UNIVERSITI KUALA LUMPUR
Malaysian Institute of Marine Engineering Technology

FINAL EXAMINATION
FEBRUARY 2025 SEMESTER SESSION

SUBJECT CODE	: **LMB31203**
SUBJECT TITLE	: **RESISTANCE AND PROPULSION**
PROGRAMME NAME (FOR MPU: PROGRAMME LEVEL)	: **BACHELOR OF MARINE ENGINEERING TECHNOLOGY WITH HONOURS**
TIME / DURATION	: **9.00 AM – 11.30 AM** (2 HOURS 30 MINUTES)
DATE	: **2 JULY 2025**

INSTRUCTIONS TO CANDIDATES

1. Please read CAREFULLY the instructions given in the question paper.

2. This question paper consists of TWO (2) sections, Section A and Section B.

3. Answer ALL questions in Section A. For Section B, answer THREE (3) This question paper consists of ONE (1) section.

4. Please write your answers on the answer booklet provided.

5. Answer all FIVE (5) questions in English language ONLY.

6. The formula and charts have been appended to use.

THERE ARE 4 PAGES OF QUESTIONS, INCLUDING THIS PAGE.

SECTION A (Total: 40 marks)

INSTRUCTION: Answer ALL questions.
Please use the answer booklet provided.

Question 1

With reference to flow phenomena and motion of ship:

a) Identify TWO (2) main types of drag or force that are combined to create the total resistance on a ship's hull, and relate each to a component of ship resistance.

(8 marks)

b) Explain SIX (6) reasons behind the use of wetted surface of a ship's hull by which it is often approximated by an 'equivalent flat plate' for calculating frictional resistance, within the study of ship resistance.

(12 marks)

Question 2

With reference to ship resistance and model testing:

a) Explain FOUR (4) purposes of using a 'Correlation Allowance' (C_A) when extrapolating model resistance test results to predict full-scale ship resistance.

(8 marks)

b) Illustrate EIGHT (8) general procedures for predicting total ship resistance using Froude's method, by outlining the key steps involved from testing the model to calculating the ITTC 1978 method of ship's total resistance.

(12 marks)

SECTION B (Total: 60 marks)

INSTRUCTION: Answer ONLY THREE (3) questions.
Please use the answer booklet provided.

Question 3

With reference to marine propeller and propulsion:

a) Relate the different power definitions in the propulsion chain: Effective Power (P_E), Thrust Power (P_T), Delivered Power (P_D), and Brake Power (P_B). Show their typical order from propeller output to engine output.

(10 marks)

b) Illustrate the concept of propeller 'Pitch' by sketching a diagram of an unwrapped helical path for a blade section at a radius 'r' and show how the pitch (P) is related to the circumference ($2\pi r$) and the pitch angle (θ).

(10 marks)

Question 4

With reference to propeller design using charts and polynomials ($K_T - K_Q$ chart):

An LNG carrier is to be designed to travel at 19 knots. The total resistance of the ship at full scale is 3125kN. The propeller consists of five blades and a blade area ratio of 0.80 equipped with a propeller with diameter of 5.8m. Using the B-series k-J chart provided for this blade area ratio, estimate the required pitch to diameter ratio of these screws, the propeller RPM, and the efficiency at which they will operate. To calculate this, you must tabulate J and K_Q values using the $K_Q - J^3$ relationship of $K_Q = 0.462J^3$, assuming the wake fraction value to be 0.23 and thrust deduction factor of 0.19.

(20 marks)

Question 5

With reference to propeller design using charts and polynomials (B_P - δ chart):

A crude oil carrier, designed for a domestic route is to have a vessel speed of 17 knots. Early resistance prediction reveals that the vessel will be installed with a 16500 kW diesel propulsion motor. The propeller diameter is set to 3.3m. Using the Bp2-δ chart for propeller Wageningen B4.70 and assuming the shafting efficiency to be 0.97, calculate the propeller shaft speed, pitch-diameter ratio, and the resulting open water efficiency of propeller. Assume the value of wake fraction, w = 0.24.

