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PERFORMANCE CHARACTERISTICS OF A JET FLAP PROPELLER

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Report 2936

NAVAL SHIP RESEARCH AND DEVELOPMENT CENTER

Washington, D.C. 20007

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TEST AND EVALUATION REPORT

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DEPARTMENT OF THE NAVY
NAVAL SHIP RESEARCH AND DEVELOPMENT CENTER
WASHINGTON, D. C. 20007

PERFORMANCE CHARACTERISTICS OF A JET FLAP PROPELLER

by

Robert R. Hunt
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NOTATION

A_j	Area of the jet at the orifice
C_p	Power coefficients, $C_p = \frac{P_D}{\frac{1}{2}\rho R^2 V^3} = \frac{16K_Q}{J^3}$
C_q	Jet flow coefficient, $C_q = \frac{q_j}{q} \times 100$
D	Propeller diameter
F_s	Spring scale force
J	Advance or speed coefficient $\frac{V_A}{ND}$
K_Q	Torque coefficient $\frac{Q}{\rho N^2 D^5}$
K_T	Thrust coefficient, $\frac{T}{\rho N^2 D^4}$
ΔK_Q	Change in torque coefficient
ΔK_T	Change in thrust coefficient
N	Revolutions per unit time
P	Absolute pressure
P_D	Power delivered at propeller
ΔP_D	Change in power delivered to the propeller
P_v	Vapor pressure
Q	Torque
q	Rate of flow through the propeller disc $\pi(R^2 - r^2)V$
q_j	Jet flow
R	Radius of propeller
r	Radius of propeller hub
R_x	Jet reaction force
T	Thrust
u	Velocity of the jet

V	Tunnel velocity
V_a	Speed of advance
η	Propeller efficiency
η_j	Propeller efficiency with jet losses included
θ	Jet deflection angle in degrees
ρ	Mass density
σ	Cavitation number $(p - p_v / \frac{1}{2} \rho v_a^2)$

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ABSTRACT

The performance characteristics of a marine propeller with a jet flap was investigated. It was found that the jet flap effectively reduced propeller blade cavitation and that for a given advance coefficient the thrust was considerably increased by using the jet flap. The propeller efficiency decreased somewhat, primarily because of the power required in delivering the jet.

ADMINISTRATIVE INFORMATION

This investigation was carried out under Subproject S-F113 11 09, Task 3801.

INTRODUCTION

The jet flap principle is used to change the flow over a foil for the purpose of controlling lift. In principle it simulates a conventional mechanical flap as used in aircraft to alter the circulation about the wing. The jet flap changes the flow by ejecting a sheet of air at some optimum angle from narrow slots in the trailing edge of the wing. Many experiments have been conducted using the jet flap in air, the first being those by Schubauer[1] and by Hagedorn and Ruden.[2] Some of this work has been reviewed by Salita[3] who has done a considerable amount of jet flap research. Although some research has been done in water on foils with jet flaps, little or no research has been done on jet flap propellers.

James F. Allen, in his paper "Aerofoil Sections in Screw Propellers," says "Jet flaps have been used in aerofoils with the effect of increasing lift without increasing drag. The purpose for putting a jet flap on a marine propeller would not only be to reduce the drag and increase the lift on the aerofoil blade sections, but to eliminate or reduce cavitation also."[4] Because the jet flap principle appeared to offer some advantages, an investigation with a marine propeller was undertaken.

The jet flap propeller requires no mechanical parts in the shafting or the propeller. This is a decided advantage over the mechanically complicated controllable pitch systems which are also designed to change the lift characteristics of a propeller blade. The jet flap must have a system for pumping water through the propeller, which requires power when in use. The controllable pitch system, however, requires power only when the pitch is varied. Whether or not the jet flap principle is advantageous must be determined by consideration of the propeller performance and a comparison of the different mechanical systems. The purpose of this report is to present the performance characteristics of one jet flap propeller.

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[1] References are listed on page 31.

The jet flap propeller, if proven reliable and advantageous from a propulsion standpoint, could be used wherever controllable-pitch propellers are used for ahead operation. It would be particularly applicable where the propeller could be designed for one condition and a jet flap incorporated when running at another condition, especially when this latter condition is only for a small percentage of time.

THE JET FLAP PROPELLER

A two-bladed propeller was selected for these experiments because the small number of blades considerably reduced the complexity of the jet flow system. There was less machining than would have been required with a larger number of blades and the total mass flow of water required was smaller.

A propeller diameter of twenty-four inches and a pitch ratio of one was selected for the propeller. The diameter was limited to this value by possible wall effects from the water tunnel.[5] The relatively large size of the propeller facilitated the machining of the jet cavities and the high thrust and torque loads made the inherent instrument and dynamometer errors small.

The propeller was manufactured at NSRDC in accordance with David Taylor Model Basin Drawings P-4218 and E-2445-5. These drawings along with propeller particulars are presented as Figures 1 and 2. Photographs of the propeller showing the jet flap cavity and cover plates are presented in Figures 3 through 5. The blades were made movable so that ducting, allowing water to flow to the jet flap, could be easily machined. Each propeller blade had fourteen jets formed by slots 0.475 inches long and 0.030 inches wide. A section along the trailing edge of the blade's face was milled away to form a cavity, one side of which formed the forward edge of the jet slot. The cavity contained thirteen raised cover support pylons which were drilled and tapped to accommodate stainless steel screws that held the cover plate in place. These support pylons divided the slot into fourteen segments, each of which formed a jet. At assembly, a small amount of silastic rubber was applied to the area of contact between the blade and cover plate. This prevented the escape of water from the blade at screw holes and around the edges of the cover plate.

The propeller was designed to have a jet deflection angle θ of approximately 60 degrees which was calculated to be the most efficient angle.[6] However, a survey of the deflection angle showed a variation from 55 degrees at the root of the blade to 35 degrees at the tip for blade A, and 50 degrees at the root to 40 degrees at the tip for blade B. A picture of the jet flap propeller on a test stand is shown in Figure 6. This picture was made during a preliminary investigation and serves only to illustrate the manner in which the jet exits from the blade. It can be seen that the jet is ejected aft and away from the face of the blade forming the deflection angle with the chord. This angle θ is defined in Figure 7.

TEST PROCEDURE

The cavitation inception studies were made in the 36-inch water tunnel. Water tunnel air content was kept below 25 percent of saturation at atmospheric pressure. Stroboscopic lights were used to illuminate the propeller during the cavitation studies. In order to improve visibility, air content of the water was kept low and was checked periodically throughout the tests with a Van Slyke air content meter. No-loads were first run with a dummy hub substituted in place of the propeller and thrust and torque data were recorded at several rpm settings while tunnel pressure was varied over the test range.* It was determined that the tunnel speed had a negligible effect on torque and thrust measurements when the dummy hub was installed. Hence, the only load corrections applied to the succeeding data were for the effect of tunnel pressure and rpm.

The propeller was installed and first observed at 900 rpm with zero flow rate through the jet flap. The tunnel velocity was varied to obtain the desired advance coefficients and the tunnel pressure (psia) was varied to bring on cavitation. Observations of cavitation inception were made and sketches were drawn of the extent of cavitation occurring at various operating conditions.

Following the cavitation observation tests, characterization tests were run on the propeller. Thrust and torque were measured while running the propeller at 600 rpm and holding the tunnel pressure at 40 psia. This amounted to a Reynolds number of 1.2×10^6 which is high enough to assure turbulent flow on the propeller. Tunnel water velocity was varied to obtain the desired advance coefficients and thrust, torque, and rpm data were recorded for 0, 48, 77, and 120 gallons per minute jet flap flow rates. Whenever water tunnel velocities were changed, flow adjustments were made to keep the jet flow constant.

At intervals during the testing period, drift was monitored by running the propeller at 200 rpm and comparing torque and thrust values with those recorded for the same rpm earlier in the test. Drift was found to be of no consequence.

INSTRUMENTATION

The standard 36-inch water tunnel instrumentation was used for all measurements except jet flow rates and forces. Torque and thrust measurements were made using a TMB dynamometer of the strain-gage bridge type. Analog outputs were converted to digital form and digitally displayed. The torque and thrust dynamometer was calibrated prior to the tests and these data are considered accurate to within ± 1.0 percent. Tunnel velocity and tunnel

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*No loads as used here are considered to be thrust and torque components that are not contributed by the propeller. For example, tunnel pressure and bearing friction.

pressure were measured by Baldwin Lima Hamilton Type MM pressure transducers. Both tunnel water velocity and tunnel pressure were digitally displayed. The tunnel pressures are considered accurate within 0.3 percent of full scale, full scale being 50 psia. Water tunnel velocities in the vicinity of the propeller are not corrected for tunnel wall effects because of lack of open water characteristics for the propeller. The tunnel velocity error should be the same for tunnel flow with and without the jet, and comparisons of propeller efficiencies for these conditions are considered valid though the propeller efficiency appears high for this propeller.

Water was supplied to the jet flap by a two-stage, end suction, centrifugal type pump which was rated at 200 gallons per minute with a 500-foot dynamic head or 350 gallons per minute with a 300-foot head. The pump operated at 3500 rpm and was driven by a 50-horsepower electric motor. The piping diagram of the water supply for the jet flap is shown in Figure 10. The flow control valve was the valve just upstream of the flow meter. The bypass valve allowed some of the flow to go directly back into the tunnel making the control valve easier to operate. The drive shaft was hollow and water entered the shafting through a water seal designed at NSRDC. The flow meter was a Fischer Porter Model 10C1516 used in conjunction with their Model 55GE2238A Oscillator/Preamplifier. The output pulses generated by the flowmeter were counted on an electronic counter. The accuracy of the flow measurements is estimated to be within 1/2 percent of the reading taken.

Jet force measurements were made on a compression type scale manufactured by John Chatillon and Sons. The catalog number is 516-520 and the scale was readable to one ounce. Estimates to the nearest half ounce could be made accurately from the scale. A flat plate, having dimensions that would allow the measurement of a force from a single jet, was affixed to the spring scale and held approximately 0.5 inch from the jet when making measurements. This method of measuring the jet force should not be considered to be more accurate than ± 5.0 percent due to the difficulty of holding the scale steady and normal to the jet. However, the average velocities computed from these measurements agrees within 1.0 percent with those computed from total flow rates, obtained from flowmeter readings and jet areas.

ANALYSIS OF JET FLAP DATA

A velocity survey of the jets emerging from the propeller was conducted by measuring the force of each jet impinging on a flat plate affixed to a spring scale. The velocity of each jet was determined by using an equation derived from the momentum equation, i.e.

$$P_1A_1 - P_2A_2 + R_x = \rho_2 u_2^2 A_2 - \rho_1 u_1^2 A_1$$

The control volume used is the unbounded jet between the jet orifice and the scale shown in Figure 8. Pressures P_1 and P_2 are considered the same, as are the areas A_1 and A_2.

The velocity u_2 drops to zero when the jet impinges on the scale so that the equation for the reaction becomes

$$R_x = \rho_1 u_1^2 A_1 \text{ or } u_1^2 = \frac{R_x}{\rho_1 A_1}$$

In terms of the velocity survey this equation becomes

$$u^2 = \frac{F_s}{\rho A_j}$$

where u is the velocity of the jet,
F_s is the spring scale force,
ρ is the density of the water, and
A_j is the area of the jet.

A mean jet velocity was obtained by dividing the total flow obtained from flow meter readings by the total jet area. Ratios of the jet velocity to the mean jet velocity are presented in Figure 9 for a total flow rate of 48 gallons per minute with the jet ejecting into ambient air. The ordinate is a ratio of the individual jet to the mean of the jet velocities for the propeller. The abscissa is a ratio of the radial position of the jet to the radius of the propeller. Average deviation from the mean is indicated by a dashed line.

PRESENTATION OF RESULTS

The results of these experiments are presented in graphic and pictorial form. Dimensionless coefficients are used, throughout the report, to depict force, flow, and velocity components. Sketches of cavitation occurring at a number of cavitation indices σ and advance coefficients J are presented in Figures 11 through 15. The extent of back and face cavitation as well as tip vortex cavitation for a range of advance coefficients J and cavitation indices is depicted in Figures 11 and 12.

Figures 13 through 15 illustrate the cavitation occurring at advance coefficient J values of 0.77, 1.0, and 1.2, respectively. Each figure presents a sequence of cavitation indices at zero and two other flow coefficients. These figures illustrate, quite well, the effect of jet flow on cavitation.

Figure 16 presents the cavitation inception curves, which are plotted in the form of cavitation index σ versus the advance coefficient J. The curves presented therein define the inception of face, back, and tip vortex cavitation, and the inception of back bubble cavitation. Since the increased propeller loading caused by the jet flap did not increase cavitation, these curves apply for all jet flow coefficients C_q's that were tested.

