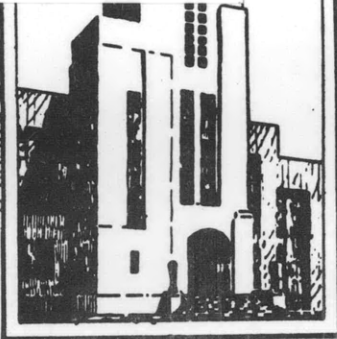


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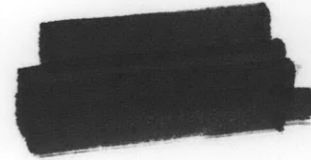
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APPLIED
MATHEMATICS

BACKING CHARACTERISTICS OF
SUPERCAVITATING PROPELLERS

by



Richard Hecker and N.A. McDonald



HYDROMECHANICS LABORATORY
TEST EVALUATION REPORT

January 1962

Report 1604



BACKING CHARACTERISTICS OF
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NOTATION

BTF	Blade thickness fraction
D	Diameter
e	Efficiency, $(\frac{T V}{2\pi Q n})$
EAR	Expanded area ratio
g	Acceleration due to gravity
H	Total head at shaft centerline less vapor pressure
J	Speed coefficient, $(\frac{V}{n D})$
K_q	Torque coefficient, $(\frac{Q}{\rho n^3 D^5})$
K_t	Thrust coefficient, $(\frac{T}{\rho n^2 D^4})$
n	Revolutions per unit time
P	Pitch
Q	Torque
T	Thrust
V	Speed of advance
Z	Number of blades
ρ	Mass density
σ	Cavitation index, $(\frac{2g H}{V^2})$

ABSTRACT

Six supercavitating propellers were tested to determine their backing characteristics. The propellers tested were TMB propellers 3671A, 3767, 3768, 3769, 3770, and 3820.

The tests were performed in open water and in the TMB 24-inch variable pressure water tunnel at several cavitation indices over a range of speed coefficients.

INTRODUCTION

As far as is known, the backing performance of supercavitating propellers has been reported only once.¹ In that instance the cavitation numbers at which the tests were performed were quite high. Hence, in order to obtain the backing characteristics of supercavitating propellers over a range of cavitation indices, six model supercavitating propellers were tested in the backing condition. The tests were performed in open water and in the TMB 24-inch variable pressure water tunnel.

The propellers tested were TMB propellers 3671A, 3767, 3768, 3769, 3770, and 3820. Physical characteristics are given in Table 1. Drawings of the propellers are given at the end of the report in Figures 25 through 30. The powering and cavitation characteristics of these propellers in the ahead condition have been reported previously in TMB reports, i.e., References 3, 4, and 5. Propellers 3767, 3768, 3769, and 3770 were designed as part of the TMB 3-bladed Series² and their experimental performance was reported in Reference 3. Propellers 3820 and 3671A have been reported in References 4 and 5, respectively.

APPARATUS AND PROCEDURES

The evaluation of the model propellers was conducted in uniform flow in the TMB 24-inch variable pressure water tunnel. The thrust, torque, and rpm were measured with the 150-horsepower dynamometer. The thrust and torque readings are accurate to 1%; and the rpm is accurate to within ± 1 count. The water velocity during the tests was measured with a pitot tube mounted

¹ References are listed on page 3.

in the plane of the propeller blade centerline at a radial distance of ten inches from the shaft centerline. The pitot tube openings are connected to a mercury manometer allowing the average water speed to be measured within ± 0.1 fps. The tunnel pressure is also measured by means of mercury manometers. A telescopic sight is provided for reading the mercury level. In this way the tunnel pressure can be maintained to within ± 0.01 psi. The open water backing tests were run in the TMB deep water basin using the 35-HP dynamometer.

The backing tests described here were performed by turning the propeller around on the shaft and maintaining the usual directions of rotation and water flow. For these tests, thrust in the direction of water flow and the corresponding torque were considered positive.

Each propeller was tested at several discrete cavitation indices over a range of speed coefficients. The procedure was to set a water speed and tunnel pressure and hold them constant during the tests, thus keeping the cavitation index constant. The speed coefficient was then varied by changing the propeller rpm. Photographs of the propellers were taken during the tunnel tests.

RESULTS

The test data are presented in terms of the usual nondimensional coefficients. The thrust coefficient, K_t , torque coefficient, K_q , and efficiency, e , are plotted against the speed coefficient, J . The sign convention, described in the preceding section, was chosen so that all coefficients remain positive.

The results are presented as a series of curves for each propeller. Each curve represents one set of tests performed at a constant cavitation index. In addition to the curves, photographs which were taken during the tests are presented as additional figures. The photographs can easily be correlated with the curves since the σ and J for each photograph is given. Table 2 is a summary of the results presented in this report.

The test results generally follow the same trend in the backing condition as in the ahead condition. That is, the thrust and torque coefficients decrease with decreasing cavitation number. The decrease is more pronounced

than in the ahead condition and from an examination of the photographs it can be seen that in many cases both sides of the propeller blade are covered or partially covered with cavitation. Considering that the blunt trailing edge acts as the leading edge in the backing condition, severe cavitation is to be expected.

REFERENCES

1. Tachmindji, A.J., et al, "The Design and Performance of Supercavitating Propellers", David Taylor Model Basin Report C-807 (Feb 1959).
2. Caster, E.B., "TMB 3-Bladed Supercavitating Propeller Series", David Taylor Model Basin Report 1245 (Aug 1959).
3. Hecker, R. and Peck, J.G., "Experimental Performance of TMB Supercavitating Propellers 3767, 3768, 3769, 3770, 3785, and 3820", David Taylor Model Basin Report 1553 (Aug 1961).
4. Venning, E., "Applicability of a Supercavitating Propeller to a Small Speedboat", David Taylor Model Basin Report 1459 (Nov 1960).
5. Hecker, R., "Powering Performance of a Ventilated Propeller", David Taylor Model Basin Report 1487 (Jun 1961).

TABLE 1

Physical Characteristics of the Propellers

Propeller	3671A	3767	3768	3769	3770	3820
Diameter inches	14.00	16.00	10.00	14.00	14.00	15.50
(Pitch) 0.7 inches	21.00	18.886	11.80	14.08	11.004	25.241
(P/D) _{0.7}	1.5	1.180	1.180	1.006	.786	1.628
No. of Blades	2	3	3	3	3	3
EAR	0.154	0.506	0.506	0.512	0.508	0.505
BTF	0.055	0.029	0.019	0.019	0.062	0.027

TABLE 2

Summary of Backing Tests

Propeller	Test σ	Test J	Figure	
			Test Data	Photographs
3671A	Open water	0 - 1.25	1	
	4.0	0.3 - 1.25	1	2
	1.0	0.25 - 0.95	1	3
	0.4	0.45 - 0.85	1	4
3767	Open water	0 - 0.9	5	
	3.89	0.35 - 0.9	5	6
	1.679	0.35 - 1.0	5	7
	0.601	0.4 - 0.75	5	8
3768	Open water	0 - 0.9	9	
	4.00	0.35 - 0.95	9	10
	1.679	0.3 - 0.95	9	11
	0.601	0.45 - 0.75	9	12
3769	Open water	0 - 0.9	13	
	3.89	0.25 - 0.9	13	14
	0.69	0.3 - 1.0	13	15
	0.19	0.65 - 0.9	13	16
3770	Open water	0 - 0.6	17	
	3.89	0.3 - 0.65	17	18
	1.20	0.25 - 0.70	17	19
	0.5	0.3 - 0.65	17	20
3820	Open water	0 - 1.3	21	
	4.0	0.4 - 1.4	21	22
	2.0	0.4 - 1.4	21	23
	1.0	0.4 - 1.4	21	24

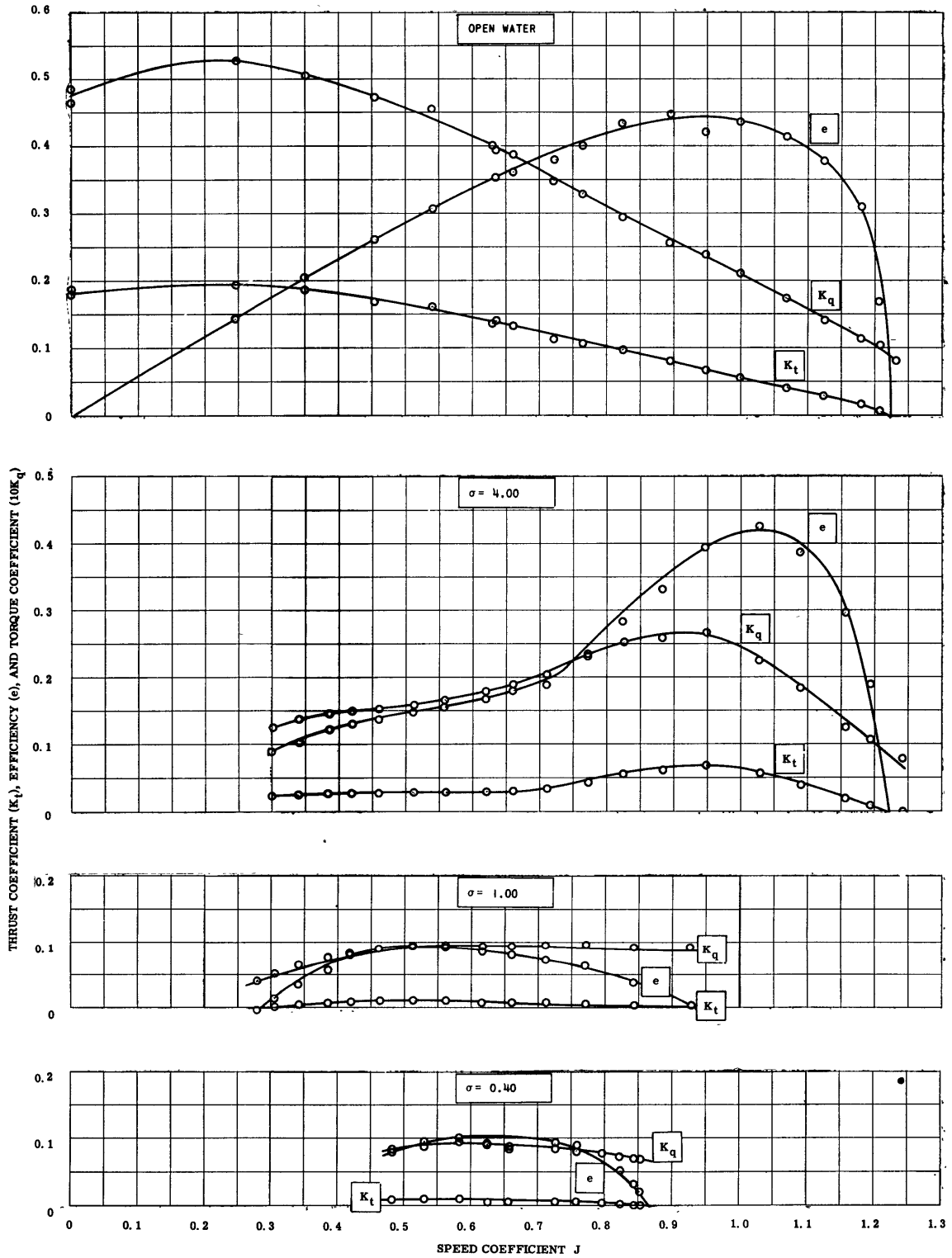
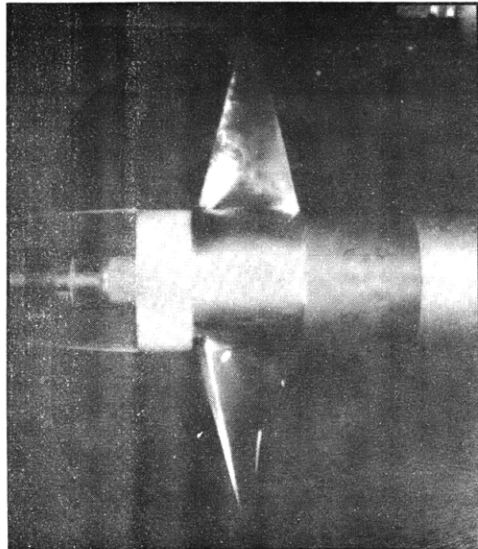
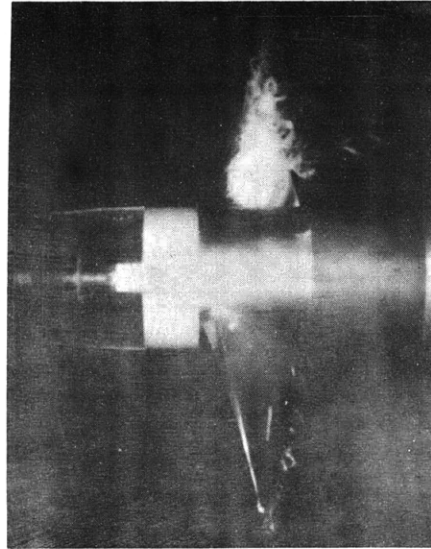