(20 marks)

Question 6

With reference to Propeller Cavitation considerations:

A 15.2 knots (advance velocity) containership is to be equipped with five-bladed propeller of 4.5 m in diameter and shaft revolution of 220 rpm, with propeller shaft axis immersion of 4.0m and thrust, T = 350kN. Using Burrill's cavitation diagram for upper limit of merchant ships, determine its blade area ratio (BAR). Assume the pitch-diameter ratio of 0.95.

(20 marks)

END OF QUESTIONS

USEFUL FORMULA & DATA

Density

Fresh water   = 1000 kg/m³
Sea water   = 1025 kg/m³
Air at 15°C   = 1.225 kg/m³

Kinematic viscosity

Fresh water at 15°C = 1.139×10^{-6} m³/s
Sea water at 15°C = 1.183×10^{-6} m³/s
Fresh water at 24°C = 9.131×10^{-7} m³/s

Granville Line Formulation

$$C_{FO} = \frac{0.0776}{(\log_{10} Re - 1.88)^2} + \frac{60}{Re}$$

Hughes Line Formulation

$$C_{FO} = \frac{0.066}{(\log_{10} Re - 2.03)^2}$$

ATTC Line Formulation

$$\frac{0.242}{\sqrt{C_F}} = \log_{10}(Re.C_F)$$

ITTC 1957 Model Ship Correlation Formulation

$$C_F = \frac{0.075}{(\log_{10} Re - 2)^2}$$

Non-dimensional coefficient for total resistance

$$C_T = \frac{R_T}{\frac{1}{2}\rho S V^2}$$

Froude's approach

$$R_T = R_F + R_R$$
$$C_T = C_F + C_R$$

Hughes's approach

$$R_T = R_V + R_W$$
$$C_T = C_V + C_W$$
$$= C_F(1+k) + C_W$$

ITTC 1978 Resistance Prediction – Updated 2014

The total ship resistance coefficient without bilge keels is given by:

$$C_{TS} = C_{FS}(1+k) + C_R + \Delta C_F + C_A + C_{AAS}$$

where:

C_{FS} = frictional coefficient of ship according to the ITTC 1957 ship model correlation line

C_R = residual resistance calculated from the total and viscous resistance of the model

$$= C_{TM} - (1+k)C_{FM}$$

Bilge keels can be allowed for by multiplying the C_{FS} and C_A terms by the ratio

$$\frac{S + S_{BK}}{S}, \quad S_{BK} = \text{surface area of the bilge keels}$$

The correlation allowance is calculated from

$$C_A = (5.68 - 0.6\log Re) \times 10^{-03}$$

The roughness allowance is calculated from

$$\Delta C_F = 0.044\left[\left(\frac{k_s}{L_{WL}}\right)^{\frac{1}{3}} - 10.Re^{-\frac{1}{3}}\right] + 0.000125$$

k_s can be taken as 150×10^{-6} m.

Air resistance is calculated from

$$C_{AAS} = C_{DA}\frac{\rho_A.A_{VS}}{\rho_S.S_S}$$

A_{VS} = transverse projected area of ship above the waterline

L : model length

V : model speed before correction

Propeller scale effect correction

$$K_{TOS} = K_{TO} - \Delta K_T$$
$$K_{QOS} = K_{QO} - \Delta K_Q$$

$$\Delta K_T = -\Delta C_D \times 0.3 \frac{P}{D} \cdot \frac{cZ}{D}$$

$$\Delta K_Q = \Delta C_D \times 0.25 \frac{cZ}{D}$$

$$\Delta C_D = C_{DM} - C_{DS}$$

$$C_{DM} = 2\left(1 + 2\frac{t}{c}\right)\left[\frac{0.044}{R_{nco}^{1/6}} - \frac{5}{R_{nco}^{2/3}}\right]$$

$$C_{DS} = 2\left(1 + 2\frac{t}{c}\right)\left[1.89 + 1.62\log_{10}\frac{c}{k_p}\right]^{-2.5}$$

