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K_T, K_Q and Efficiency Curves for the Wageningen B-Series Propellers

by

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ABSTRACT

The B-series propellers were designed and tested at the Netherlands Ship Model Basin in Wageningen. The open-water characteristics of 120 propeller models of the B-series were tested at N.S.M.B. and analyzed with multiple polynomial regression analysis [1]. The derived polynomials express the thrust and torque coefficients in terms of the number of blades, the blade area ratio, the pitch-diameter ratio and the advance coefficient. The Reynolds number effect and the effect of variation of blade thickness on the B-series propeller characteristics have also been evaluated at N.S.M.B. In this report the polynomials derived in [1] are used to plot the open water propeller characteristics for Reynolds number 2.0×10^6 and for the ranges of number of blades, blade area ratio and pitch-diameter ratio recommended by N.S.M.B. The extent of applicability of the regression polynomials is also discussed.

ACKNOWLEDGEMENTS

This report was prepared in fulfillment of the requirements for the design project in the graduate computer-aided design course, NA 574, of the Department of Naval Architecture and Marine Engineering of the University of Michigan. Computer funds were provided by the department. Thanks are due to Professor R.F. Beck for his constructive comments and Mrs. Paula Bousley for the excellent typing and editing of this report.

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NOMENCLATURE

A_E/A_O	blade area ratio
$C^Q_{s,t,u,v}$	coefficient in the K_Q polynomial expression
$C^T_{s,t,u,v}$	coefficient in the K_T polynomial expression
D	propeller diameter
J	advance coefficient
K_Q	torque coefficient
K_T	thrust coefficient
n	propeller revolutions per second
P/D	pitch-diameter ratio
Q	propeller torque
Re	Reynolds number
T	propeller thrust
t/c	thickness to cord ratio for propeller blades
V_A	speed of advance
Z	number of blades

Greek Symbols

η	open-water propeller efficiency
ρ	fluid density

INTRODUCTION

The open-water propeller characteristics conventionally are presented in the form of the thrust and torque coefficients K_T and K_Q in terms of the advance coefficient J where

$$K_T = \frac{T}{\rho n^2 D^4} \tag{1}$$

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

$$J = \frac{V_A}{nD} \tag{3}$$

where

- T is the propeller thrust,
- Q is the propeller torque,
- ρ is the fluid density,
- n is the number of propeller revolutions per second,
- D is the propeller diameter and
- V_A is the speed of advance.

The open-water efficiency of the propeller is

$$\eta_o = \frac{J}{2\pi} \frac{K_T}{K_Q} \tag{4}$$

The thrust and torque coefficients can be written as:

$$K_T = f_T\left(J , \frac{P}{D} , \frac{A_E}{A_o} , Z , Re , \frac{t}{c}\right) \tag{5}$$

and

$$K_Q = f_Q\left(J , \frac{P}{D} , \frac{A_E}{A_o} , Z , Re , \frac{t}{c}\right) \tag{6}$$

where

- P/D is the pitch diameter ratio
- A_E/A_o is the blade area ratio
- Z is the number of propeller blades

Re is the Reynolds number of a characteristic radius (0.75 R)

t/c is the ratio of the maximum propeller blade thickness to the length of the cord at a characteristic radius (0.75 R)

K_T and K_Q can be expressed in terms of polynomials of J, $\frac{P}{D}$, $\frac{A_E}{A_o}$, and Z (see Table 1) [1].

The Reynolds number effect on the propeller characteristics has been taken into account using Lerbs method [2]. The Reynolds number corrections for K_T and K_Q are polynomial expressions of Re, P/D, A_E/A_o and J (see Table 2).

Finally the effect of variation of blade thickness on propeller characteristics can be represented as a change in the Reynolds number and need not be formulated in a polynomial form [1].

K_T, K_Q POLYNOMIALS AND REYNOLDS NUMBER CORRECTIONS

The polynomials for K_T and K_Q derived with multiple regression analysis are

$$K_T = \sum_{s,t,u,v} C^T_{s,t,u,v} (J)^s (P/D)^t (A_E/A_o)^u (Z)^v \tag{7}$$

$$K_Q = \sum_{s,t,u,v} C^Q_{s,t,u,v} (J)^s (P/D)^t (A_E/A_o)^u (Z)^v \tag{8}$$

The coefficients $C^T_{s,t,u,v}$ and $C^Q_{s,t,u,v}$ and terms s,t,u,v are given in Table 1.

For Reynolds number greater than 2×10^6 the open water propeller characteristics should be corrected. The corrections

$$\Delta K_T(Re,\ J,\ P/D,\ A_E/A_o,\ z) \tag{9}$$

and

$$\Delta K_Q(Re,\ J,\ P/D,\ A_E/A_o,\ z) \tag{10}$$

are given in Table 2.

TABLE 1

Coefficients and terms of the K_T and K_Q polynomials for the Wageningen B-screw Series for $R_n=2\times10^6$. Reproduced from [1]

$$K_T = \sum_{s,t,u,v} C^T_{s,t,u,v} \cdot (J)^s \cdot (P/D)^t \cdot (A_E/A_O)^u \cdot (z^v)$$

$$K_Q = \sum_{s,t,u,v} C^Q_{s,t,u,v} \cdot (J)^s \cdot (P/D)^t \cdot (A_E/A_O)^u \cdot (z^v)$$

K_T

$C^T_{s,t,u,v}$	s (J)	t (P/D)	u (A_E/A_O)	v (Z)
+0.00880496	0	0	0	0
-0.204554	1	0	0	0
+0.166351	0	1	0	0
+0.158114	0	2	0	0
-0.147581	2	0	1	0
-0.481497	1	1	1	0
+0.415437	0	2	1	0
+0.0144043	0	0	0	1
-0.0530054	2	0	0	1
+0.0143481	0	1	0	1
+0.0606826	1	1	0	1
-0.0125894	0	0	1	1
+0.0109689	1	0	1	1
-0.133698	0	3	0	0
+0.00638407	0	6	0	0
-0.00132718	2	6	0	0
+0.168496	3	0	1	0
-0.0507214	0	0	2	0
+0.0854559	2	0	2	0
-0.0504475	3	0	2	0
+0.010465	1	6	2	0
-0.00648272	2	6	2	0
-0.00841728	0	3	0	1
+0.0168424	1	3	0	1
-0.00102296	3	3	0	1
-0.0317791	0	3	1	1
+0.018604	1	0	2	1
-0.00410798	0	2	2	1
-0.000606848	0	0	0	2
-0.0049819	1	0	0	2
+0.0025983	2	0	0	2
-0.000560528	3	0	0	2
-0.00163652	1	2	0	2
-0.000328787	1	6	0	2
+0.000116502	2	6	0	2
+0.000690904	0	0	1	2
+0.00421749	0	3	1	2
+0.0000565229	3	6	1	2
-0.00146564	0	3	2	2

$C^Q_{s,t,u,v}$	s (J)	t (P/D)	u (A_E/A_O)	v (Z)
+0.00379368	0	0	0	0
+0.00886523	2	0	0	0
-0.032241	1	1	0	0
+0.00344778	0	2	0	0
-0.0408811	0	1	1	0
-0.108009	1	1	1	0
-0.0885381	2	1	1	0
+0.188561	0	2	1	0
-0.00370871	1	0	0	1
+0.00513696	0	1	0	1
+0.0209449	1	1	0	1
+0.00474319	2	1	0	1
-0.00723408	2	0	1	1
+0.00438388	1	1	1	1
-0.0269403	0	2	1	1
+0.0558082	3	0	1	0
+0.0161886	0	3	1	0
+0.00318086	1	3	1	0
+0.015896	0	0	2	0
+0.0471729	1	0	2	0
+0.0196283	3	0	2	0
-0.0502782	0	1	2	0
-0.030055	3	1	2	0
+0.0417122	2	2	2	0
-0.0397722	0	3	2	0
-0.00350024	0	6	2	0
-0.0106854	3	0	0	1
+0.00110903	3	3	0	1
-0.000313912	0	6	0	1
+0.0035985	3	0	1	1
-0.00142121	0	6	1	1
-0.00383637	1	0	2	1
+0.0126803	0	2	2	1
-0.00318278	2	3	2	1
+0.00334268	0	6	2	1
-0.00183491	1	1	0	2
+0.000112451	3	2	0	2
-0.0000297228	3	6	0	2
+0.000269551	1	0	1	2
+0.00083265	2	0	1	2
+0.00155334	0	2	1	2
+0.000302683	0	6	1	2
-0.0001843	0	0	2	2
-0.000425399	0	3	2	2
+0.0000869243	3	3	2	2
-0.0004659	0	6	2	2
+0.0000554194	1	6	2	2

$R_n = 2 \times 10^6$

TABLE 2

Polynomials for Reynolds number effect (above $R_n = 2\times10^6$) on K_T and K_Q

$$
\begin{aligned}
\Delta K_T = \; & 0.000353485 \\
& -0.00333758(A_E/A_o)J^2 \\
& -0.00478125(A_E/A_o)(P/D)J \\
& +0.000257792(\log R_n-0.301)^2(A_E/A_o)J^2 \\
& +0.0000643192(\log R_n-0.301)(P/D)^6J^2 \\
& -0.0000110636(\log R_n-0.301)^2(P/D)^6J^2 \\
& -0.0000276305(\log R_n-0.301)^2 z(A_E/A_o)J^2 \\
& +0.0000954(\log R_n-0.301)z(A_E/A_o)(P/D)J \\
& +0.0000032049(\log R_n-0.301)z^2(A_E/A_o)(P/D)^3J
\end{aligned}
$$

$$
\begin{aligned}
\Delta K_Q = \; & -0.000591412 \\
& +0.00696898(P/D) \\
& -0.0000666654z(P/D)^6 \\
& +0.0160818(A_E/A_o)^2 \\
& -0.000938091(\log R_n-0.301)(P/D) \\
& -0.00059593(\log R_n-0.301)(P/D)^2 \\
& +0.0000782099(\log R_n-0.301)^2(P/D)^2 \\
& +0.0000052199(\log R_n-0.301)z(A_E/A_o)J^2 \\
& -0.00000088528(\log R_n-0.301)^2 z(A_E/A_o)(P/D)J \\
& +0.0000230171(\log R_n-0.301)z(P/D)^6 \\
& -0.00000184341(\log R_n-0.301)^2 z(P/D)^6 \\
& -0.00400252(\log R_n-0.301)(A_E/A_o)^2 \\
& +0.000220915(\log R_n-0.301)^2(A_E/A_o)^2
\end{aligned}
$$

LIMITATIONS OF APPLICABILITY OF THE REGRESSION POLYNOMIALS

The derived regression polynomials can be used to evaluate the thrust and torque coefficients for

$$2 \leq Z \leq 7 \quad , \tag{11}$$

$$0.30 \leq A_E/A_O \leq 1.05 \quad , \tag{12}$$

and

$$0.5 \leq P/D \leq 1.40 \tag{13}$$

However, at the extremes of the above ranges the results are not fully reliable. For instance the thrust coefficient K_T displays a local maximum for low values of J, high number of blades, low blade area ratio and high pitch-diameter ratio. This minor error is due to regression analysis.

96 open-water propeller characteristics curves are included in this report. For each set of blades between 2 and 7, sixteen graphs have been plotted for blade area ratio varying between 0.30 and 1.05 in steps of 0.05 and pitch diameter ratio varying between 0.50 and 1.40 in steps of 0.10. These graphs have been plotted with the aid of the Michigan Computer Center plotting routines which are included in the public file *PLOTSYS [3].

REFERENCES

1. Oosterveld, M.W.C. and P. Van Oosanen, "Further Computer-Analyzed Data of the Wageningen B-Screw Series," IV International Symposium on Ship Automation, Genova, Italy, Nov. 1974.

2. Lerbs, H.W., "On the Effect of Scale and Roughness on Free Running Propellers," Journal ASME, 1951.

3. MTS Volume 11: "Plot Description System," University of Michigan Computing Center, 1978.

FIGURE 1. WAGENINGEN B-SERIES PROPELLERS
FOR 2 BLADES AE/AO= 0.300
P/D=0.50 TO 1.40

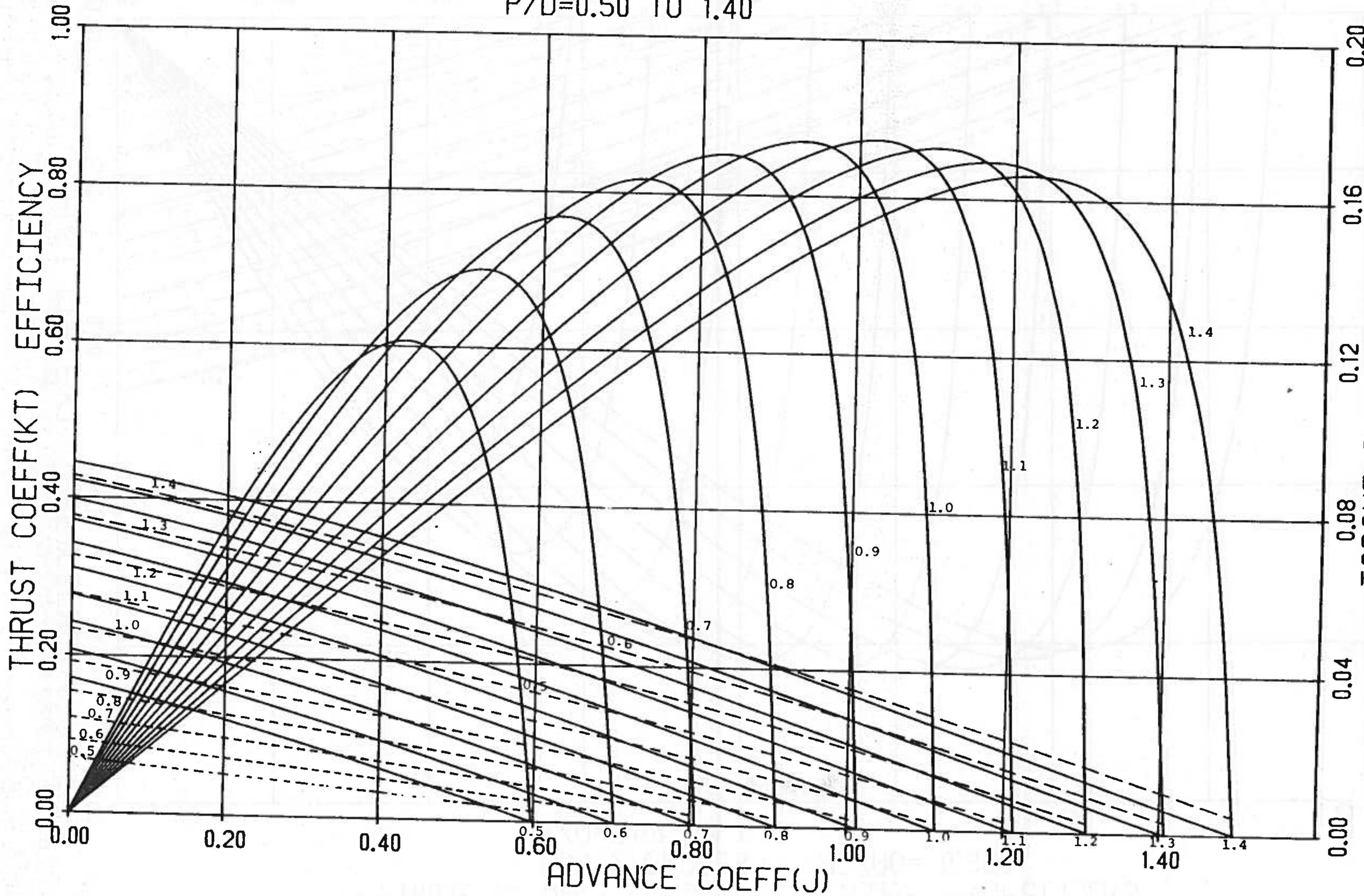

FIGURE 2. WAGENINGEN B-SERIES PROPELLERS
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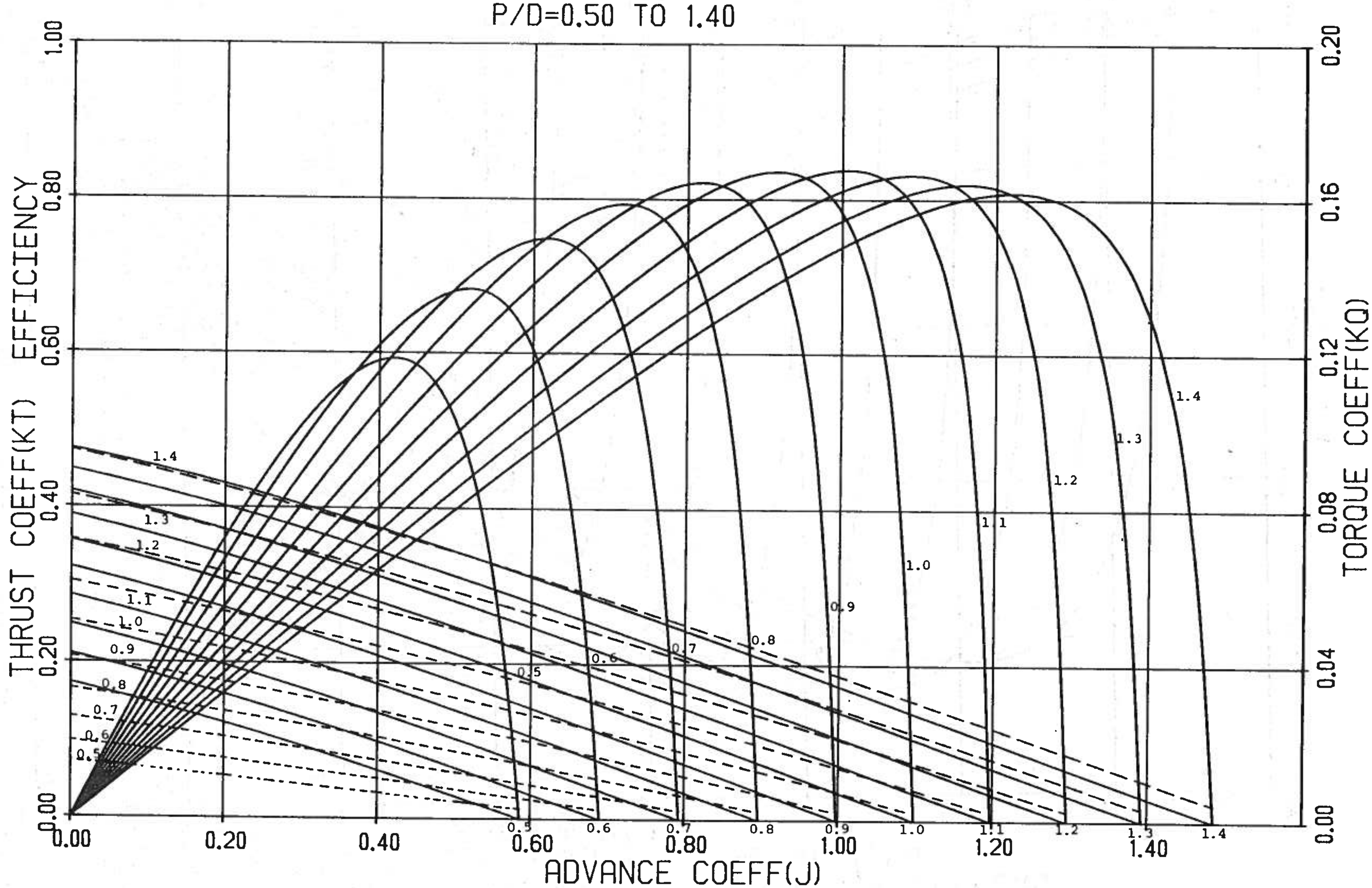


FIGURE 3. WAGENINGEN B-SERIES PROPELLERS
FOR 2 BLADES AE/AO= 0.400
P/D=0.50 TO 1.40

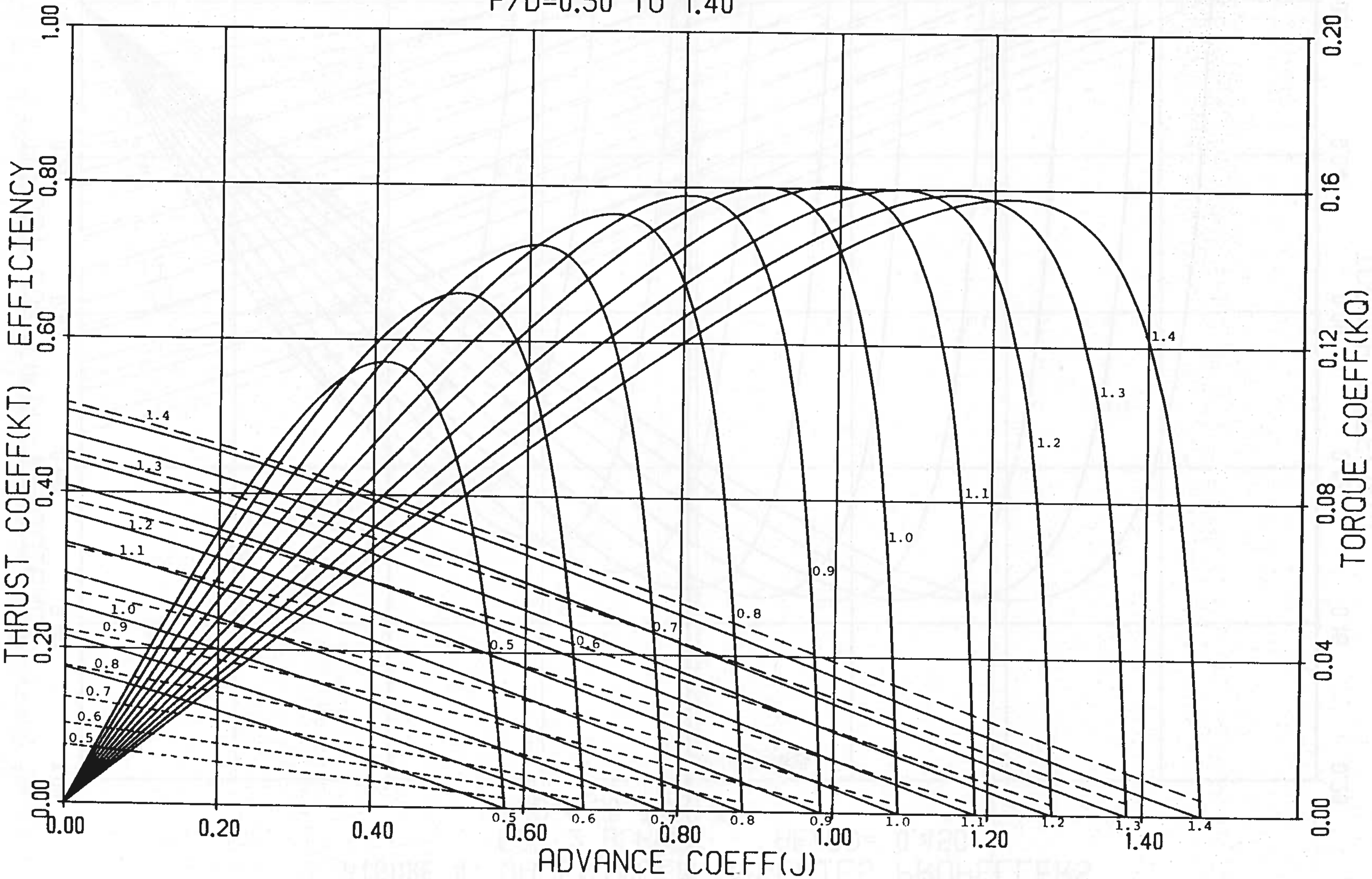
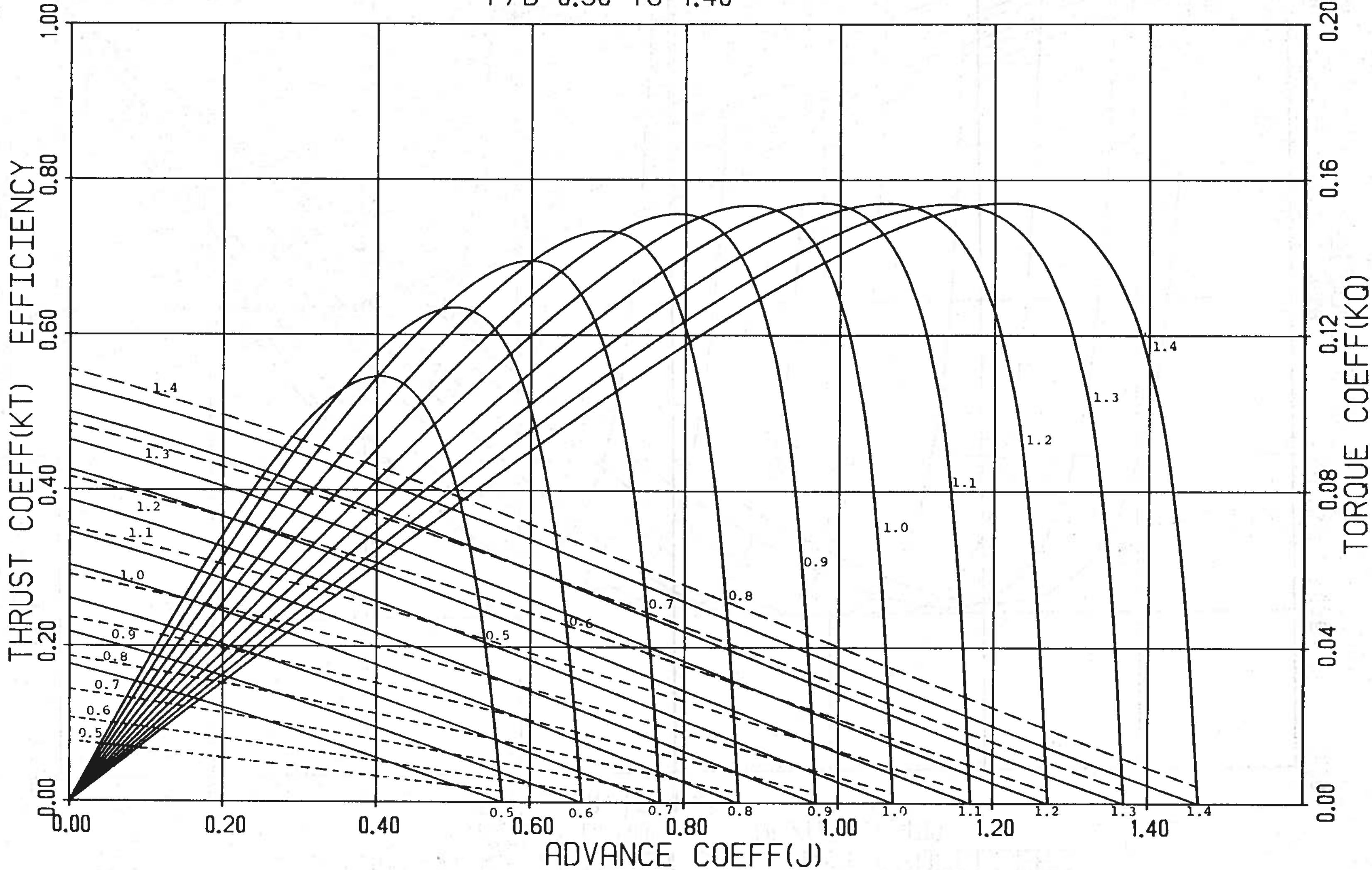


FIGURE 4. WAGENINGEN B-SERIES PROPELLERS
FOR 2 BLADES AE/AO= 0.450
P/D=0.50 TO 1.40



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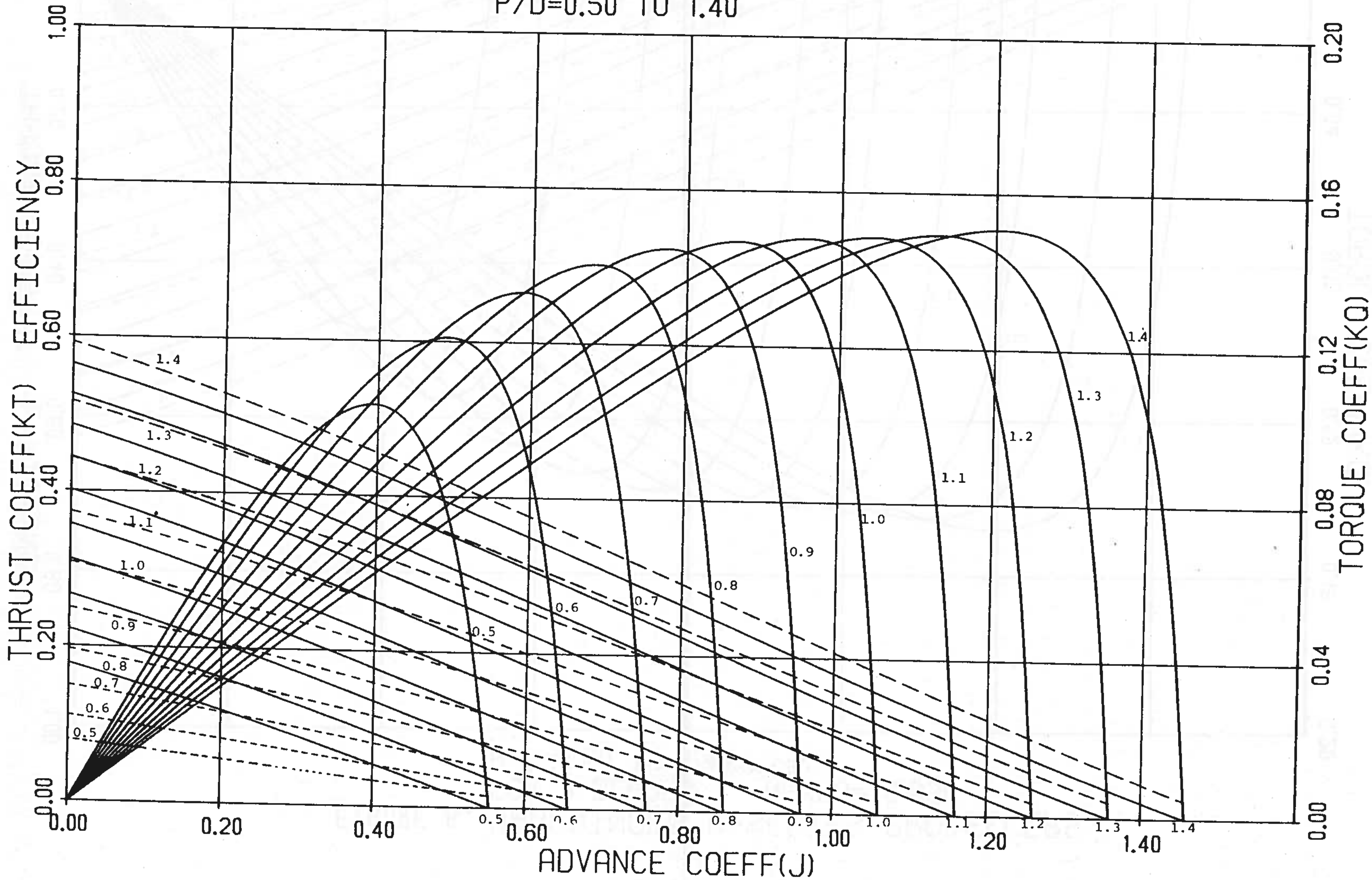

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P/D=0.50 TO 1.40

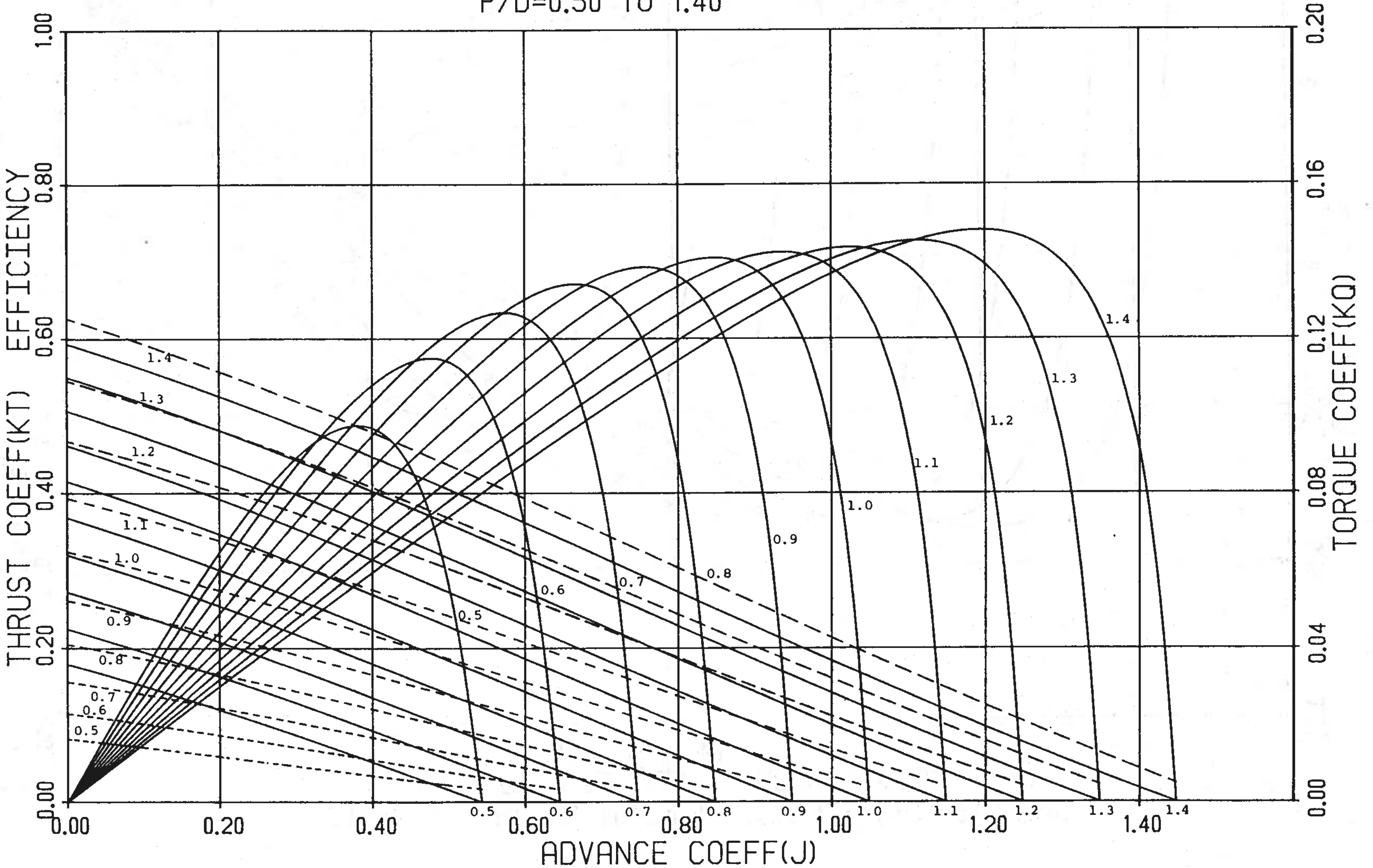

FIGURE 7. WAGENINGEN B-SERIES PROPELLERS
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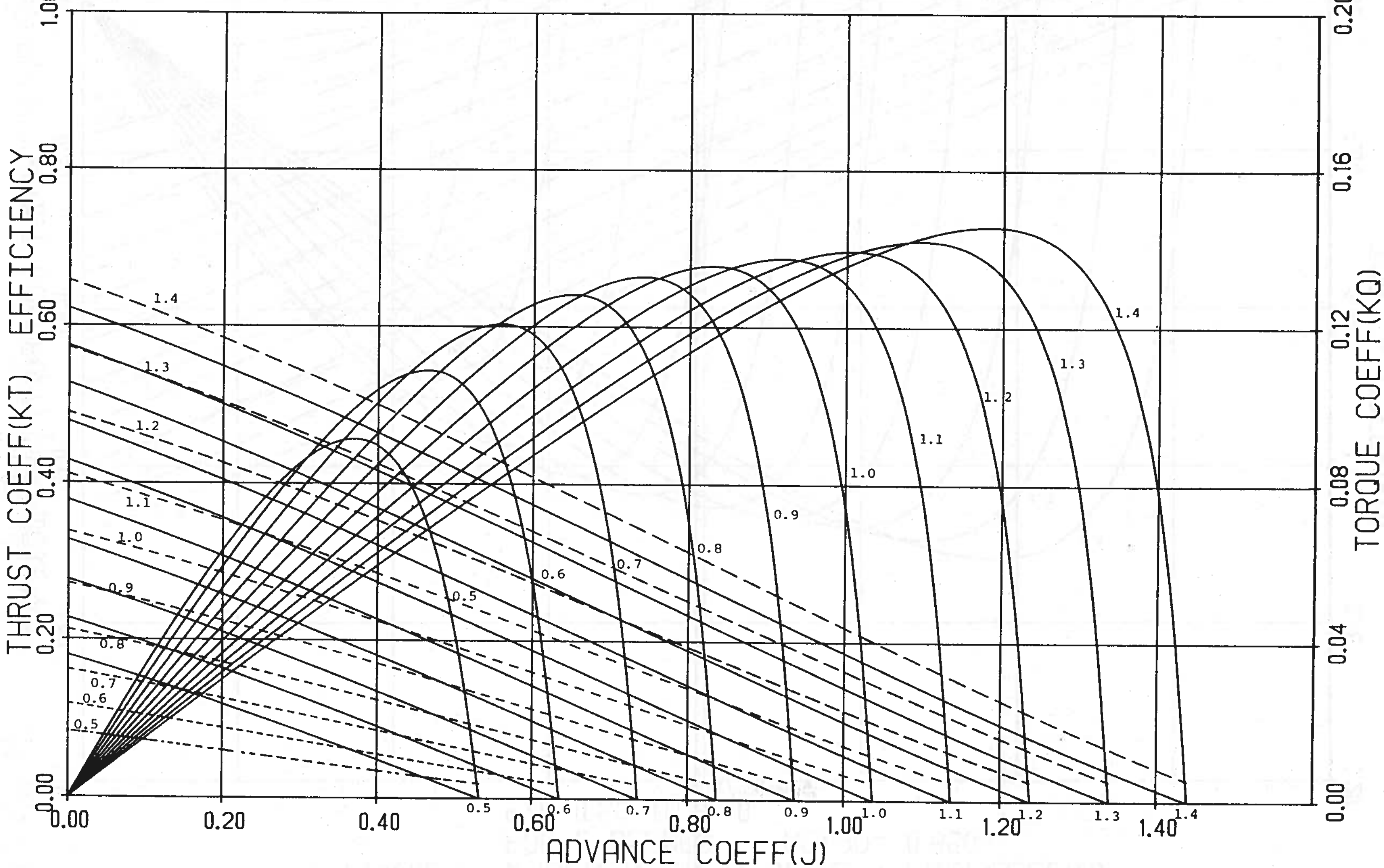
P/D=0.50 TO 1.40



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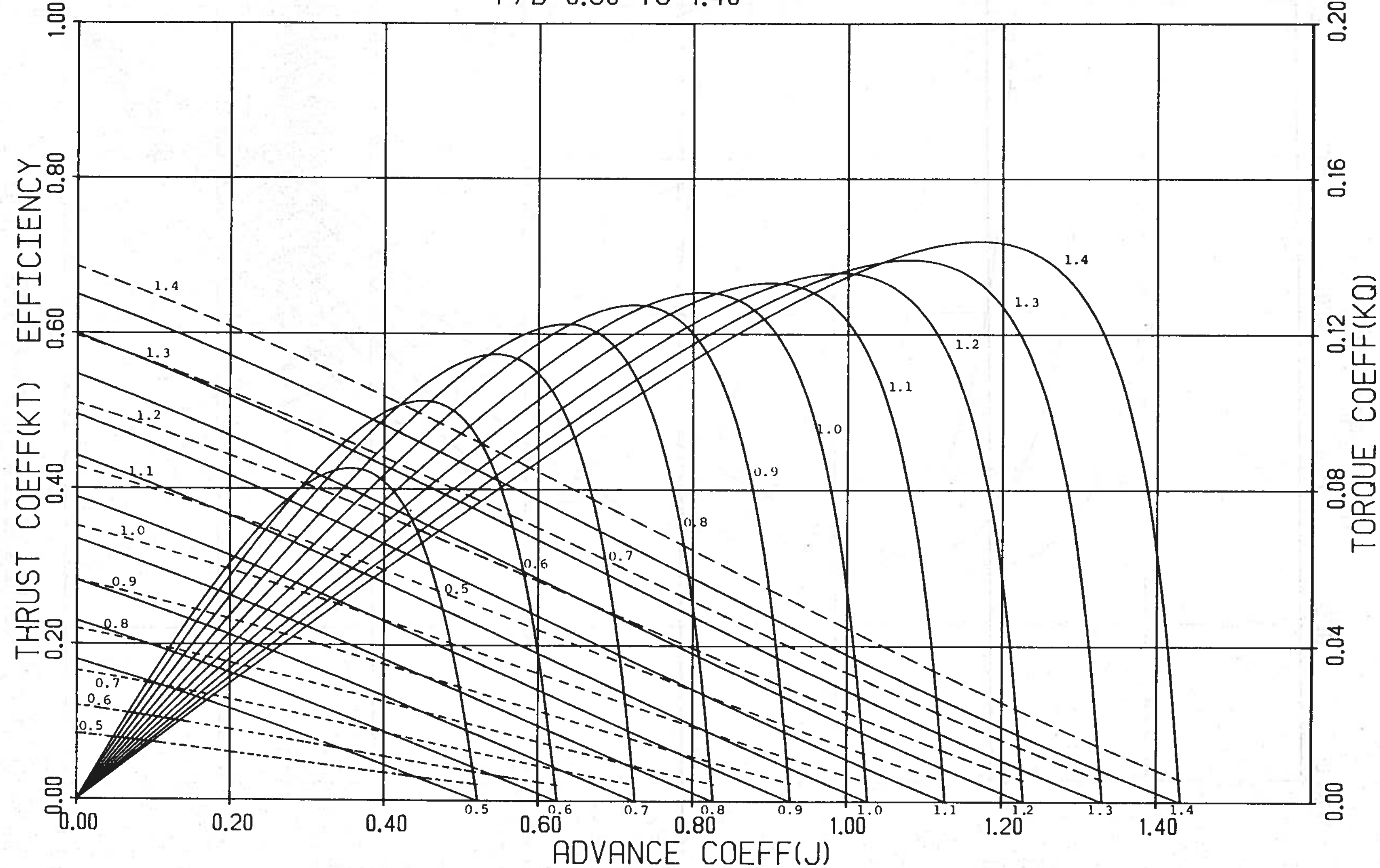
FOR 2 BLADES   AE/AO= 0.650
P/D=0.50 TO 1.40



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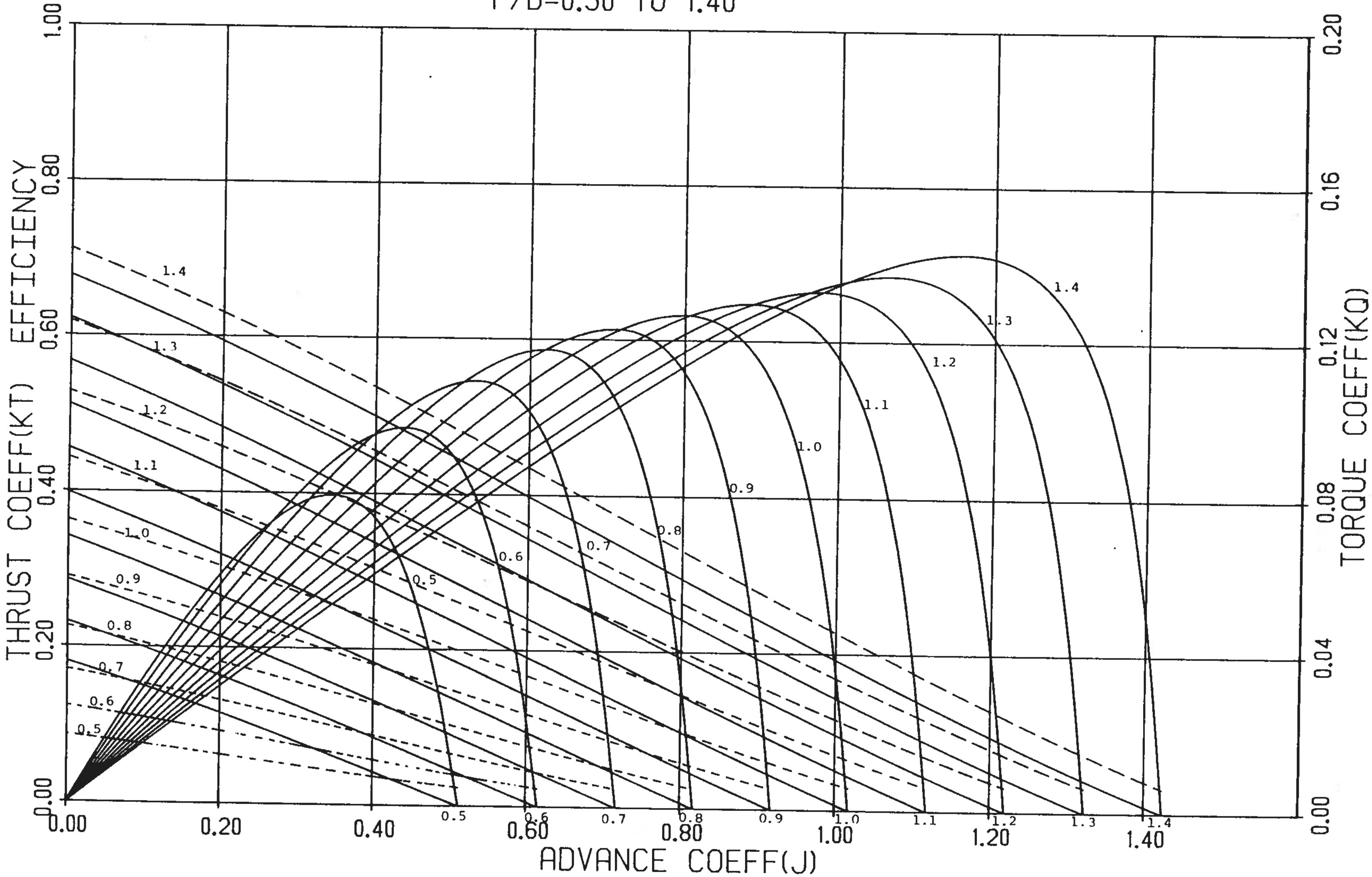

