

FDL-TDR-64-16

FOREWORD

The research work described in this report was performed by the Bell Aerosystems Company, Buffalo, New York for the Flight Dynamics Laboratory, Research and Technology Division, Wright Patterson Air Force Base, Ohio. The work was accomplished under Contract No. AF33(657)-7486, Project No. 8219, Task No. 821901 and entitled "Nonlinear Thermoelastic Effects on Hypersonic Stability and Control". Mr. H.M. Davis and Mr. J.E. Jenkins have been the Air Force Project Officers since the initiation of the program in November 1961. The study program was carried out by the Vehicle Structures Department of Bell Aerosystems Company under the technical direction of Mr. V.W. Donato and Mr. J.R. Batt.

Results of this program are being presented in a two-part report of which this is Part I, Volume 2. Part II presents a method for obtaining hypersonic static aerothermoelastic solutions in the presence of nonlinear aerodynamic and structural behavior and includes data from tests simulating this behavior. A computer program for the solution of nonlinear static aerothermoelastic problems is also described.

The results of a feasibility study employing Moire' fringe techniques to measure the angular displacements of practical wing structures are given under separate cover in FDL-TDR-64-42.

Acknowledgment is given to Messrs. W. Luberacki and F. Braun for their assistance in the computation and preparation of the tables and figures in this report. Appreciation is also expressed to Mr. R. Watkins for the preparation of the digital computer program employed in this part of the study.

Contrails

ABSTRACT

The curves presented in this volume of the final report are to be used to obtain aerodynamic influence coefficient matrices for slender two-dimensional airfoils in hypersonic inviscid flow. Influence coefficients are presented for ten airfoil shapes as a function of thickness ratio, Mach number and geometric angle of attack. Part I, Volume 1 of the final report illustrates the use of these coefficients in determining influence coefficient matrices. The use of these matrices in nonlinear static aeroelastic analyses is presented in Part II of this report.

This Technical Documentary Report has been reviewed and is approved.

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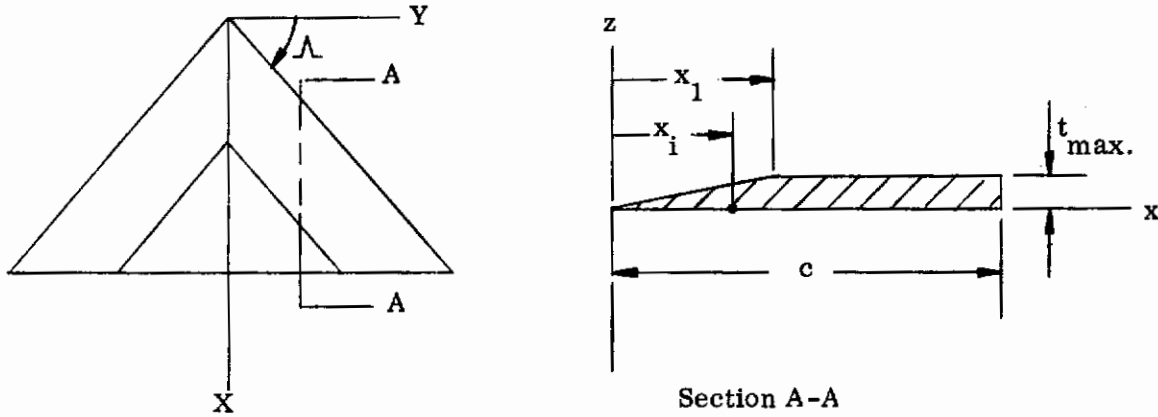
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Contrails

The aerodynamic influence coefficients; \bar{q}_{n_i} , $n = 0, 1, 2, 3$, are presented in standard format. Two types of format are used, namely; (a) ordinate \bar{q}_{n_i} , abscissa K and parameter $\alpha(0)$; (b) ordinate \bar{q}_{n_i} , abscissa $\bar{\alpha}(0)$ and parameter K . Note that units of $\alpha(0)$ are degrees for the flat plate coefficients, whereas units of $\bar{\alpha}(0)$ are reduced radians for all other airfoils.

The notation used in the presentation of the figures in this report is defined below. An index of the graphs is given in Table I.



$$\xi = \frac{x}{c}, \text{ nondimensional streamwise coordinate}$$

$$\xi_1 = \frac{x_1}{c}, \quad \xi_i = \frac{x_i}{c}$$

$$\bar{\alpha}(0) = \frac{\alpha(0)}{\tau}, \text{ angle of attack at leading edge}$$

$$\tau = \frac{t_{\max}}{c}, \text{ thickness ratio}$$

M_∞ , free stream Mach number

$$K = M_\infty \tau$$

$$\bar{q}_{0_i} = \frac{q_{0_i}}{\tau^2}, \quad \bar{q}_{1_i} = \frac{q_{1_i}}{\tau}, \quad \bar{q}_{2_i} = q_{2_i}, \quad \bar{q}_{3_i} = q_{3_i} \tau$$

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TABLE I
INDEX OF AERODYNAMIC INFLUENCE COEFFICIENT GRAPHS

Shape	Figures	Pages
Flat Plate $0 \leq \xi_i \leq 1.00$	1-4	4-7
Half Diamond $0 \leq \xi_i \leq 0.50$ $0.5 \leq \xi_i \leq 1.00$	5-9 10-14	8-12 13-17
Double Wedge $0 \leq \xi_i \leq 1.00$	15-18	18-21
Diamond $0 \leq \xi_i \leq 0.50$ $0.5 \leq \xi_i \leq 1.00$	19-22 23-26	22-25 26-29
Single Parabolic $\xi_i = 0$ $\xi_i = 0.20$ $\xi_i = 0.40$ $\xi_i = 0.60$ $\xi_i = 0.80$ and 1.00	27-30 31-34 35-38 39-42 43-46	30-33 34-37 38-41 42-45 46-49
Double Parabolic, B.T.E. $\xi_i = 0$ $\xi_i = 0.20$ $\xi_i = 0.40$ $\xi_i = 0.60$ $\xi_i = 0.80$ $\xi_i = 1.00$	(See Figure 19-22) 47-50 51-54 55-58 59-62 63-66	22-25 50-53 54-57 58-61 62-65 66-69
Single Wedge $0 \leq \xi_i \leq 1.00$	67-70	70-73

TABLE I (Cont)

Shape	Figures	Pages
Single Parabolic, B.T.E.		
$\xi_i = 0$	(See Figures 5-9)	8-12
$\xi_i = 0.20$	71-74	74-77
$\xi_i = 0.40$	75-78	78-81
$\xi_i = 0.60$	79-82	82-85
$\xi_i = 0.80$	83-86	86-89
$\xi_i = 1.00$	86, 87-89	89, 90-92
Single Wedge-Plate		
$\xi_1 = 0.25, 0.50, 0.75$		
$0 \leq \xi_i \leq 0.25$	90-93	93-96
$0 \leq \xi_i \leq 0.50$	(See Figures 5-9)	8-12
$0 \leq \xi_i \leq 0.75$	94-97	97-100
$0.25 \leq \xi_i \leq 1.00$	98a-101	101-104
$0.50 \leq \xi_i \leq 1.00$	98b-101	101-104
$0.75 \leq \xi_i \leq 1.00$	98c-101	101-104
Modified Double Wedge		
$\xi_1 = 0.20, 0.30, 0.40$		
$0 \leq \xi_i \leq 0.20$	102-105	105-108
$0.20 \leq \xi_i \leq 0.80$	106-108	109-111
$0.80 \leq \xi_i \leq 1.00$	109-111	112-114
$0 \leq \xi_i \leq 0.30$	112-115	115-118
$0.30 \leq \xi_i \leq 0.70$	116-118	119-121
$0.70 \leq \xi_i \leq 1.00$	119-121	122-124
$0 \leq \xi_i \leq 0.40$	122-125	125-128
$0.40 \leq \xi_i \leq 0.60$	126-128	129-131
$0.60 \leq \xi_i \leq 1.00$	129-131	132-134

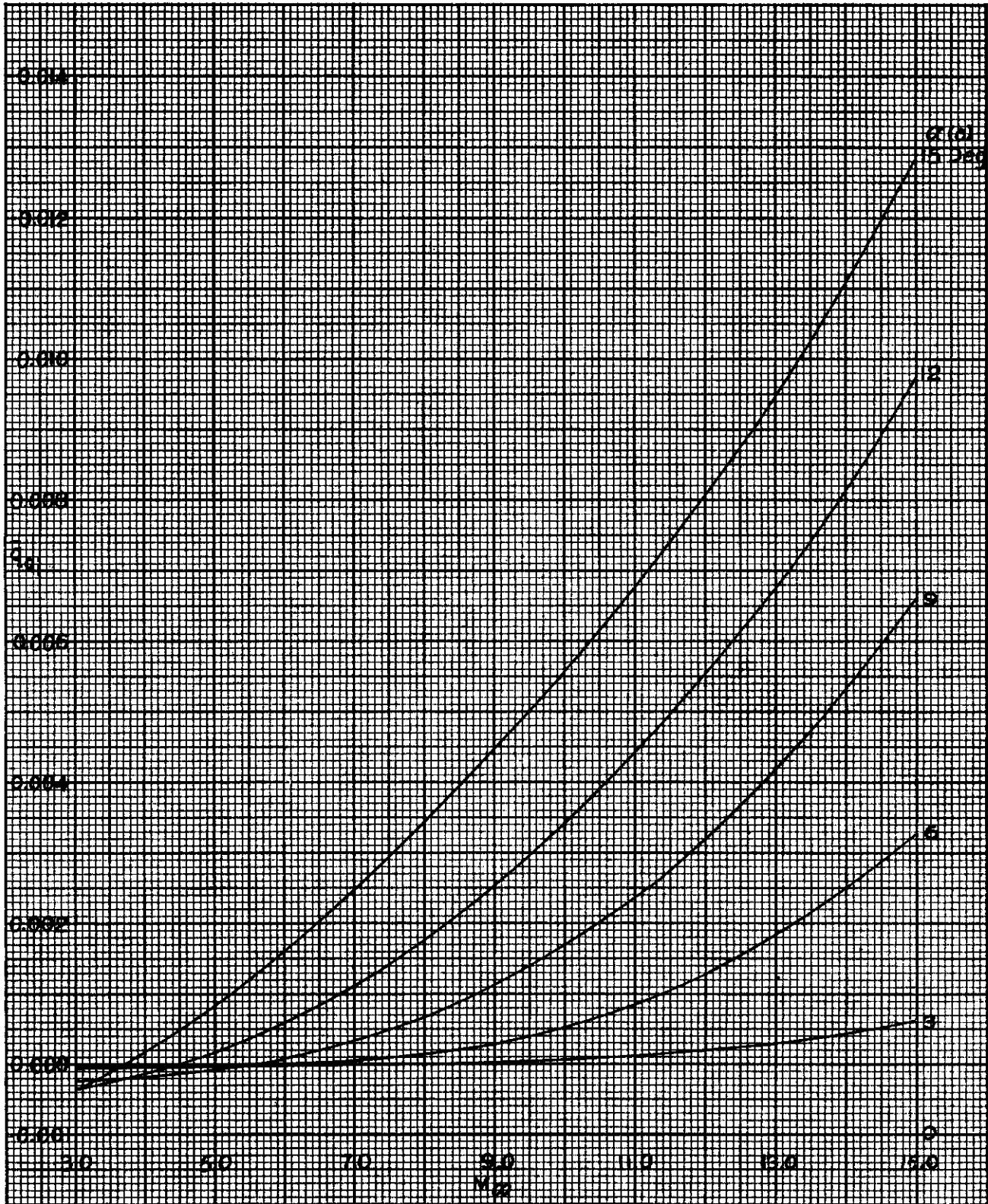


Figure 1. Flat Plate, $0 \leq \xi_i \leq 1.00$ for $-\alpha(0)$ Use $-q_{01}$

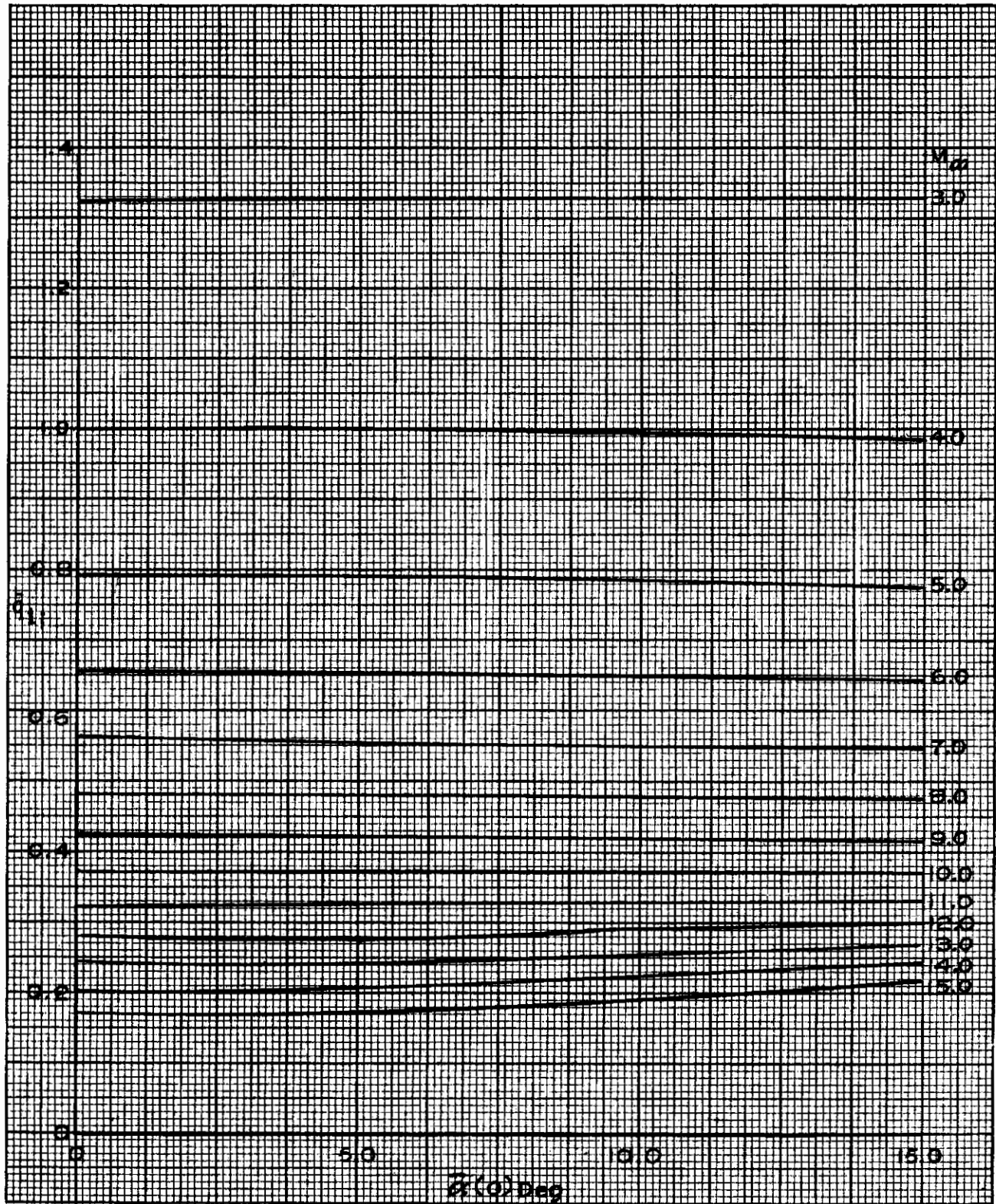


Figure 2. Flat Plate, $0 \leq \xi_i \leq 1.00$ for $-\alpha(0)$ Use $+q_{1_i}$

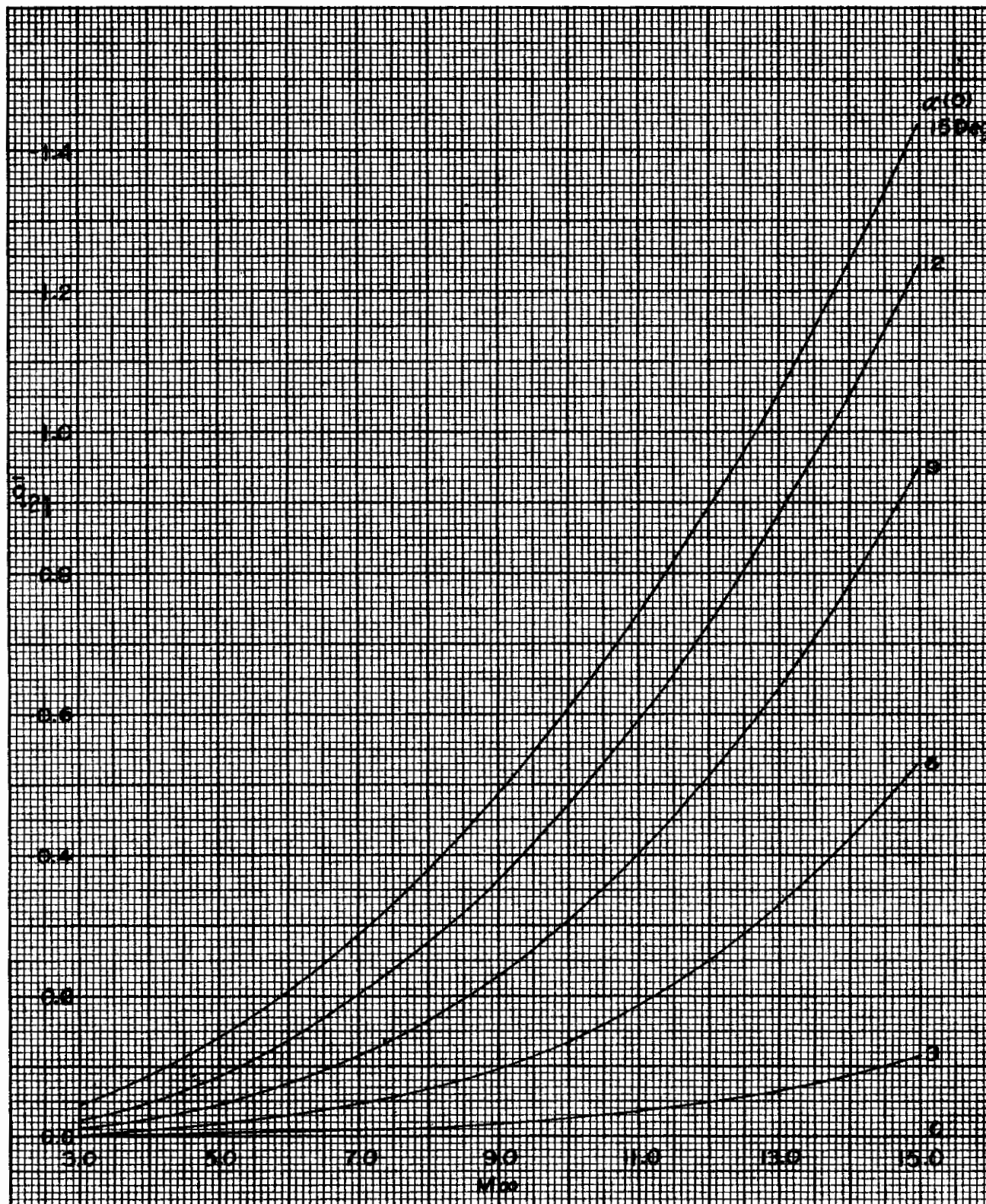


Figure 3. Flat Plate, $0 \leq \xi_i \leq 1.00$ for $-\alpha(0)$ Use $-q_{2_i}$



Figure 4. Flat Plate, $0 \leq \xi_i \leq 1.00$ for $- \alpha (0)$; Use $+ q_{3_i}$