$$k_p = 30 \times 10^{-6}\, m$$

$$R_{nco} = \frac{c\sqrt{V_A^2 + (2\pi nr)^2}}{v}$$

Emerson Blockage correction

$$\frac{\Delta V}{V} = 1.65 \frac{m_3}{1 - m_3 - F_{nh}^2}$$

$$m_1 = \frac{A_M}{A}$$

$$m_2 = \frac{\nabla}{A \times L}$$

$$m_3 = \frac{m_1 + m_2}{2}$$

$$F_{nh} = \frac{V}{\sqrt{gh}}$$

A_M : midship sectional area f model

A : tank cross sectional area

∇ : model volume displacement

Schuster Blockage correction

$$\frac{\Delta V}{V} = \frac{m_1}{1 - m_1 - F_{nh}^2} + \left(1 - \frac{R_V}{R_T}\right)\frac{2}{3} F_{nh}^{10}$$

$$m_1 = \frac{A_M}{A_T}$$

where A_M is the maximum sectional area of the model and A_T is the maximum sectional area of the full scale vessel.

Ship Flow of Transmission of Power

$$P_E = R_T V_S$$

$$P_T = T V_A$$

$$K_T = \frac{T}{\rho n^2 D^4}$$

$$K_Q = \frac{Q}{\rho n^2 D^5}$$

$$J = \frac{V_A}{nD}$$

$$\eta_O = \frac{K_T}{K_Q} \cdot \frac{J}{2\pi}$$

$$\eta_H = \frac{P_E}{P_T} = \frac{R_T V_S}{T V_A}$$

$$\eta_S = \frac{P_D}{P_B}$$

$$\eta_B = \frac{P_T}{P_D}$$

$$\eta_D = QPC = \frac{P_E}{P_D} = \eta_R \eta_O \eta_H = \frac{(1-t)}{(1-w)}\eta_B$$

Propeller Torque $Q = \dfrac{P_D}{2\pi n}$

Propeller Thrust $T = \dfrac{P_T}{V_A}$

$\eta_R = \dfrac{\eta_B}{\eta_O} = \dfrac{P_T}{P_D} \cdot \dfrac{P_{DO}}{P_{TO}}$

Thrust Identity; $P_T = P_{TO}; \therefore \eta_R = \dfrac{P_{DO}}{P_D}$

Torque identity; $P_D = P_{DO}; \therefore \eta_R = \dfrac{P_T}{P_{TO}}$

$\dfrac{P_E}{P_B} = \eta_S \eta_R \eta_O \eta_H$

$t = \dfrac{T - R_T}{T}$ or $\dfrac{R_T}{T} = 1 - t$

$\omega = \dfrac{V_S - V_A}{V_S}$ or $\dfrac{V_A}{V_S} = 1 - \omega$

Apparent Slip $= \left(1 - \dfrac{V}{Pn}\right)$

True Propeller Slip $= \left(1 - \dfrac{V_A}{Pn}\right)$

Propeller Design using Charts and Polynomials

Known power, RPM and advance velocity

$\dfrac{K_Q}{J^5} = \dfrac{Q}{\rho n^2 D^5}\left(\dfrac{nD}{V_A}\right)^5 = \dfrac{Qn^3}{\rho V_A^5}$

Known power, diameter and advance velocity

$\dfrac{K_Q}{J^3} = \dfrac{Q}{\rho n^2 D^5}\left(\dfrac{nD}{V_A}\right)^3 = \dfrac{Qn}{\rho D^2 V_A^3} = \dfrac{P_D}{2\pi\rho D^2 V_A^3}$

Known thrust, diameter and advance velocity

$\dfrac{K_T}{J^2} = \dfrac{T}{\rho n^2 D^4}\left(\dfrac{nD}{V_A}\right)^2 = \dfrac{T}{\rho V_A^2 D^2}$