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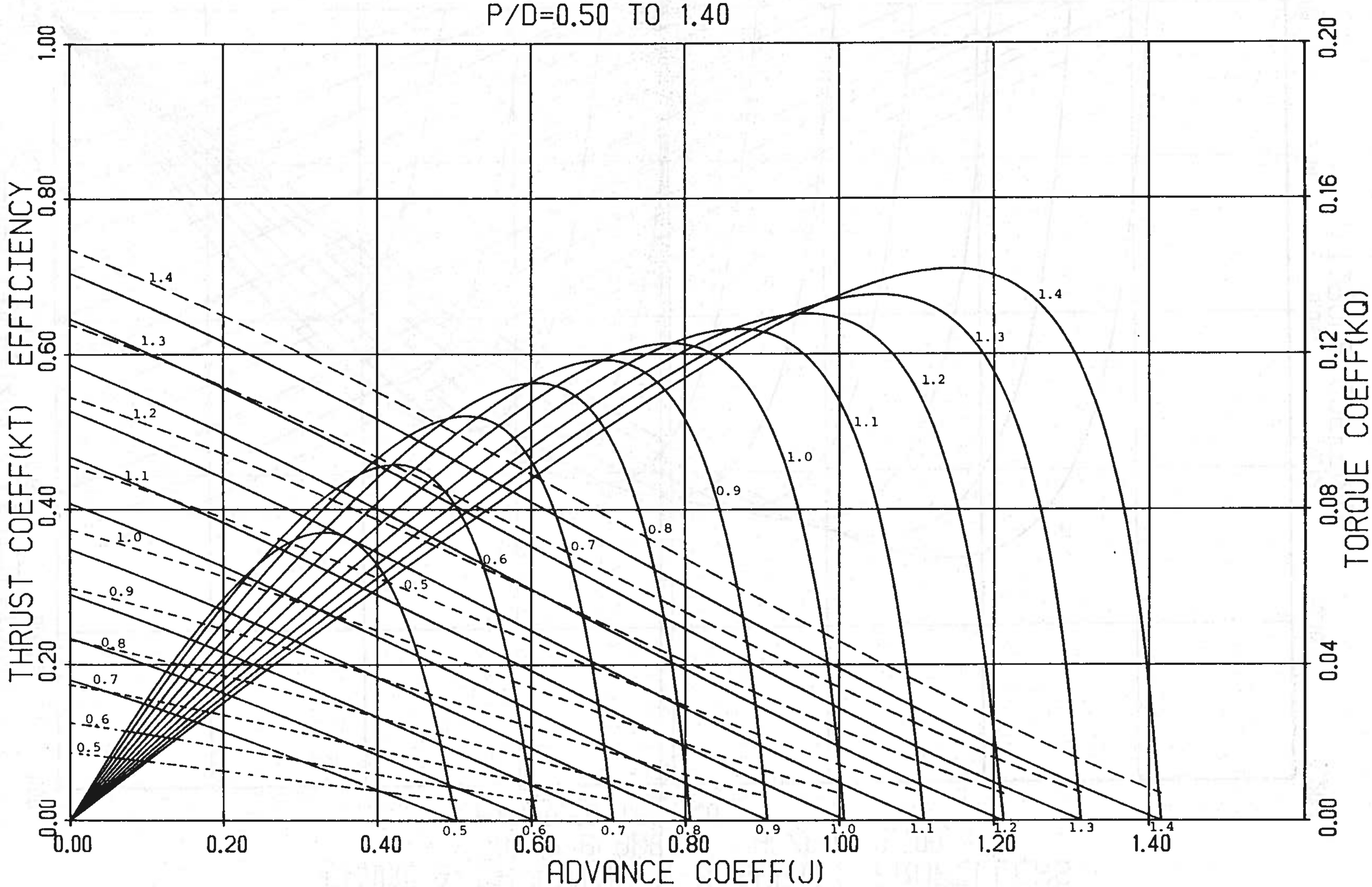
P/D=0.50 TO 1.40



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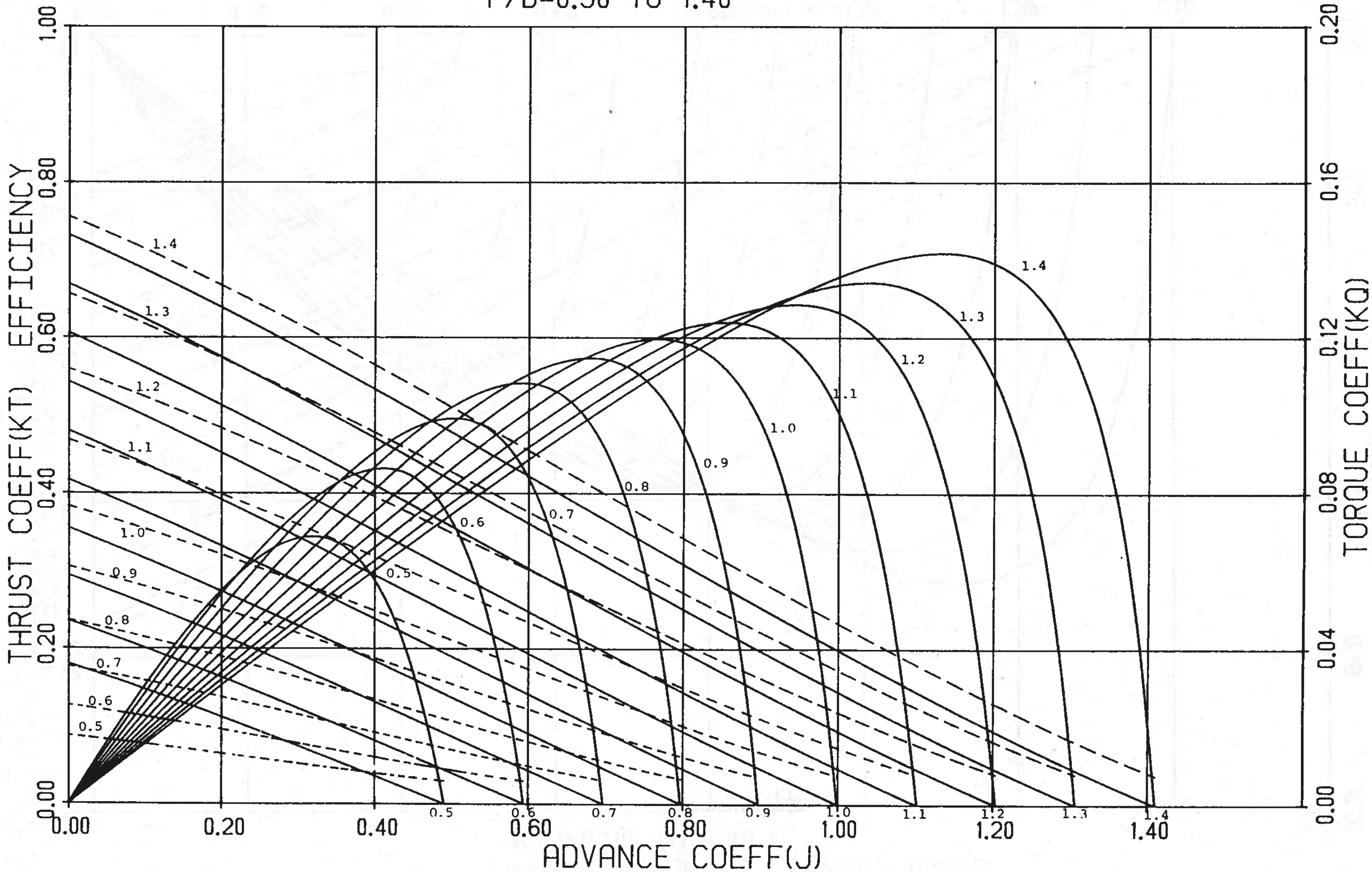
P/D=0.50 TO 1.40



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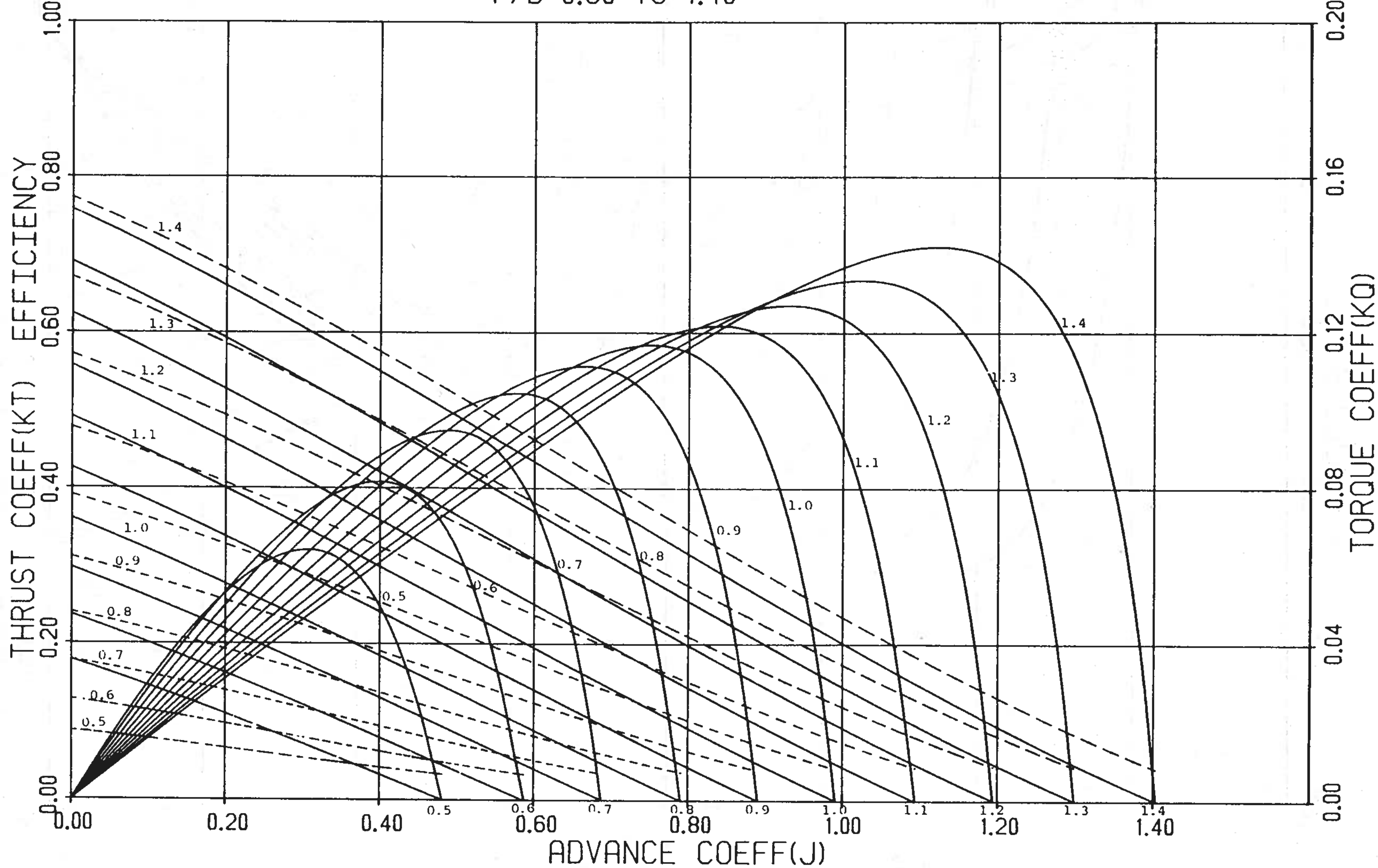
FOR 2 BLADES AE/AO= 0.850
P/D=0.50 TO 1.40



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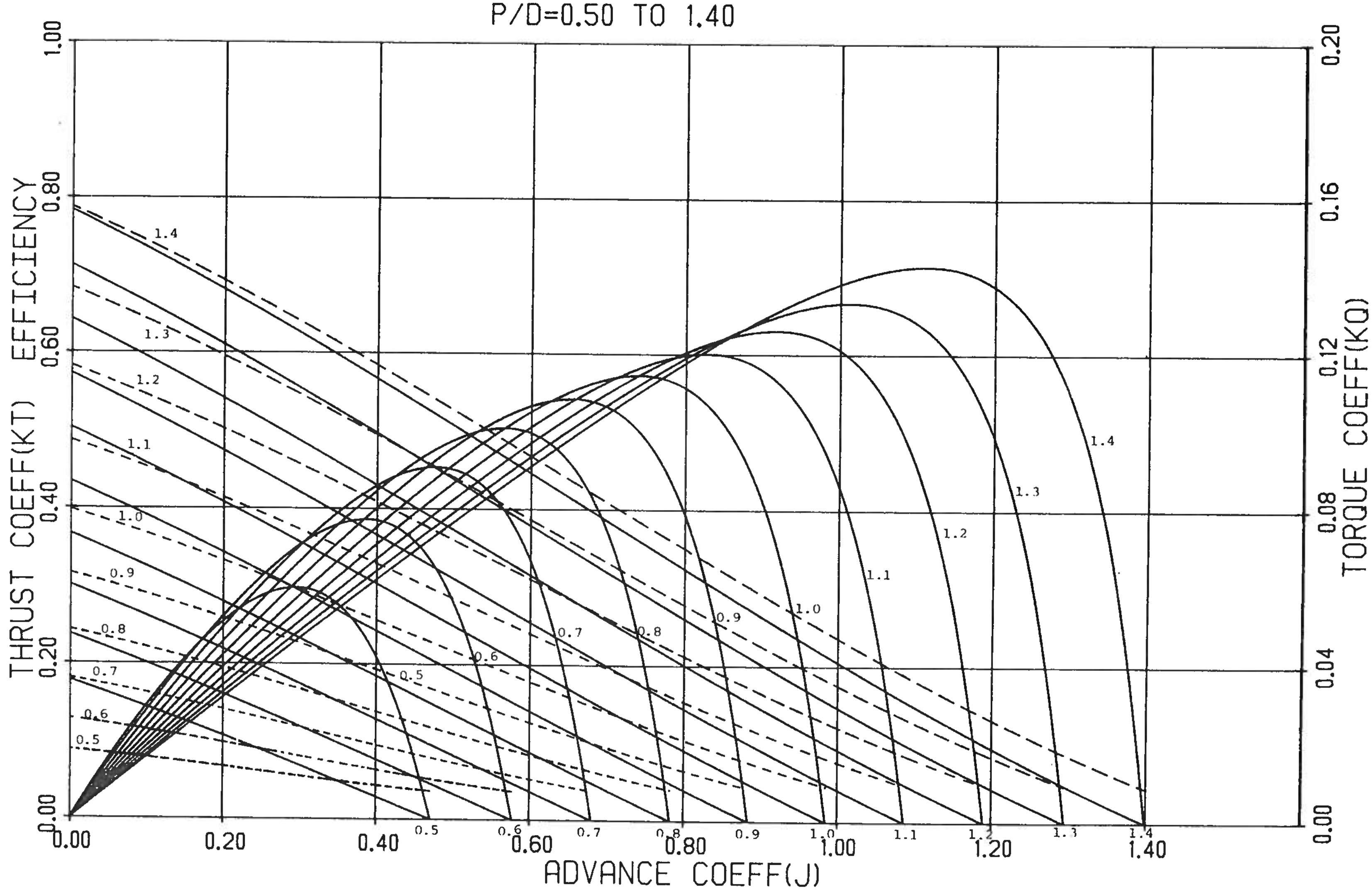
FOR 2 BLADES AE/AO= 0.900
P/D=0.50 TO 1.40



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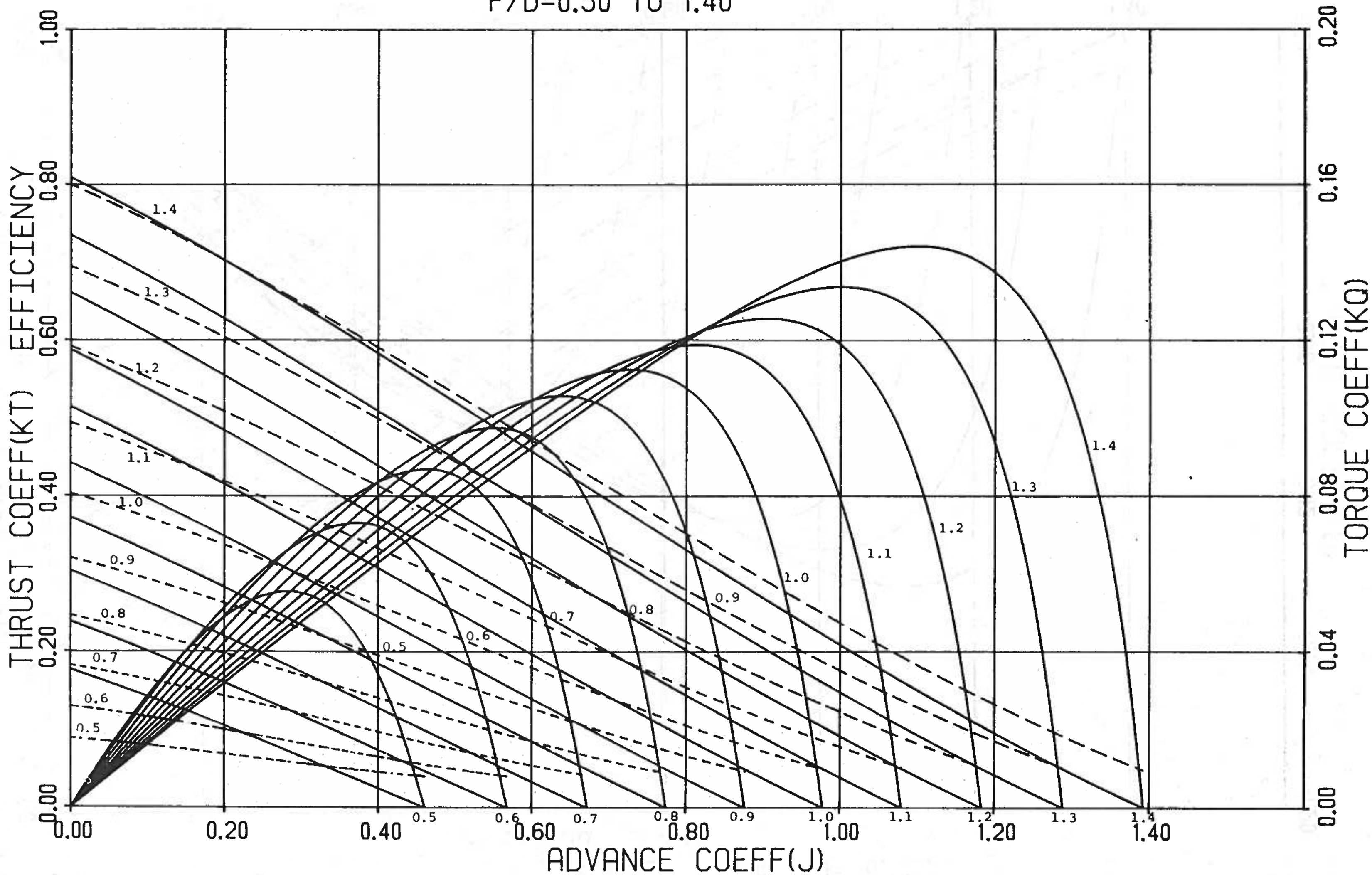
P/D=0.50 TO 1.40



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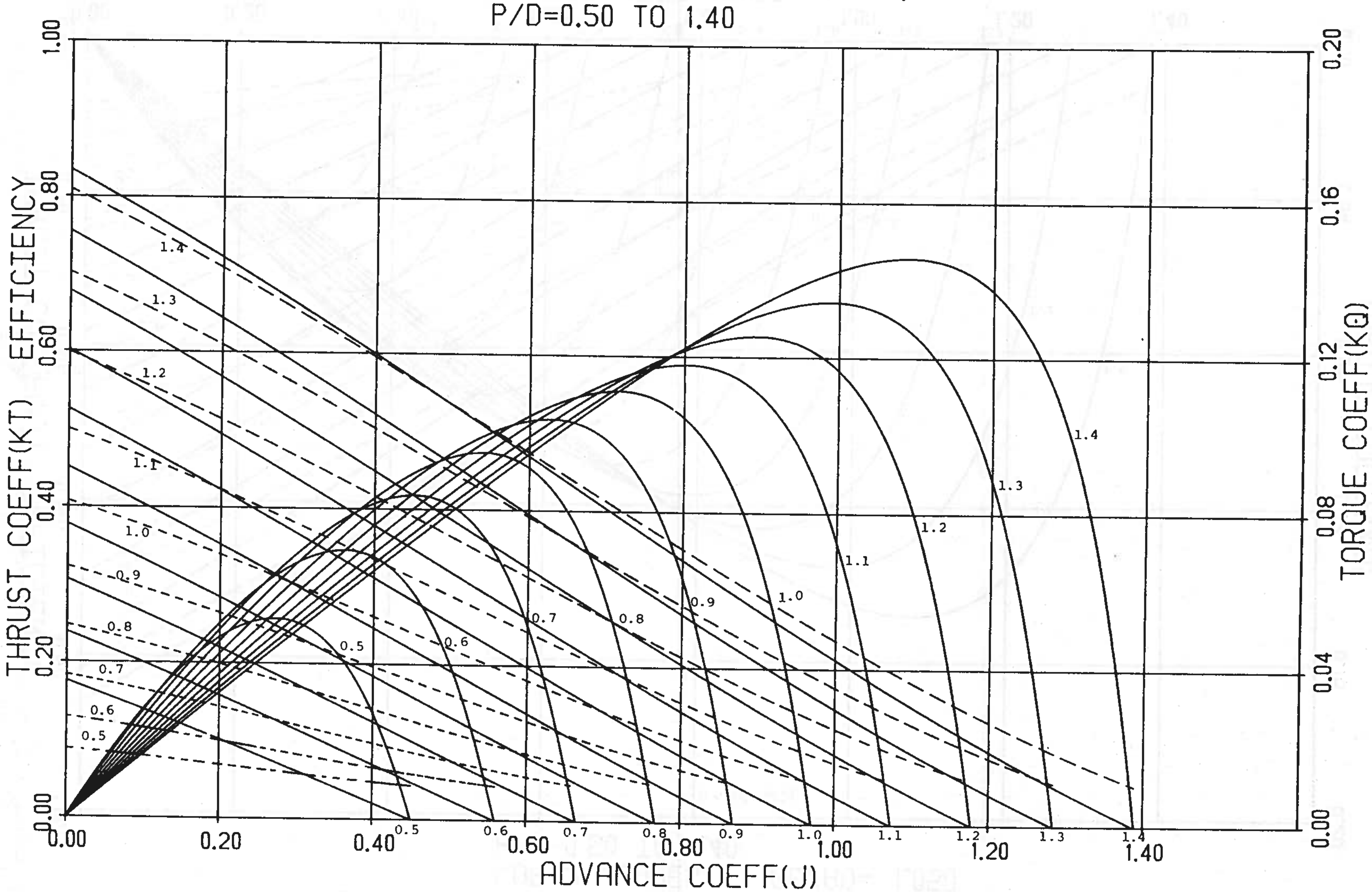
FOR 2 BLADES AE/AO= 1.000
P/D=0.50 TO 1.40



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FOR 2 BLADES AE/AO= 1.050
P/D=0.50 TO 1.40

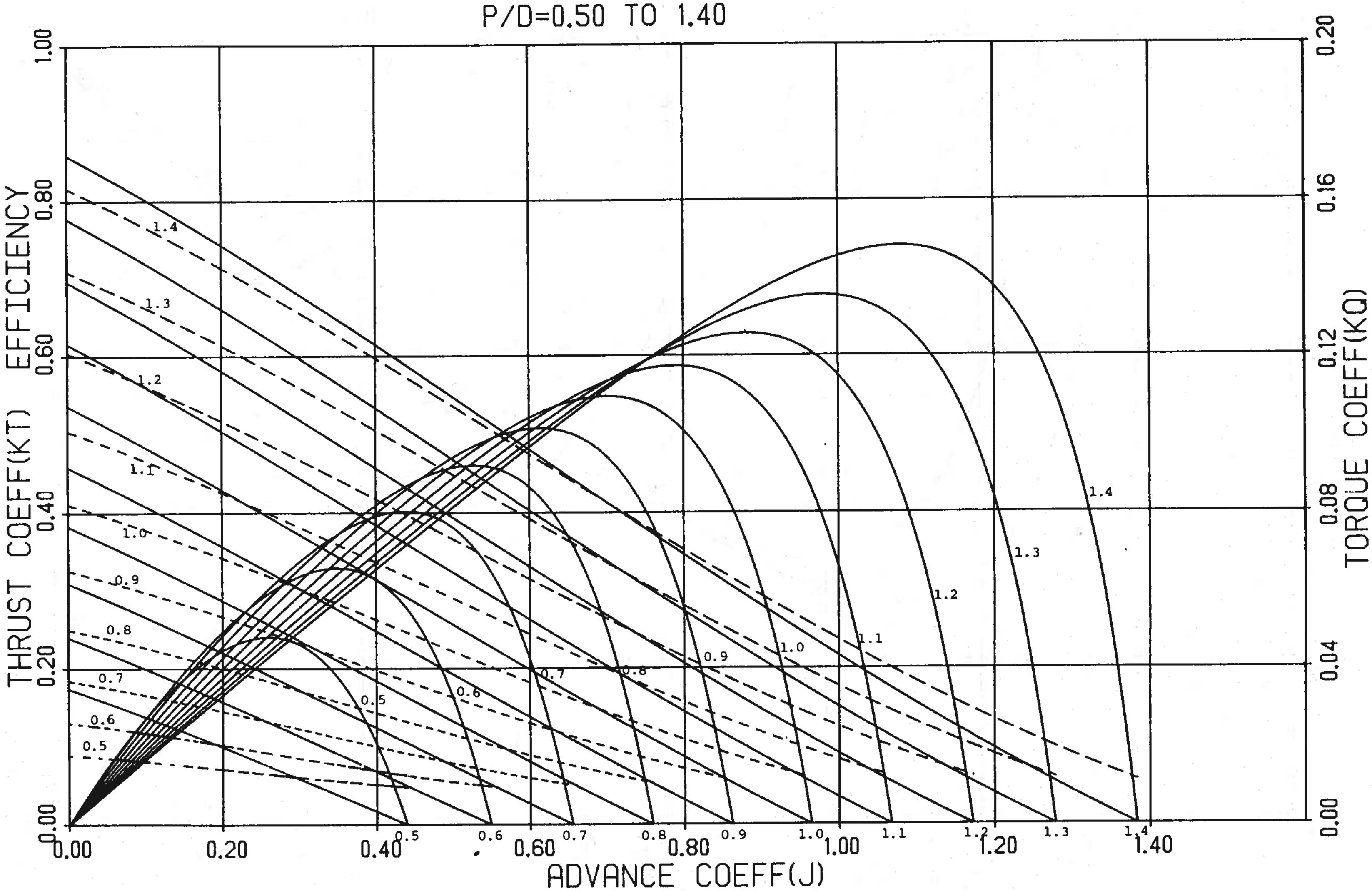

FIGURE 17. WAGENINGEN B-SERIES PROPELLERS
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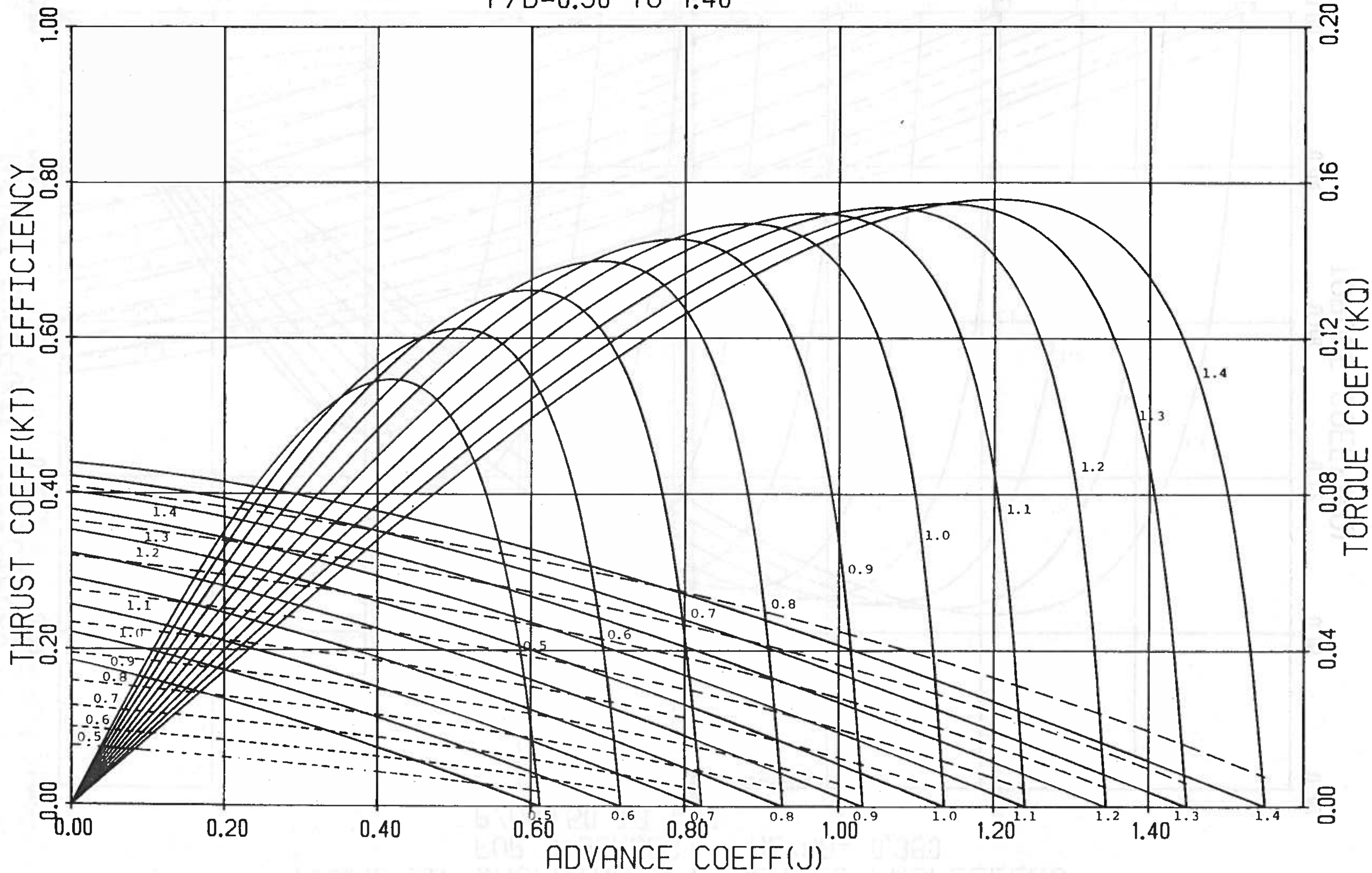
P/D=0.50 TO 1.40



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P/D=0.50 TO 1.40

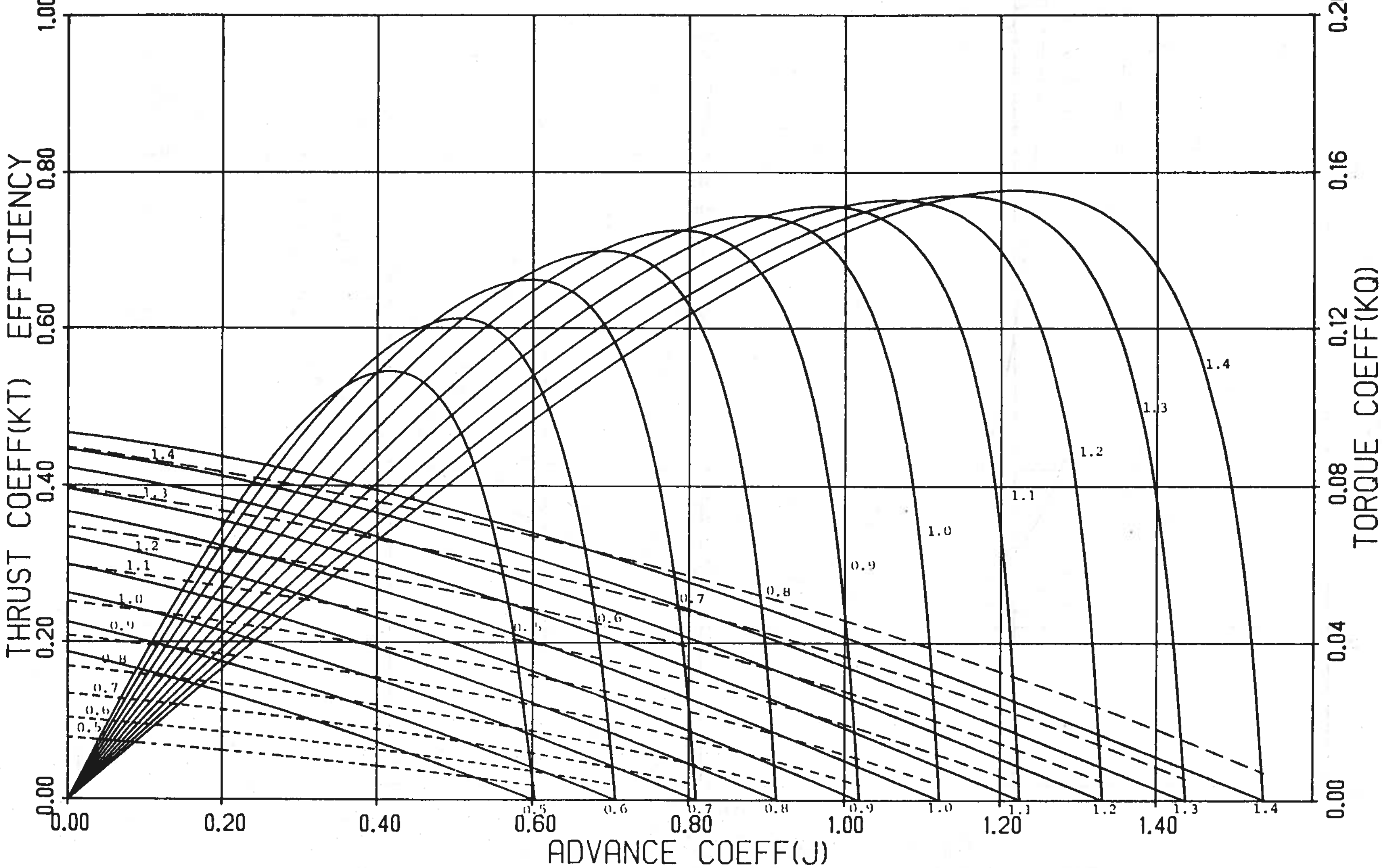


FIGURE 19. WAGENINGEN B-SERIES PROPELLERS
FOR 3 BLADES AE/AO= 0.400
P/D=0.50 TO 1.40

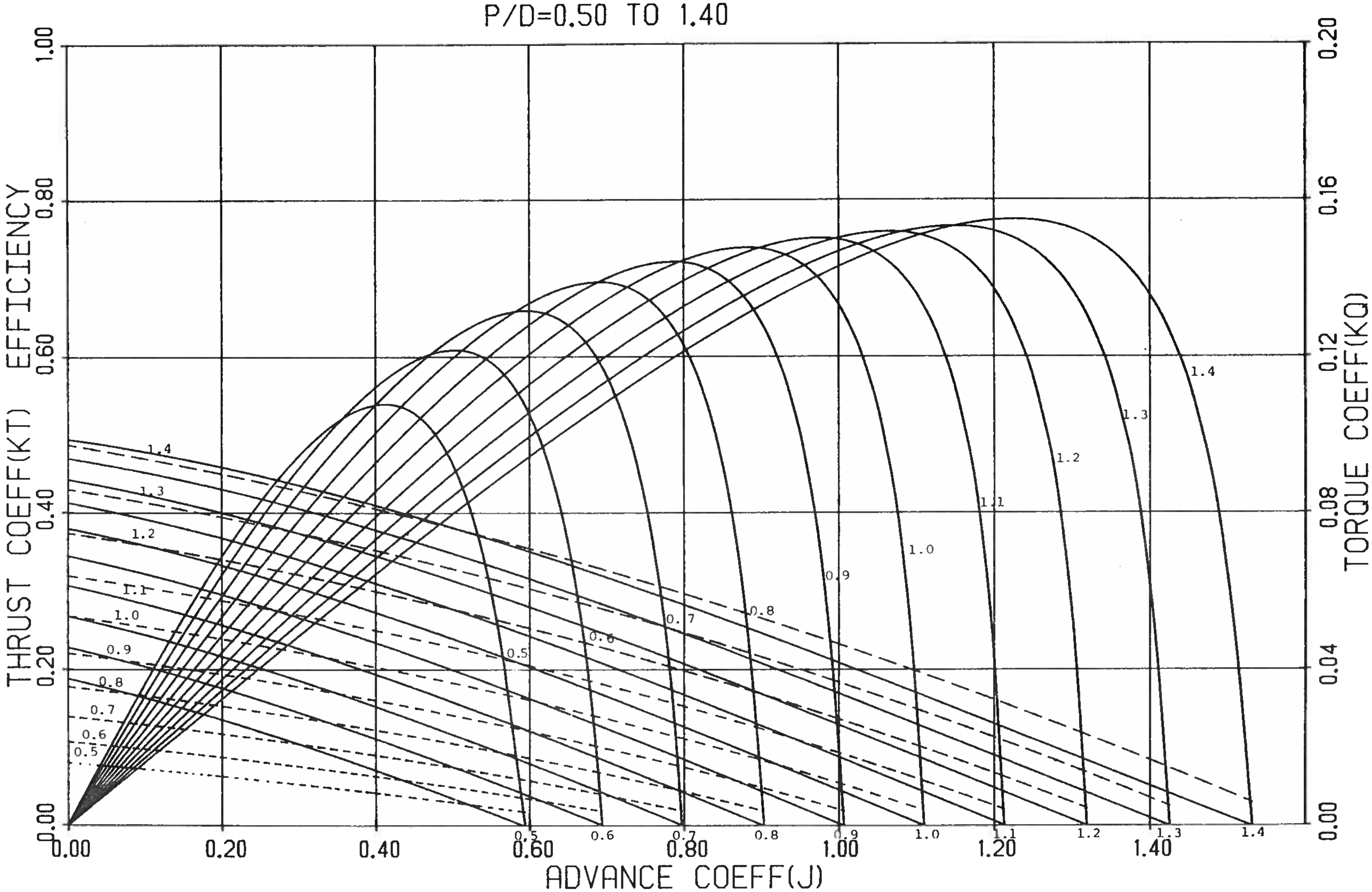


FIGURE 20. WAGENINGEN B-SERIES PROPELLERS
FOR 3 BLADES AE/AO= 0.450
P/D=0.50 TO 1.40

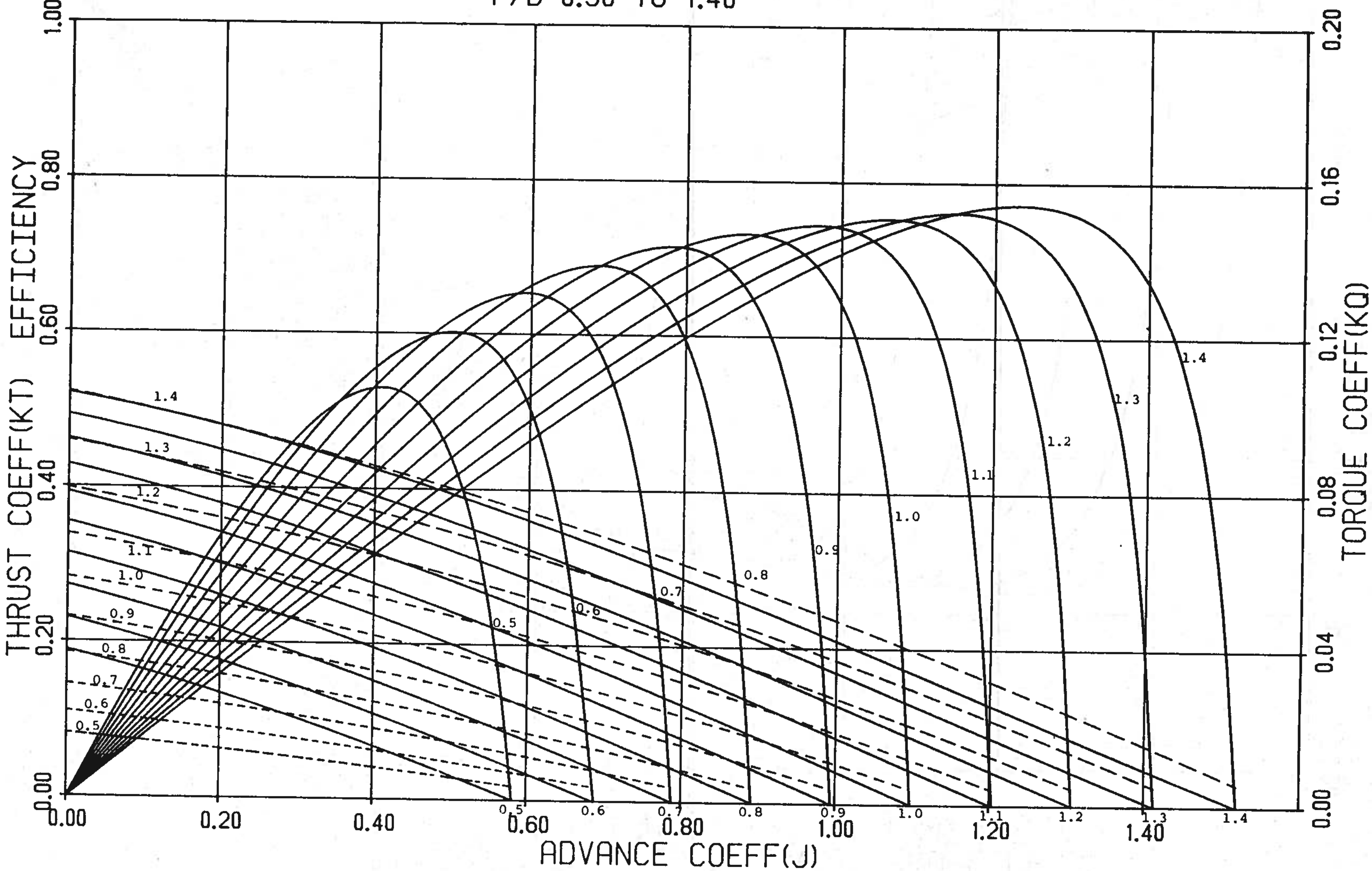
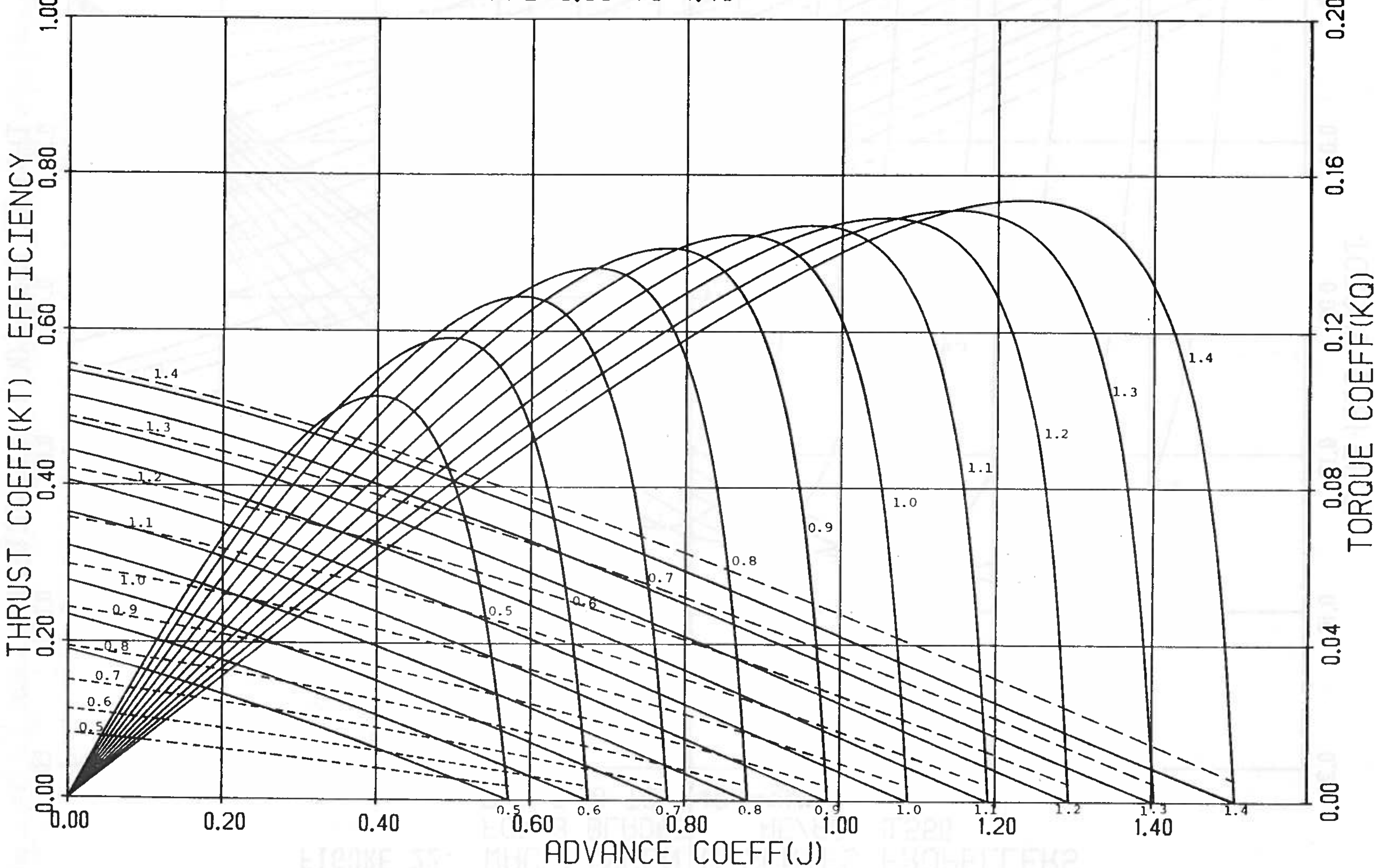