Results of the characterization tests are presented in graphic form in Figures 17 through 26. The thrust coefficient K_t versus the advance coefficient J for a number of jet flow coefficients C_q is presented in Figure 17. Lines indicating constant power coefficients C_p are included so that the curves can be evaluated more readily.* Figure 18 presents the torque coefficient K_Q in the same manner. These figures clearly indicate that for a constant power delivered to the propeller drive shaft a substantial increase in K_T is obtained by increasing C_q. For example at a C_p of 0.32, there is approximately a 70 percent increase in K_T from a C_q of 0 to 0.5. For this change in K_T, K_Q increases approximately 50 percent. This may appear to be an increase in efficiency, however, such is not the case as K_Q does not include the power absorbed in delivering the jet. The inclusion of jet losses gives an overall loss in efficiency and the efficiency curves in Figure 19 reflect some of this power loss. The propeller efficiency including jet losses was obtained by using the equation

$$' \quad J = \frac{VT}{2\pi QN + \frac{1}{2}\rho q_j u^2}$$

The term $\frac{1}{2}\rho q_j u^2$ is the power expended in the jet itself, q_j is the flow of the jet in cubic feet per second, and u is the velocity of the jet in feet per second. Losses incurred in the piping are not considered because the test installation may not be representative of an actual ship installation. It is evident that the flow losses in the piping will further reduce the propeller efficiency. Figure 20 shows the efficiency of the propeller at three flow rates tested, without including the jet losses. Here again lines of constant power are drawn for comparison purposes.

A ratio is jet horsepower to the change in shaft horsepower for a range of J's are plotted versus C_q in Figure 21. For convenience Figure 22 is included; this graph shows the same power ratio versus J for various C_q's. It also serves to give a relationship of the jet power requirements to shaft horsepower requirements. These figures indicate that for increasing J's and C_q's more jet horsepower is required to bring about the same changes in shaft horsepower P_D that are obtained at lower C_q's and J's. The remaining Figures 23 through 25 are included to supplement the K_T and K_Q curves previously described; they include K_T and K_Q and the change in K_T and K_Q (ΔK_T and ΔK_Q) plotted for advance and flow coefficients (J and C_q).

DISCUSSION

The application of the jet flap at the conditions tested effectively increased the propeller thrust. At any given flow rate the thrust coefficient K_T decreases with an increasing advance coefficient J. However, an increasing J appears to make the jet flap more effective and the change in K_T (ΔK_T) increases with J. At a J-value of 0.8 and a flow

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*See Notation for definition of C_p.

coefficient C_q of 0.5, these data indicate that one could expect an increase in thrust of nearly 95 percent over the no jet flap condition. Torque is affected in the same manner as thrust, the torque coefficient K_Q falls off with increasing J at any given C_q and the change in K_Q (ΔK_Q) becomes increasingly large with increasing J. At a J-value of 0.8 and a C_q of 0.5, the torque increase was approximately 85 percent. This is approximately 10 percent less than the thrust increase. This apparent increase in efficiency is offset by the power consumed in delivering the jet. This additional loss reduces the propeller efficiency below that of the jet flap condition. From a J-value of 0.6 to 0.85, efficiency drops off with C_q. Above a J-value of 0.85, the jet flow peaks at a C_q of approximately 0.3 and then drops off with greater C_q values. The jet flap does effectively change the propeller thrust, at the expense of some loss in efficiency. However, it should be noted that for a given thrust coefficient and advance coefficient it can be more efficient to use a jet flap than to change the pitch of the propeller. This statement is based on neglecting the pumping and piping losses. The advantages gained by employing the jet flap may in some applications offset the loss in efficiency, since the propeller efficiency may be partially regained by more effectively utilizing the ship power plant. This may be accomplished by operating at the most efficient engine rpm range and using the jet flap to change the propeller lift in order to absorb the power.

No comparison has been made with the jet flap as used with aerofoils. An attempt to make comparisons with some of the work of G.K. Korbacker[6] on jet flaps was made, but it was determined that the jet momentum coefficient derived for the jet flap in water was so small that no meaningful comparison could be made. The fact that air is compressible allows much higher jet flap exit velocities and greater volume of flow than can be obtained with water. These differences greatly affect the jet momentum and the jet momentum coefficient.

It was thought that flow changes induced by the jet would affect the propeller cavitation. It is noteworthy that the only increase in cavitation is that created by the jet itself.* Even this is not very significant at the lower jet flow coefficients. When one considers the increase in propeller loading at these flow coefficients the reduction in cavitation is considerable. For example, at a J of 1.0 and a jet flow coefficient of 0.142, there is approximately a 300 percent increase in the thrust coefficient K_T with little or no increase in cavitation.

It was observed that the jet had a slight effect on the back bubble cavitation inception. This could not be well established because of poor visibility caused by air bubbles at the low tunnel pressures necessary to induce bubble cavitation. Here again there is an improvement in the cavitation characteristics because of increased propeller loading with increased jet flow rate.

No difficulties were experienced with the pumping system which supplied water to the jet. Flow to the jet was easily controlled and there were no problems with the seals in the shafting and propeller. Some problems may be encountered in shipboard installations that

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*The jet cavitation is that appearing at the trailing edge of the propeller.

were not encountered here. For example, propellers having more than three blades may be excessively weakened by duct work or increased torque and thrust loads may require the propeller shaft diameter to be increased in the areas where it conducts water to the propeller. Water intakes in the hull and related clogging problems may also be encountered, but these problems will be similar to existing cooling system problems and can be resolved.

CONCLUSIONS

1. The jet flap proved very effective in reducing propeller blade cavitation although the jet itself cavitated.

2. Thrust and torque increased considerably when the jet flap was used. Values were as high as 80 percent greater than with no jet flap.

3. Propeller efficiency was moderately reduced compared to the no-jet condition, when the power used in the jet was included in the efficiency calculations. However, it should be noted that for a given thrust coefficient and advance coefficient it can be more efficient to use a jet flap than to change the pitch of the propeller. This statement is based on neglecting the pumping and piping losses.

RECOMMENDATIONS

It is recommended that:

1. Other jet flap angles be investigated to determine an optimum angle.
2. Thrust reversal potential of the jet flap be investigated.
3. A program be set up to determine if, by cyclically controlling the flow to the jet flap, the propeller alternating thrust forces can be reduced.

ACKNOWLEDGMENTS

The authors wish to express their appreciation to Mr. Richard Cumming of the Naval Ship Research and Development Center for the initial design work done on this project and under whose guidance the investigation was carried out. They would also like to thank Dr. William B. Morgan, also of NSRDC, for the assistance he has rendered on this report.

PROP. NO.	LINEAR RATIO	DIA. MODEL IN.	DIA SHIP IN.	PITCH MODEL IN.	PITCH SHIP IN.	PITCH RATIO	NUMBER OF BLADES	EXP. BLADE AREA	E.A. / D.A.	M.W.R.	PROJ. AREA	P.A. / D.A.	B.T.F.	RAKE ANGLE	ROTATION SHIP	MODEL	[illegible] IN. @ 70 %
4218		24.000		24.000		1.000	2	131.656	.291	.291	110.546	.244	.063	–	R.H.		7.870