Known thrust, RPM and advance velocity

$\dfrac{K_T}{J^4} = \dfrac{T}{\rho n^2 D^4}\left(\dfrac{nD}{V_A}\right)^4 = \dfrac{Tn^2}{\rho V_A^4}$

Cavitation Considerations

Burrill's Method

$V_R = \left[(0.7\pi nD)^2 + V_A^2\right]^{\frac{1}{2}}$

$P_O = P_{atm} + \rho g h$

Atmospheric pressure

$P_{atm} = 101300 N/m^2$

Vapour pressure of water

$P_V = 1700\, N/m^2$ at 15°C
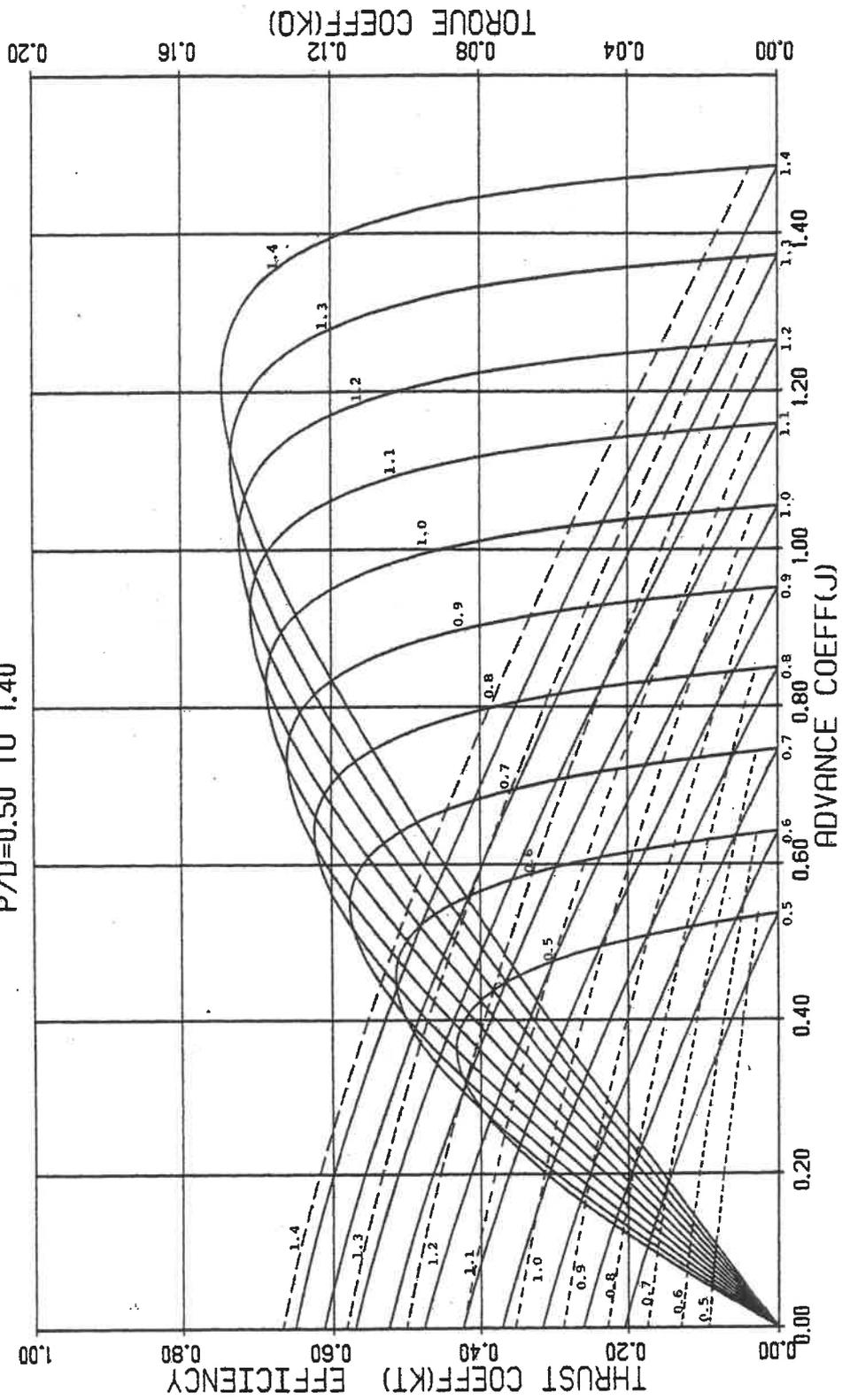
$\sigma = \dfrac{P_O - P_V}{q_T}$