FIGURE 21. WAGENINGEN B-SERIES PROPELLERS
FOR 3 BLADES AE/AO= 0.500
P/D=0.50 TO 1.40



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P/D=0.50 TO 1.40

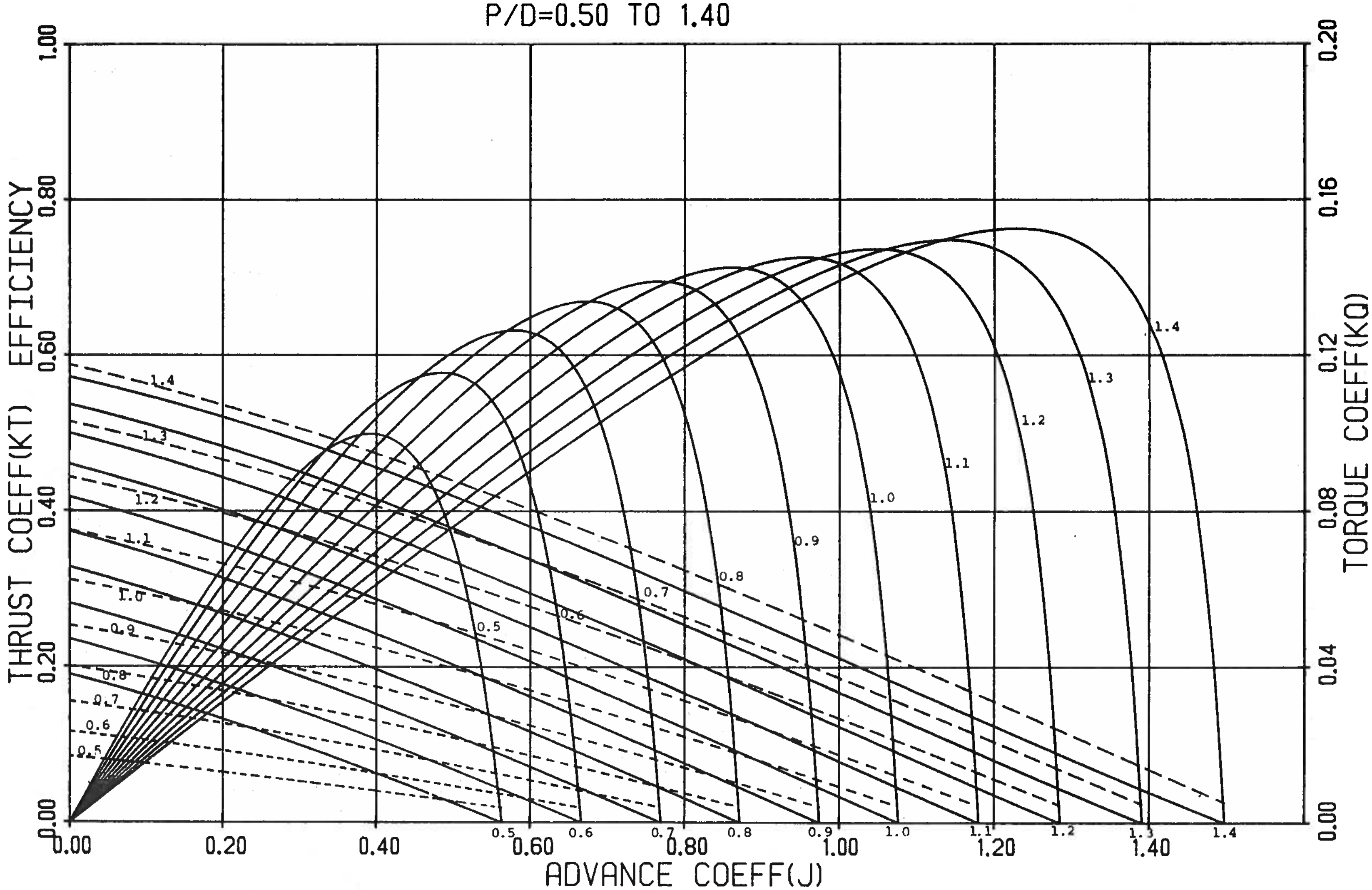
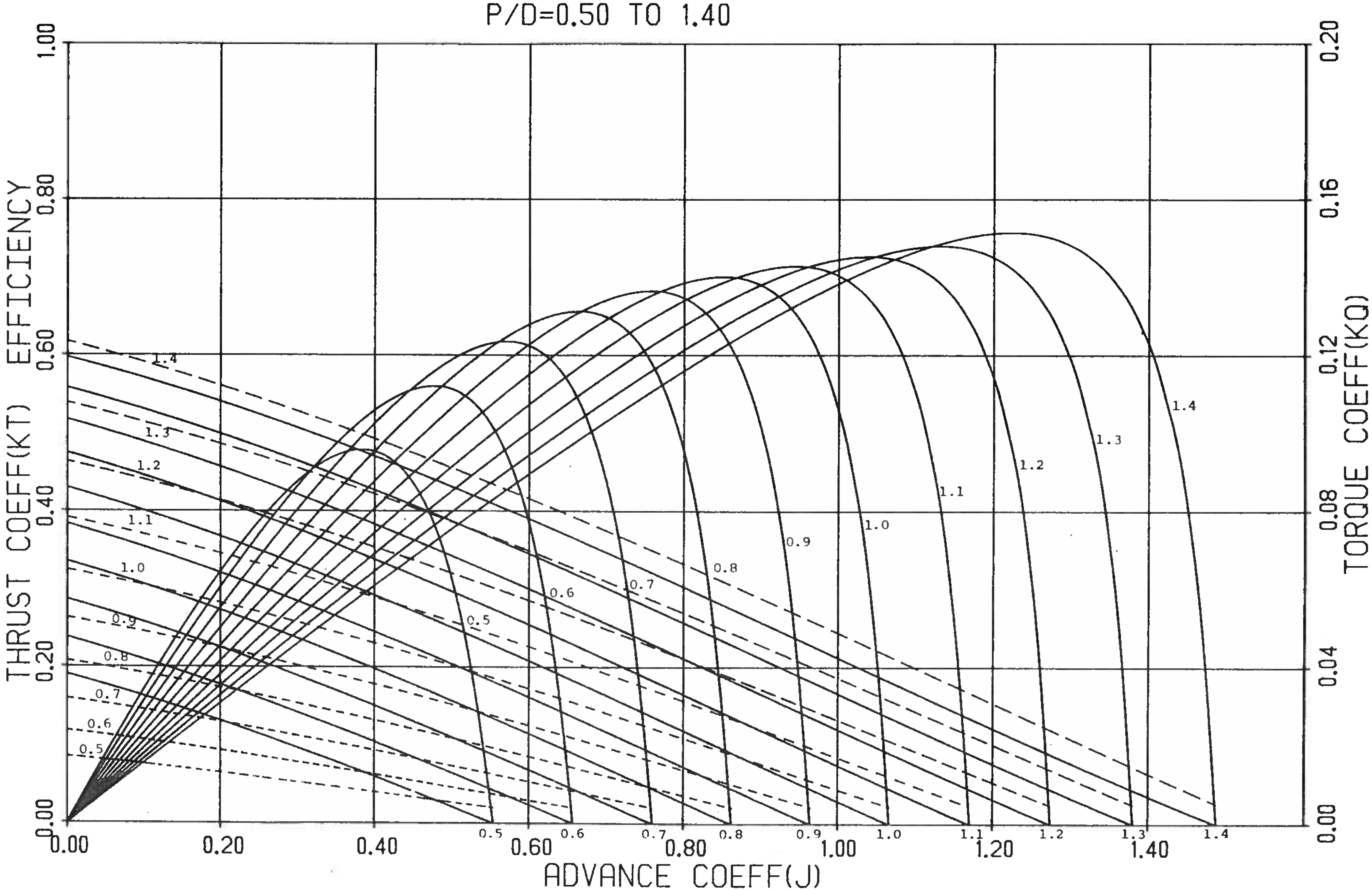


FIGURE 23. WAGENINGEN B-SERIES PROPELLERS
FOR 3 BLADES AE/AO= 0.600
P/D=0.50 TO 1.40



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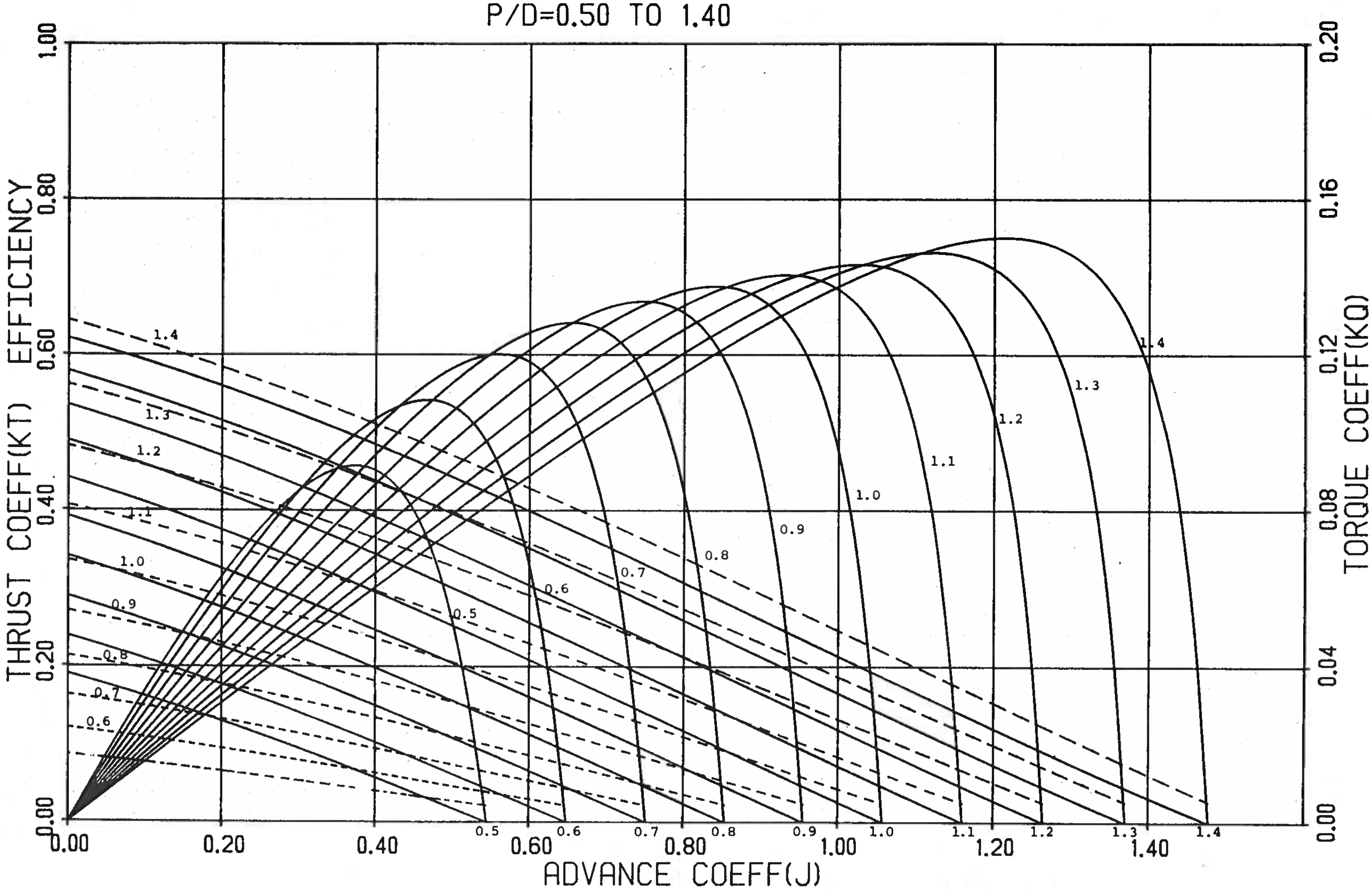
FOR 3 BLADES AE/AO= 0.650
P/D=0.50 TO 1.40



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FOR 3 BLADES AE/AO= 0.700
P/D=0.50 TO 1.40