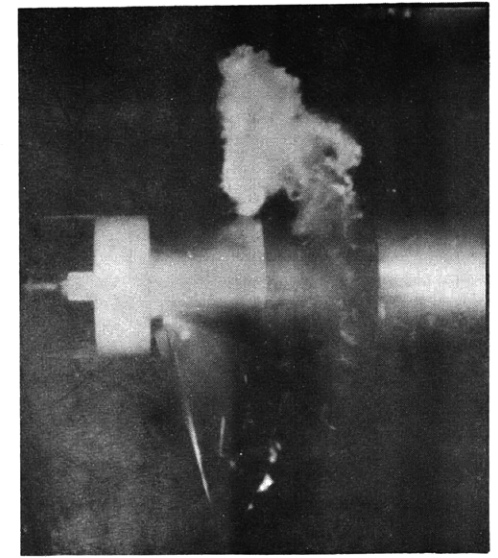
Figure 1 - Backing Performance of Propeller 3671A



J = 1.242

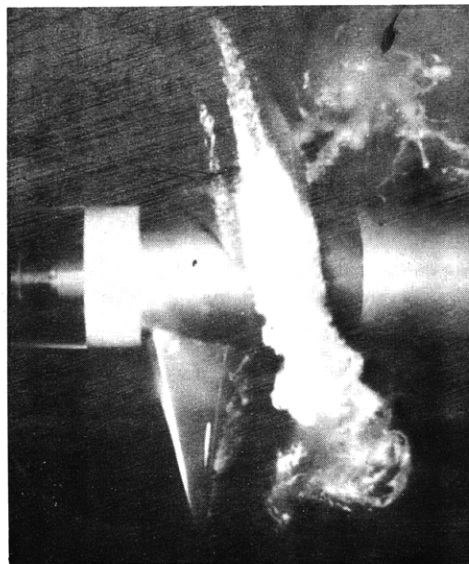


J = 0.882

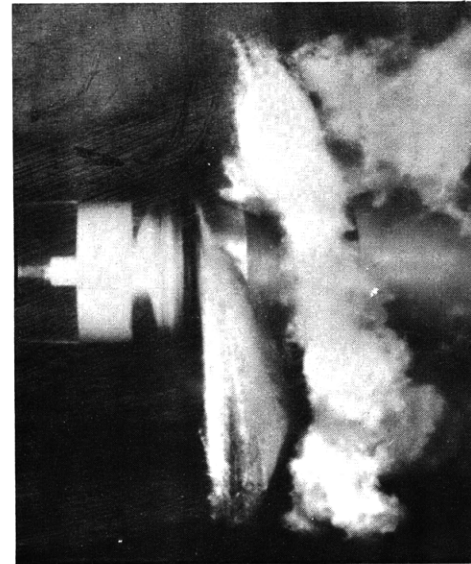


J = 0.560

9

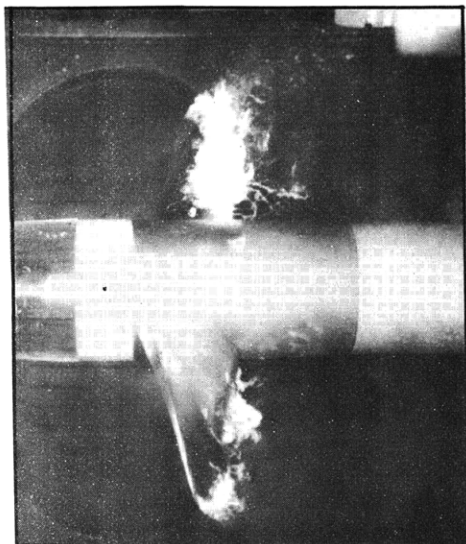


J = 0.421

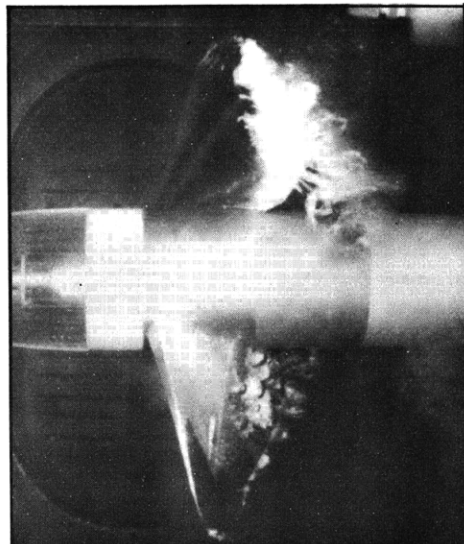


J = 0.307

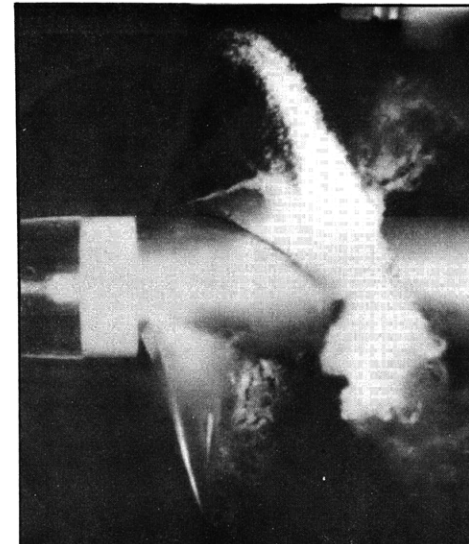
Figure 2 - Photographs of Propeller 3671A Backing, $\sigma = 4.00$



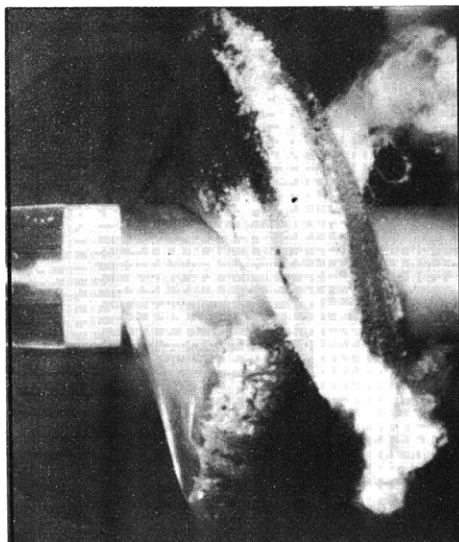
J = 1.322



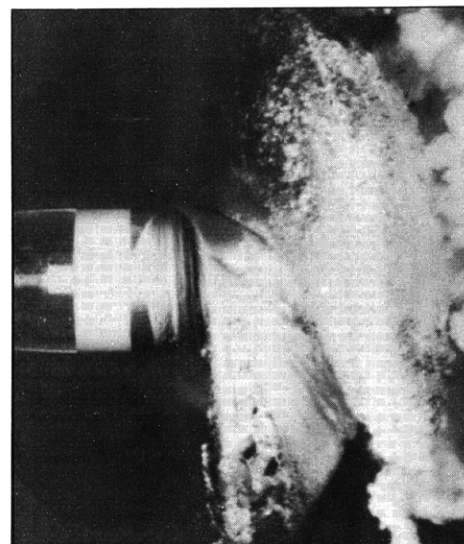
J = 1.029



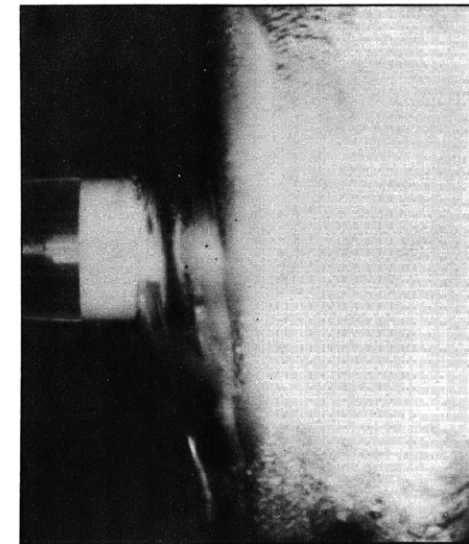
J = 0.771



J = 0.617

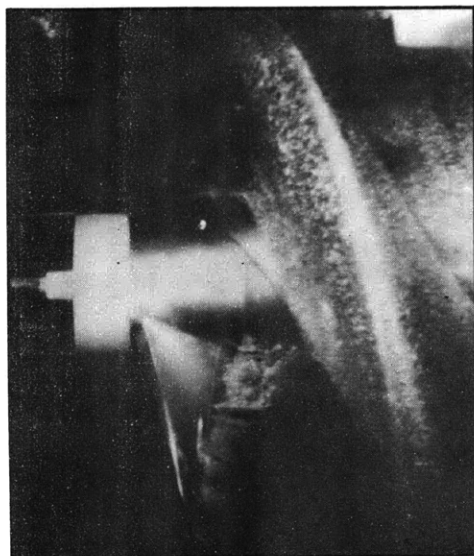


J = 0.463

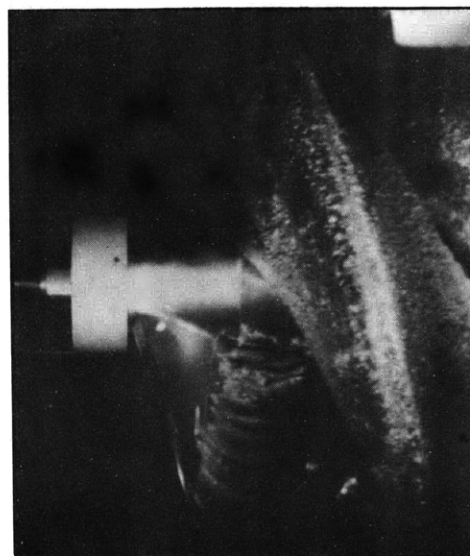


J = 0.255

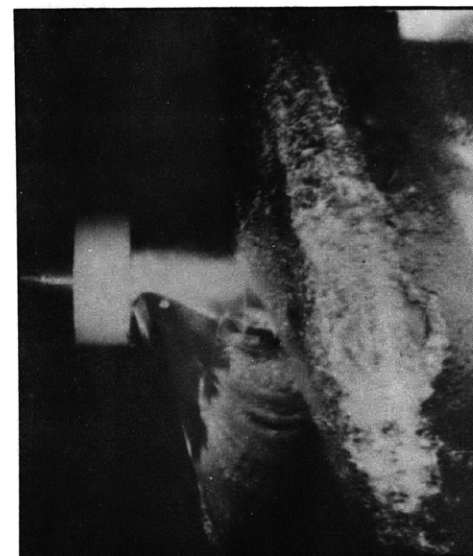
Figure 3 - Photographs of Propeller 3671A Backing, $\sigma = 1.00$