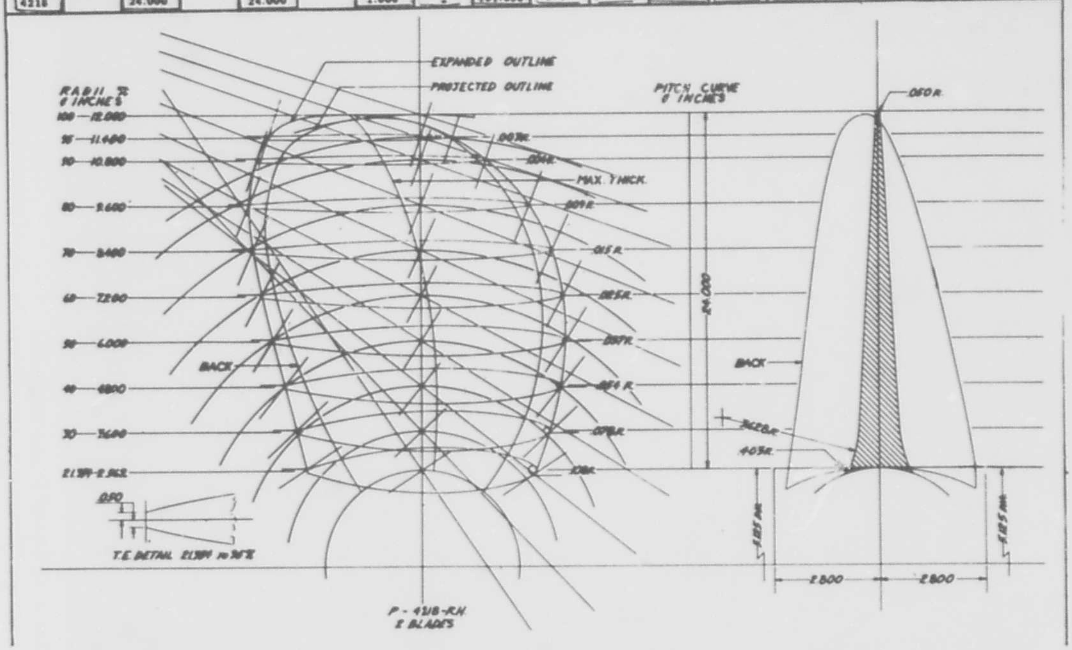


Figure 1 – Propeller 4218

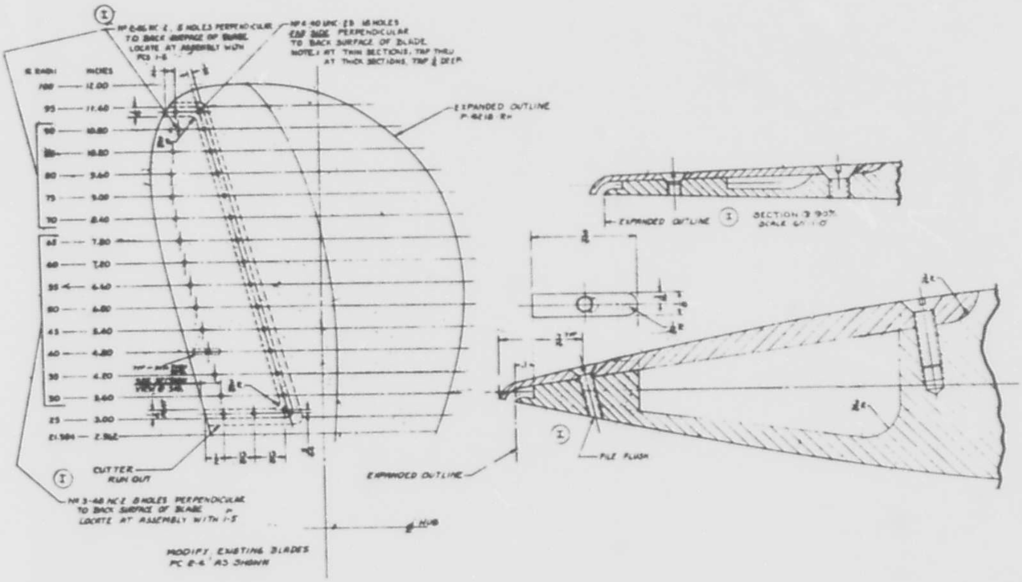


Figure 2 – Jet Flap Propeller, Blade Cavity Details

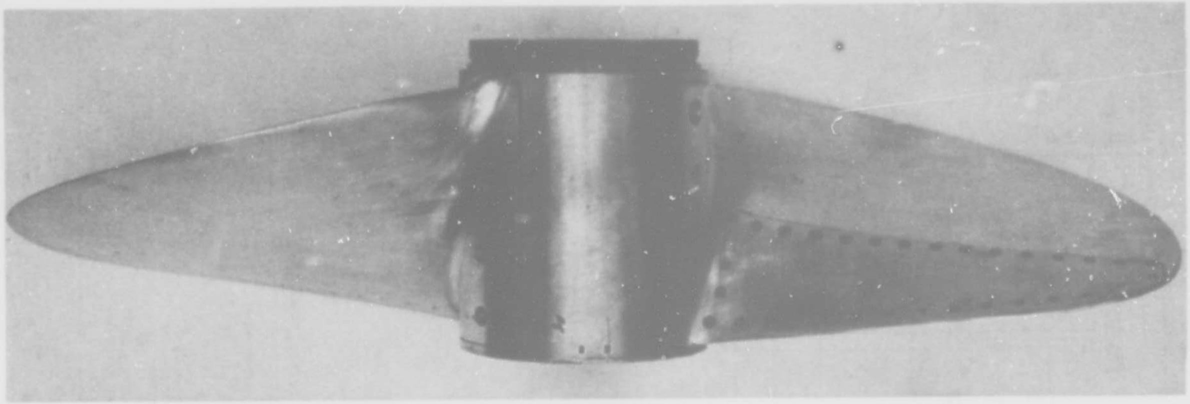


Figure 3 – Jet Flap Propeller Assembly

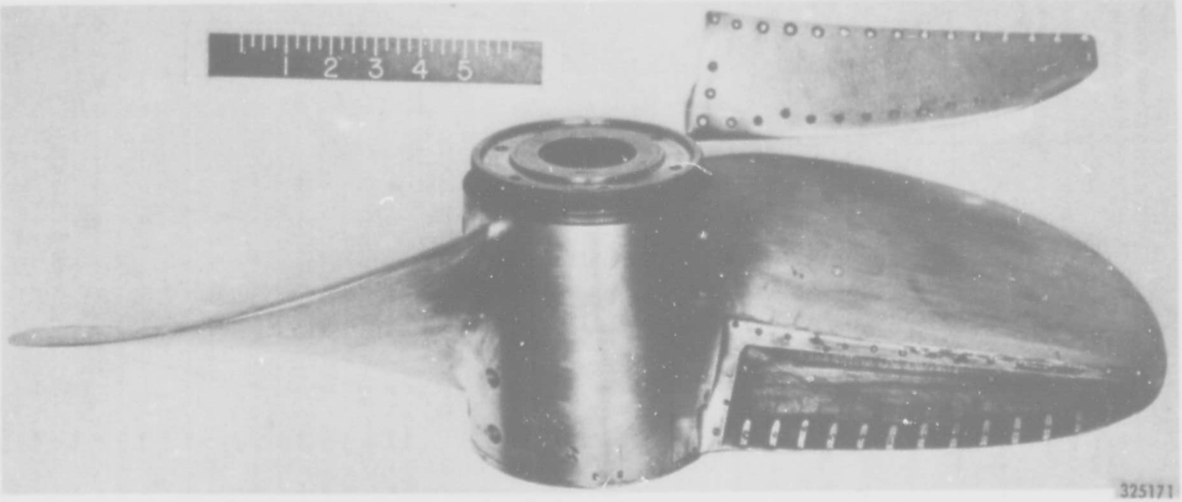


Figure 4 – Jet Flap Propeller with Cover Plate Removed

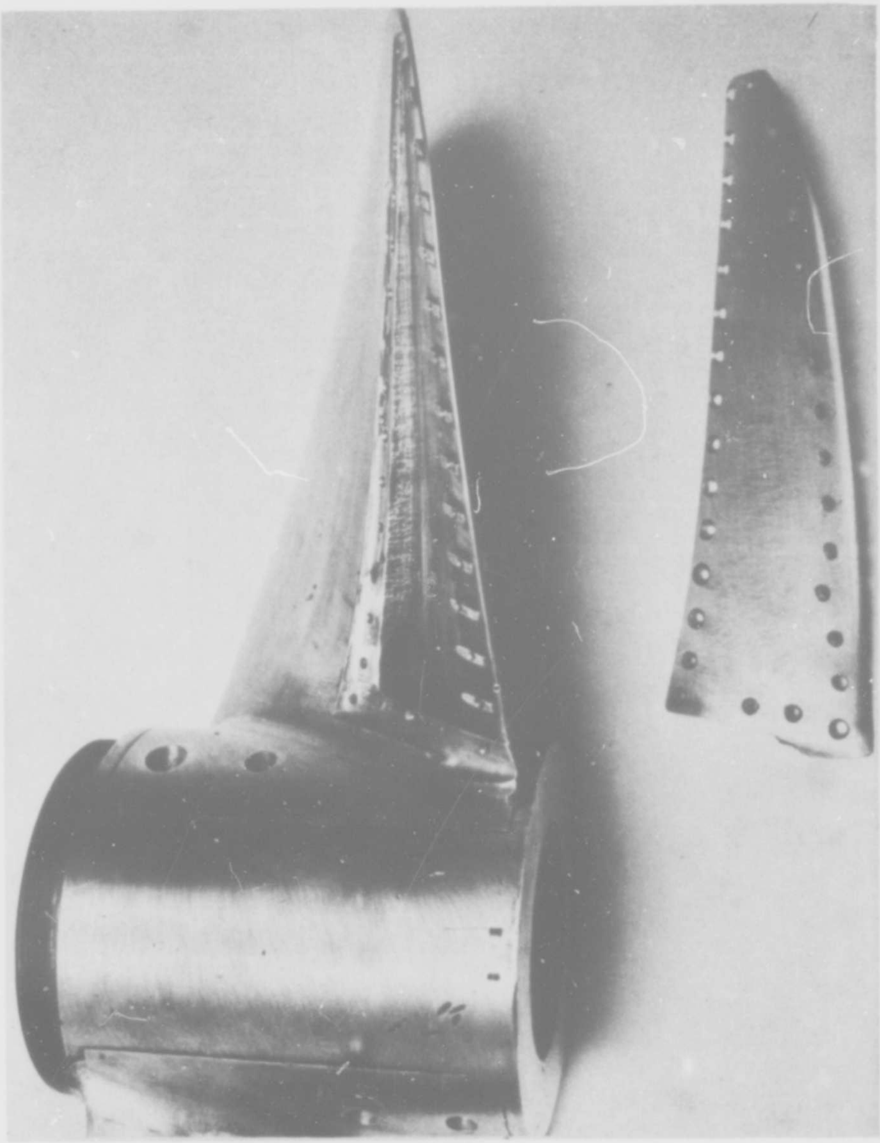


Figure 5 – Jet Flap Propeller Showing Closeup of Cavity

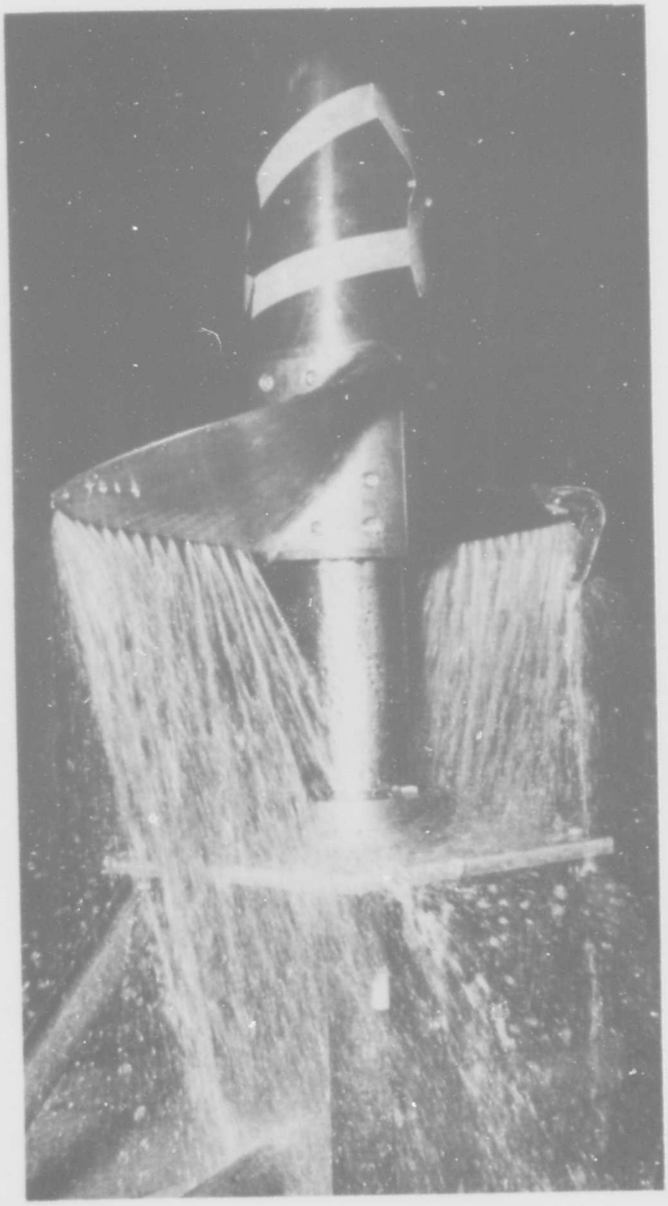


Figure 6 – Jet Flap Propeller