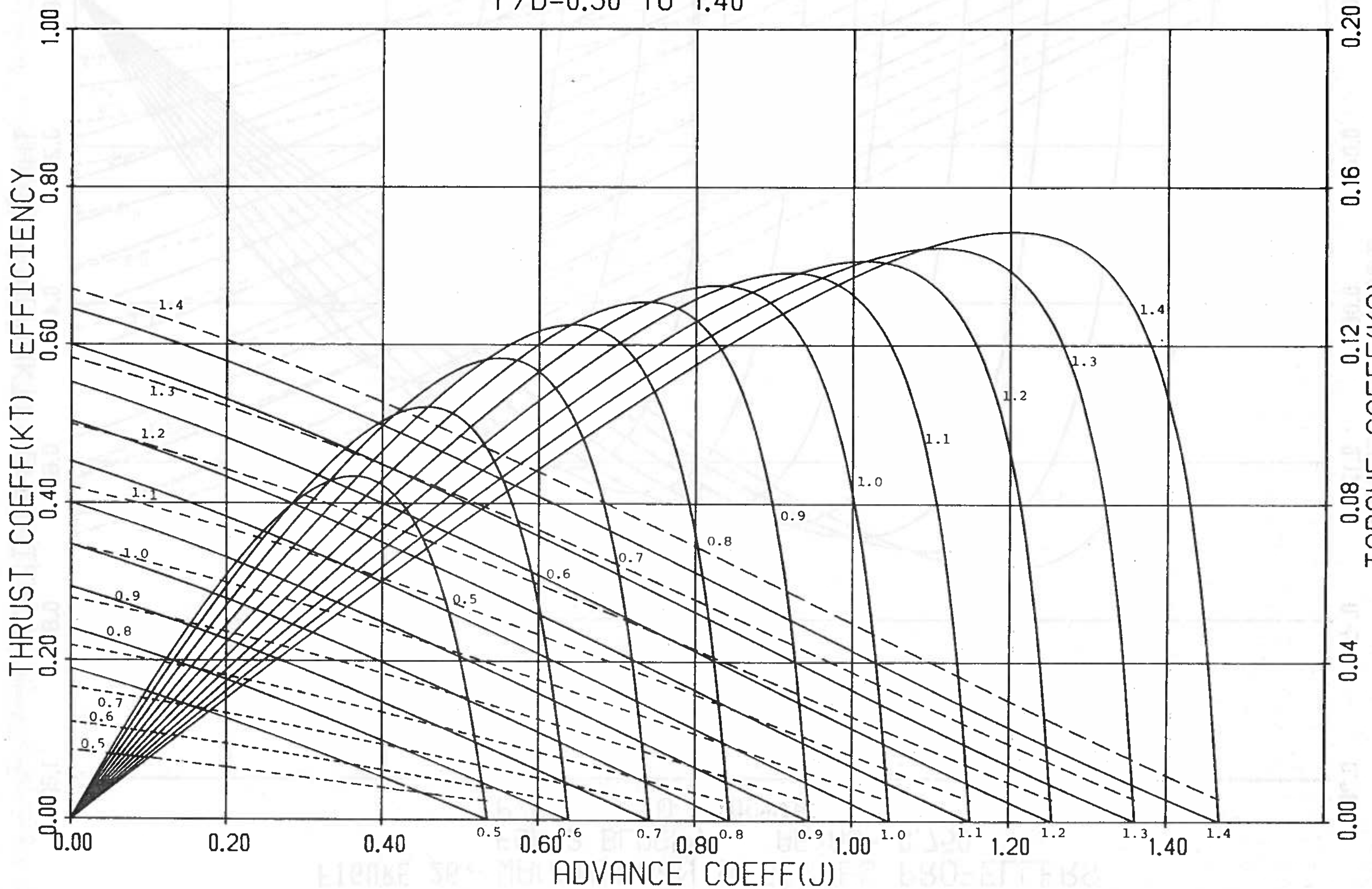


FIGURE 26. WAGENINGEN B-SERIES PROPELLERS
FOR 3 BLADES AE/AO= 0.750
P/D=0.50 TO 1.40

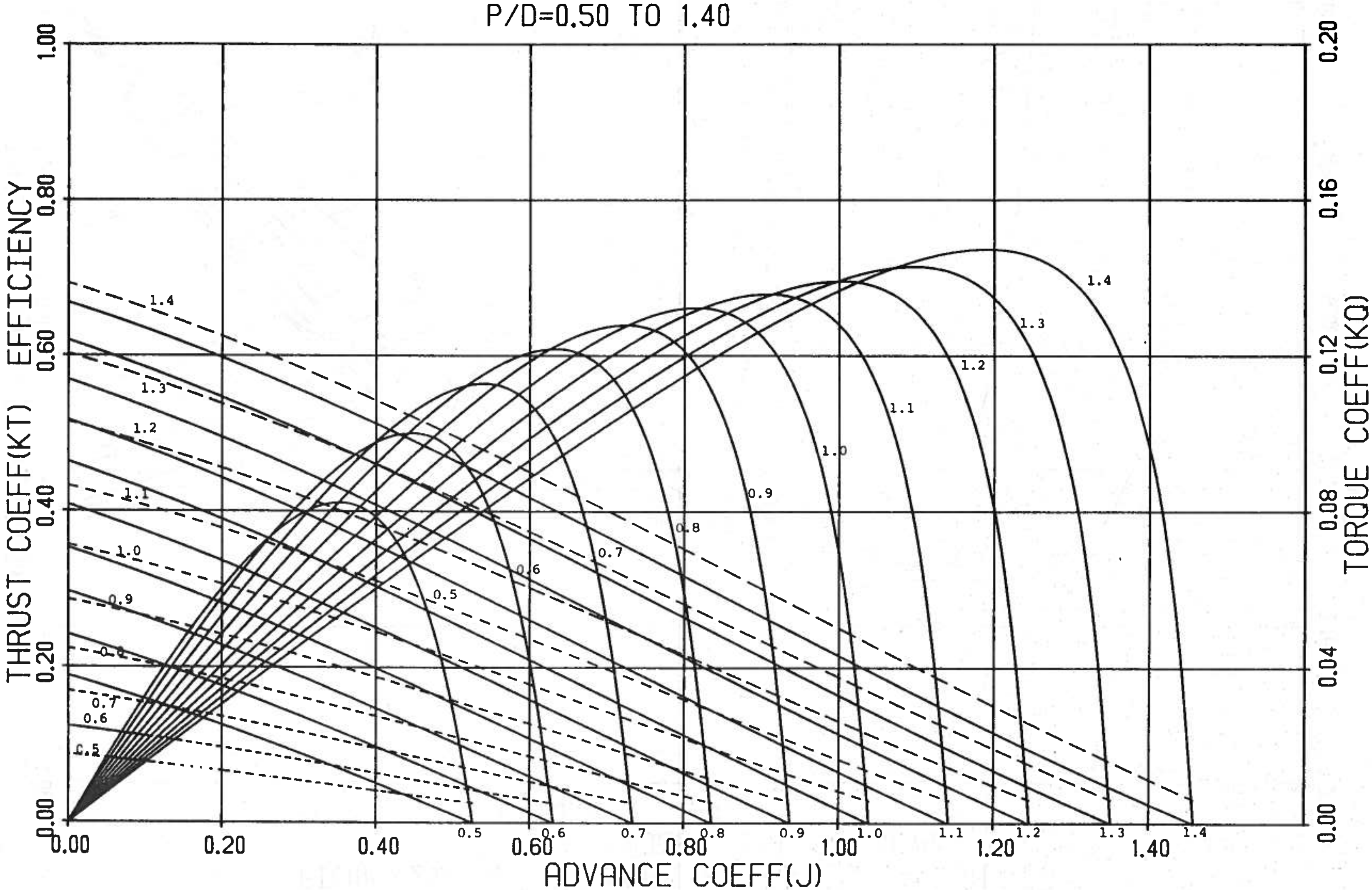


FIGURE 27. WAGENINGEN B-SERIES PROPELLERS
FOR 3 BLADES AE/AO= 0.800
P/D=0.50 TO 1.40

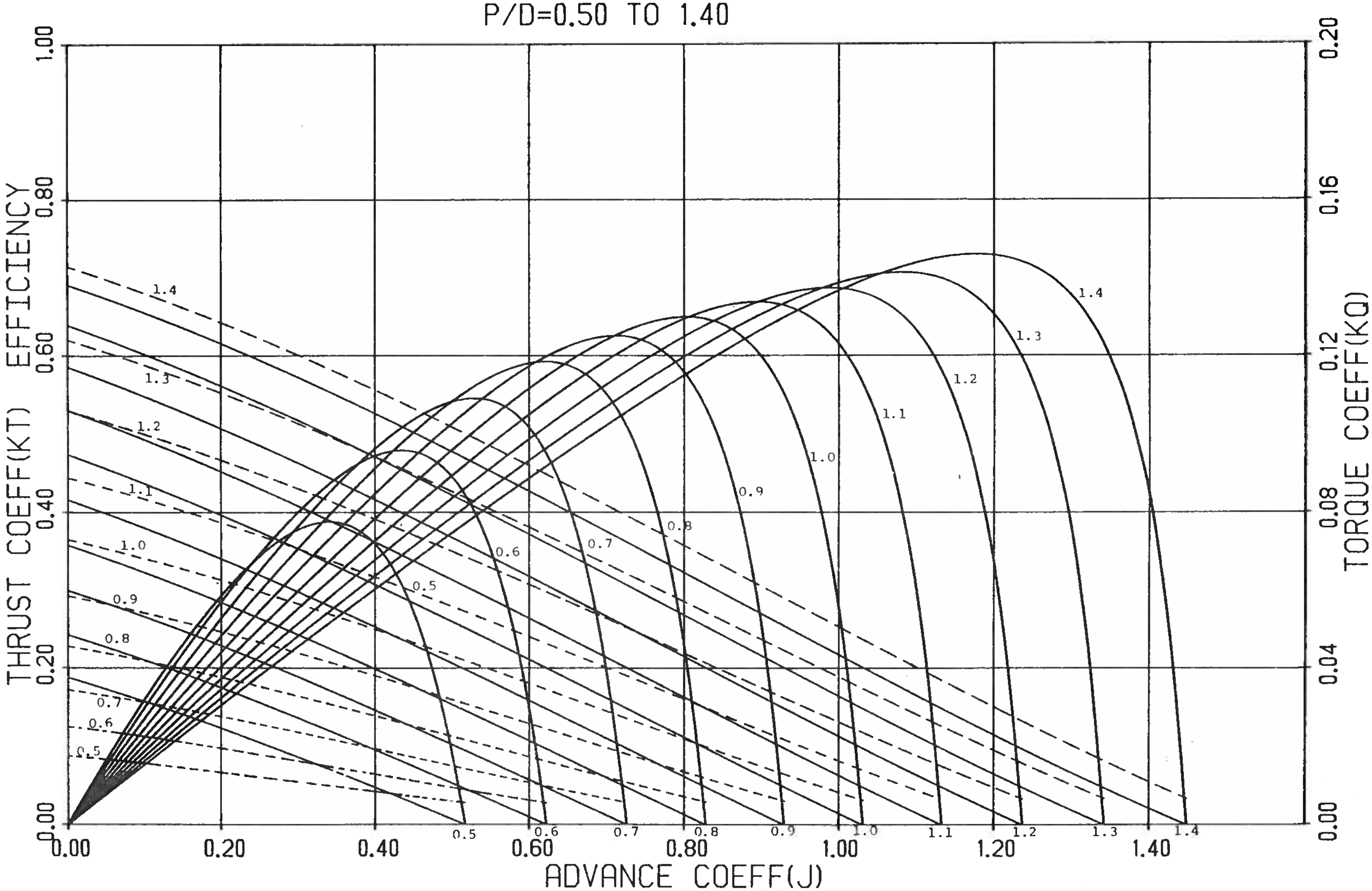


FIGURE 28. WAGENINGEN B-SERIES PROPELLERS
FOR 3 BLADES AE/AO= 0.850
P/D=0.50 TO 1.40

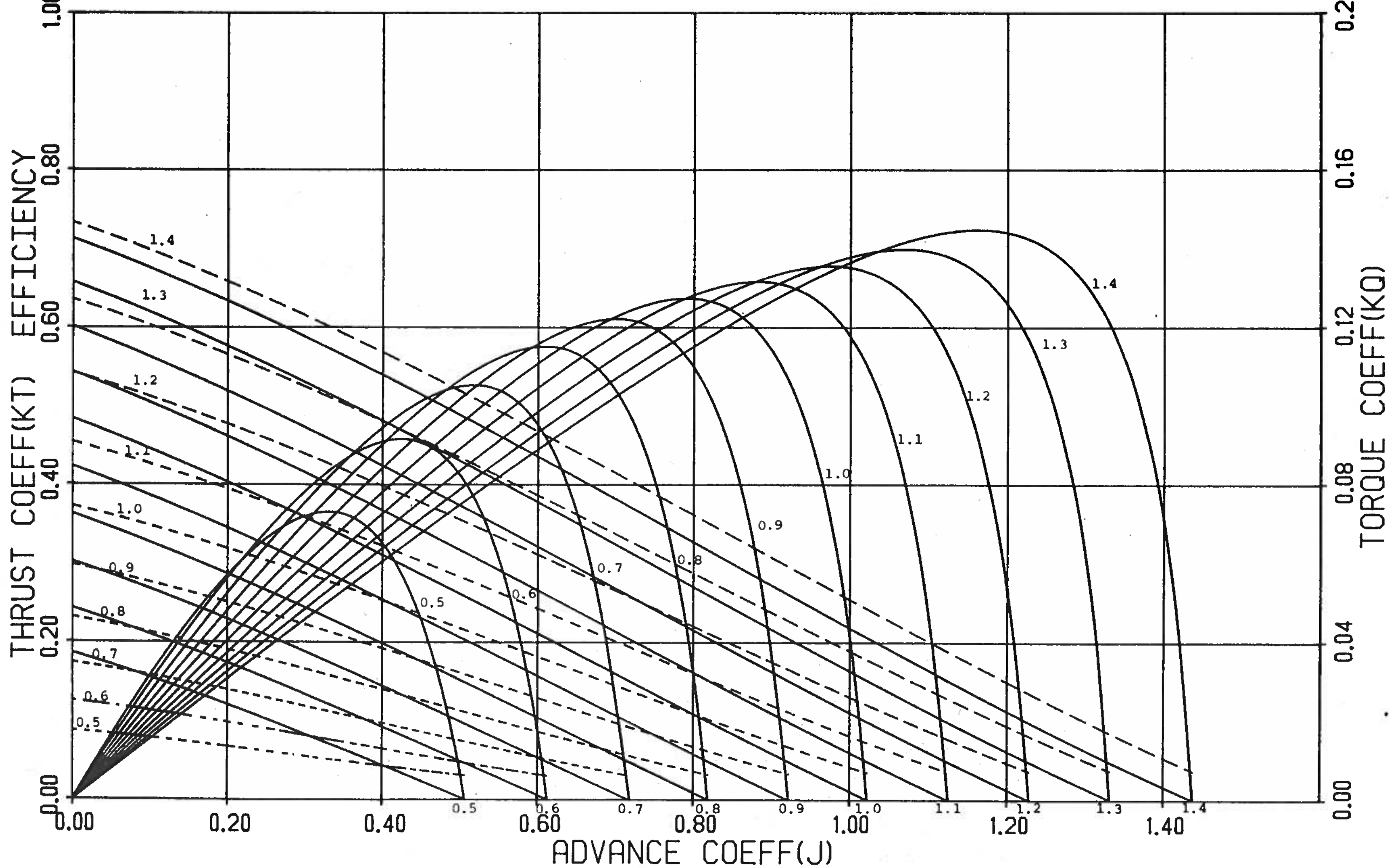


FIGURE 29. WAGENINGEN B-SERIES PROPELLERS
FOR 3 BLADES AE/AO= 0.900
P/D=0.50 TO 1.40

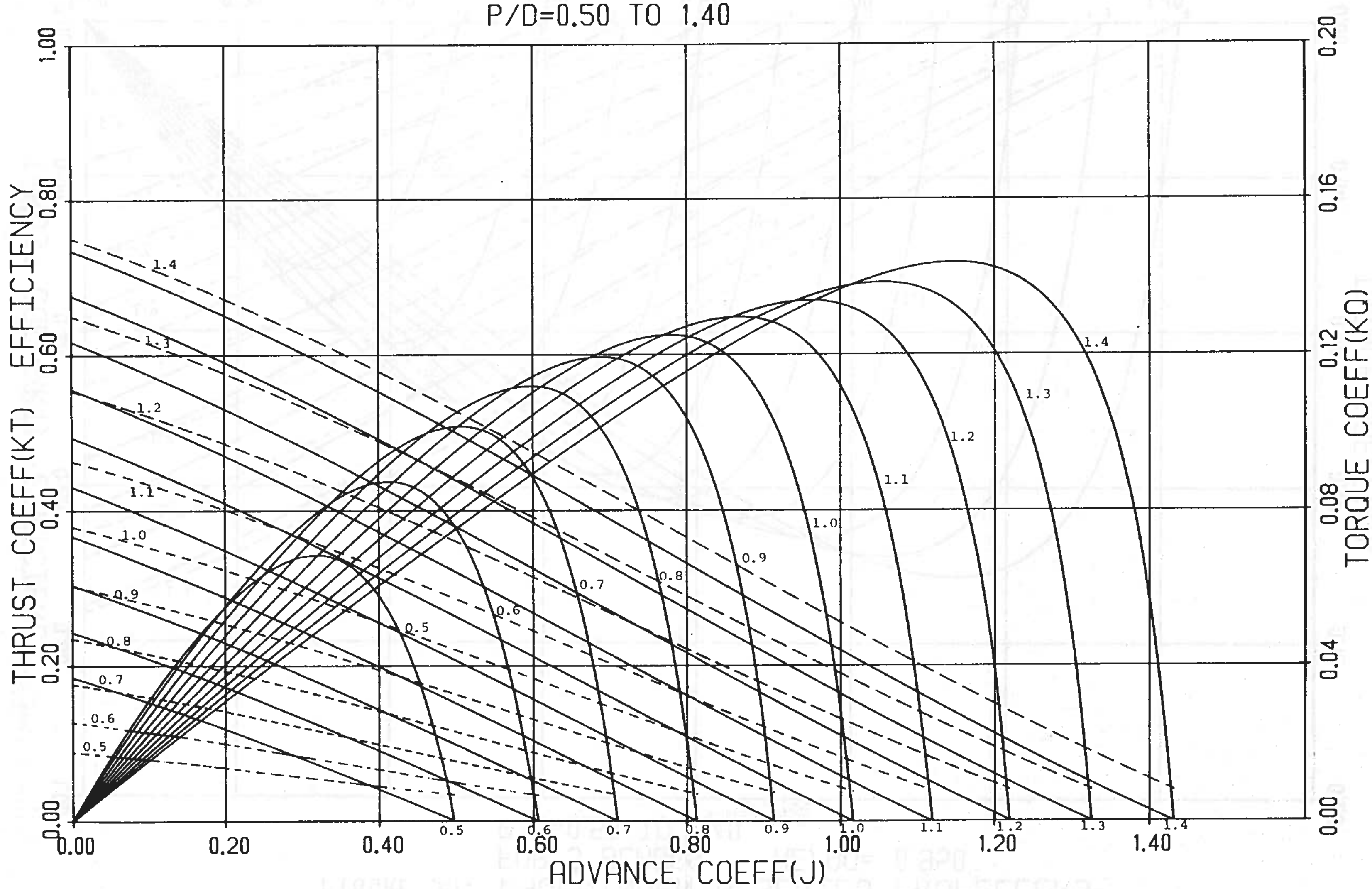


FIGURE 30. WAGENINGEN B-SERIES PROPELLERS
FOR 3 BLADES AE/AO= 0.950
P/D=0.50 TO 1.40

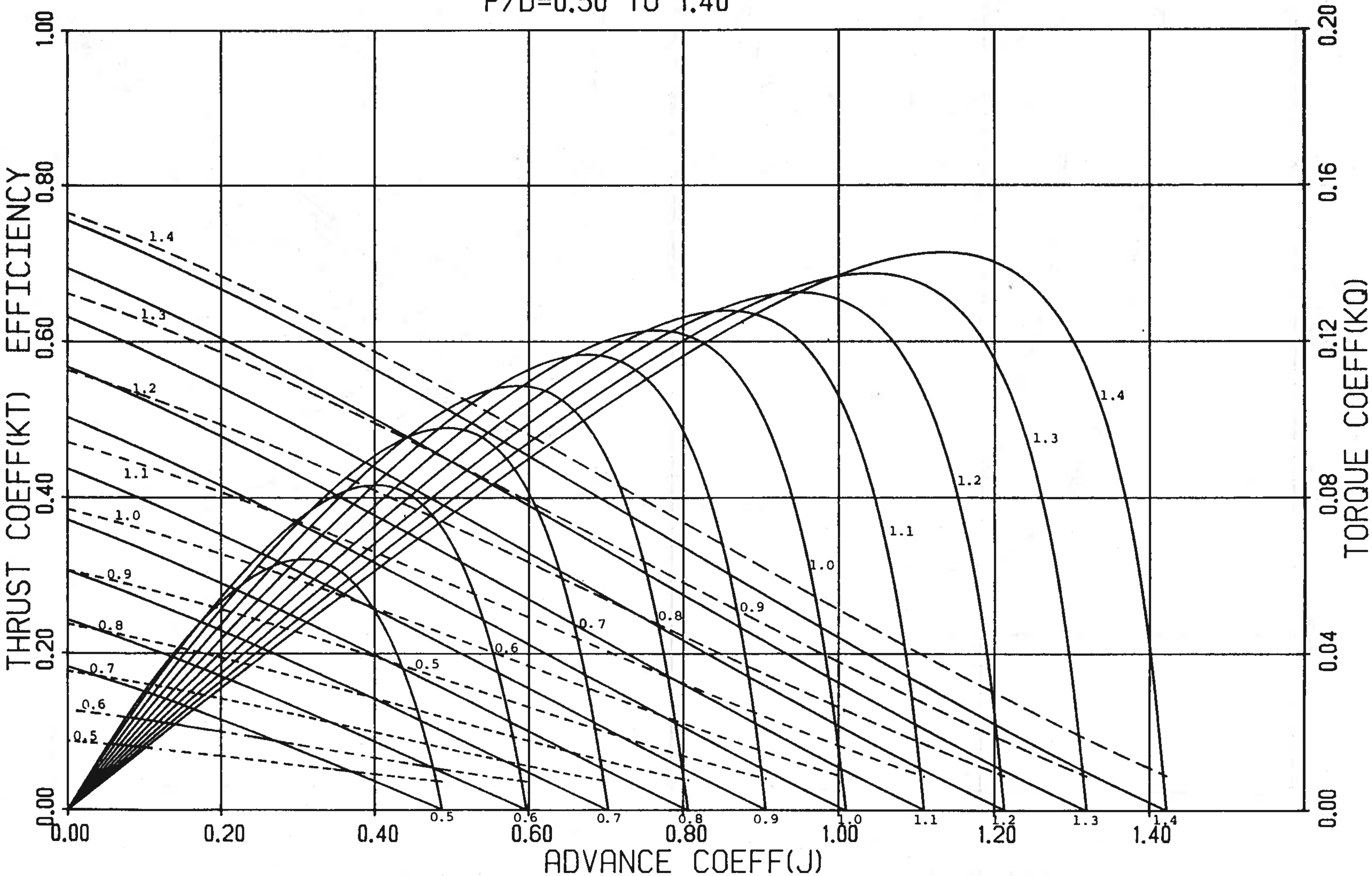


FIGURE 31. WAGENINGEN B-SERIES PROPELLERS
FOR 3 BLADES AE/AO= 1.000
P/D=0.50 TO 1.40

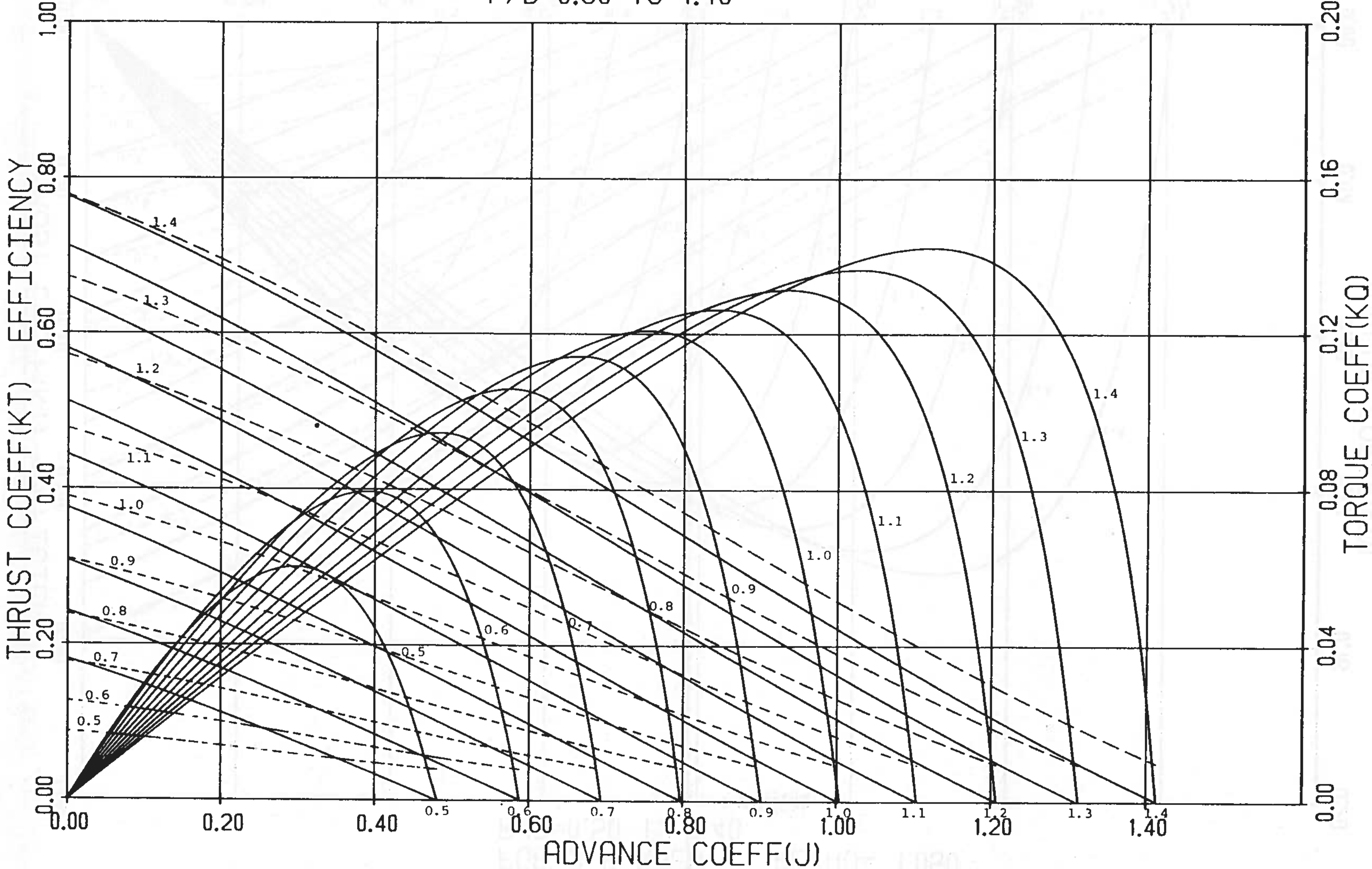


FIGURE 32. WAGENINGEN B-SERIES PROPELLERS
FOR 3 BLADES AE/AO= 1.050
P/D=0.50 TO 1.40

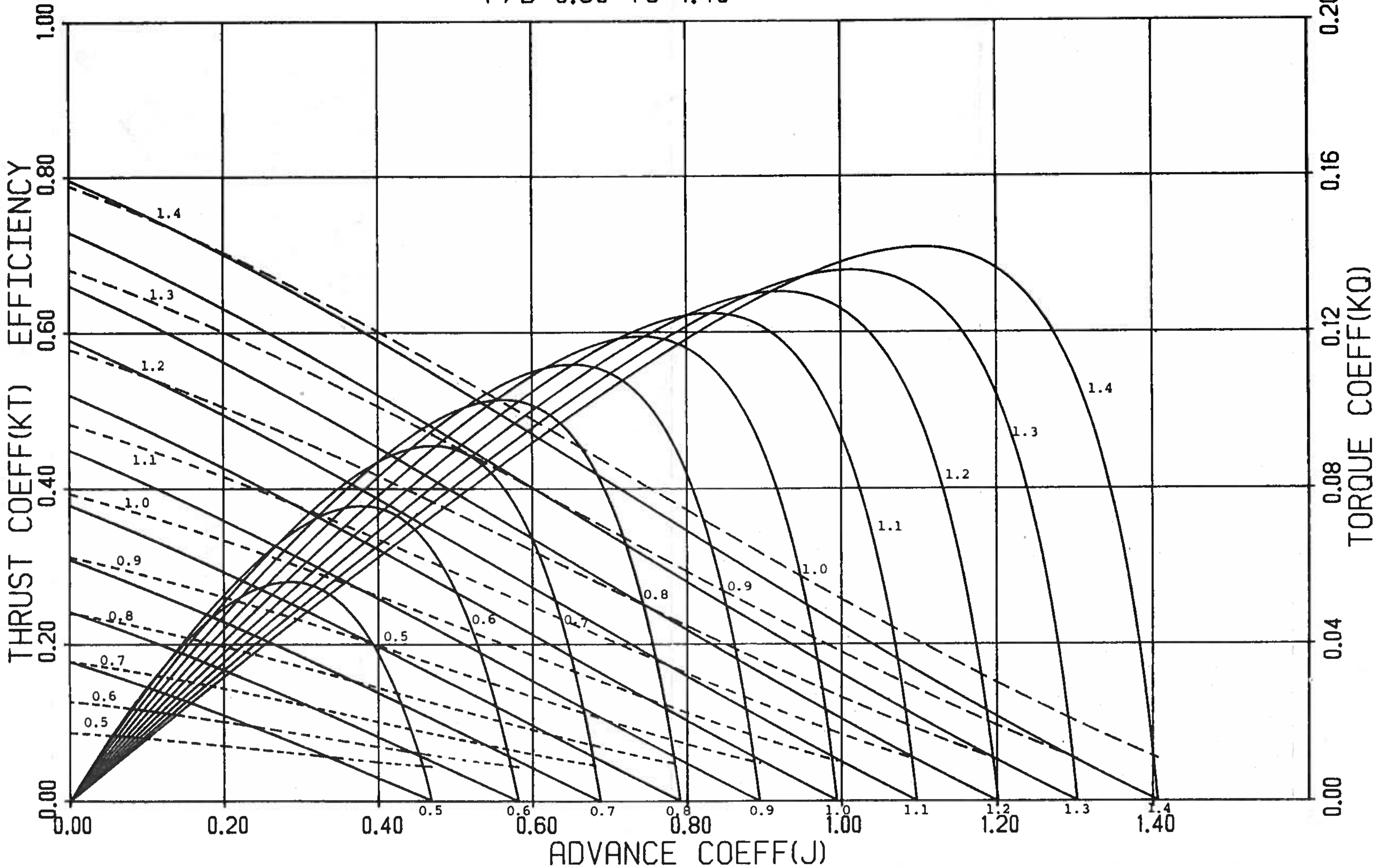


FIGURE 33. WAGENINGEN B-SERIES PROPELLERS
FOR 4 BLADES AE/AO= 0.300
P/D=0.50 TO 1.40

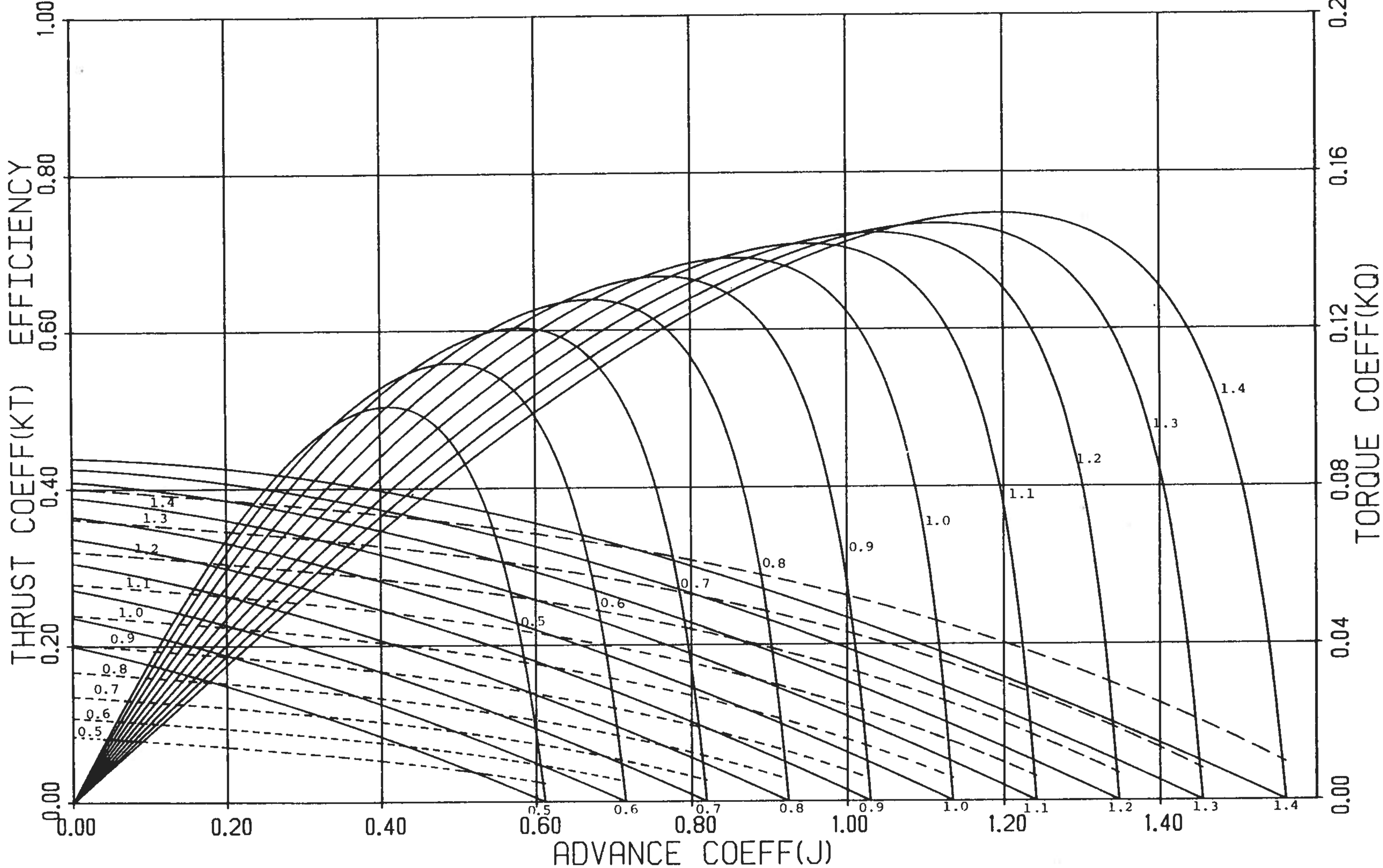


FIGURE 34. WAGENINGEN B-SERIES PROPELLERS
FOR 4 BLADES AE/AO= 0.350
P/D=0.50 TO 1.40

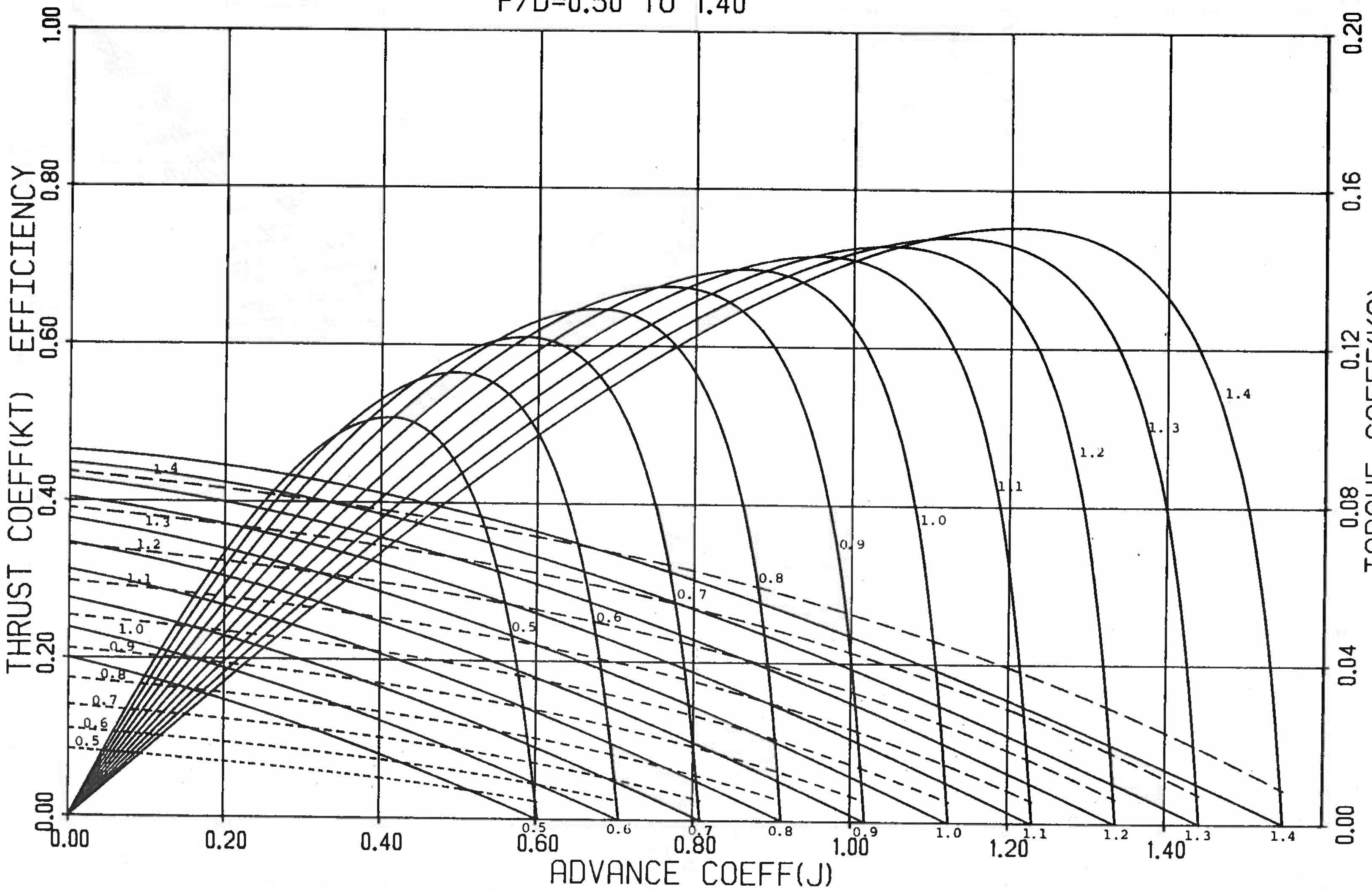


FIGURE 35. WAGENINGEN B-SERIES PROPELLERS
FOR 4 BLADES AE/AO= 0.400
P/D=0.50 TO 1.40

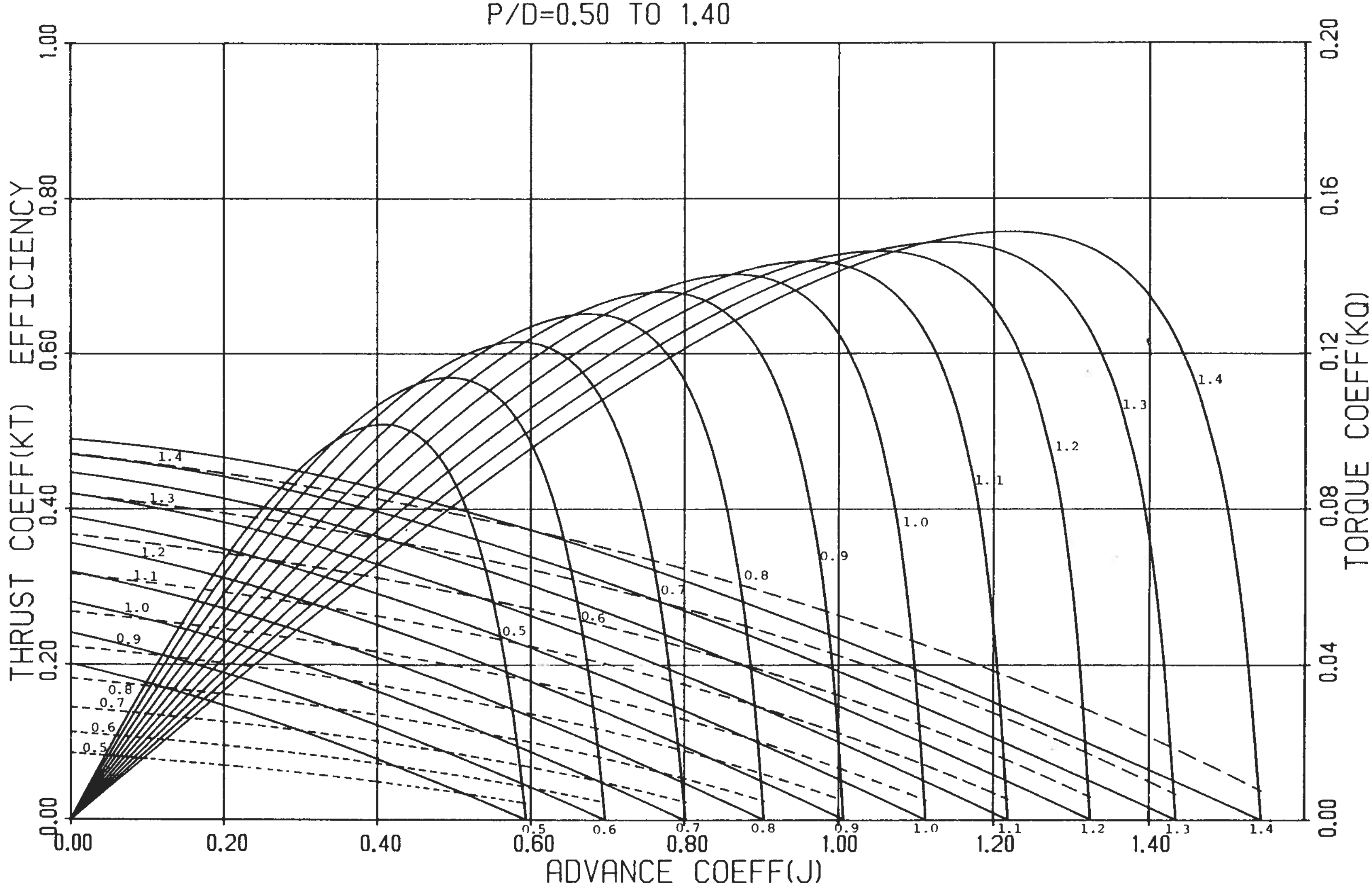


FIGURE 36. WAGENINGEN B-SERIES PROPELLERS
FOR 4 BLADES AE/AO= 0.450
P/D=0.50 TO 1.40

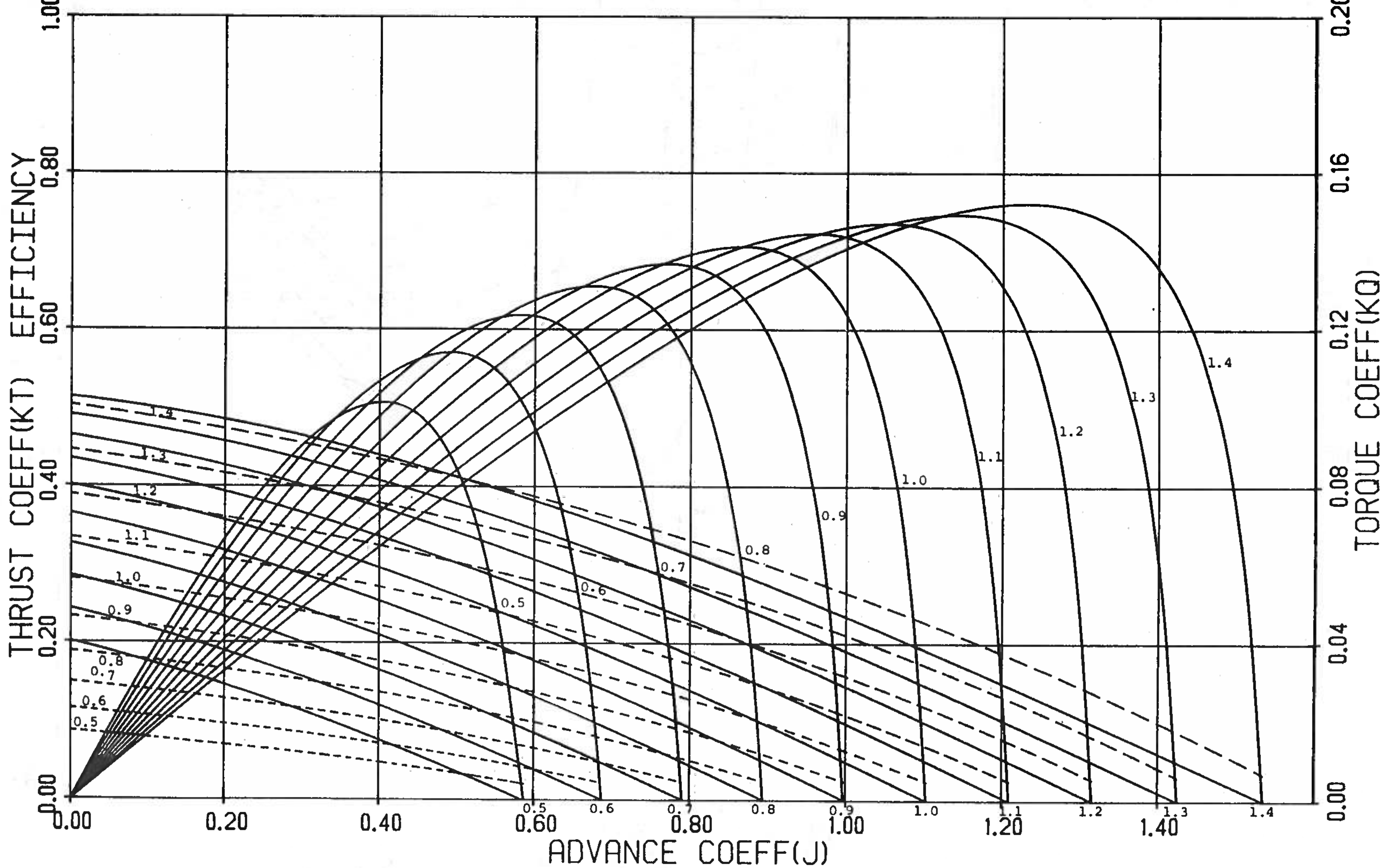


FIGURE 37. WAGENINGEN B-SERIES PROPELLERS
FOR 4 BLADES AE/AO= 0.500
P/D=0.50 TO 1.40

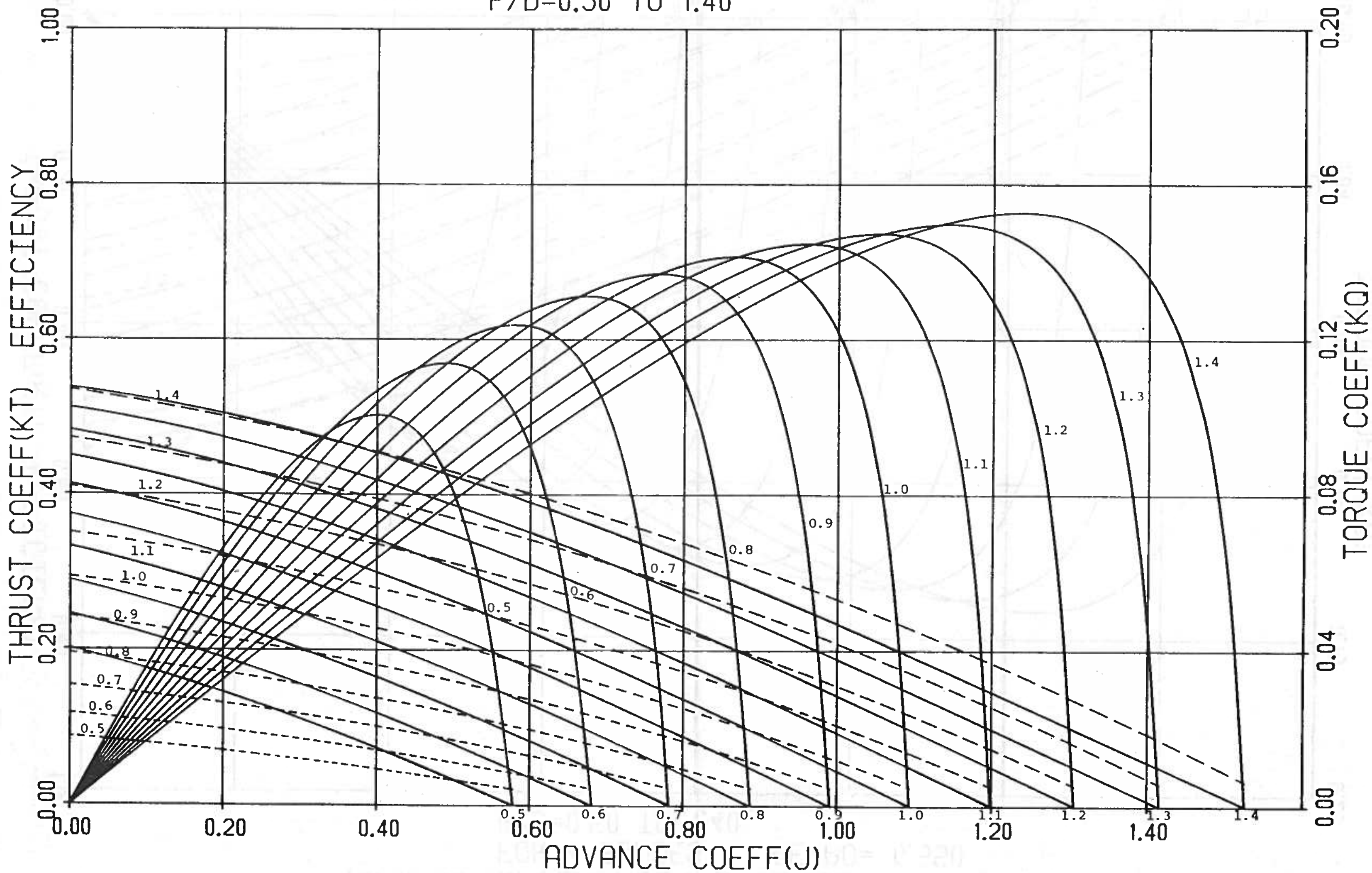


FIGURE 38. WAGENINGEN B-SERIES PROPELLERS
FOR 4 BLADES AE/AO= 0.550
P/D=0.50 TO 1.40

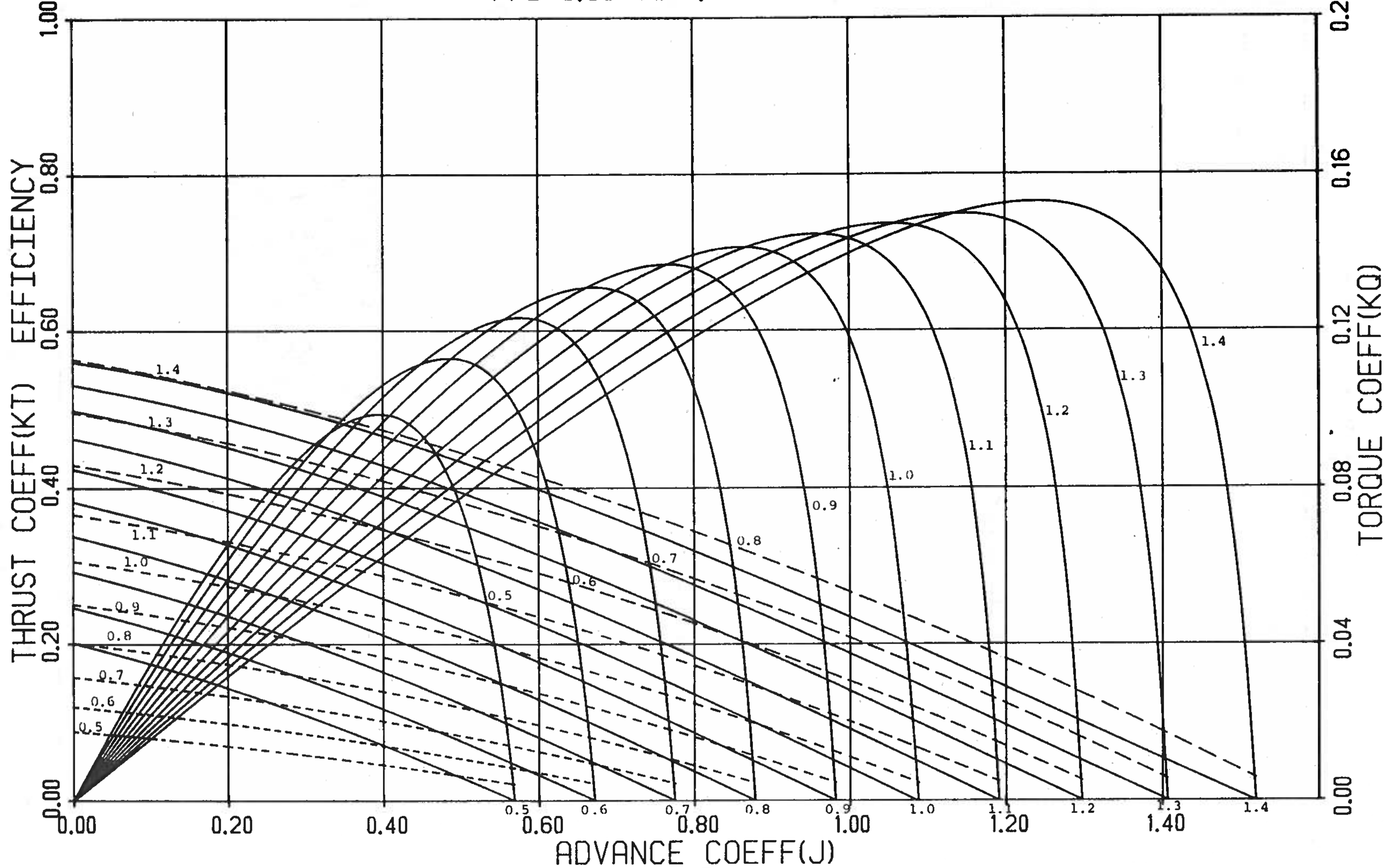


FIGURE 39. WAGENINGEN B-SERIES PROPELLERS
FOR 4 BLADES AE/AO= 0.600
P/D=0.50 TO 1.40