J = 0.852

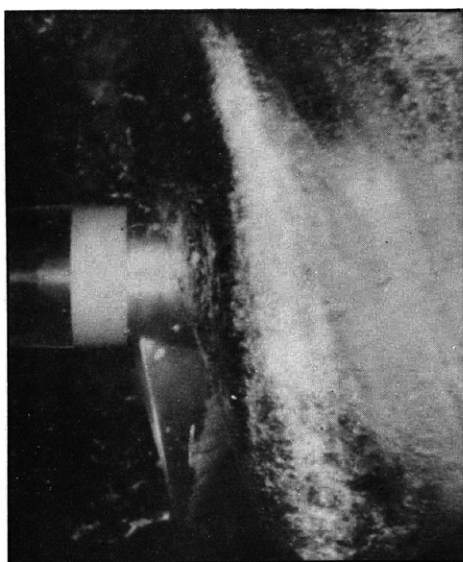


J = 0.797

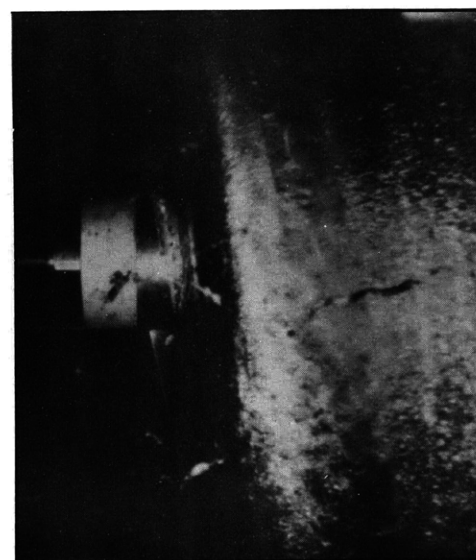


J = 0.657

∞



J = 0.584



J = 0.484

Figure 4 - Photographs of Propeller 3671A Backing, $\sigma = 0.40$

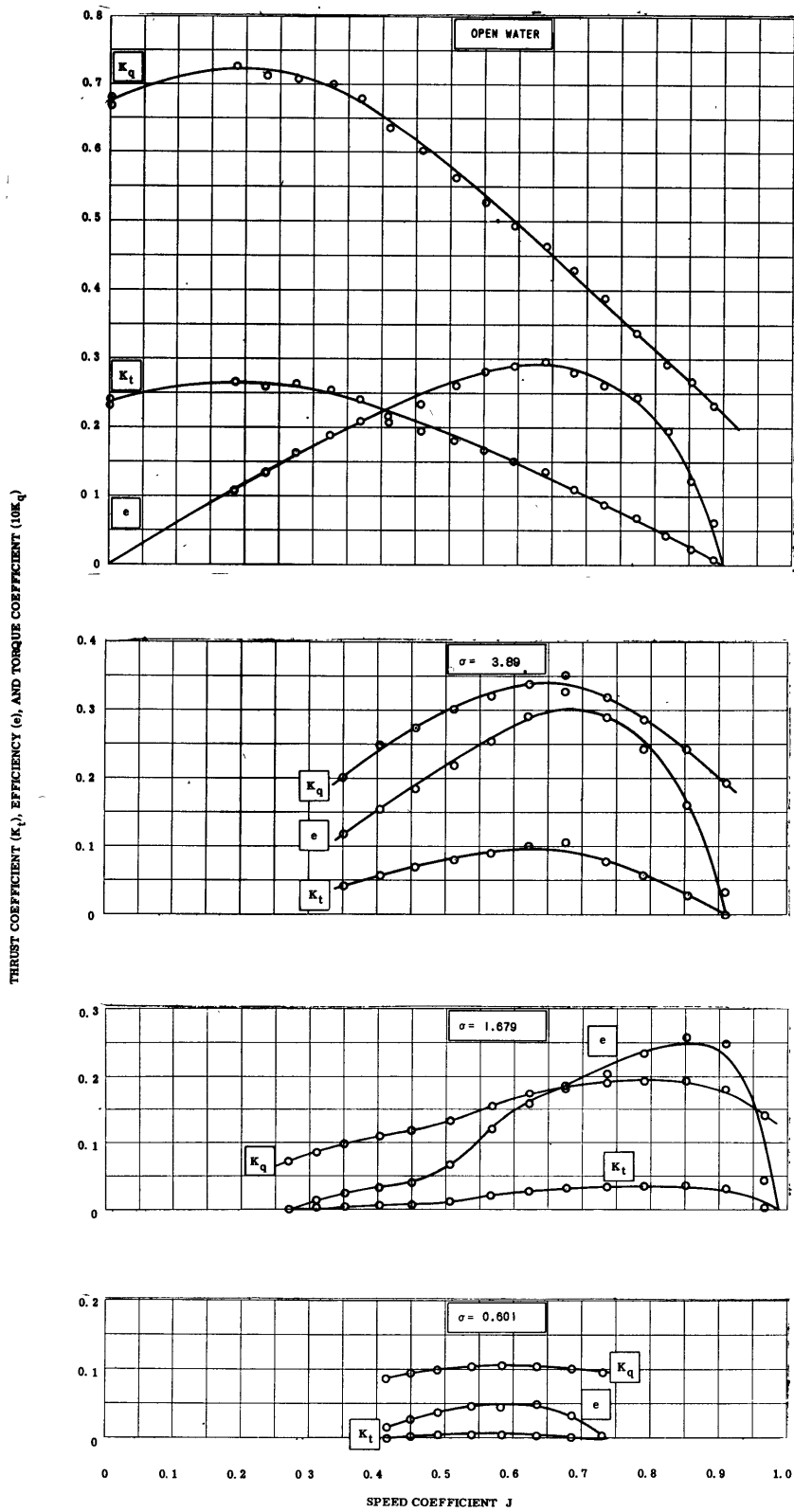
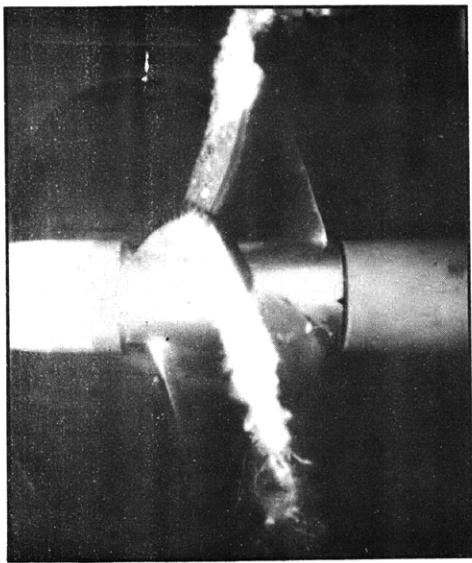
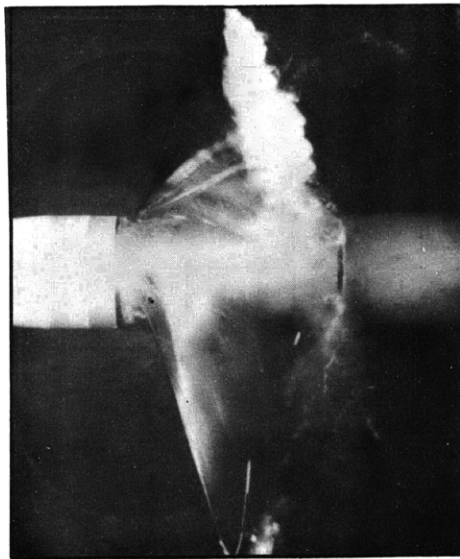


Figure 5 - Backing Performance of Propeller 3767



J = 0.909



J = 0.736



J = 0.568

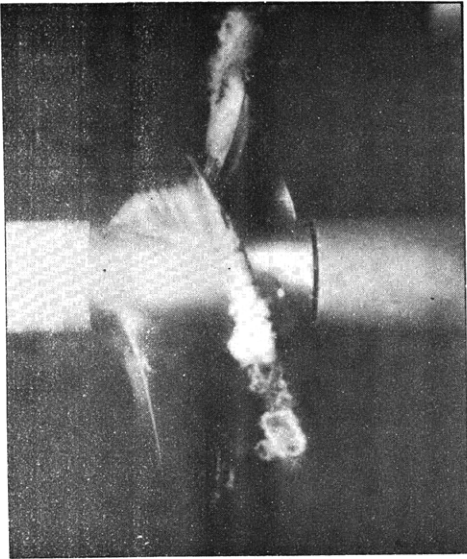


J = 0.457

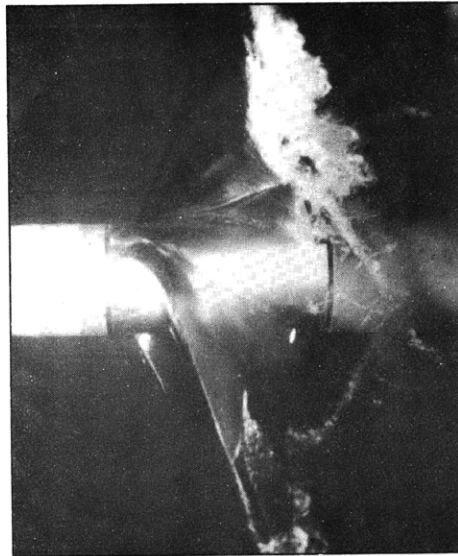


J = 0.352

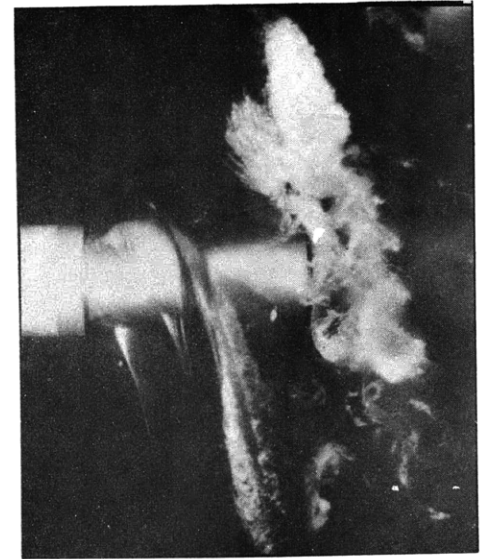
Figure 6 - Photographs of Propeller 3767 Backing, $\sigma = 3.89$



J = 0.966

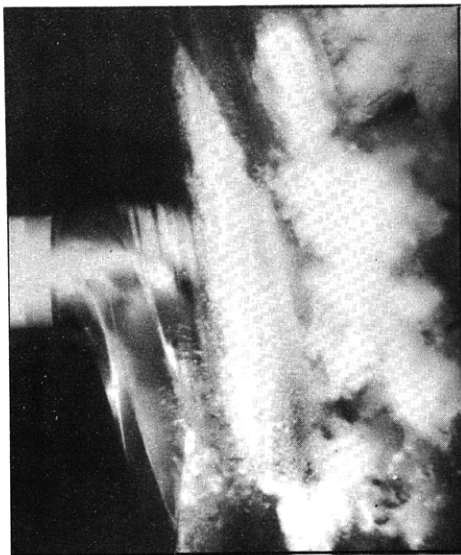


J = 0.790



J = 0.623

11



J = 0.450



J = 0.311

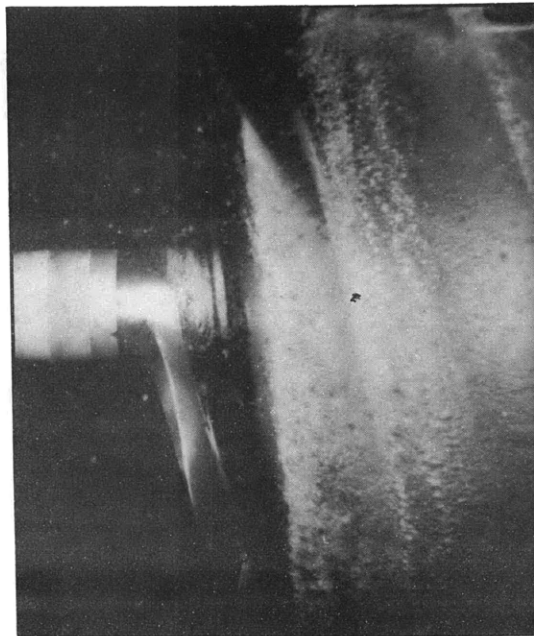
Figure 7 - Photographs of Propeller 3767 Backing, $\sigma = 1.679$



J = 0.731



J = 0.584



J = 0.450

Figure 8 - Photographs of Propeller 3767 Backing, $\sigma = 0.601$

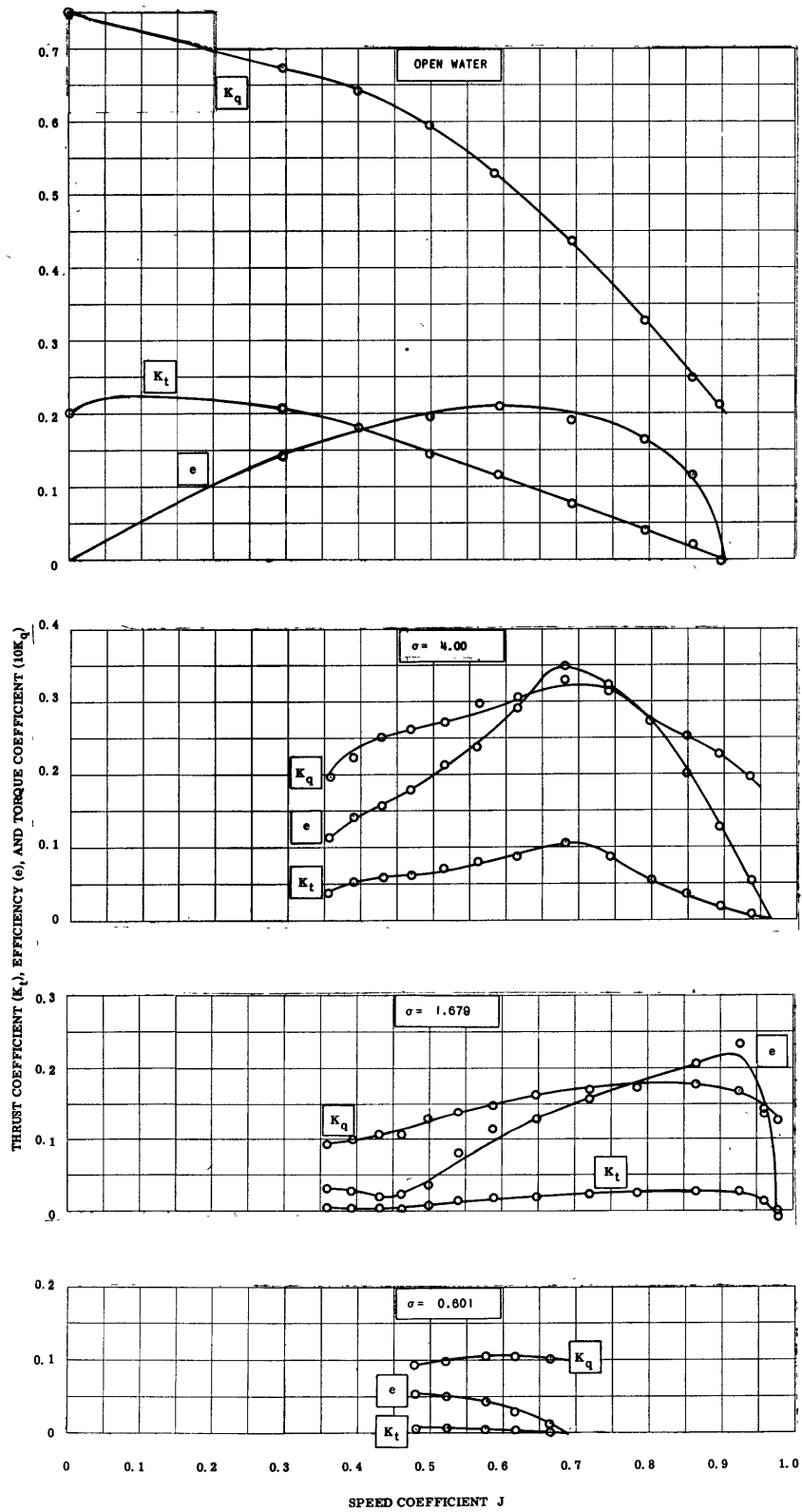
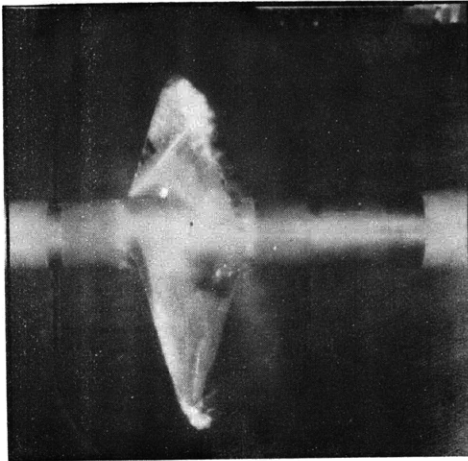
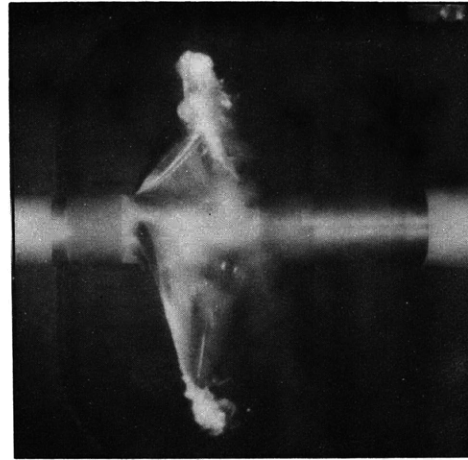