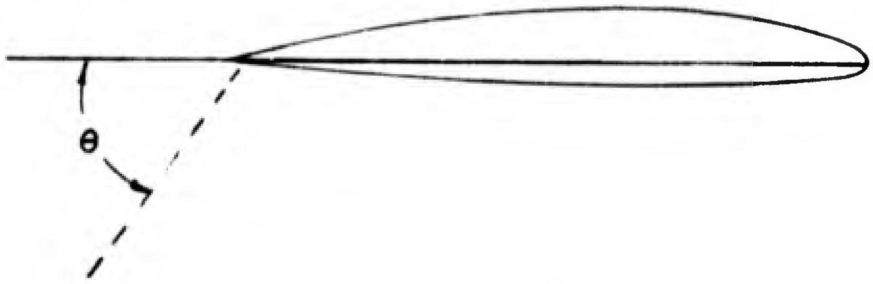


Figure 7 – Jet Angle from Chord

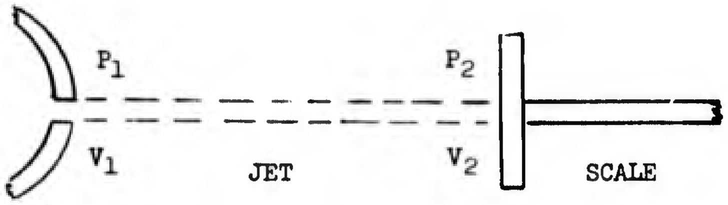


Figure 8 – Jet Velocity Measurement

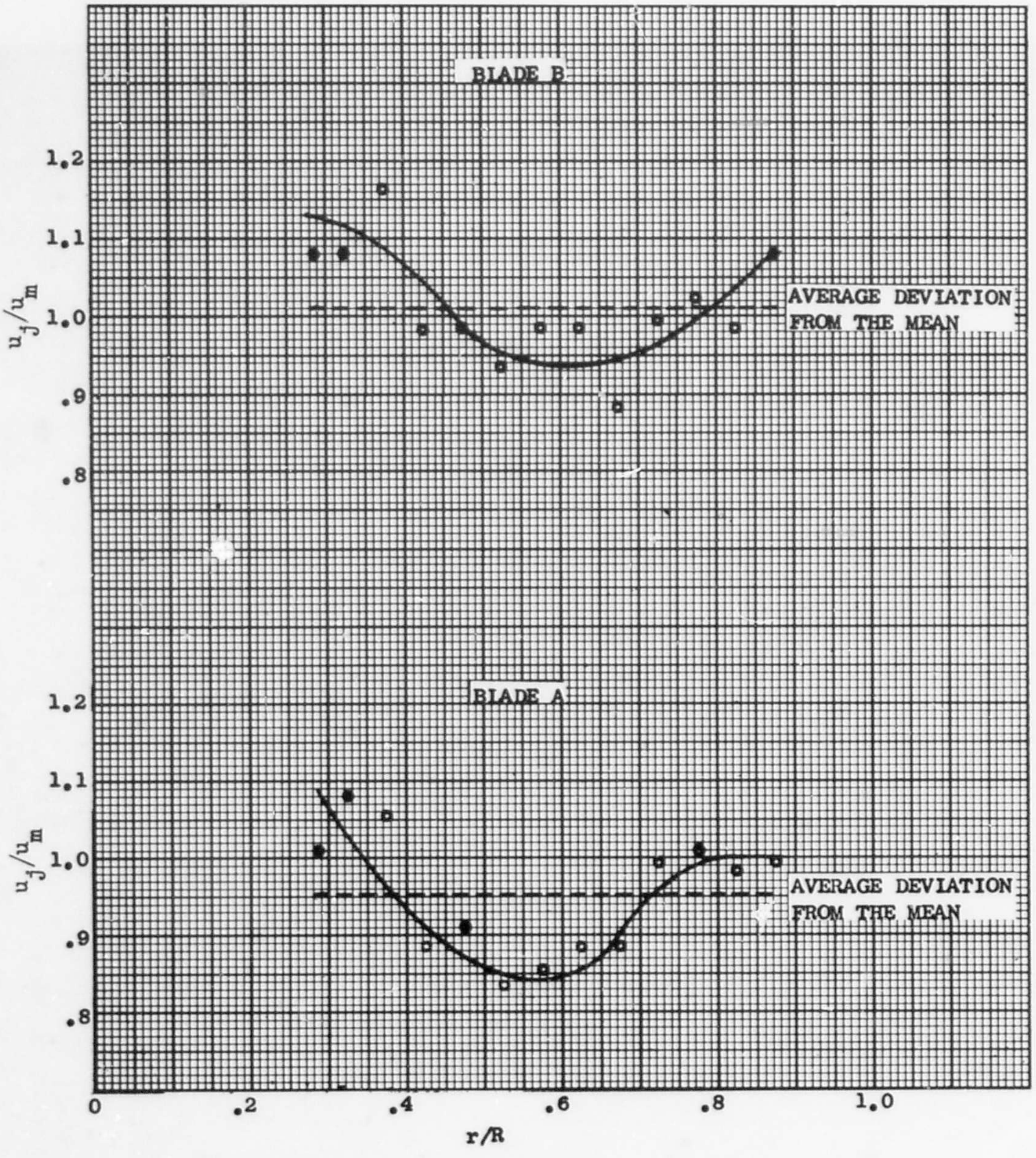


Figure 9 – Jet Flap Velocity Distribution

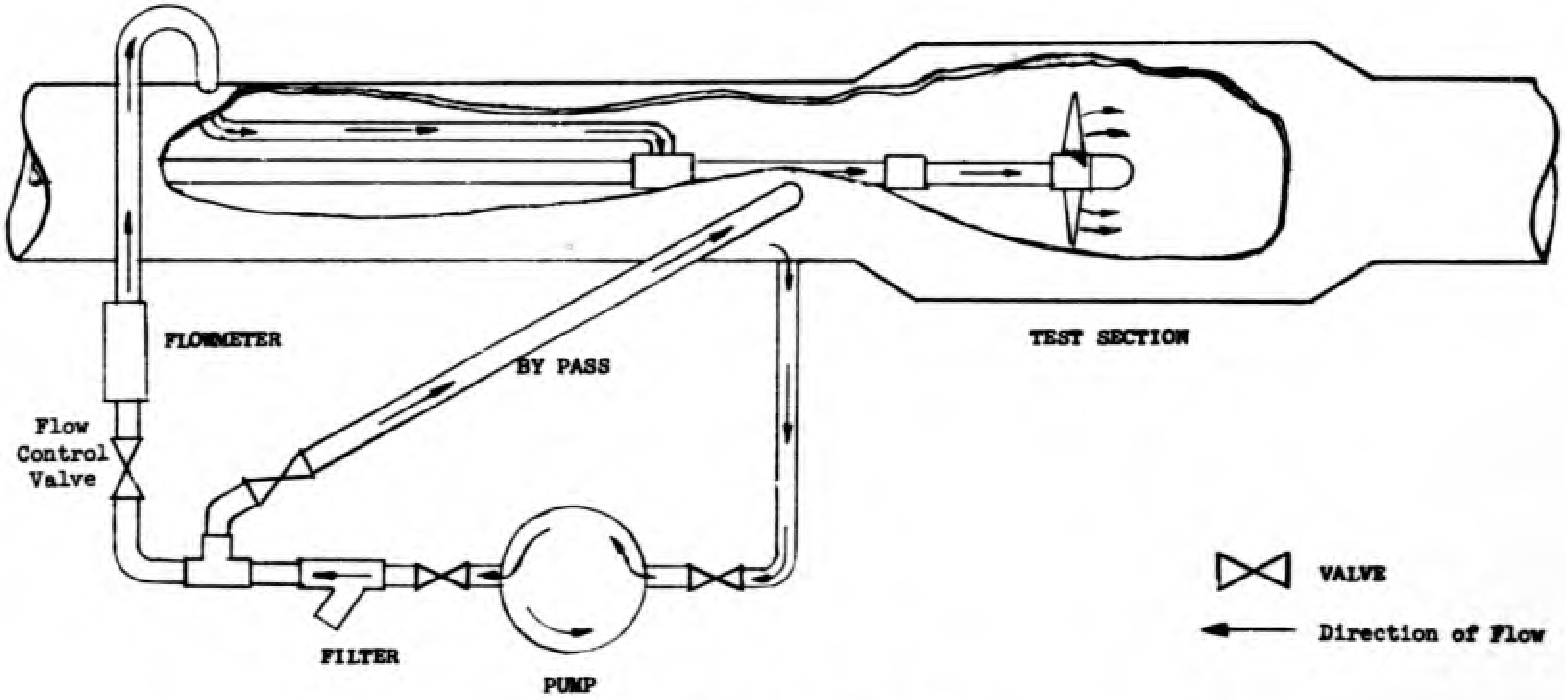


Figure 10 – Jet Flap Pump System

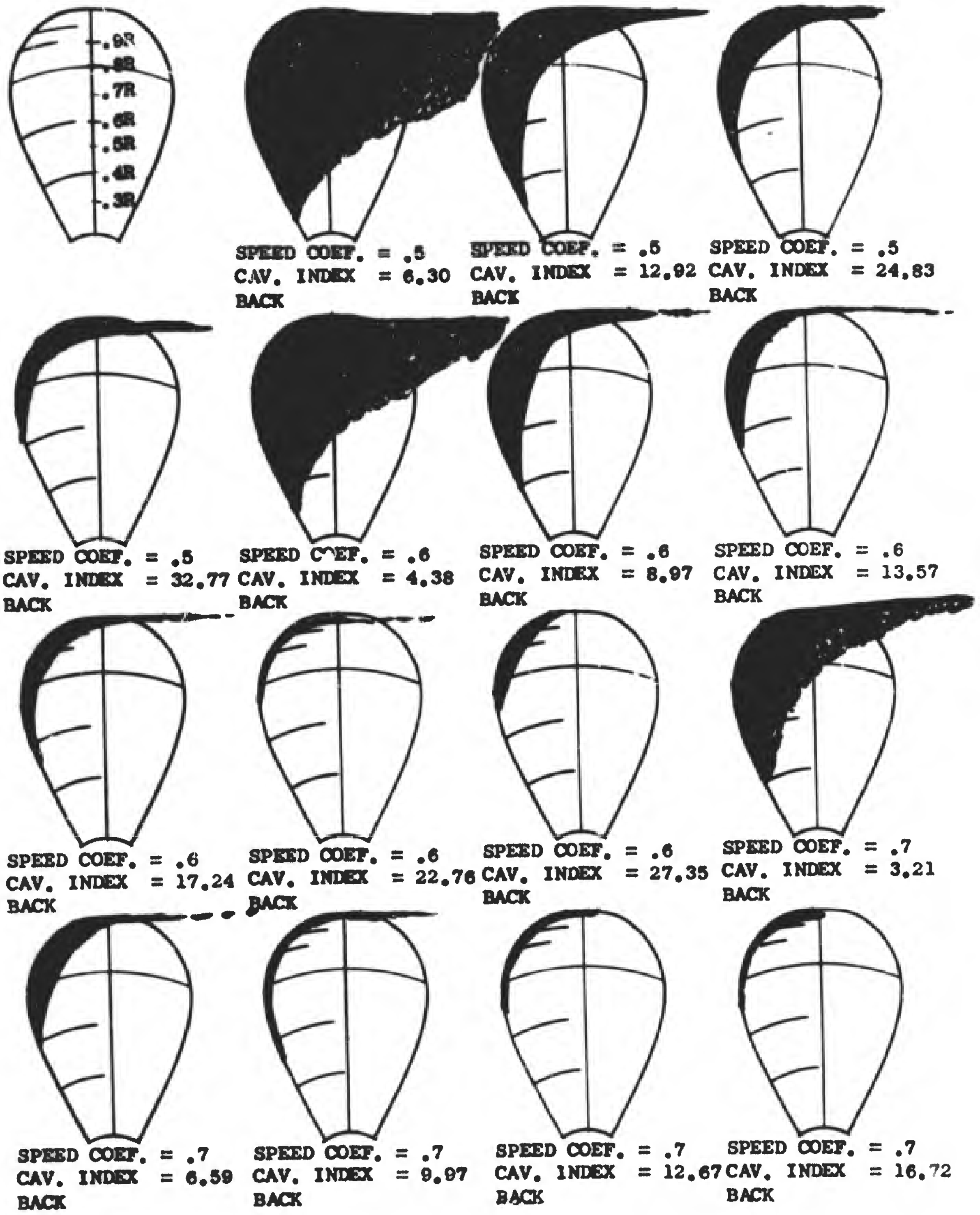
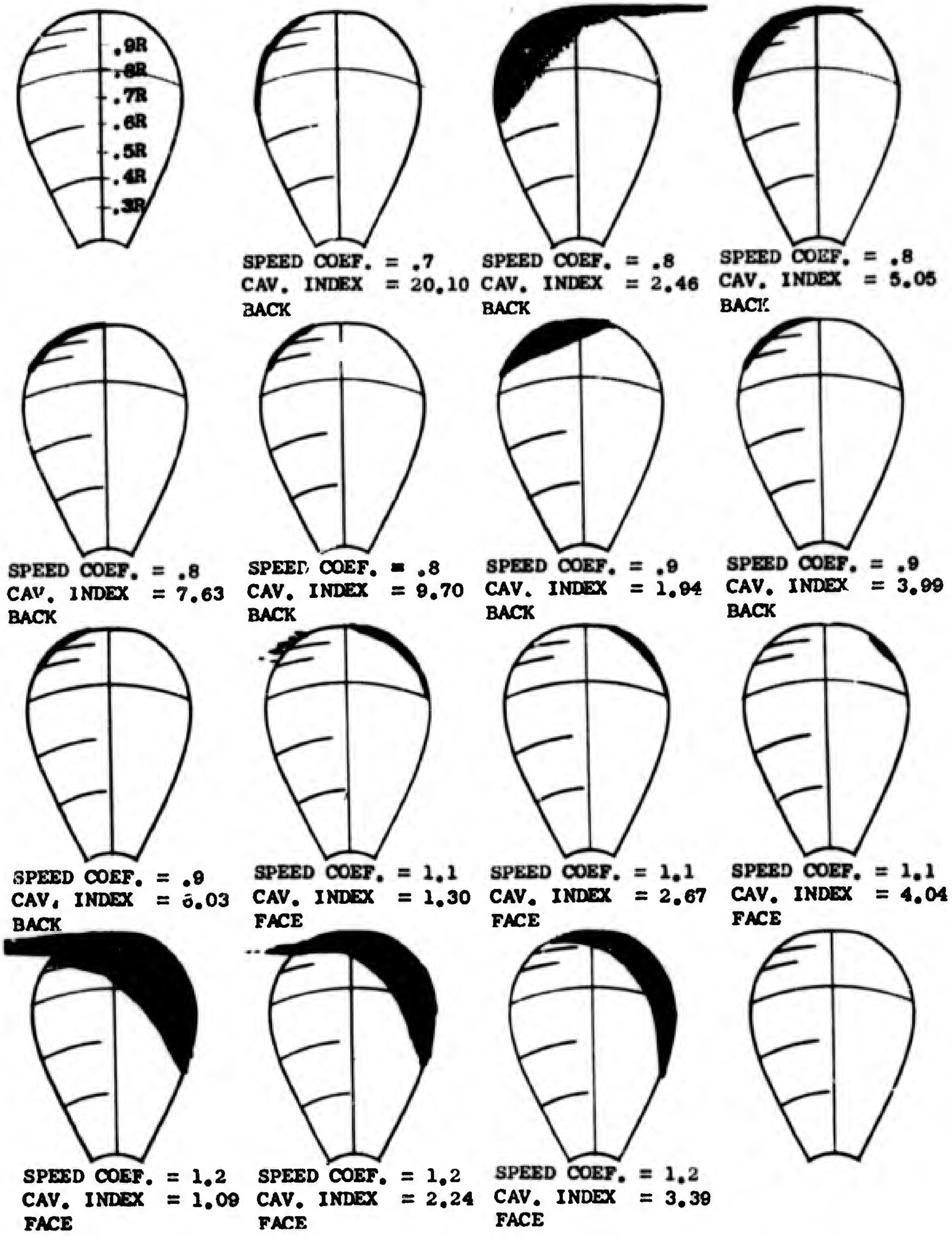


Figure 11 – Back Cavitation at a Number of Advance Coefficients and Cavitation Indices