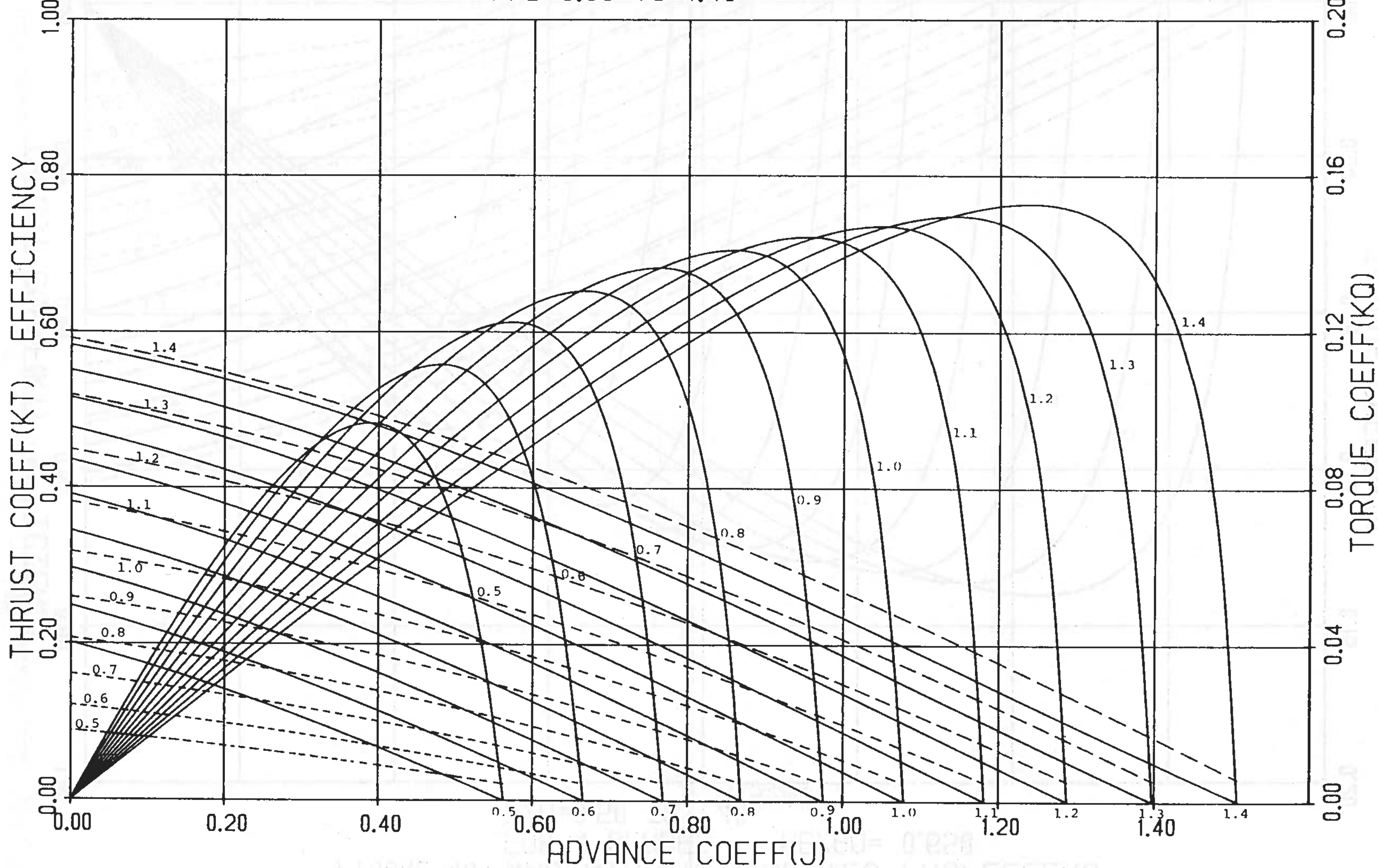


FIGURE 40. WAGENINGEN B-SERIES PROPELLERS
FOR 4 BLADES   AE/AO= 0.650
P/D=0.50 TO 1.40

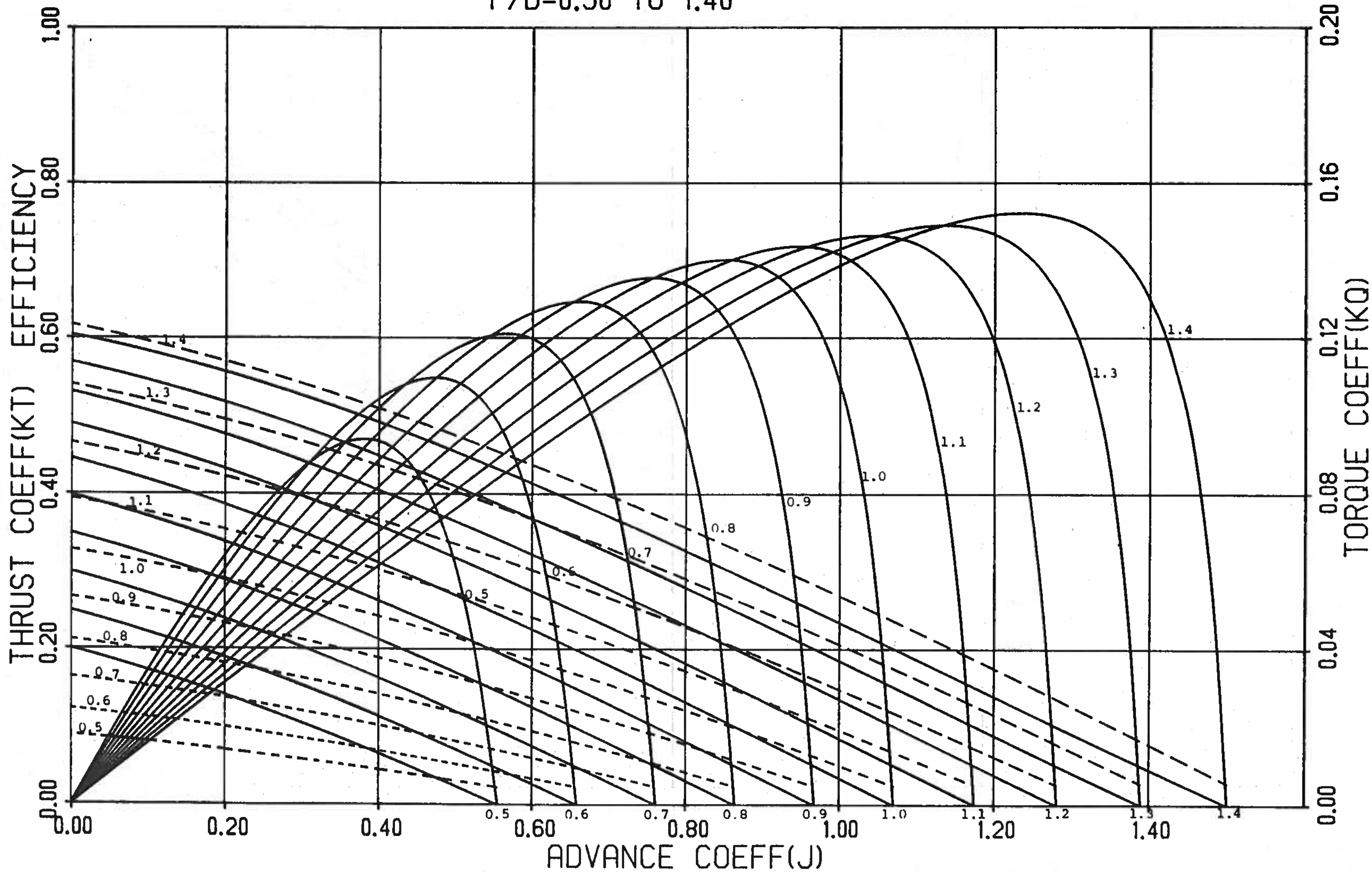


FIGURE 41. WAGENINGEN B-SERIES PROPELLERS
FOR 4 BLADES AE/AO= 0.700
P/D=0.50 TO 1.40

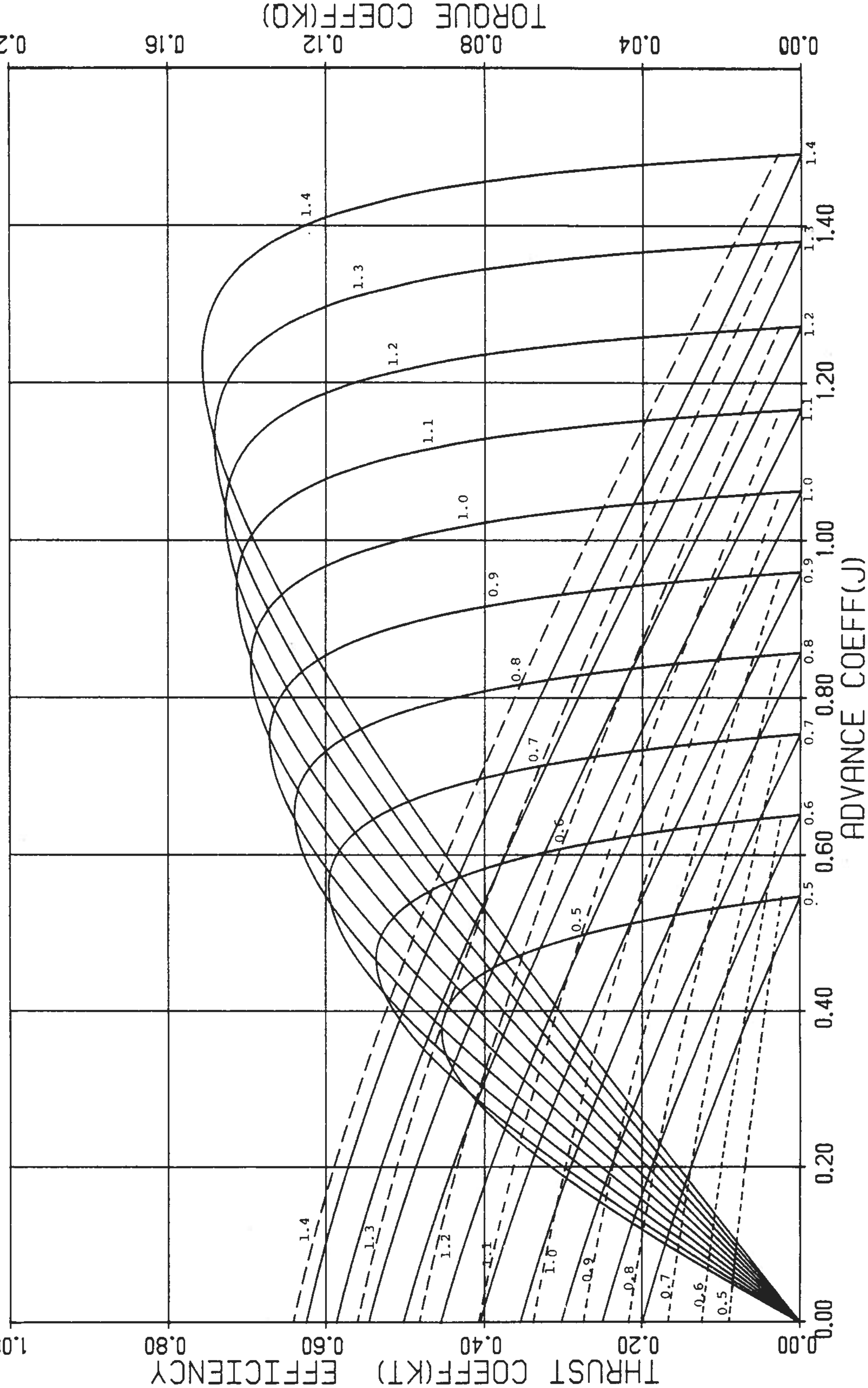


FIGURE 42. WAGENINGEN B-SERIES PROPELLERS
FOR 4 BLADES AE/AO= 0.750
P/D=0.50 TO 1.40

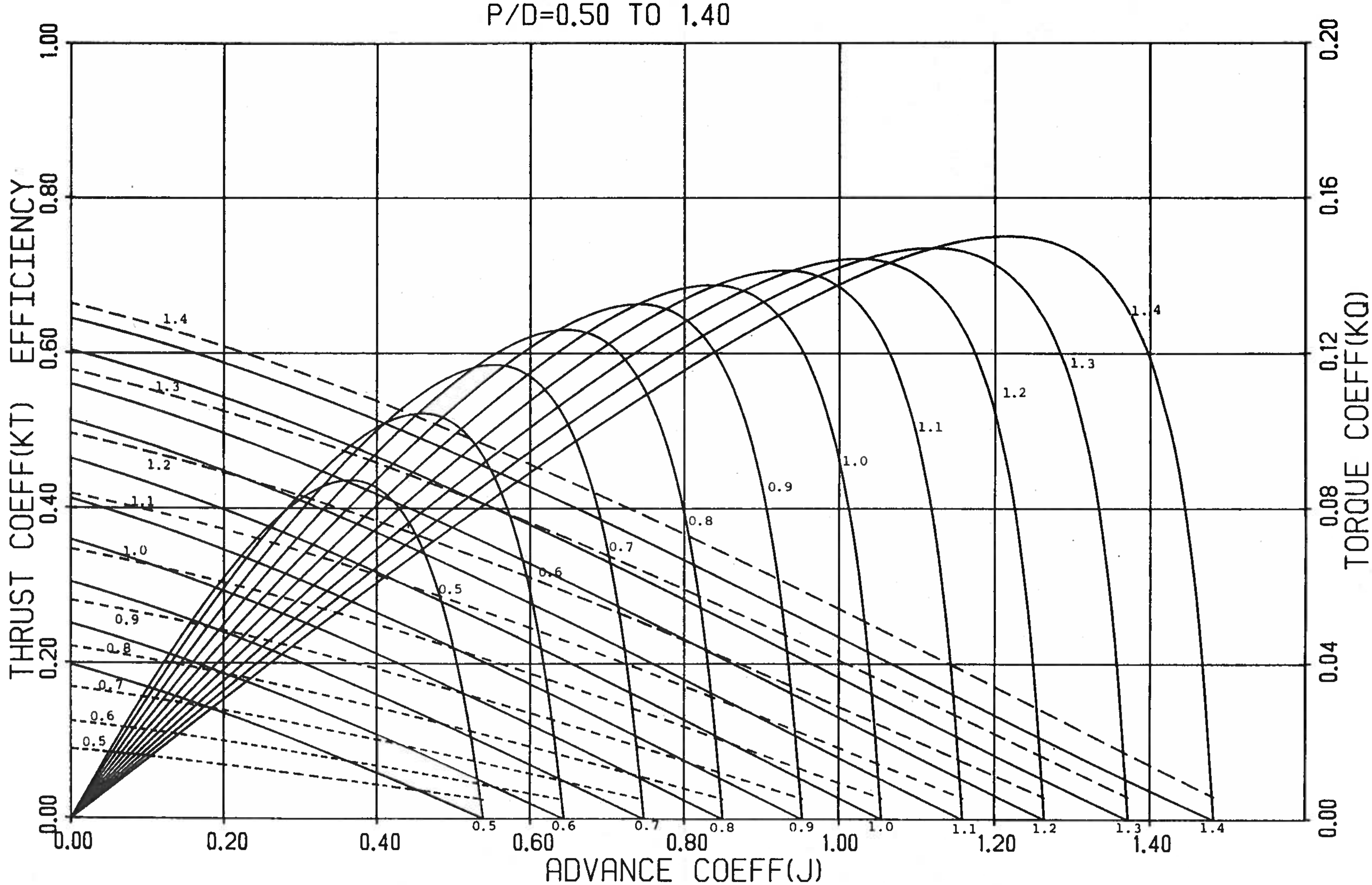


FIGURE 43. WAGENINGEN B-SERIES PROPELLERS
FOR 4 BLADES AE/AO= 0.800
P/D=0.50 TO 1.40

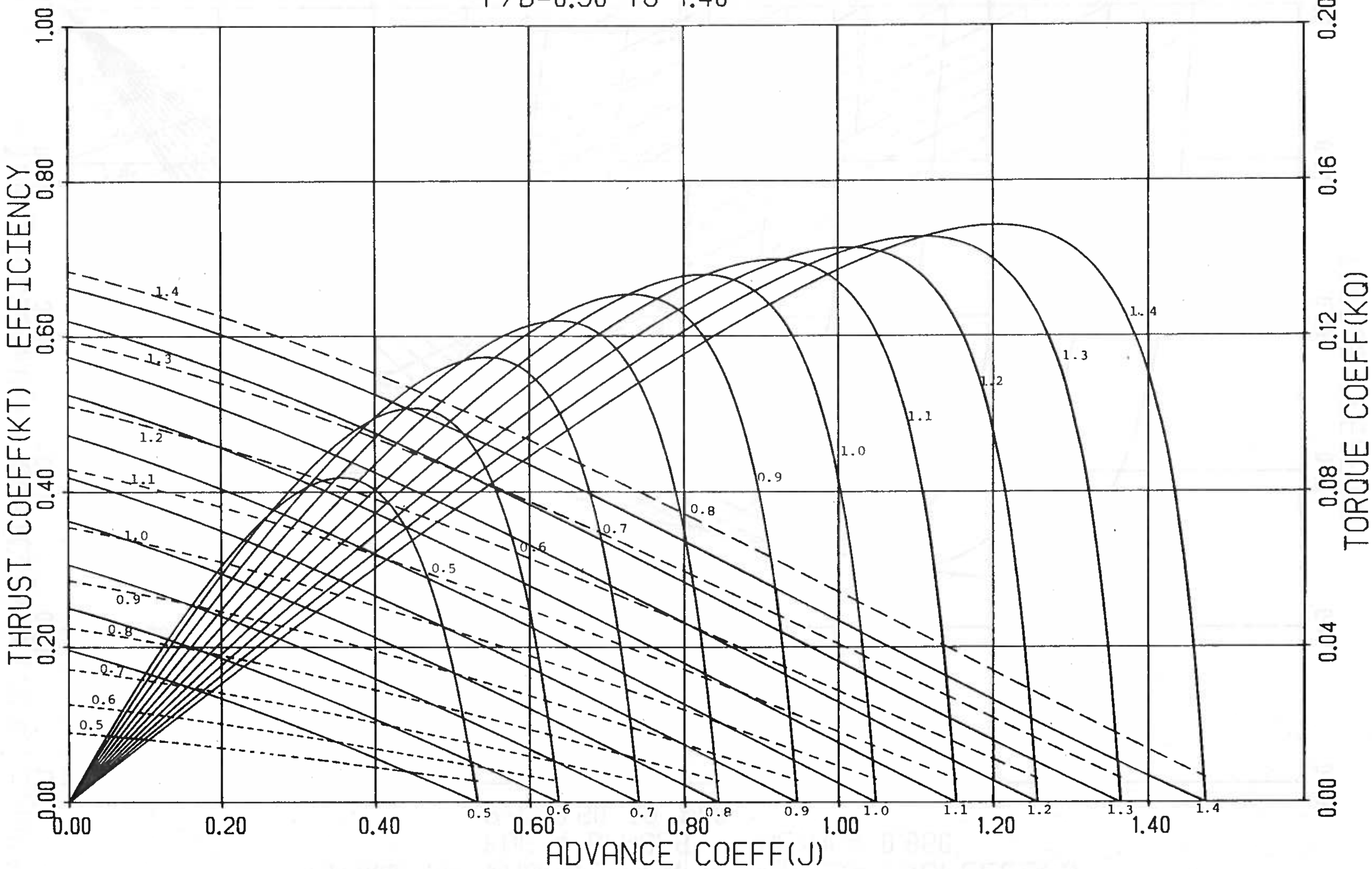


FIGURE 44. WAGENINGEN B-SERIES PROPELLERS
FOR 4 BLADES AE/AO= 0.850
P/D=0.50 TO 1.40

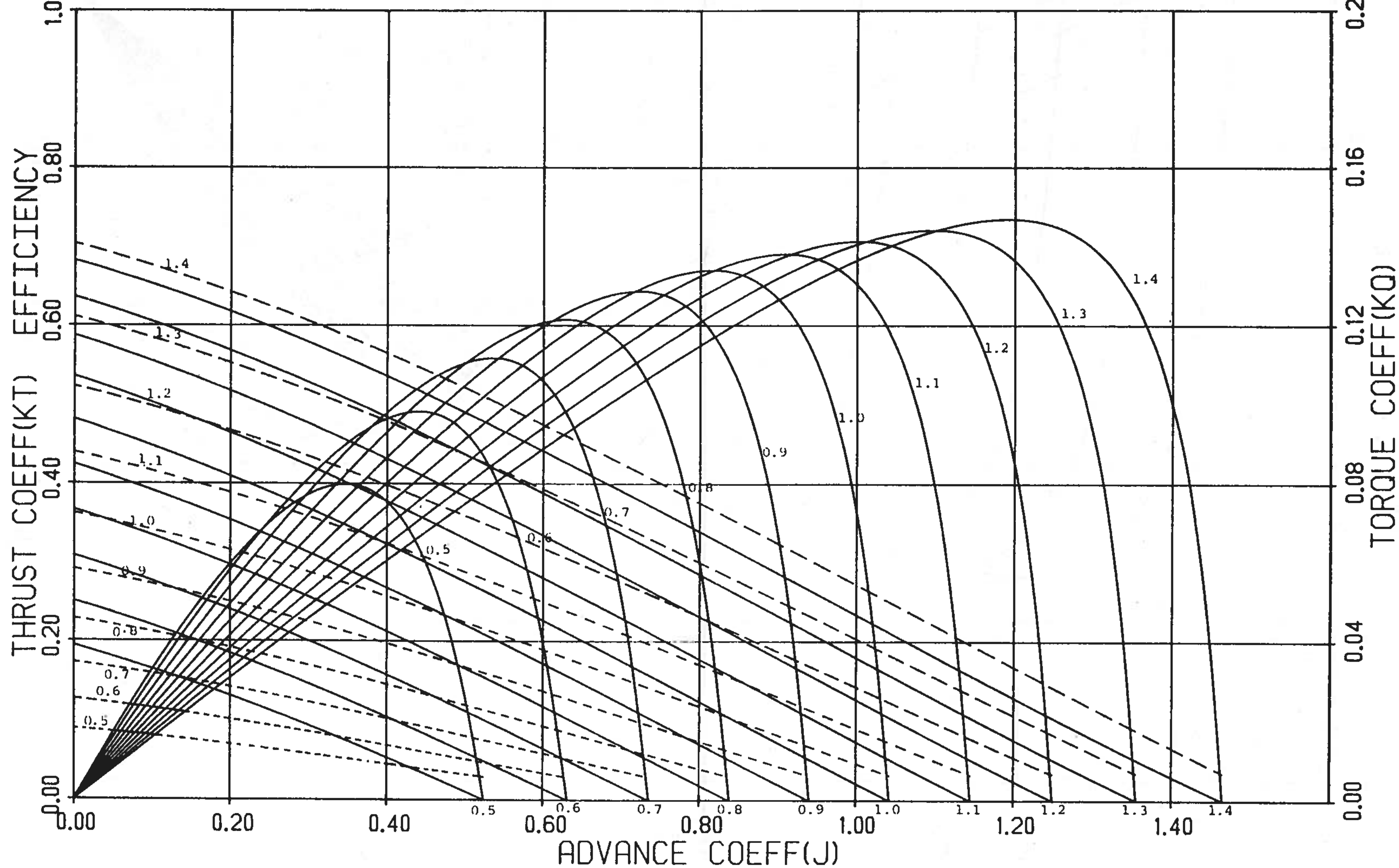


FIGURE 45. WAGENINGEN B-SERIES PROPELLERS
FOR 4 BLADES AE/AO= 0.900
P/D=0.50 TO 1.40

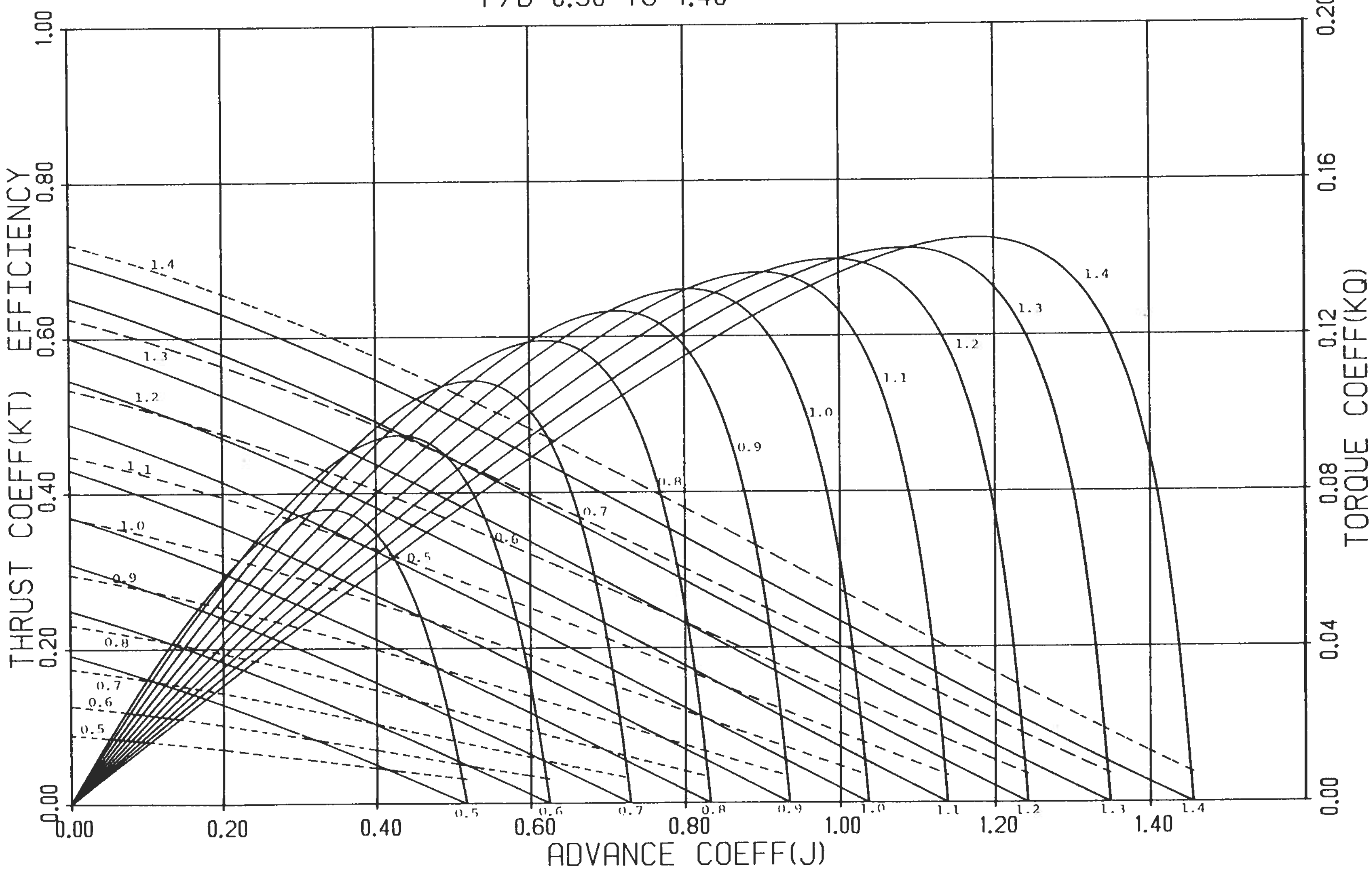


FIGURE 46. WAGENINGEN B-SERIES PROPELLERS
FOR 4 BLADES AE/AO= 0.950
P/D=0.50 TO 1.40

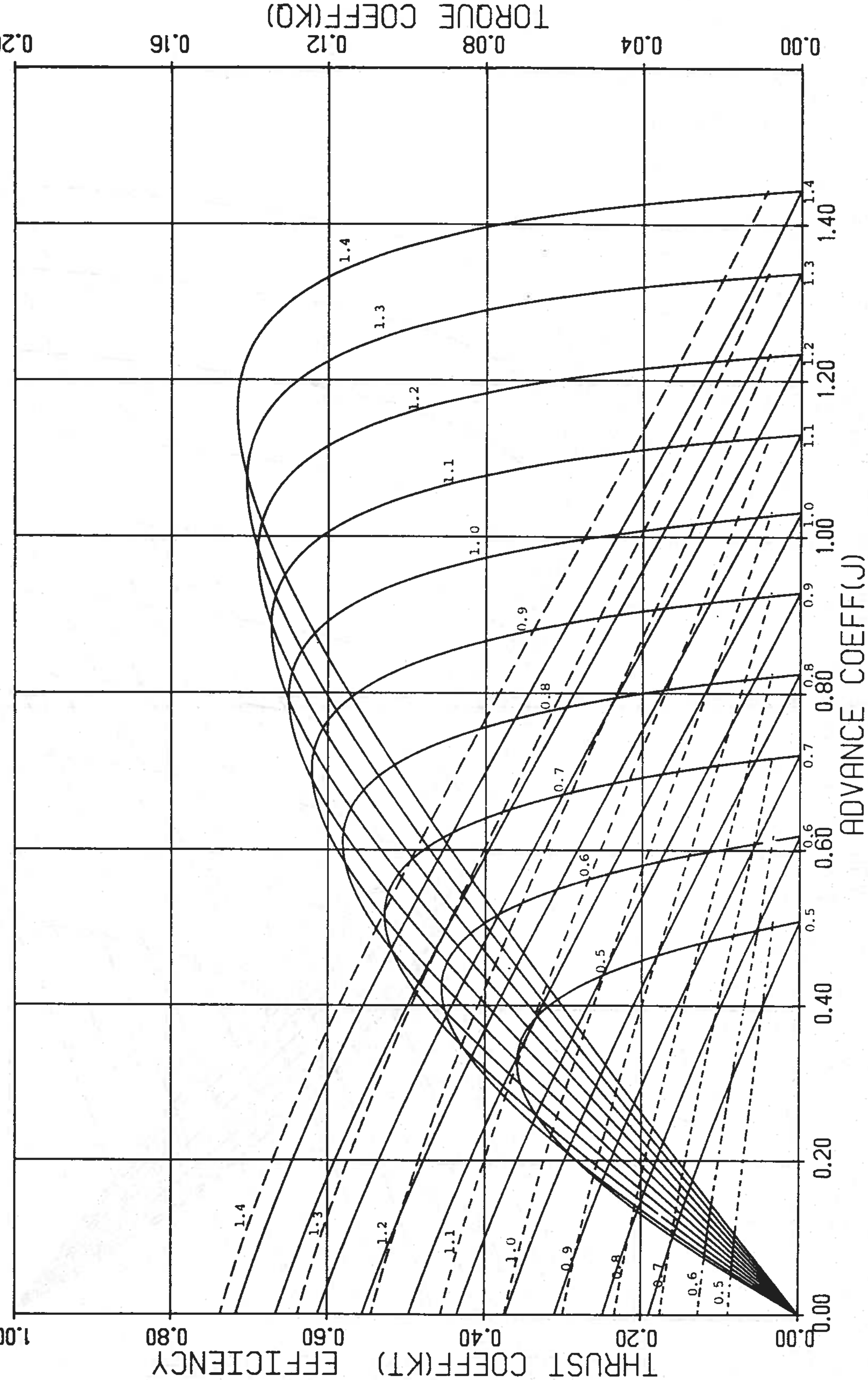


FIGURE 47. WAGENINGEN B-SERIES PROPELLERS
FOR 4 BLADES AE/AO= 1.000
P/D=0.50 TO 1.40

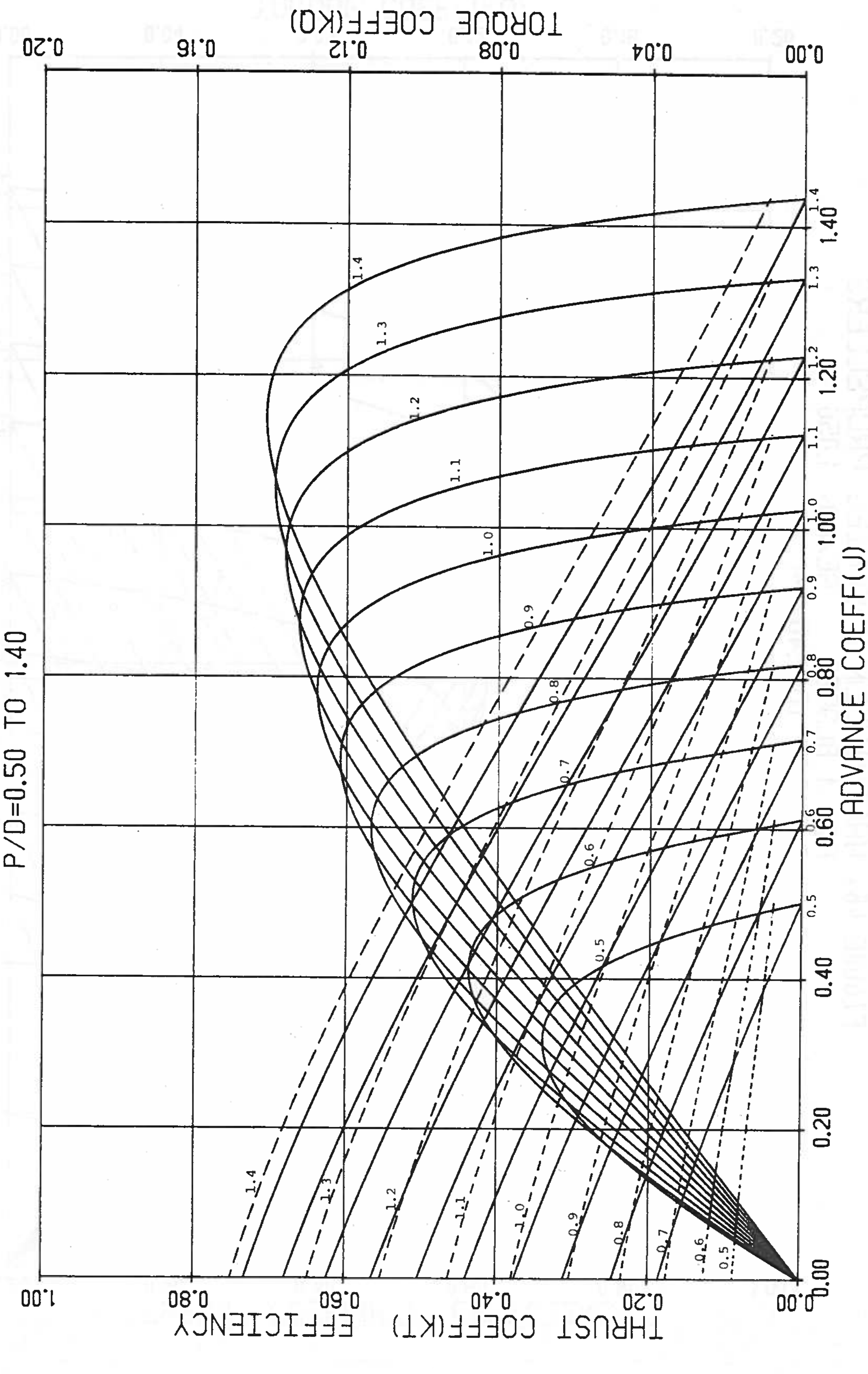


FIGURE 48. WAGENINGEN B-SERIES PROPELLERS
FOR 4 BLADES AE/AO= 1.050
P/D=0.50 TO 1.40

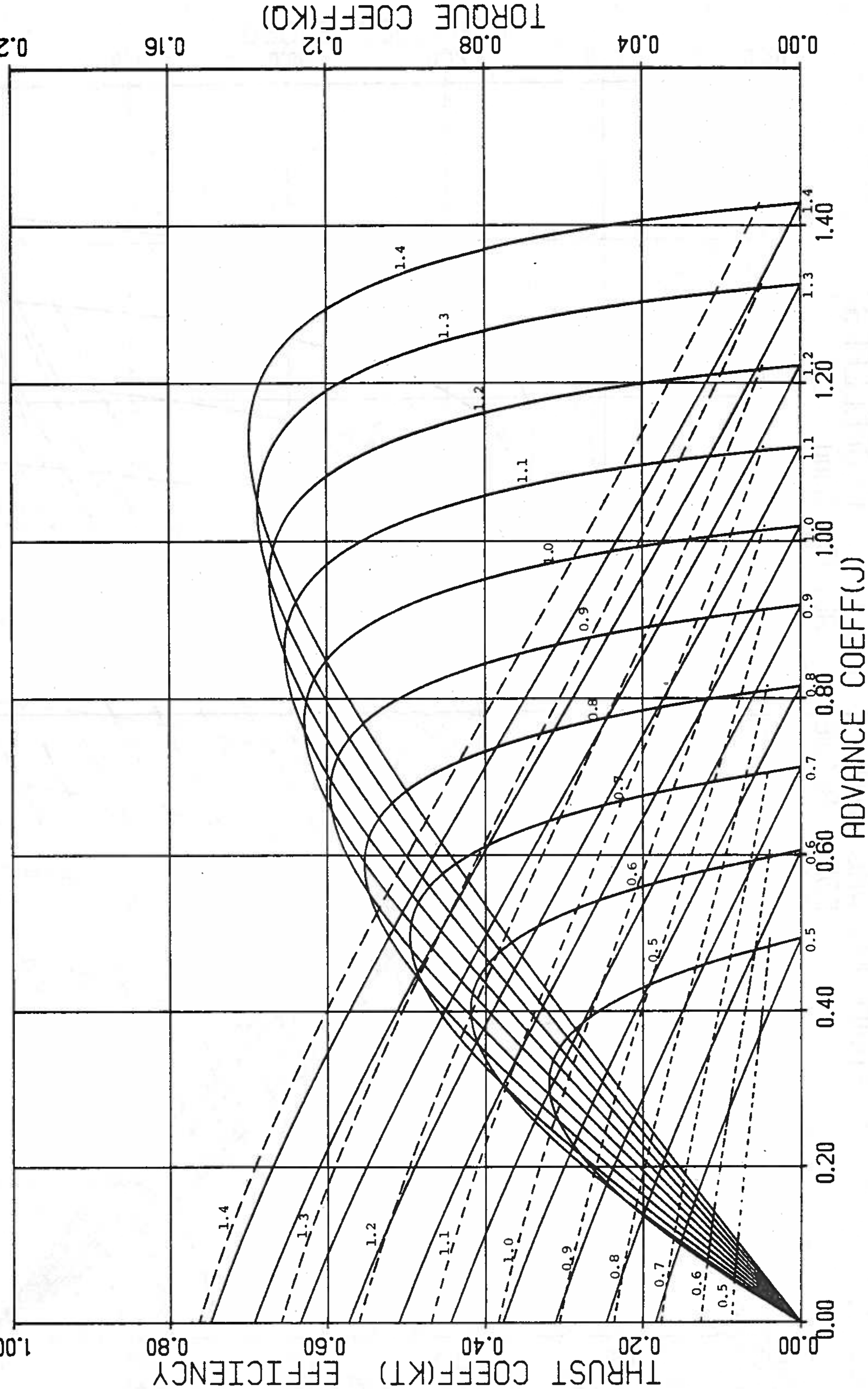


FIGURE 49. WAGENINGEN B-SERIES PROPELLERS
FOR 5 BLADES AE/AO= 0.300
P/D=0.50 TO 1.40

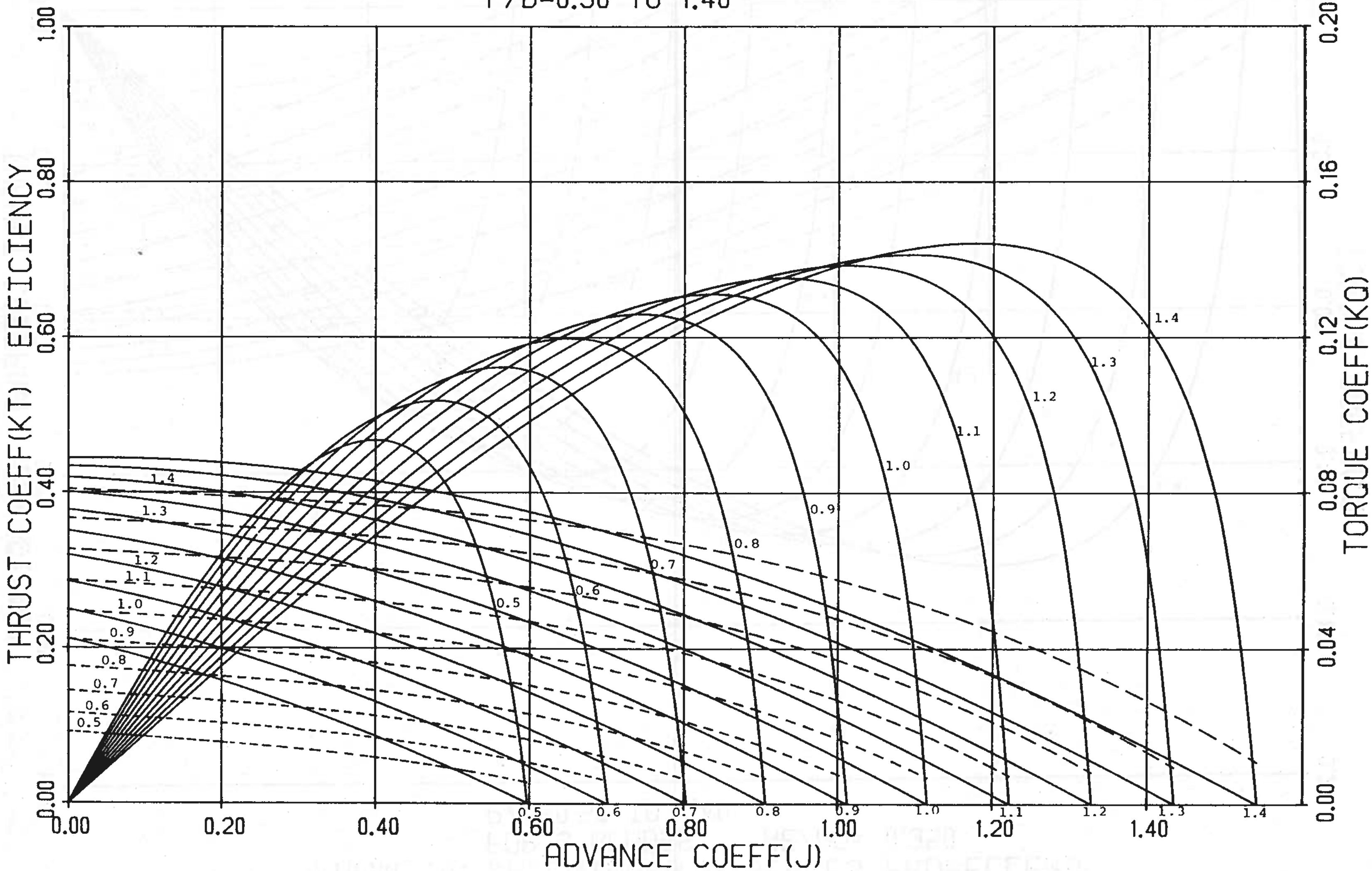


FIGURE 50. WAGENINGEN B-SERIES PROPELLERS
FOR 5 BLADES AE/AO= 0.350
P/D=0.50 TO 1.40

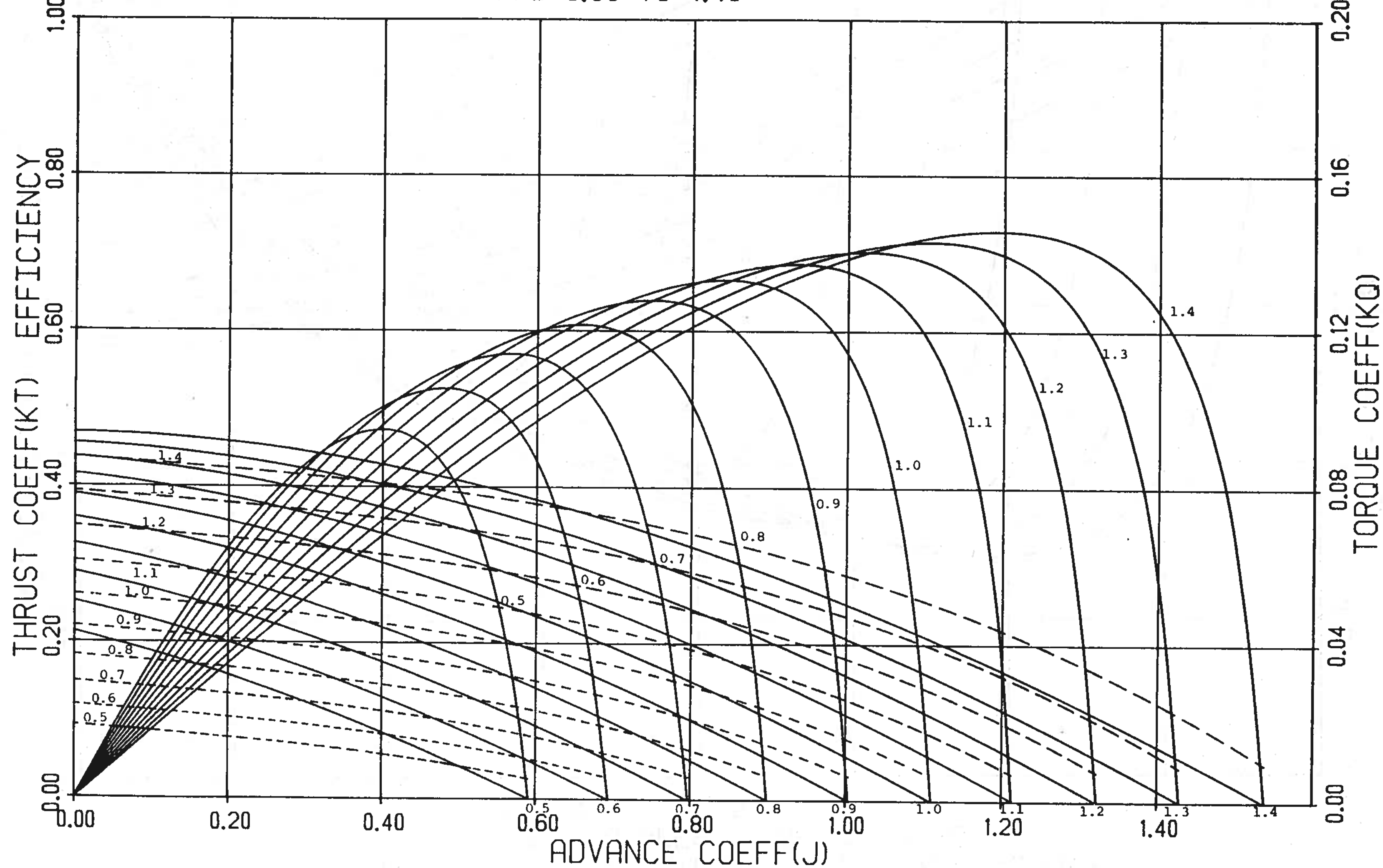


FIGURE 51. WAGENINGEN B-SERIES PROPELLERS
FOR 5 BLADES AE/AO= 0.400
P/D=0.50 TO 1.40

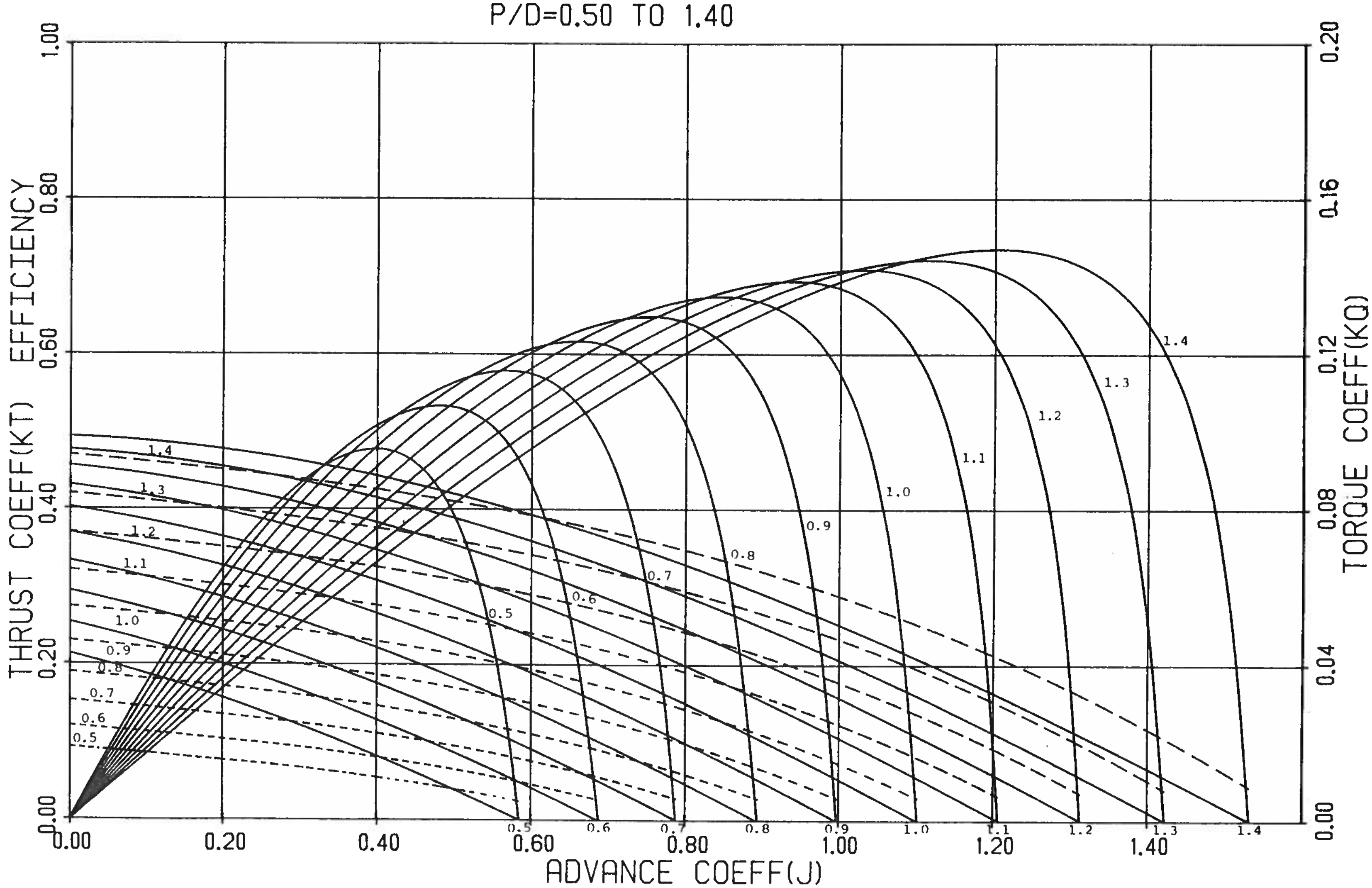


FIGURE 52. WAGENINGEN B-SERIES PROPELLERS
FOR 5 BLADES AE/AO= 0.450
P/D=0.50 TO 1.40

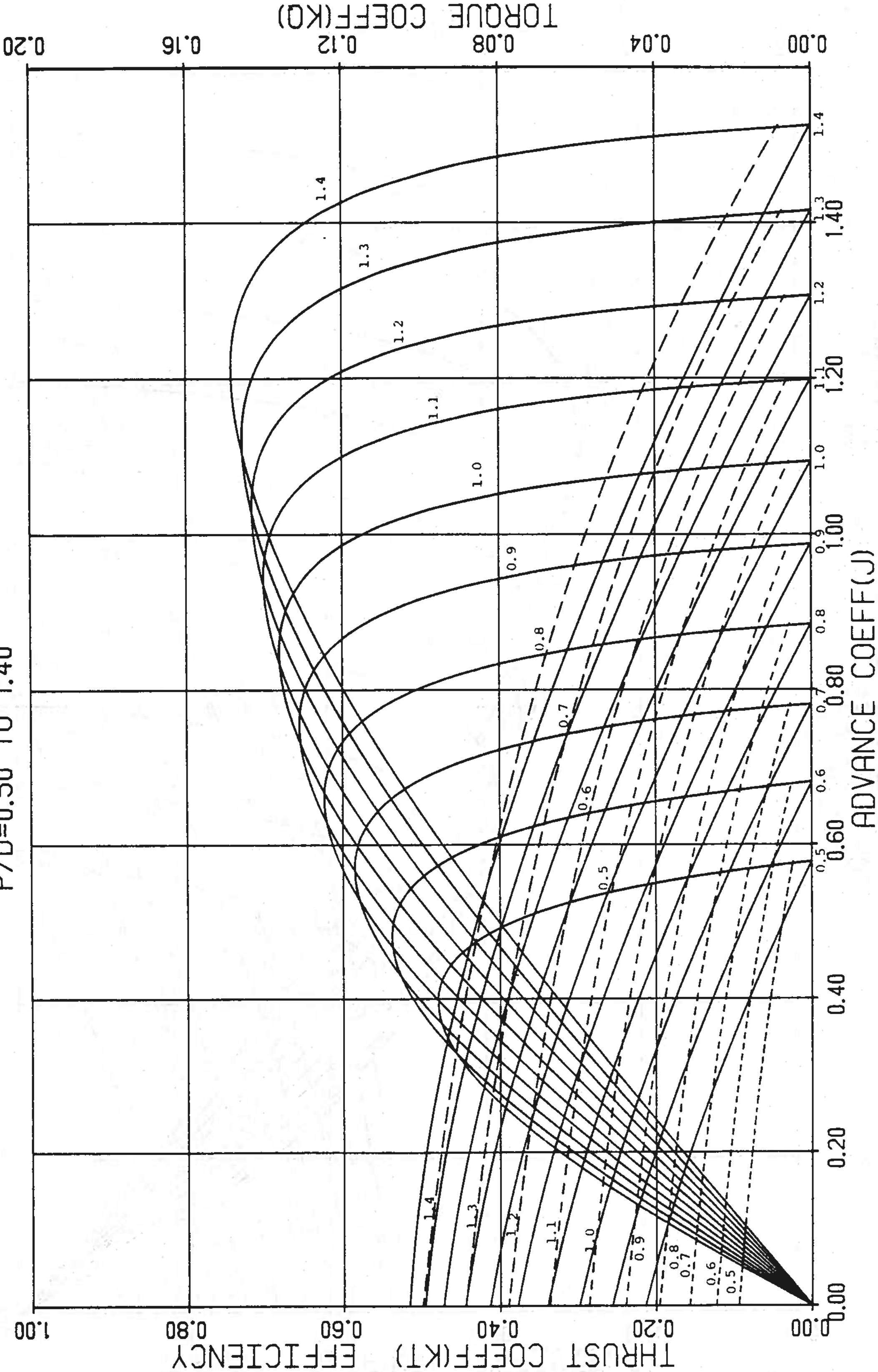


FIGURE 53. WAGENINGEN B-SERIES PROPELLERS
FOR 5 BLADES AE/AO= 0.500
P/D=0.50 TO 1.40

