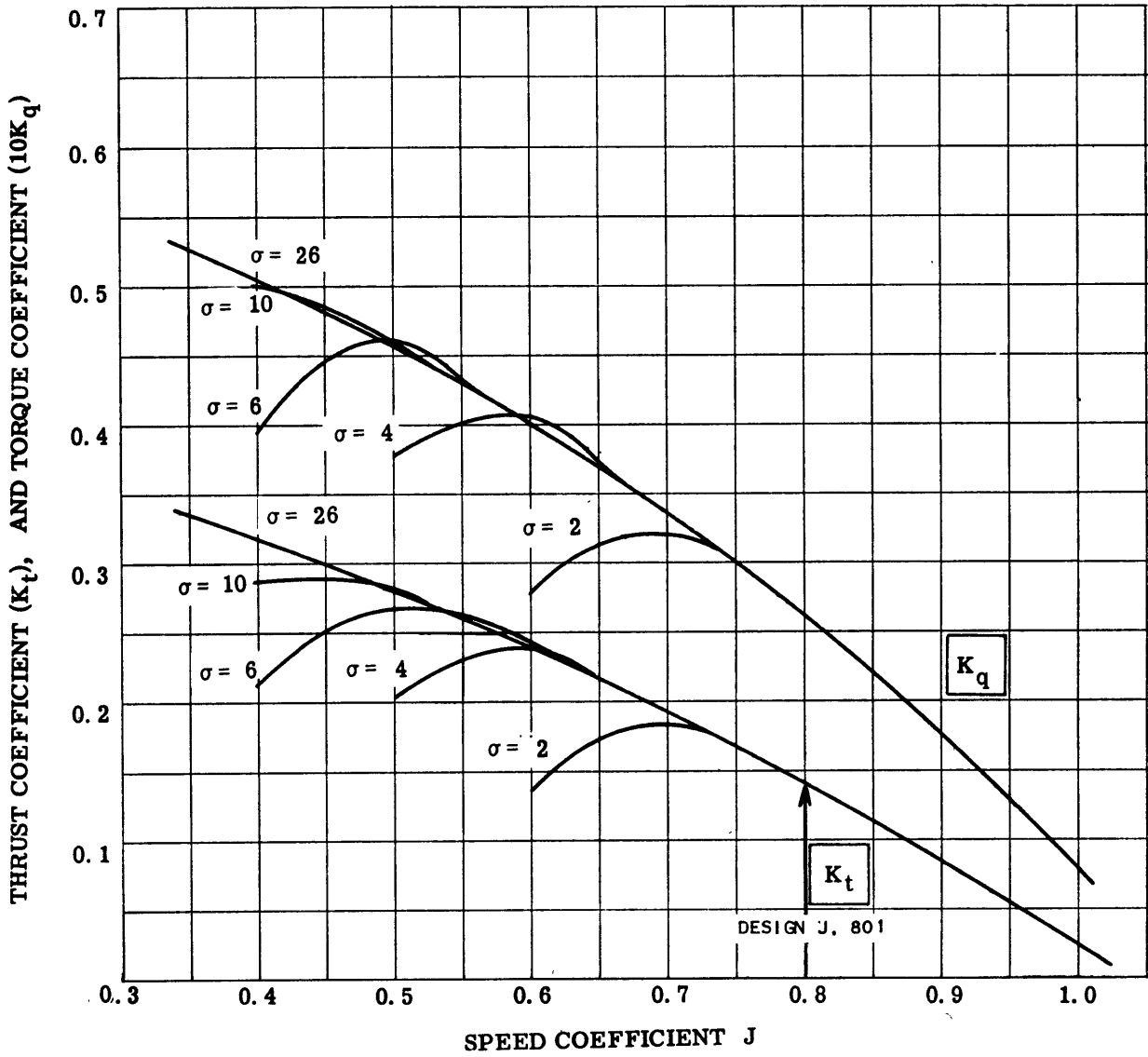


Figure 8 - Cavitation Characteristic Curves of Propeller 3924

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  3. Propellers--Design--Model tests
  4. Propeller models--Model TMB 3924-3925
  5. AOE-1 (U.S. fast combat support ship)
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