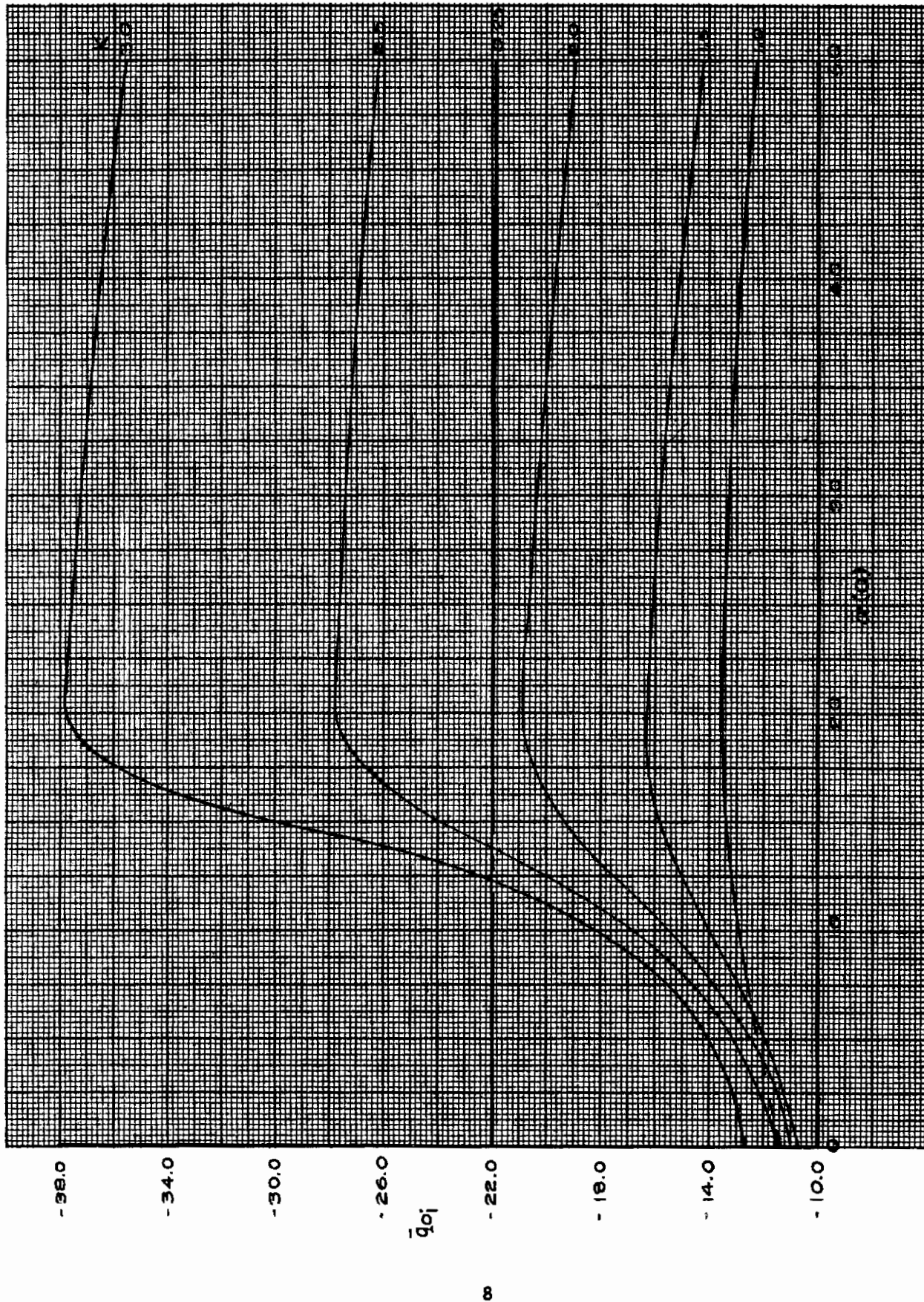


Figure 5. Half Diamond, $0 \leq \xi_i \leq 0.50$

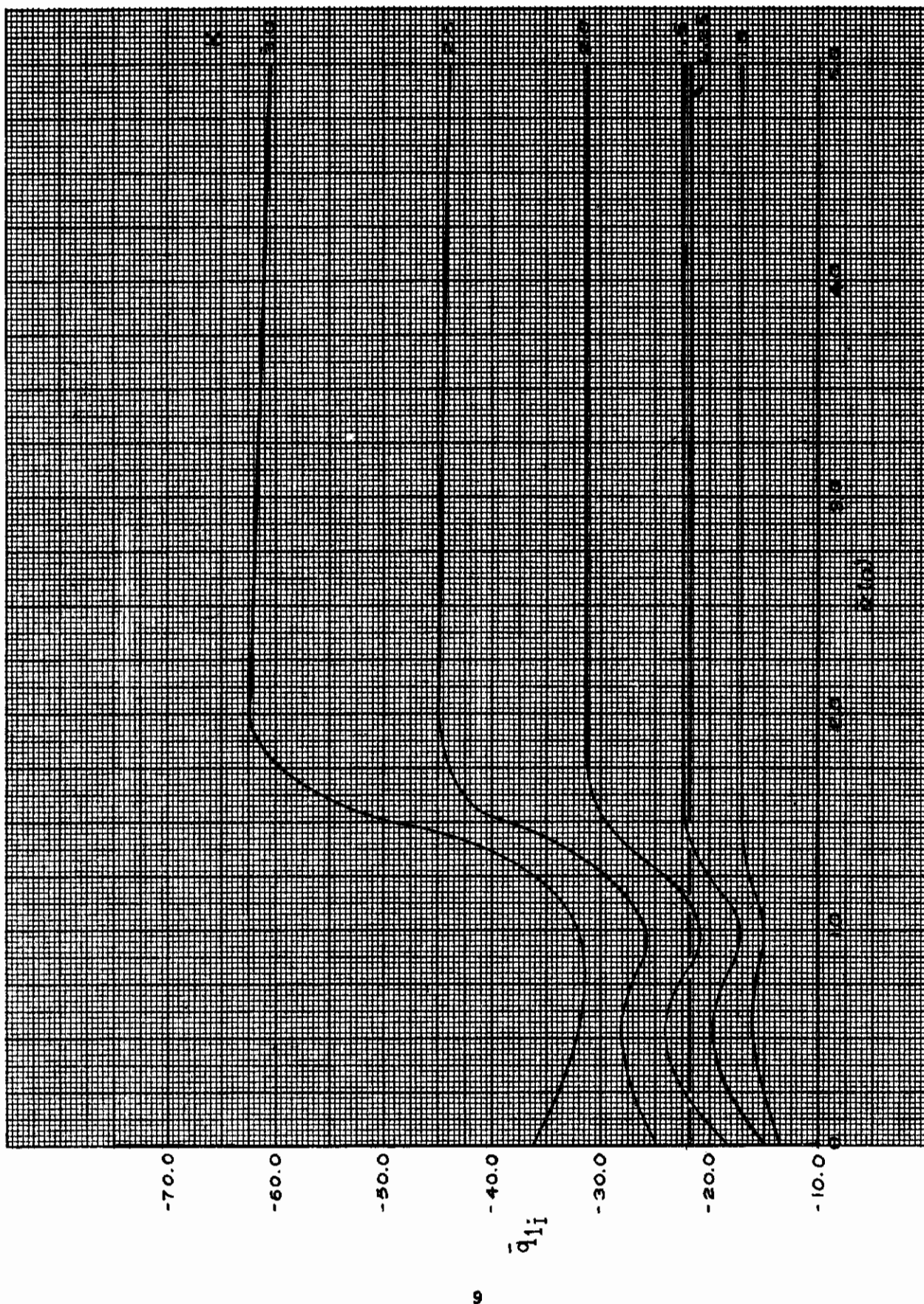


Figure 6. Half Diamond, $0 \leq \xi_i \leq 0.50$

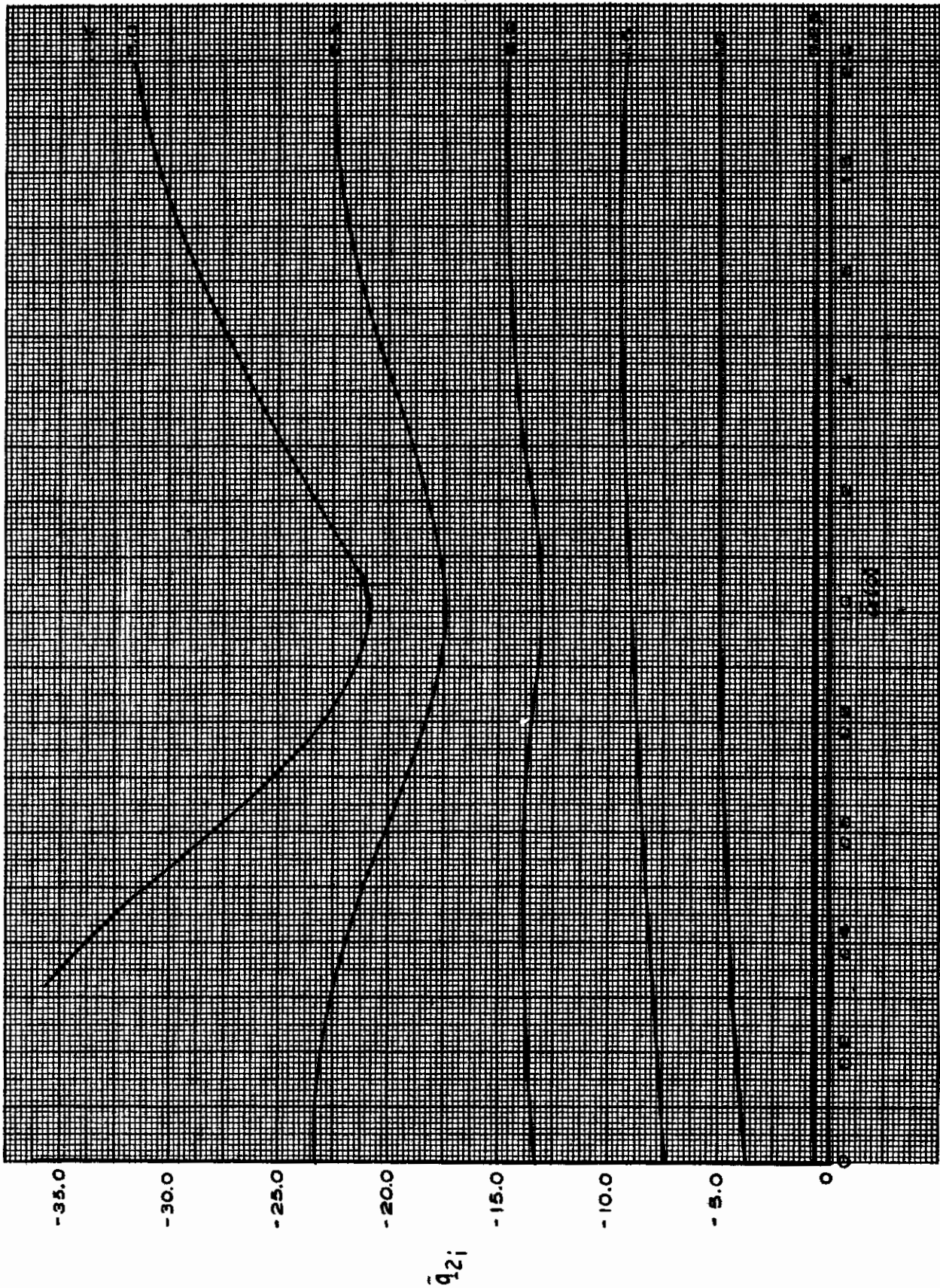


Figure 7. Half Diamond, $0 \leq \xi_i \leq 0.50$

9.21

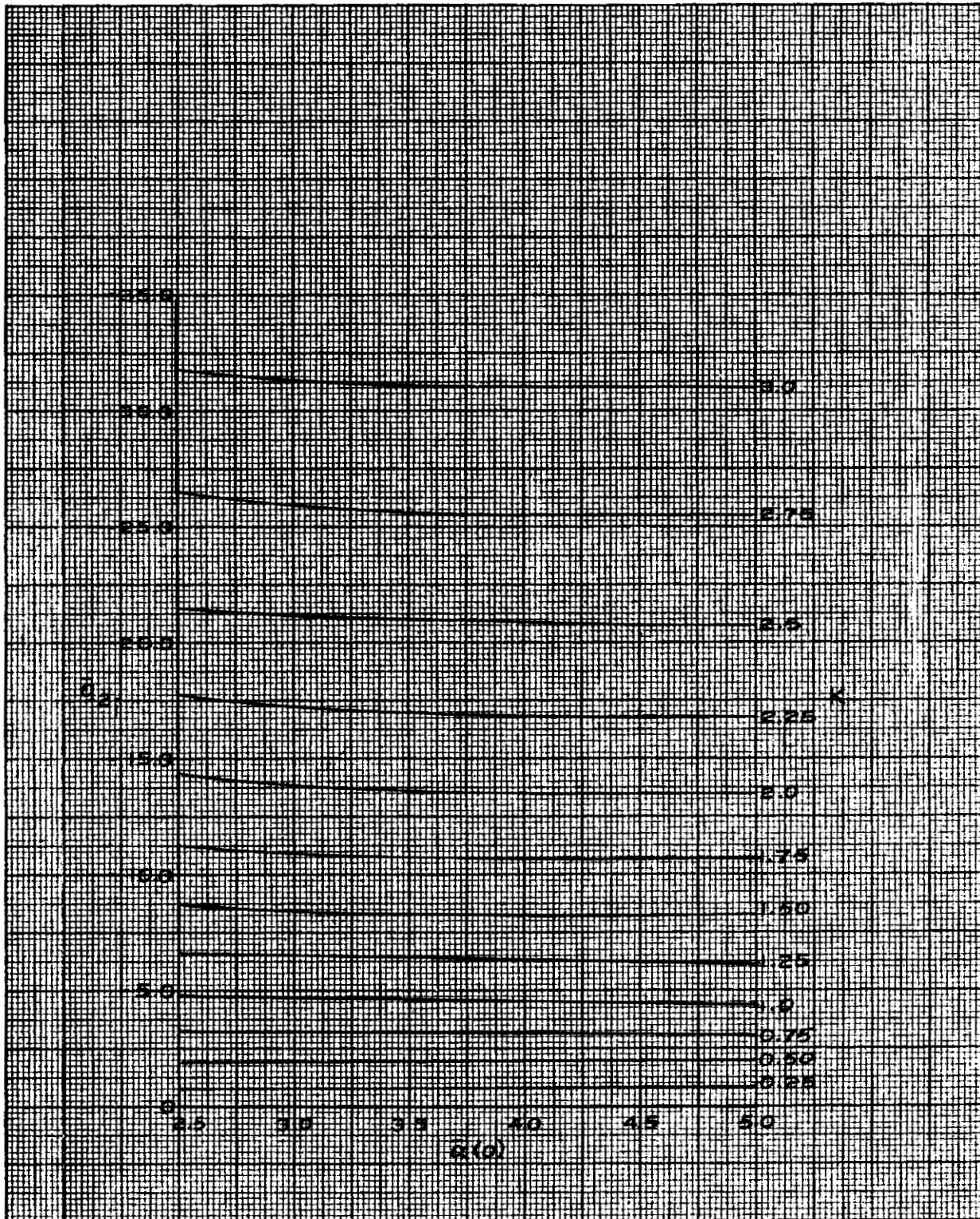


Figure 8. Half Diamond, $0 \leq \xi_i \leq 0.50$

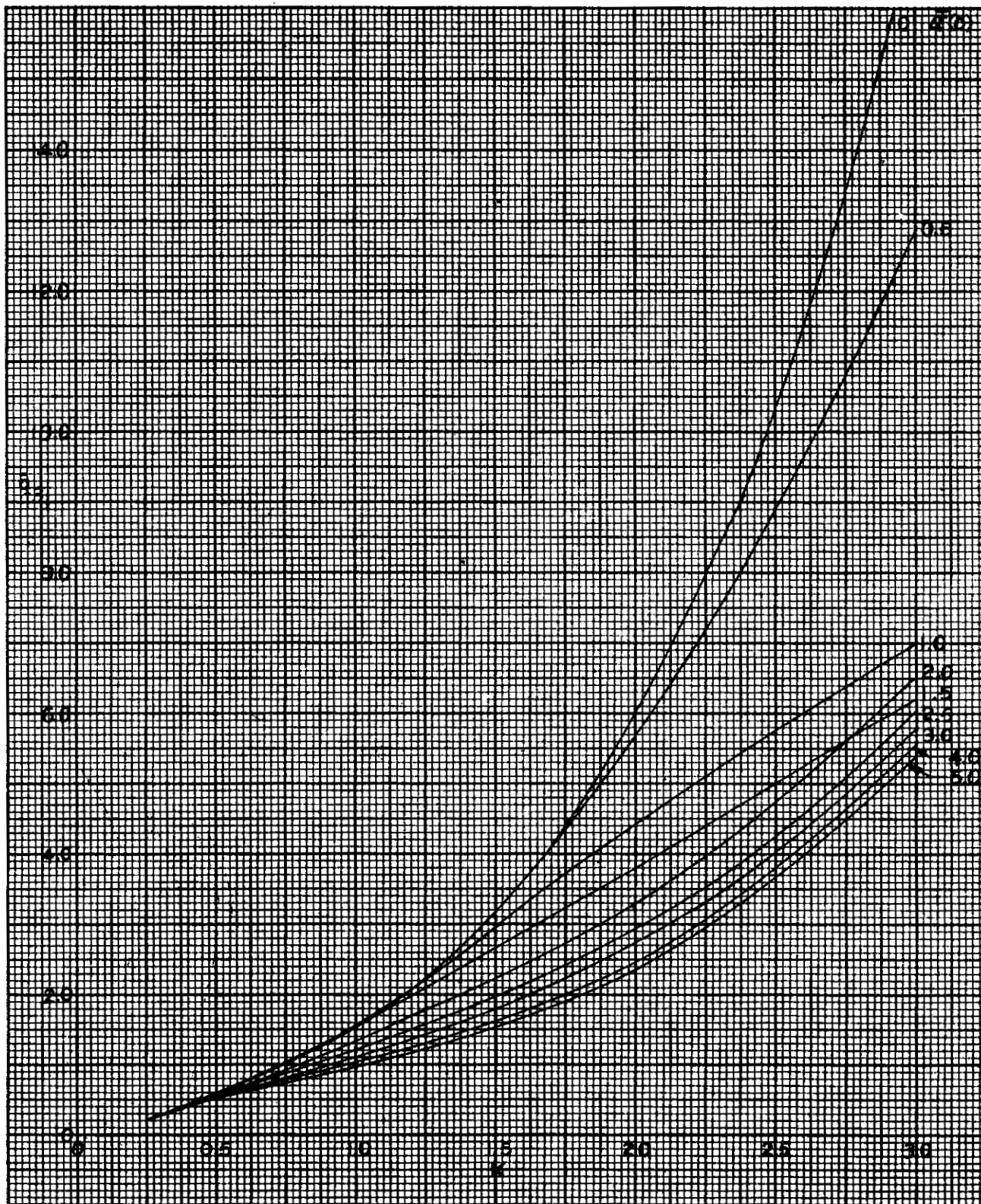


Figure 9. Half Diamond, $0 \leq \xi_i \leq 0.50$

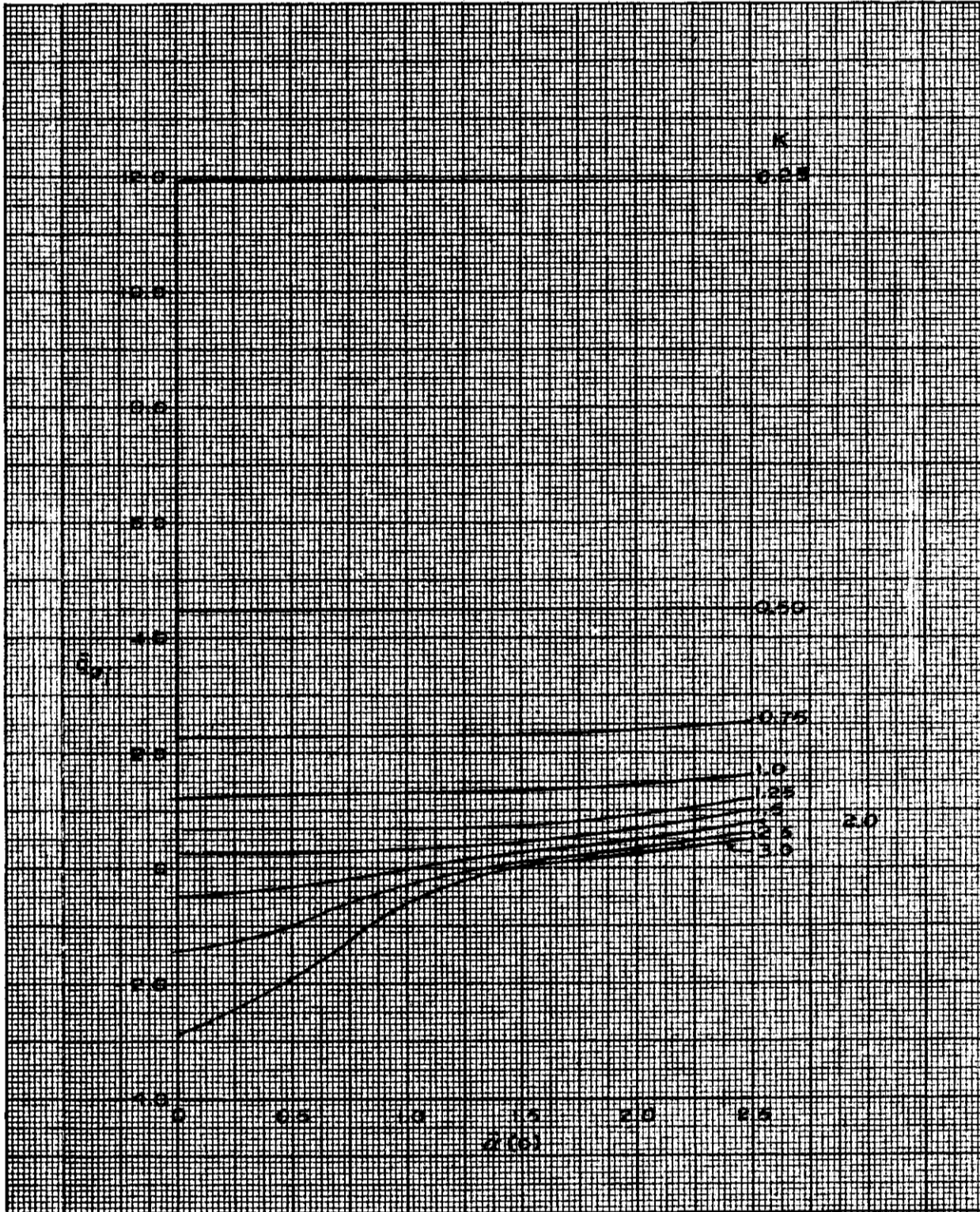


Figure 10. Half Diamond, $0.50 \leq \xi_i \leq 1.00$

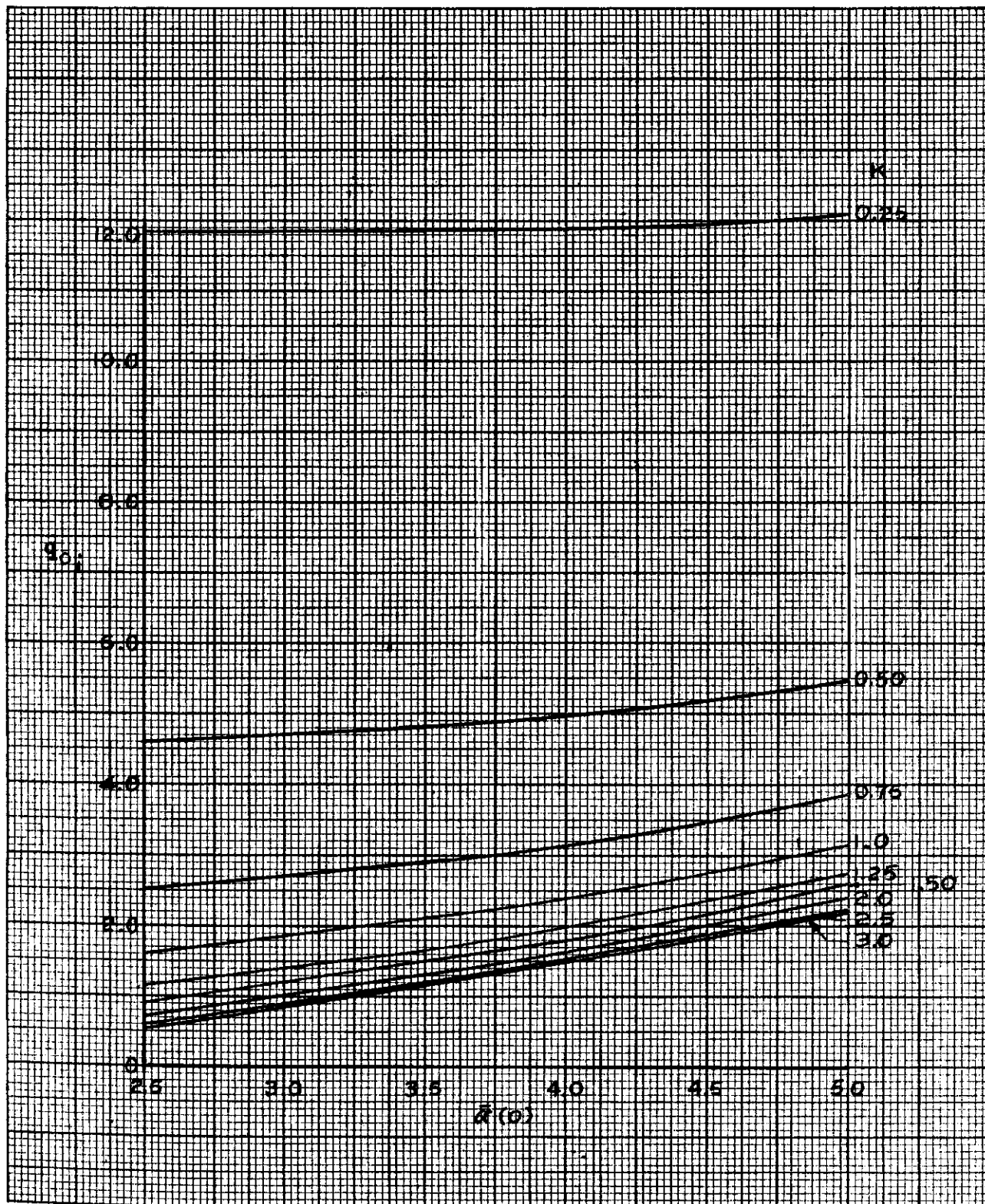


Figure 11. Half Diamond, $0.50 \leq \xi_1 \leq 1.00$

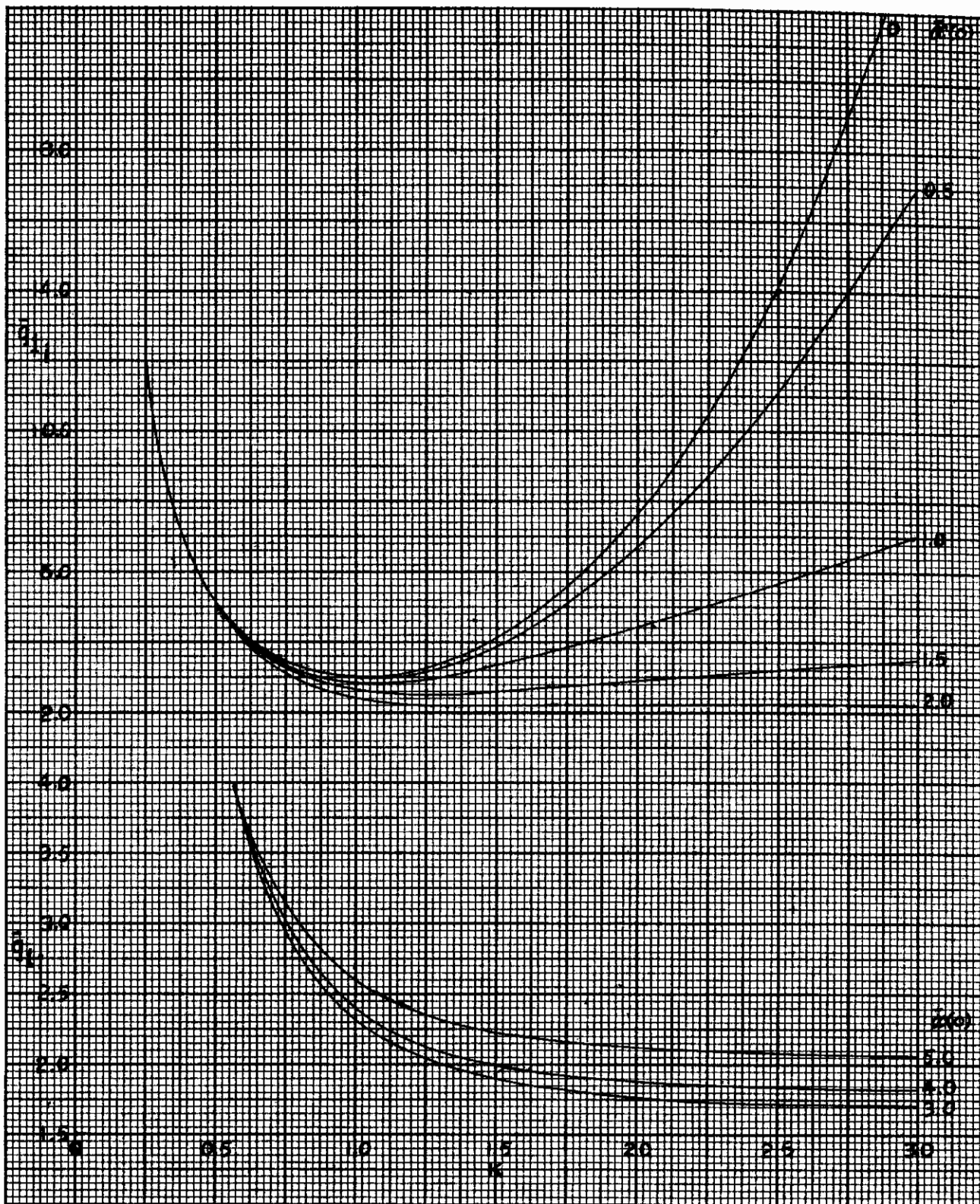


Figure 12. Half Diamond, $0.50 \leq \xi_i \leq 1.00$

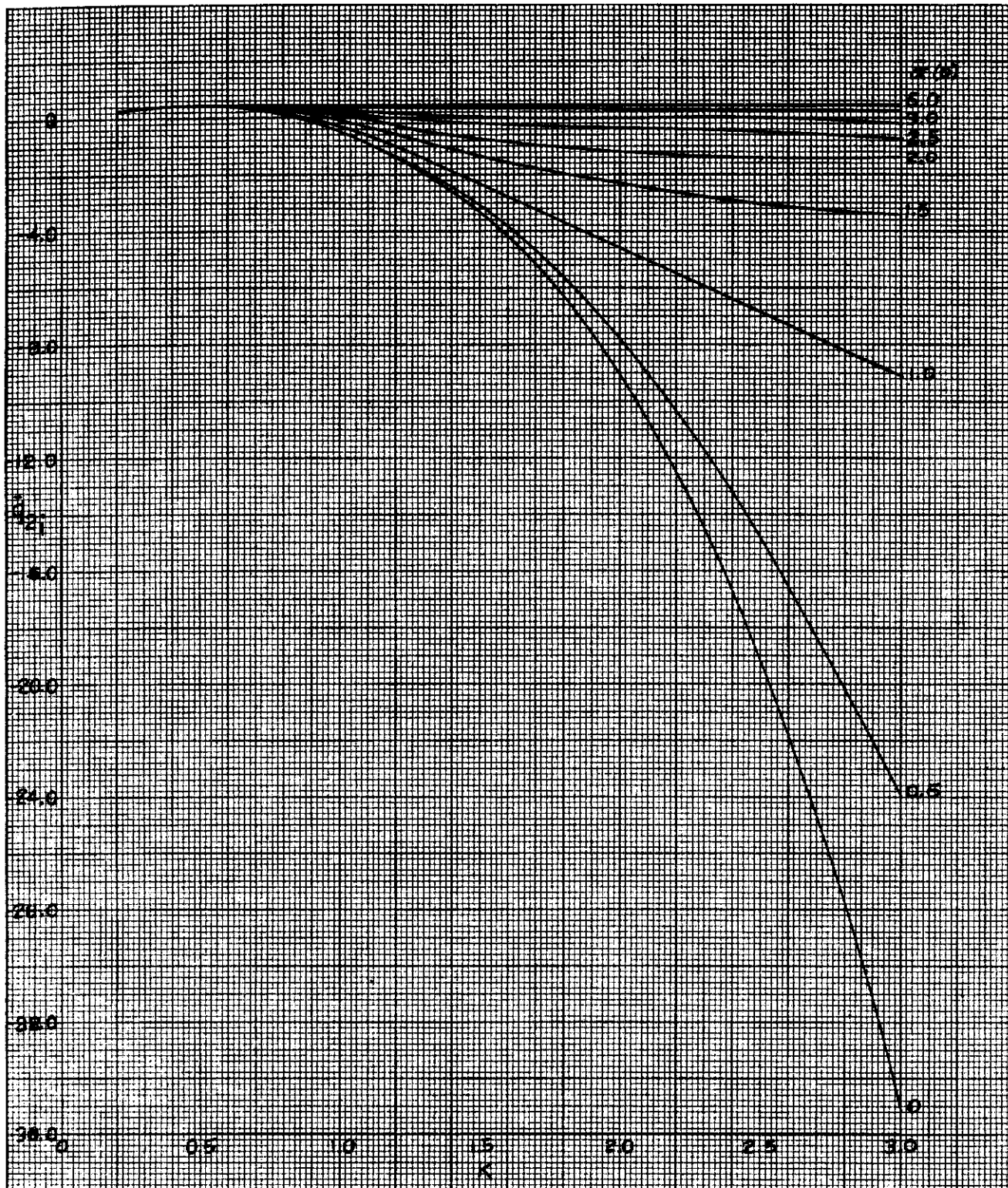


Figure 13. Half Diamond, $0.50 \leq \xi_i \leq 1.00$