$q_T = 0.5\rho V_R^2$
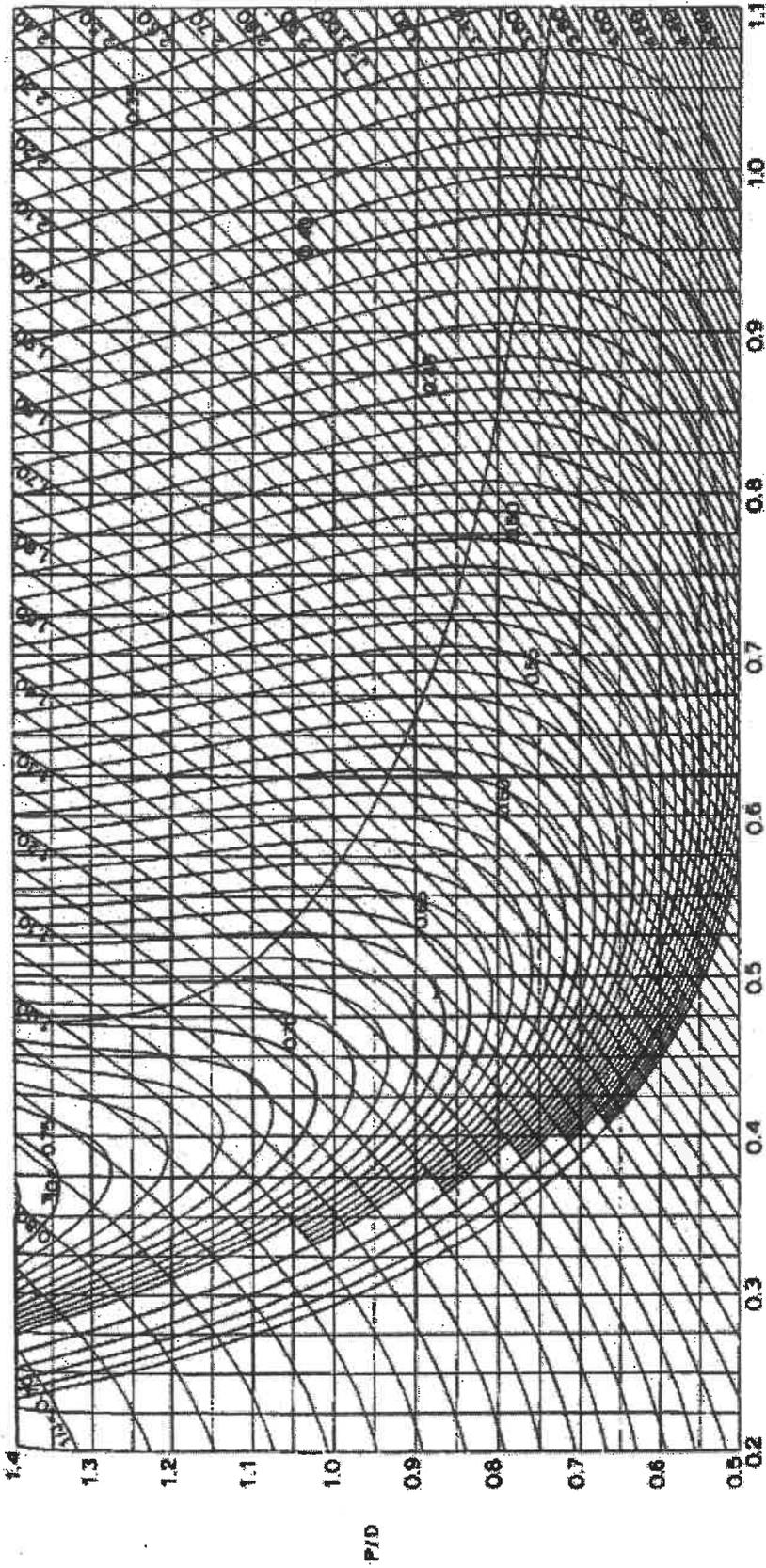
$\dfrac{A_P}{A_D} = \left[1.067 - 0.229\dfrac{P}{D}\right]$