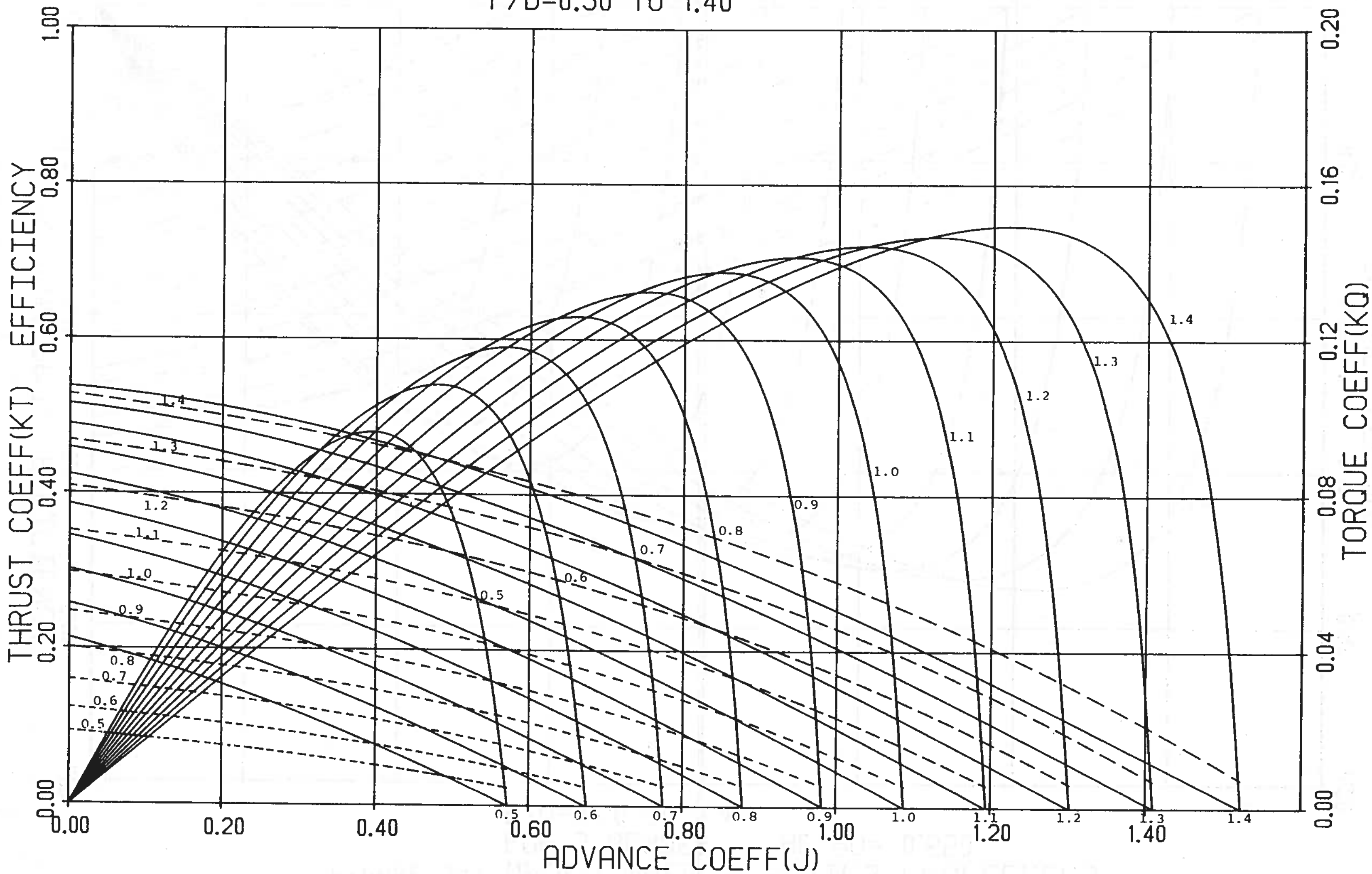


FIGURE 54. WAGENINGEN B-SERIES PROPELLERS
FOR 5 BLADES AE/AO= 0.550
P/D=0.50 TO 1.40

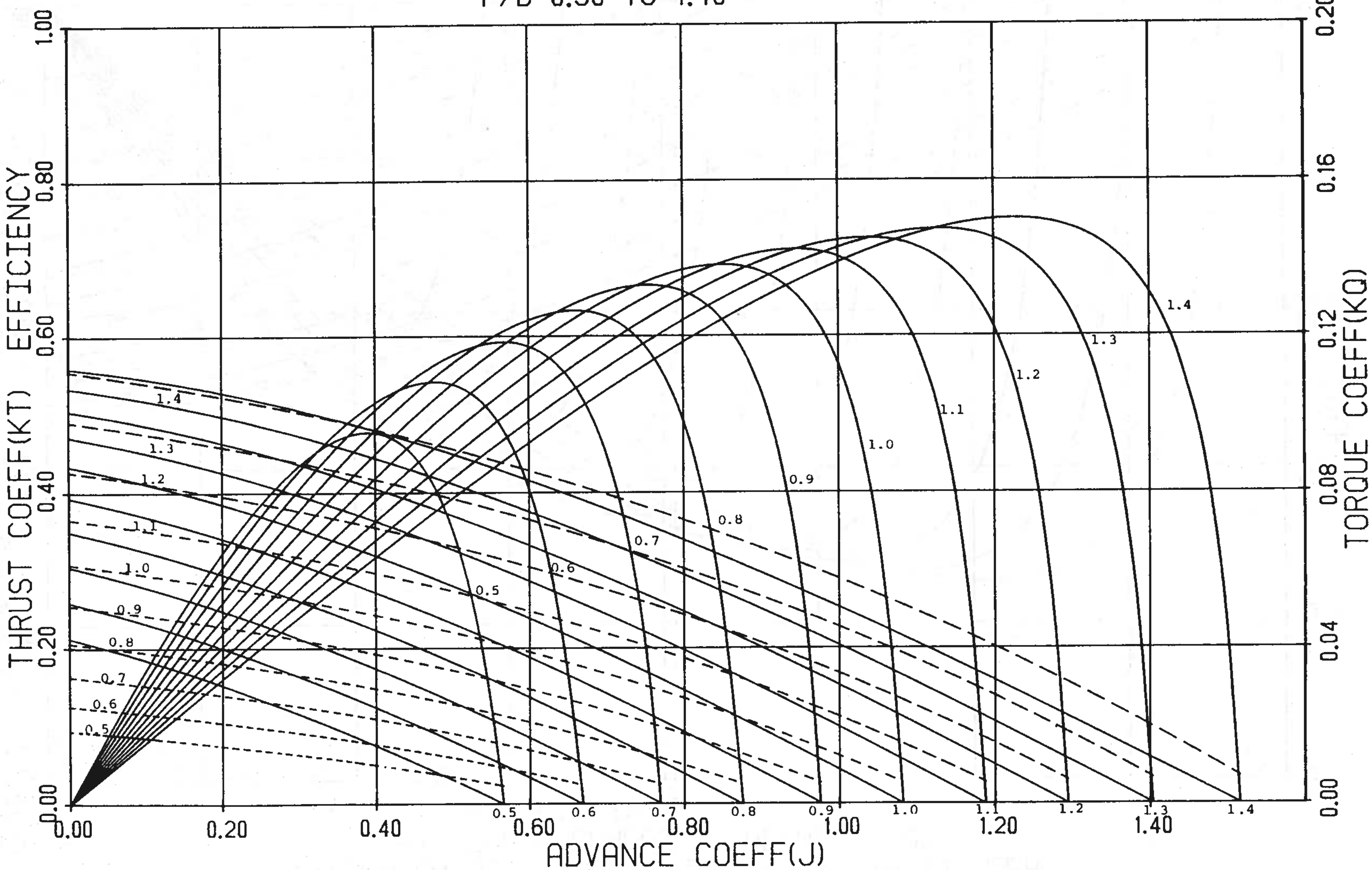


FIGURE 55. WAGENINGEN B-SERIES PROPELLERS
FOR 5 BLADES AE/AO= 0.600
P/D=0.50 TO 1.40

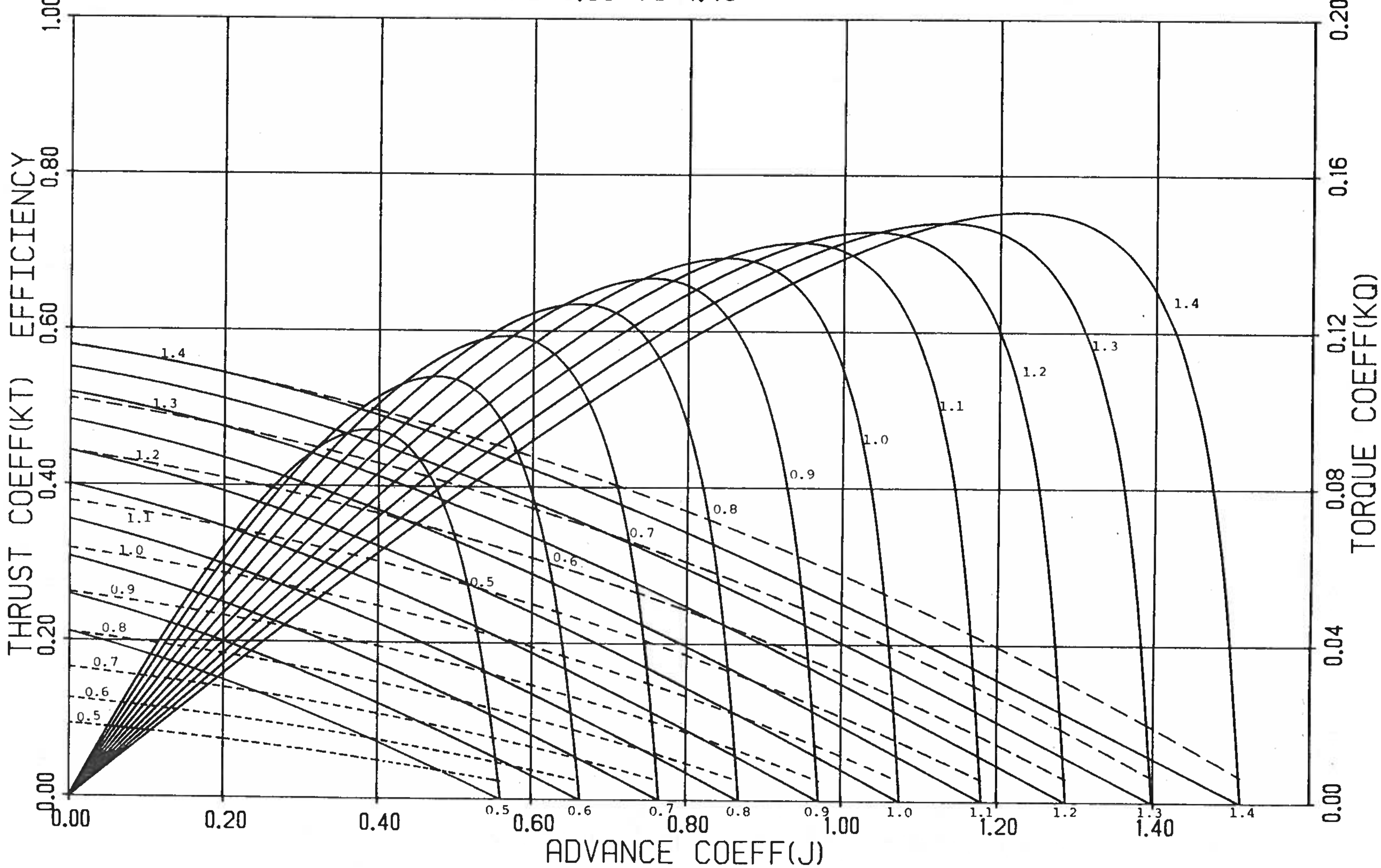


FIGURE 56. WAGENINGEN B-SERIES PROPELLERS
FOR 5 BLADES AE/AO= 0.650
P/D=0.50 TO 1.40

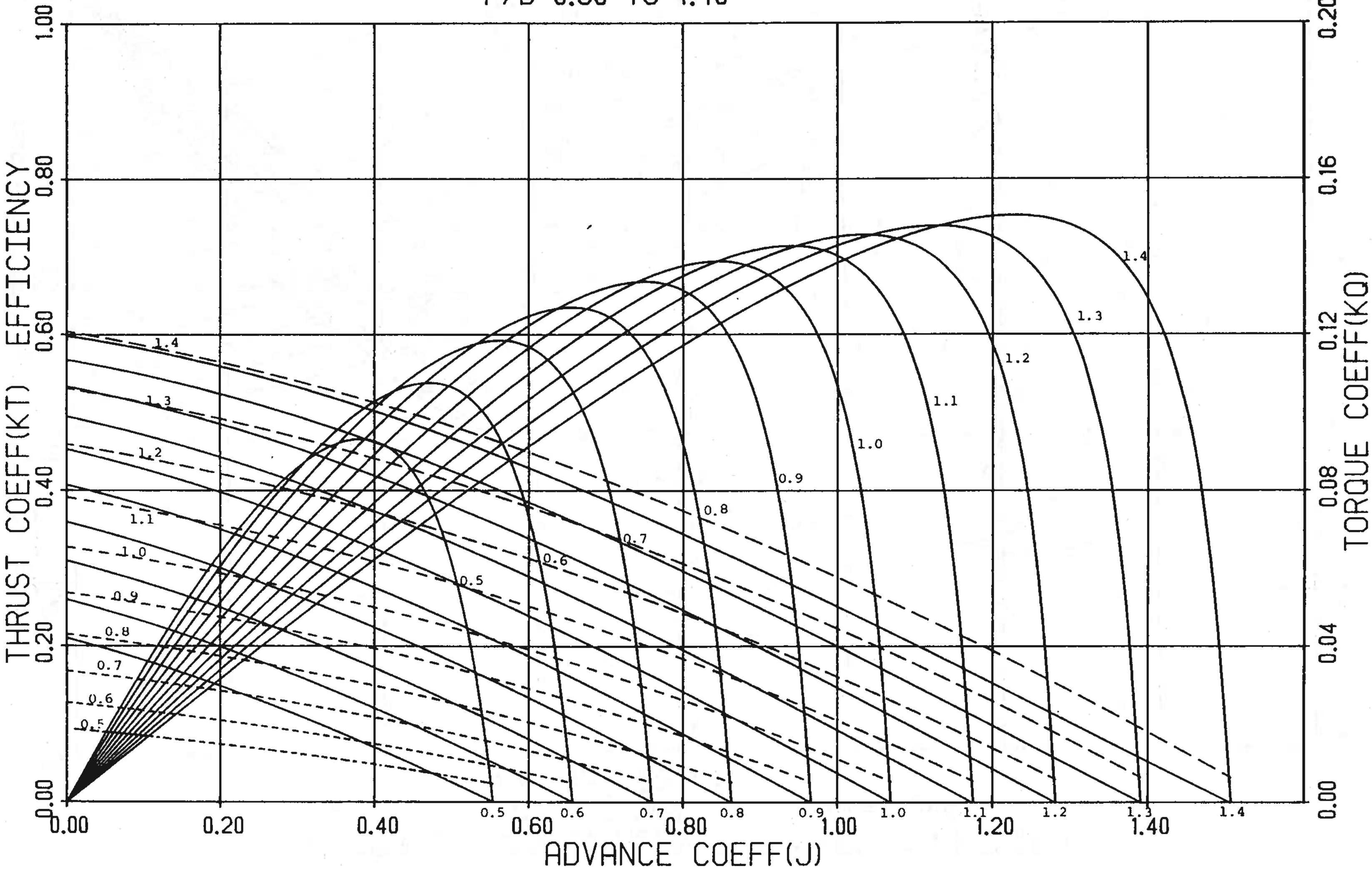


FIGURE 57. WAGENINGEN B-SERIES PROPELLERS
FOR 5 BLADES AE/AO= 0.700
P/D=0.50 TO 1.40

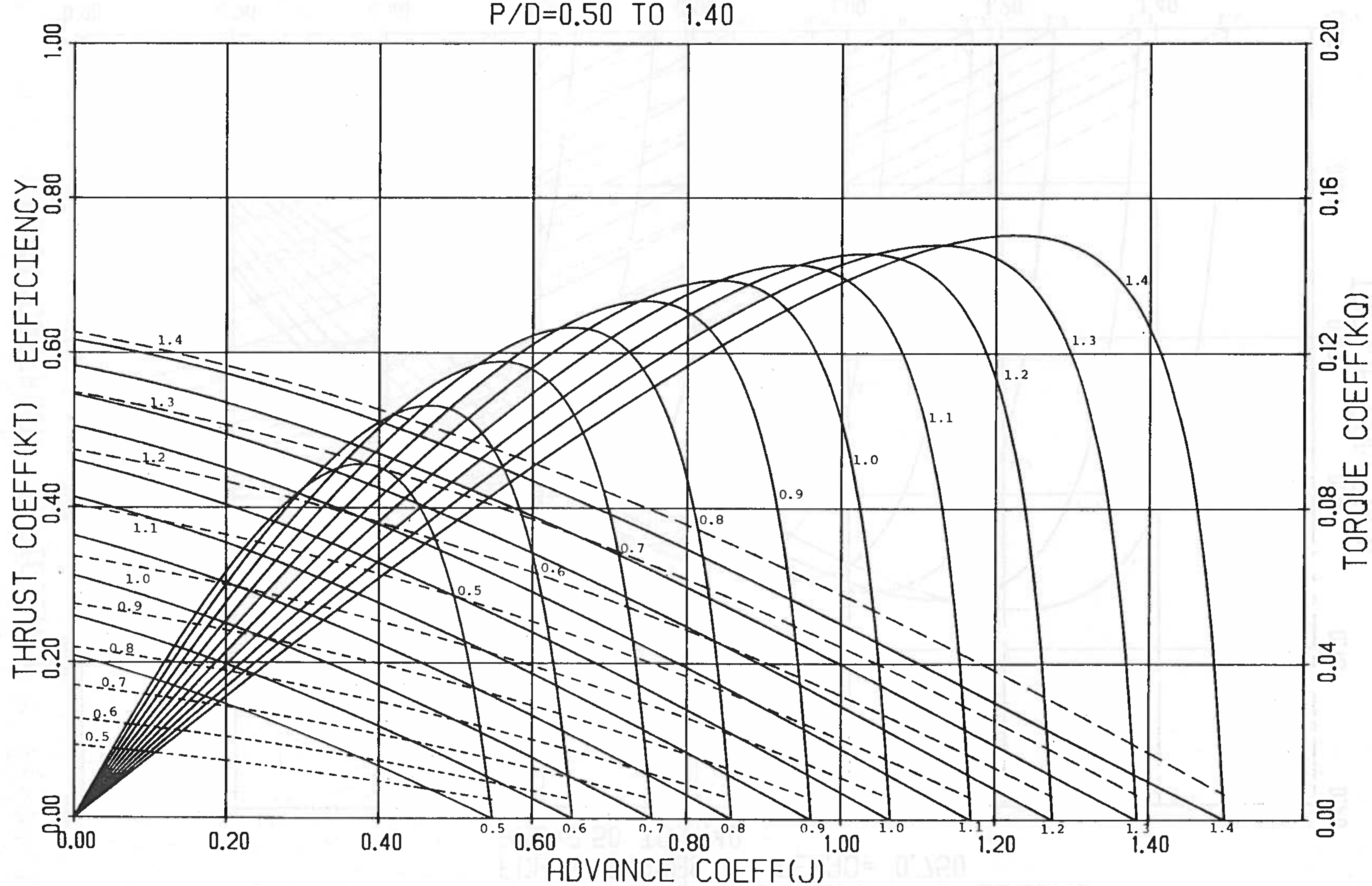


FIGURE 58. WAGENINGEN B-SERIES PROPELLERS
FOR 5 BLADES AE/AO= 0.750
P/D=0.50 TO 1.40

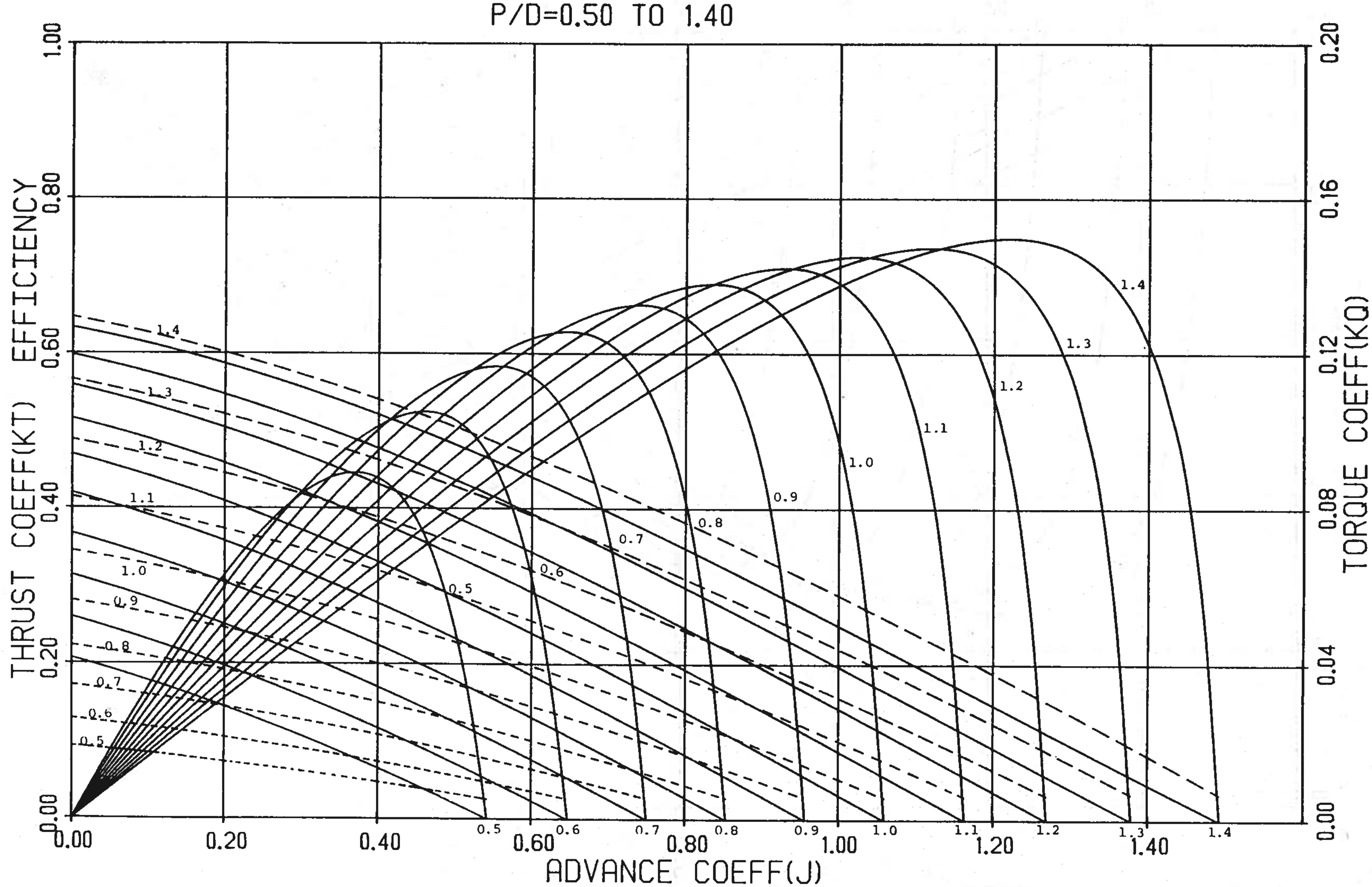


FIGURE 59. WAGENINGEN B-SERIES PROPELLERS
FOR 5 BLADES AE/AO= 0.800
P/D=0.50 TO 1.40

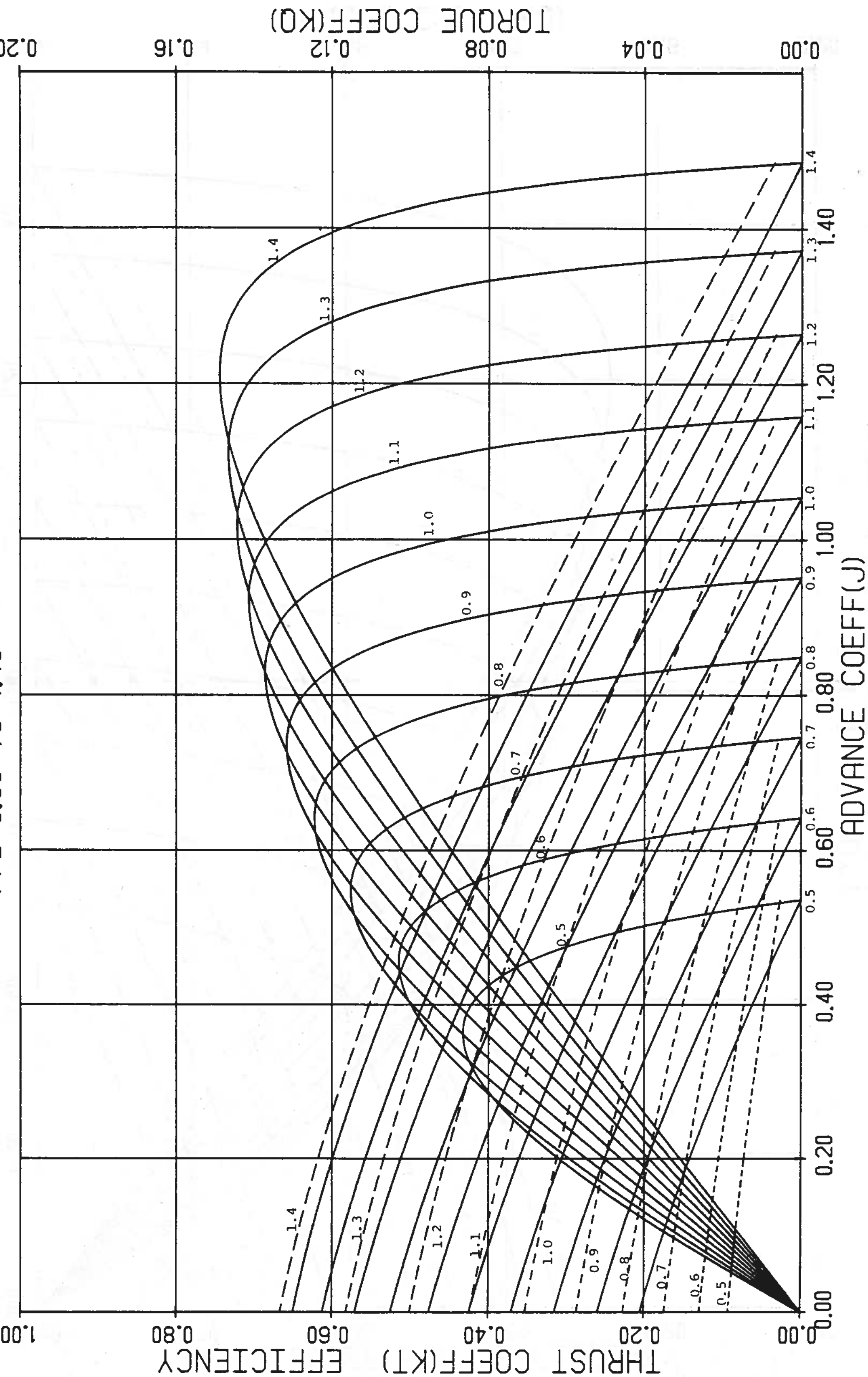


FIGURE 60. WAGENINGEN B-SERIES PROPELLERS
FOR 5 BLADES AE/AO= 0.850
P/D=0.50 TO 1.40

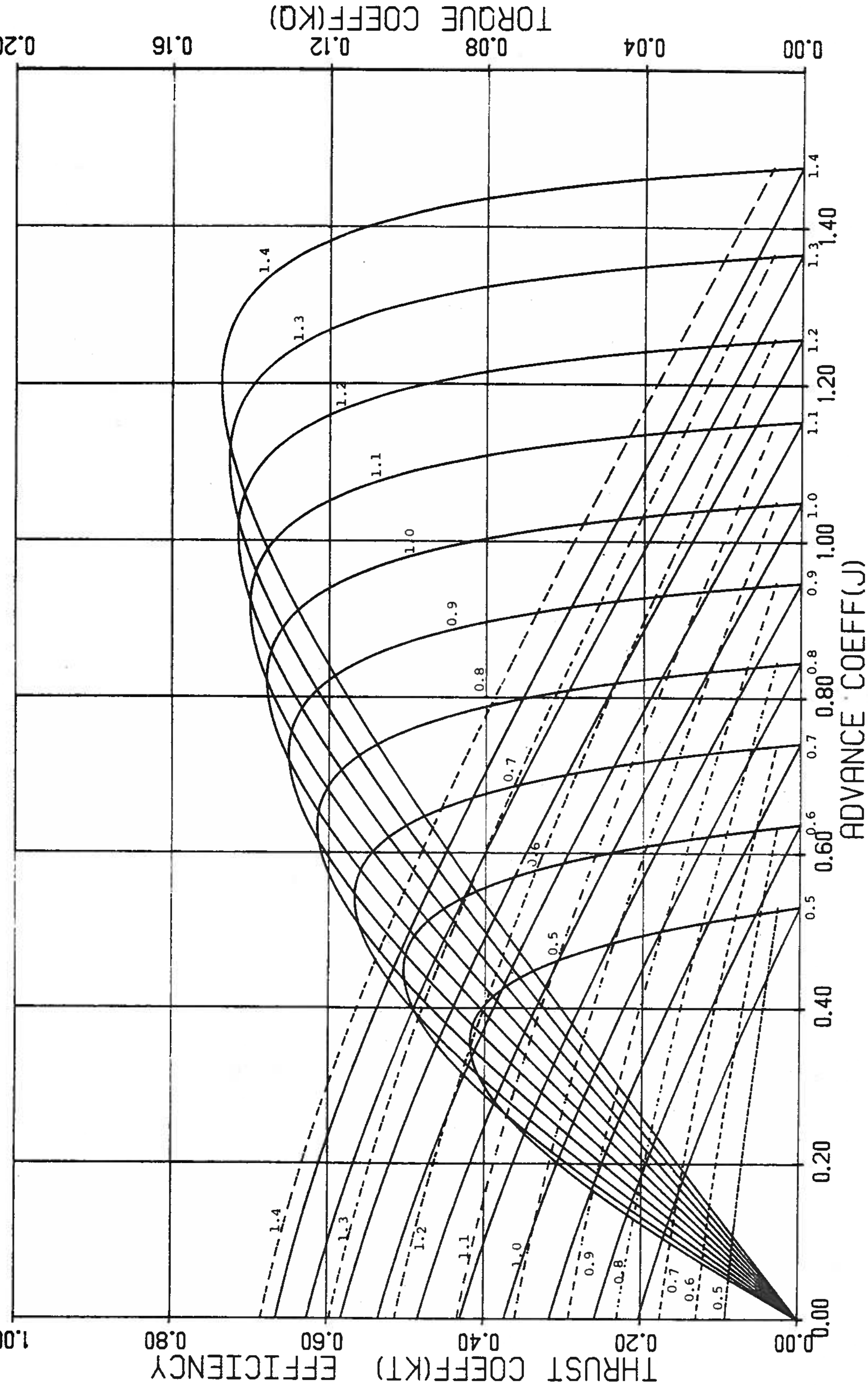


FIGURE 61. WAGENINGEN B-SERIES PROPELLERS
FOR 5 BLADES AE/AO= 0.900
P/D=0.50 TO 1.40

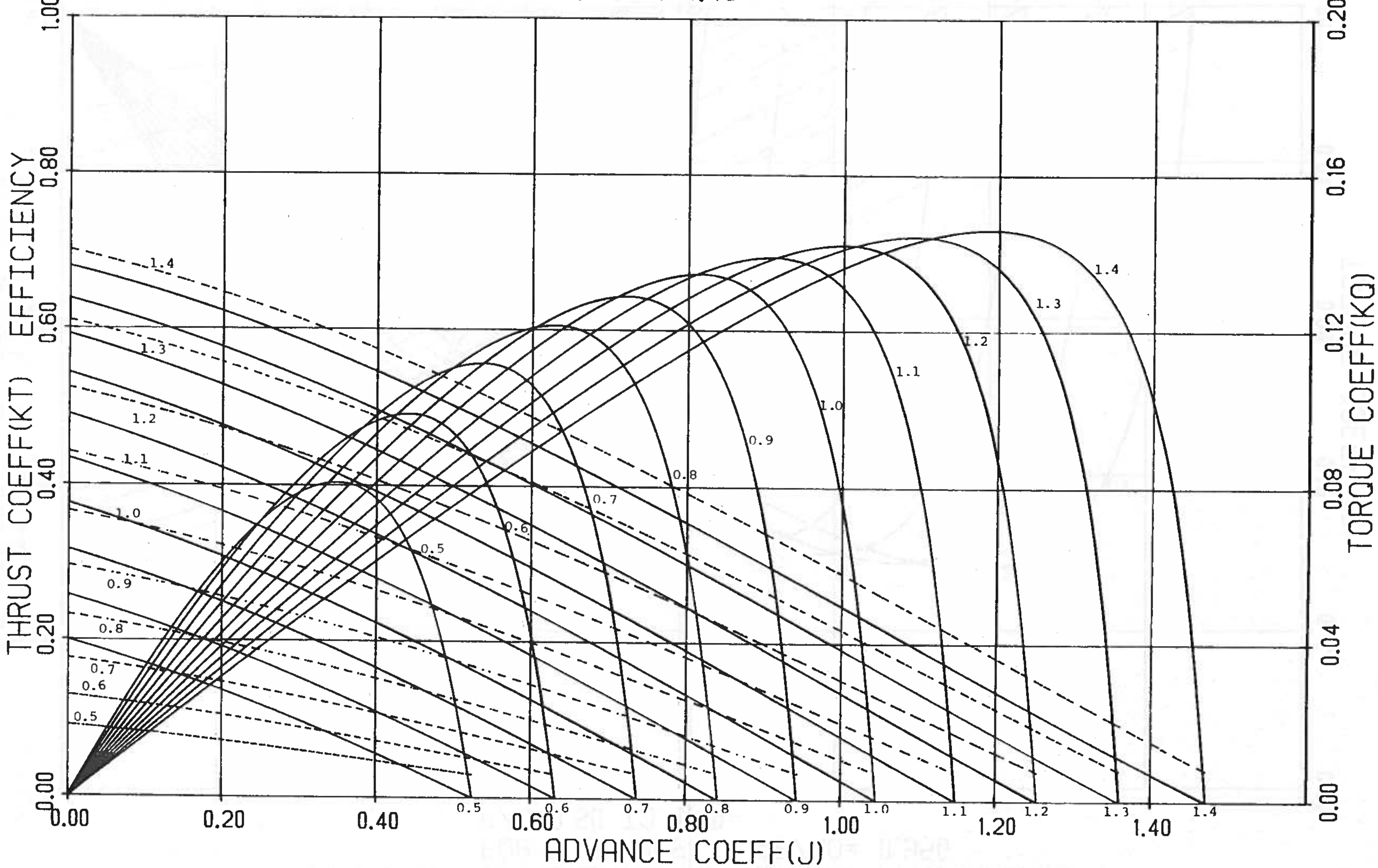


FIGURE 62. WAGENINGEN B-SERIES PROPELLERS
FOR 5 BLADES AE/AO= 0.950
P/D=0.50 TO 1.40

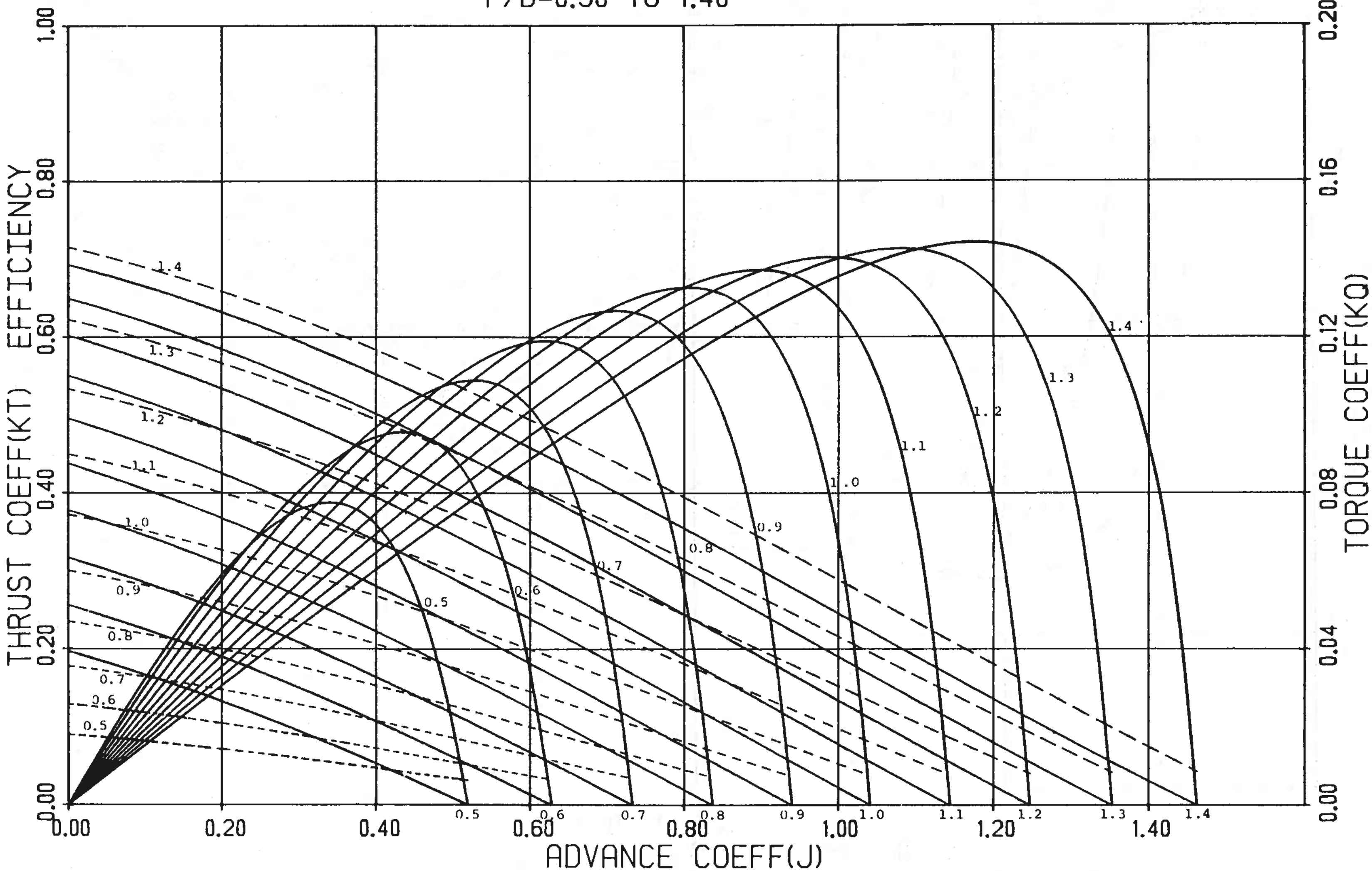


FIGURE 63. WAGENINGEN B-SERIES PROPELLERS
FOR 5 BLADES AE/AO= 1.000
P/D=0.50 TO 1.40

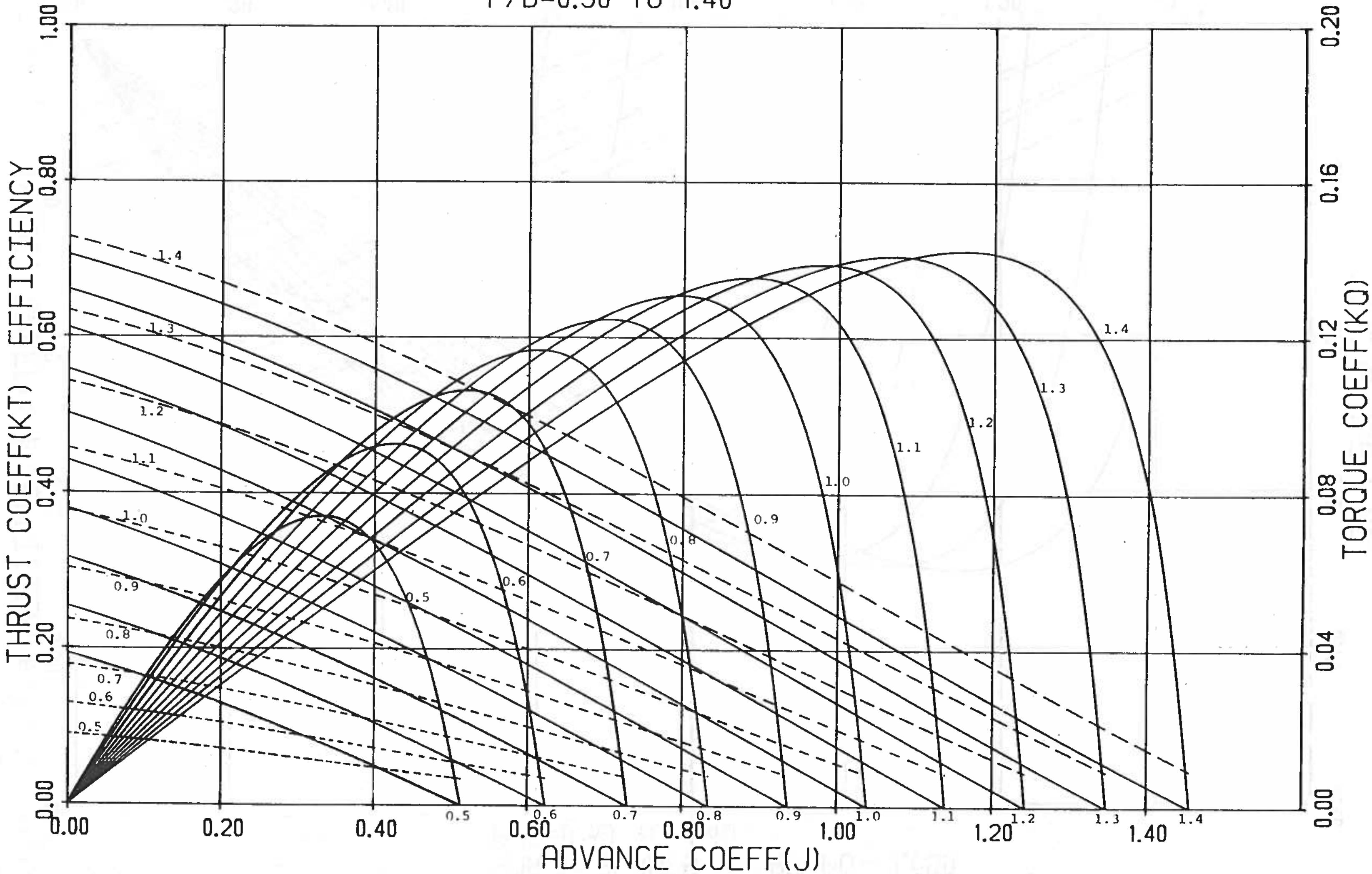


FIGURE 64. WAGENINGEN B-SERIES PROPELLERS
FOR 5 BLADES AE/AO= 1.050
P/D=0.50 TO 1.40

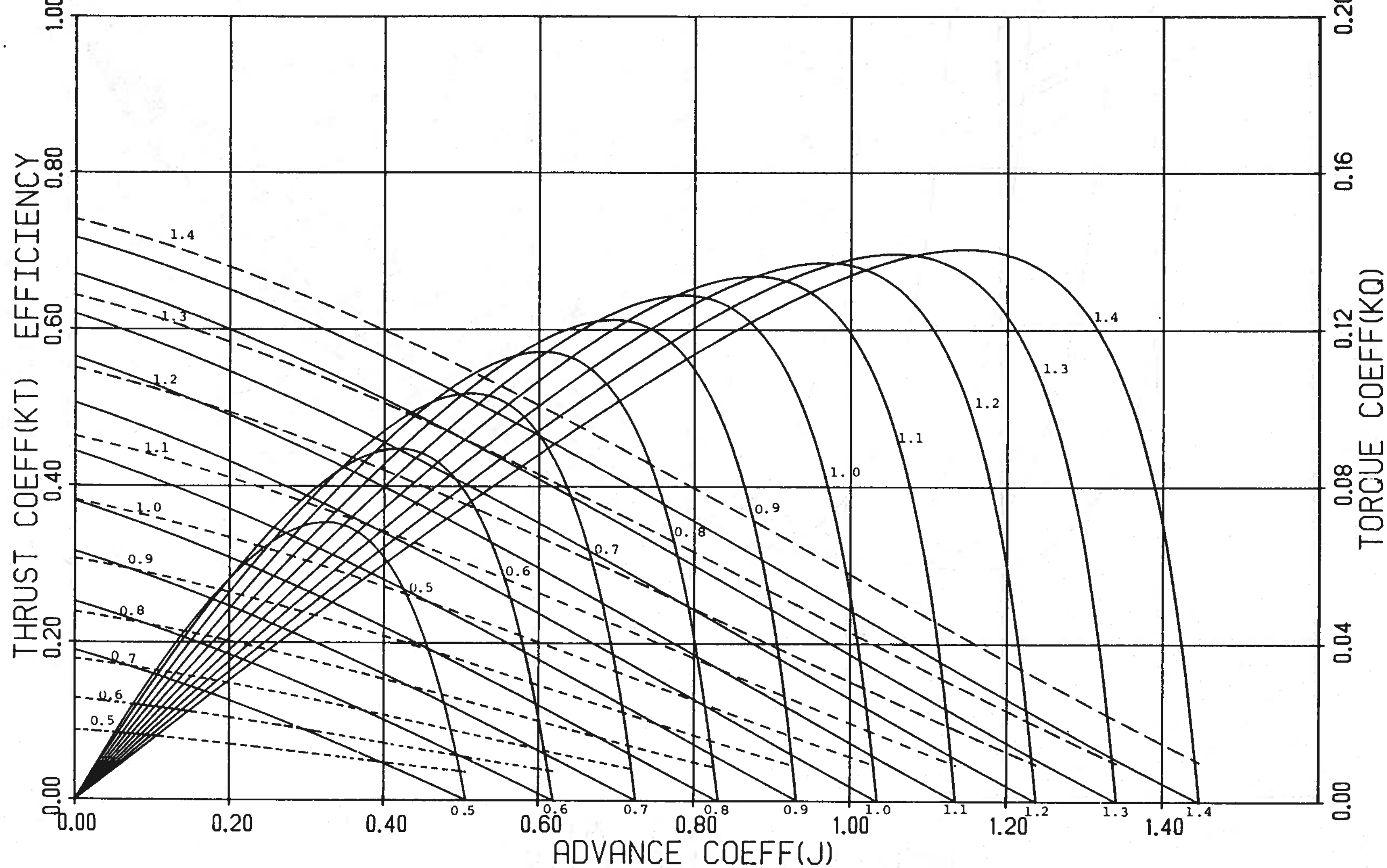


FIGURE 65. WAGENINGEN B-SERIES PROPELLERS
FOR 6 BLADES AE/AO= 0.300
P/D=0.50 TO 1.40

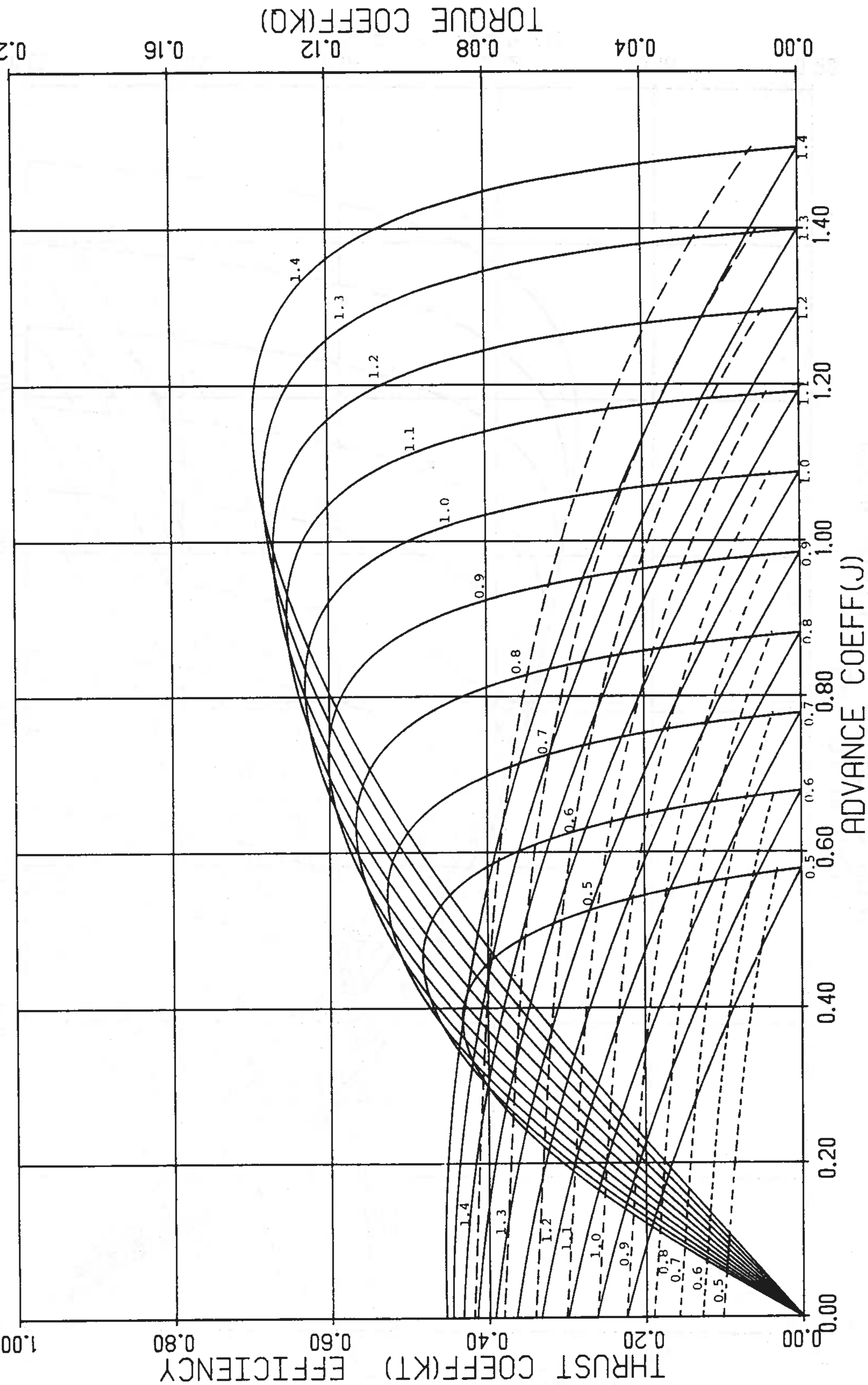
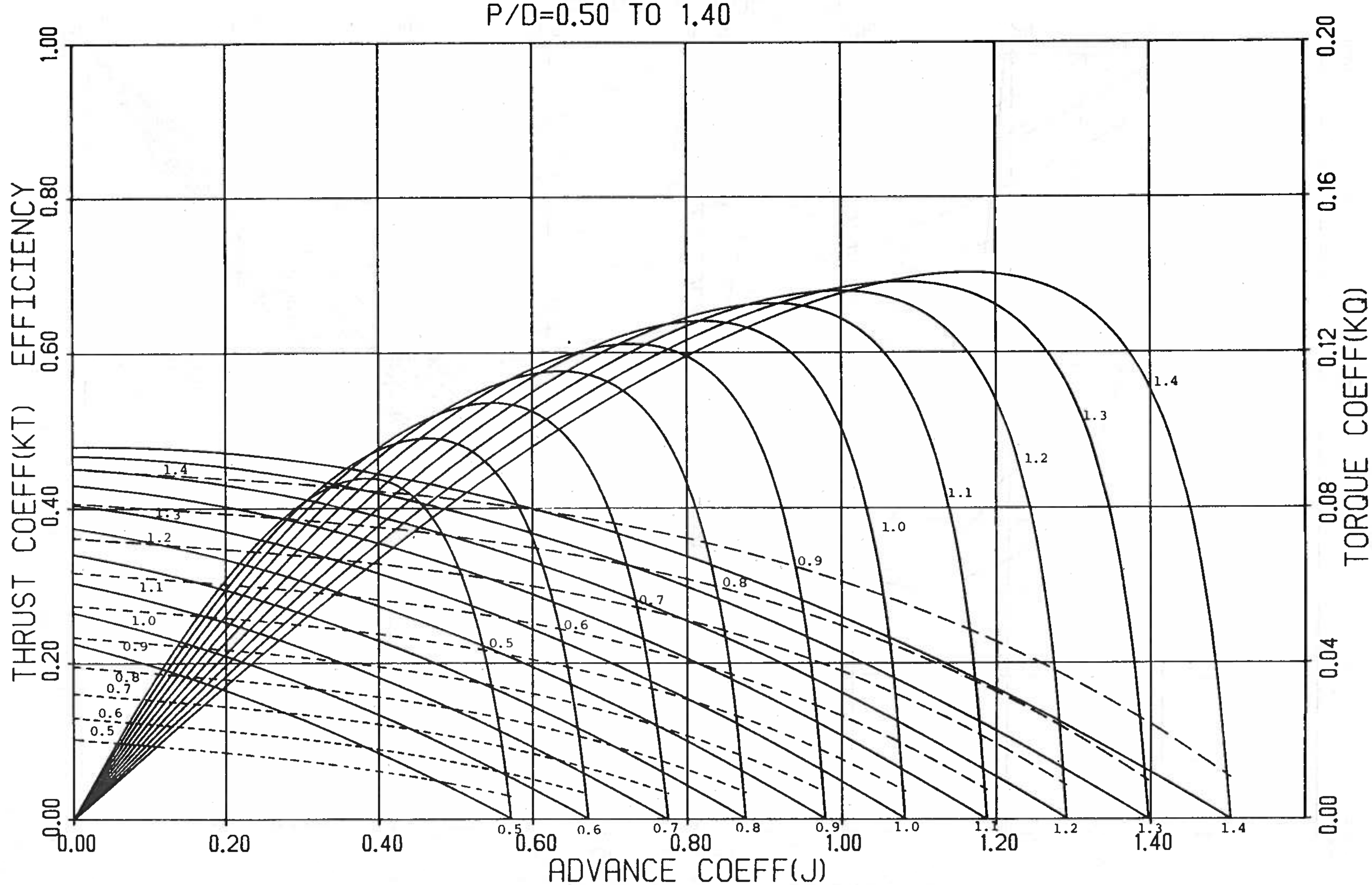


FIGURE 66. WAGENINGEN B-SERIES PROPELLERS
FOR 6 BLADES AE/AO= 0.350
P/D=0.50 TO 1.40



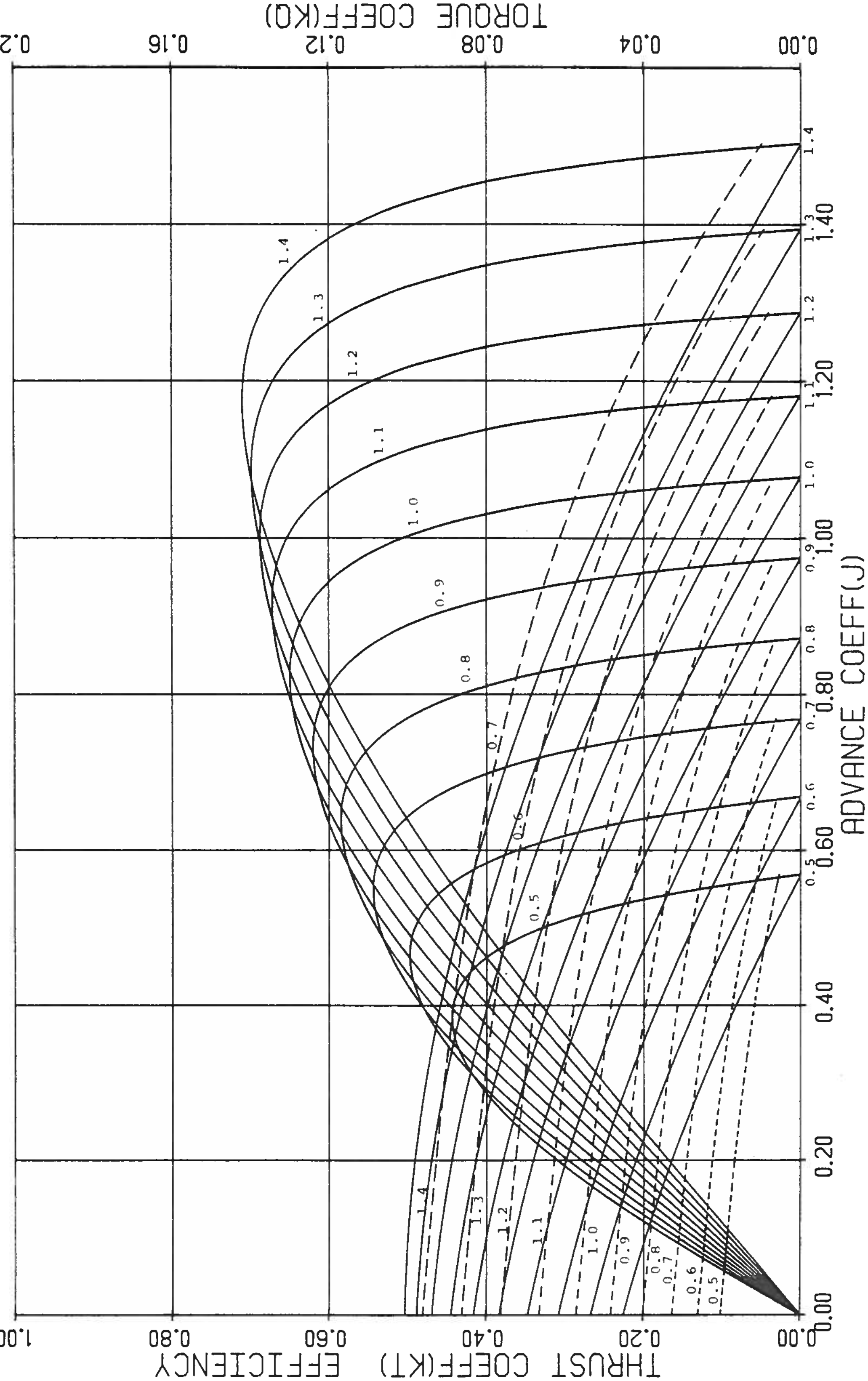
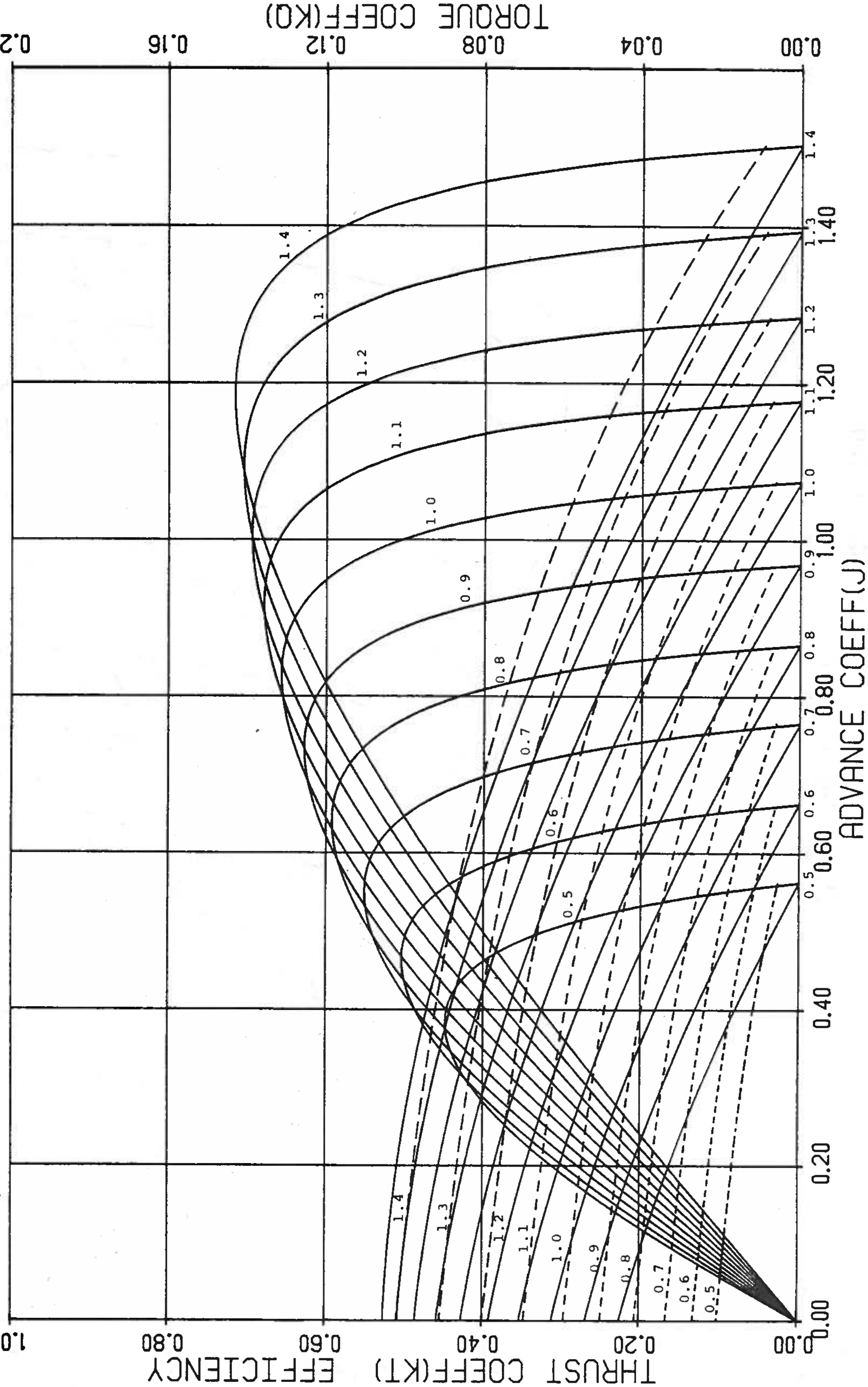