SPEED COEF. = .7
CAV. INDEX = 20.10
BACK

SPEED COEF. = .8
CAV. INDEX = 2.46
BACK

SPEED COEF. = .8
CAV. INDEX = 5.05
BACK

SPEED COEF. = .8
CAV. INDEX = 7.63
BACK

SPEED COEF. = .8
CAV. INDEX = 9.70
BACK

SPEED COEF. = .9
CAV. INDEX = 1.94
BACK

SPEED COEF. = .9
CAV. INDEX = 3.99
BACK

SPEED COEF. = .9
CAV. INDEX = 6.03
BACK

SPEED COEF. = 1.1
CAV. INDEX = 1.30
FACE

SPEED COEF. = 1.1
CAV. INDEX = 2.67
FACE

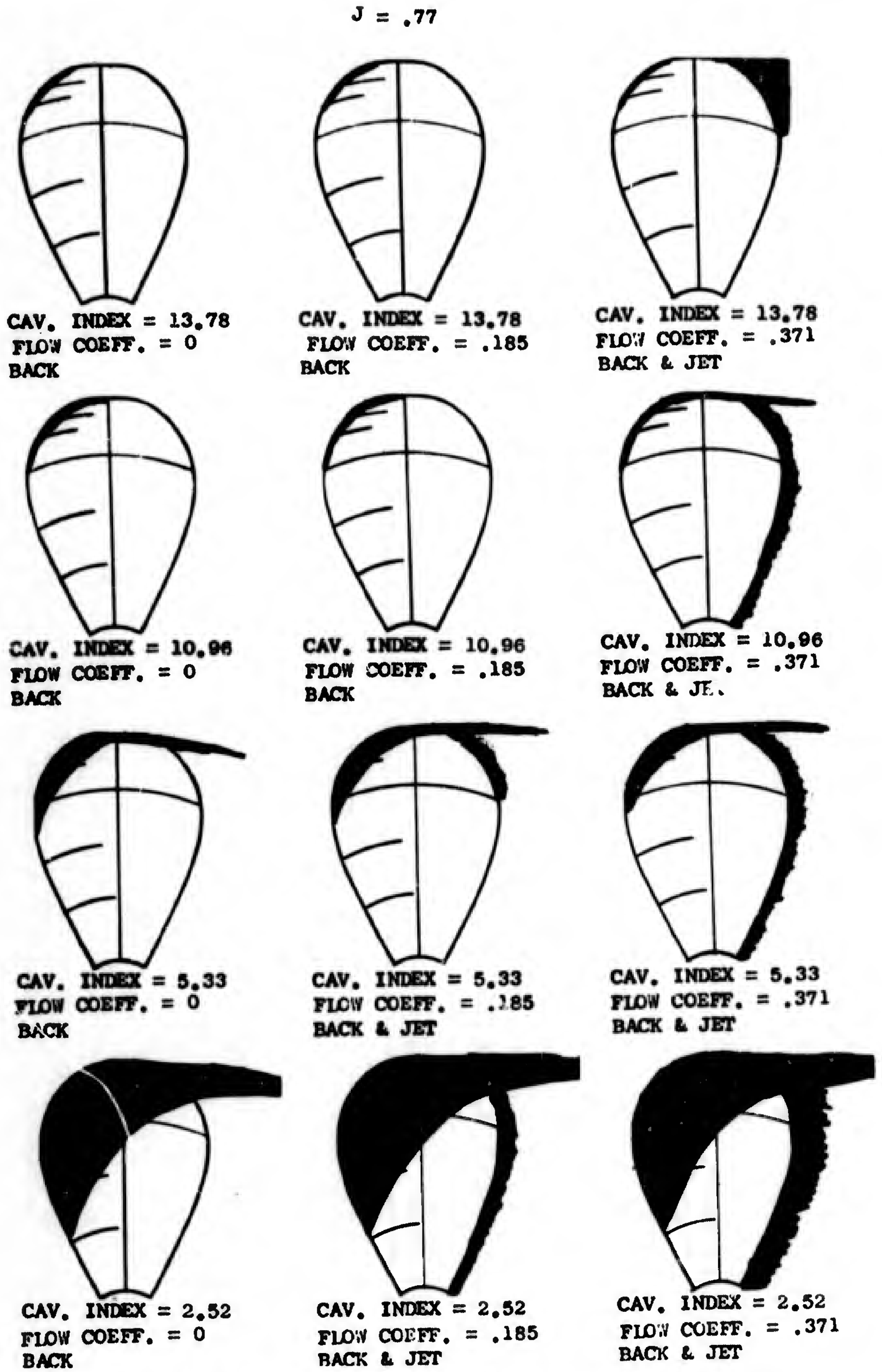
SPEED COEF. = 1.1
CAV. INDEX = 4.04
FACE

SPEED COEF. = 1.2
CAV. INDEX = 1.09
FACE

SPEED COEF. = 1.2
CAV. INDEX = 2.24
FACE

SPEED COEF. = 1.2
CAV. INDEX = 3.39
FACE

Figure 12 – Back and Face Cavitation at a Number of Cavitation Indices



CAV. INDEX = 13.78
FLOW COEFF. = 0
BACK

CAV. INDEX = 13.78
FLOW COEFF. = .185
BACK

CAV. INDEX = 13.78
FLOW COEFF. = .371
BACK & JET

CAV. INDEX = 10.96
FLOW COEFF. = 0
BACK

CAV. INDEX = 10.96
FLOW COEFF. = .185
BACK

CAV. INDEX = 10.96
FLOW COEFF. = .371
BACK & JET

CAV. INDEX = 5.33
FLOW COEFF. = 0
BACK

CAV. INDEX = 5.33
FLOW COEFF. = .185
BACK & JET

CAV. INDEX = 5.33
FLOW COEFF. = .371
BACK & JET

CAV. INDEX = 2.52
FLOW COEFF. = 0
BACK

CAV. INDEX = 2.52
FLOW COEFF. = .185
BACK & JET

CAV. INDEX = 2.52
FLOW COEFF. = .371
BACK & JET

Figure 13 – Back Cavitation at an Advance Coefficient of 0.77

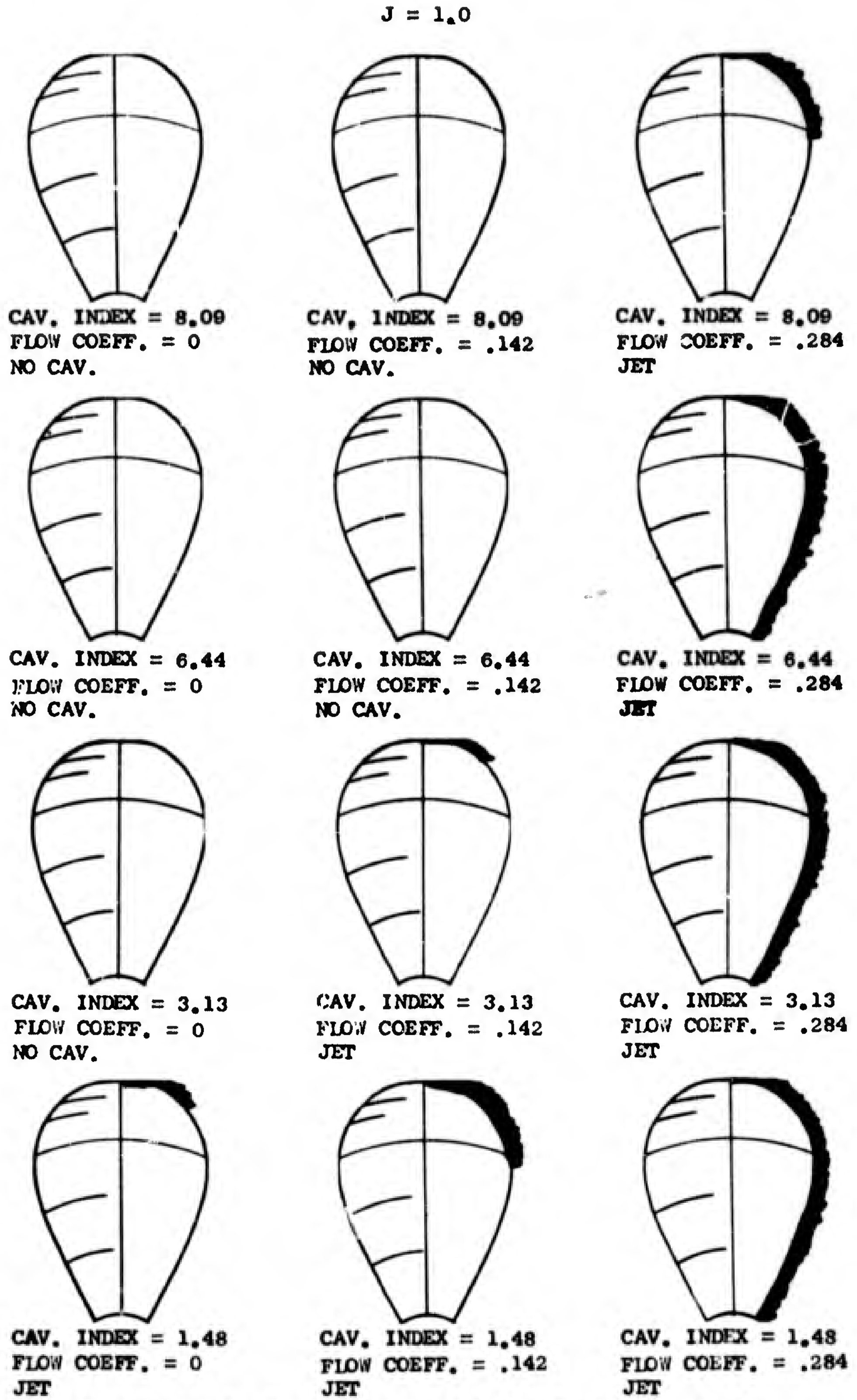
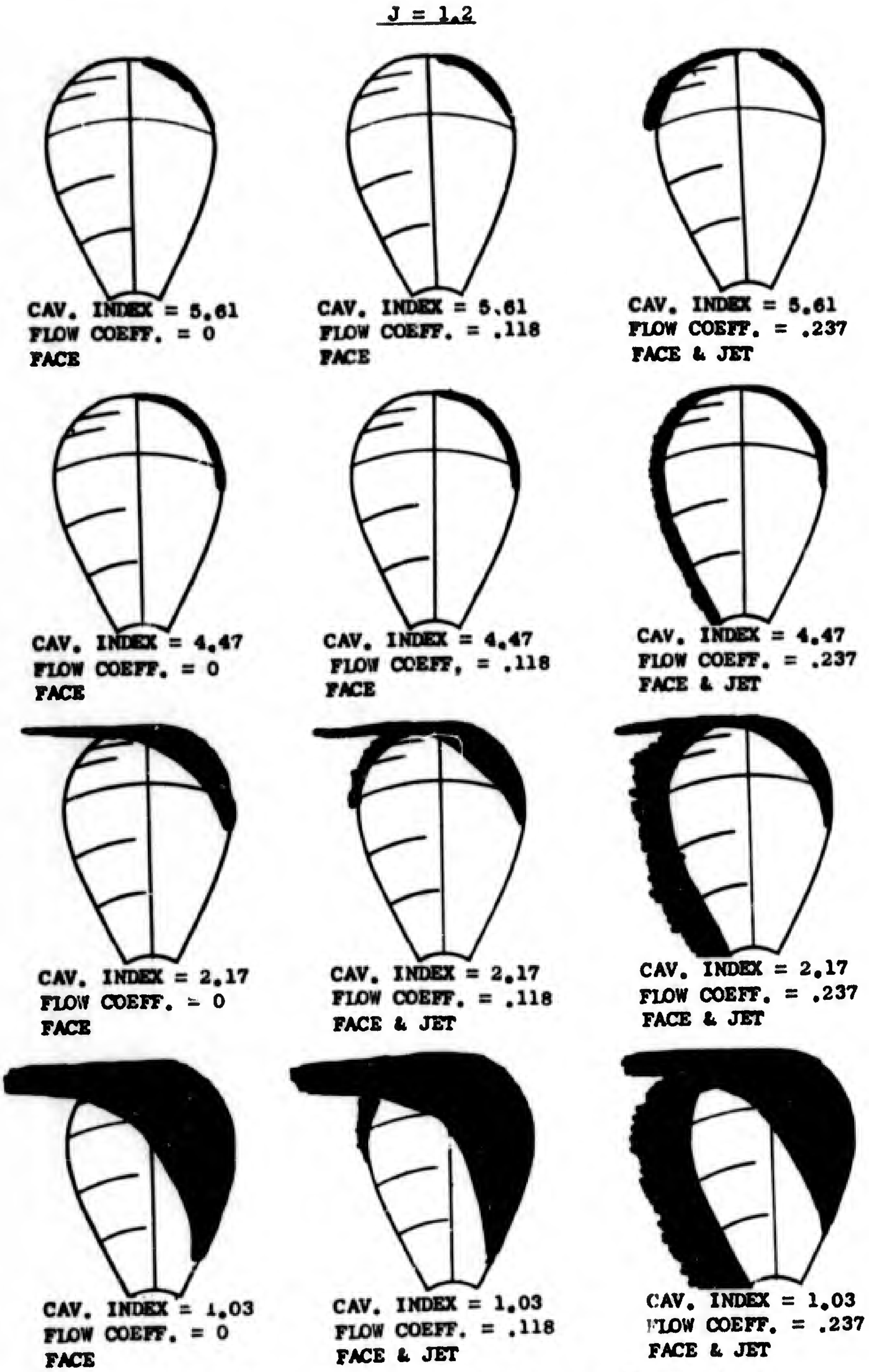