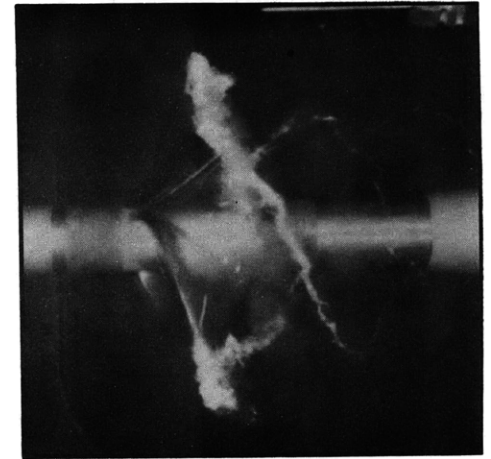
Figure 9 - Backing Performance of Propeller 3768



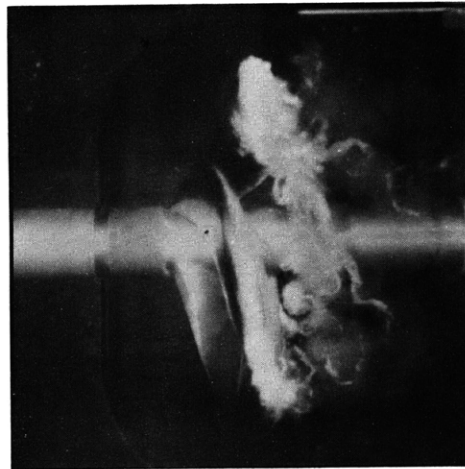
J = 0.936



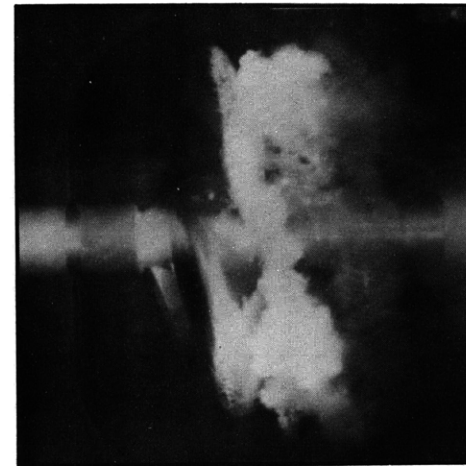
J = 0.798



J = 0.617

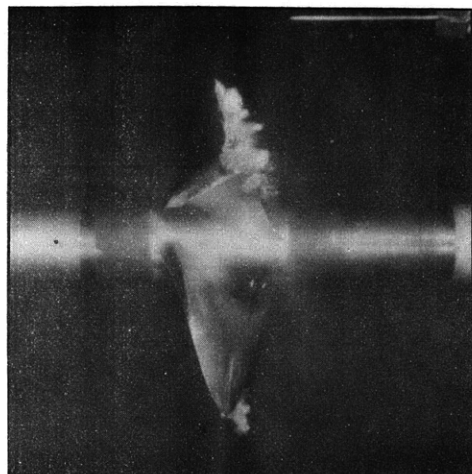


J = 0.471

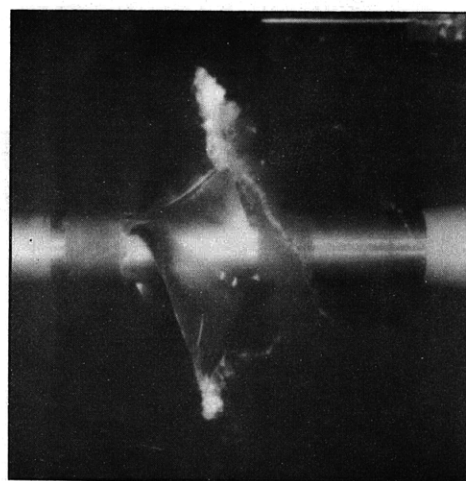


J = 0.360

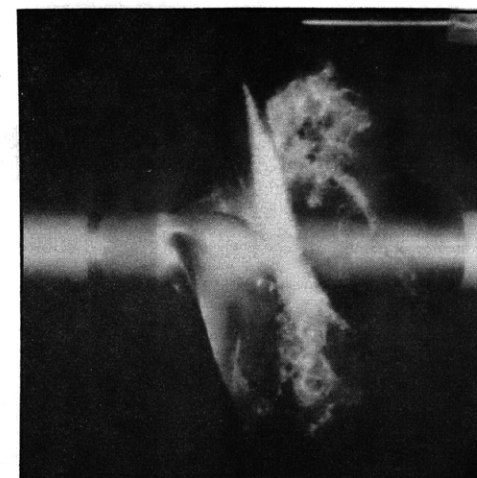
Figure 10 - Photographs of Propeller 3768 Backing, $\sigma = 4.00$



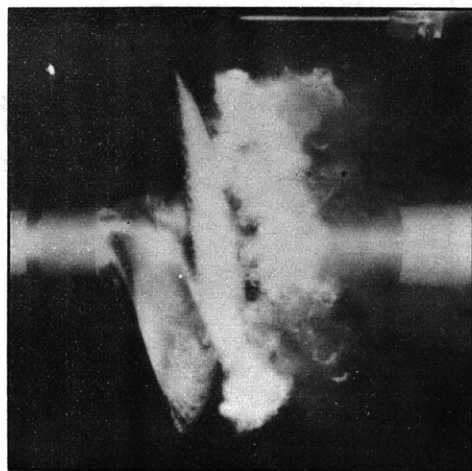
J = 0.979



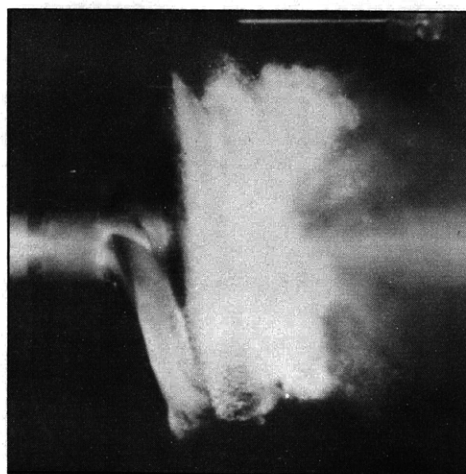
J = 0.866



J = 0.648



J = 0.498

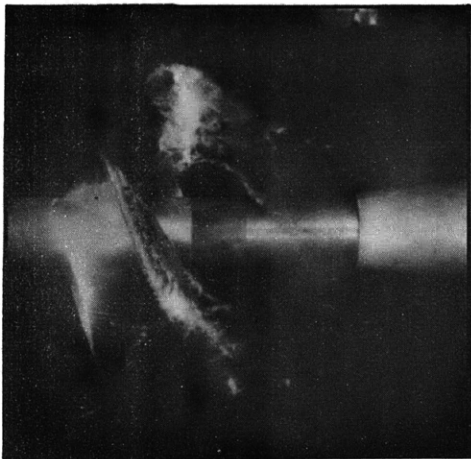


J = 0.393



J = 0.360

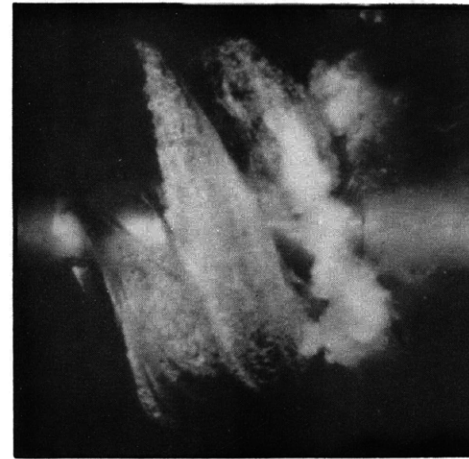
Figure 11 - Photographs of Propeller 3768 Backing, $\sigma = 1.679$