FIGURE 67. WAGENINGEN B-SERIES PROPELLERS
FOR 6 BLADES AE/AO= 0.400
P/D=0.50 TO 1.40

FIGURE 68. WAGENINGEN B-SERIES PROPELLERS
FOR 6 BLADES AE/AO= 0.450
P/D=0.50 TO 1.40



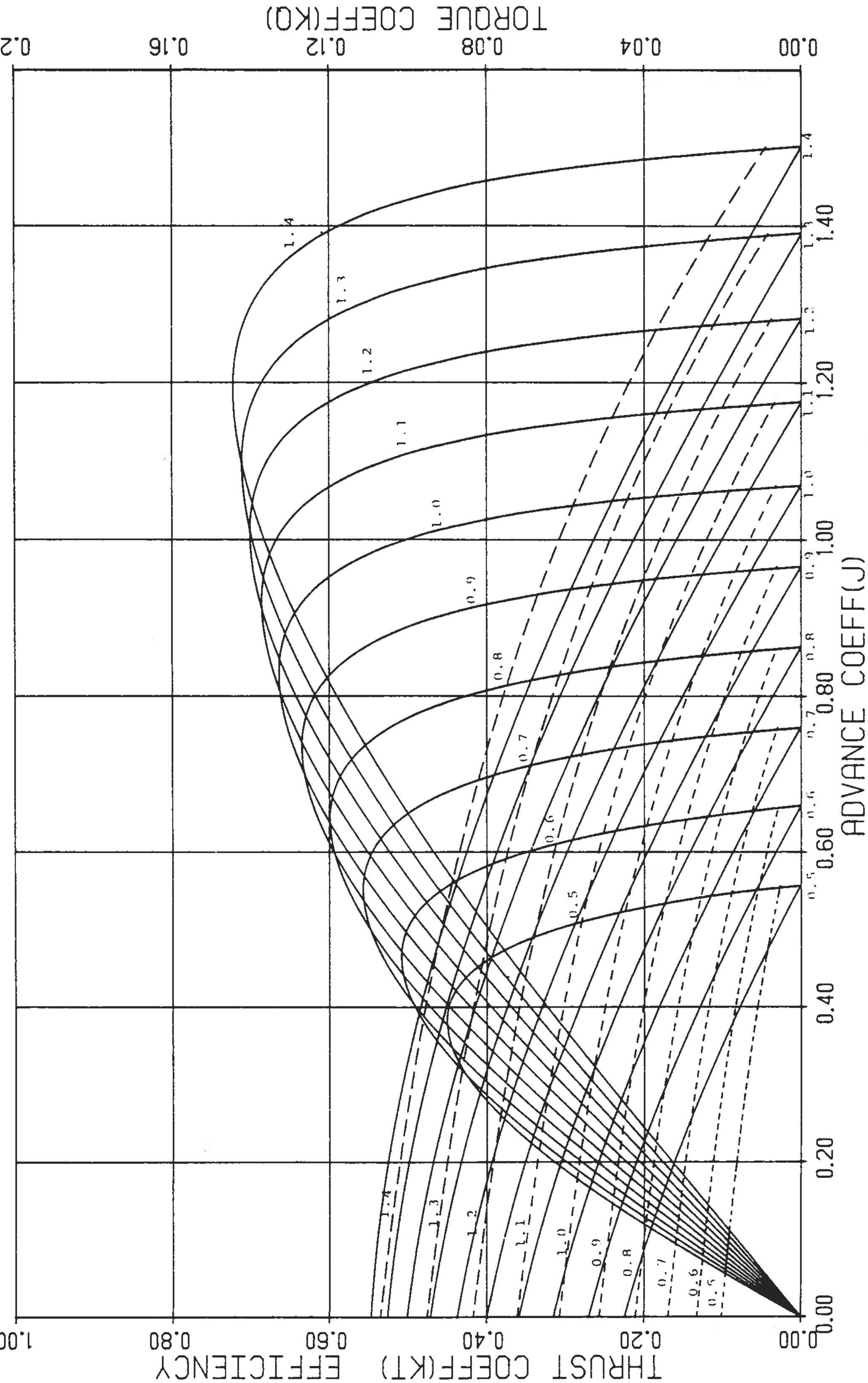


FIGURE 69. WAGENINGEN B-SERIES PROPELLERS
FOR 6 BLADES AE/AO= 0.500
P/D=0.50 TO 1.40

FIGURE 70. WAGENINGEN B-SERIES PROPELLERS
FOR 6 BLADES AE/AO= 0.550
P/D=0.50 TO 1.40

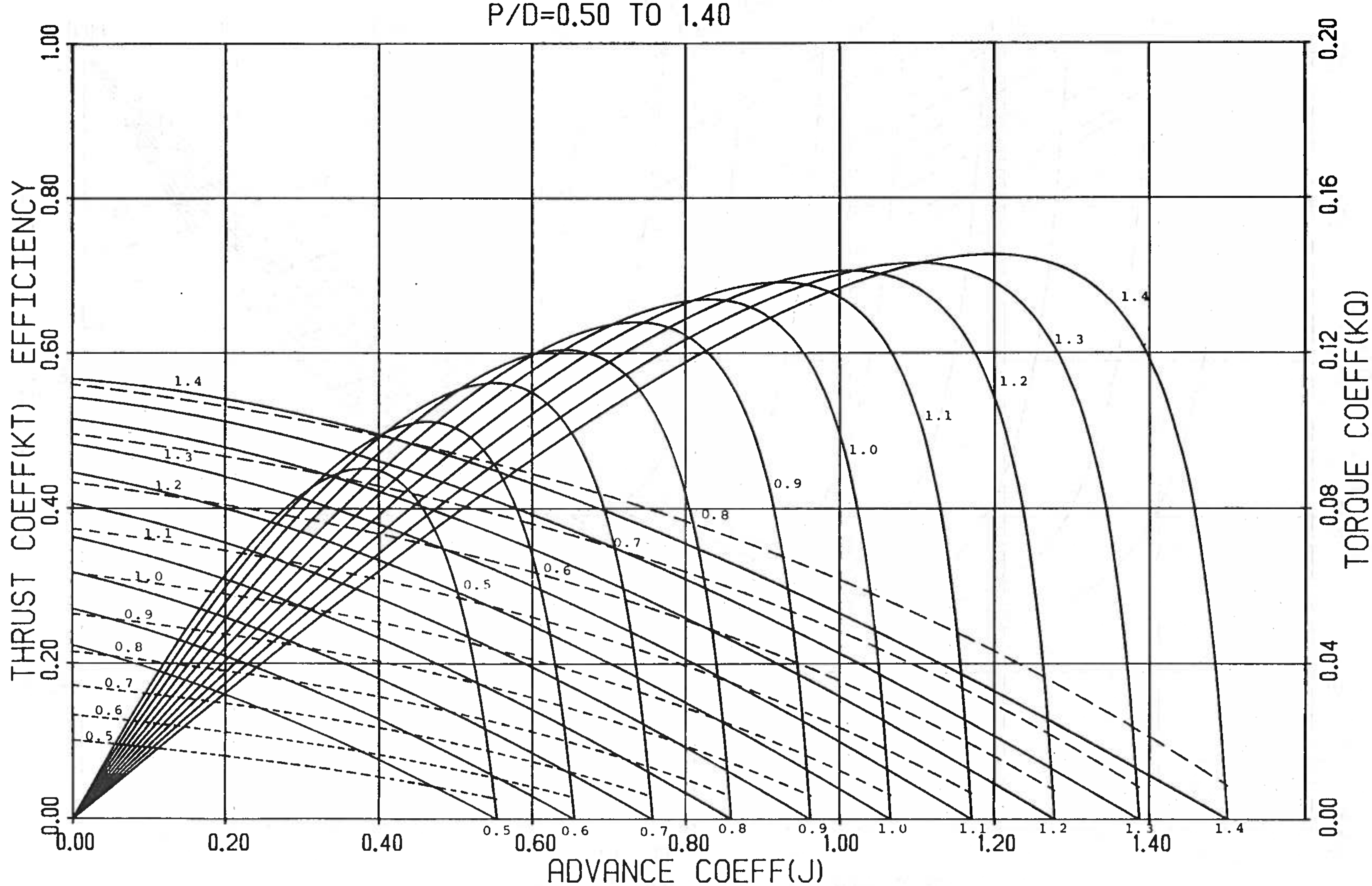


FIGURE 71. WAGENINGEN B-SERIES PROPELLERS
FOR 6 BLADES AE/AO= 0.600
P/D=0.50 TO 1.40

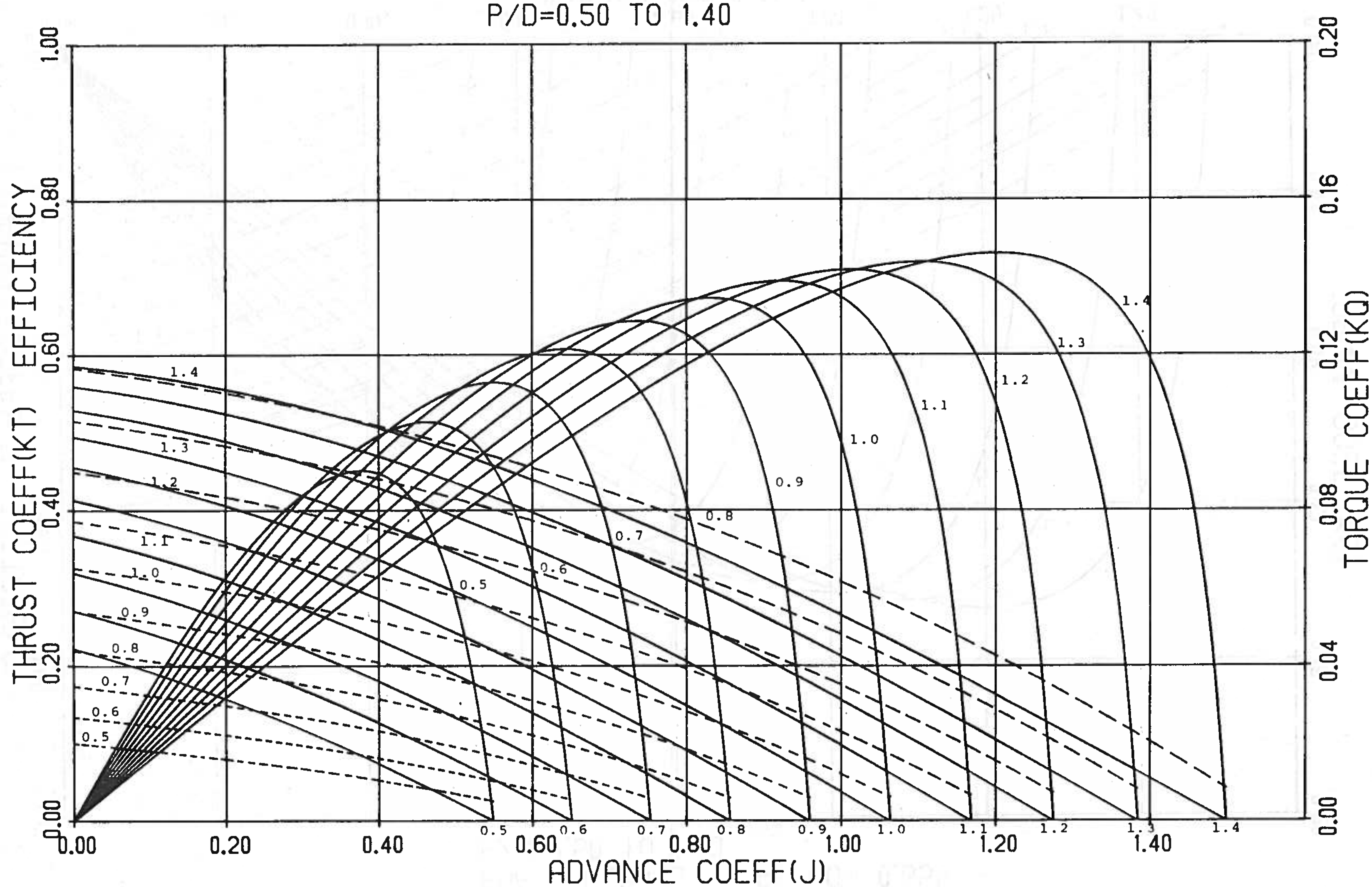


FIGURE 72. WAGENINGEN B-SERIES PROPELLERS
FOR 6 BLADES AE/AO= 0.650
P/D=0.50 TO 1.40

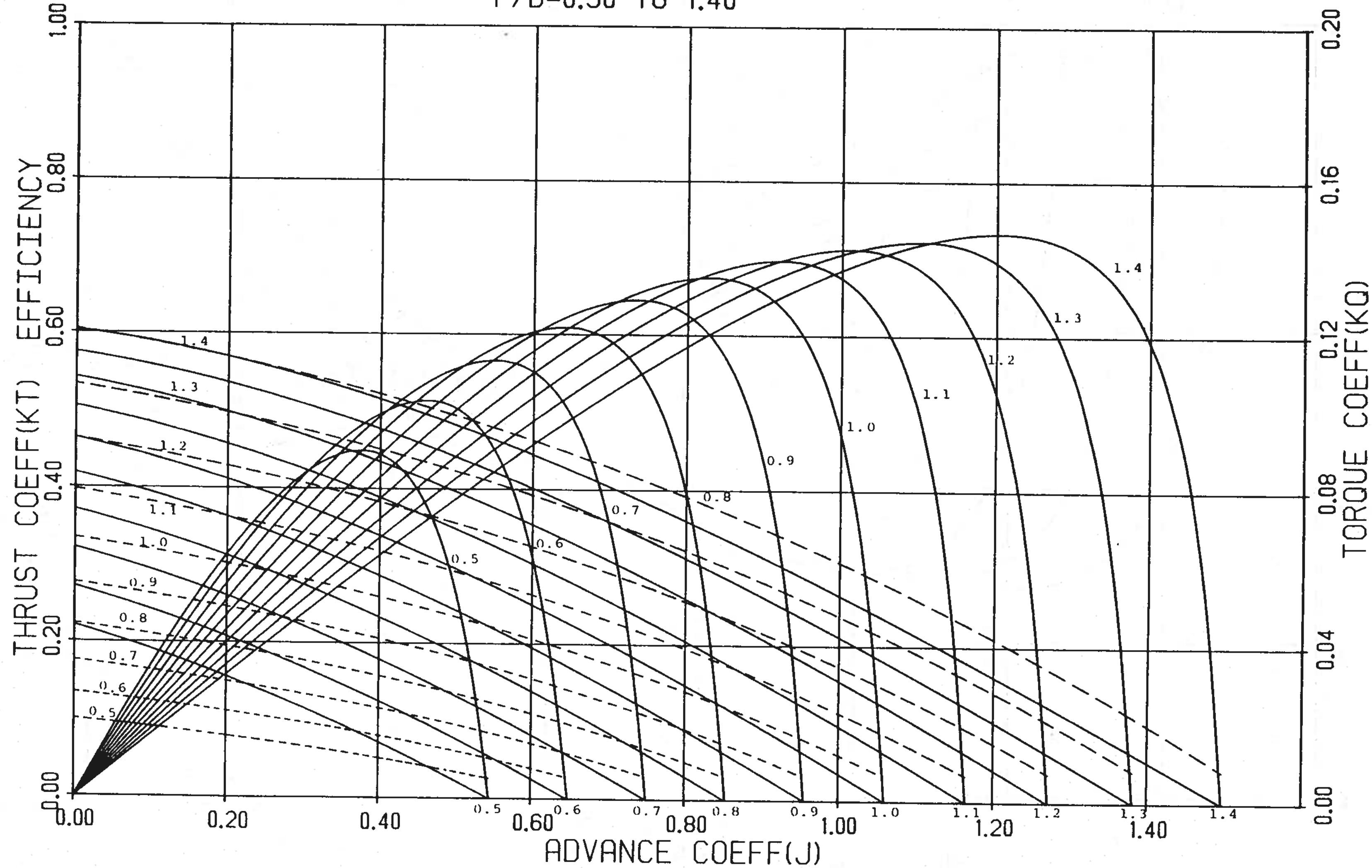


FIGURE 73. WAGENINGEN B-SERIES PROPELLERS
FOR 6 BLADES AE/AO= 0.700
P/D=0.50 TO 1.40

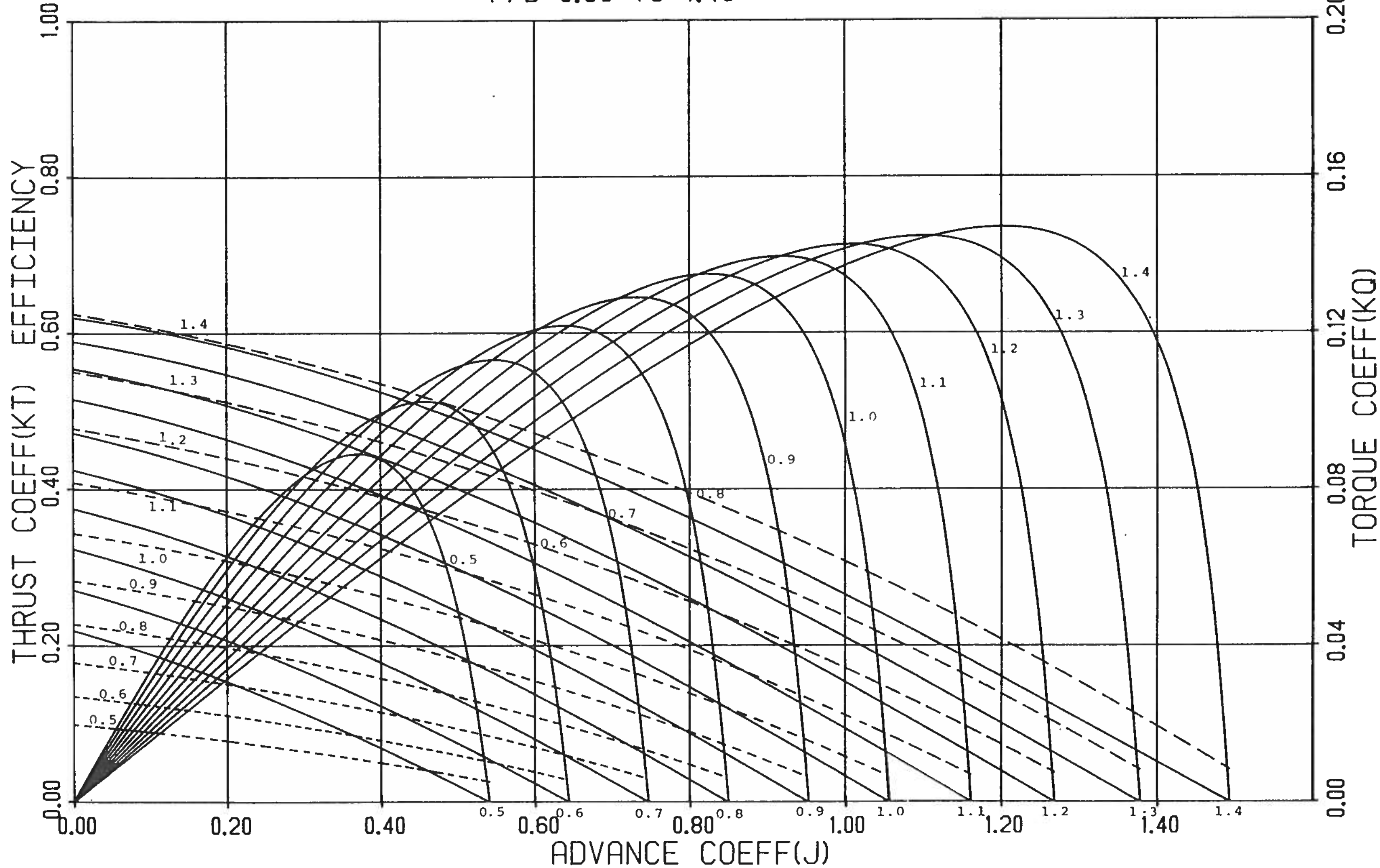


FIGURE 74. WAGENINGEN B-SERIES PROPELLERS
FOR 6 BLADES AE/AO= 0.750
P/D=0.50 TO 1.40

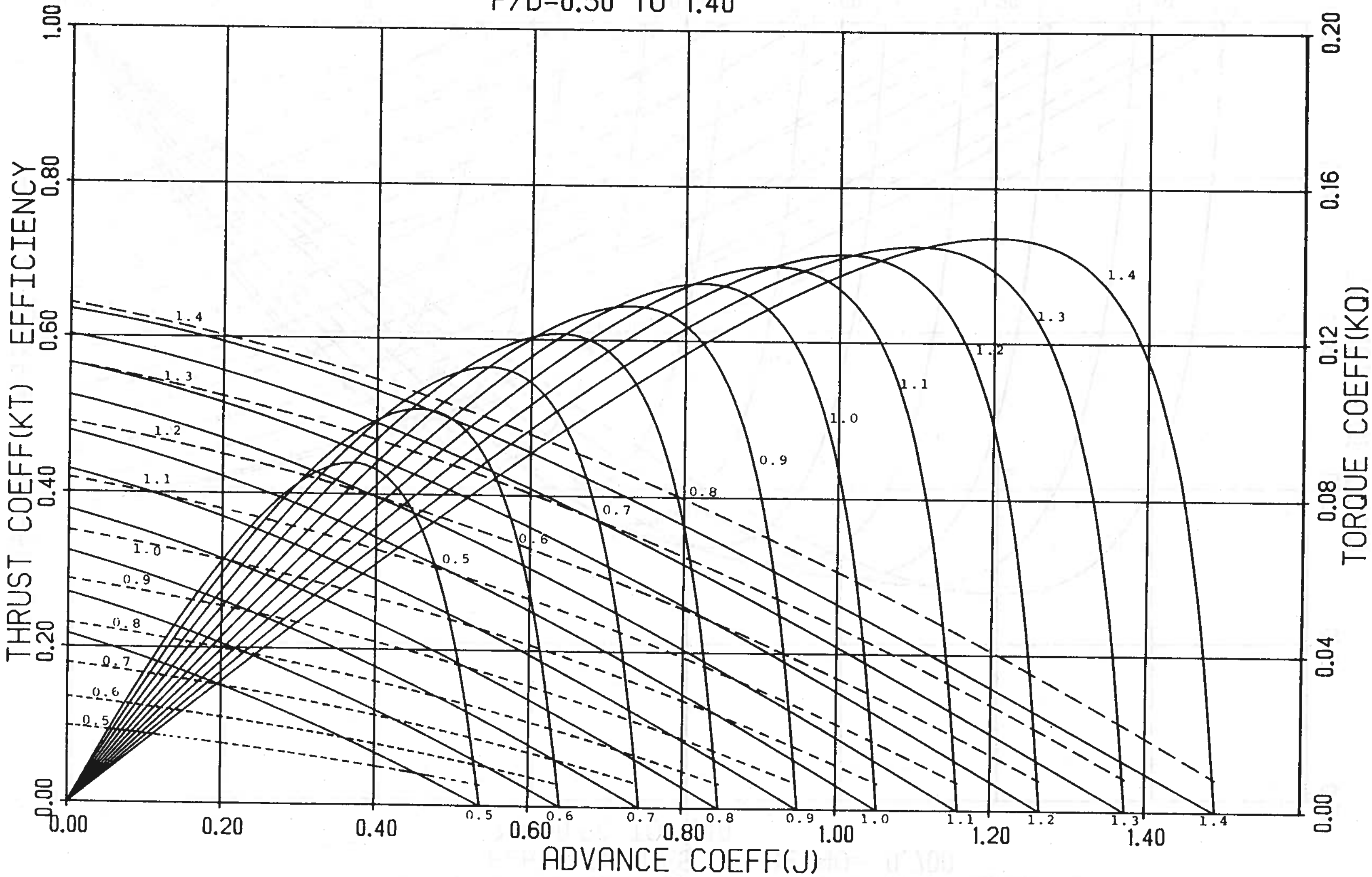


FIGURE 75. WAGENINGEN B-SERIES PROPELLERS
FOR 6 BLADES AE/AO= 0.800
P/D=0.50 TO 1.40

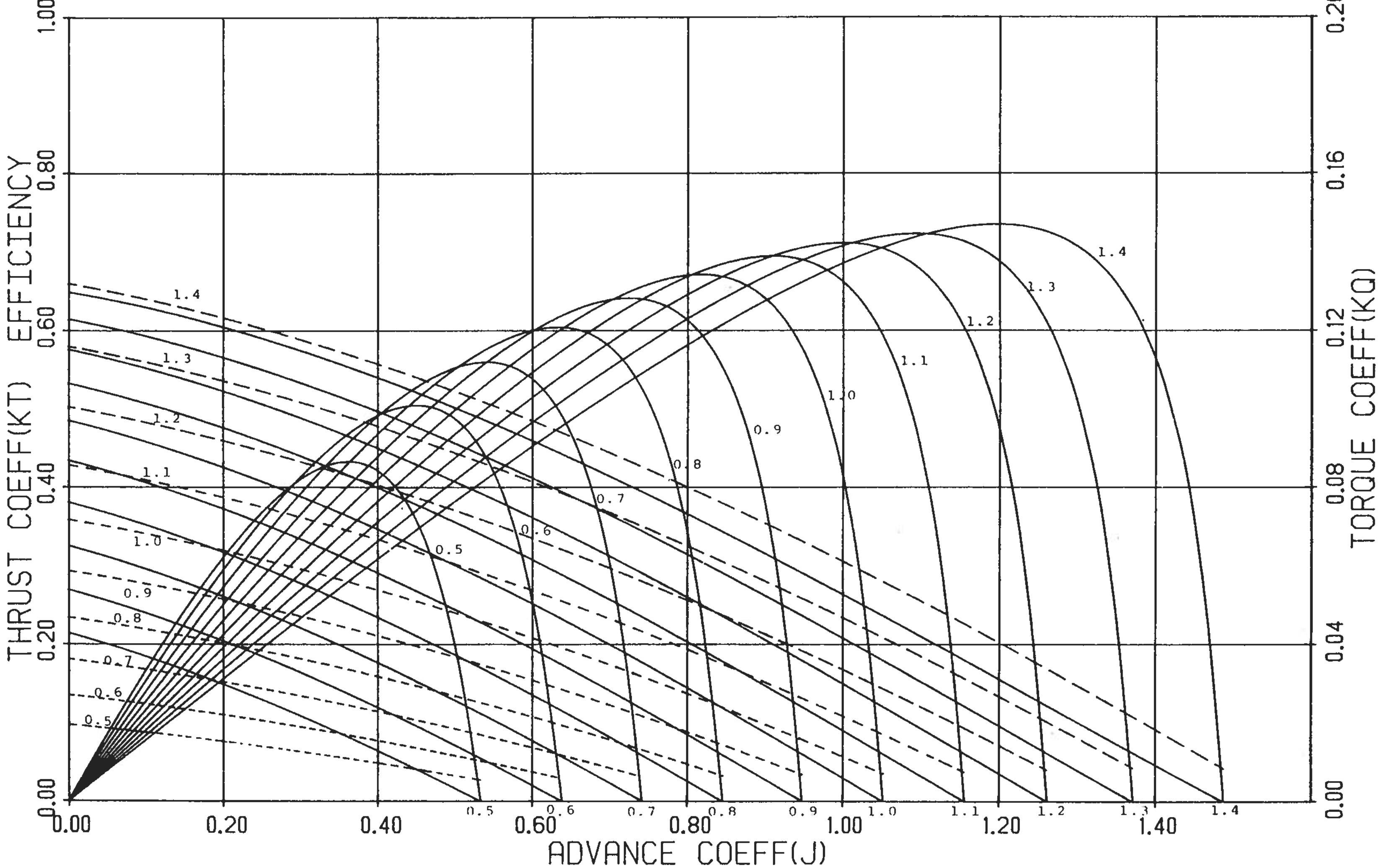


FIGURE 76. WAGENINGEN B-SERIES PROPELLERS
FOR 6 BLADES AE/AO= 0.850
P/D=0.50 TO 1.40

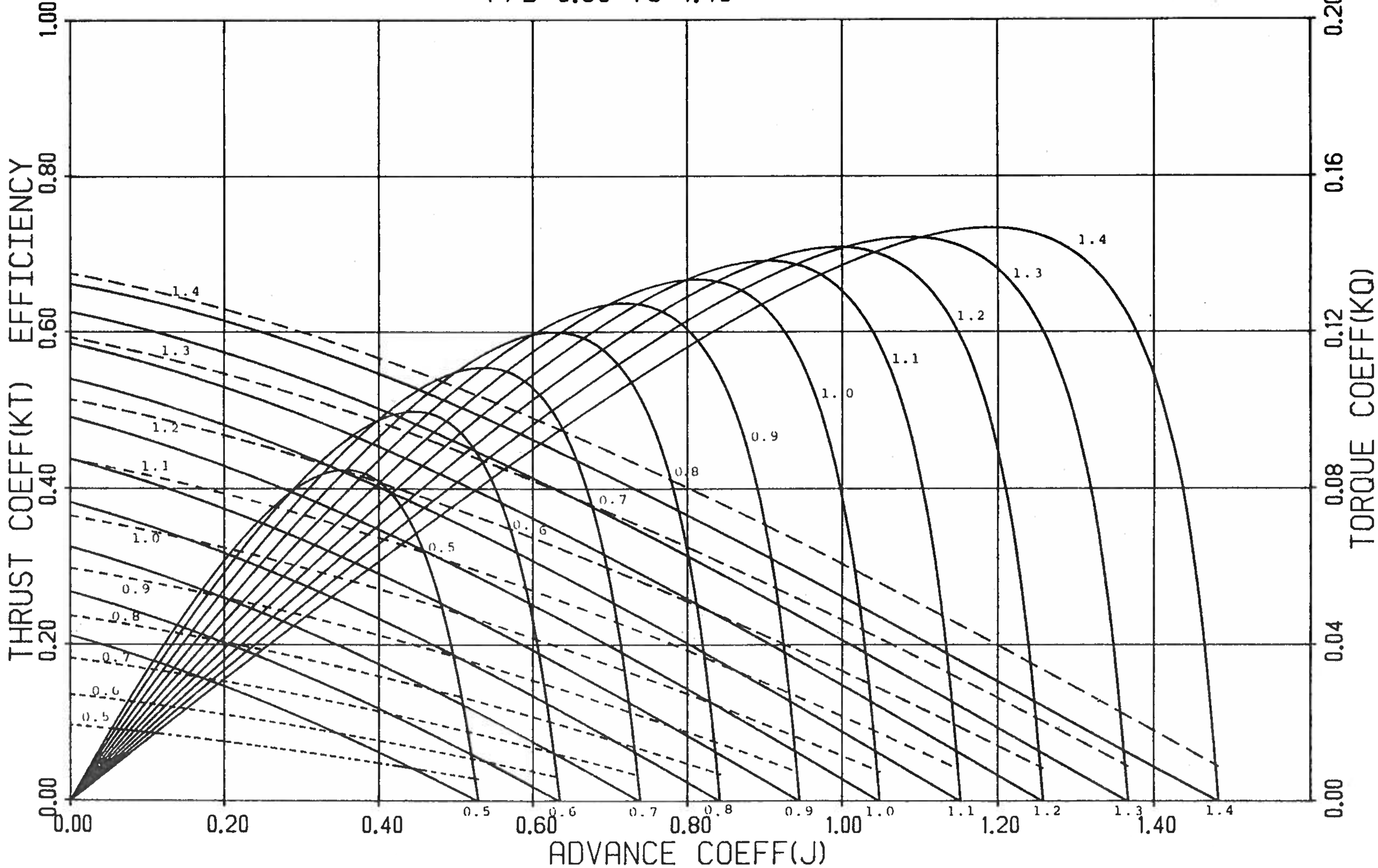


FIGURE 77. WAGENINGEN B-SERIES PROPELLERS
FOR 6 BLADES AE/AO= 0.900
P/D=0.50 TO 1.40

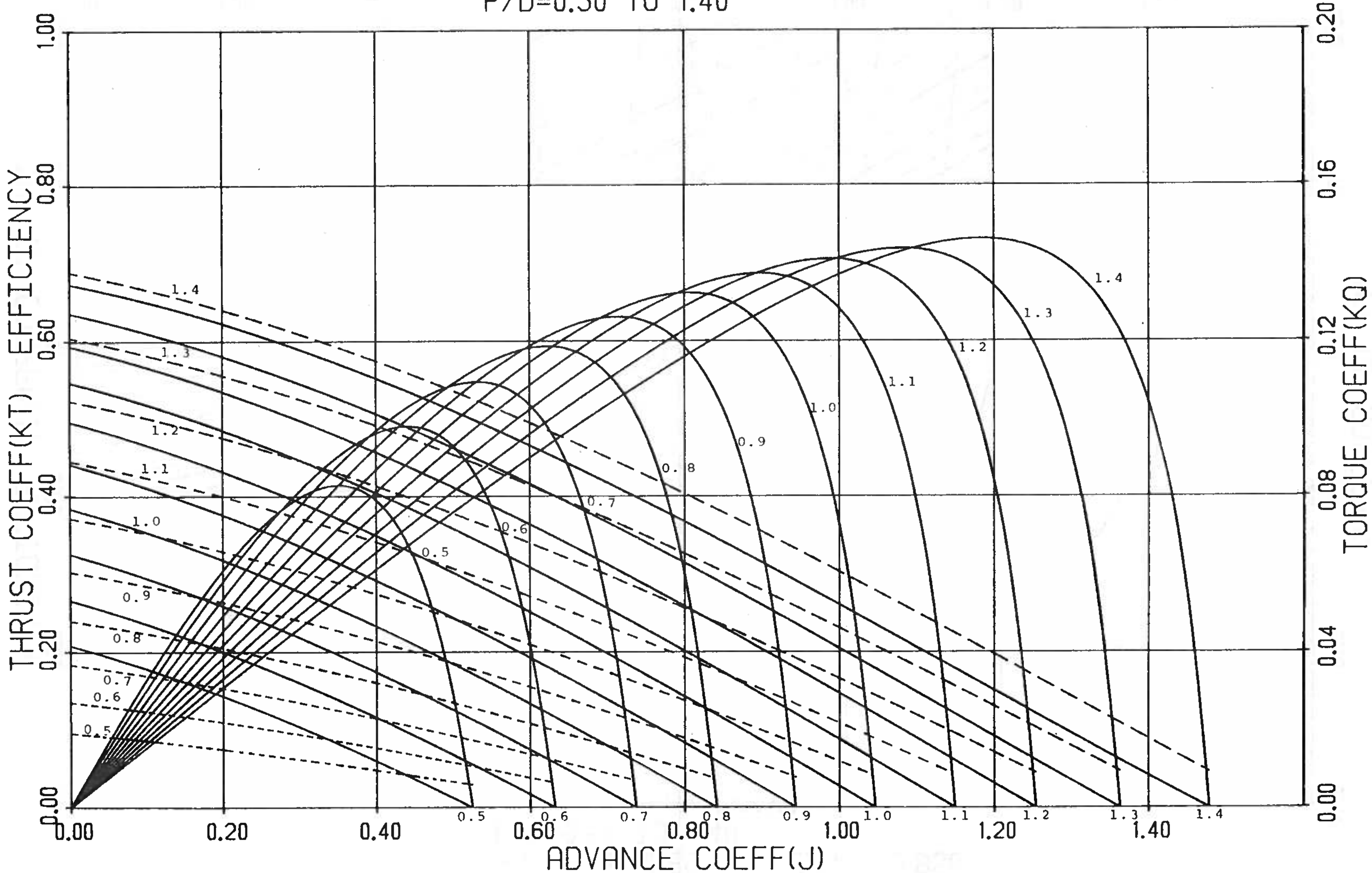


FIGURE 78. WAGENINGEN B-SERIES PROPELLERS
FOR 6 BLADES AE/AO= 0.950
P/D=0.50 TO 1.40

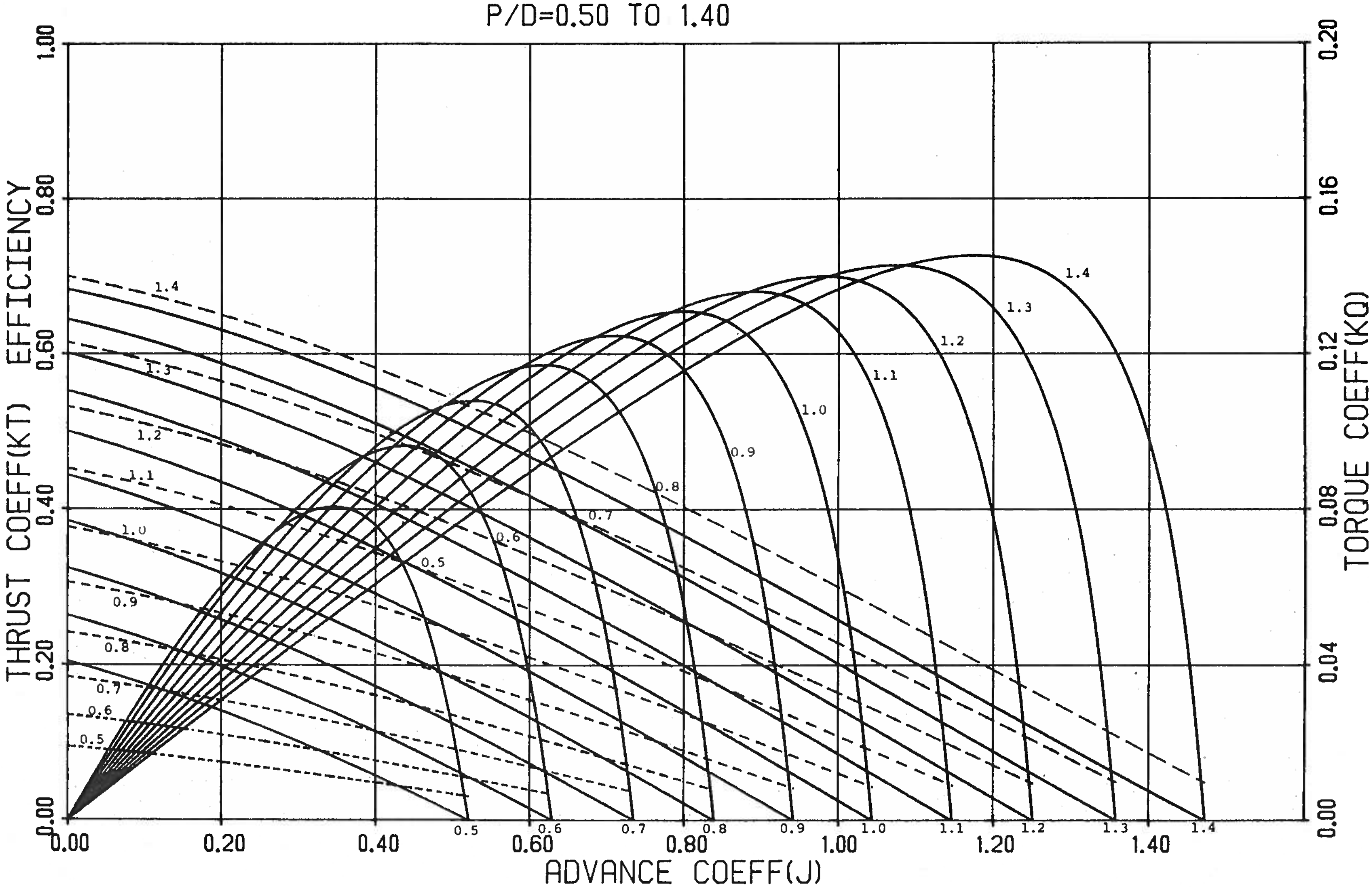


FIGURE 79. WAGENINGEN B-SERIES PROPELLERS
FOR 6 BLADES AE/AO= 1.000
P/D=0.50 TO 1.40

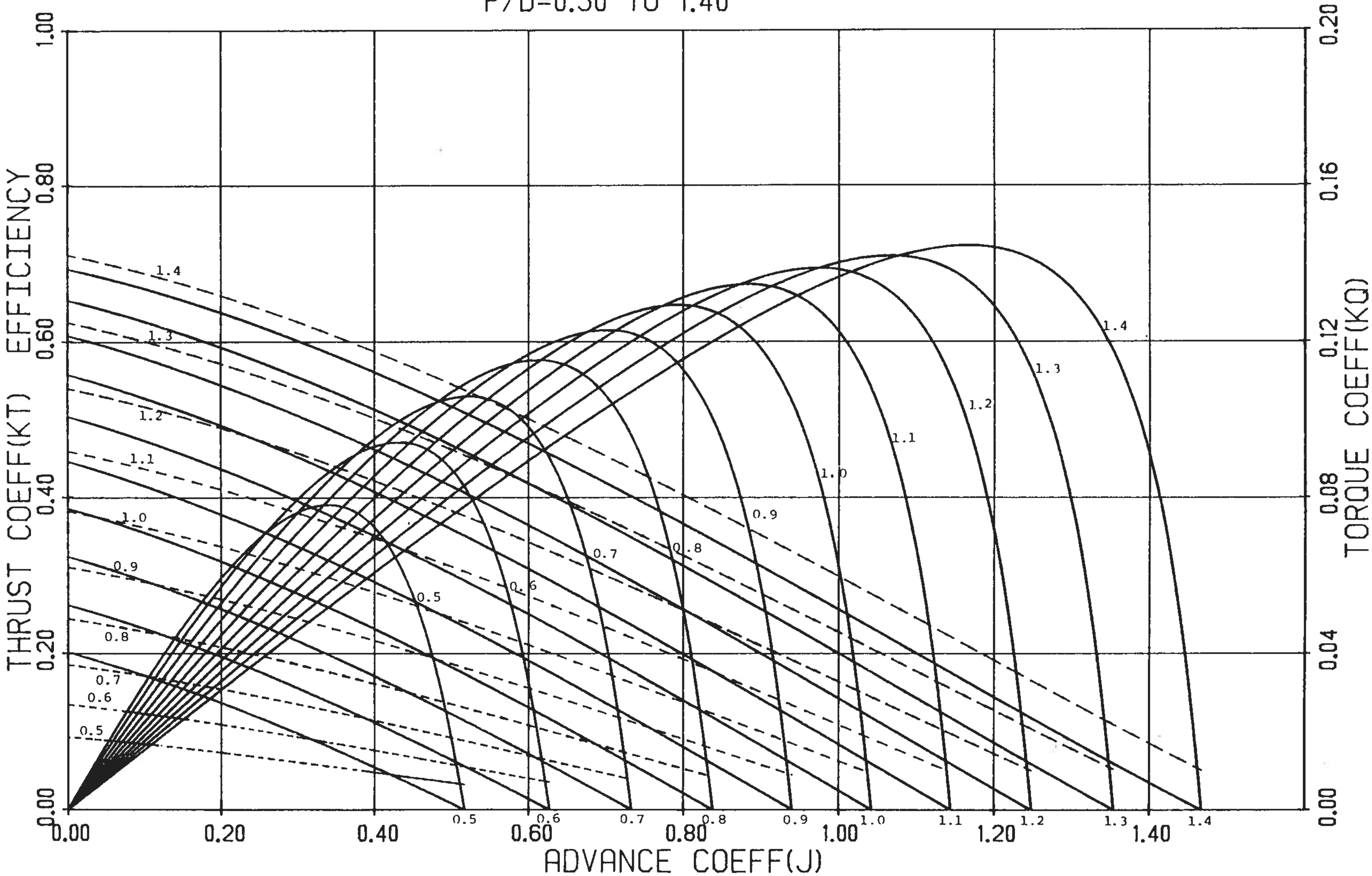


FIGURE 80. WAGENINGEN B-SERIES PROPELLERS
FOR 6 BLADES AE/AO= 1.050
P/D=0.50 TO 1.40

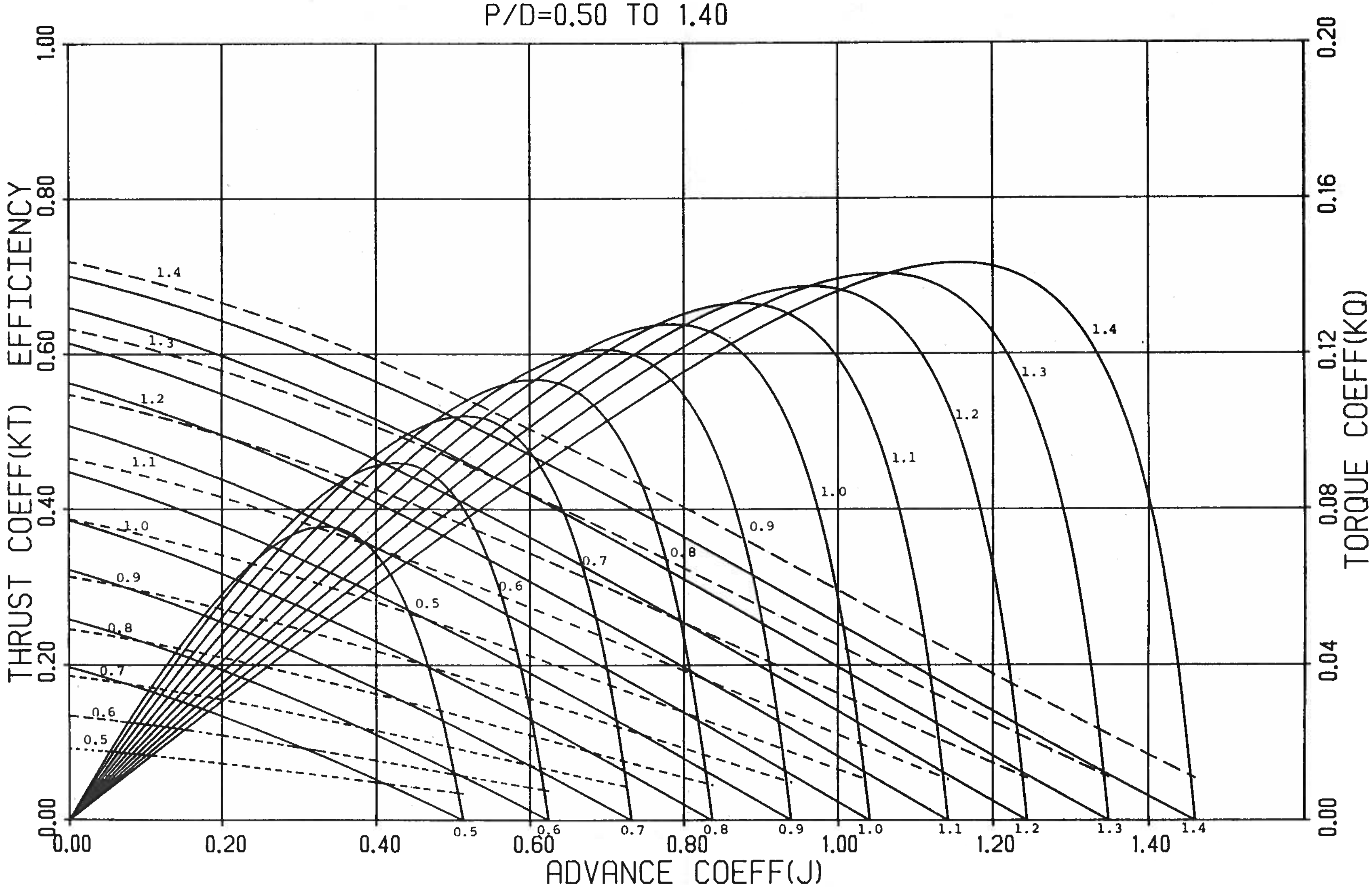


FIGURE 81. WAGENINGEN B-SERIES PROPELLERS
FOR 7 BLADES AE/AO= 0.300
P/D=0.50 TO 1.40

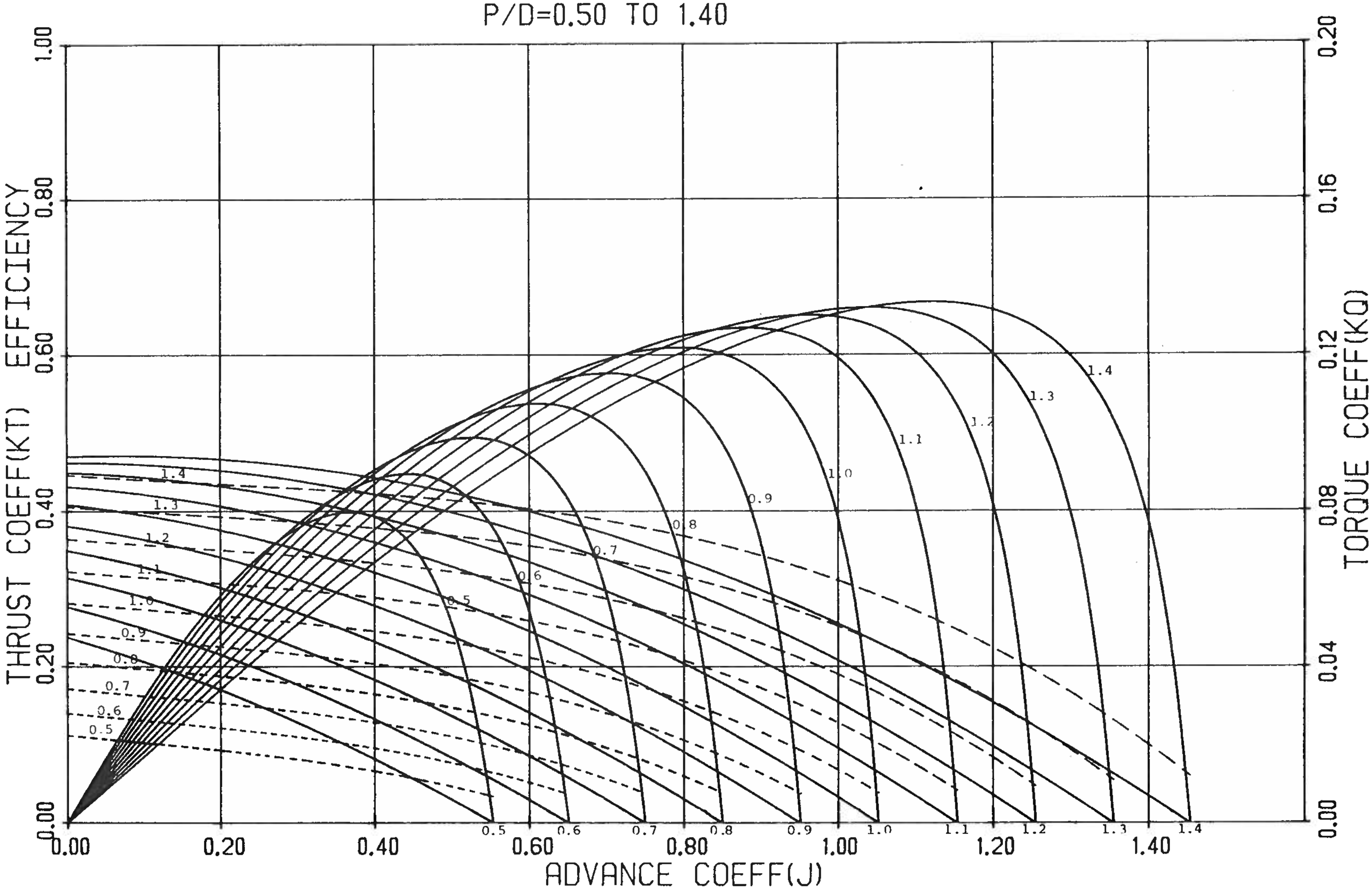


FIGURE 82. WAGENINGEN B-SERIES PROPELLERS