$\bar{\alpha}(0)$

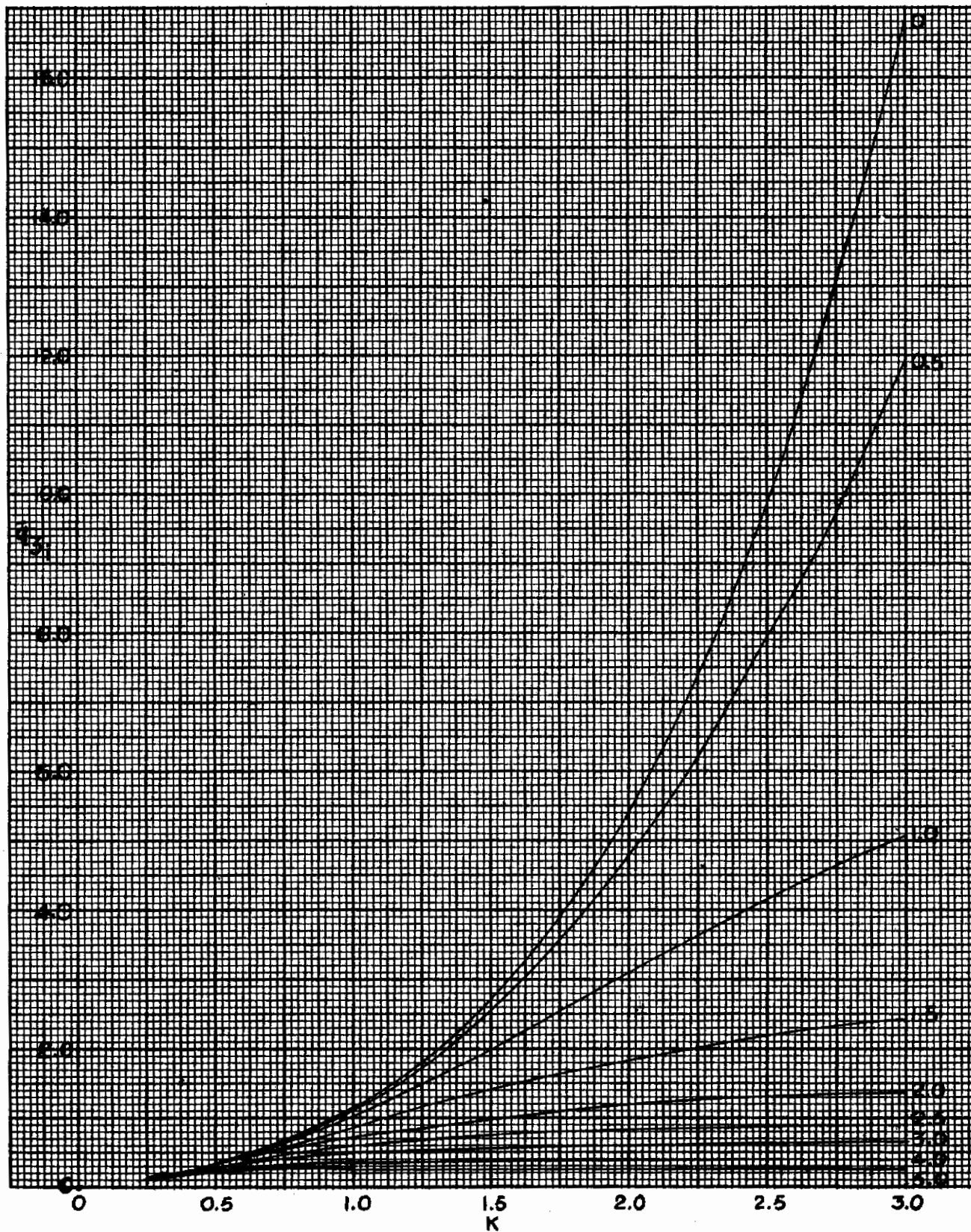


Figure 14. Half Diamond, $0.50 \leq \xi_1 \leq 1.00$

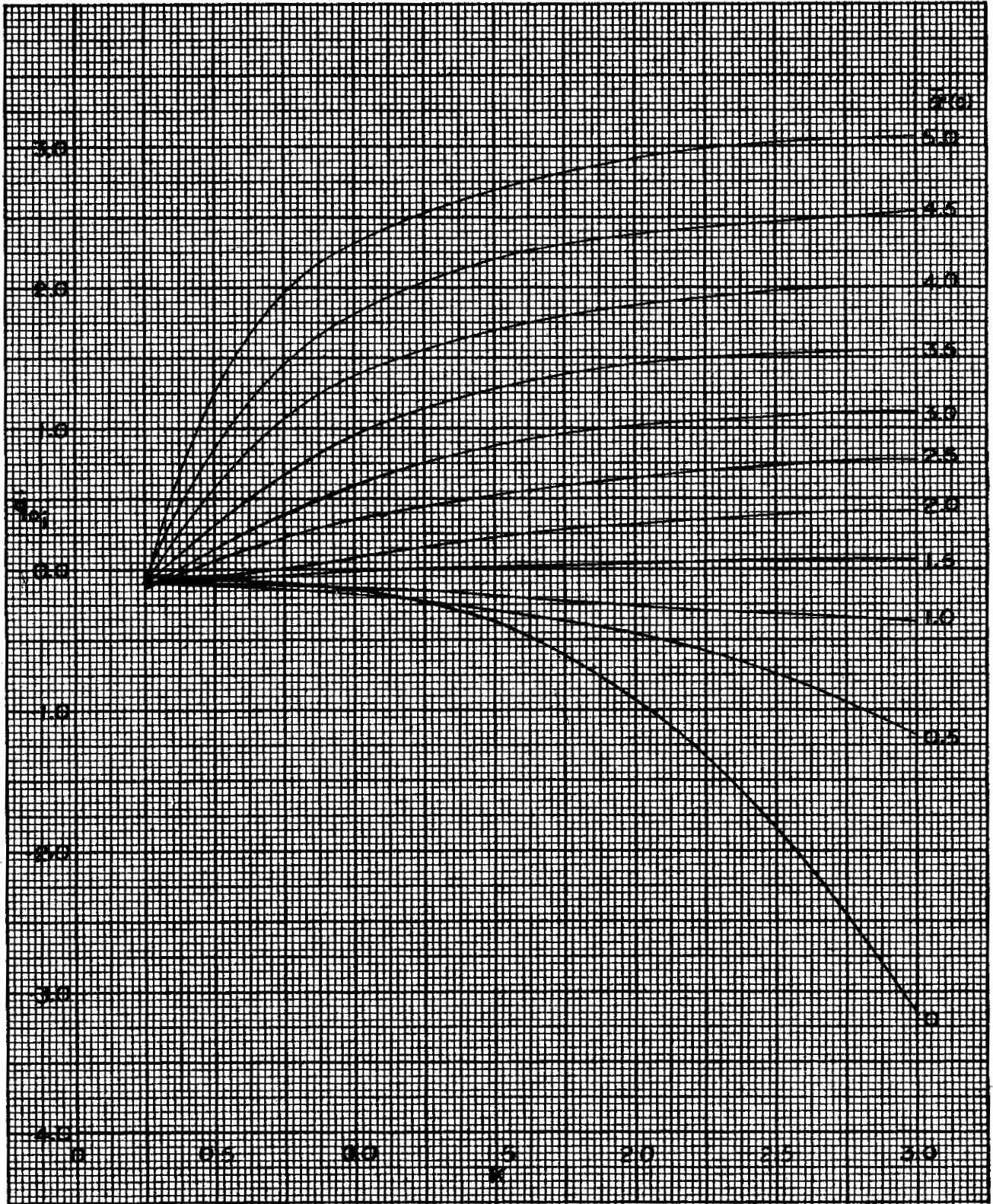


Figure 15. Double Wedge, $0 \leq \xi_i \leq 1.00$

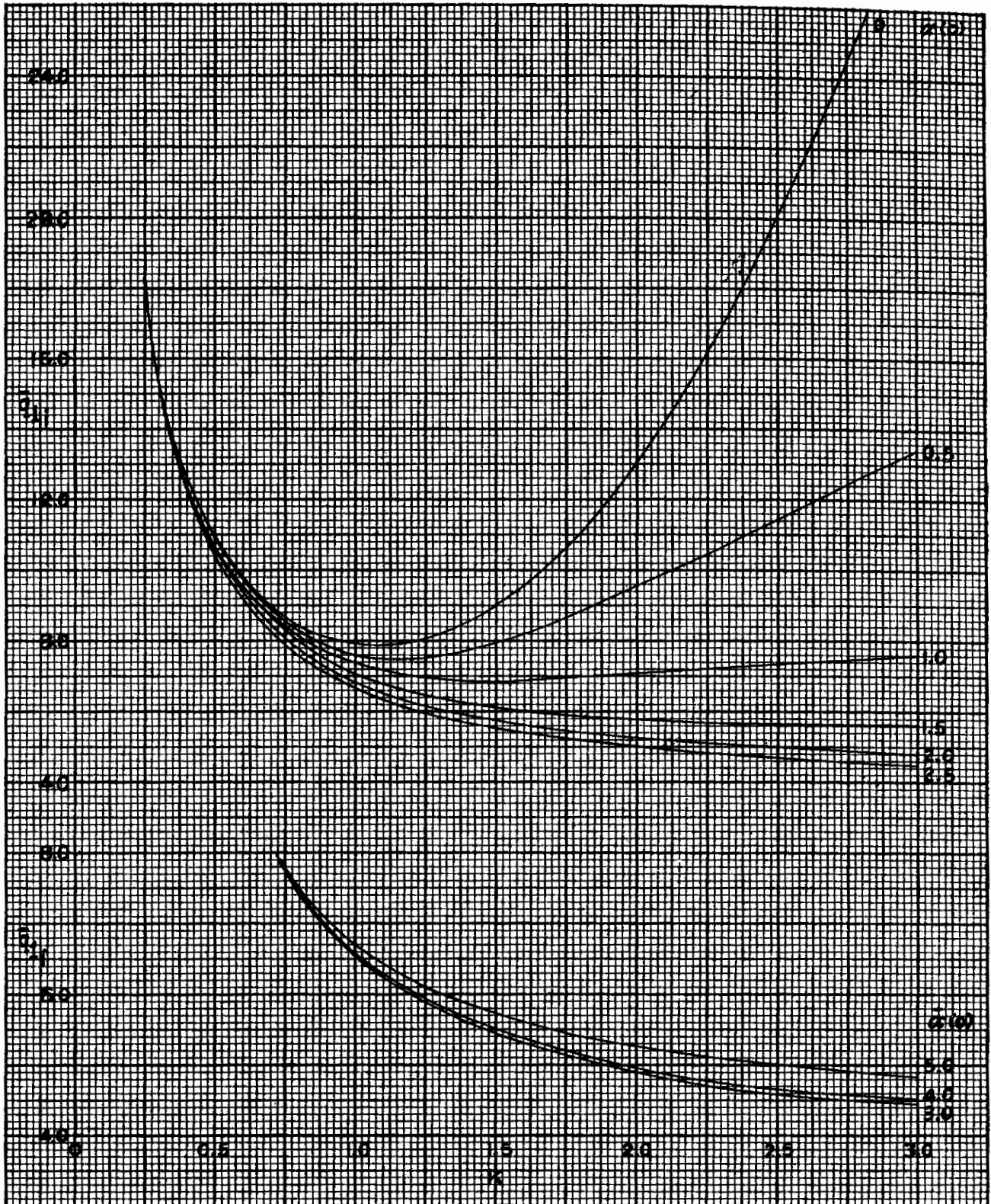


Figure 16. Double Wedge, $0 \leq \xi_1 \leq 1.00$

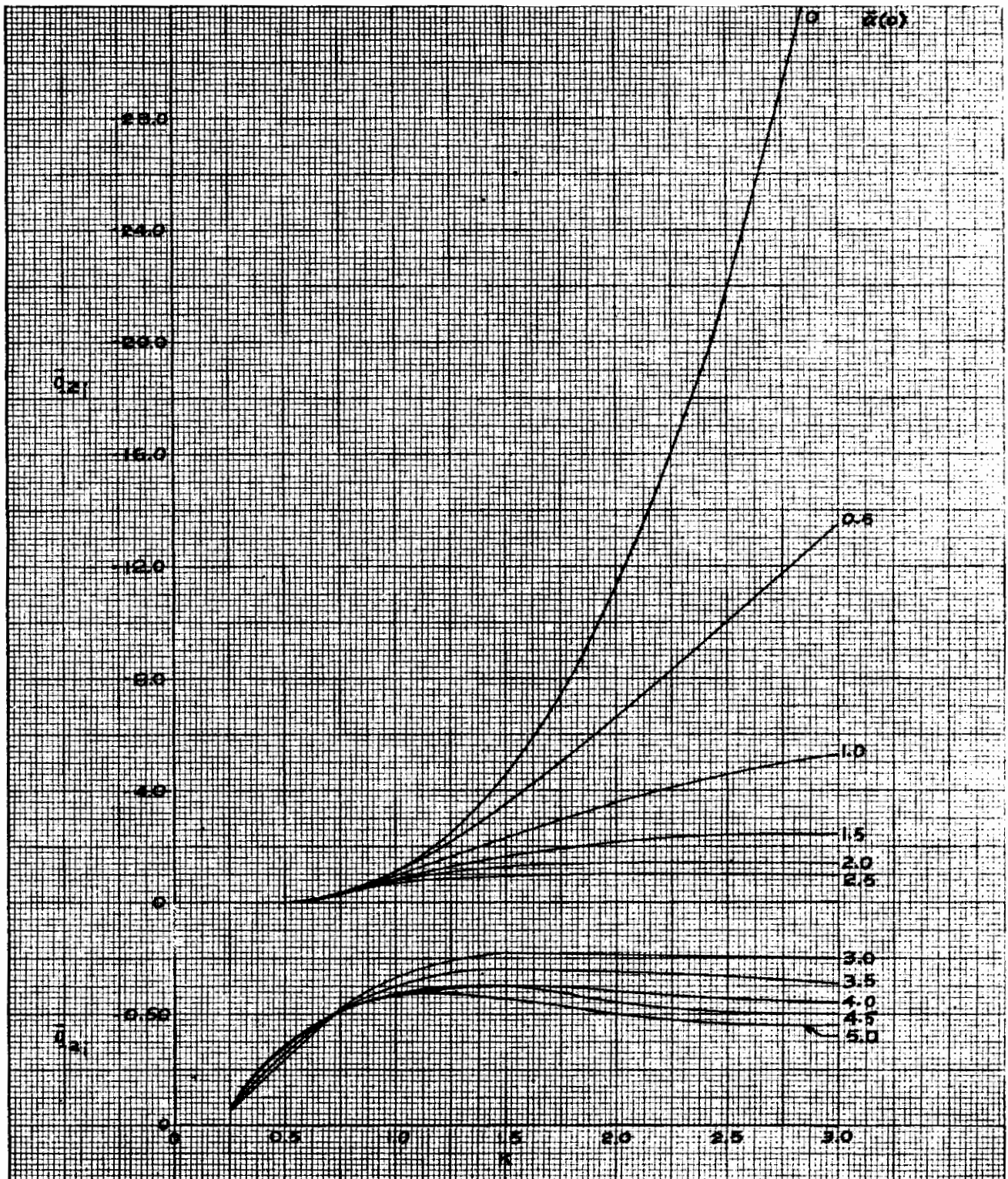


Figure 17. Double Wedge, $0 \leq \xi_i \leq 1.00$

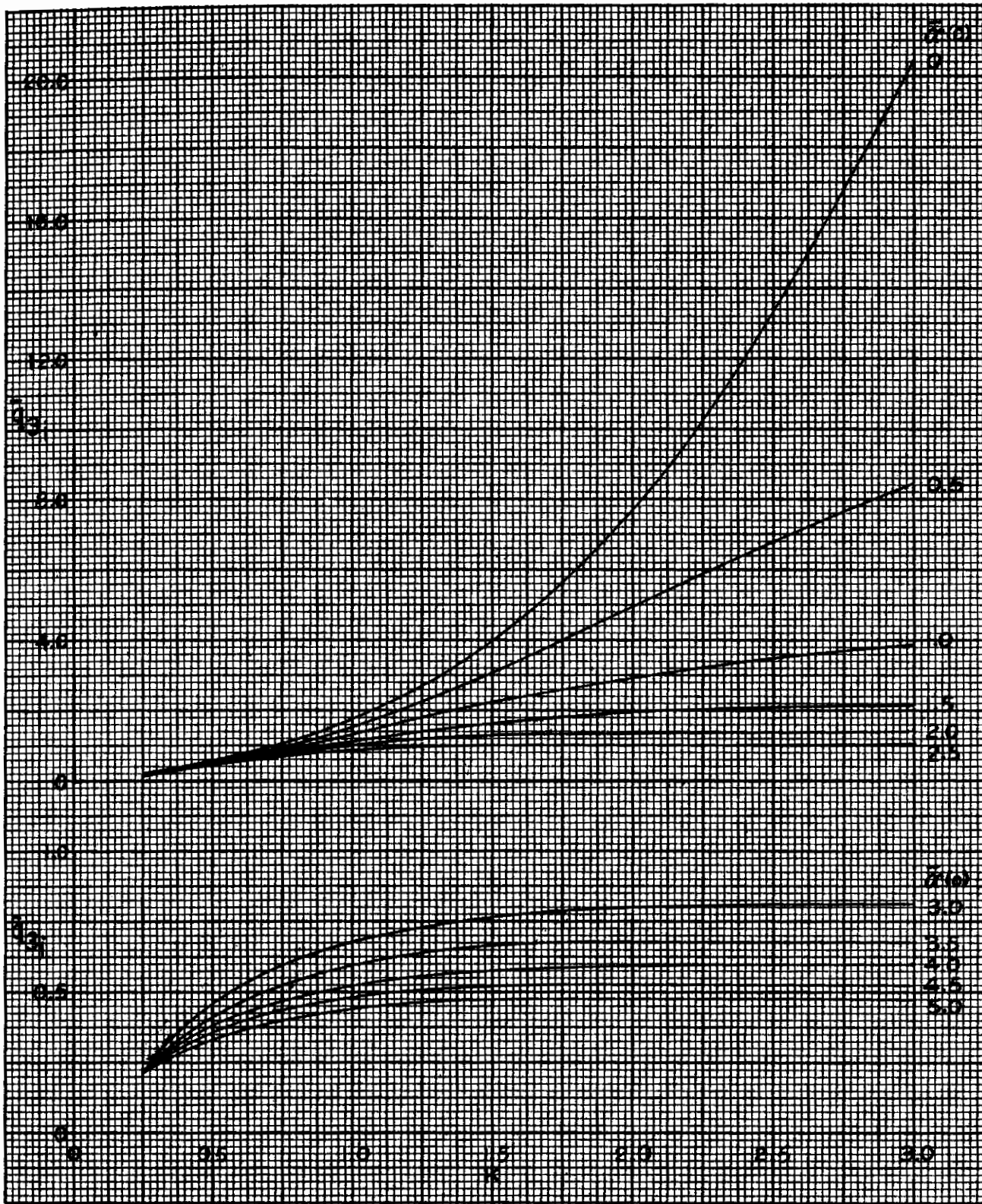


Figure 18. Double Wedge, $0 \leq \xi_i \leq 1.00$

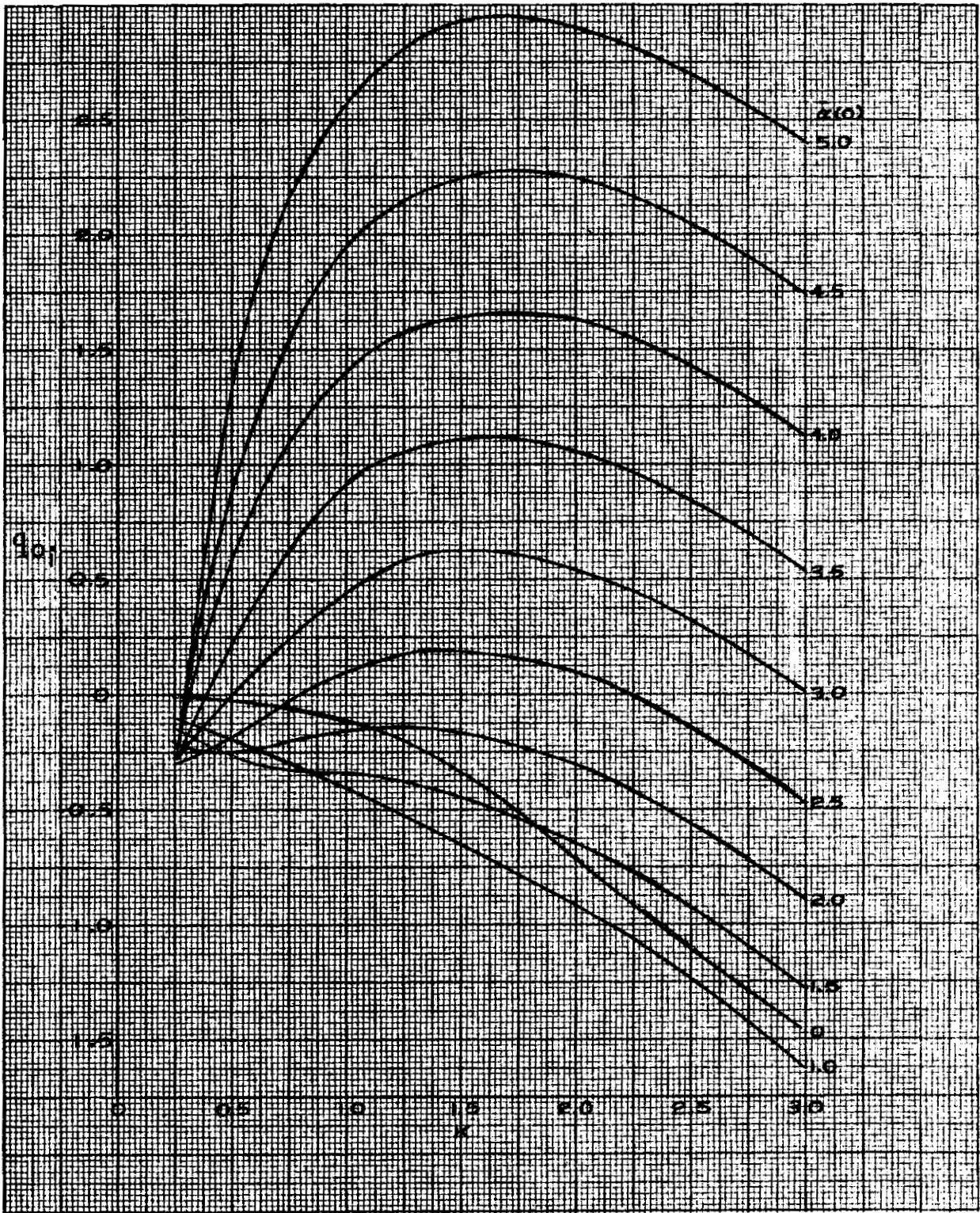


Figure 19. Diamond, $0 \leq \xi_i \leq 0.50$

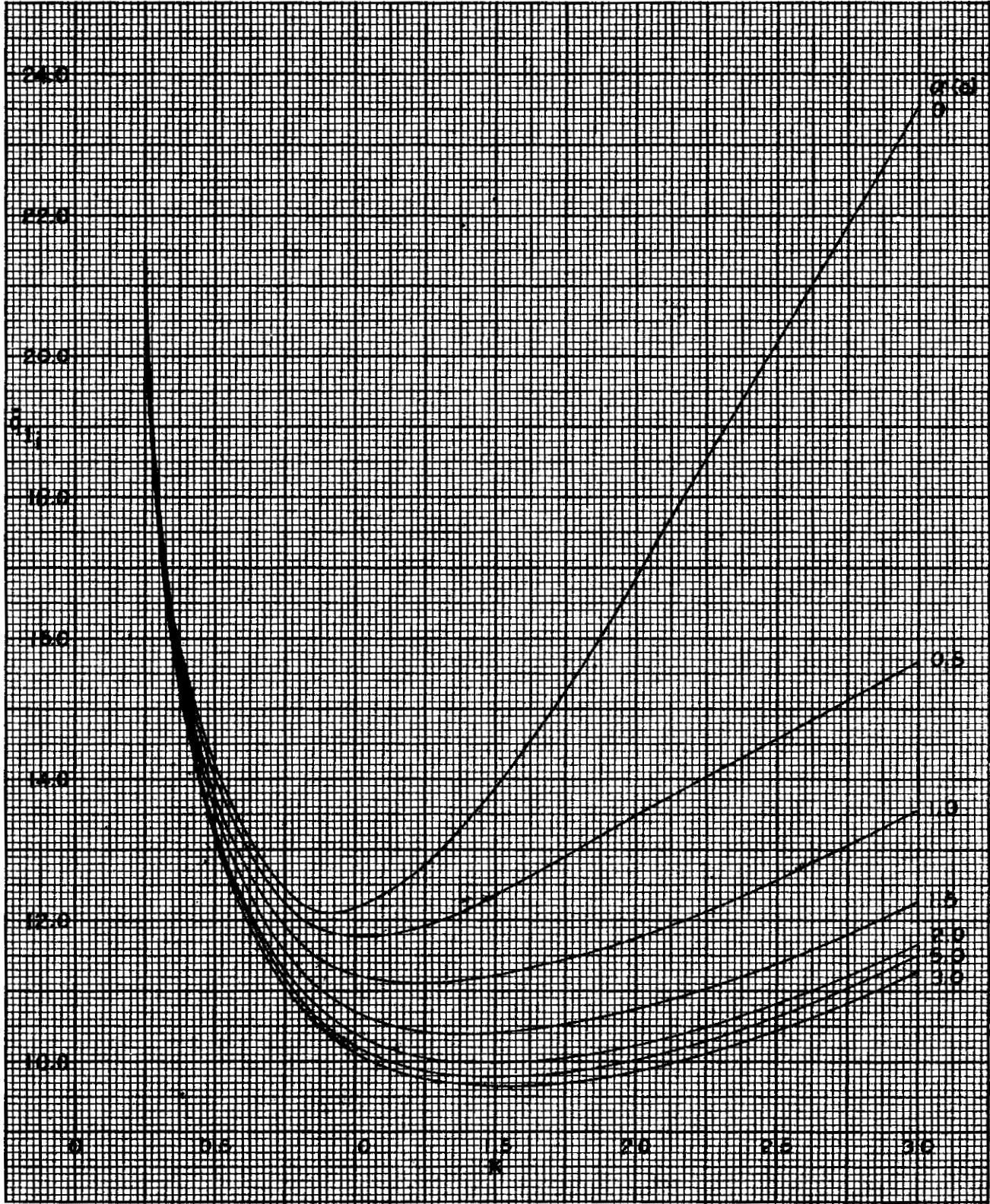


Figure 20. Diamond, $0 \leq \xi_1 \leq 0.50$

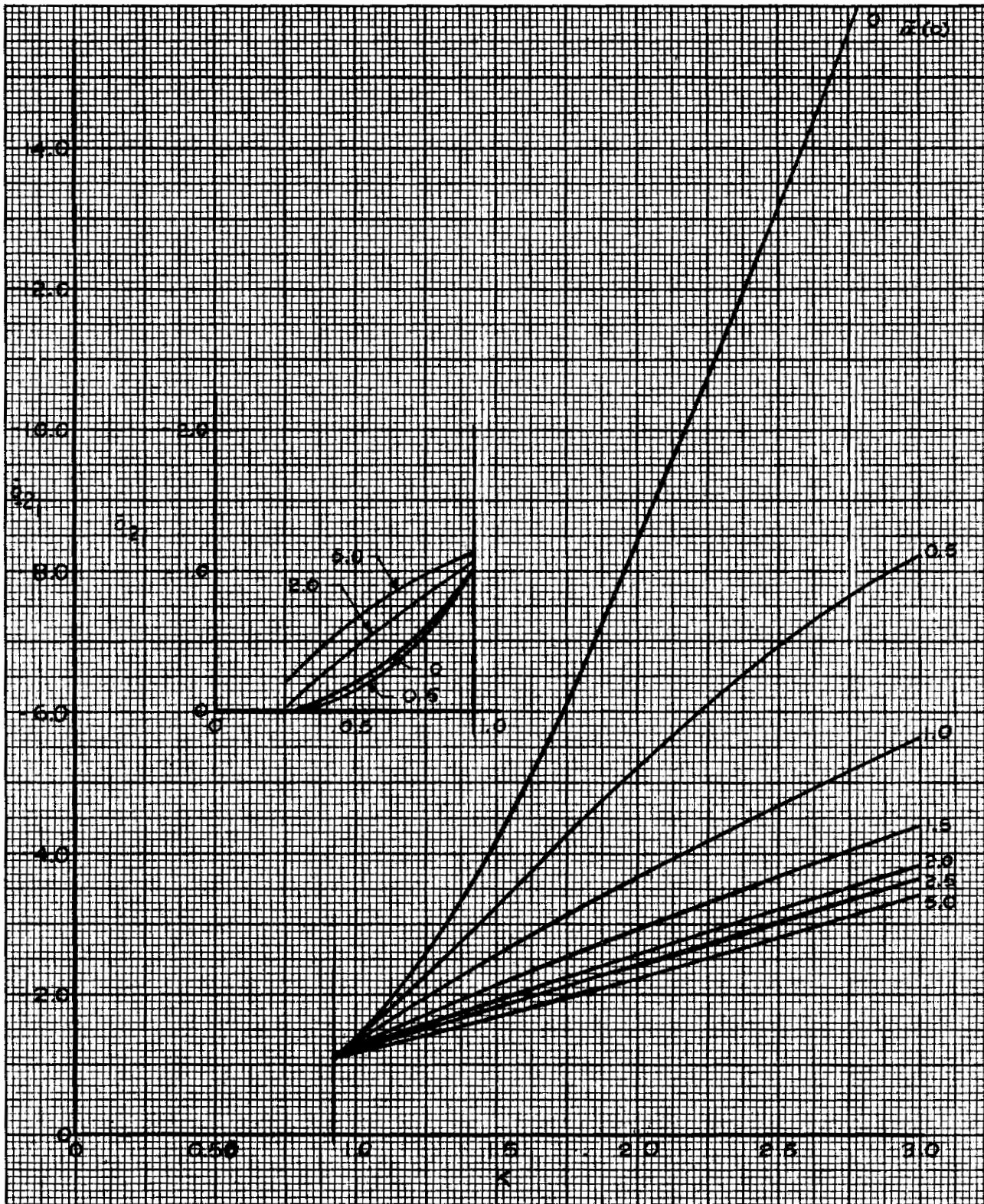


Figure 21. Diamond, $0 \leq \xi_i \leq 0.50$

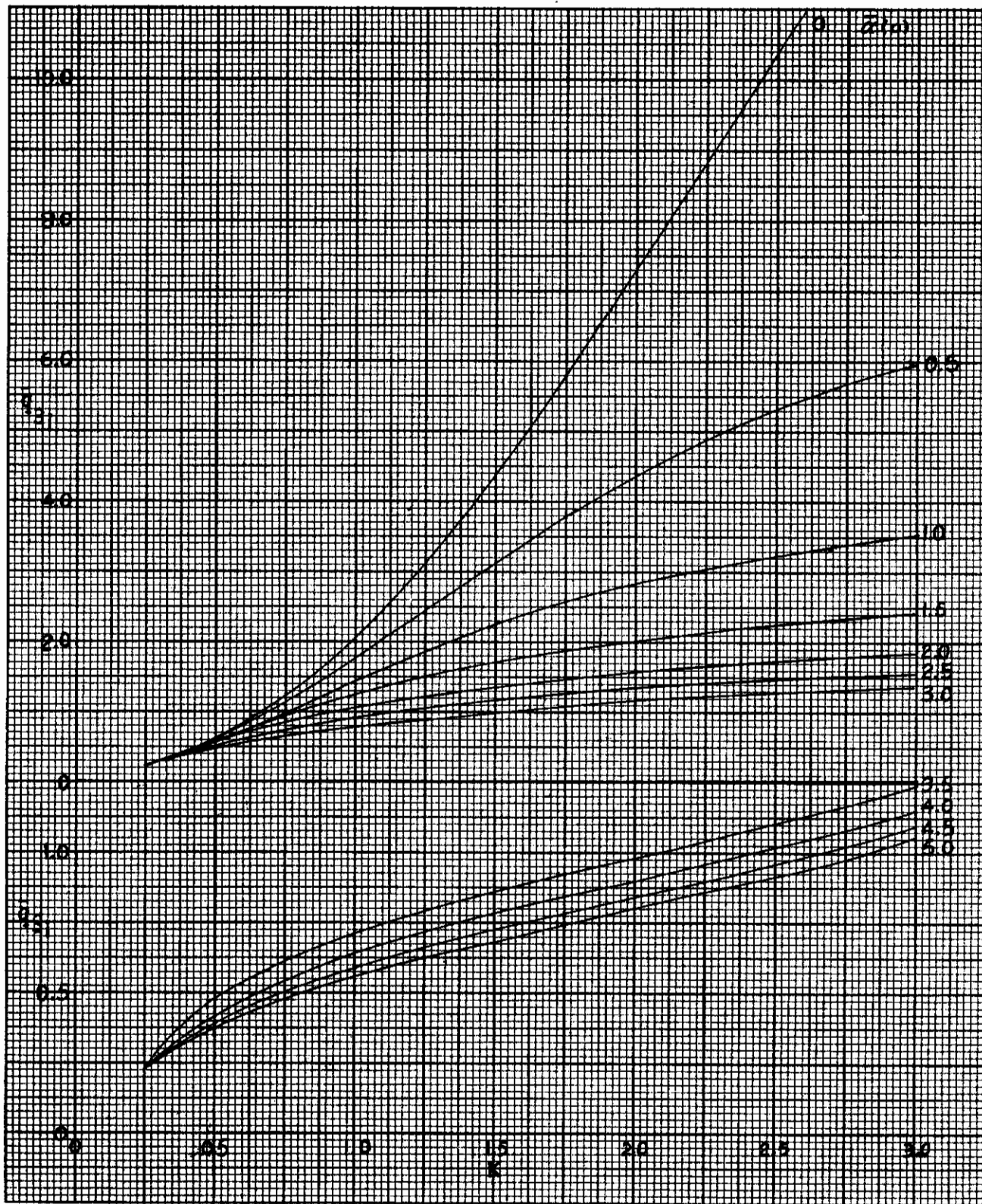


Figure 22. Diamond, $0 \leq \xi_1 \leq 0.50$

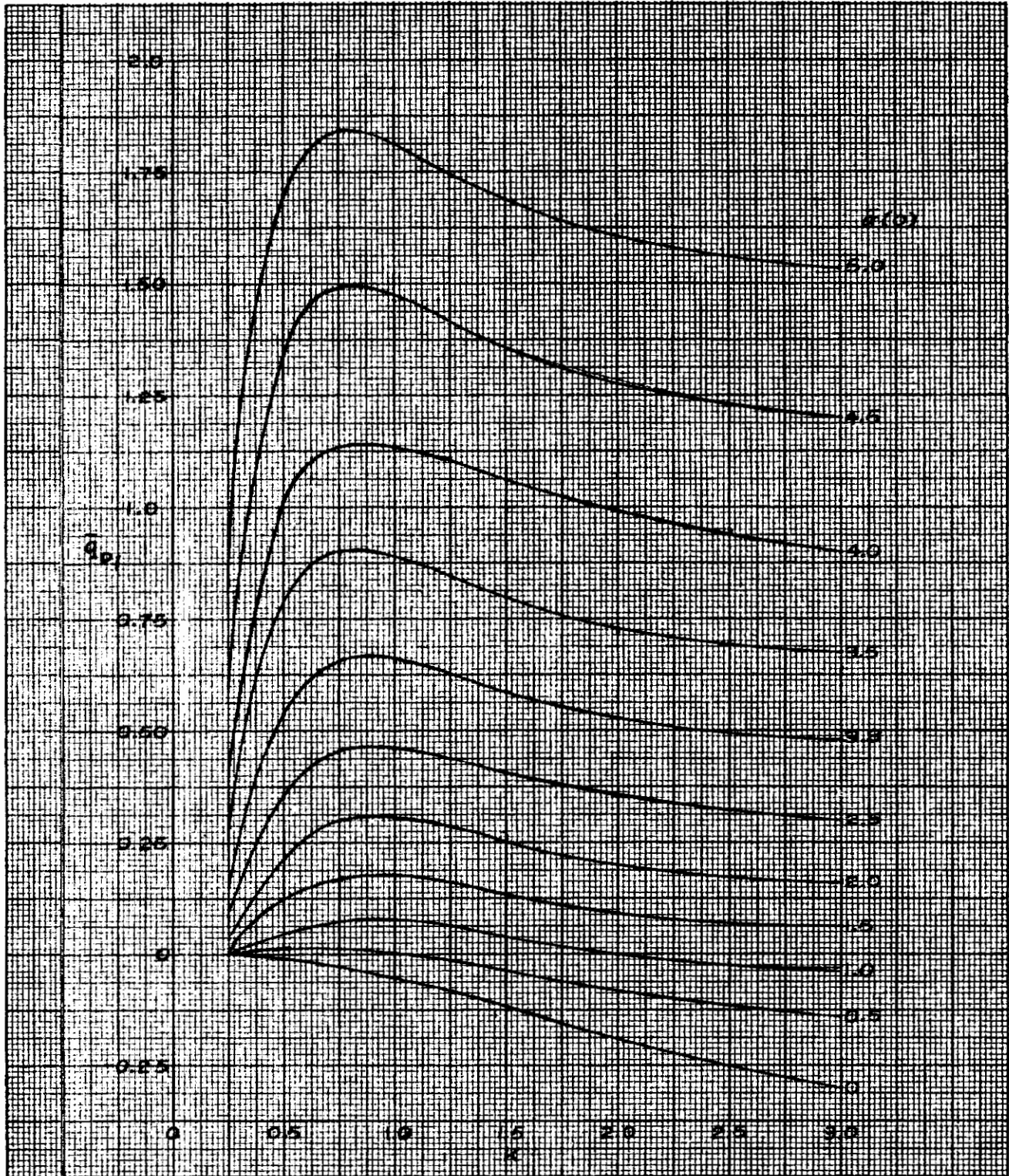