J = 1.152



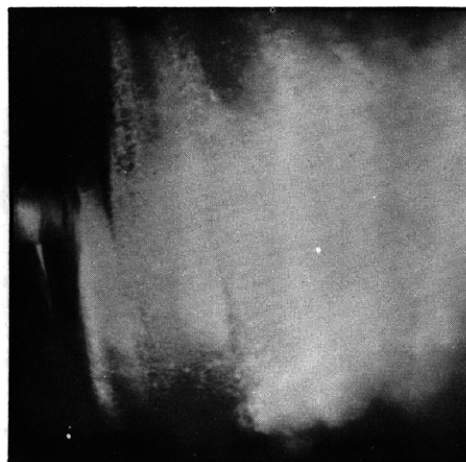
J = 0.960



J = 0.720



J = 0.576



J = 0.480

Figure 12 - Photographs of Propeller 3768 Backing, $\sigma = 0.601$

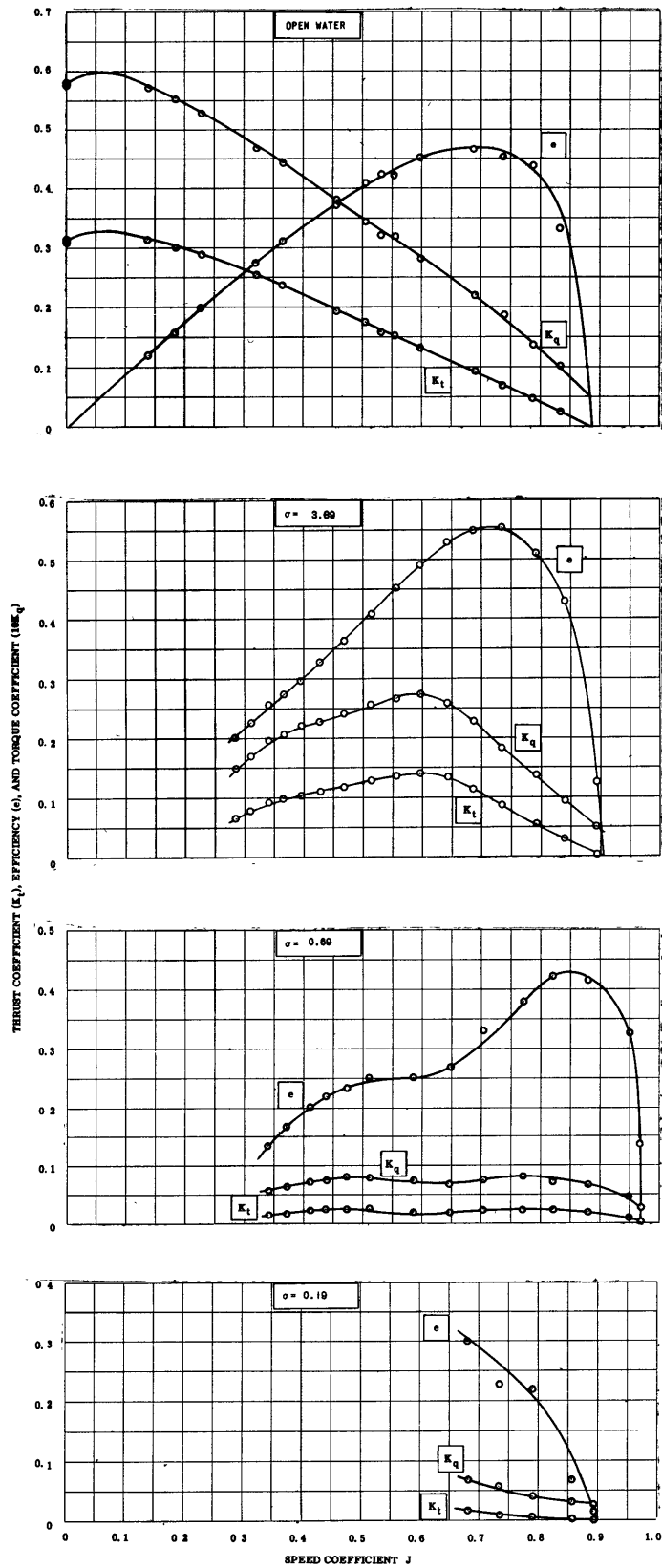
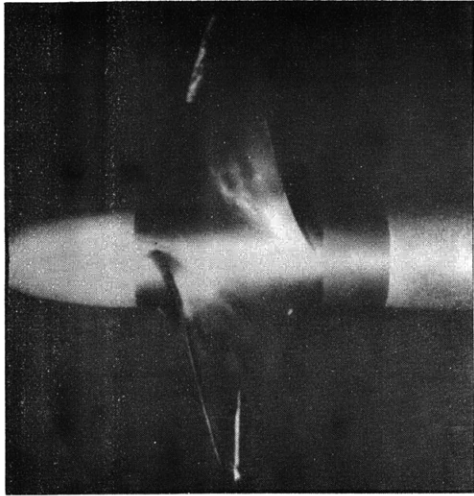
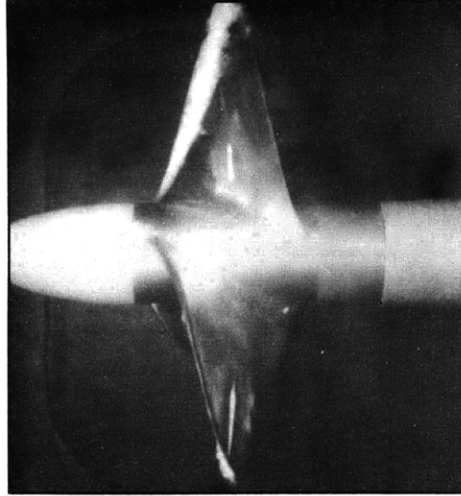


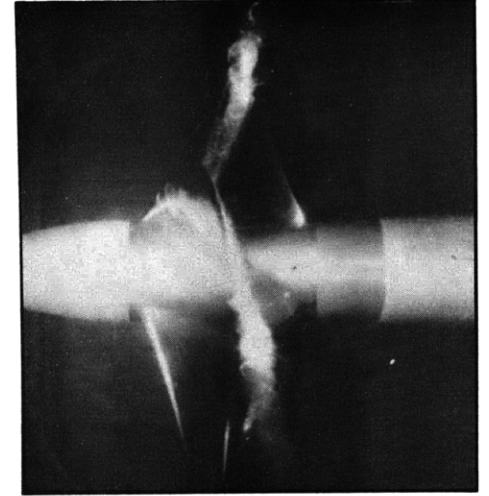
Figure 13 - Backing Performance of Propeller 3769



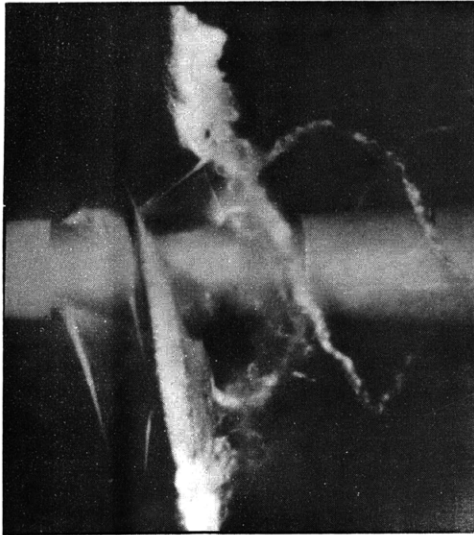
J = 0.893



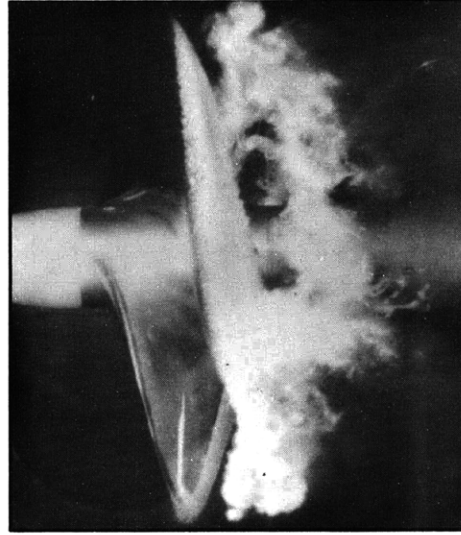
J = 0.792



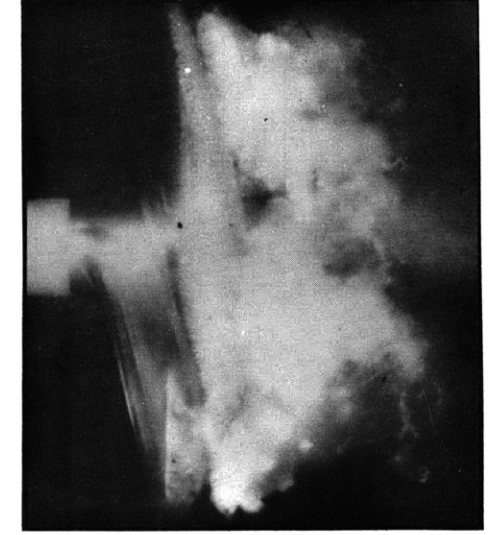
J = 0.643



J = 0.396

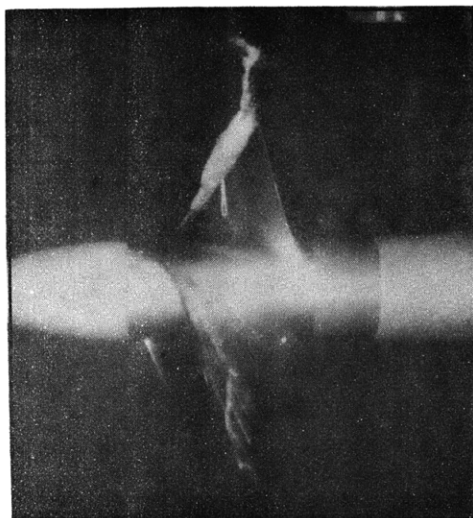


J = 0.342

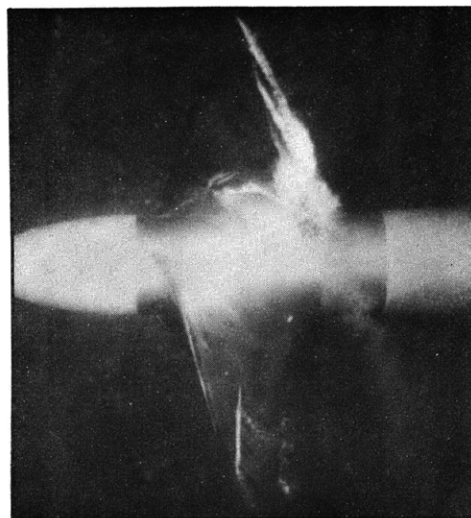


J = 0.287

Figure 14 - Photographs of Propeller 3769 Backing, $\sigma = 3.89$



J = 0.888



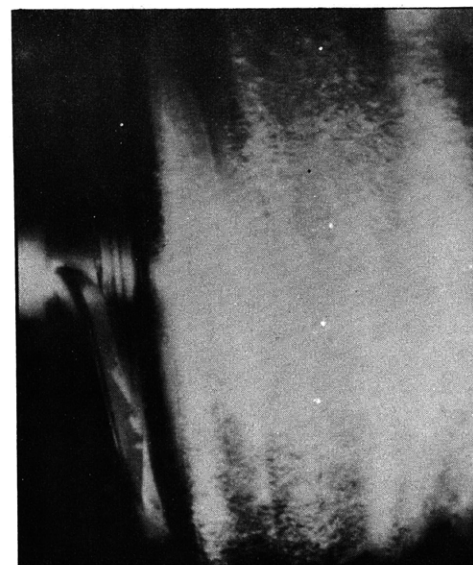
J = 0.881



J = 0.649



J = 0.475

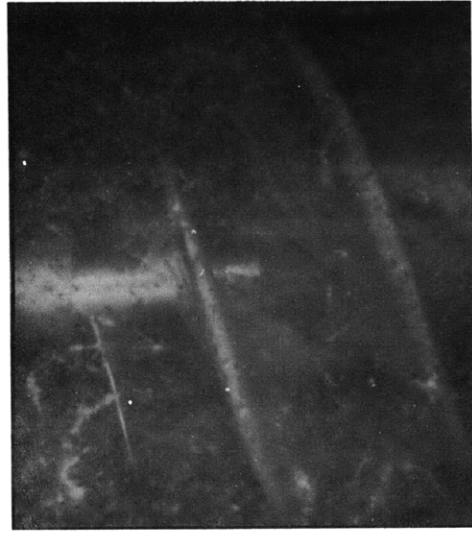


J = 0.343

Figure 15 - Photographs of Propeller 3769 Backing, $\sigma = 0.69$



J = 0.957



J = 0.894



J = 0.735



J = 0.683

Figure 16 - Photographs of Propeller 3769 Backing, $\sigma = 0.19$

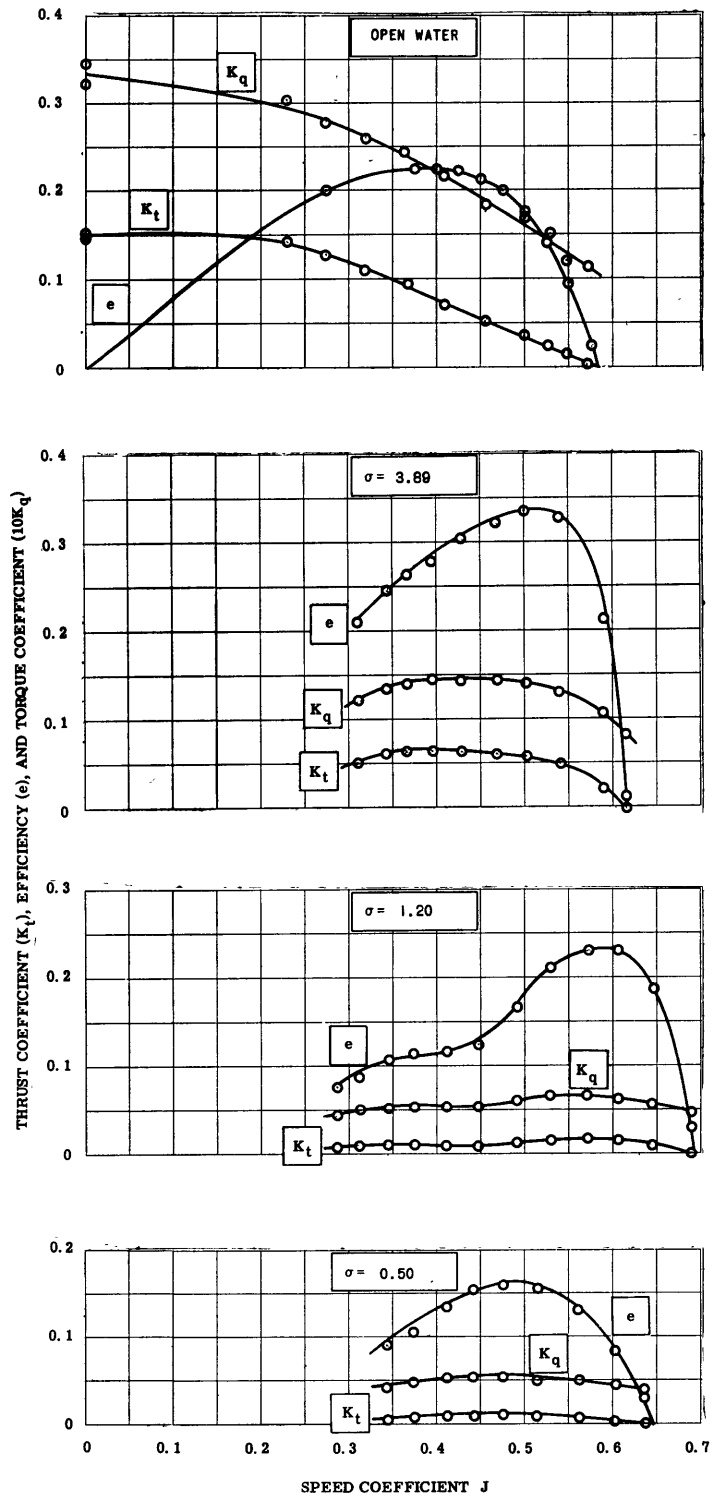
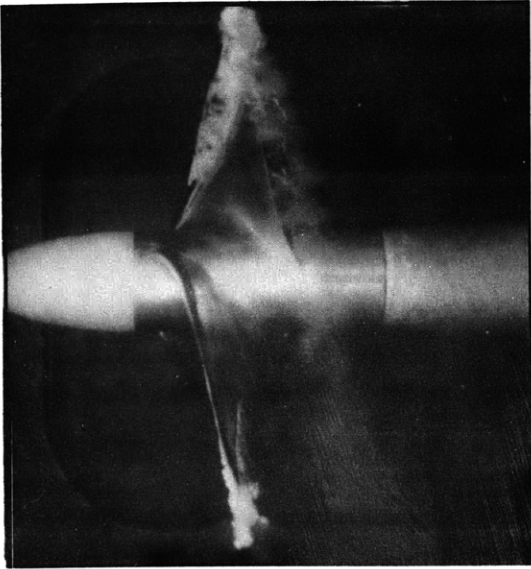
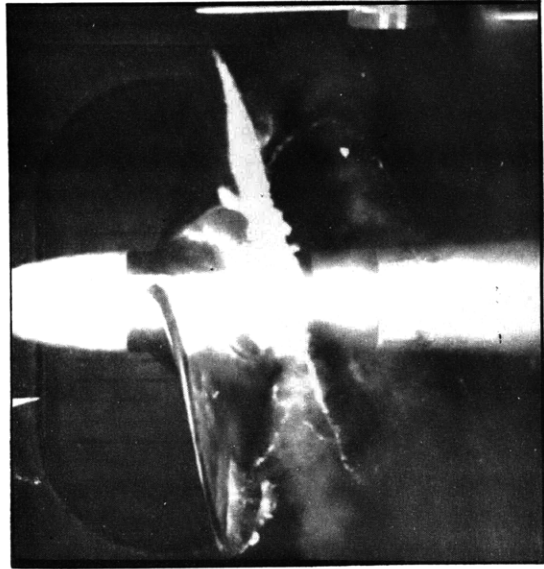