$\tau_C = \dfrac{T}{\dfrac{1}{2}\rho A_P V_{R(0.7)}^2}$

Keller's method

$\dfrac{A_E}{A_O} = \dfrac{(1.3 + 0.3Z)T}{(P_O - P_V)D^2} + K$

FIGURE 59. WAGENINGEN B-SERIES PROPELLERS
FOR 5 BLADES   AE/AO= 0.800
P/D=0.50 TO 1.40
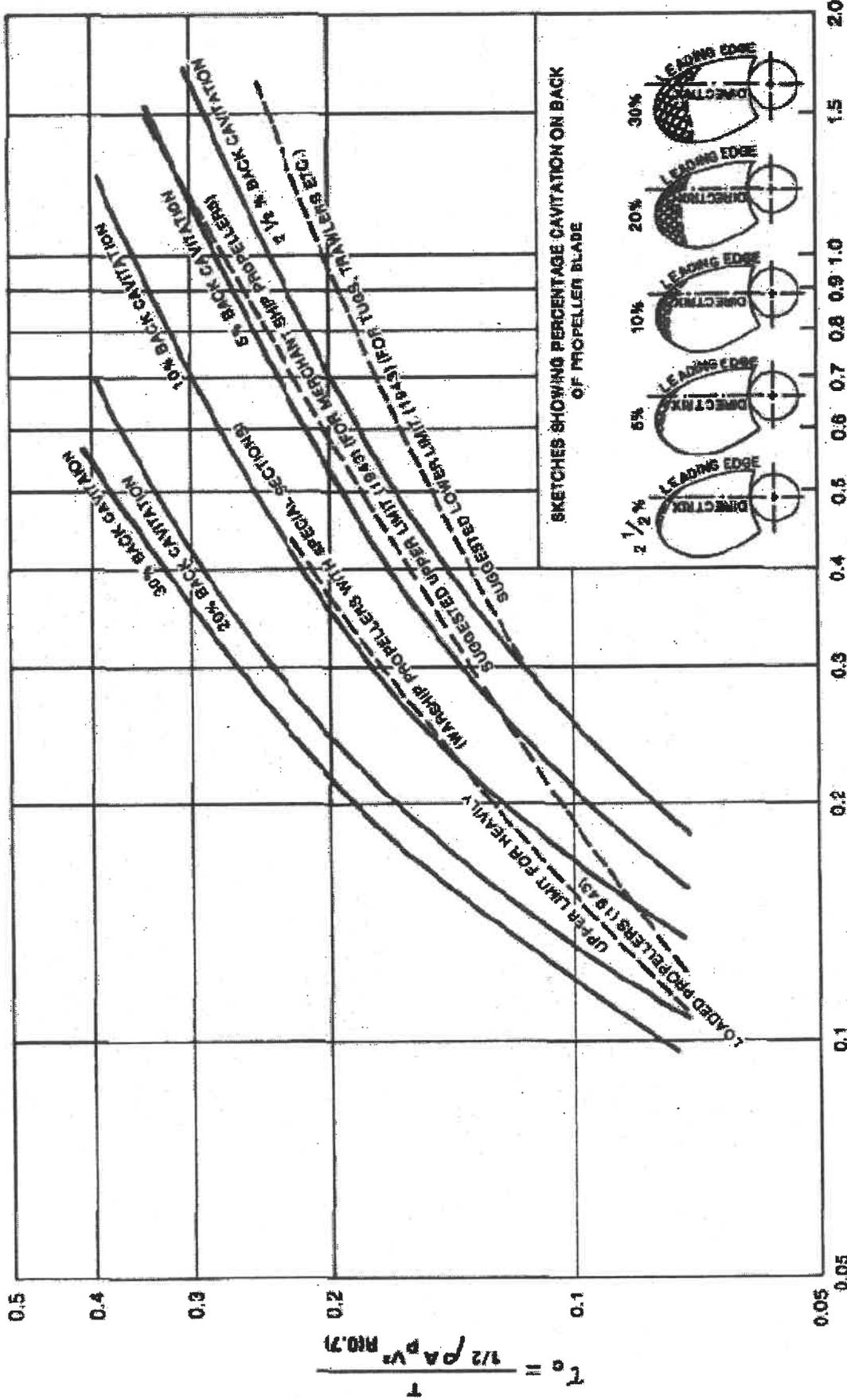
B.4 - 70