Figure 23. Diamond $0.50 \leq \xi_i \leq 1.00$

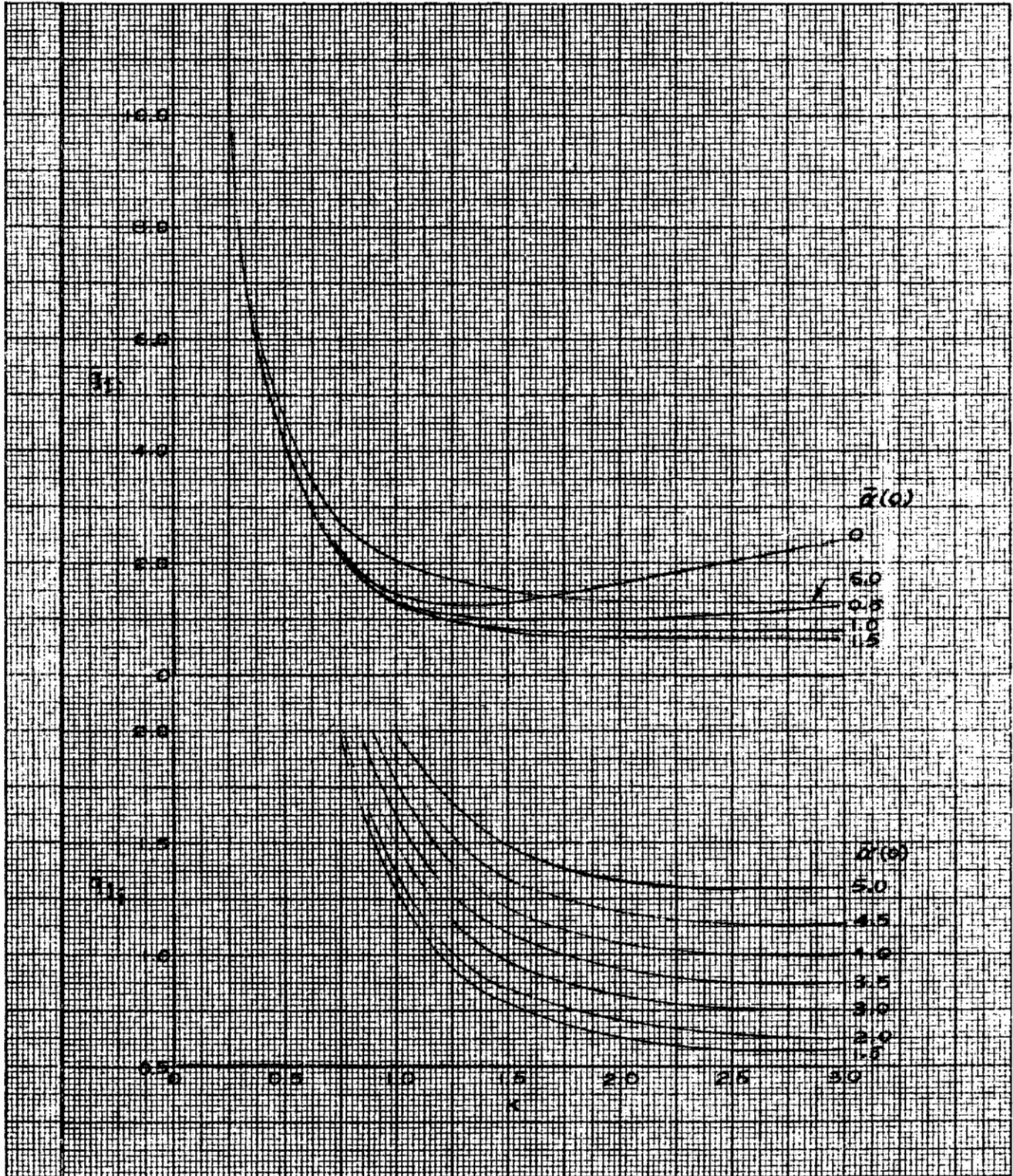


Figure 24. Diamond $0.50 \leq \xi_i \leq 1.00$

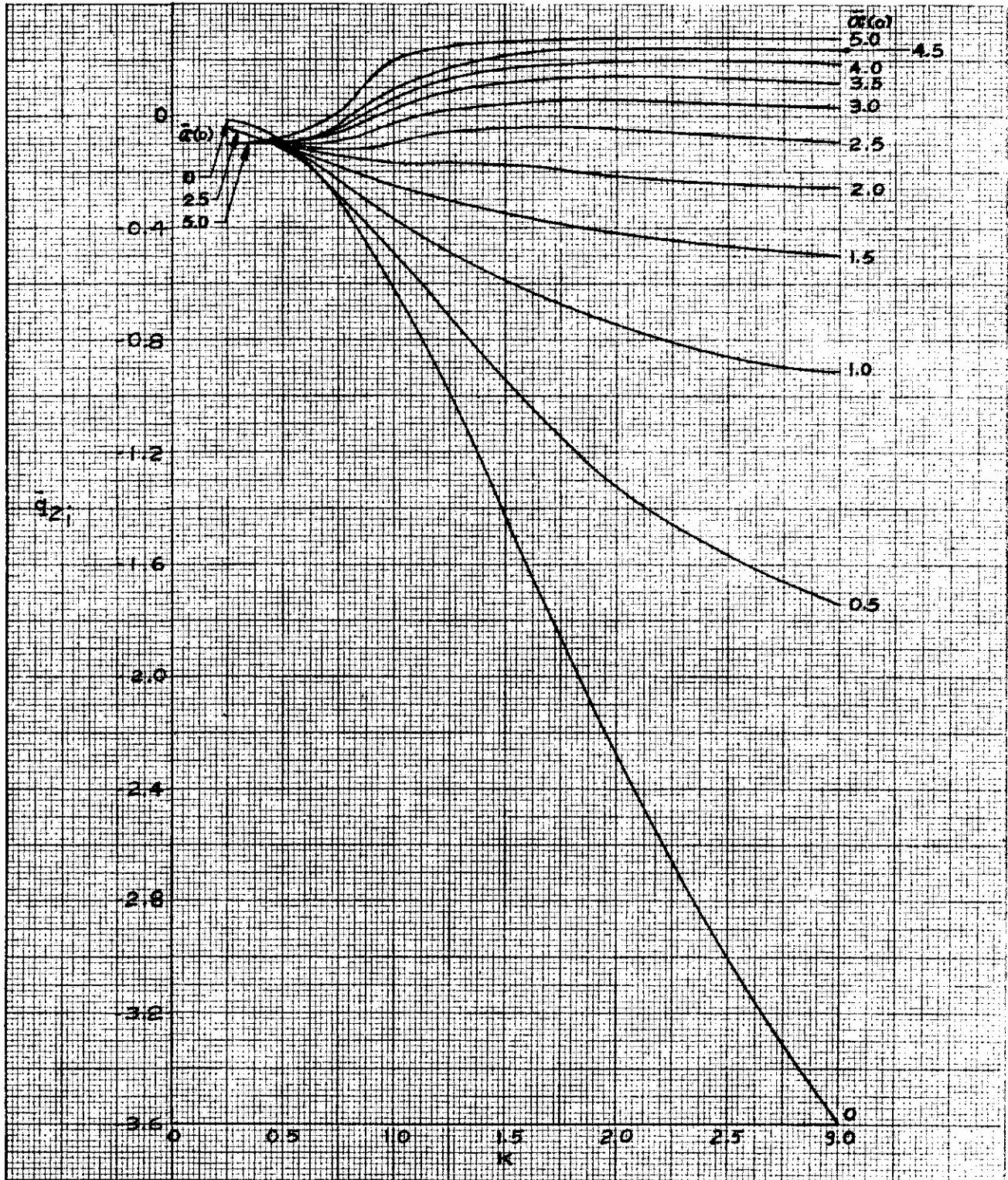


Figure 25. Diamond, $0.50 \leq \xi_i \leq 1.00$

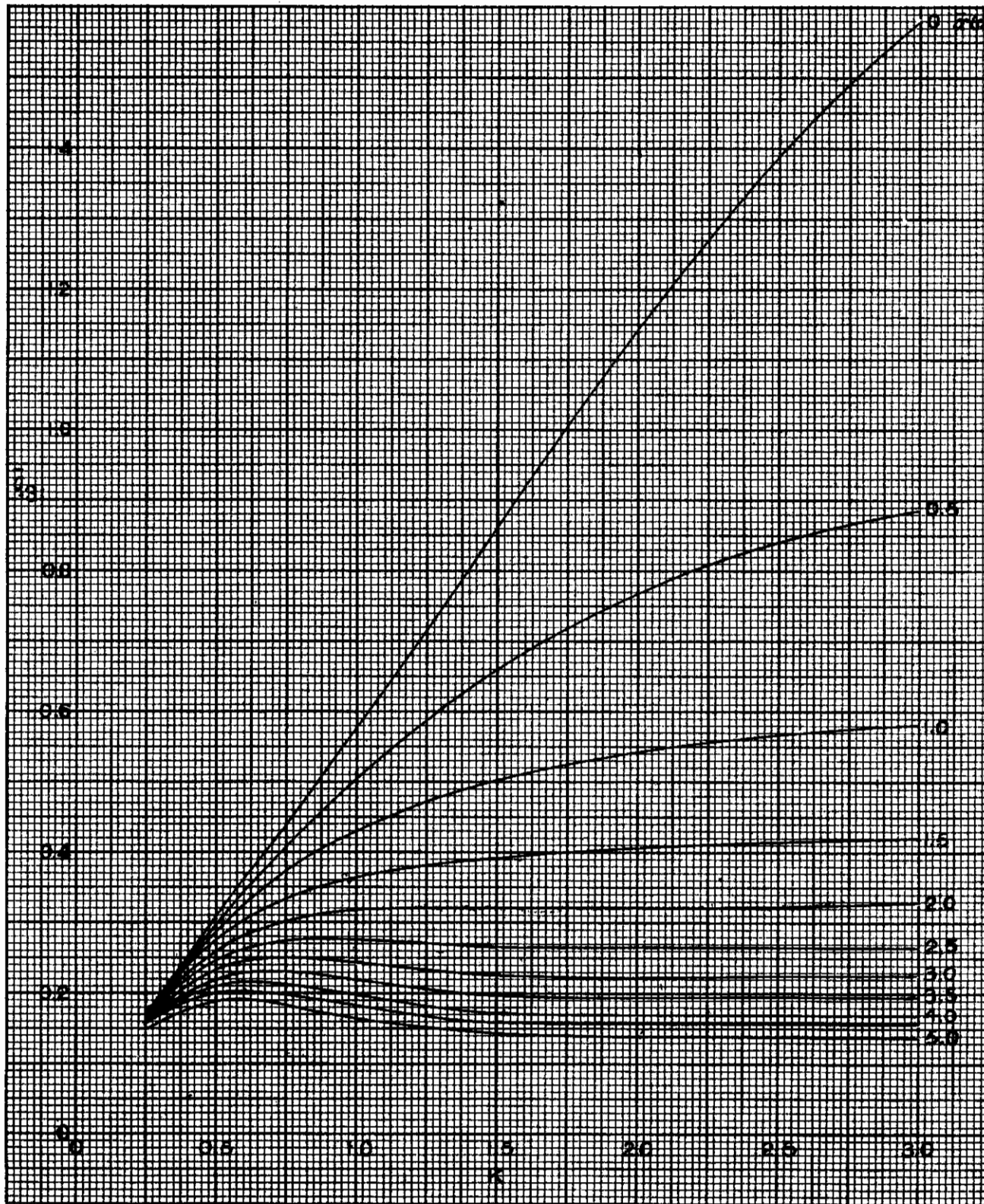


Figure 26. Diamond, $0.50 \leq \xi_1 \leq 1.00$

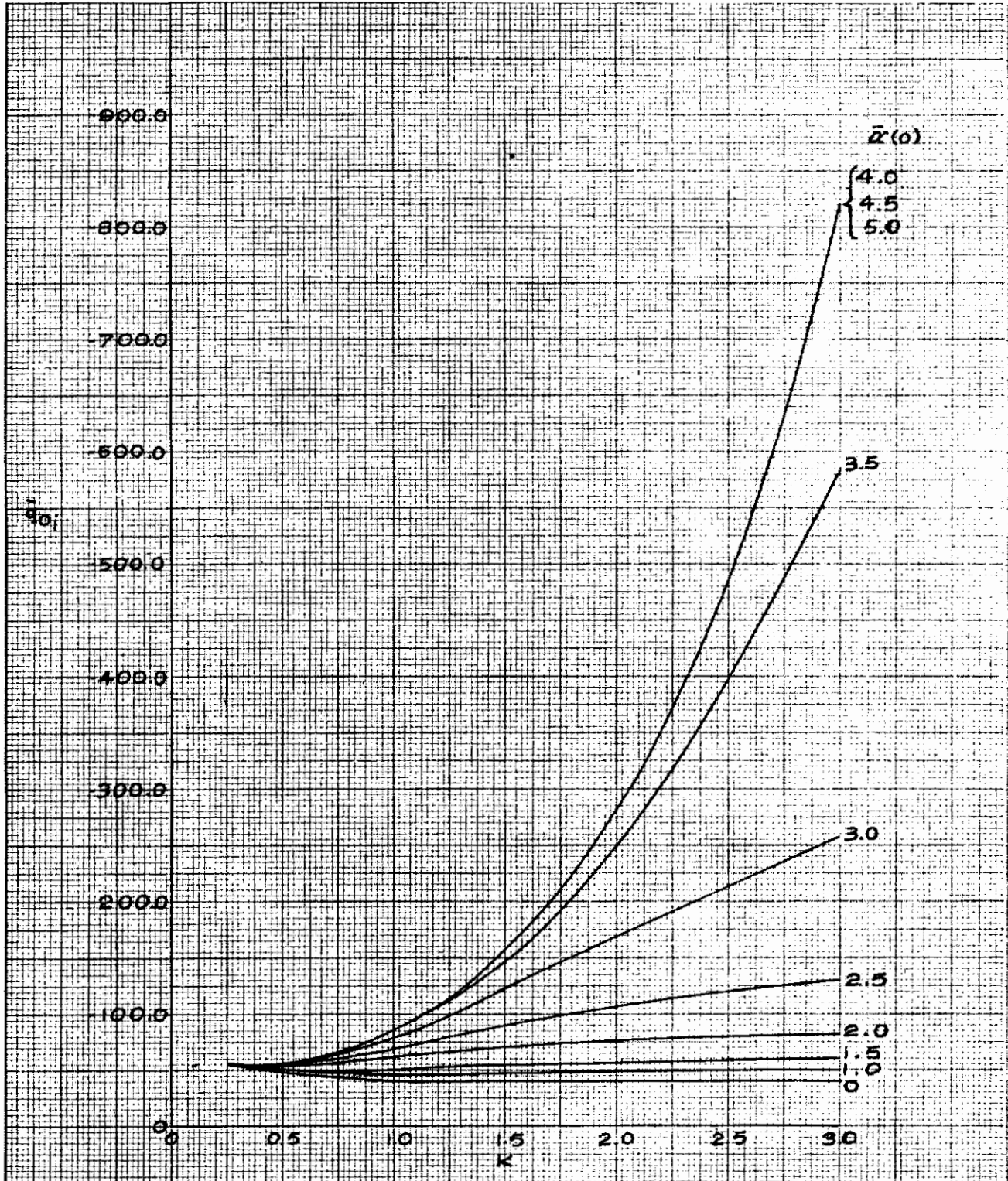


Figure 27. Single Parabolic, $\xi_1 = 0$

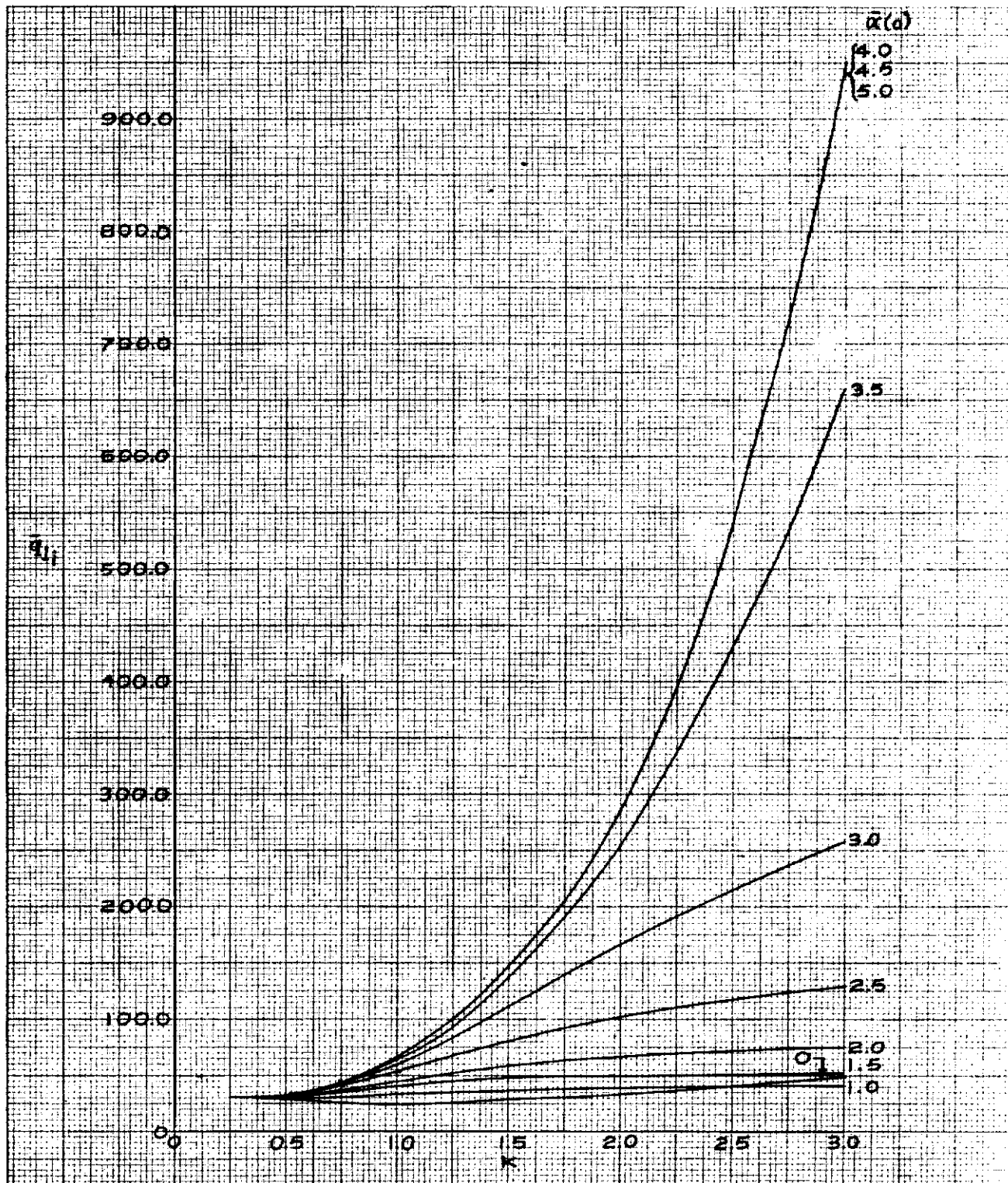


Figure 28. Single Parabolic, $\xi_i = 0$

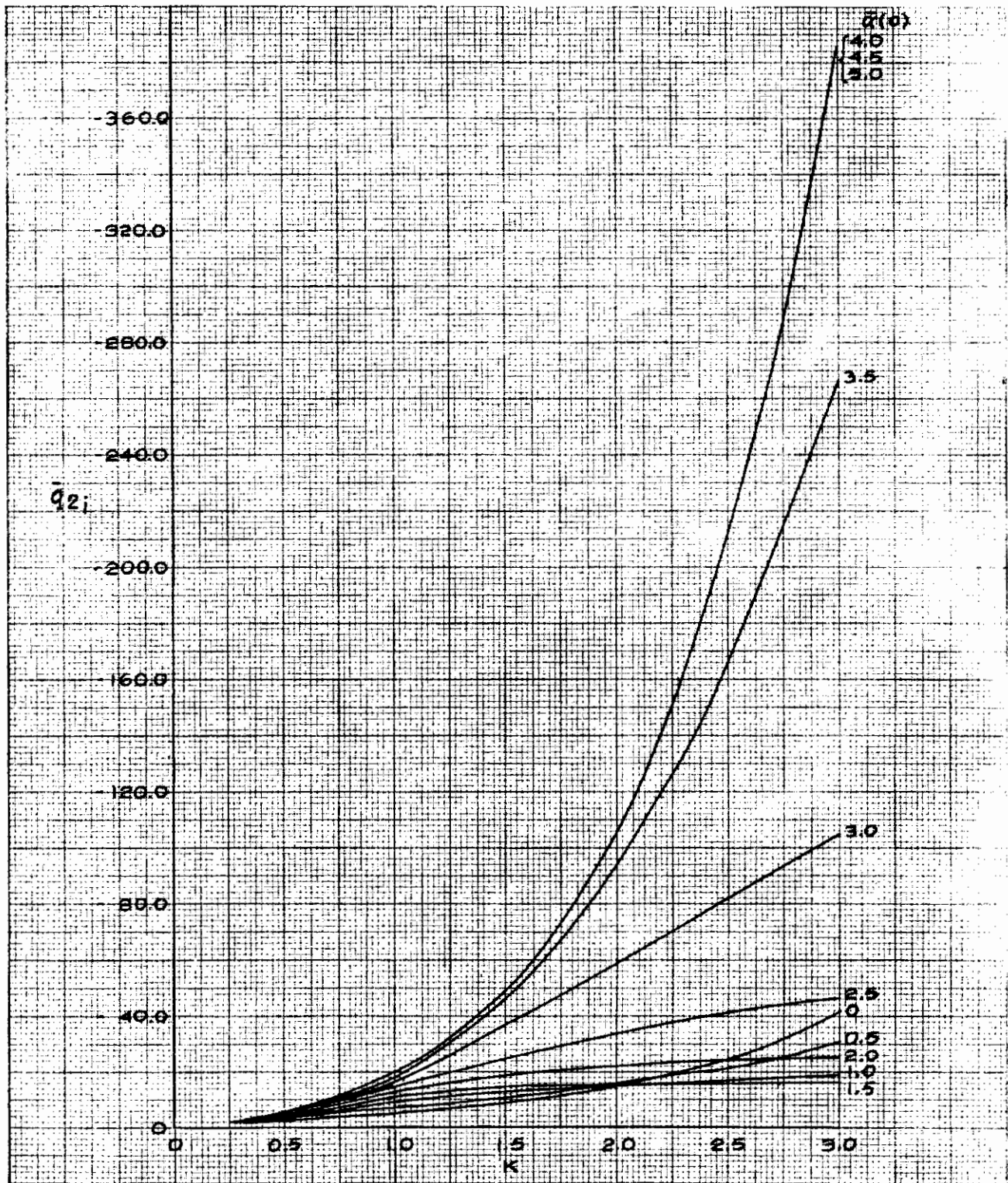


Figure 29. Single Parabolic, $\xi_i = 0$

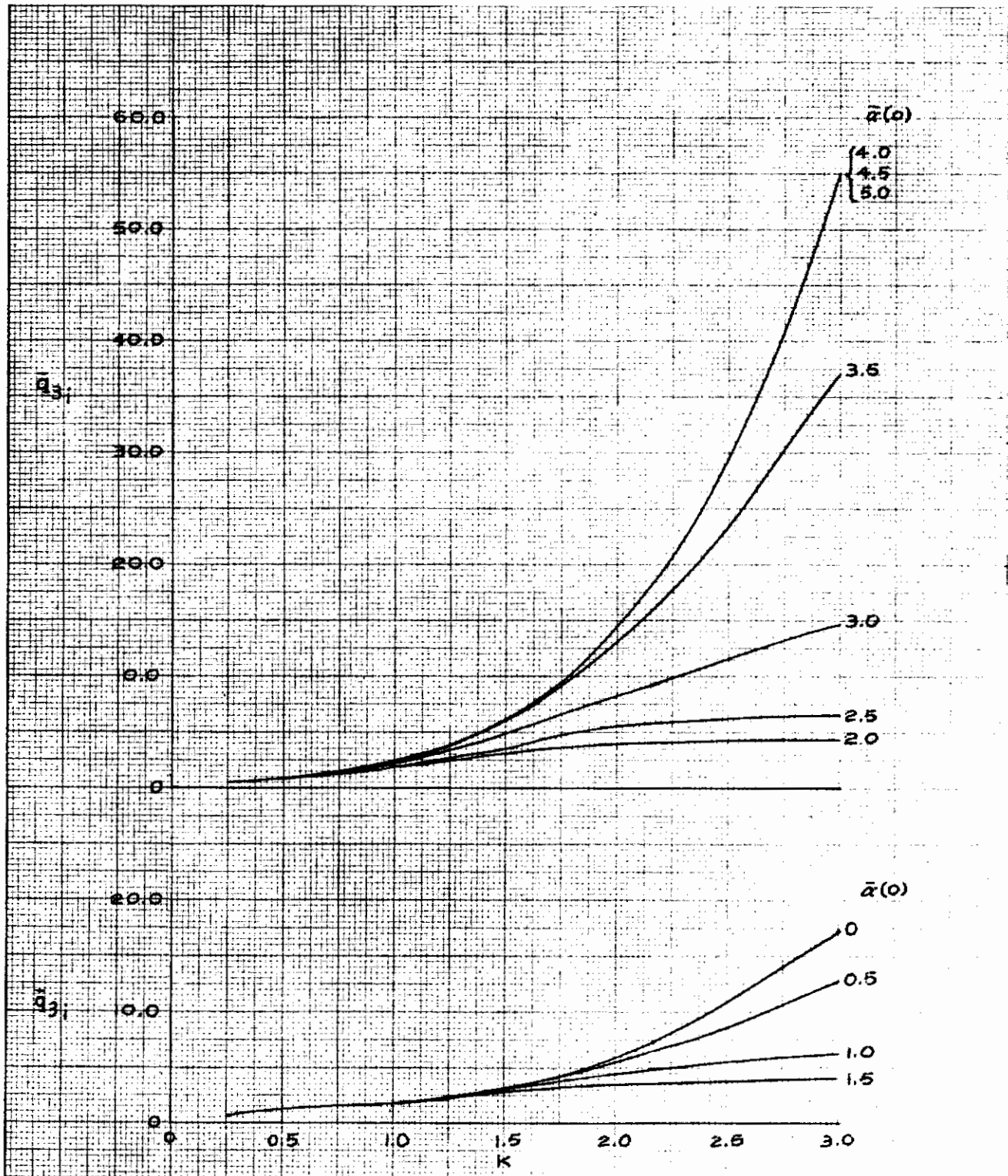


Figure 30. Single Parabolic, $\xi_i = 0$

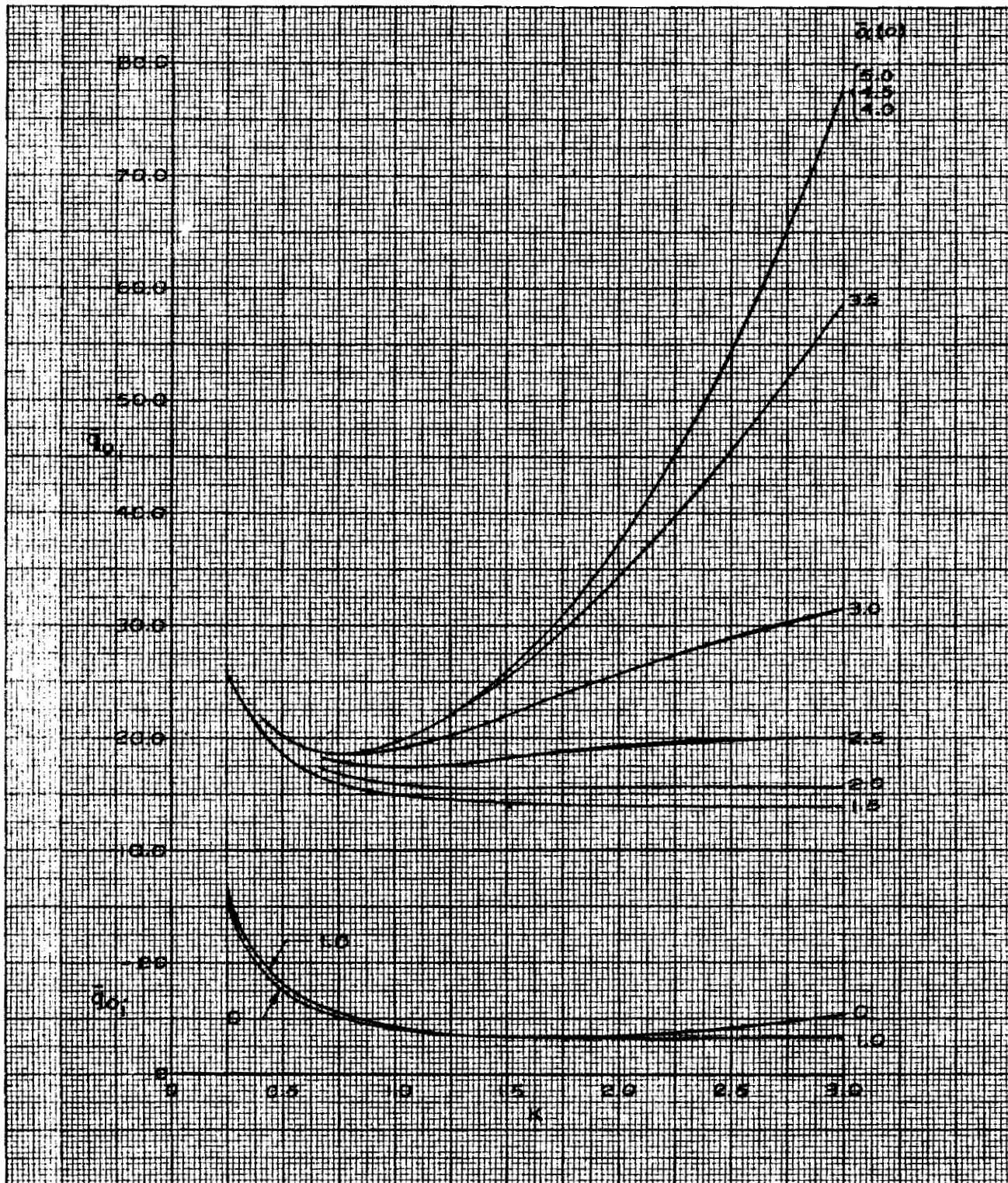


Figure 31. Single Parabolic, $\xi_i = 0.20$

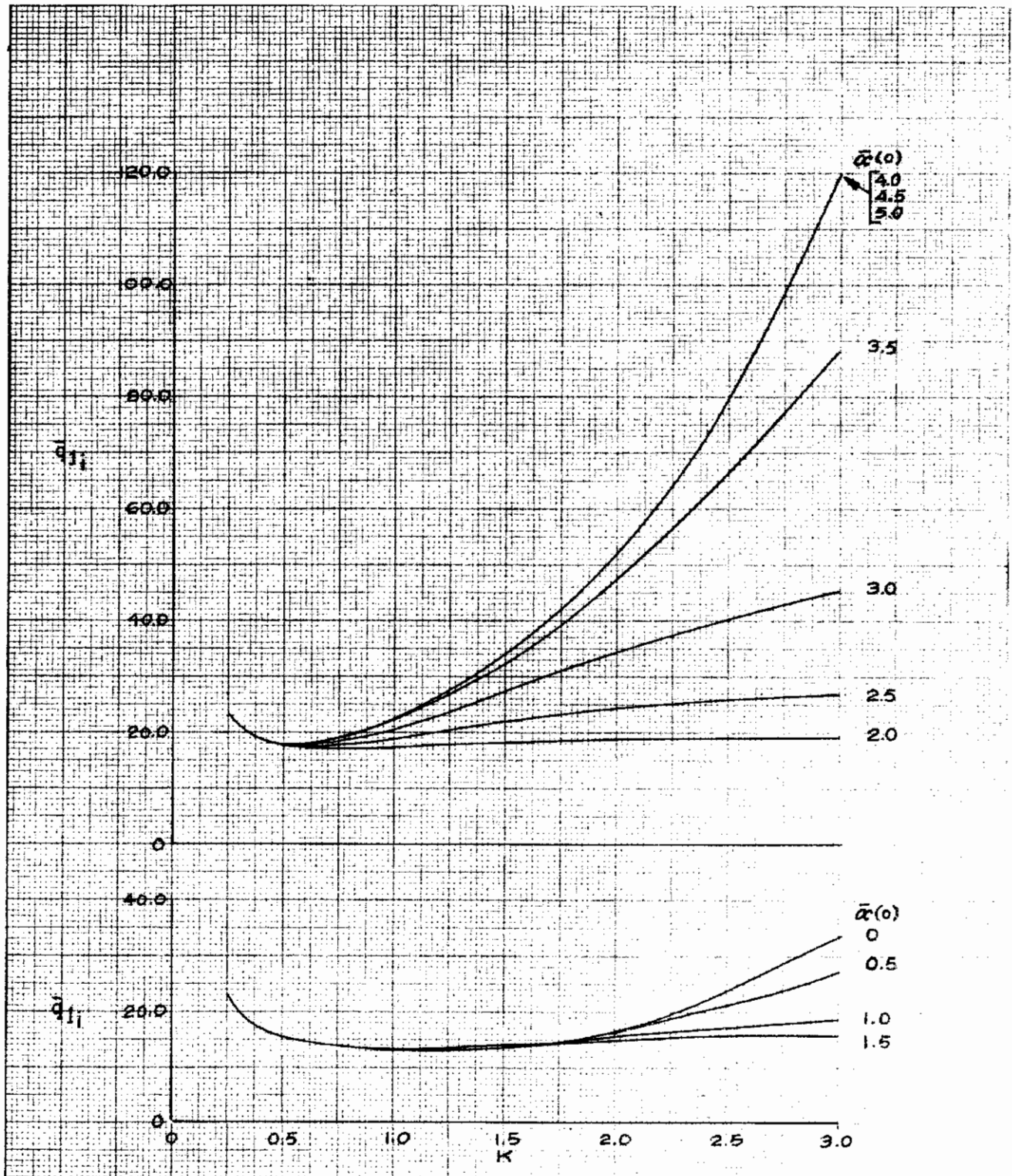


Figure 32. Single Parabolic, $\xi_i = 0.20$