Figure 17 - Backing Performance of Propeller 3770



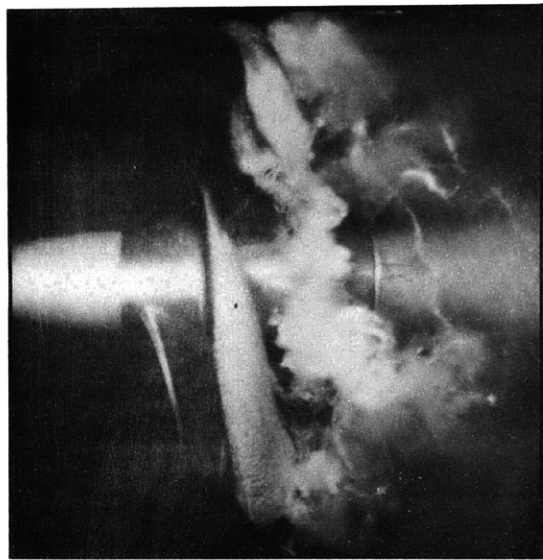
J = 0.615



J = 0.502

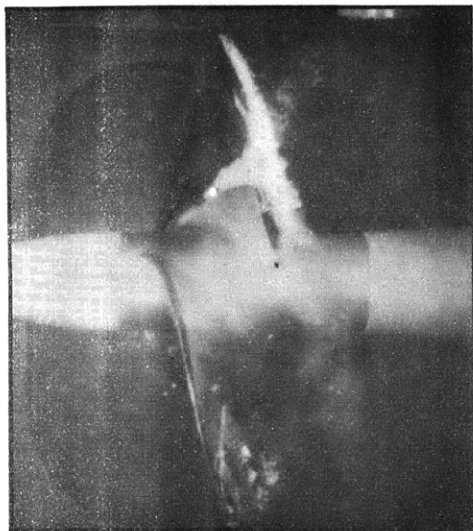


J = 0.395

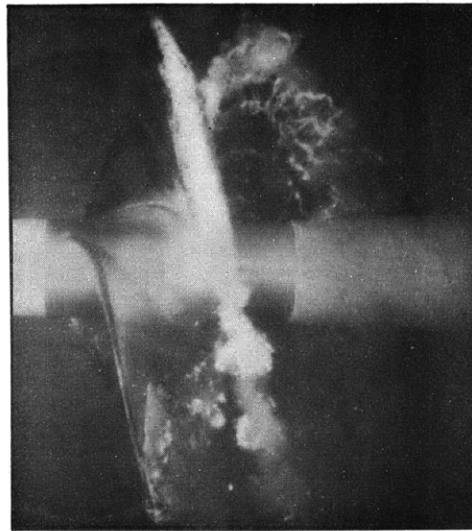


J = 0.343

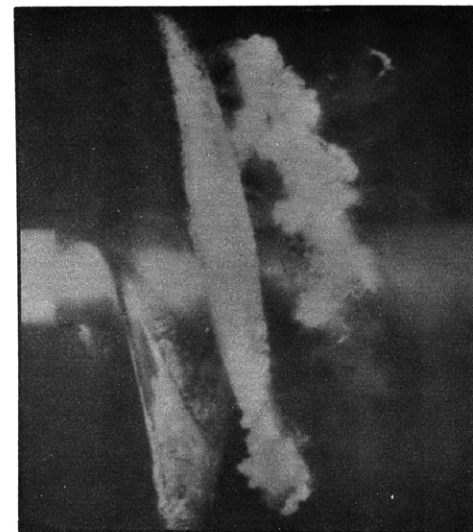
Figure 18 - Photographs of Propeller 3770 Backing, $\sigma = 3.89$



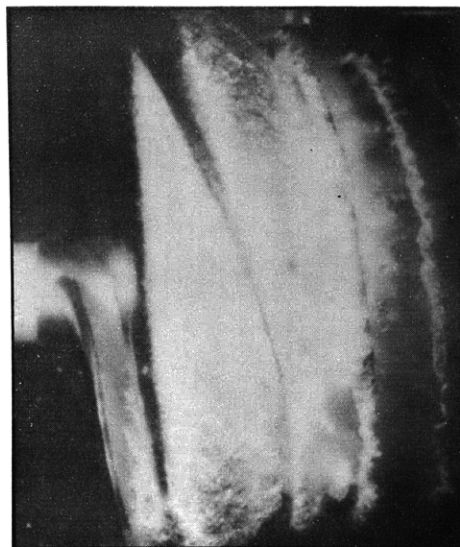
J = 0.687



J = 0.571



J = 0.447

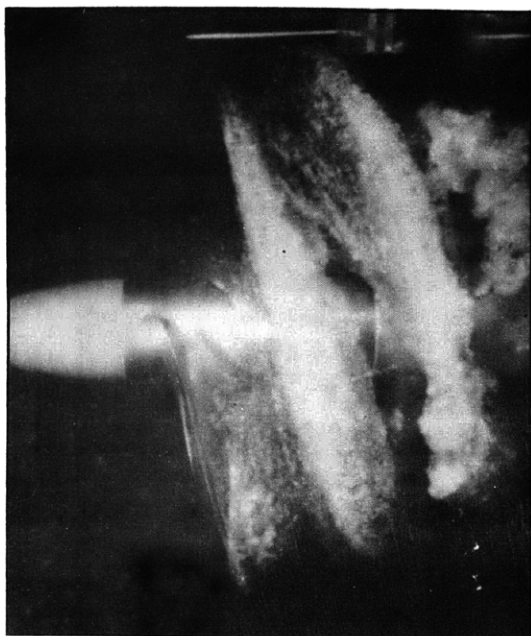


J = 0.343

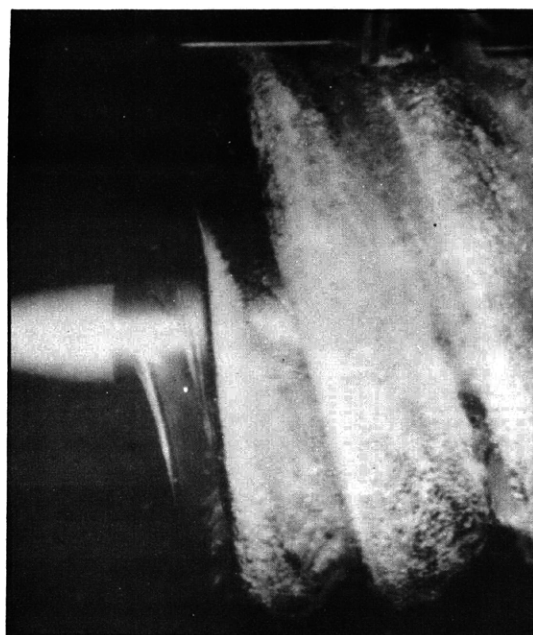


J = 0.286

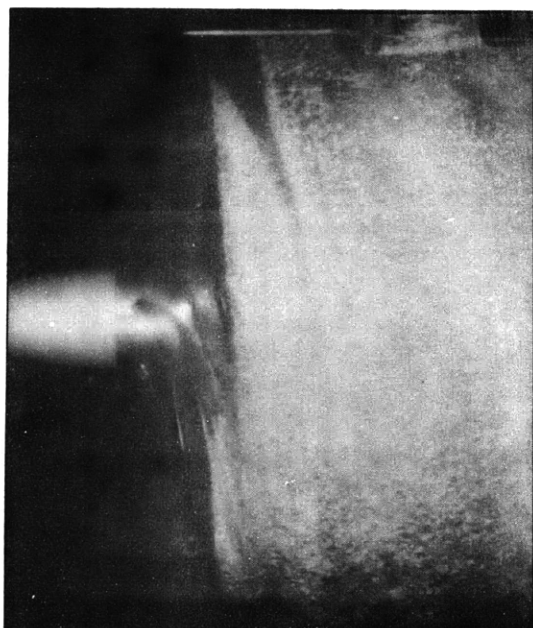
Figure 19 - Photographs of Propeller 3770 Backing, $\sigma = 1.20$