Figure 14 – Jet Cavitation at an Advance Coefficient of 1.0



CAV. INDEX = 5.61
FLOW COEFF. = 0
FACE

CAV. INDEX = 5.61
FLOW COEFF. = .118
FACE

CAV. INDEX = 5.61
FLOW COEFF. = .237
FACE & JET

CAV. INDEX = 4.47
FLOW COEFF. = 0
FACE

CAV. INDEX = 4.47
FLOW COEFF. = .118
FACE

CAV. INDEX = 4.47
FLOW COEFF. = .237
FACE & JET

CAV. INDEX = 2.17
FLOW COEFF. = 0
FACE

CAV. INDEX = 2.17
FLOW COEFF. = .118
FACE & JET

CAV. INDEX = 2.17
FLOW COEFF. = .237
FACE & JET

CAV. INDEX = 1.03
FLOW COEFF. = 0
FACE

CAV. INDEX = 1.03
FLOW COEFF. = .118
FACE & JET

CAV. INDEX = 1.03
FLOW COEFF. = .237
FACE & JET

Figure 15 – Face Cavitation at an Advance Coefficient of 1.2

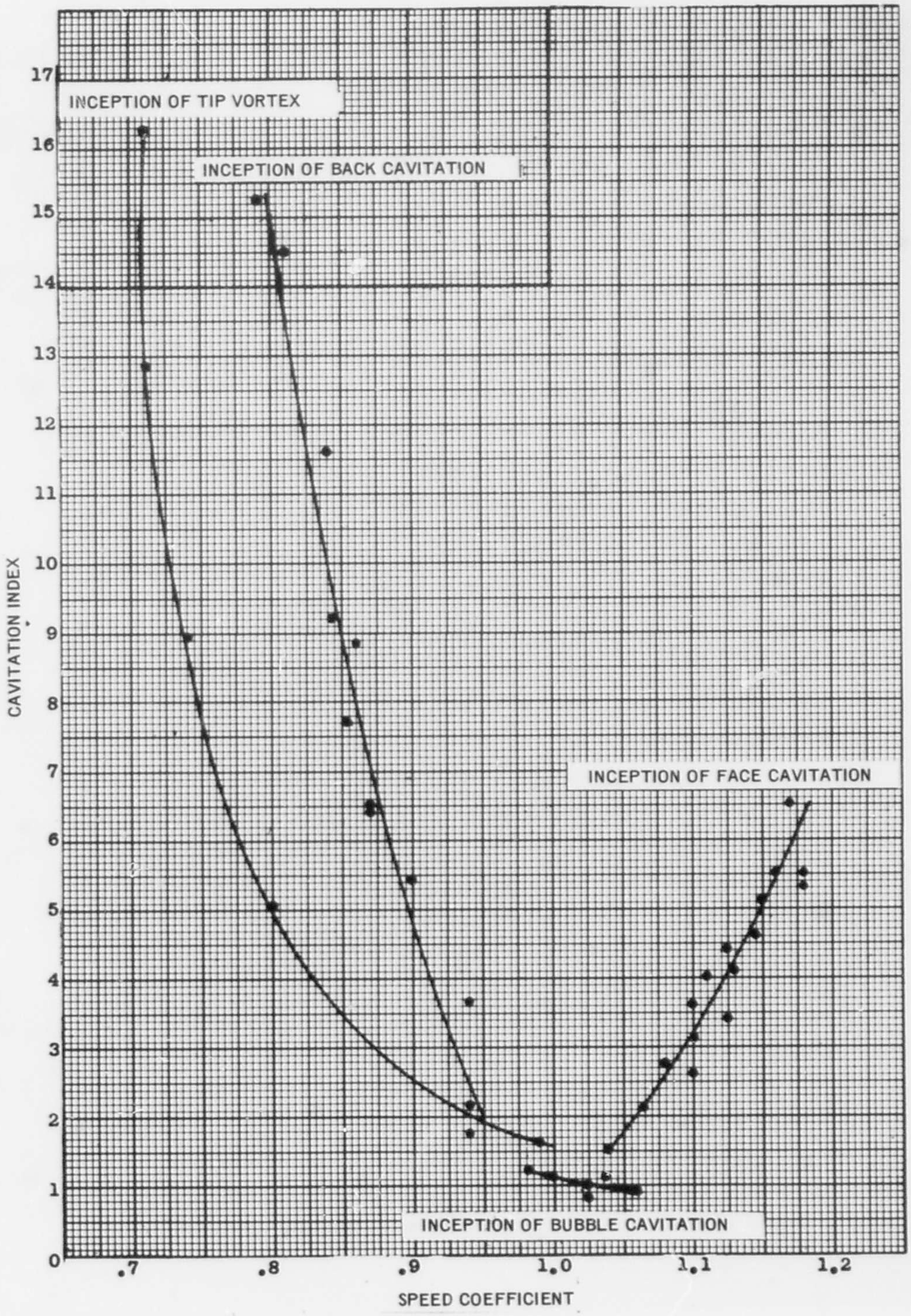


Figure 16 – Cavitation Inception Curves

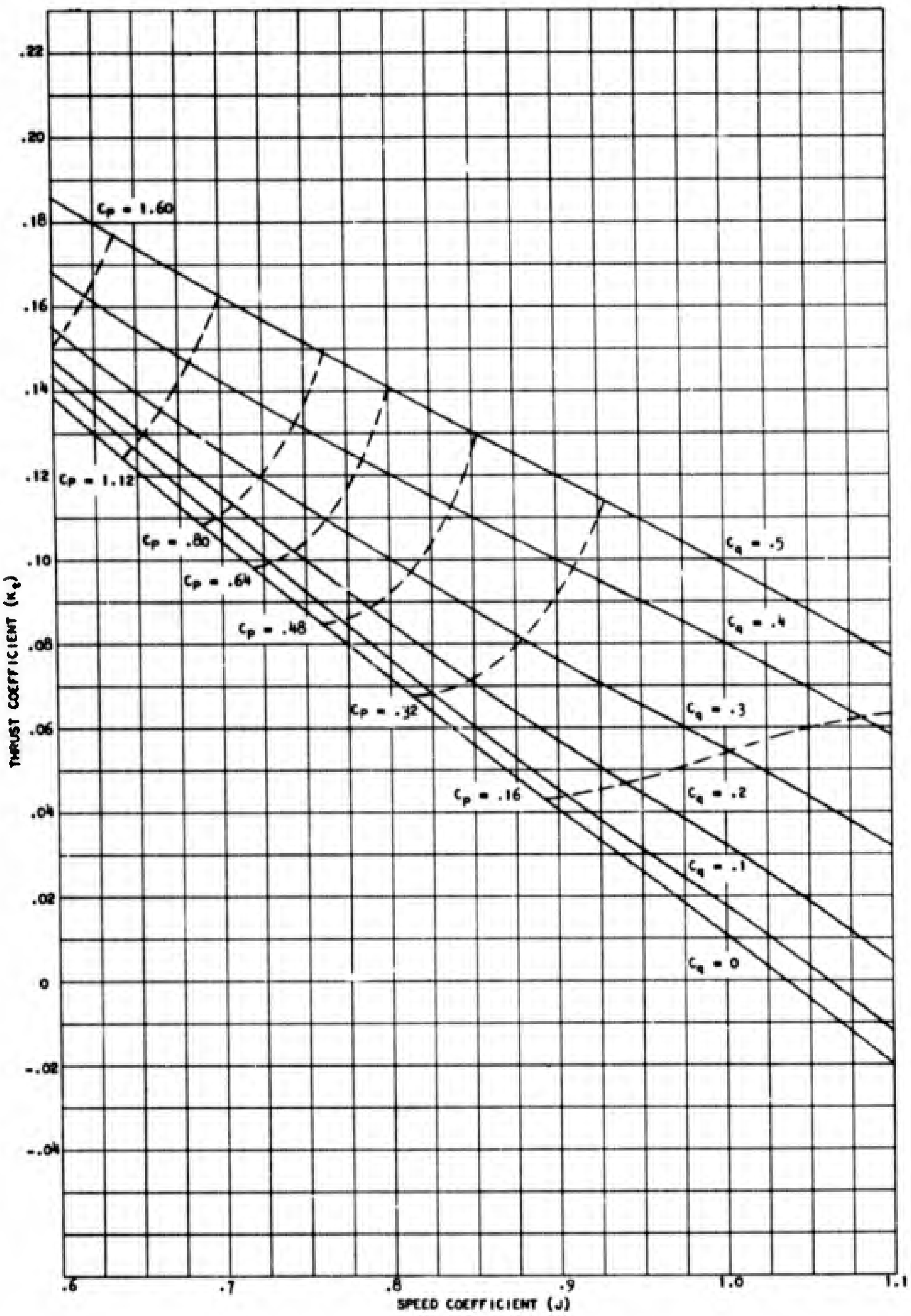


Figure 17 – Curves of Thrust Coefficient versus Advance Coefficient for Constant Power and Flow Coefficients

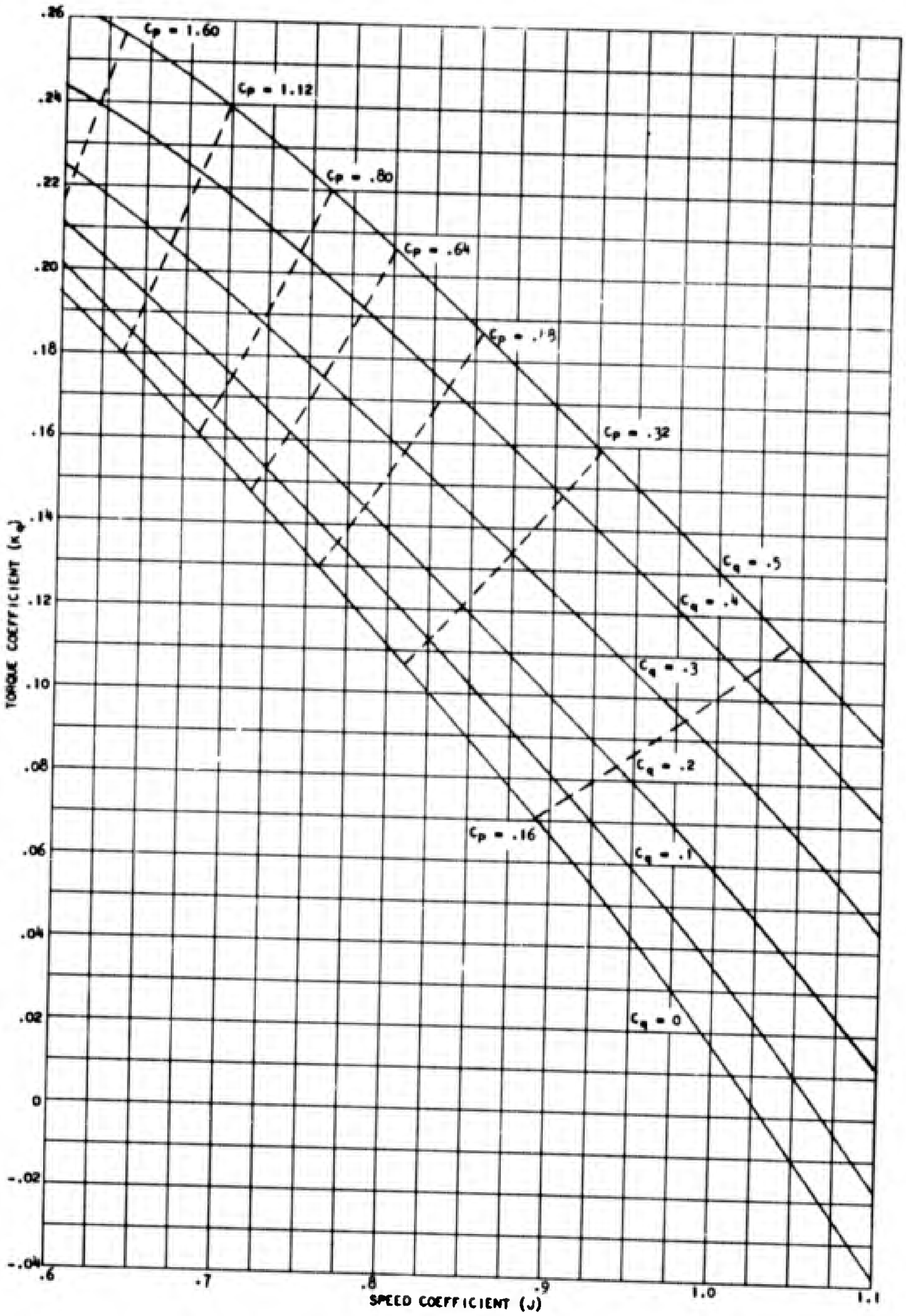


Figure 18 – Curves of Torque Coefficient versus Advance Coefficient for Constant Power and Flow Coefficients