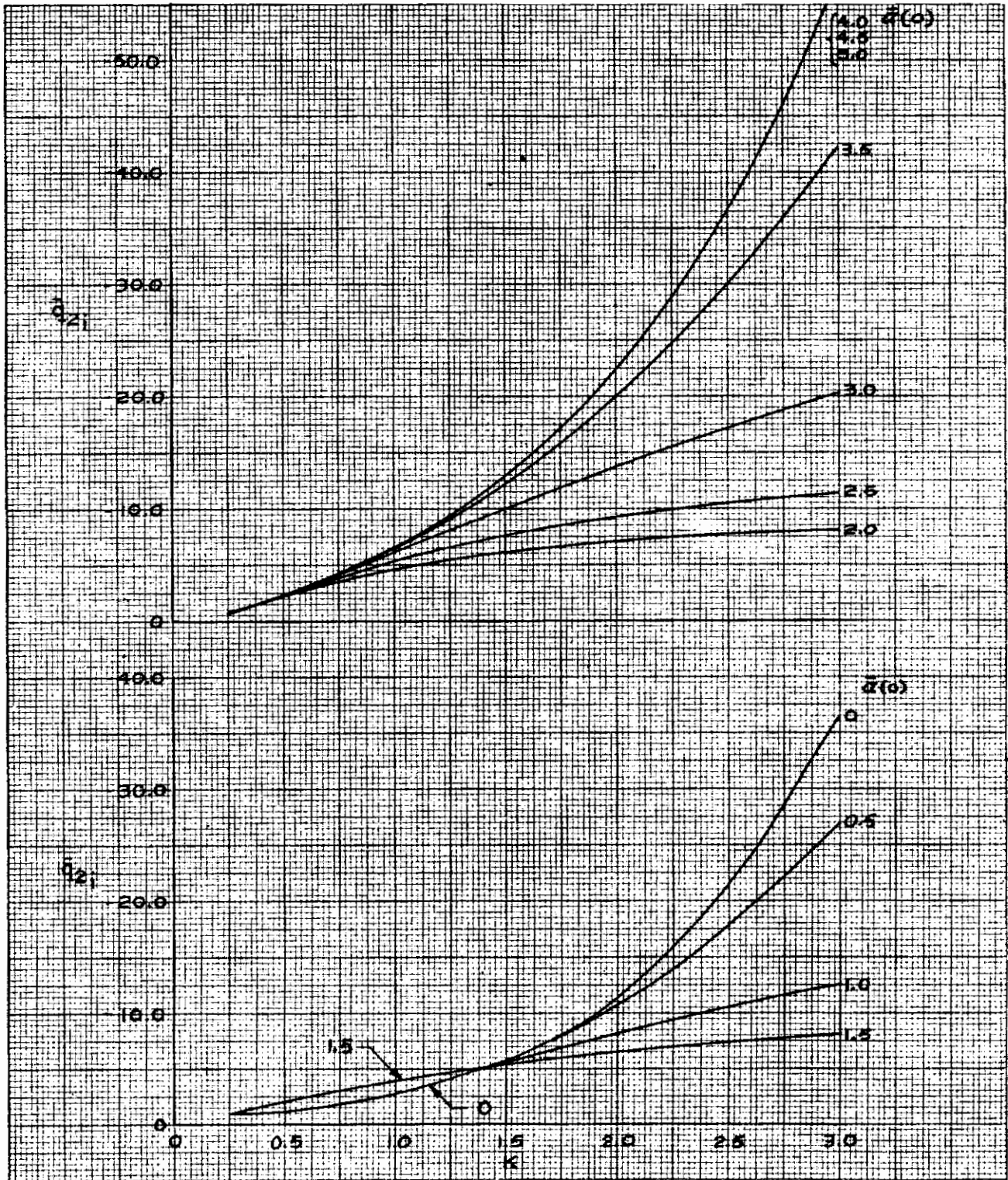


Figure 33. Single Parabolic, $\xi_i = 0.20$

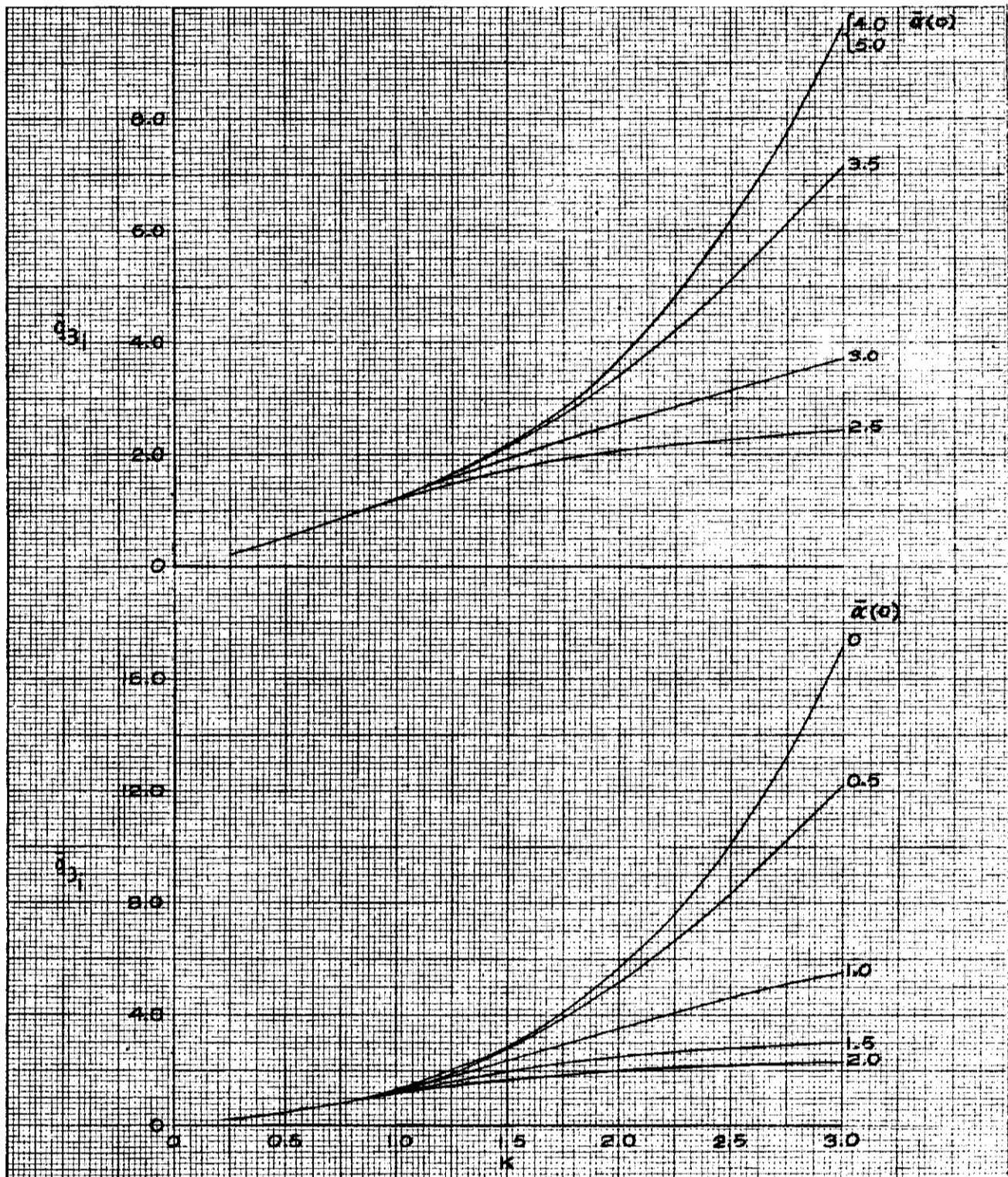


Figure 34. Single Parabolic, $\xi_i = 0.20$

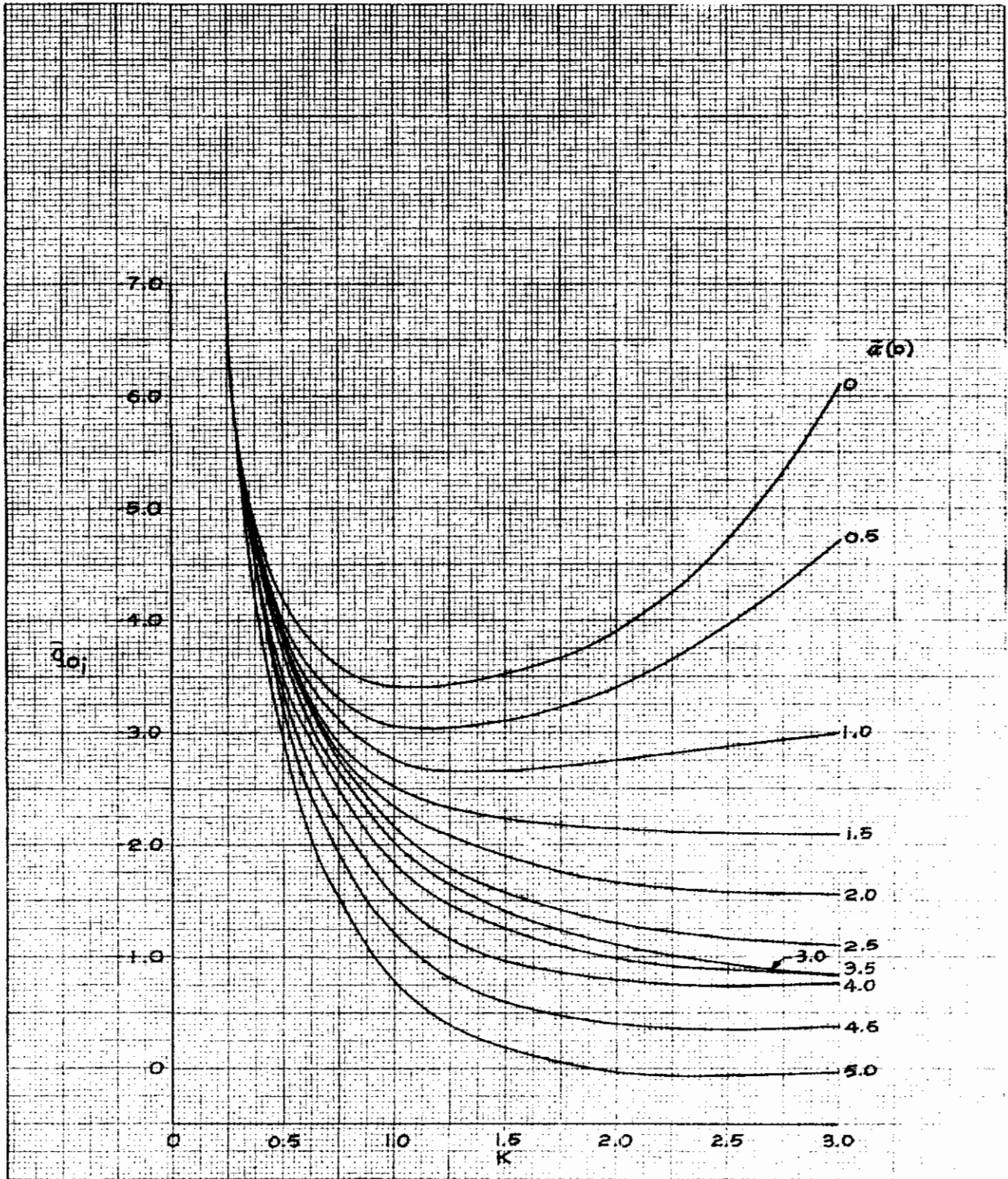


Figure 35. Single Parabolic, $\xi_i = 0.40$

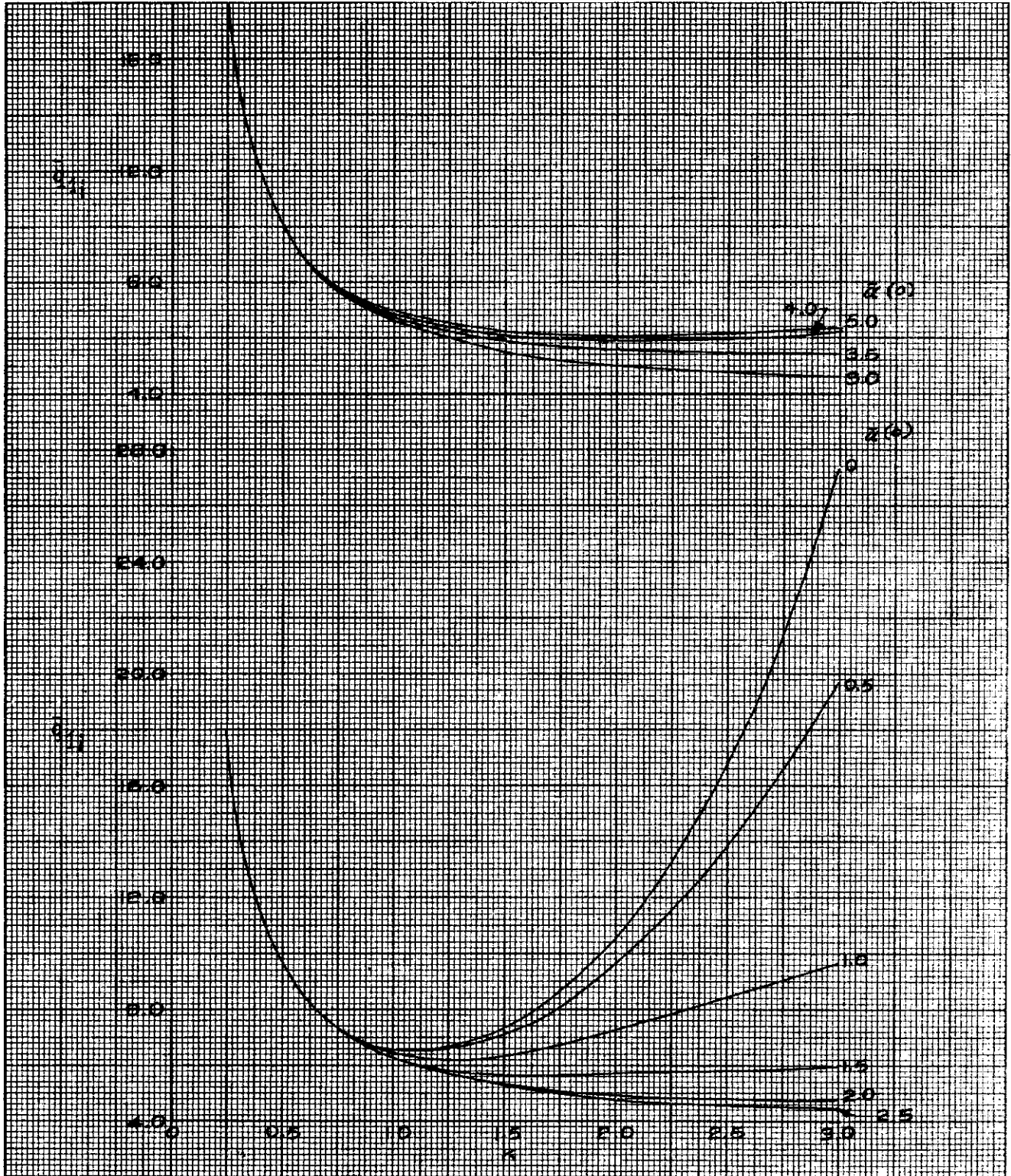


Figure 36. Single Parabolic, $\xi_i = 0.40$

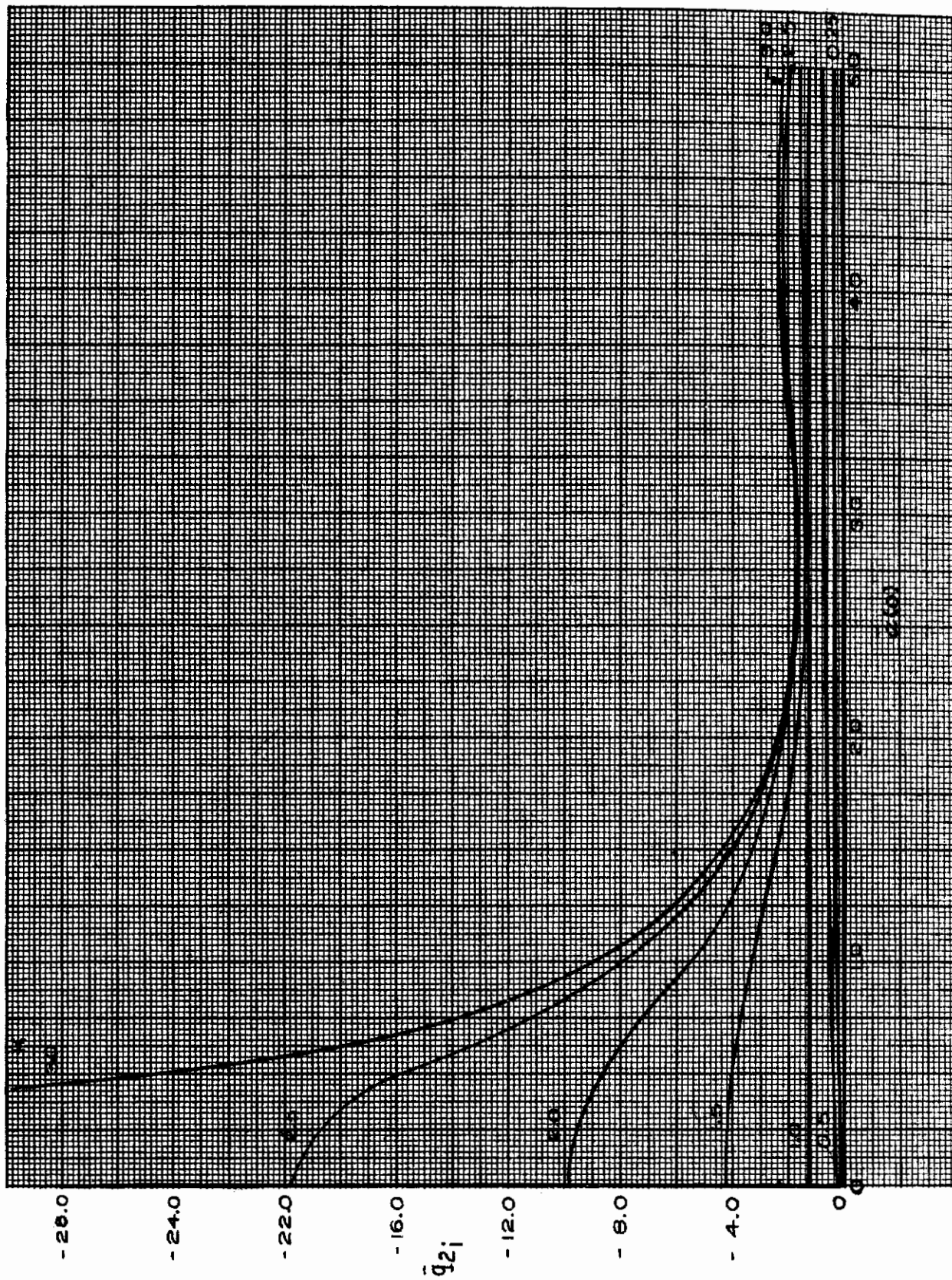


Figure 37. Single Parabolic, $\xi_i = 0.40$

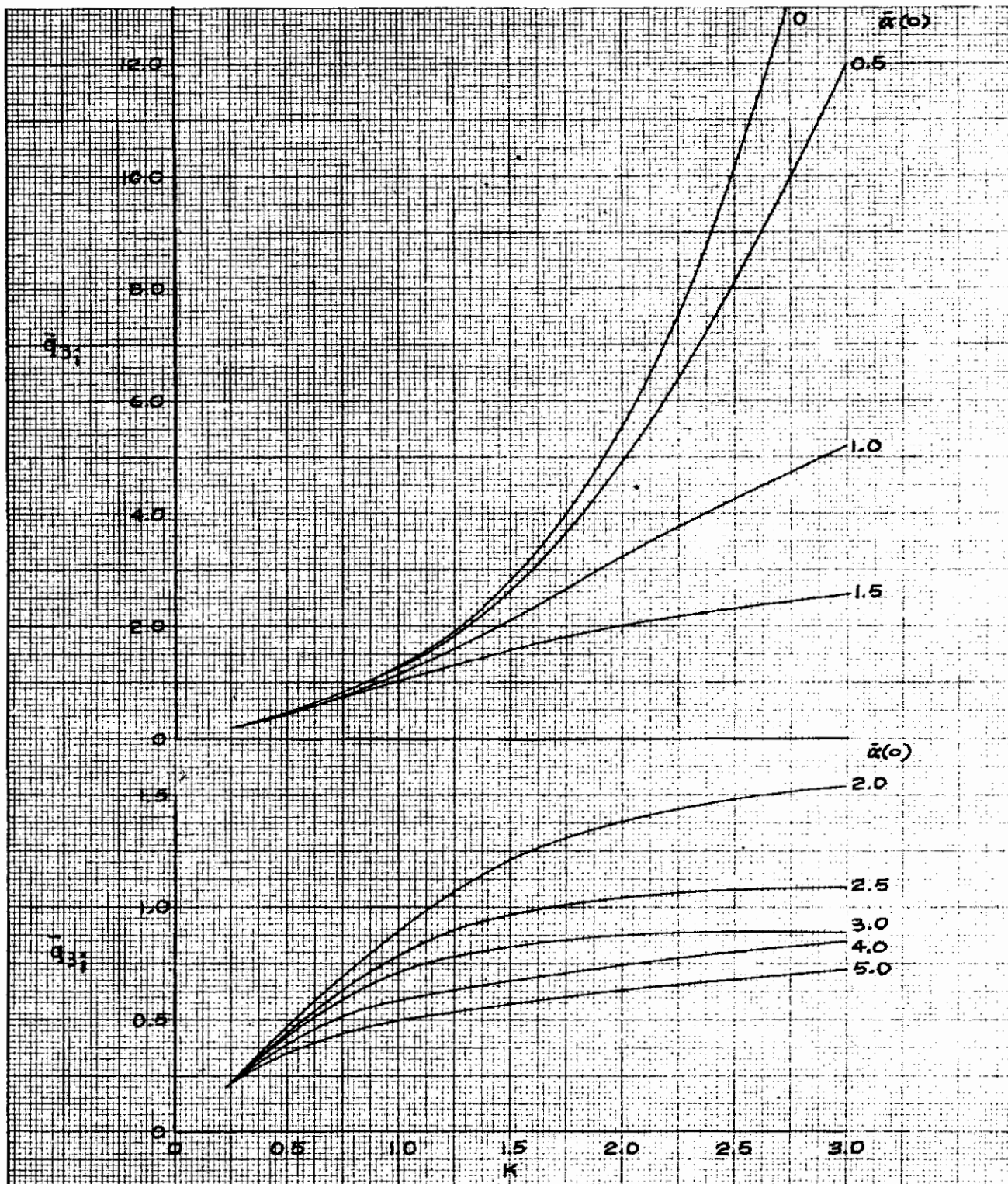


Figure 38. Single Parabolic, $\xi_i = 0.40$

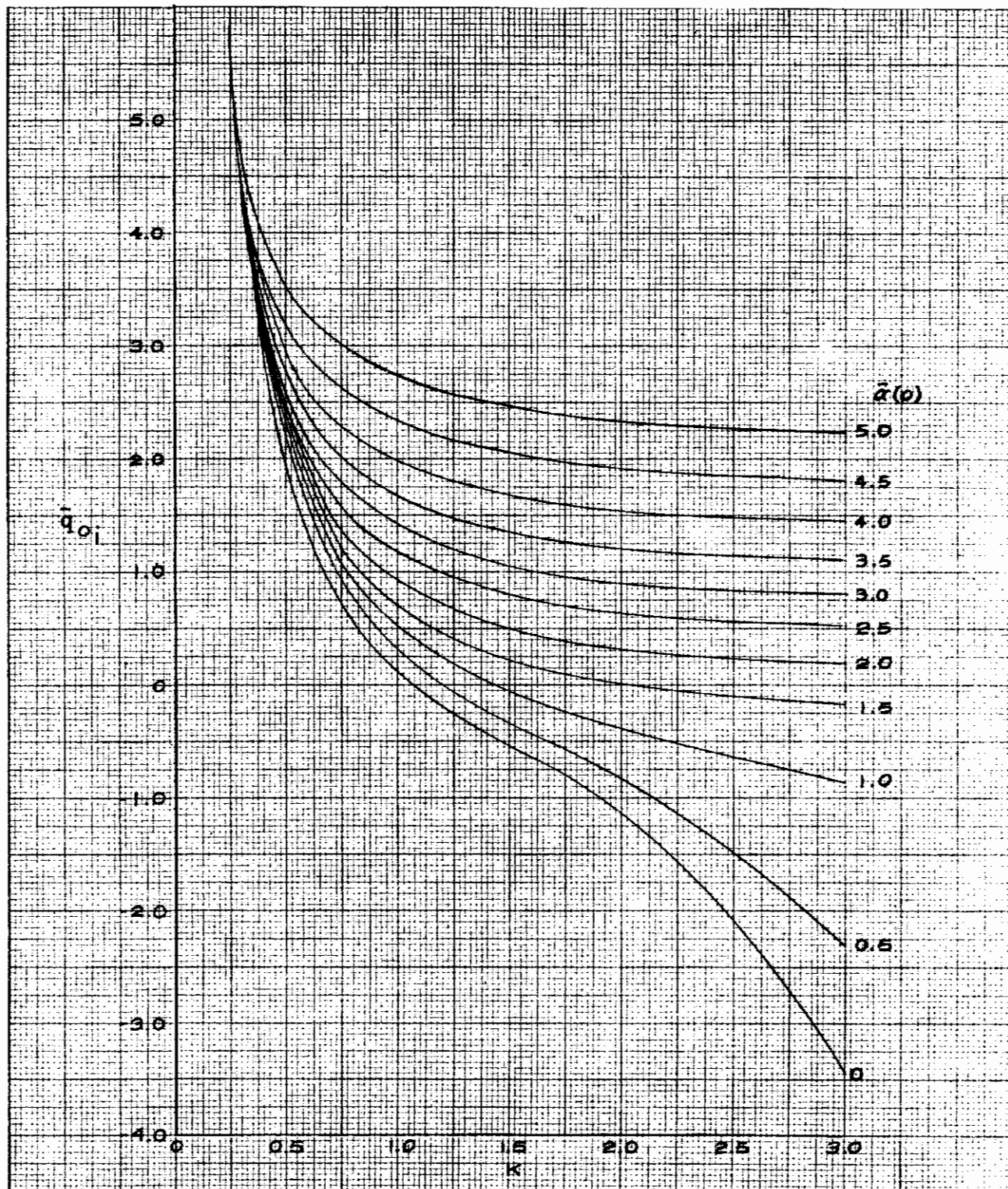


Figure 39. Single Parabolic, $\xi_i = 0.60$

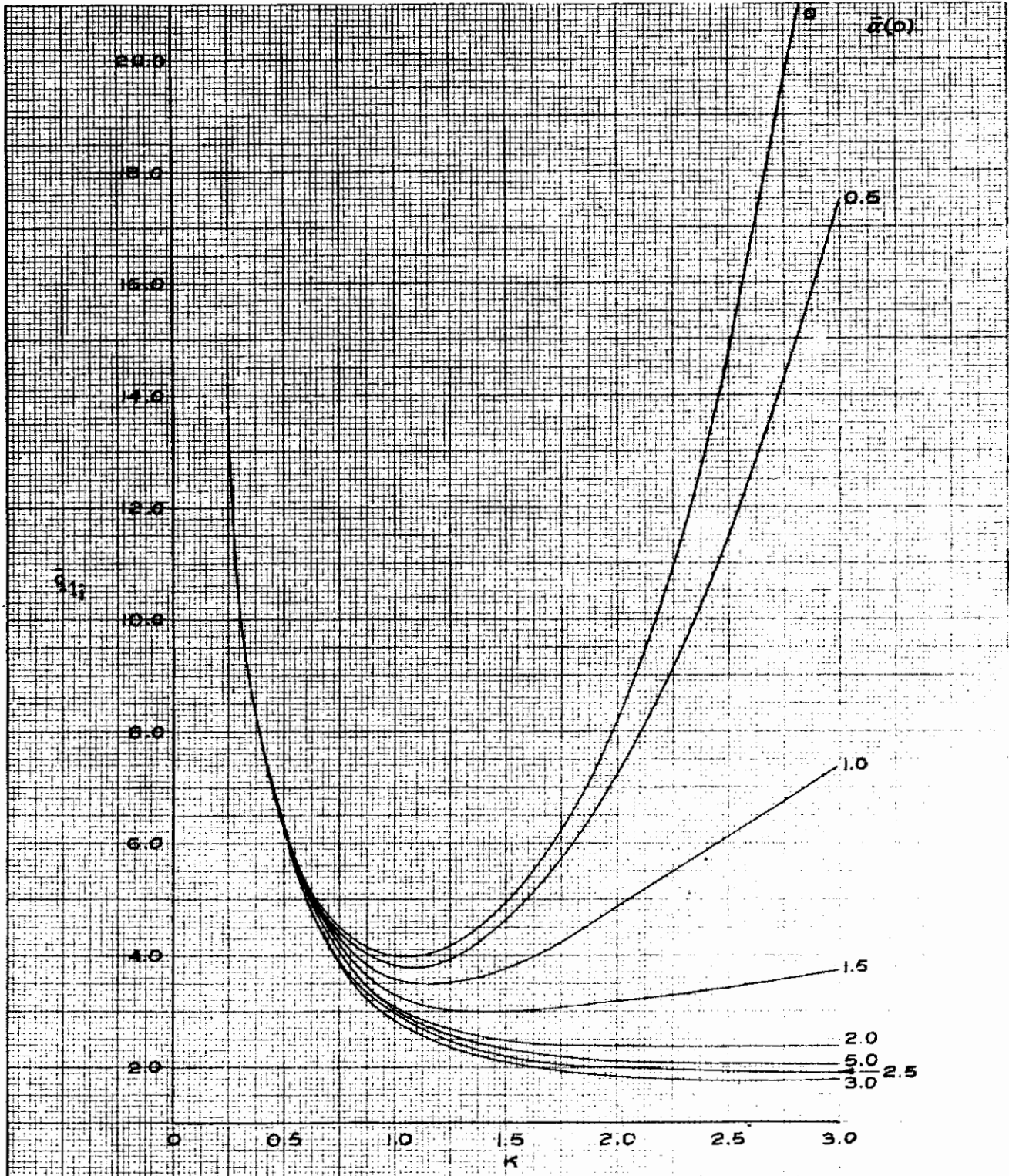


Figure 40. Single Parabolic, $\xi_i = 0.60$

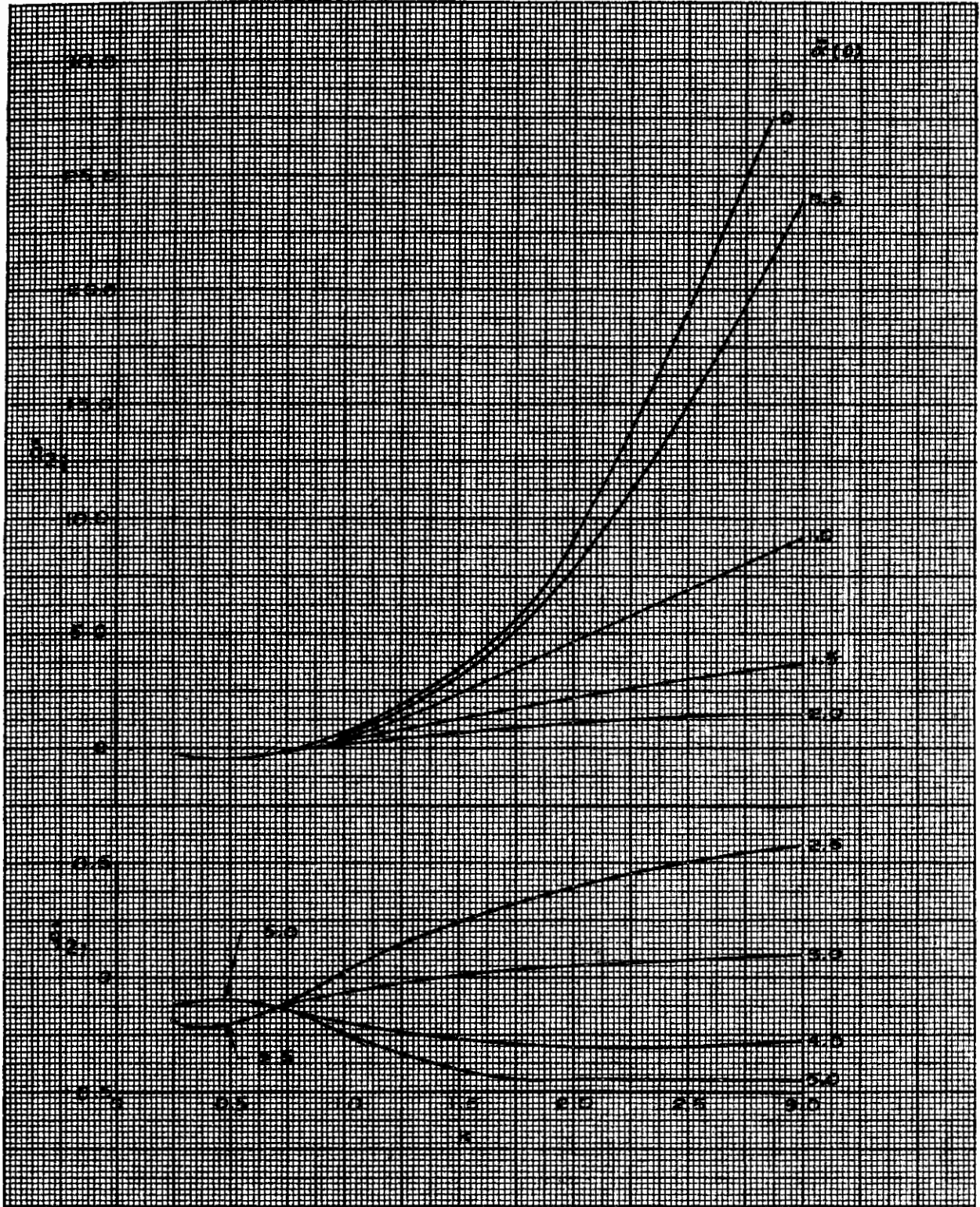


Figure 41. Single Parabolic, $\xi_i = 0.60$

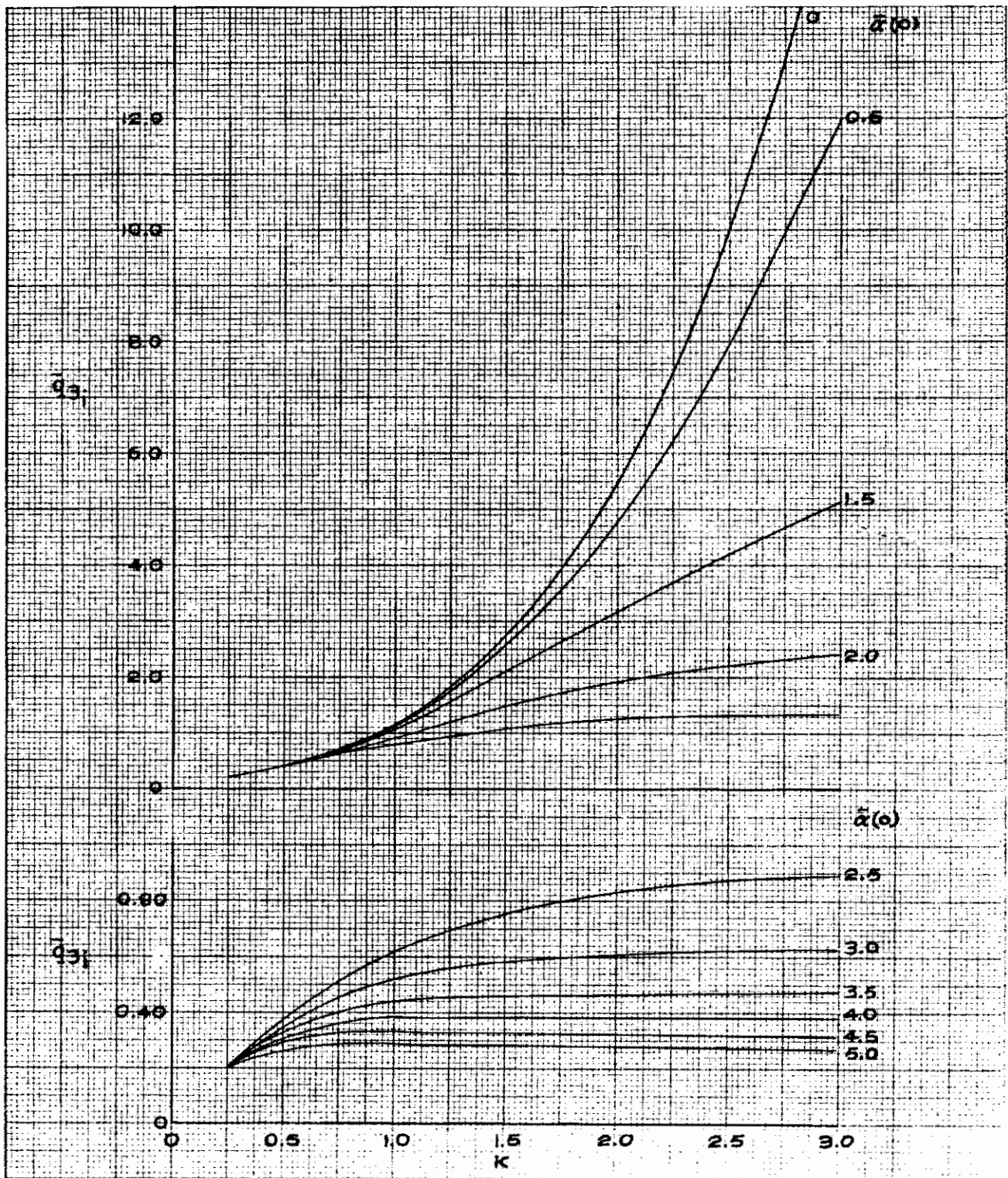


Figure 42. Single Parabolic, $\xi_i = 0.60$