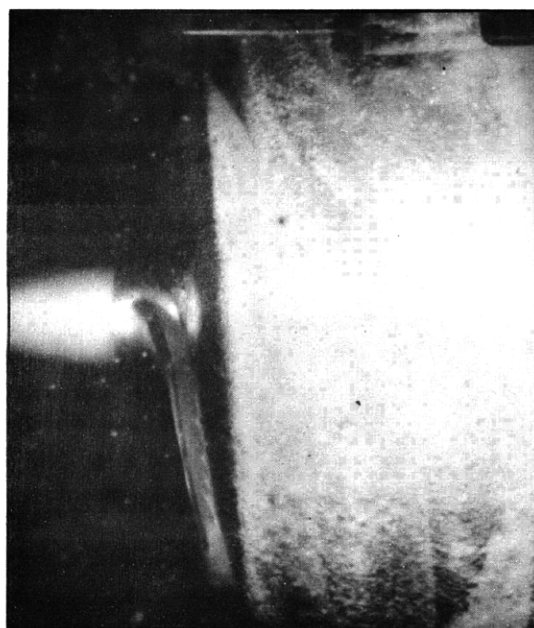
J = 0.635



J = 0.514



J = 0.411



J = 0.343

Figure 20 - Photographs of Propeller 3770 Backing, $\sigma = 0.50$

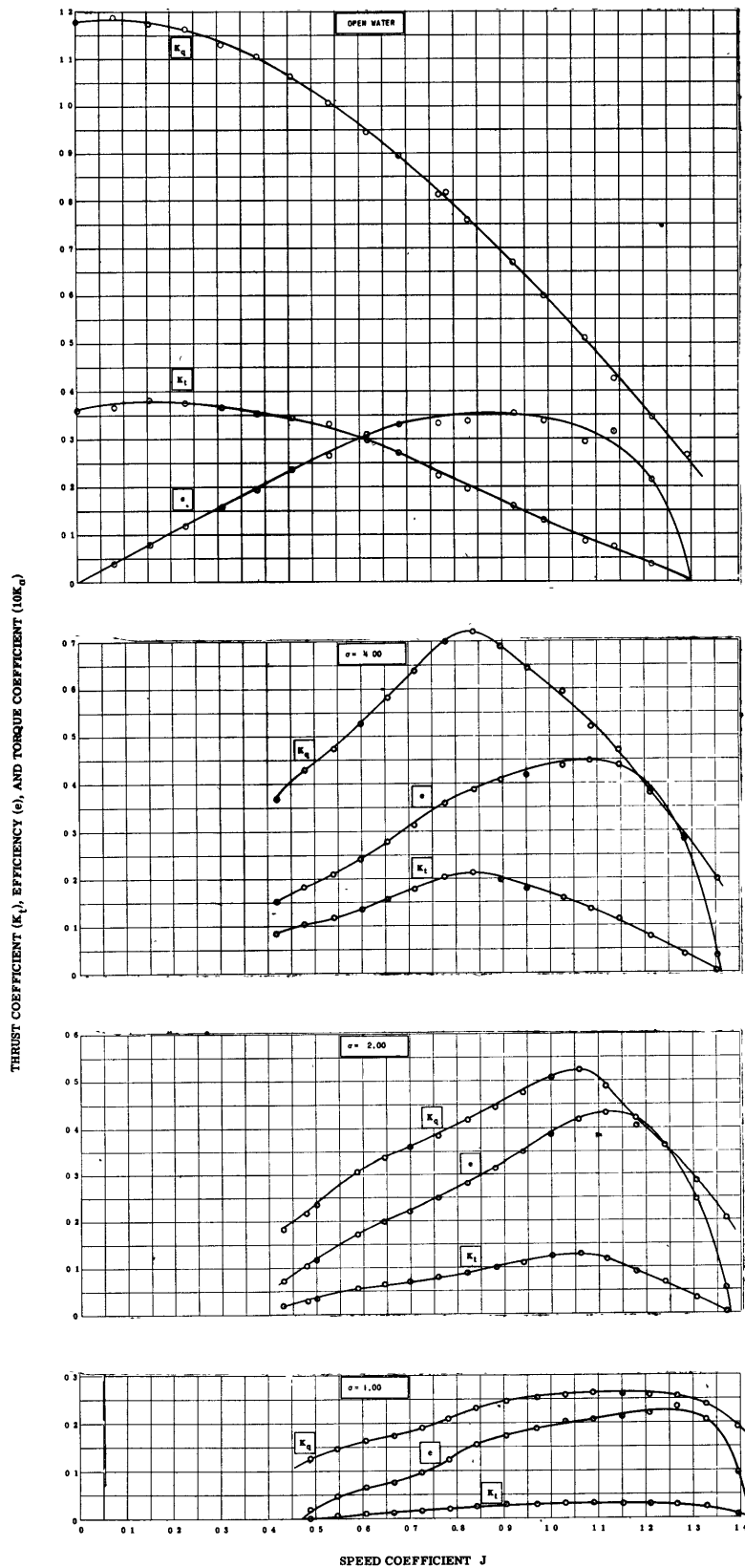
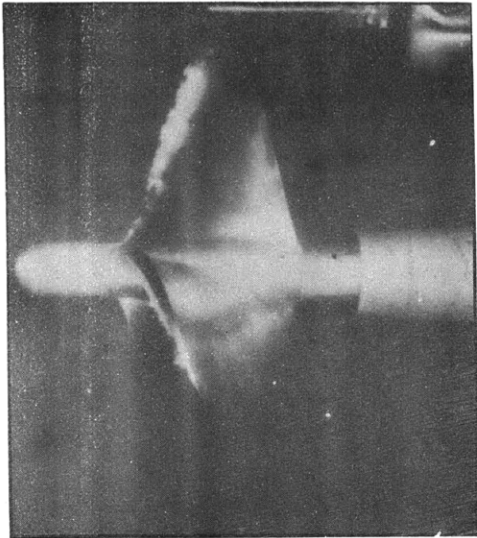
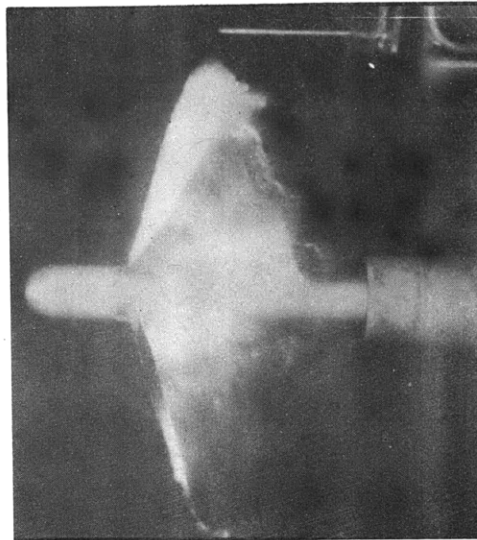


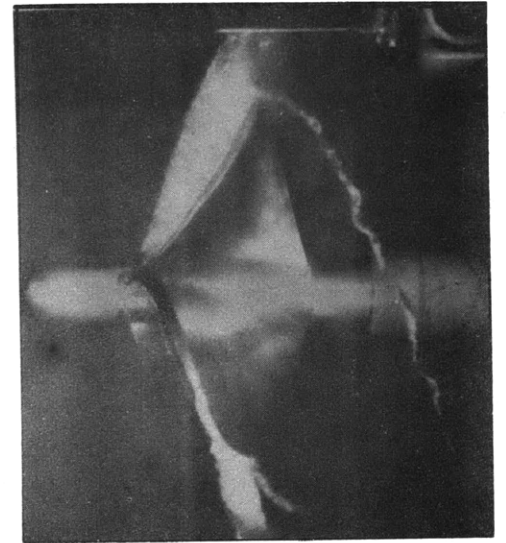
Figure 21 - Backing Performance of Propeller 3820



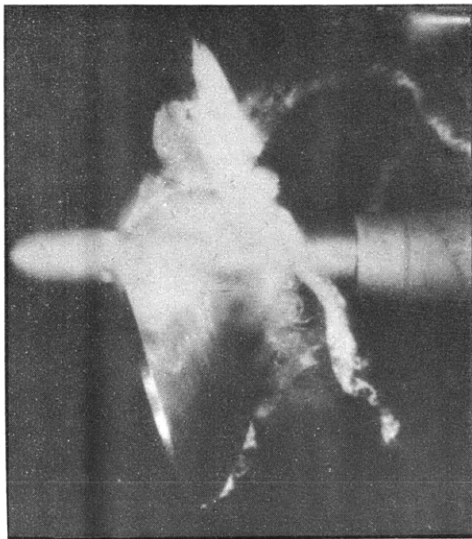
$J = 1.353$



$J = 1.145$



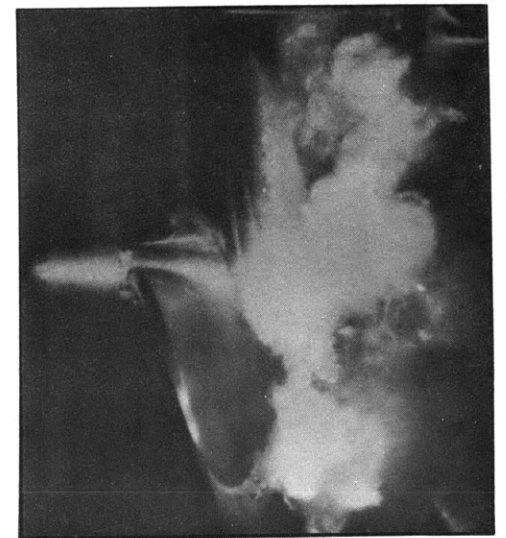
$J = 0.950$



$J = 0.777$

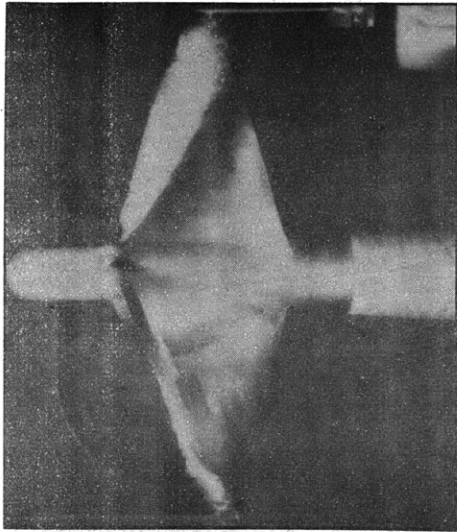


$J = 0.598$

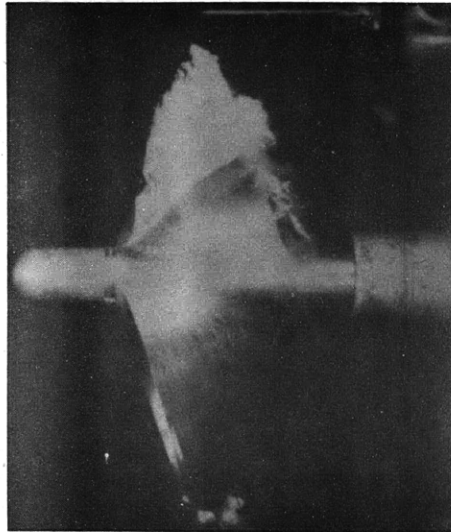


$J = 0.418$

Figure 22 - Photographs of Propeller 3820 Backing, $\sigma = 4.00$



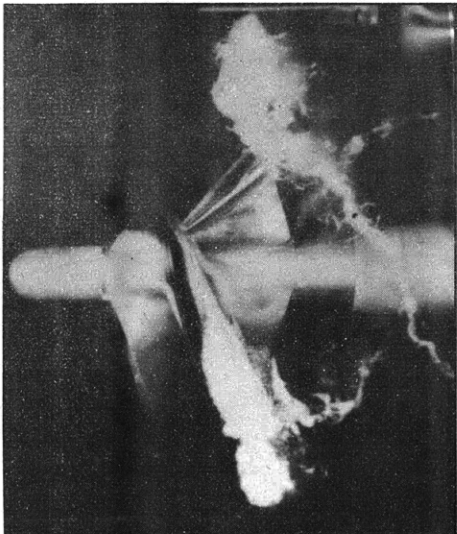
J = 1.369



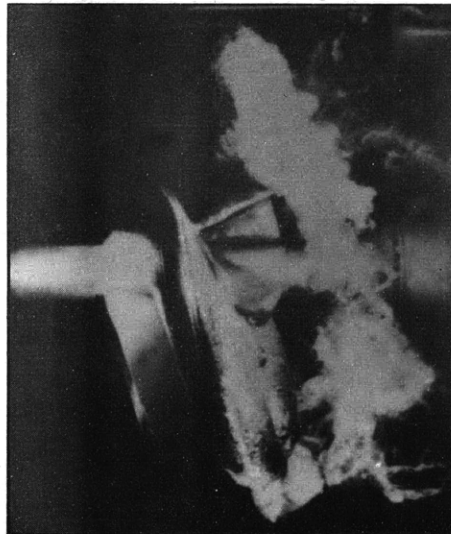
J = 1.178



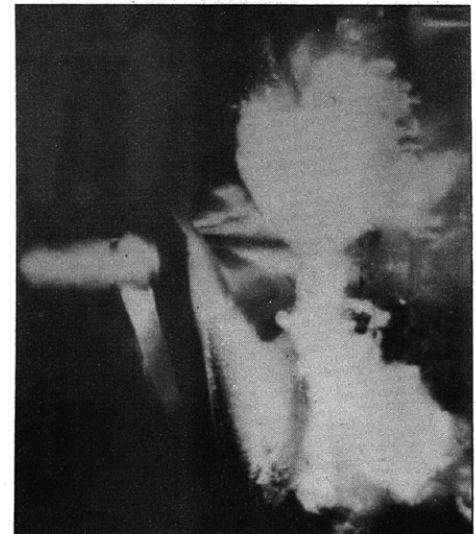
J = 1.000



J = 0.821

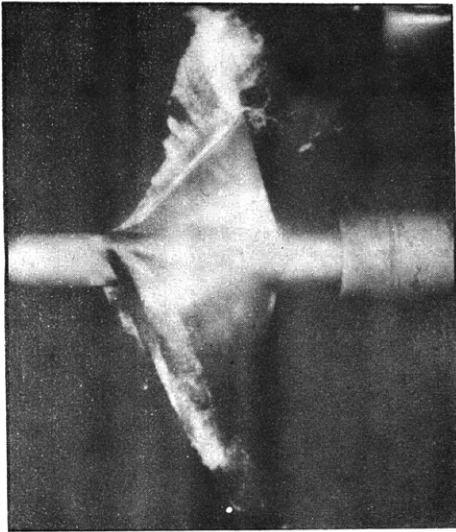


J = 0.643

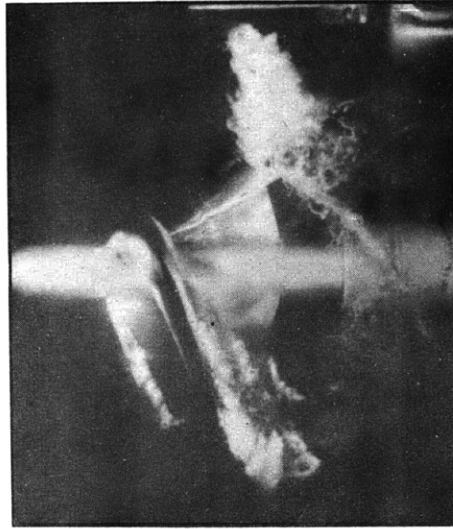


J = 0.478

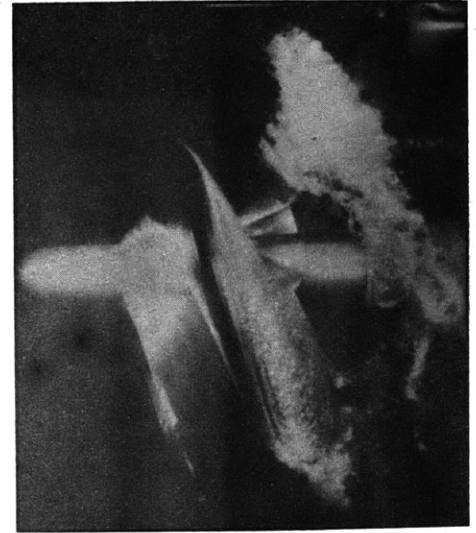
Figure 23 - Photographs of Propeller 3820 Backing, $\sigma = 2.00$