FOR 7 BLADES AE/AO= 0.350
P/D=0.50 TO 1.40

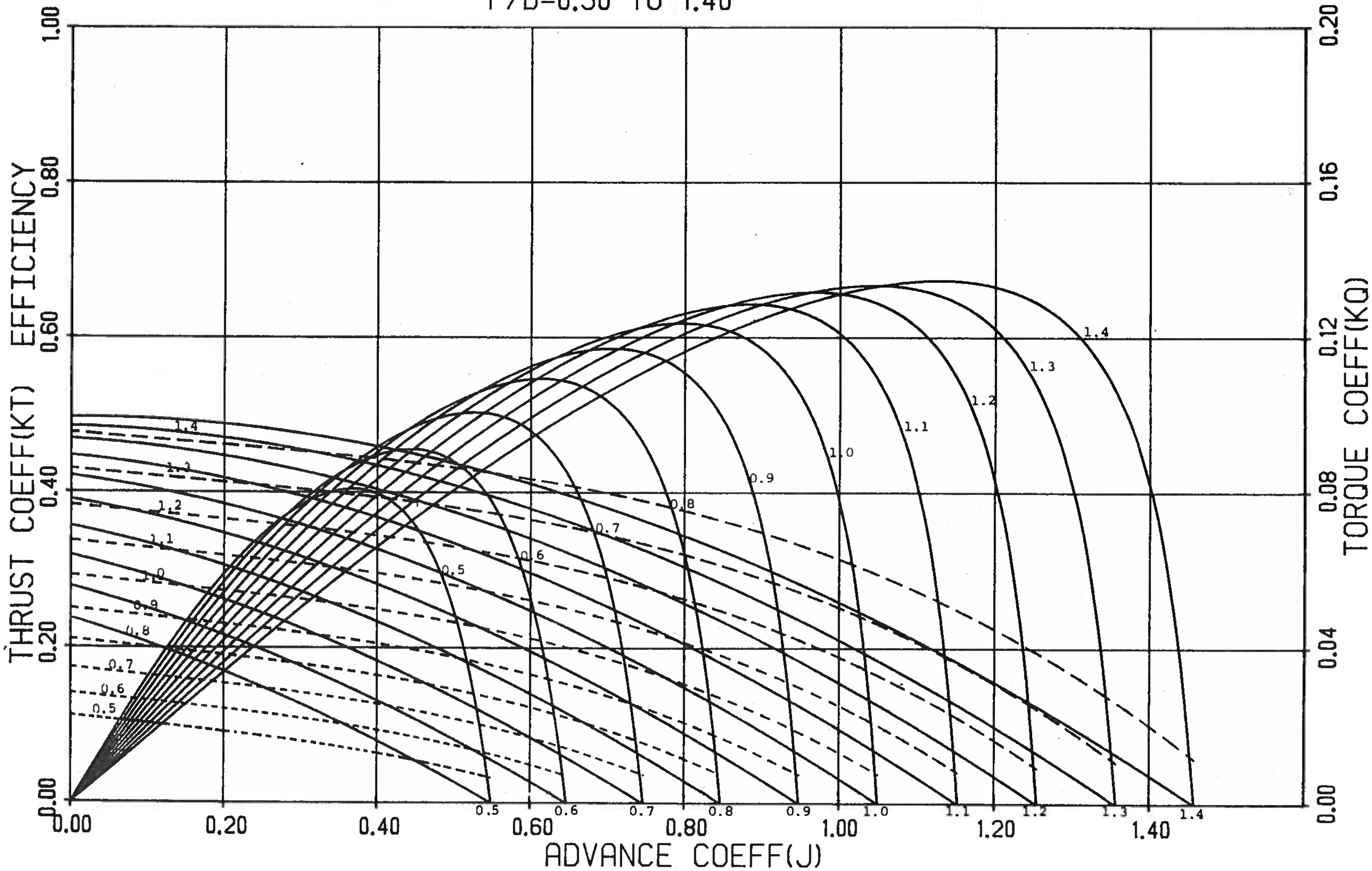


FIGURE 83. WAGENINGEN B-SERIES PROPELLERS
FOR 7 BLADES AE/AO= 0.400
P/D=0.50 TO 1.40

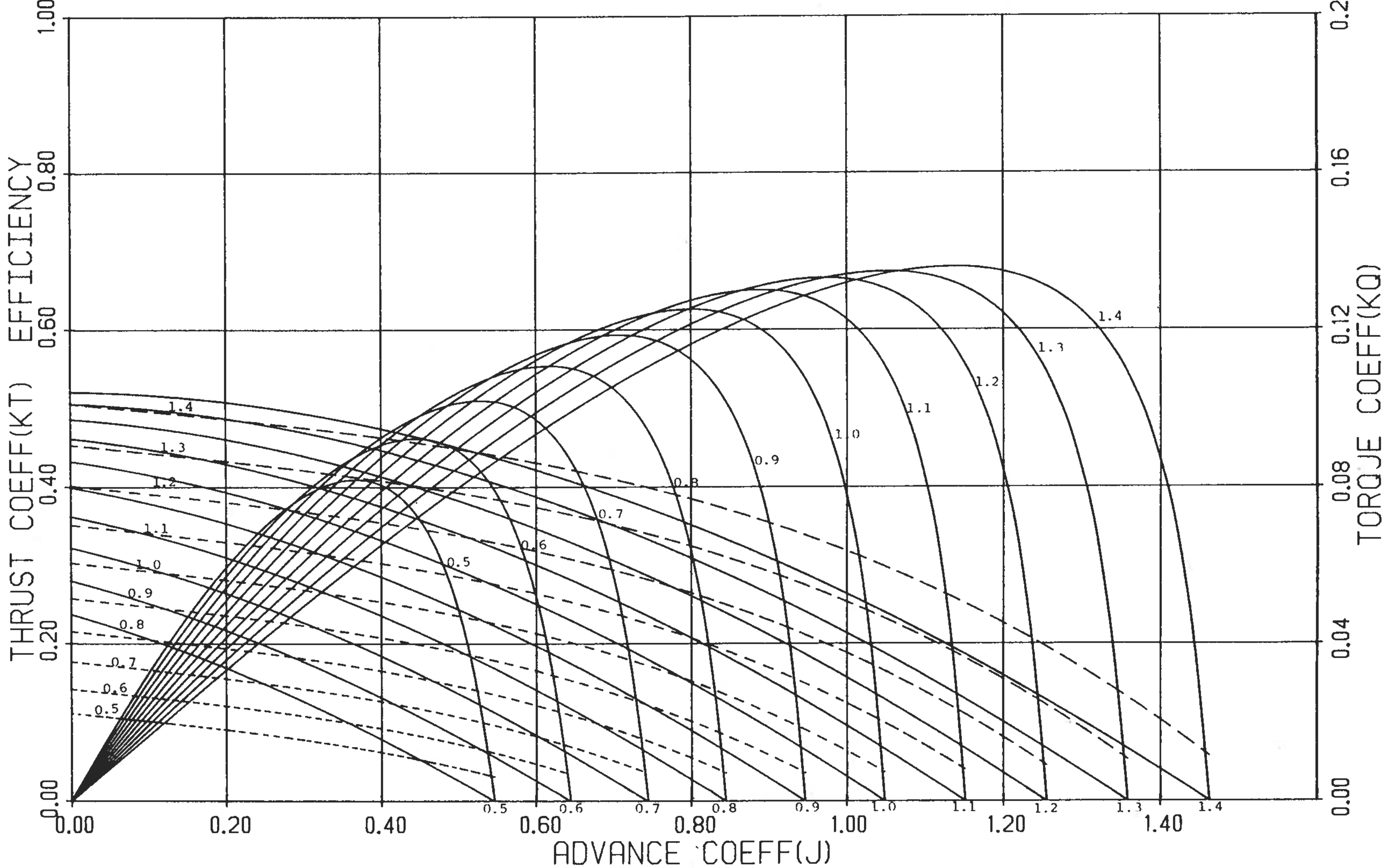


FIGURE 84. WAGENINGEN B-SERIES PROPELLERS
FOR 7 BLADES AE/AO= 0.450
P/D=0.50 TO 1.40

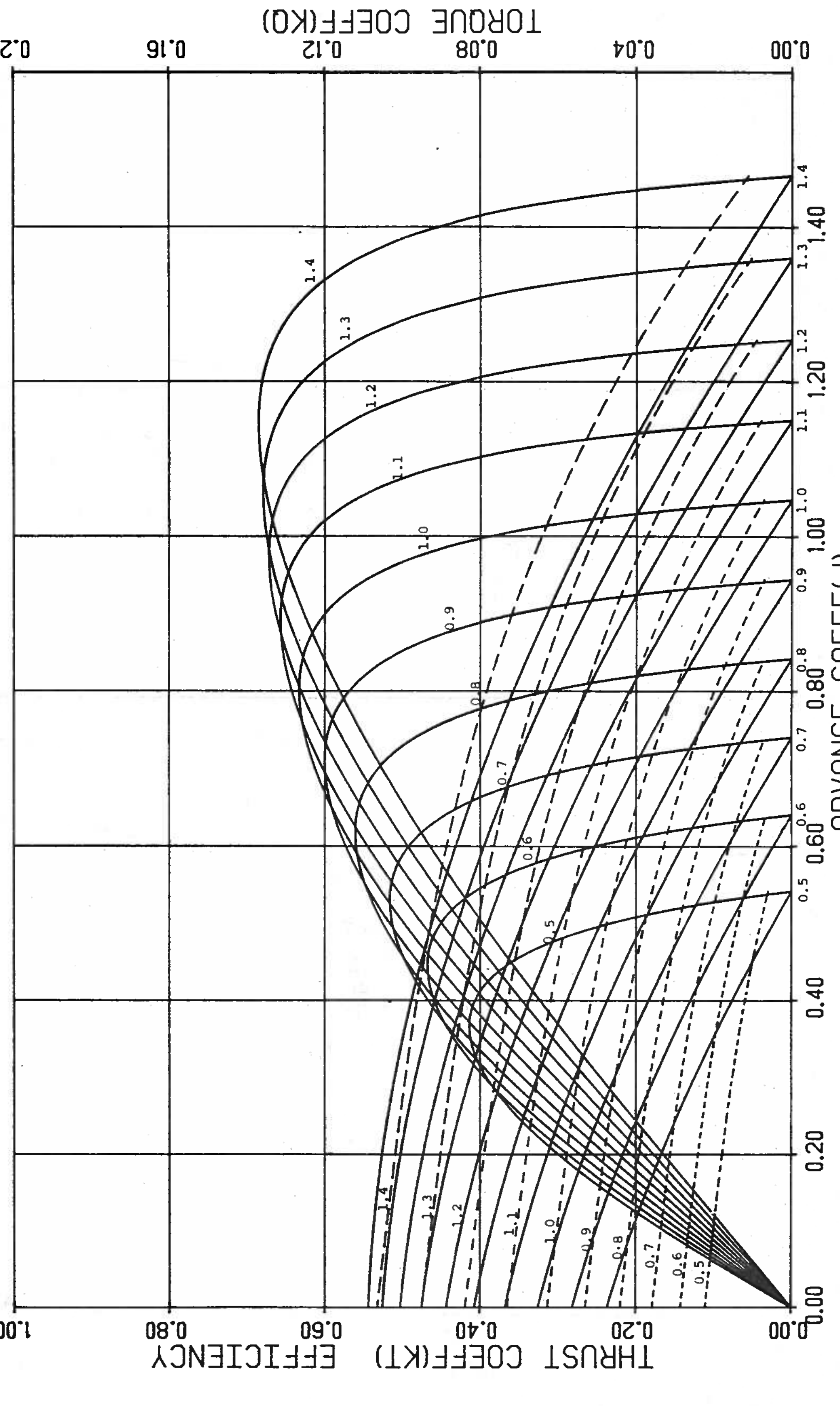


FIGURE 85. WAGENINGEN B-SERIES PROPELLERS
FOR 7 BLADES AE/AO= 0.500
P/D=0.50 TO 1.40

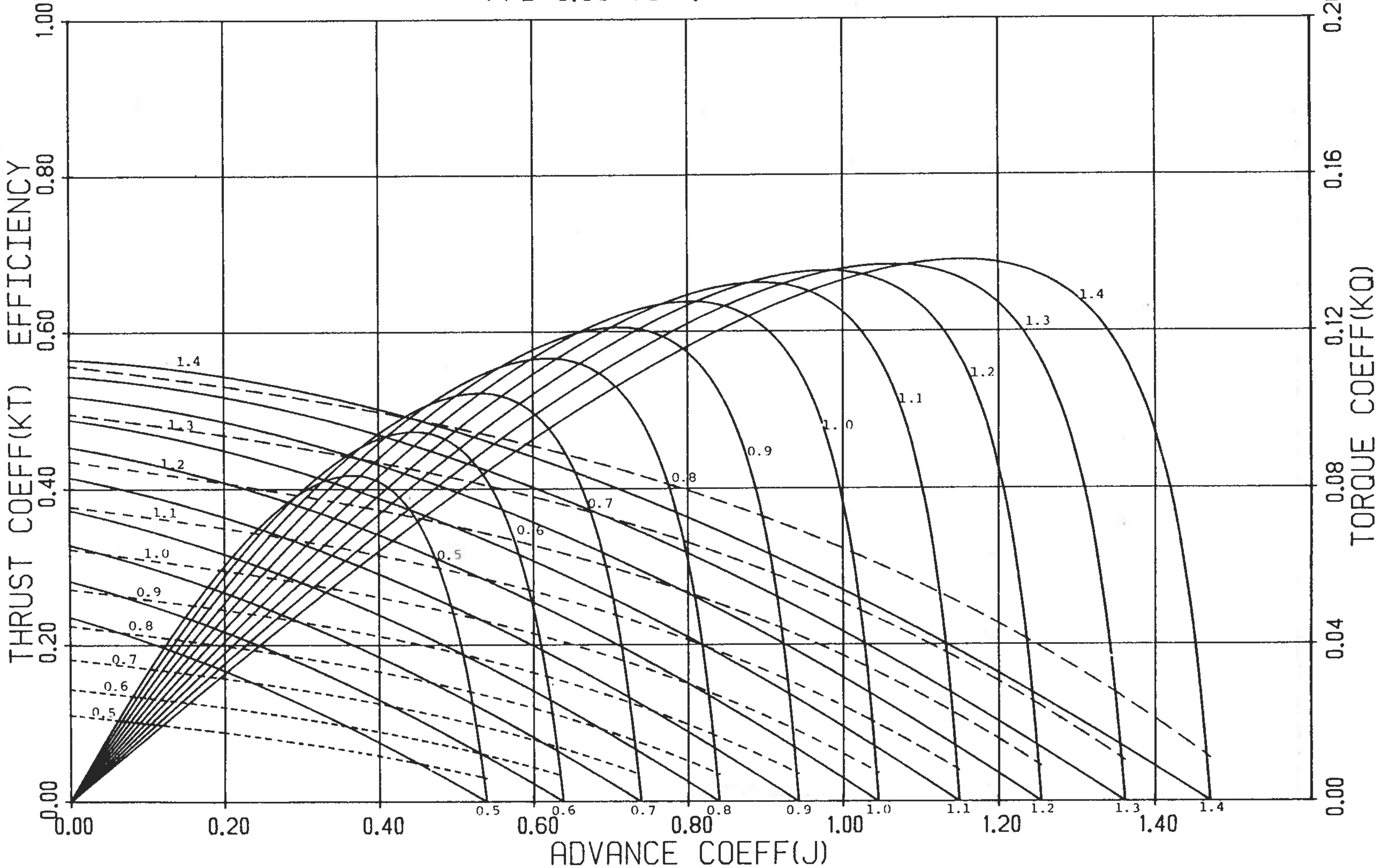


FIGURE 86. WAGENINGEN B-SERIES PROPELLERS
FOR 7 BLADES   AE/AO= 0.550
P/D=0.50 TO 1.40

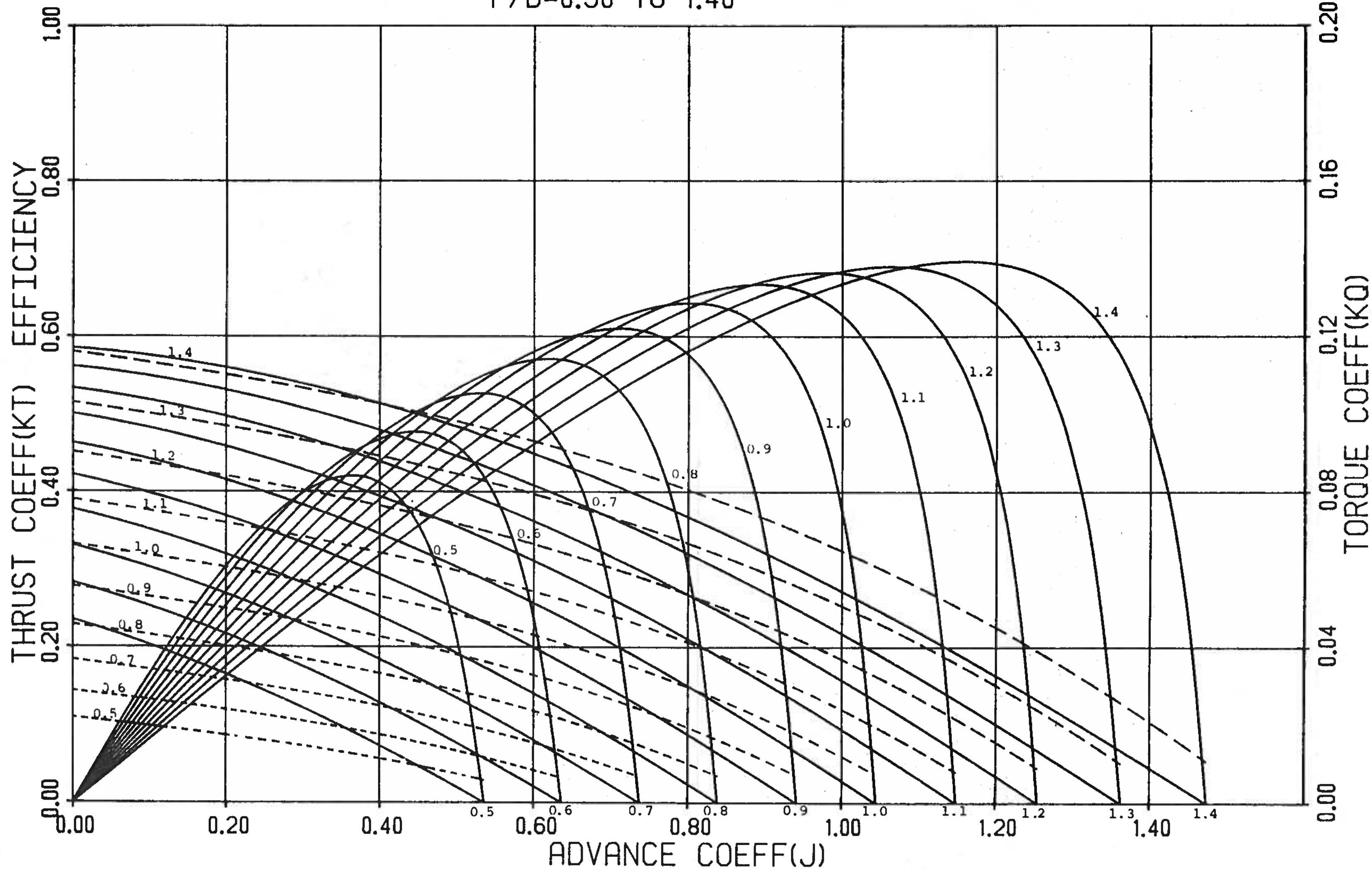


FIGURE 87. WAGENINGEN B-SERIES PROPELLERS
FOR 7 BLADES AE/AO= 0.600
P/D=0.50 TO 1.40

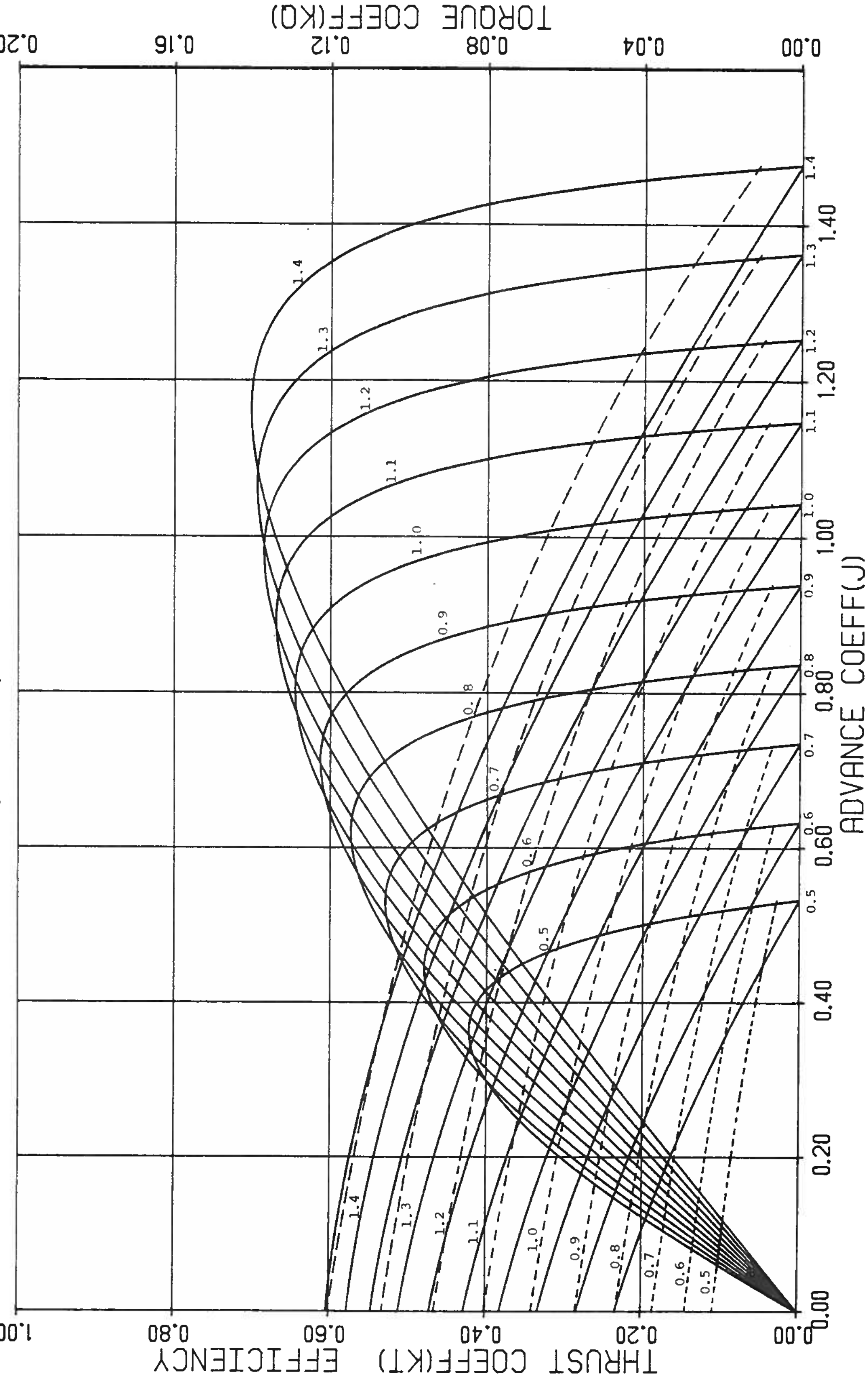


FIGURE 88. WAGENINGEN B-SERIES PROPELLERS
FOR 7 BLADES AE/AO= 0.650
P/D=0.50 TO 1.40

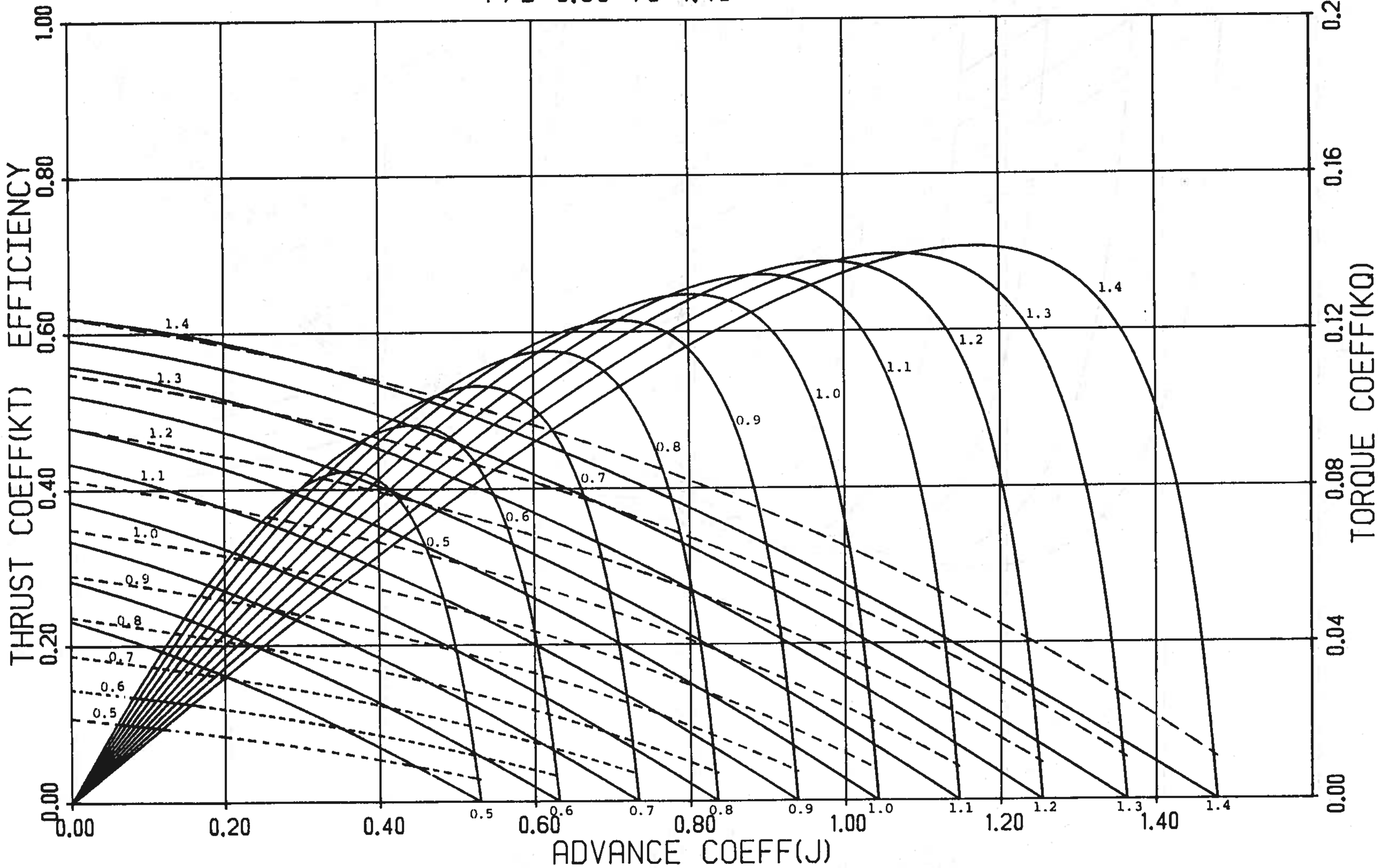


FIGURE 89. WAGENINGEN B-SERIES PROPELLERS
FOR 7 BLADES AE/AO= 0.700
P/D=0.50 TO 1.40

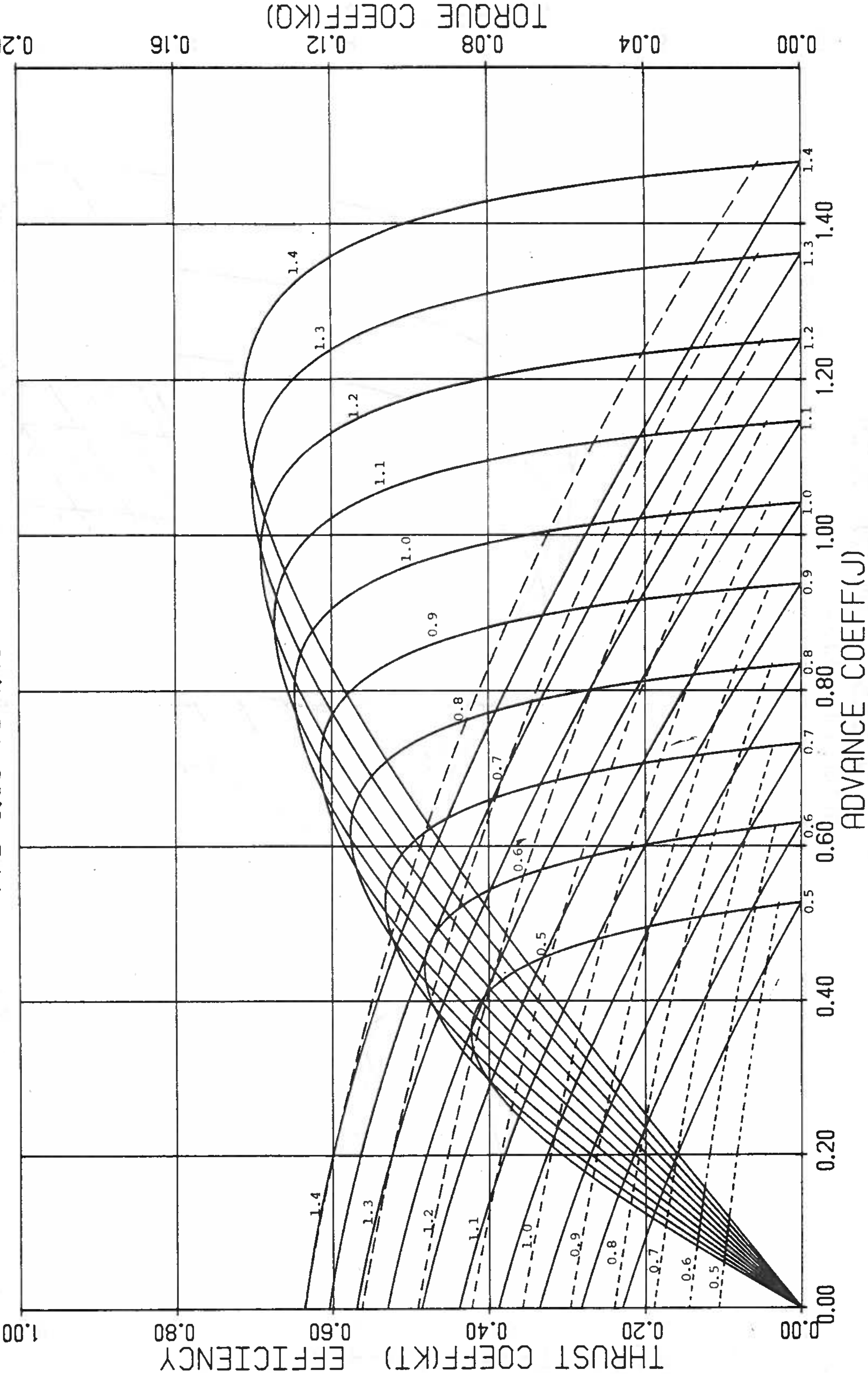


FIGURE 90. WAGENINGEN B-SERIES PROPELLERS
FOR 7 BLADES   AE/AO= 0.750
P/D=0.50 TO 1.40

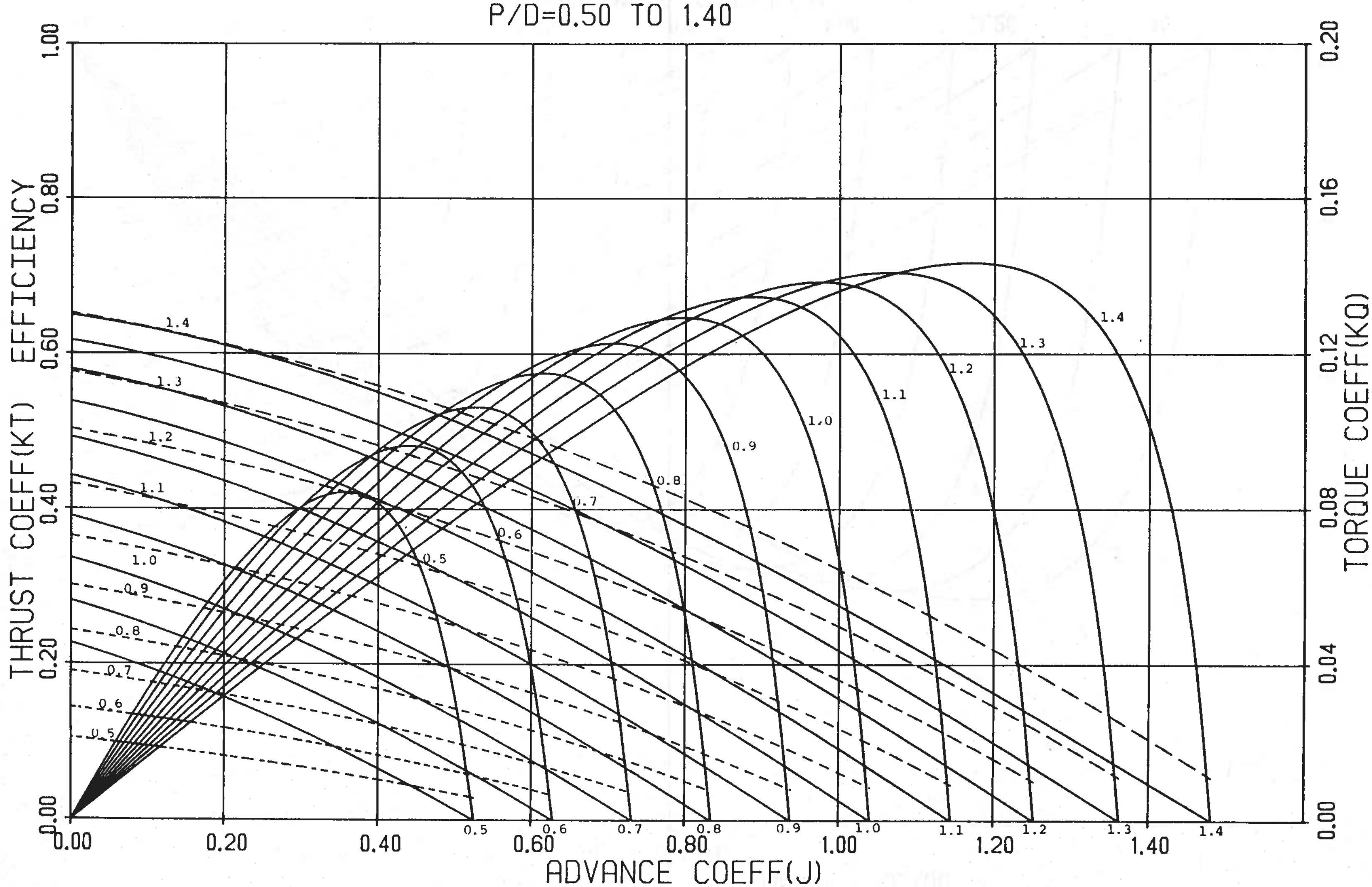


FIGURE 91. WAGENINGEN B-SERIES PROPELLERS
FOR 7 BLADES AE/AO= 0.800
P/D=0.50 TO 1.40

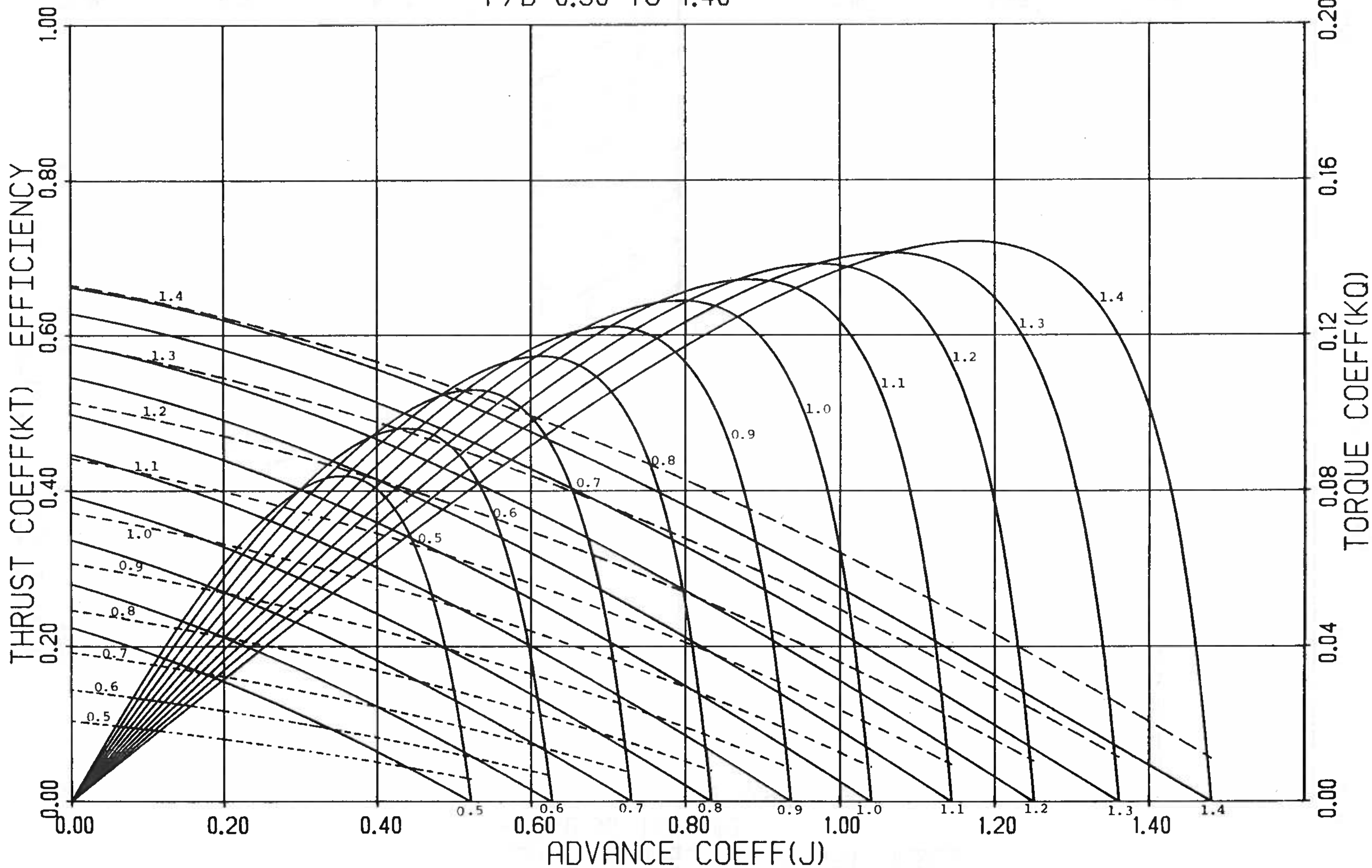


FIGURE 92. WAGENINGEN B-SERIES PROPELLERS
FOR 7 BLADES AE/AO= 0.850
P/D=0.50 TO 1.40

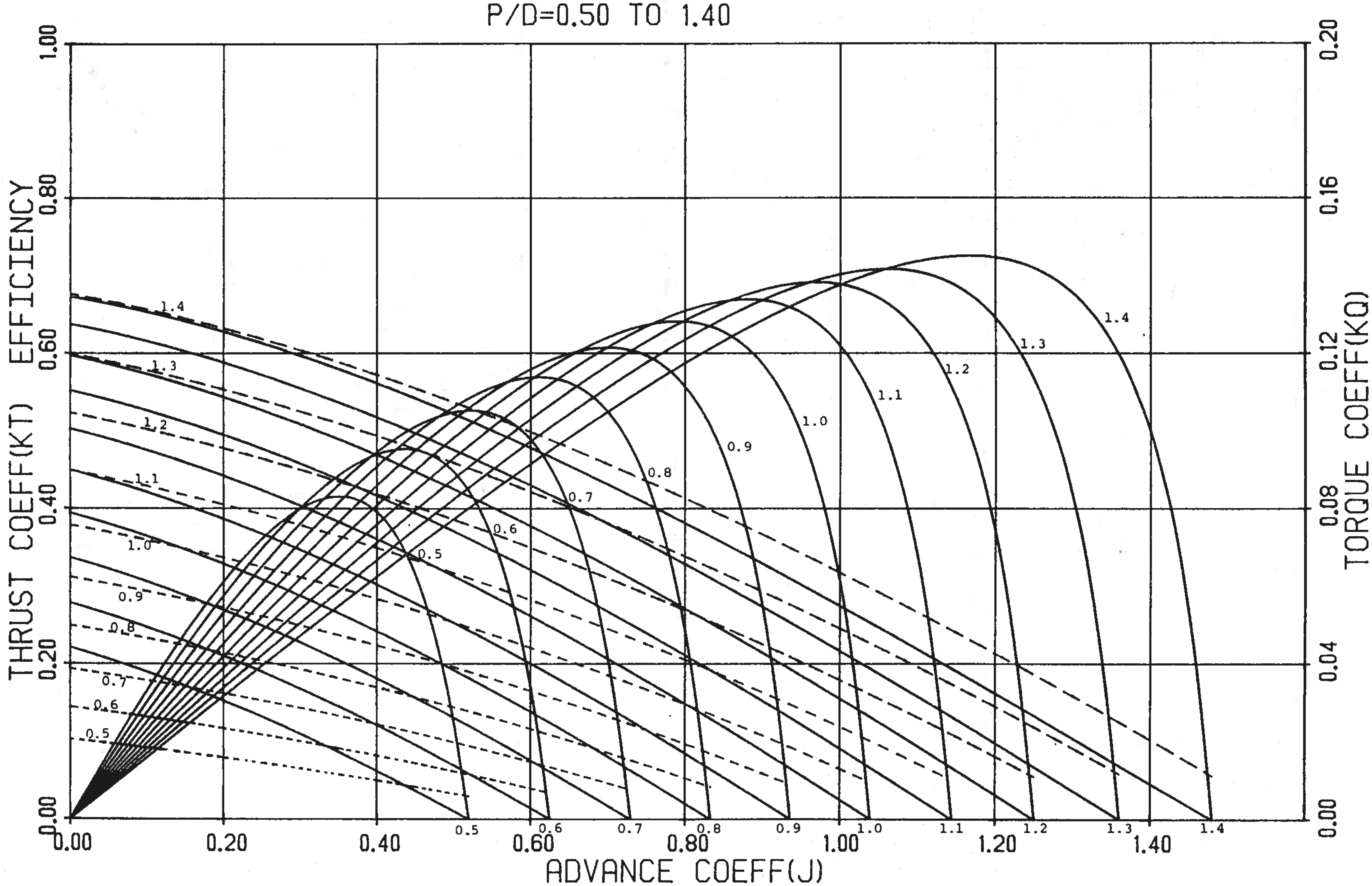


FIGURE 93. WAGENINGEN B-SERIES PROPELLERS
FOR 7 BLADES AE/AO= 0.900
P/D=0.50 TO 1.40

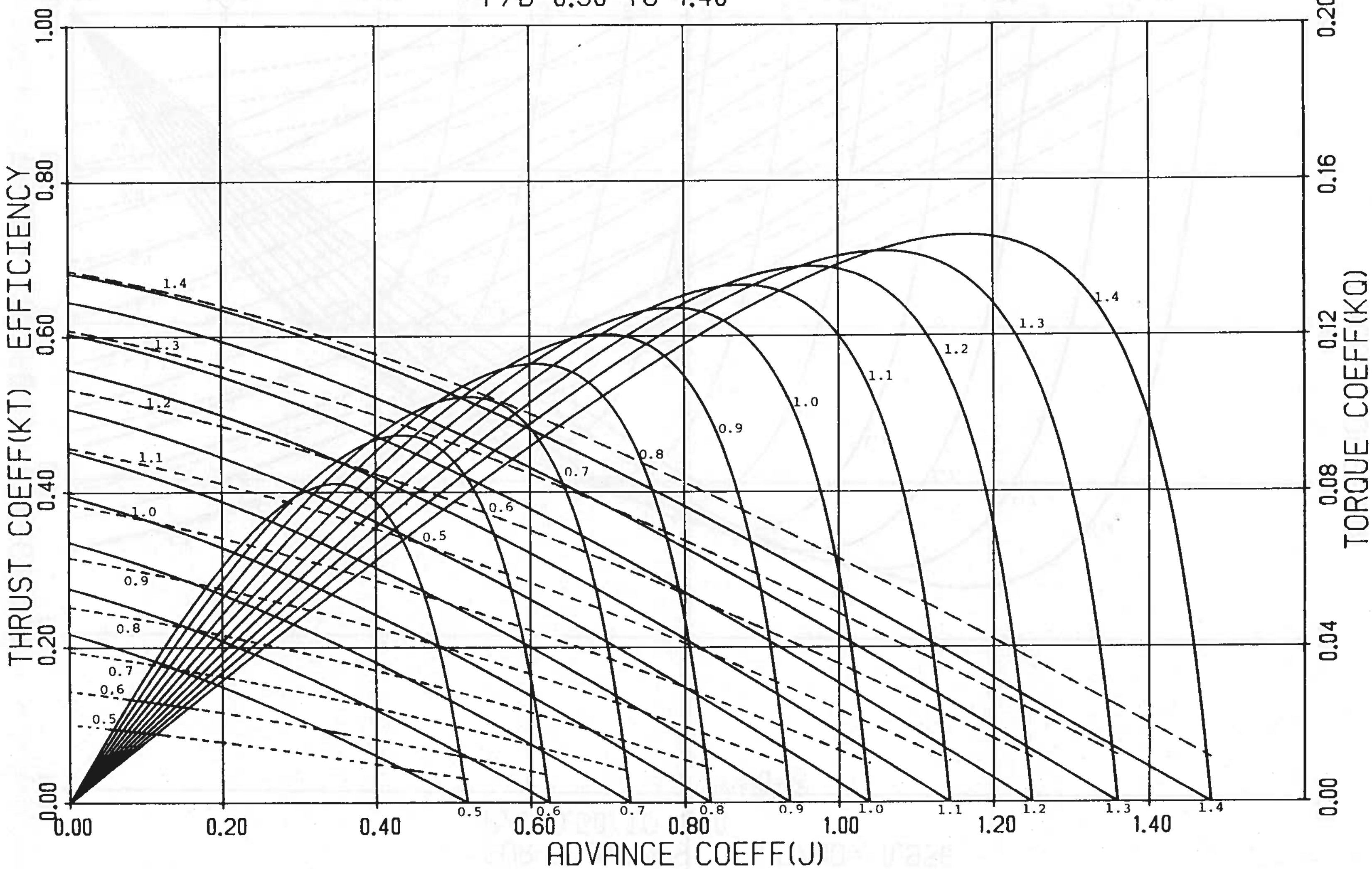


FIGURE 94. WAGENINGEN B-SERIES PROPELLERS
FOR 7 BLADES AE/AO= 0.950
P/D=0.50 TO 1.40

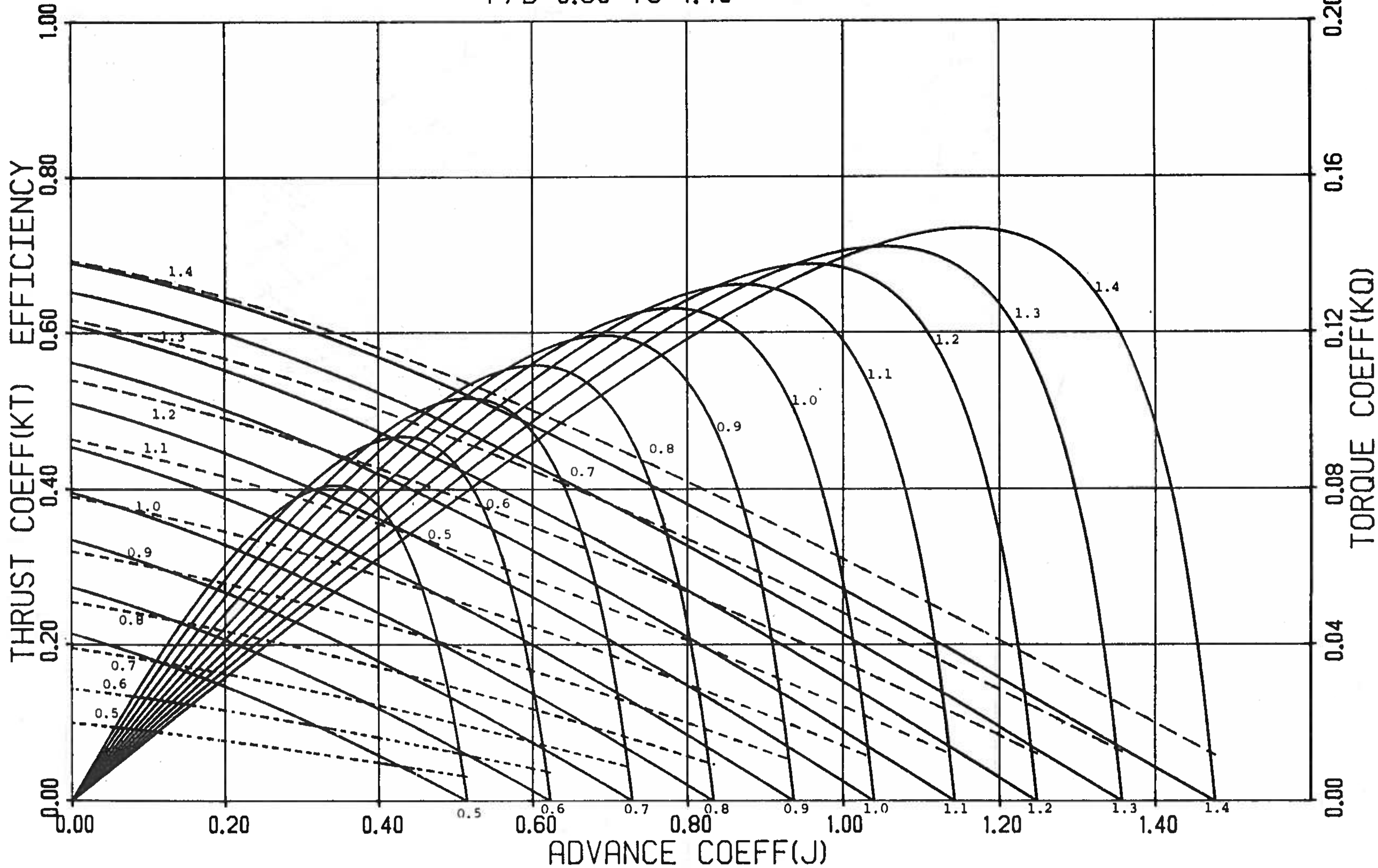


FIGURE 95. WAGENINGEN B-SERIES PROPELLERS
FOR 7 BLADES AE/AO= 1.000
P/D=0.50 TO 1.40

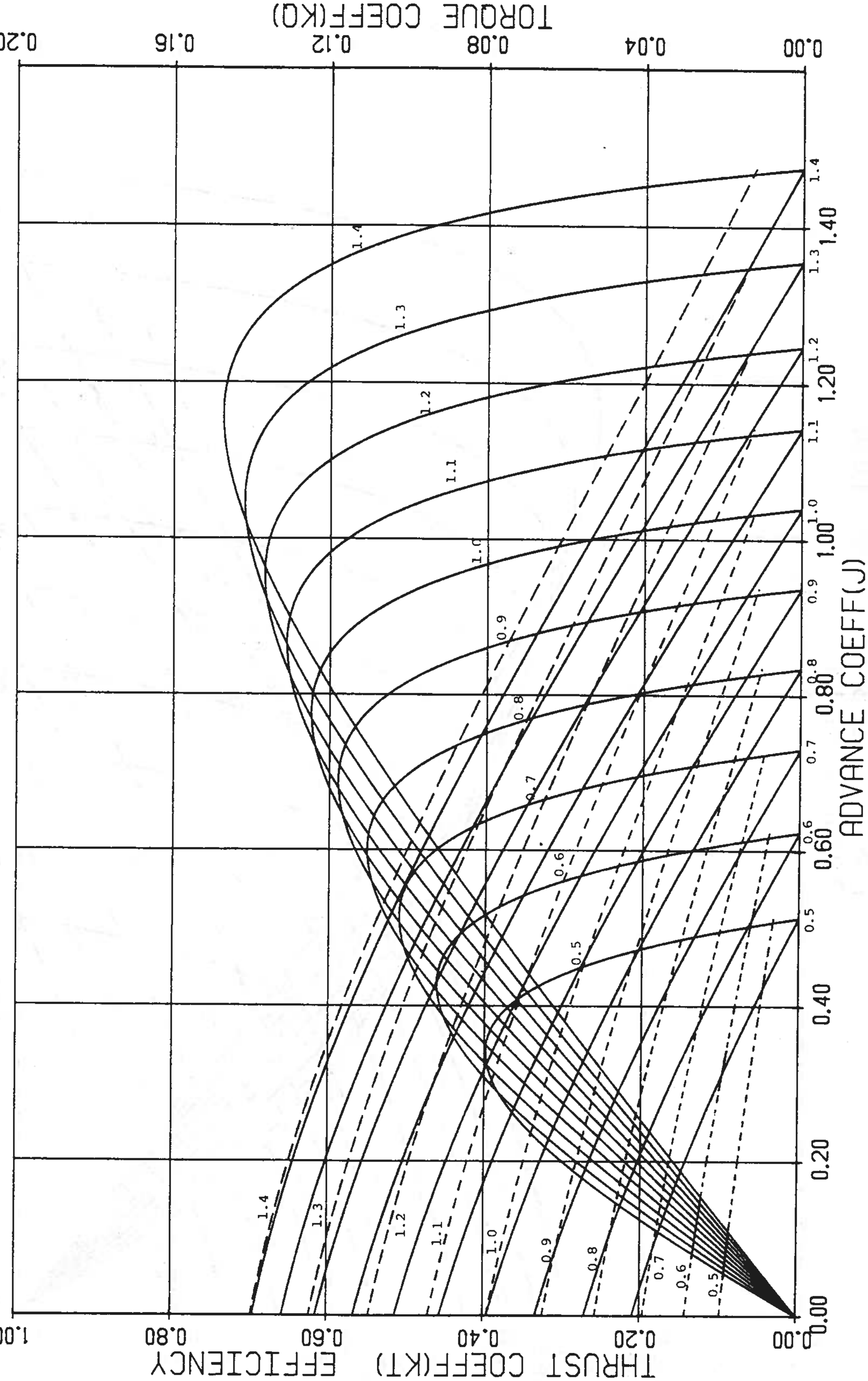


FIGURE 96. WAGENINGEN B-SERIES PROPELLERS
FOR 7 BLADES AE/AO= 1.050
P/D=0.50 TO 1.40