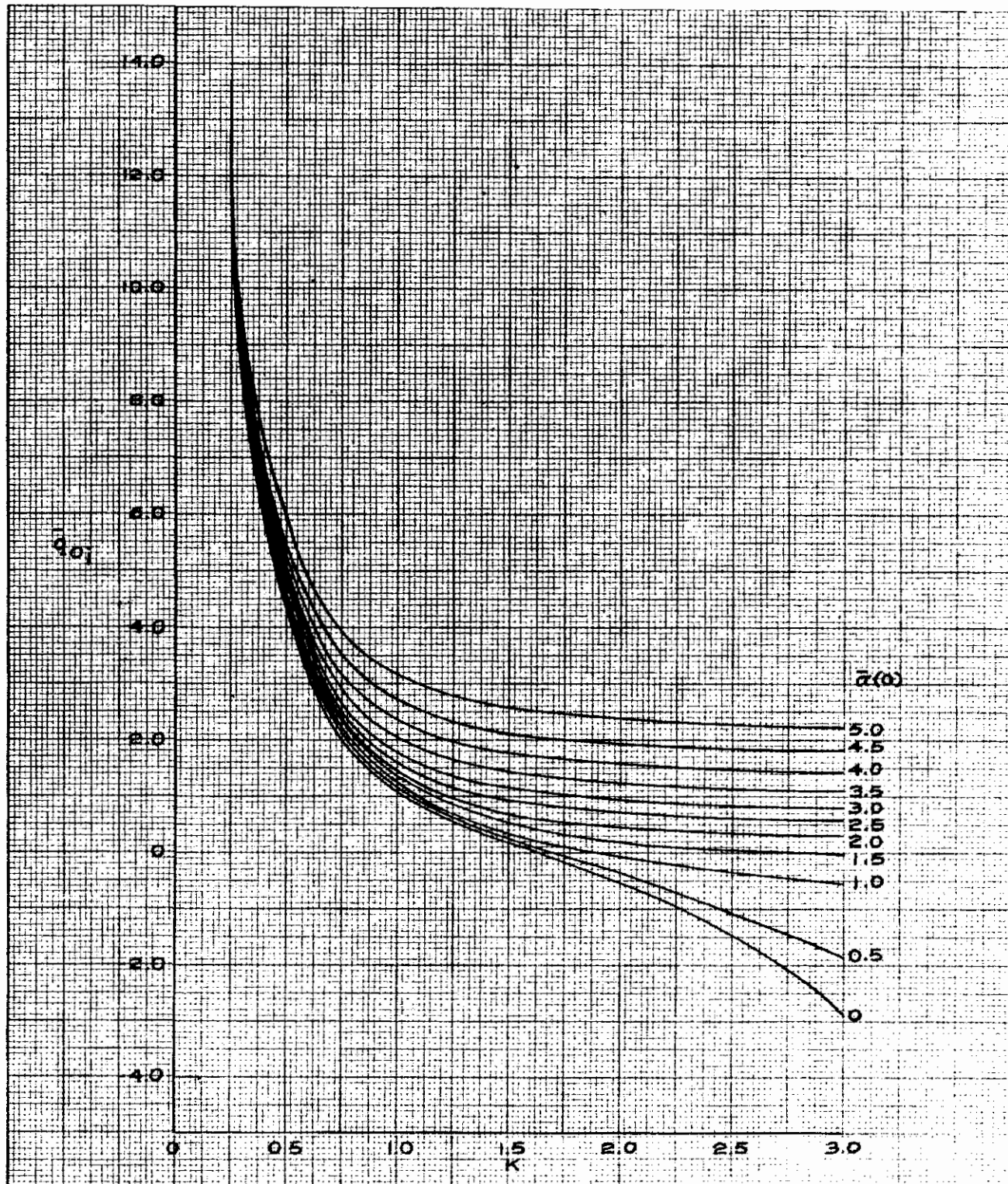


Figure 43. Single Parabolic, $\xi_i = 0.80$ and 1.00

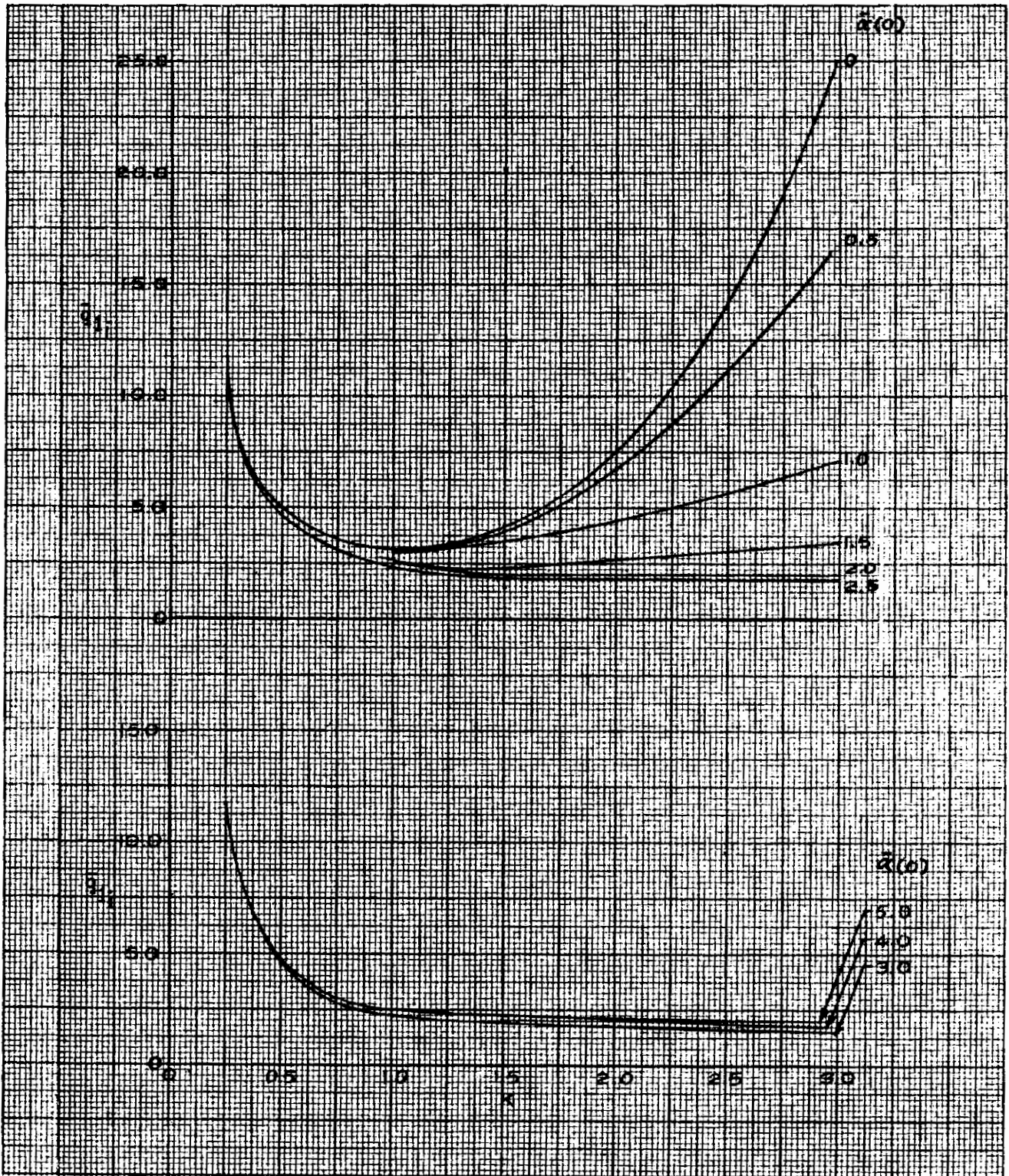


Figure 44. Single Parabolic, $\xi_i = 0.80$ and 1.00

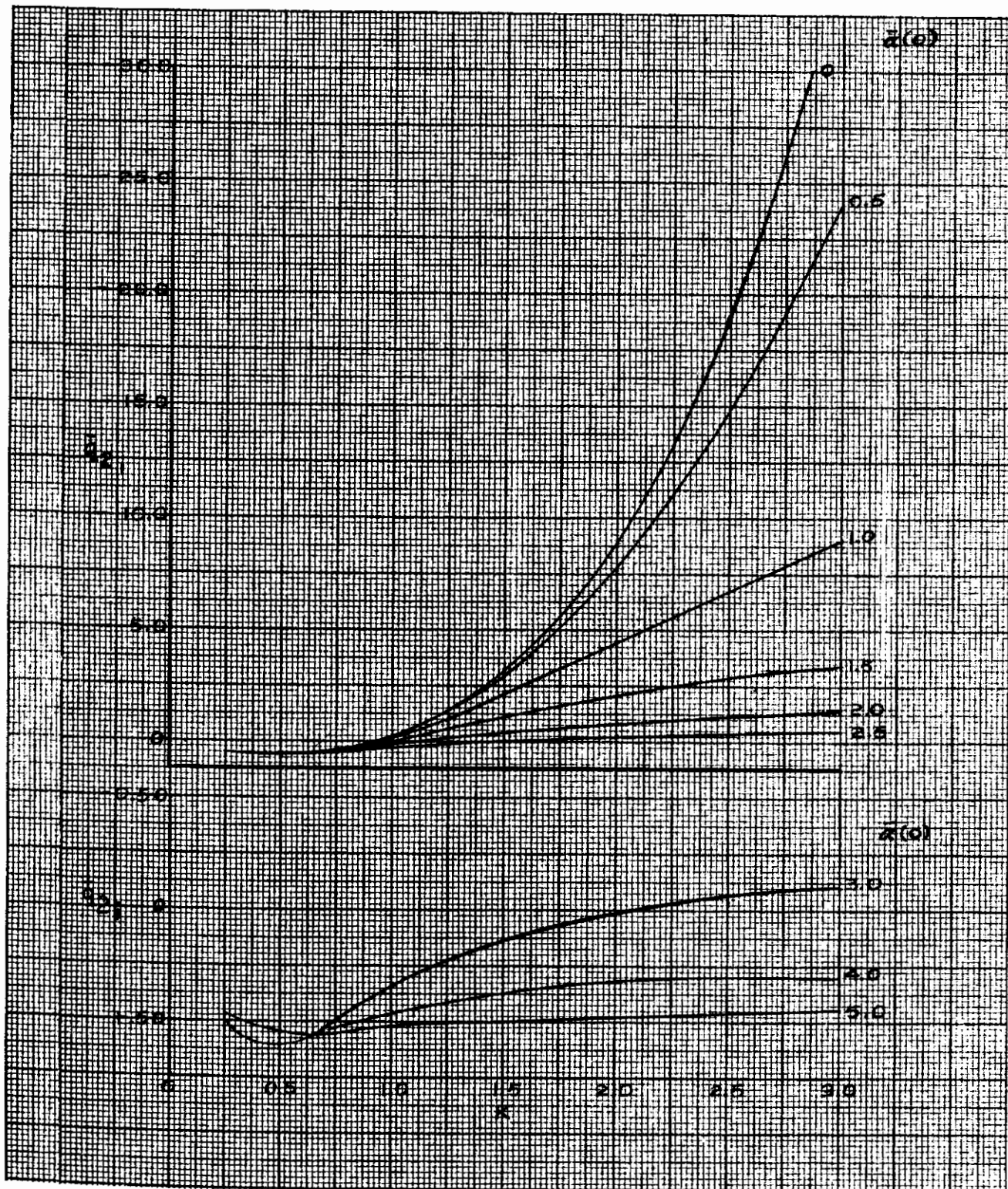


Figure 45. Single Parabolic, $\xi_i = 0.80$ and 1.00

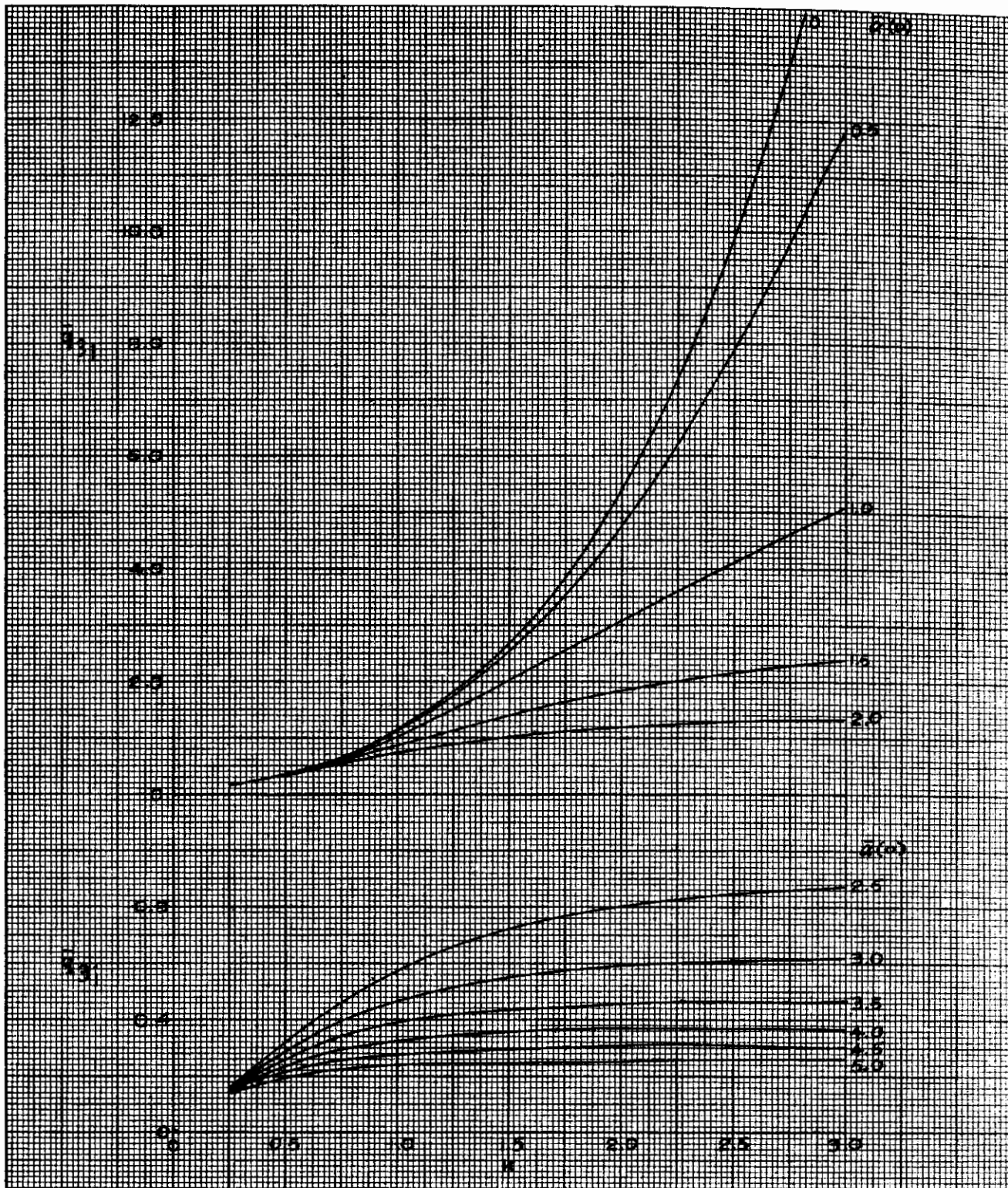


Figure 46. Single Parabolic, $\xi_i = 0.80$ and $\xi_i = 1.00$

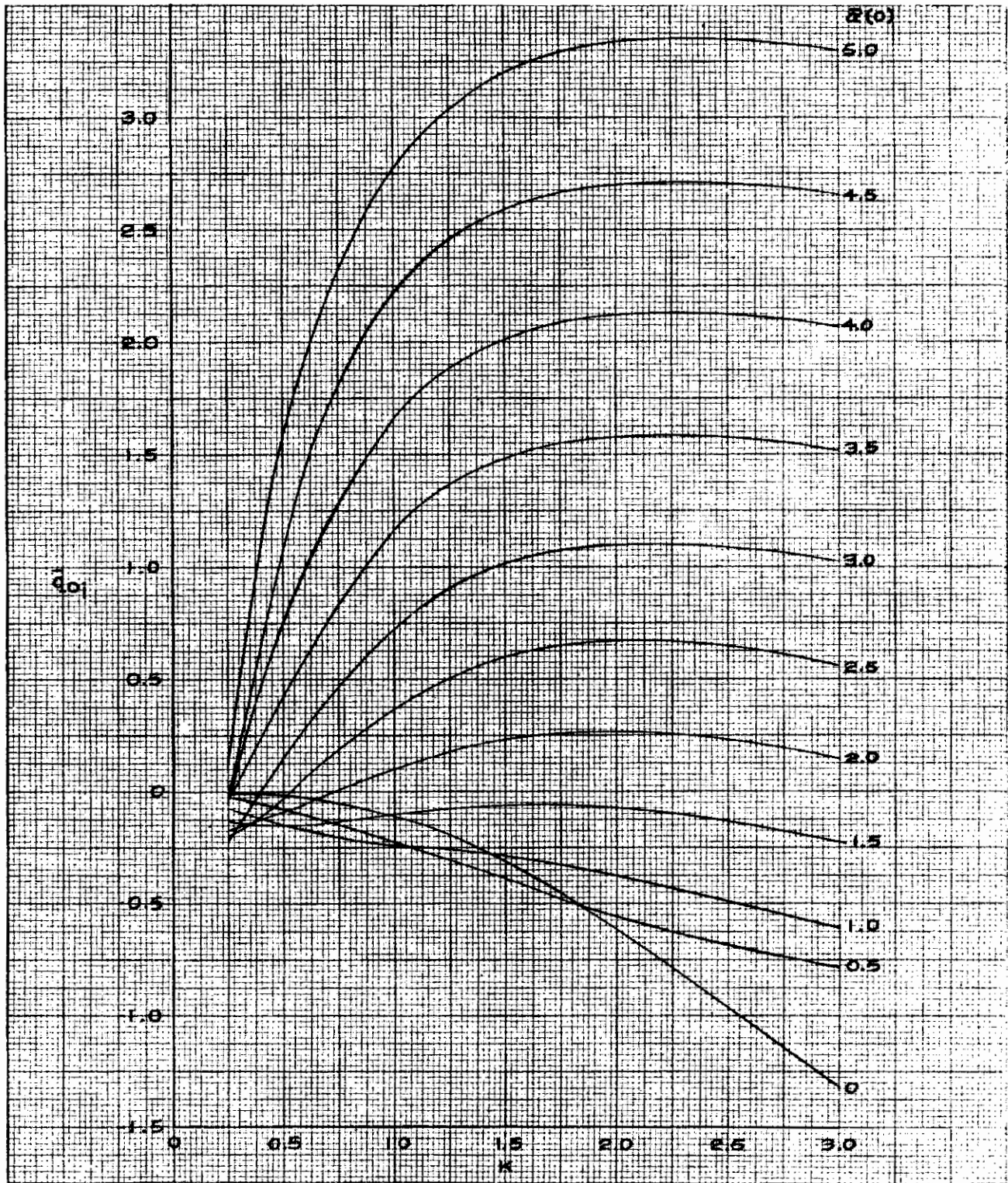


Figure 47. Double Parabolic B.T.E., $\xi_i = 0.20$

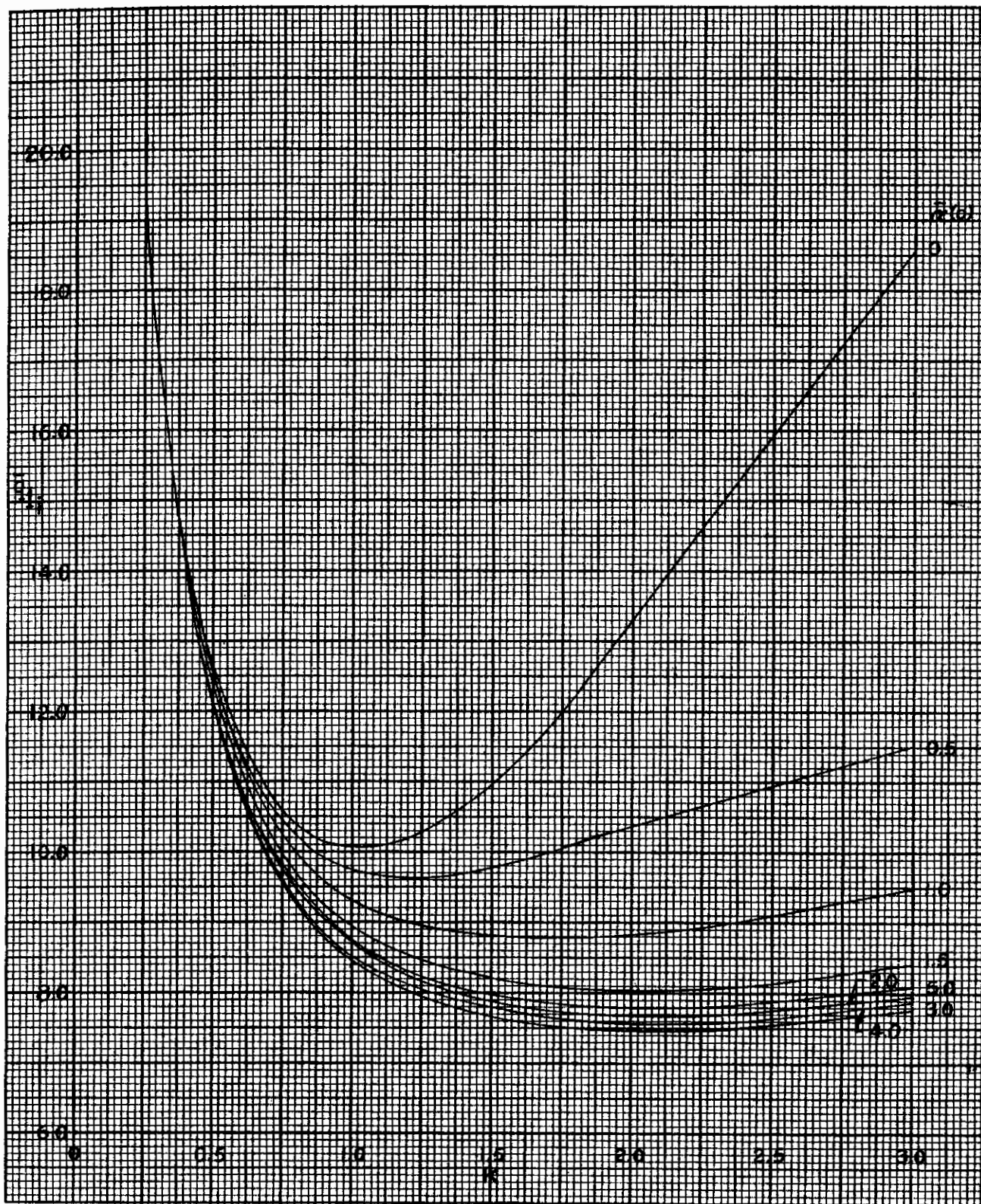


Figure 48. Double Parabolic B.T.E., $\xi_i = 0.20$

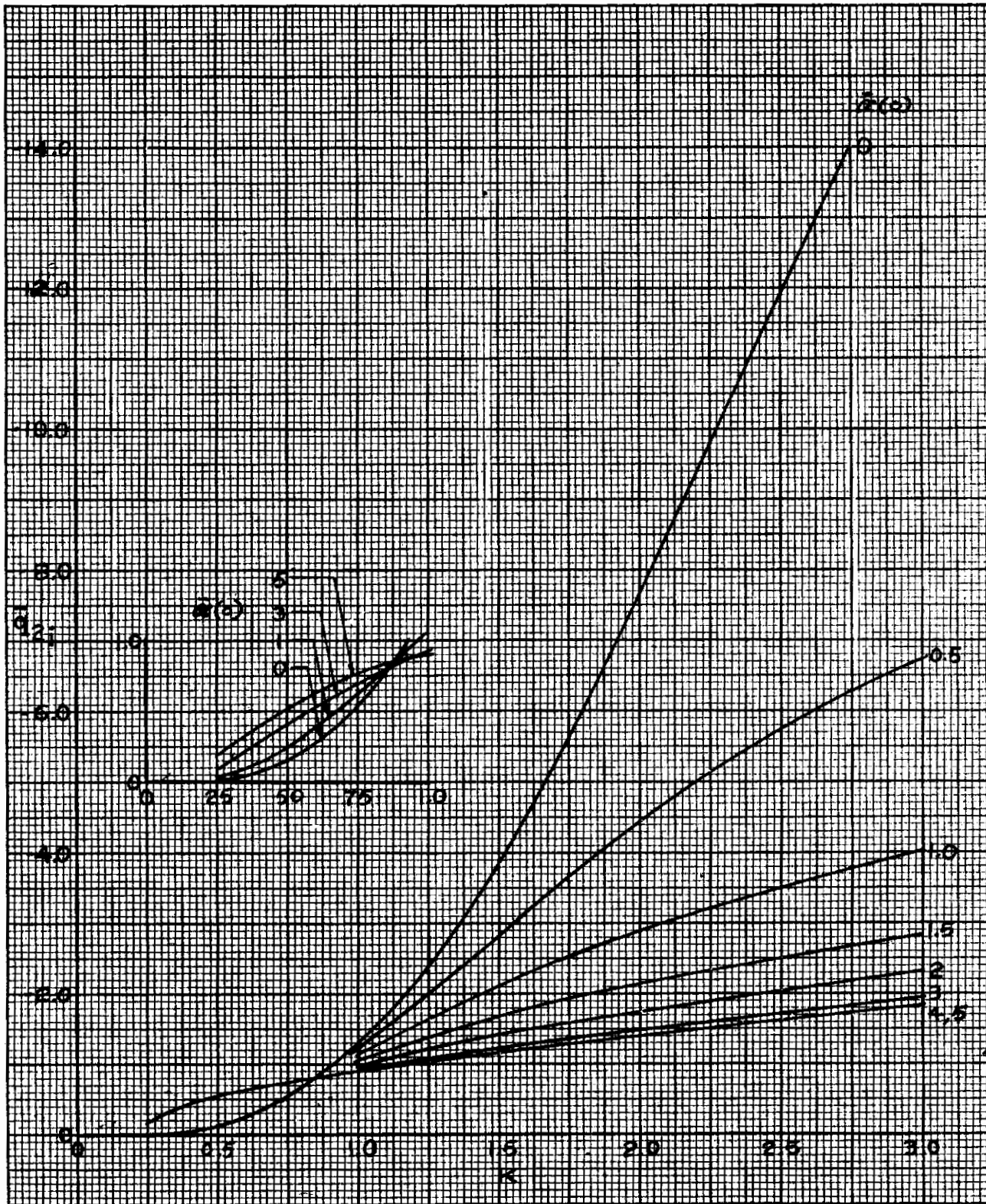


Figure 49. Double Parabolic B.T.E., $\xi_i = 0.20$

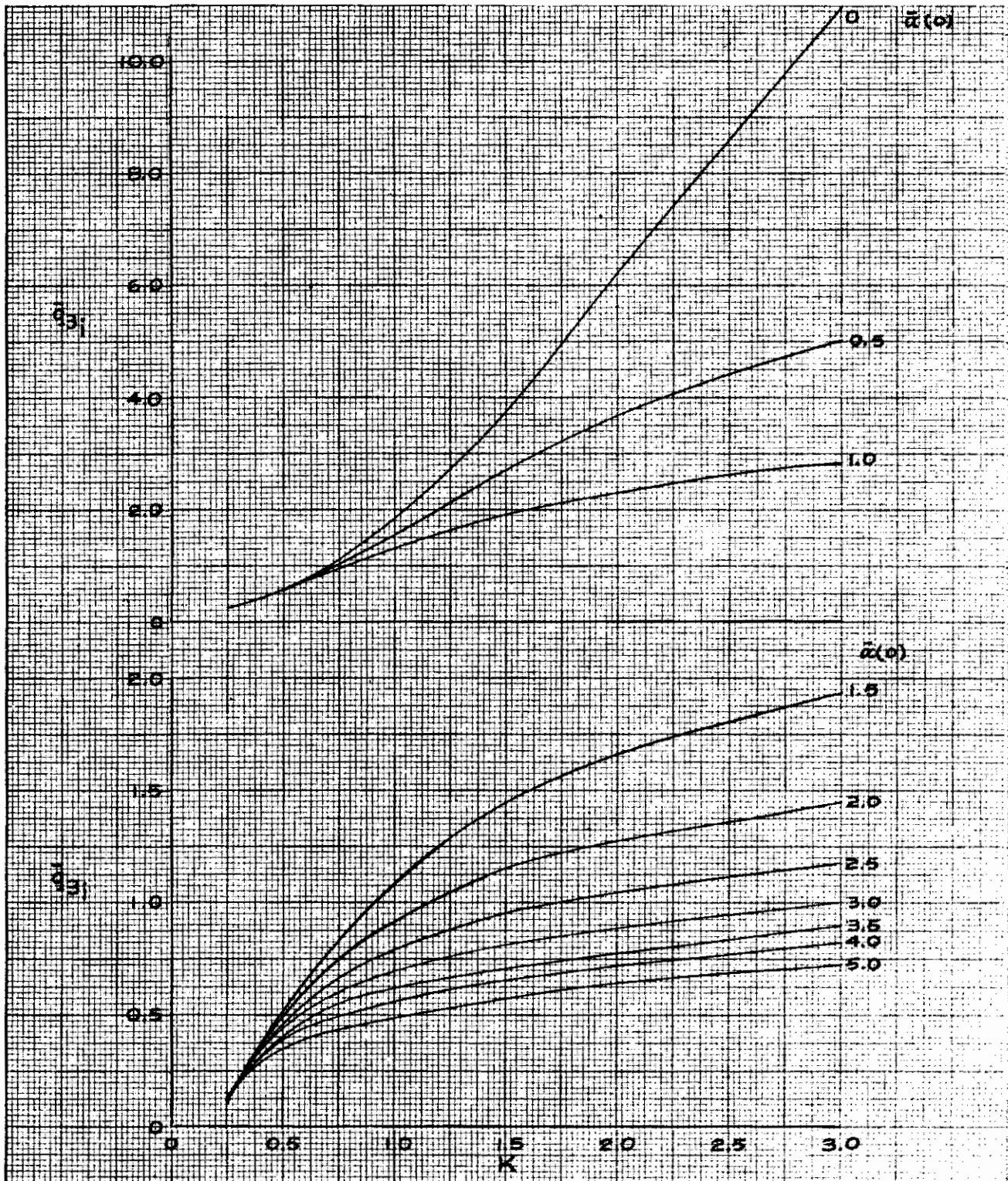


Figure 50. Double Parabolic B.T.E., $\xi_i = 0.20$

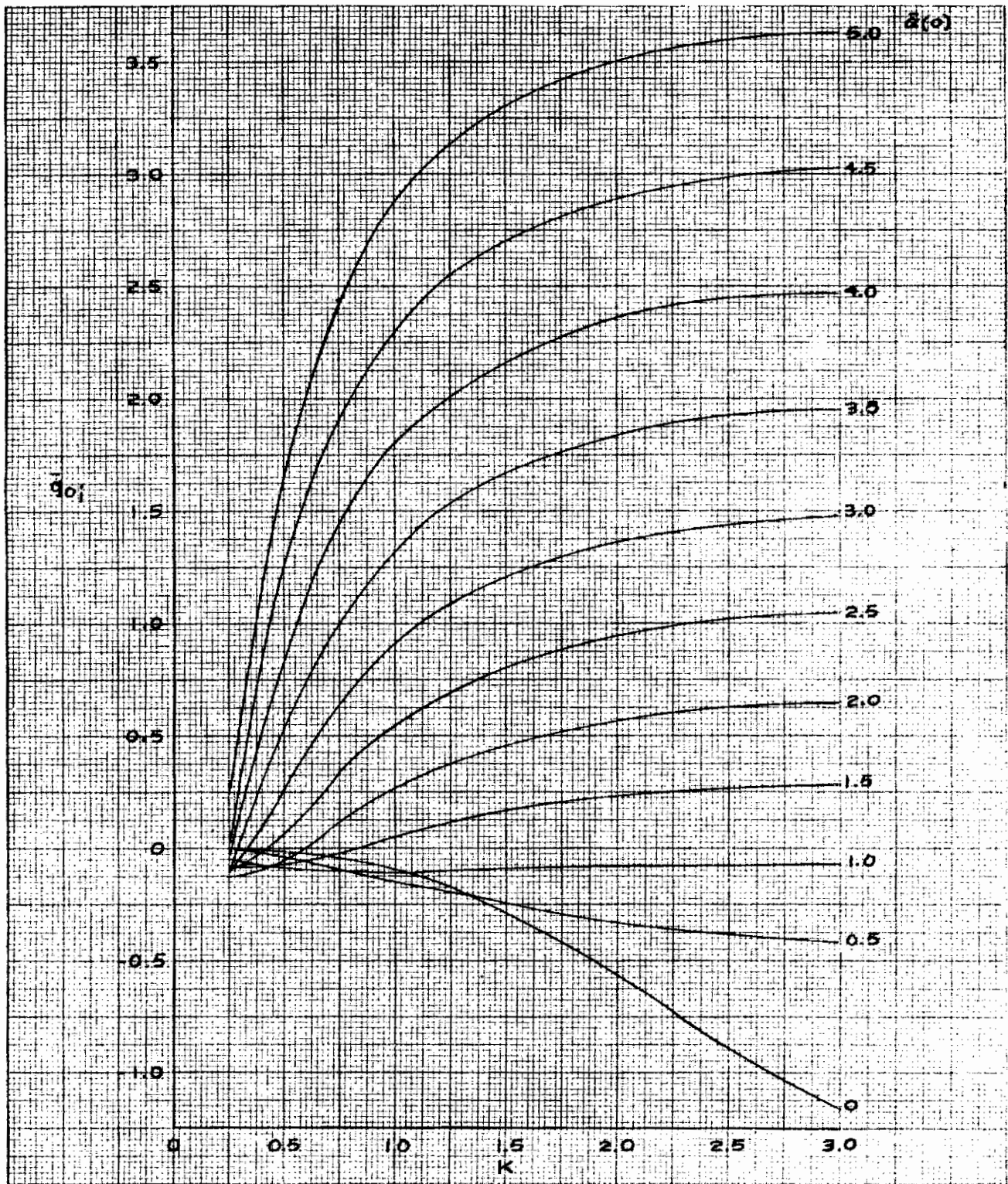


Figure 51. Double Parabolic B.T.E., $\xi_1 = 0.40$