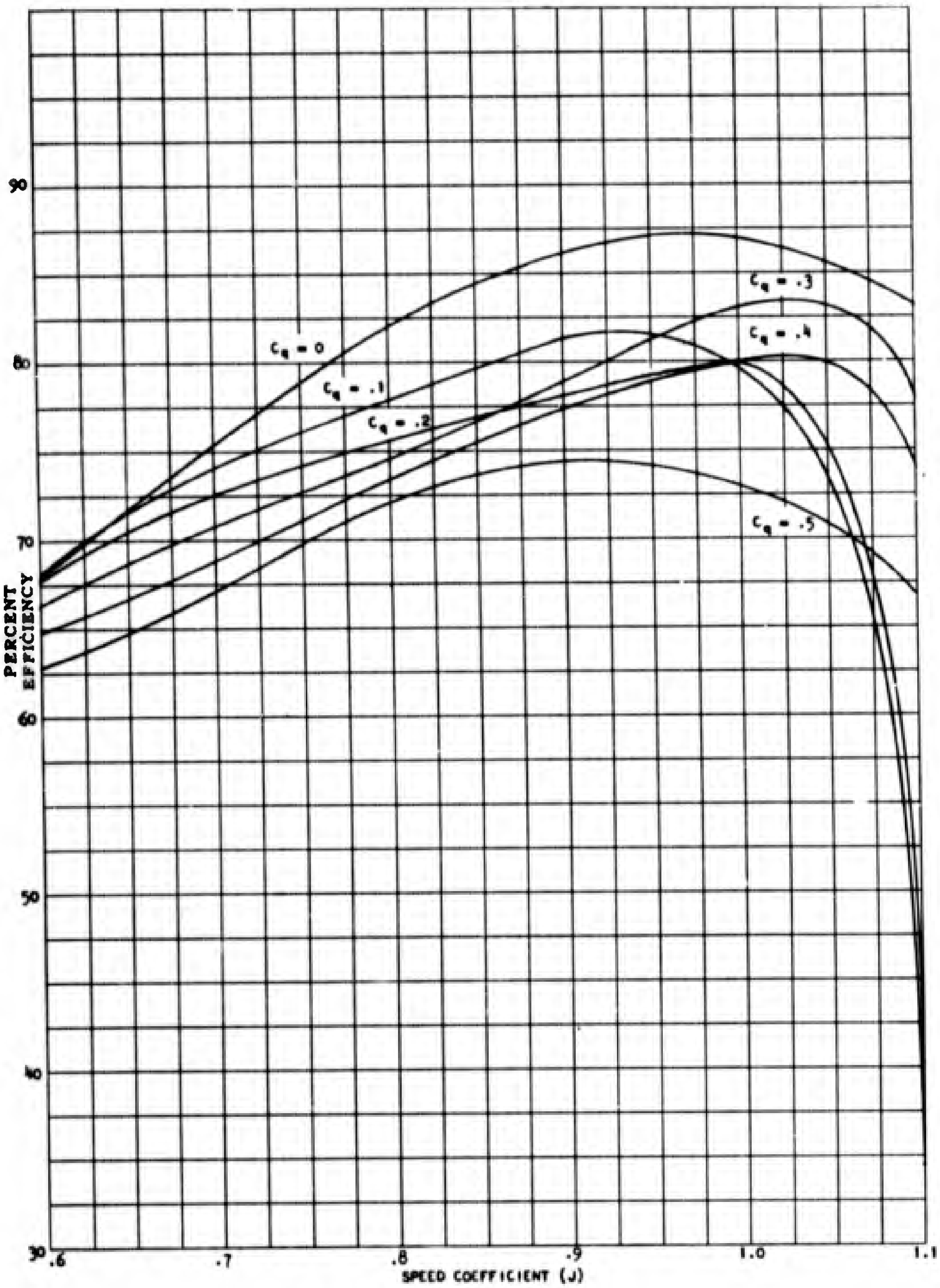


Figure 19 – Propeller Efficiency Curves, Jet Losses Included

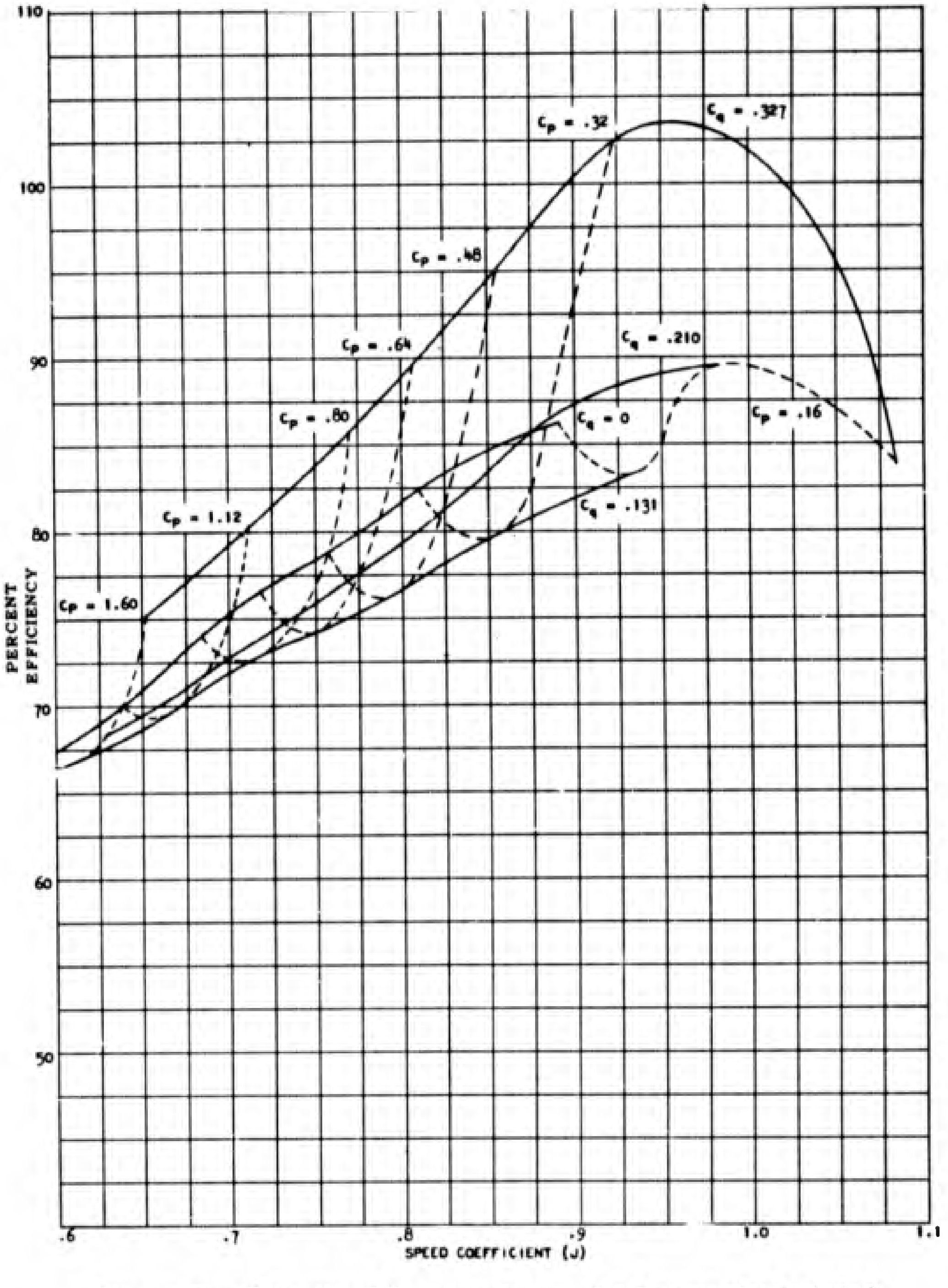


Figure 20 – Propeller Efficiency Curves, Jet Losses Not Included

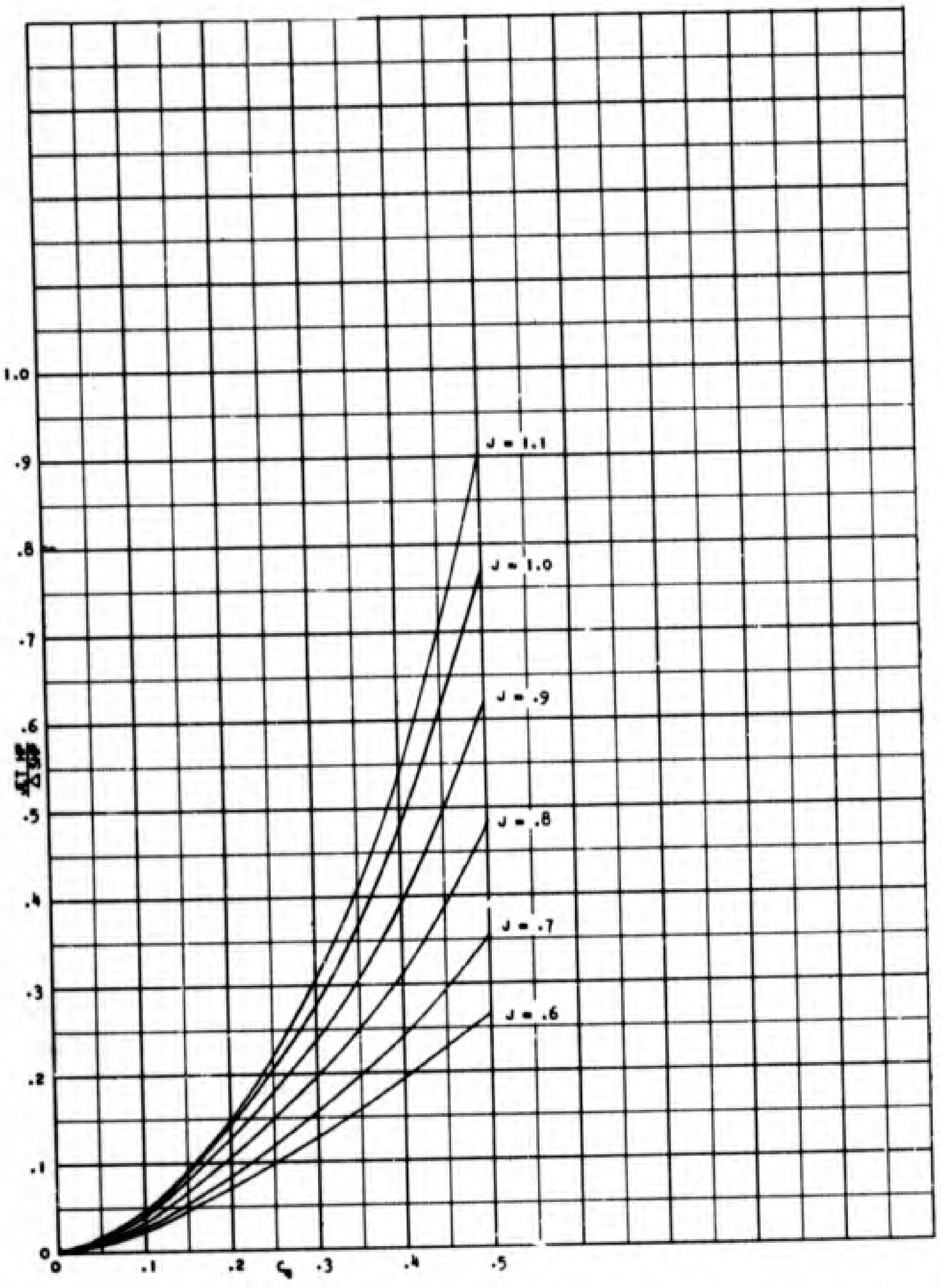


Figure 21 – Ratio of Jet Horsepower to Change in Shaft Horsepower for a Range of Advance Coefficients versus Flow Coefficients

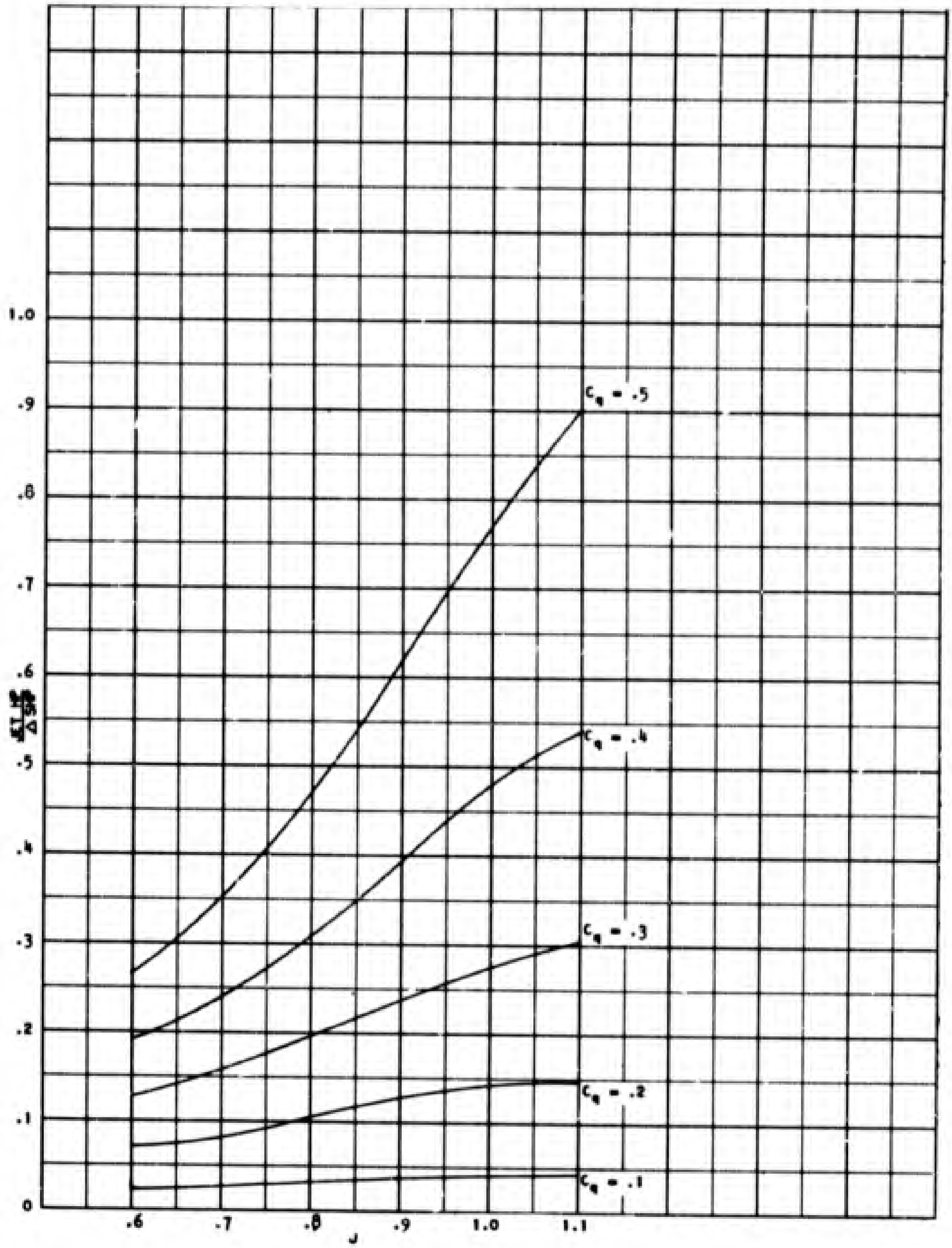


Figure 22 – Ratio of Jet Horsepower to Change in Shaft Horsepower for a Range of Flow Coefficients versus a Range of Advance Coefficients