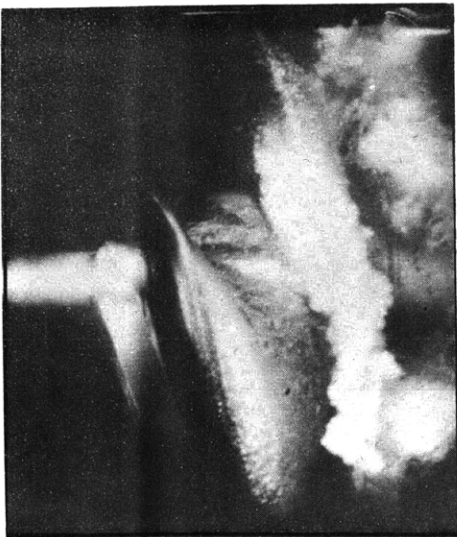
J = 1.396



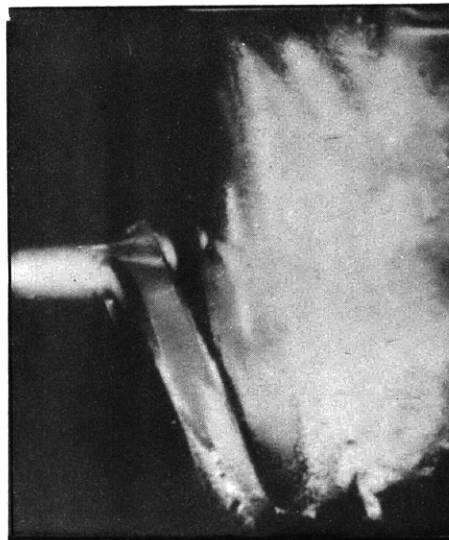
J = 1.032



J = 0.843



J = 0.669



J = 0.492



J = 0.398

Figure 24 - Photographs of Propeller 3820 Backing, $\sigma = 1.00$

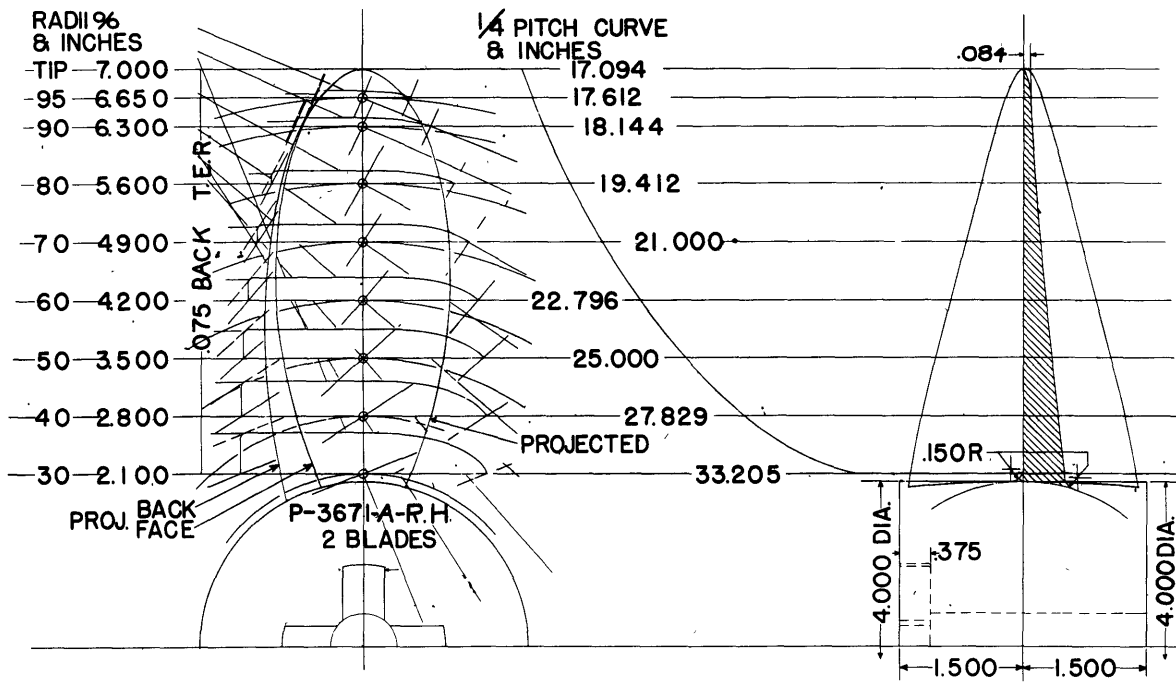


Figure 25 - Drawing of Propeller 3671A

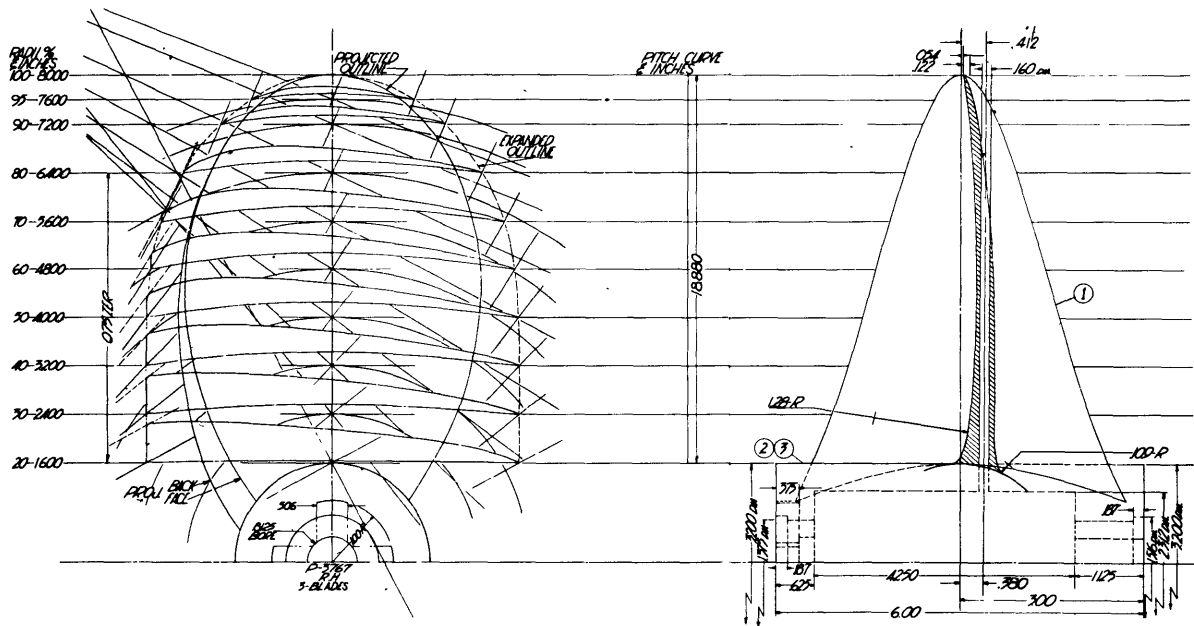


Figure 26 - Drawing of Propeller 3767

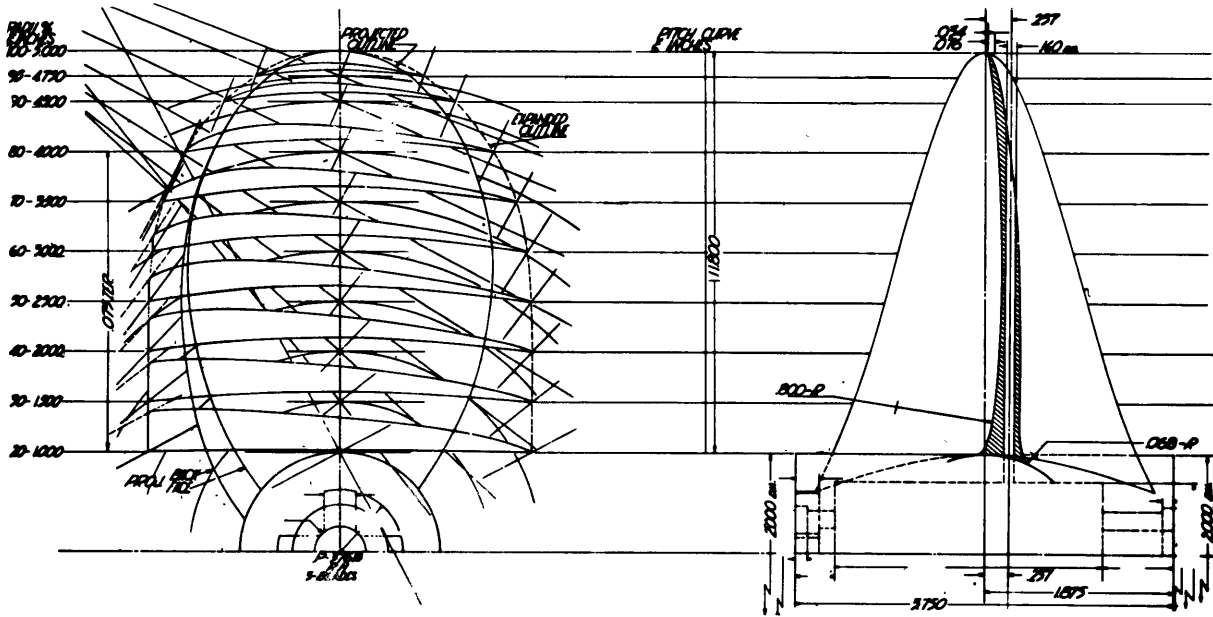


Figure 27 - Drawing of Propeller 3768

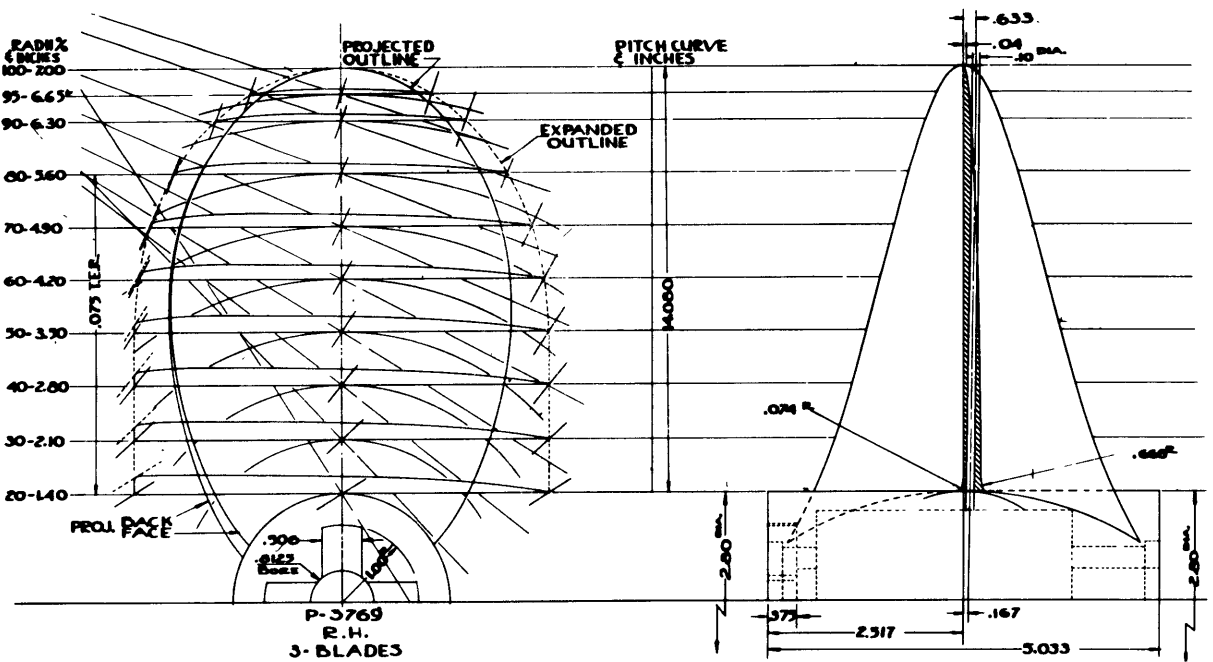


Figure 28 - Drawing of Propeller 3769

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