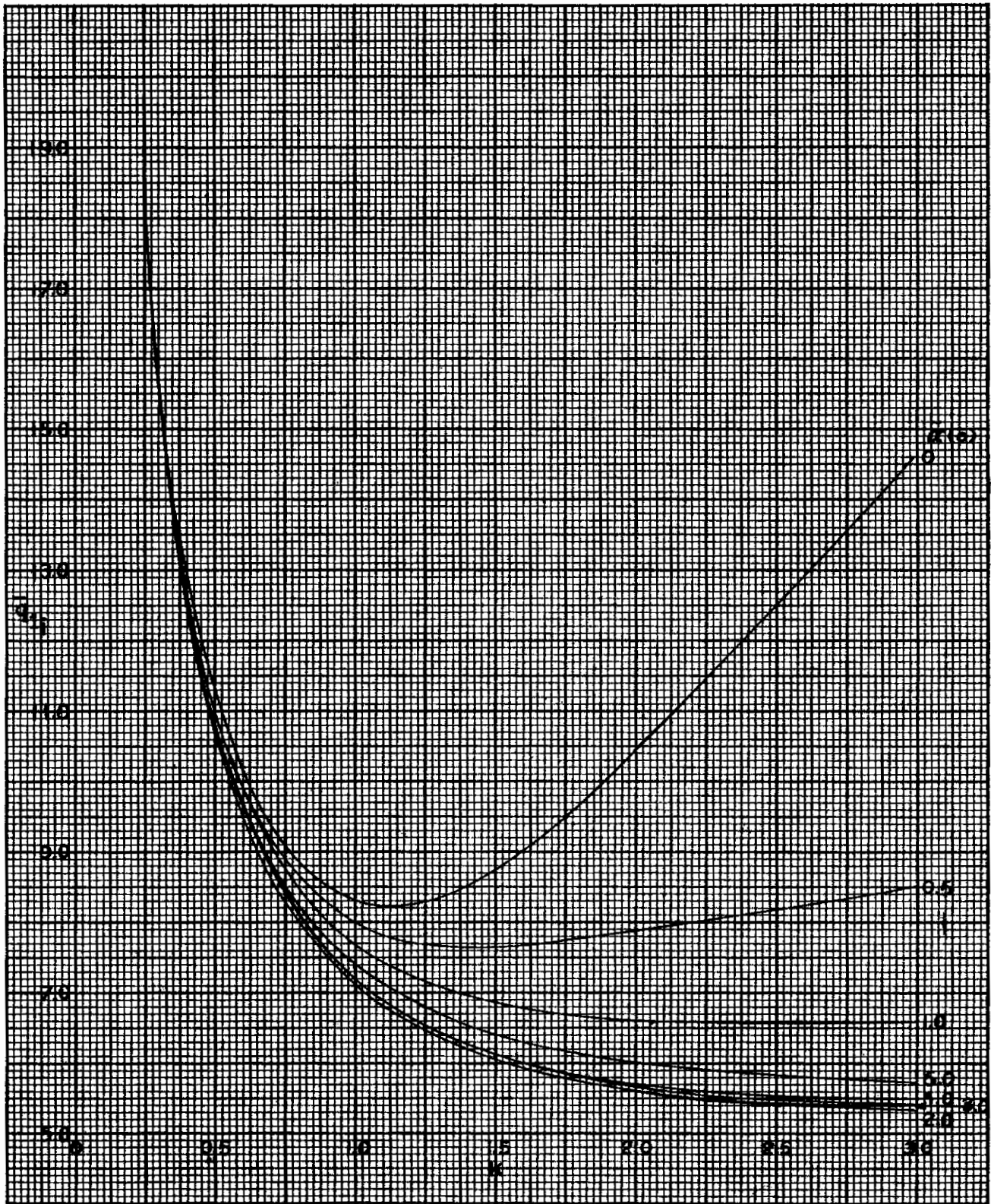


Figure 52. Double Parabolic B.T.E., $\xi_1 = 0.40$

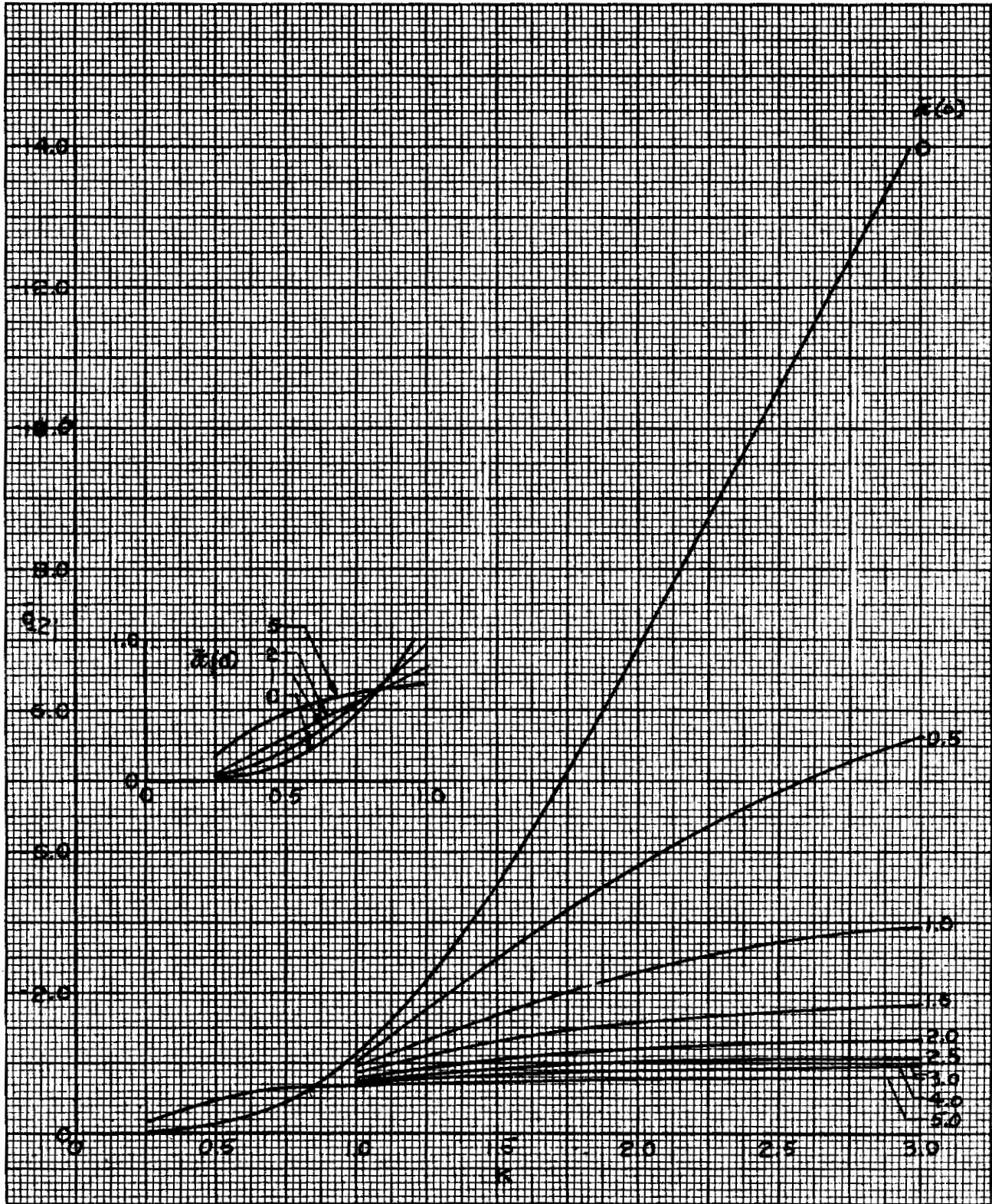


Figure 53. Double Parabolic B.T.E., $\xi_i = 0.40$

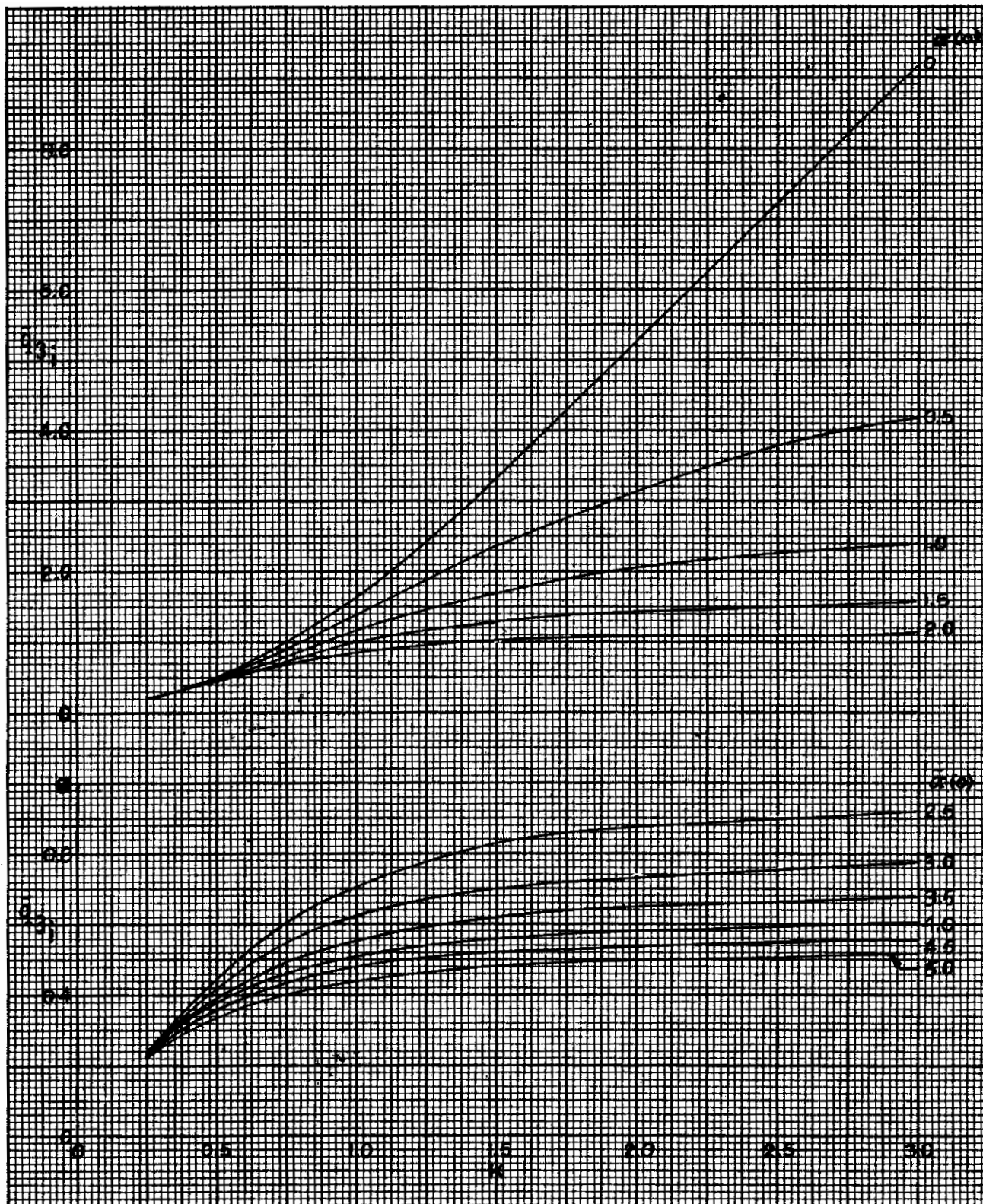


Figure 54. Double Parabolic B.T.E., $\xi_1 = 0.40$

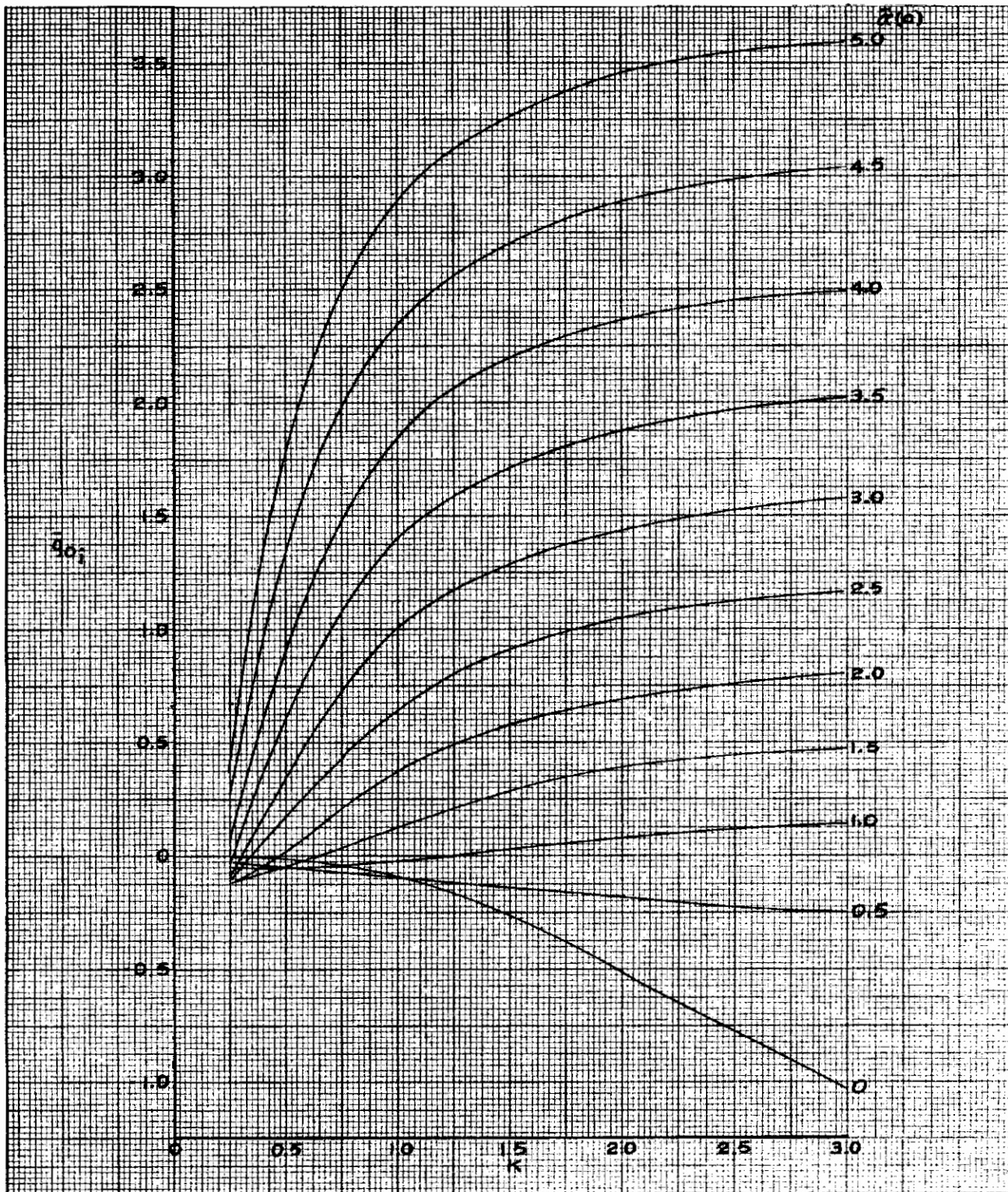


Figure 55. Double Parabolic B.T.E., $\xi_i = 0.60$

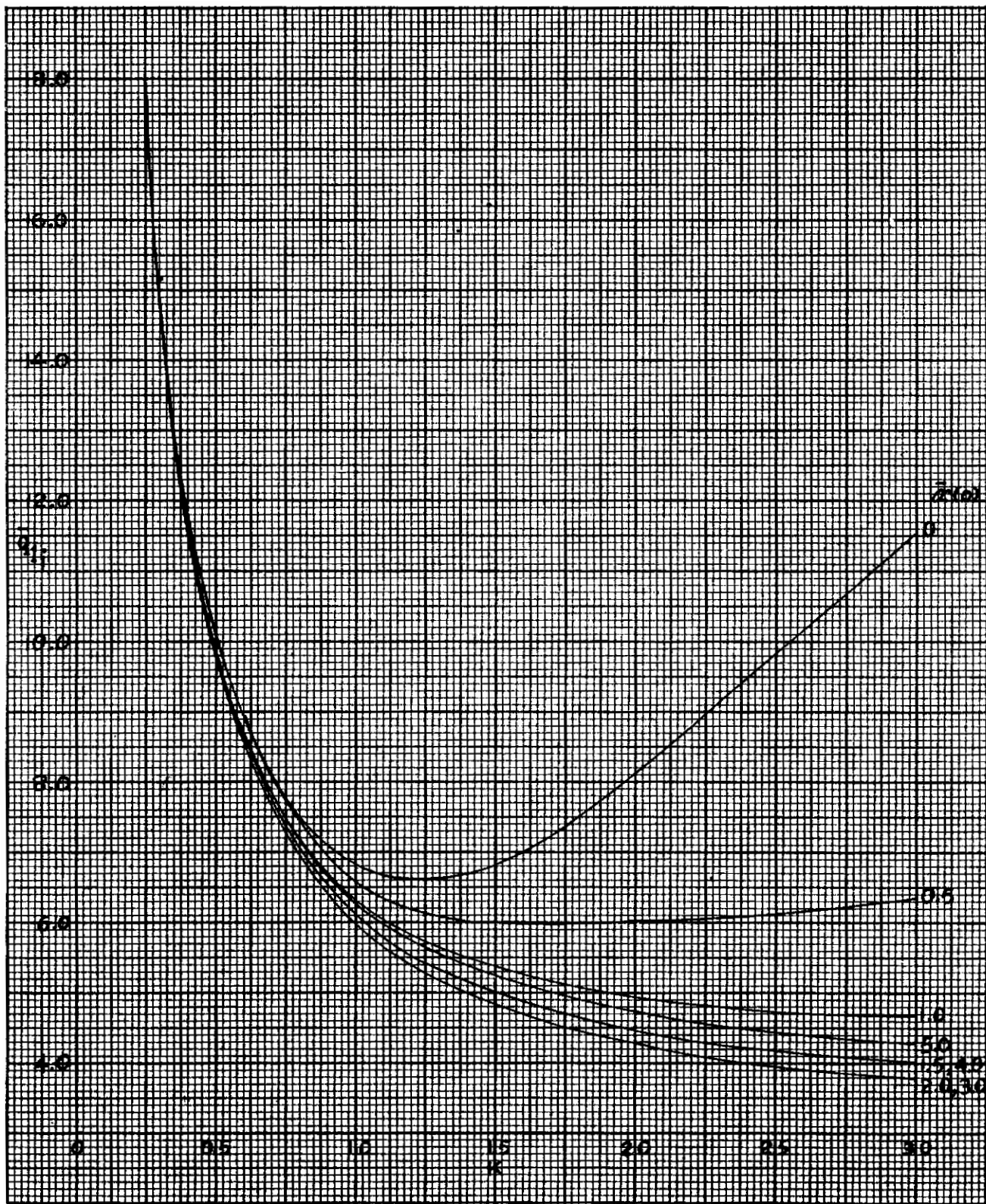


Figure 56. Double Parabolic B.T.E., $\xi_i = 0.60$

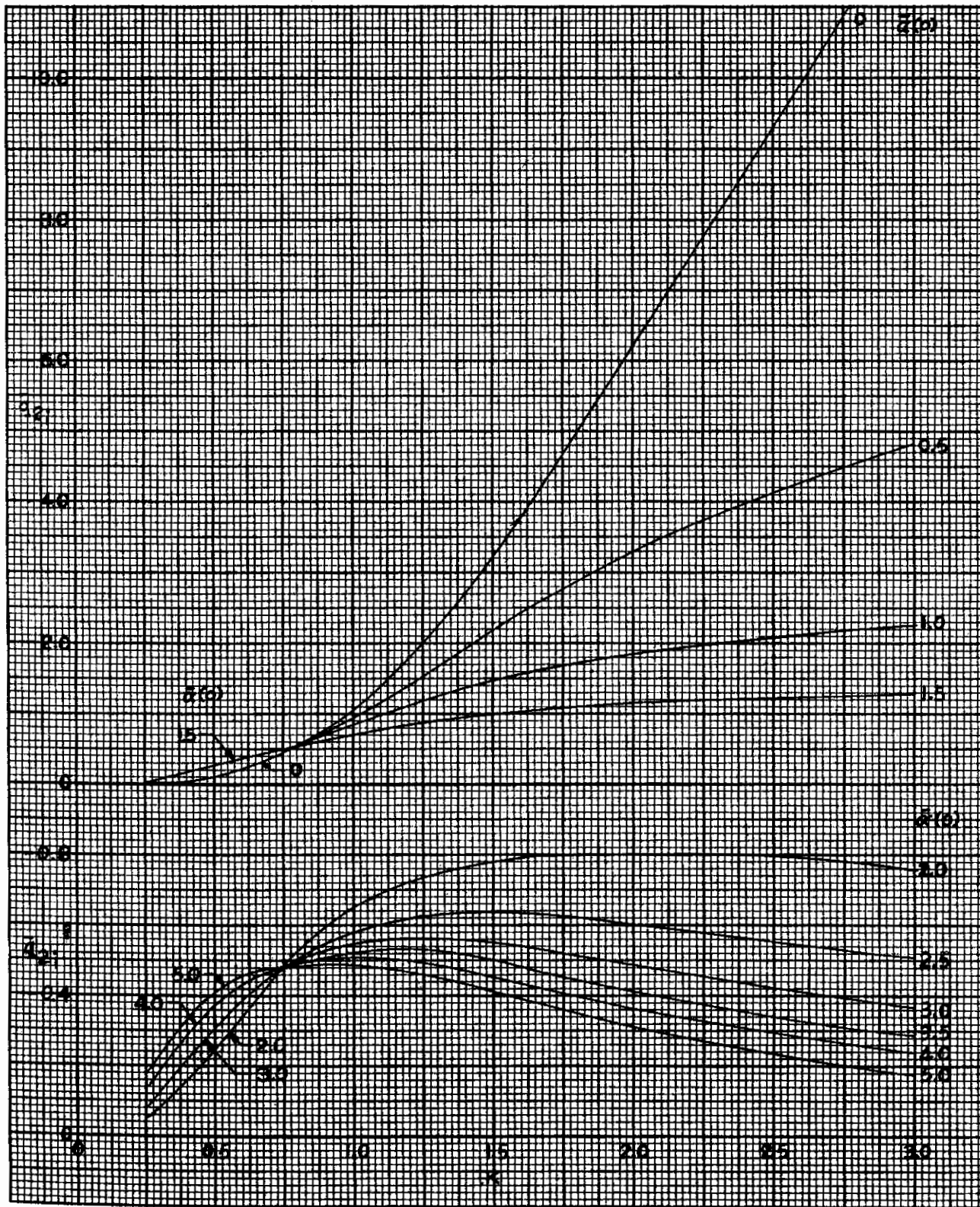


Figure 57. Double Parabolic B.T.E., $\xi_i = 0.60$

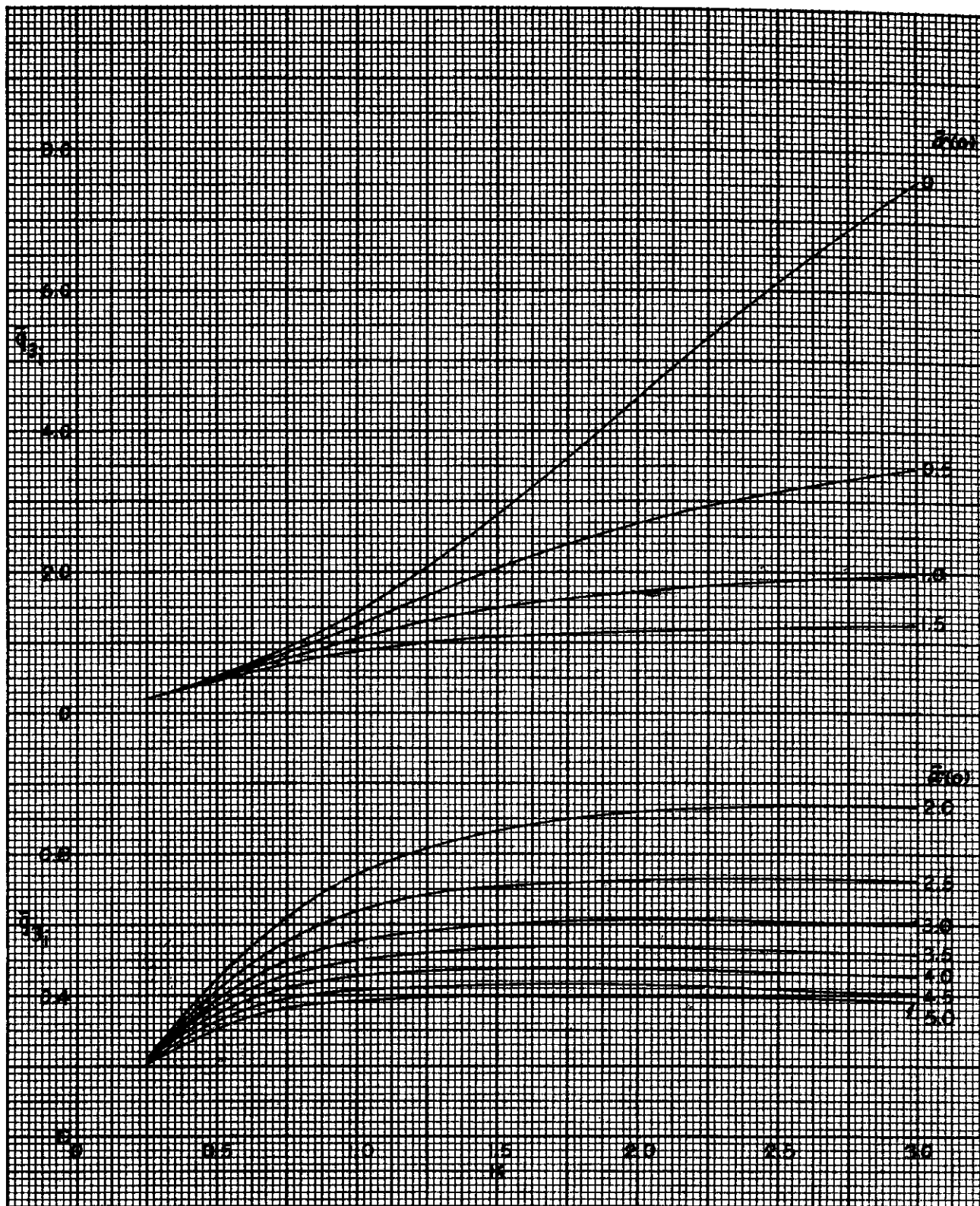


Figure 58. Double Parabolic B.T.E. $\xi_i = 0.60$

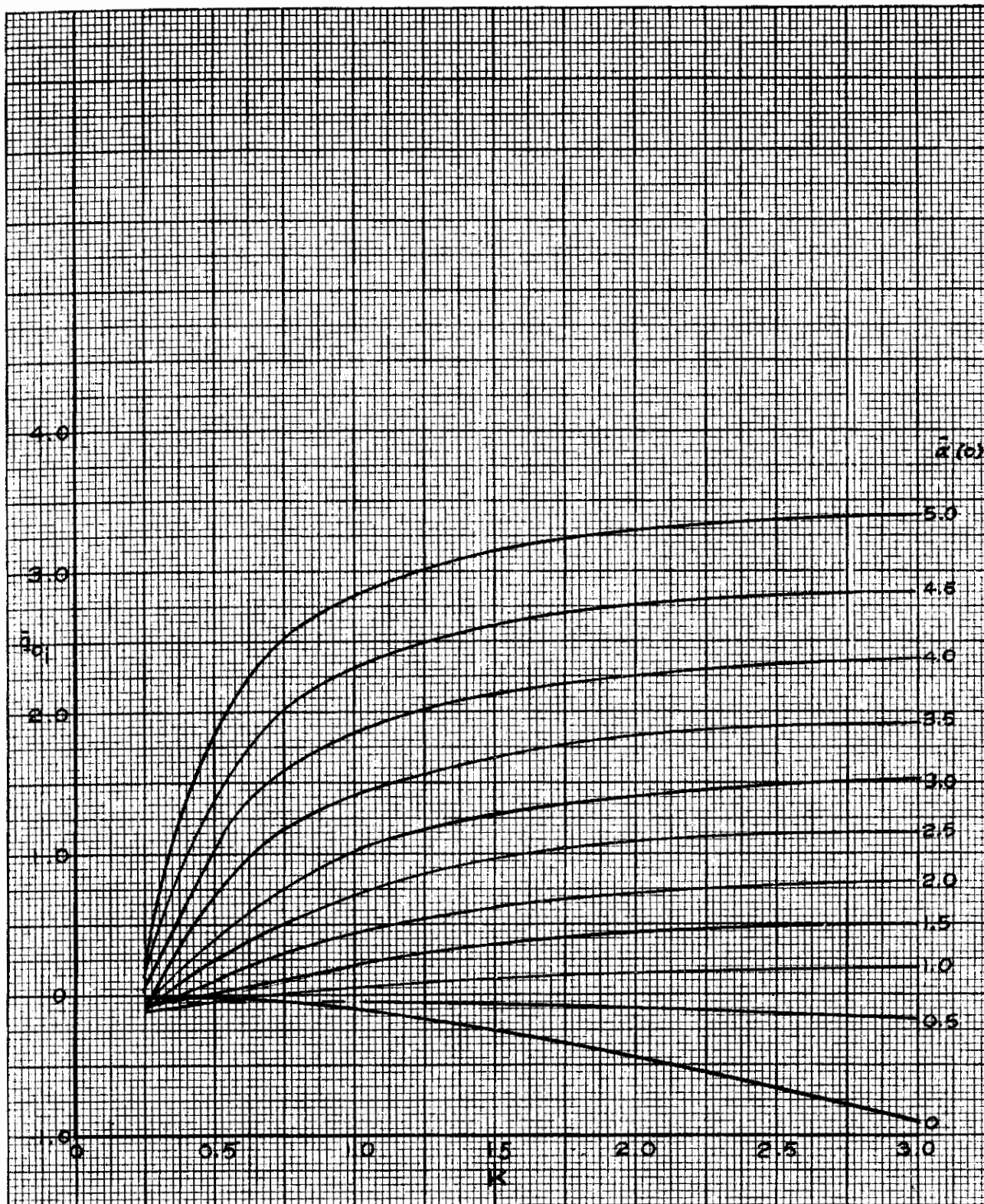


Figure 59. Double Parabolic B.T.E., $\xi_1 = 0.80$

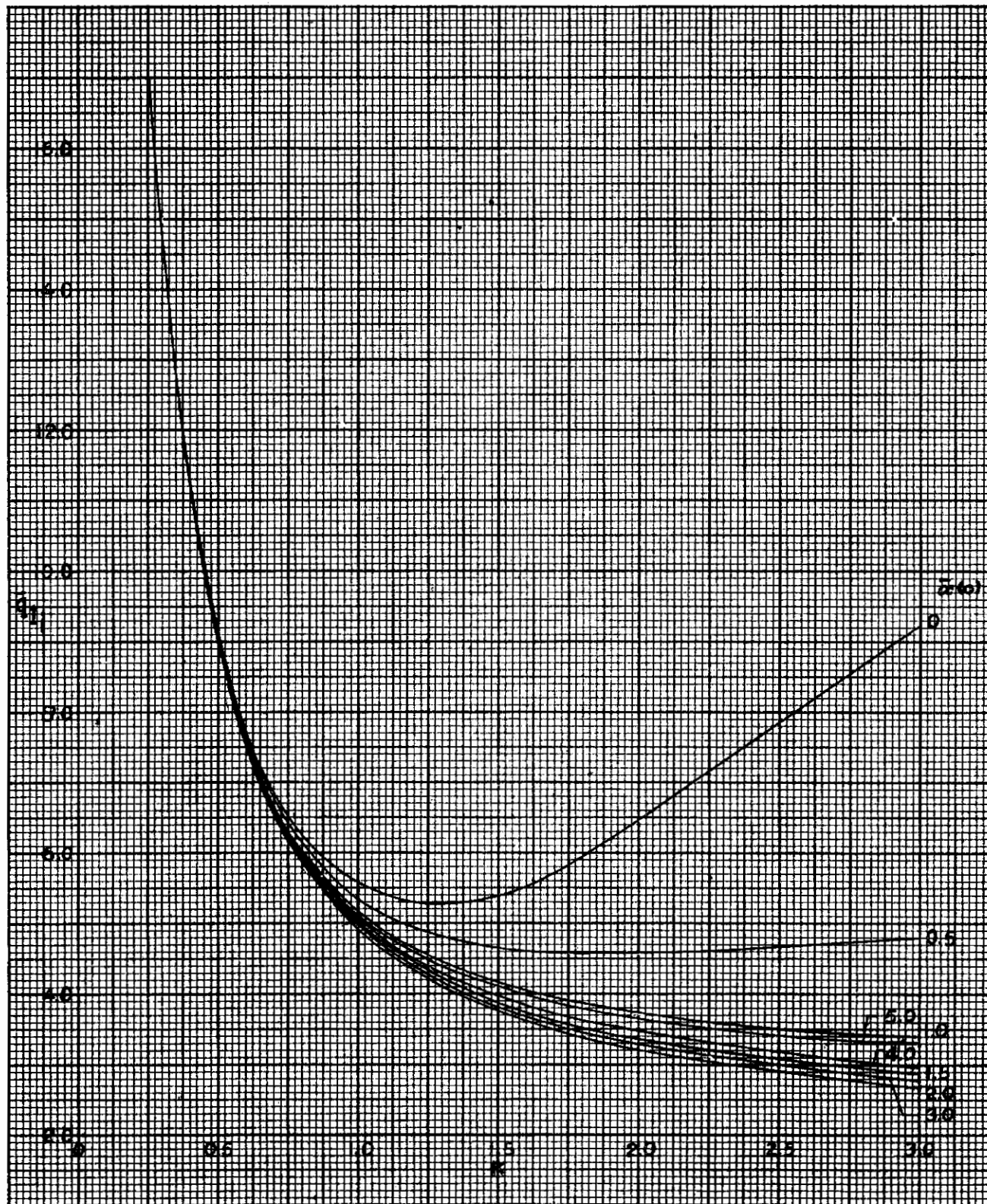


Figure 60. Double Parabolic B.T.E., $\xi_1 = 0.80$