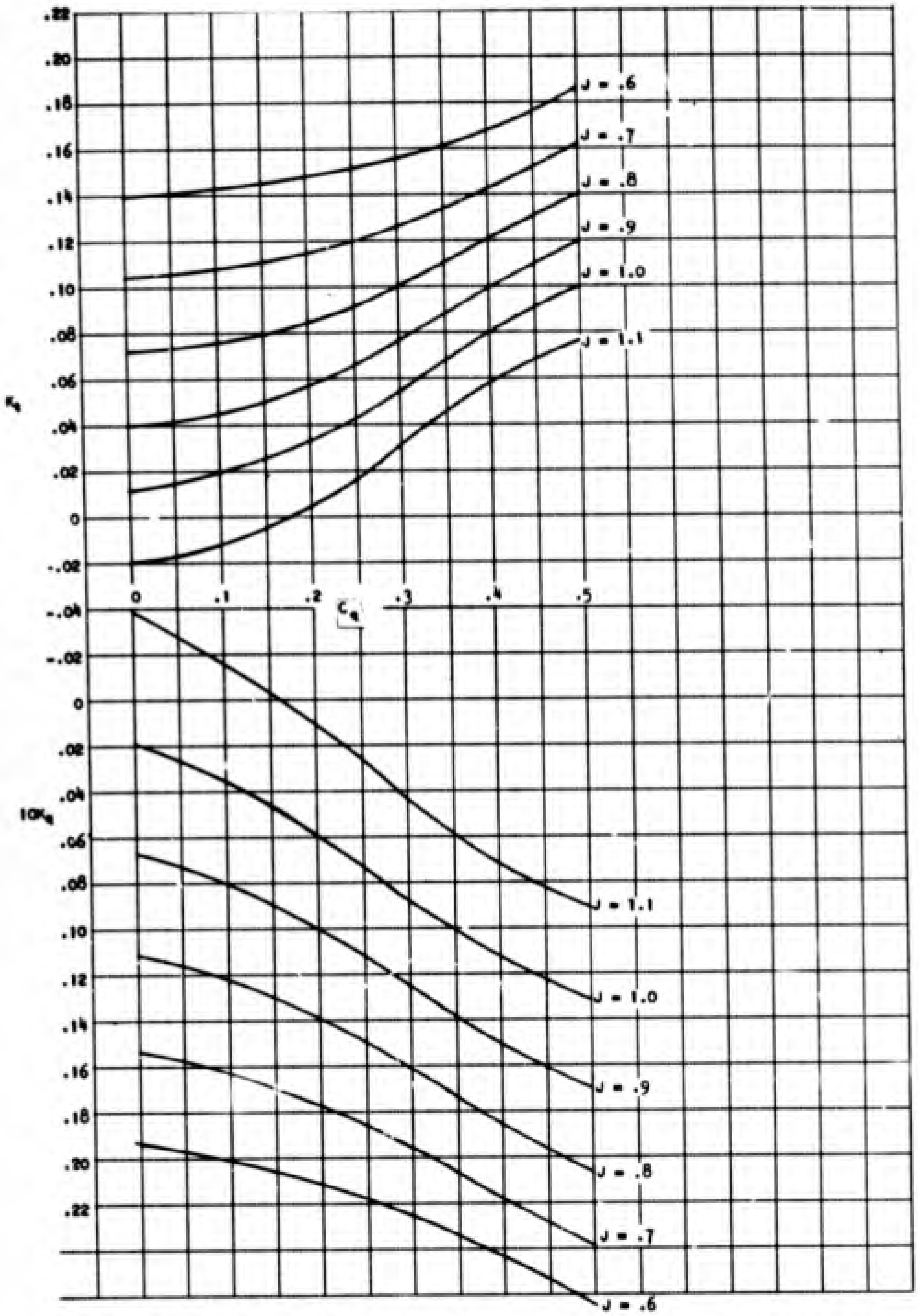


Figure 23 – Thrust and Torque Coefficient for a Range of Advance Coefficients versus Flow Coefficient

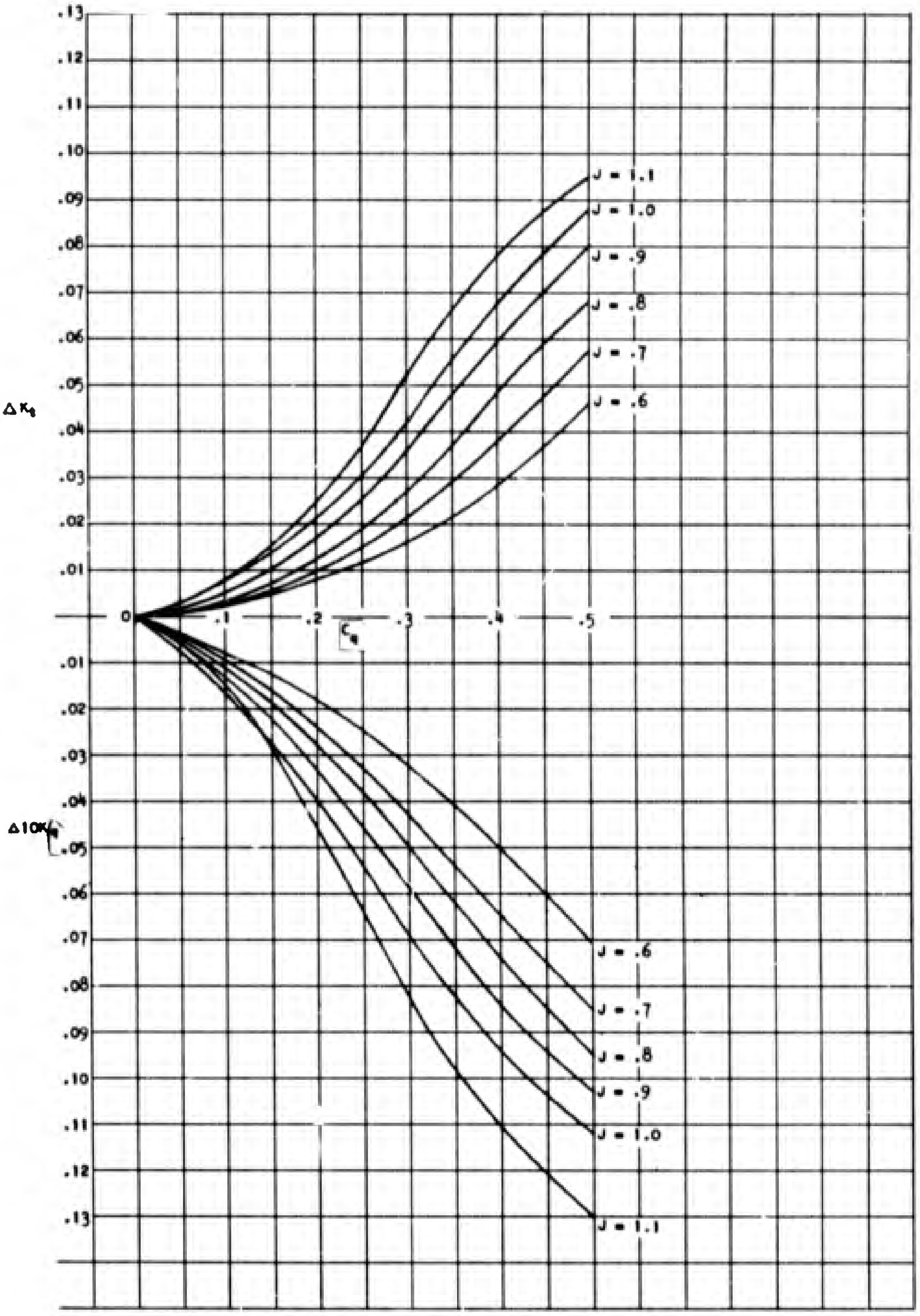


Figure 24 – Change in Thrust and Torque Coefficients for a Range of Advance Coefficients versus Flow Coefficient

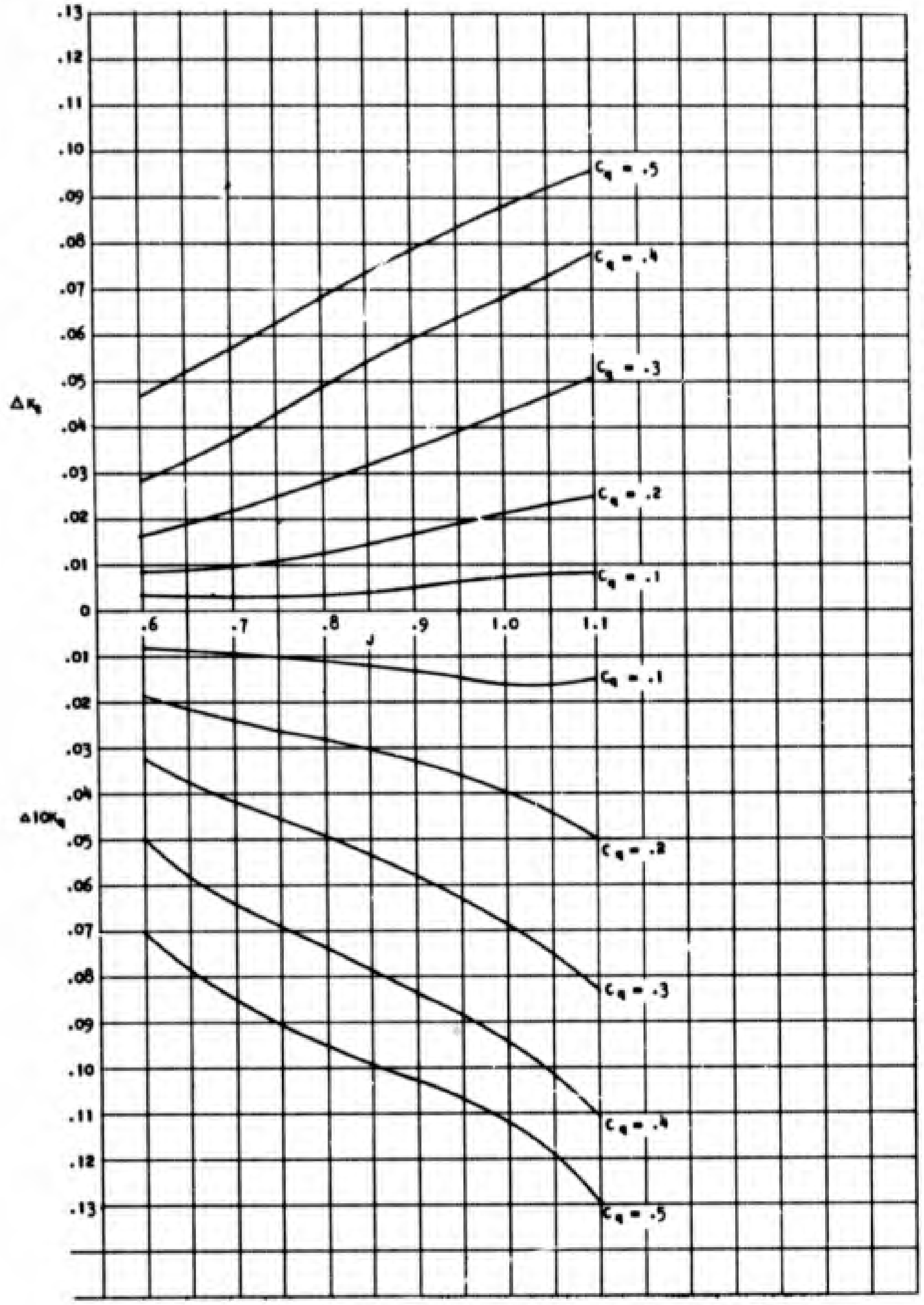


Figure 25 – Change in the Thrust and Torque Coefficients for a Range of Flow Coefficients versus Advance Coefficient

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13. ABSTRACT

The performance characteristics of a marine propeller with a jet flap was investigated. It was found that the jet flap effectively reduced propeller blade cavitation and that for a given advance coefficient the thrust was considerably increased by using the jet flap. The propeller efficiency decreased somewhat, primarily because of the power required in delivering the jet.

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