1975

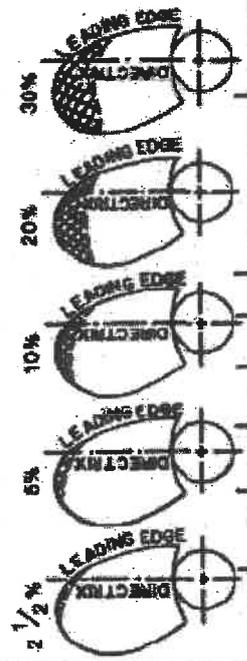$$1.75\sqrt{B_{p2}} = K_Q^{1/4} \cdot J^{-3/4}$$

$$Bp_2 = P^{1/2} \cdot D^{-1} \cdot V_A^{-3/2}$$

D = PROPELLER DIAMETER IN FEET
V_A = $V_S (1-w)$
V_S = SHIP SPEED IN KNOTS
w = WAKE FRACTION
P = SHAFT HORSEPOWER (BRITISH)

$$K_Q^{1/4} \cdot J^{-3/4} = \left[\frac{Q n}{\rho D^2 V_A^3}\right]^{1/4}$$

$$= \left[\frac{P}{2\pi \rho D^2 V_A^3}\right]^{1/4} \cdot$$

Q = PROPELLER TORQUE IN KGM.
n = PROPELLER REVOLUTIONS PER SECOND
ρ = WATER DENSITY (TANK) = 101.94 KGSEC^2 M^{-4}
D = PROPELLER DIAMETER IN METER
V_A = $V_S (1-w)$
V_S = SHIP SPEED IN M/SEC.
w = WAKE FRACTION
P = SHAFT POWER IN KGM/SEC.

LOCAL CAVITATION NUMBER AT 0.7R $= \sigma_{(0.7R)} = \dfrac{P_L - P_V}{q_T}$

$\tau_c = \dfrac{T}{1/2 \, \rho A_p V^2 R(0.7)}$

NON CAVITATION

5% BACK CAVITATION

10% BACK CAVITATION

20% BACK CAVITATION

30% BACK CAVITATION

2 1/2 % BACK CAVITATION

SUGGESTED UPPER LIMIT (1945) (FOR TUGS, TRAWLERS ETC.)

SUGGESTED LOWER LIMIT (1943) (FOR MERCHANT SHIP PROPELLERS)

SUGGESTED UPPER LIMIT FOR HEAVILY LOADED PROPELLERS (1945)

BURRILL (WITH SPECIAL SECTIONS) (WARSHIP PROPELLERS)

SKETCHES SHOWING PERCENTAGE CAVITATION ON BACK OF PROPELLER BLADE

2 1/2 %   5%   10%   20%   30%

LEADING EDGE

DIRECTRIX

0.05   0.1   0.2   0.3   0.4   0.5   0.6   0.7   0.8   0.9   1.0   1.5   2.0

0.05   0.1   0.2   0.3   0.4   0.5