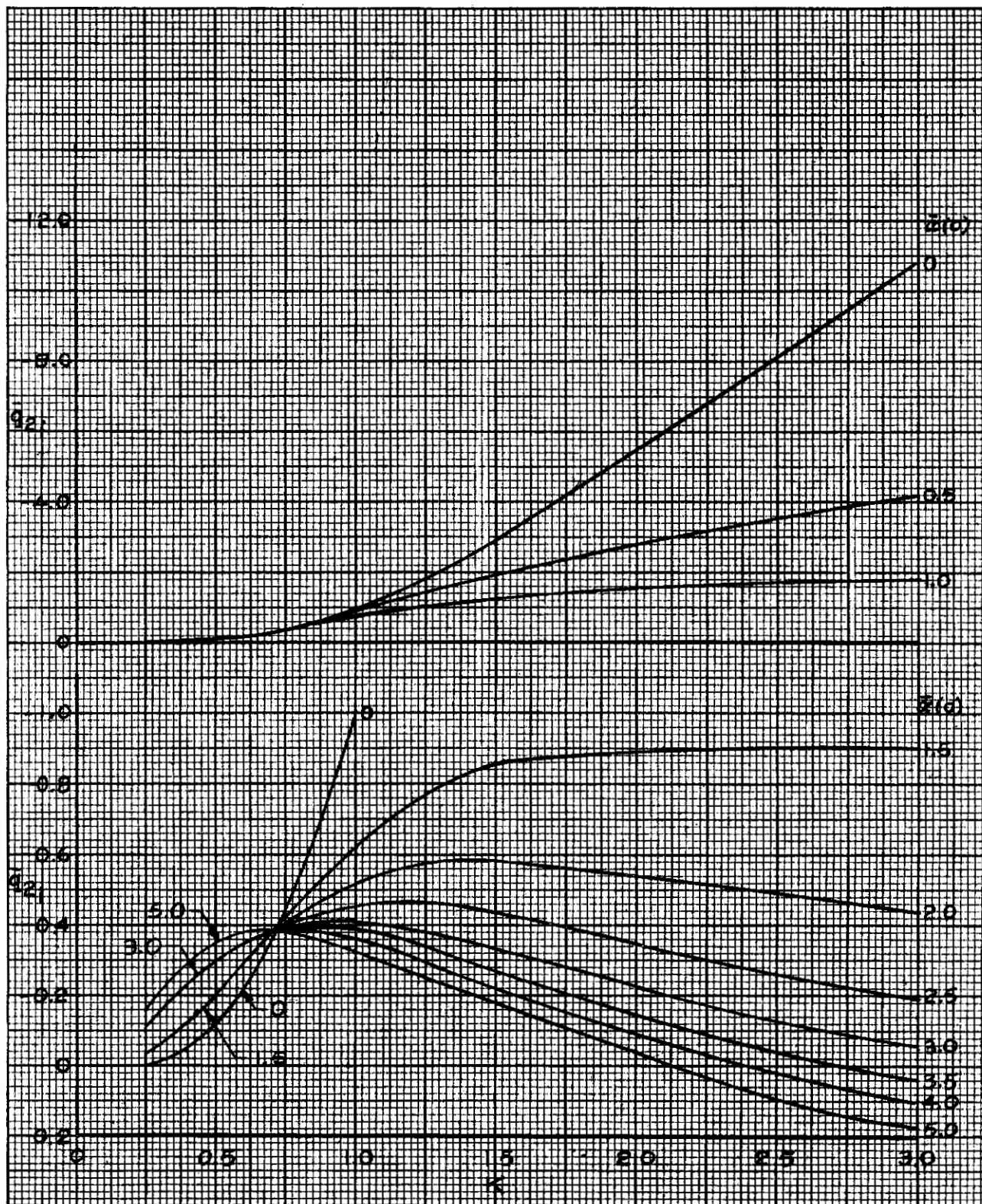


Figure 61. Double Parabolic B.T.E., $\xi_1 = 0.80$

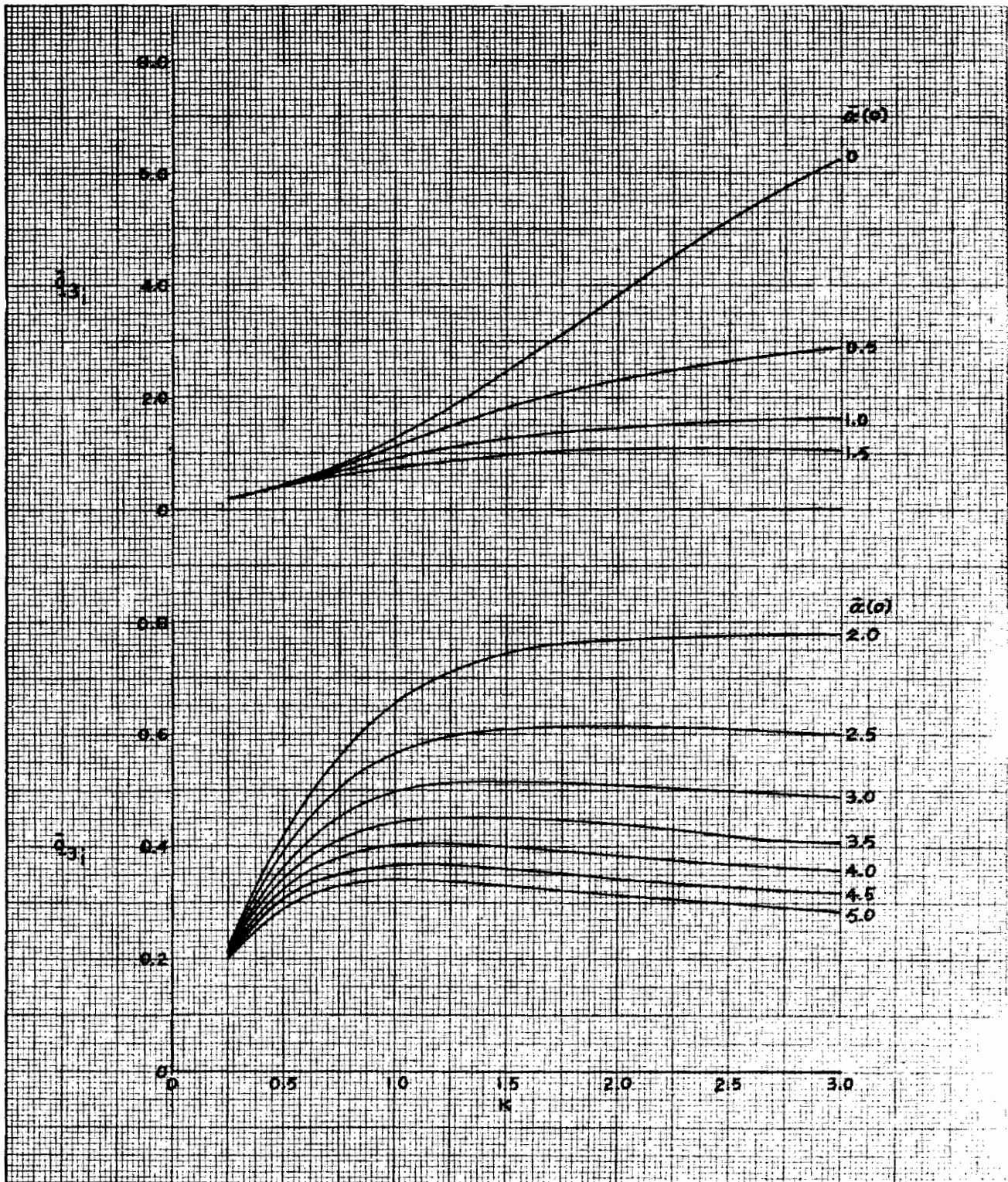


Figure 62. Double Parabolic B.T.E., $\epsilon_i = 0.80$

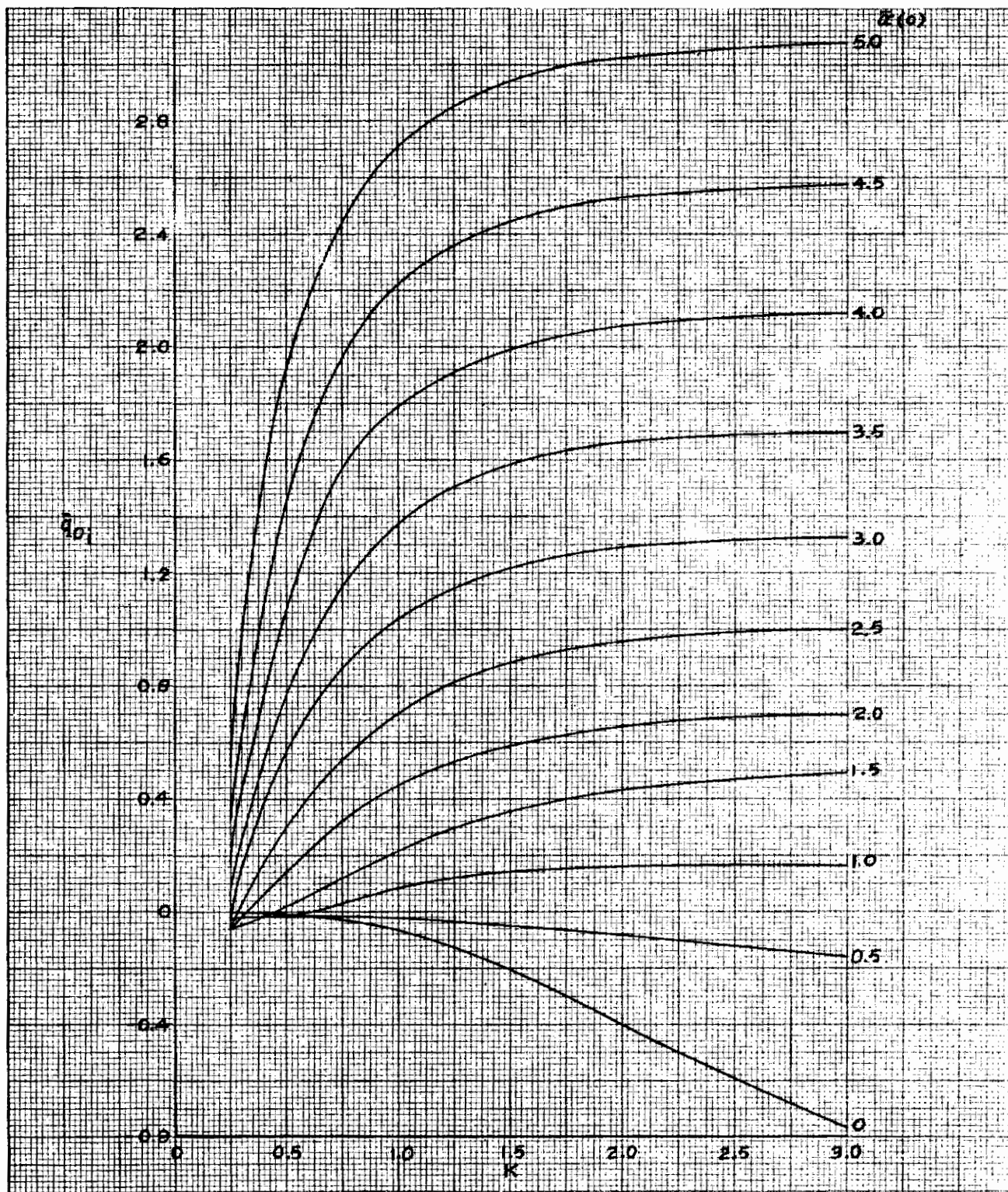


Figure 63. Double Parabolic B.T.E., $\xi_i = 1.00$

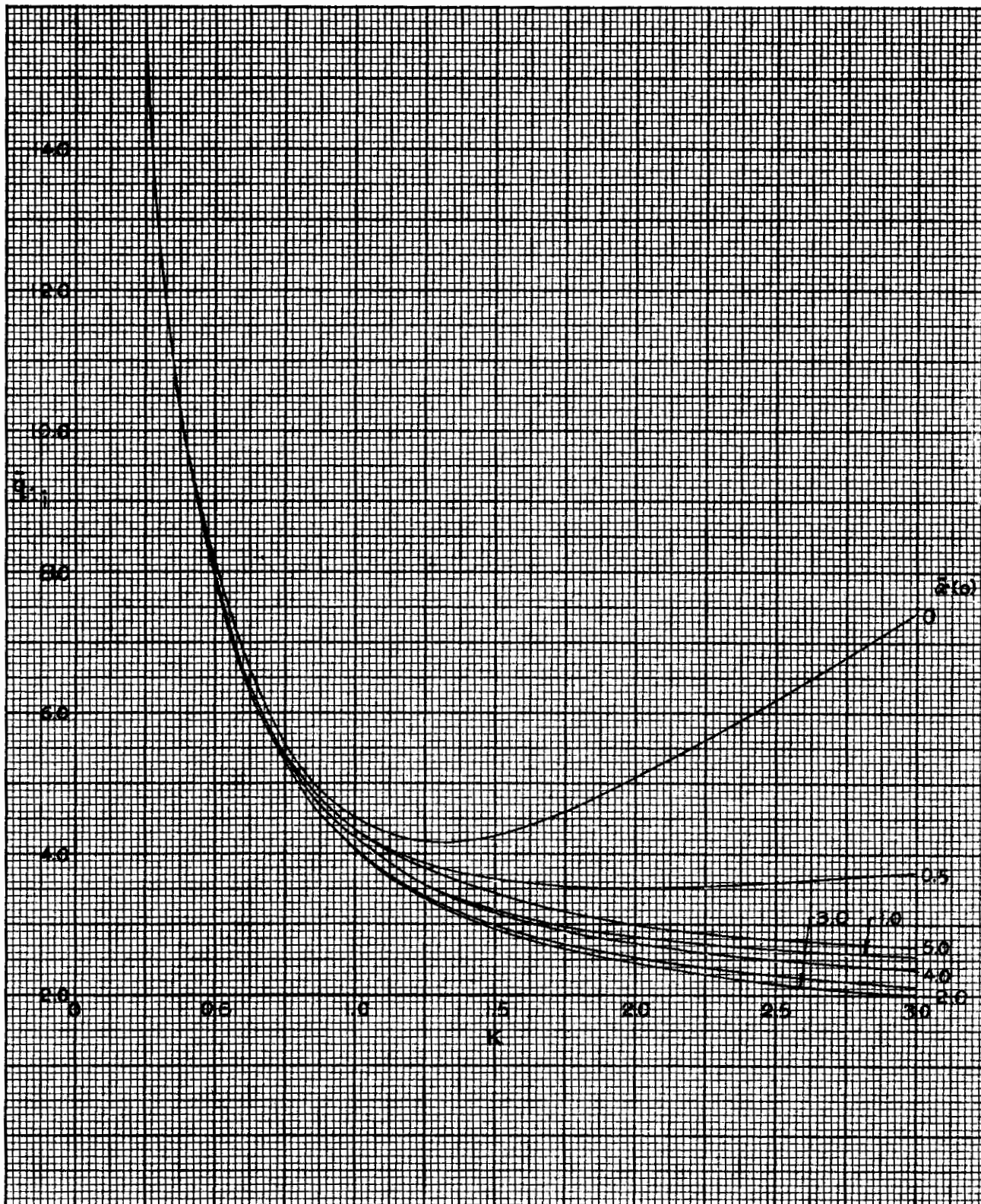


Figure 64. Double Parabolic B.T.E., $\xi_1 = 1.00$

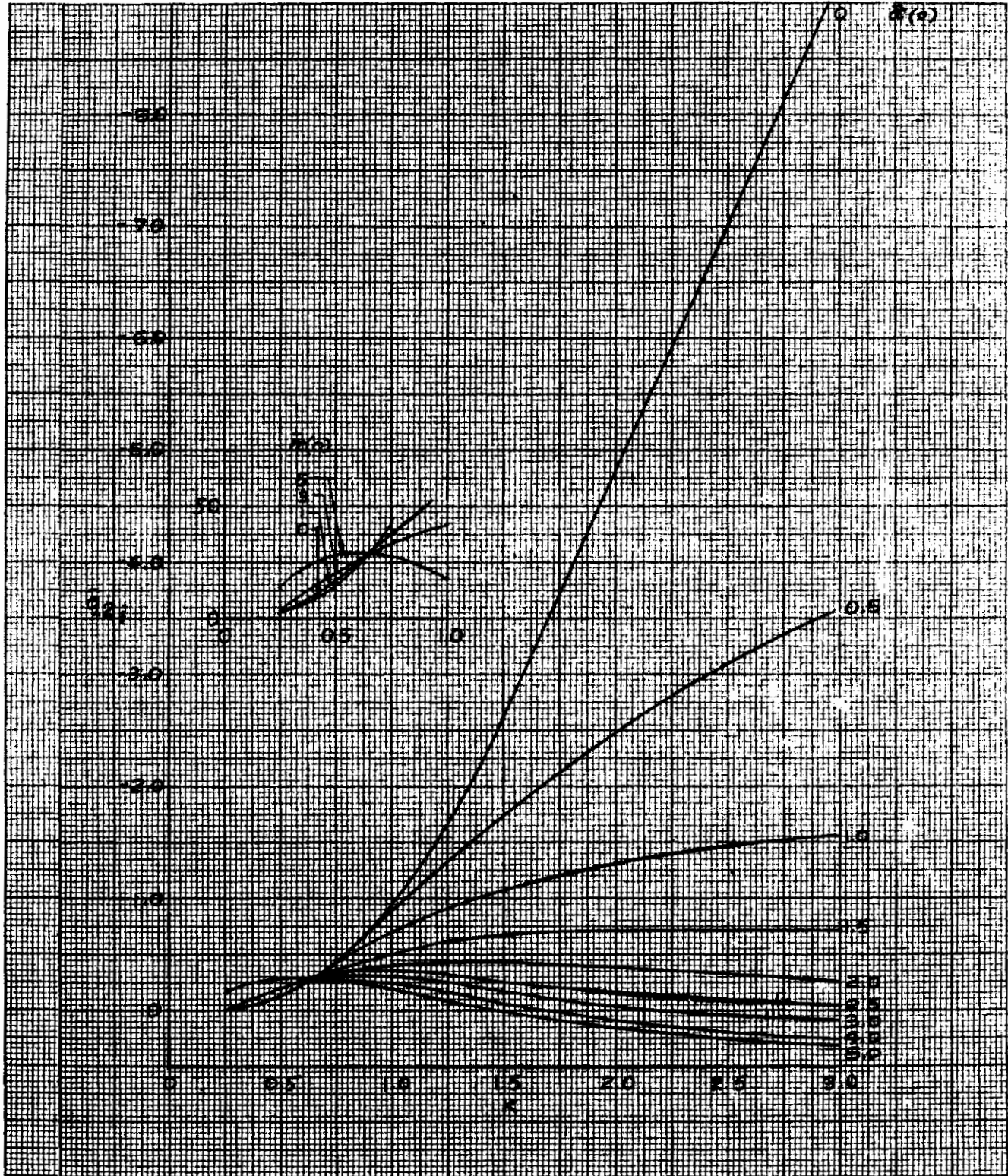


Figure 65. Double Parabolic B.T.E., $\xi_1 = 1.00$

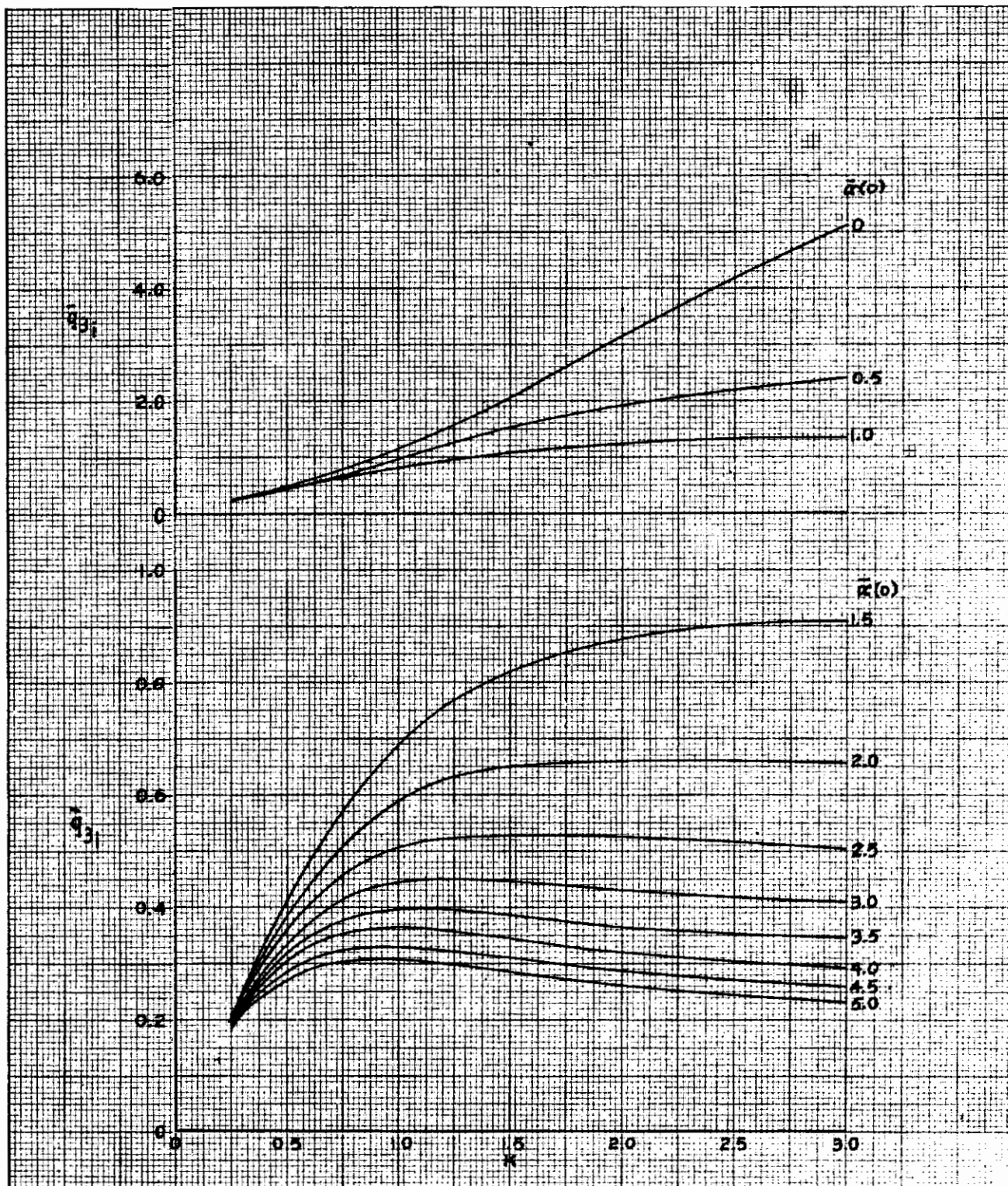


Figure 66. Double Parabolic B.T.E., $\xi_i = 1.00$

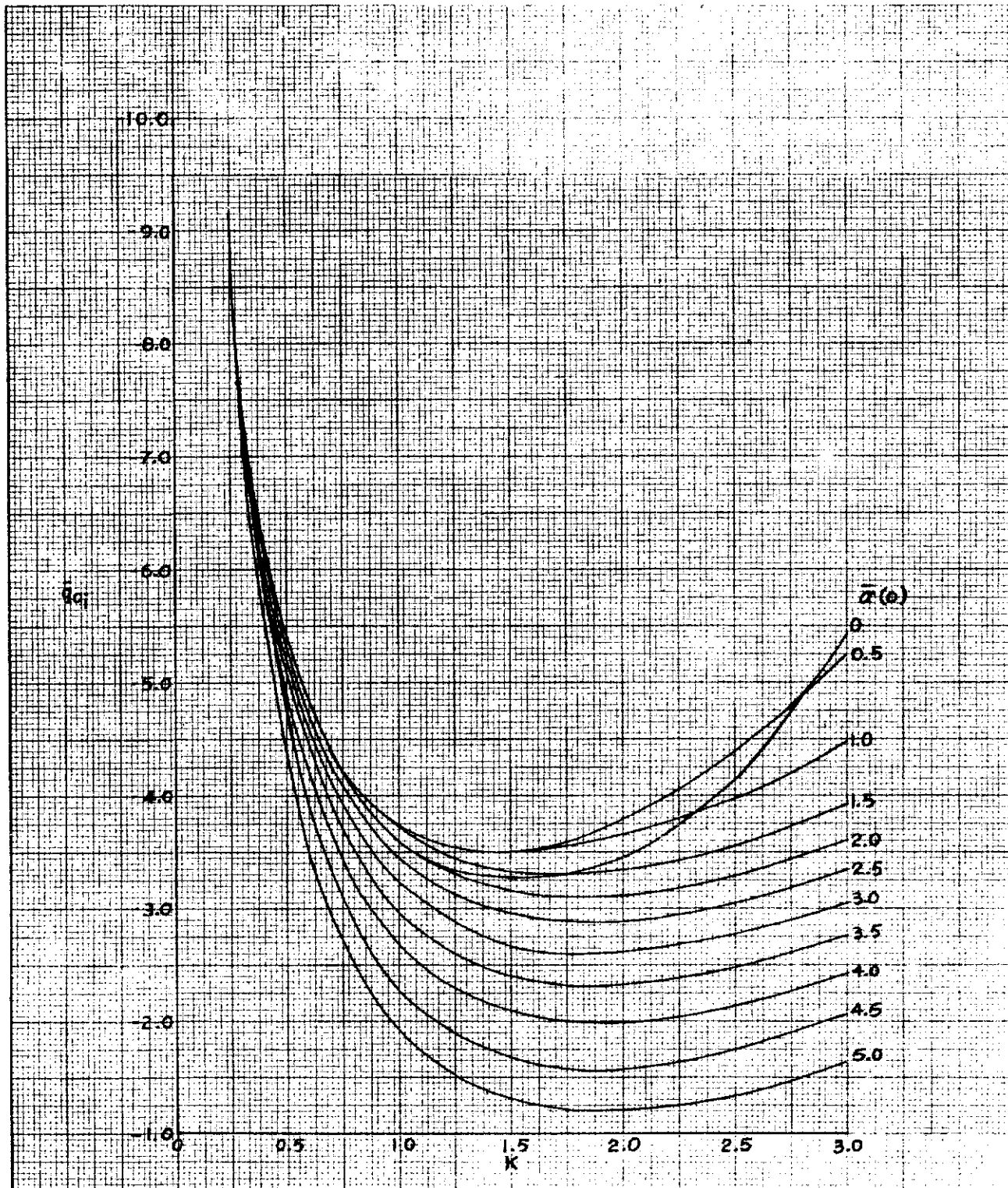


Figure 67. Single Wedge, $0 \leq \xi_i \leq 1.00$

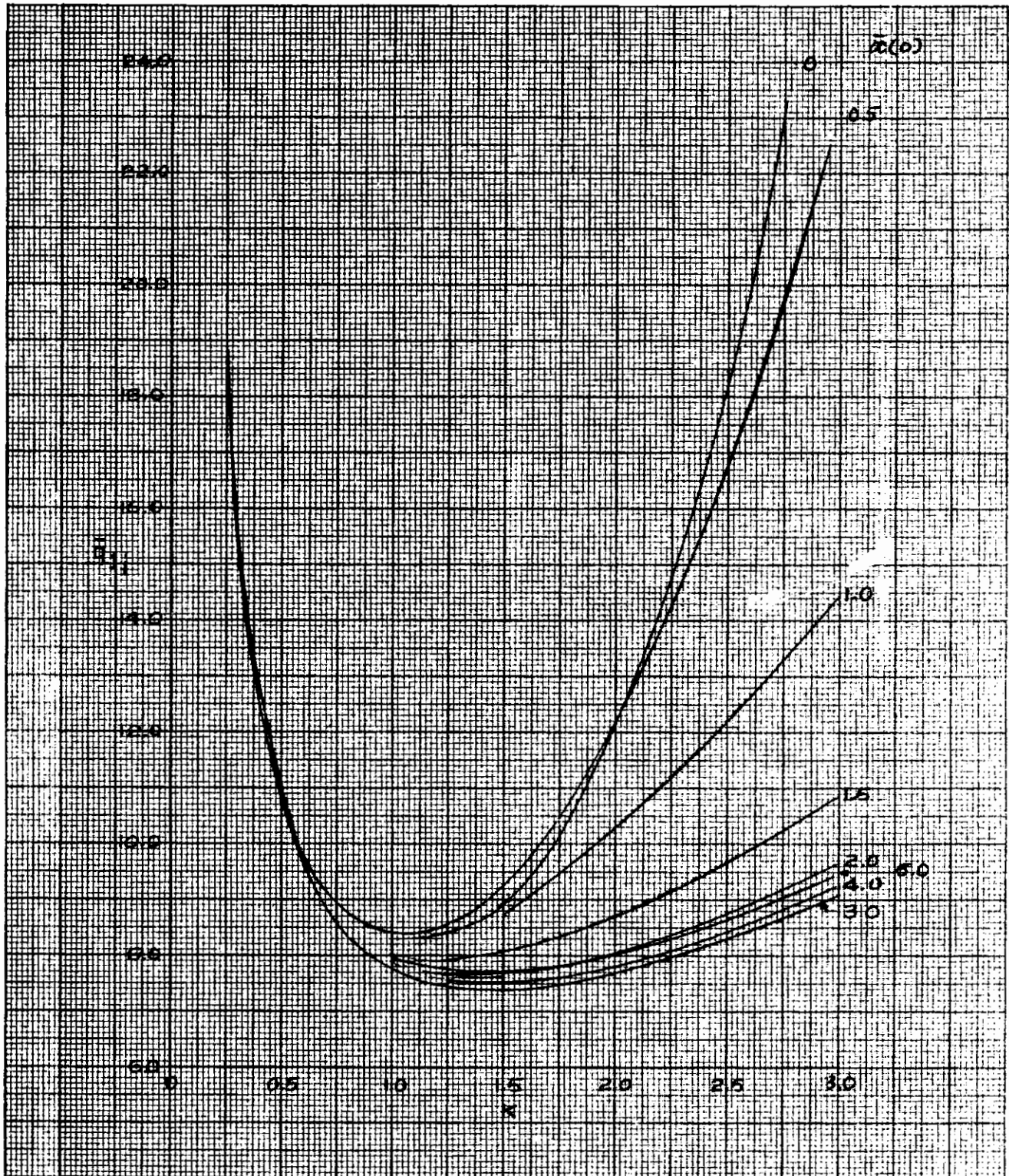


Figure 68. Single Wedge, $0 \leq \xi_i \leq 1.00$

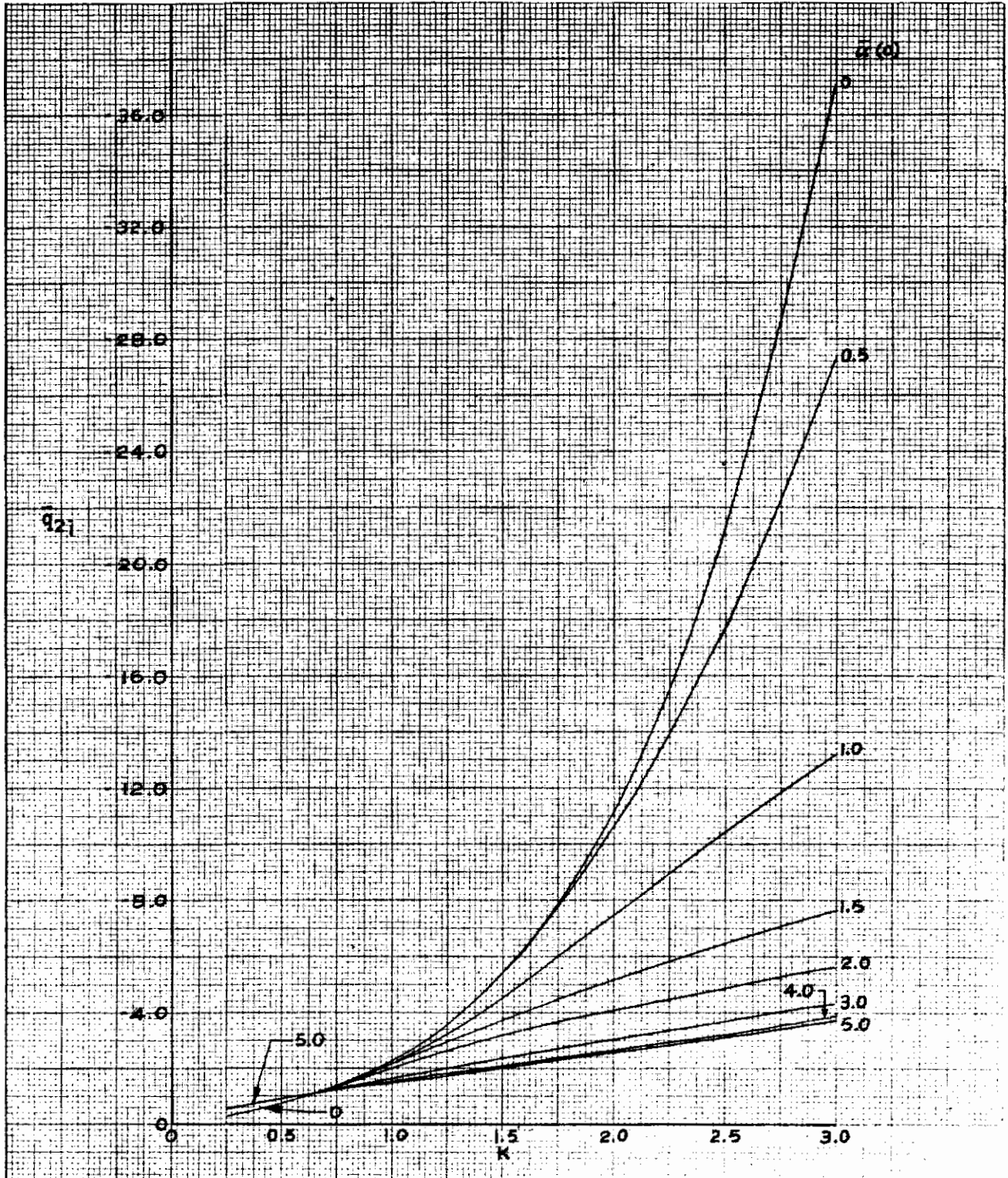


Figure 69. Single Wedge, $0 \leq \xi_i \leq 1.00$

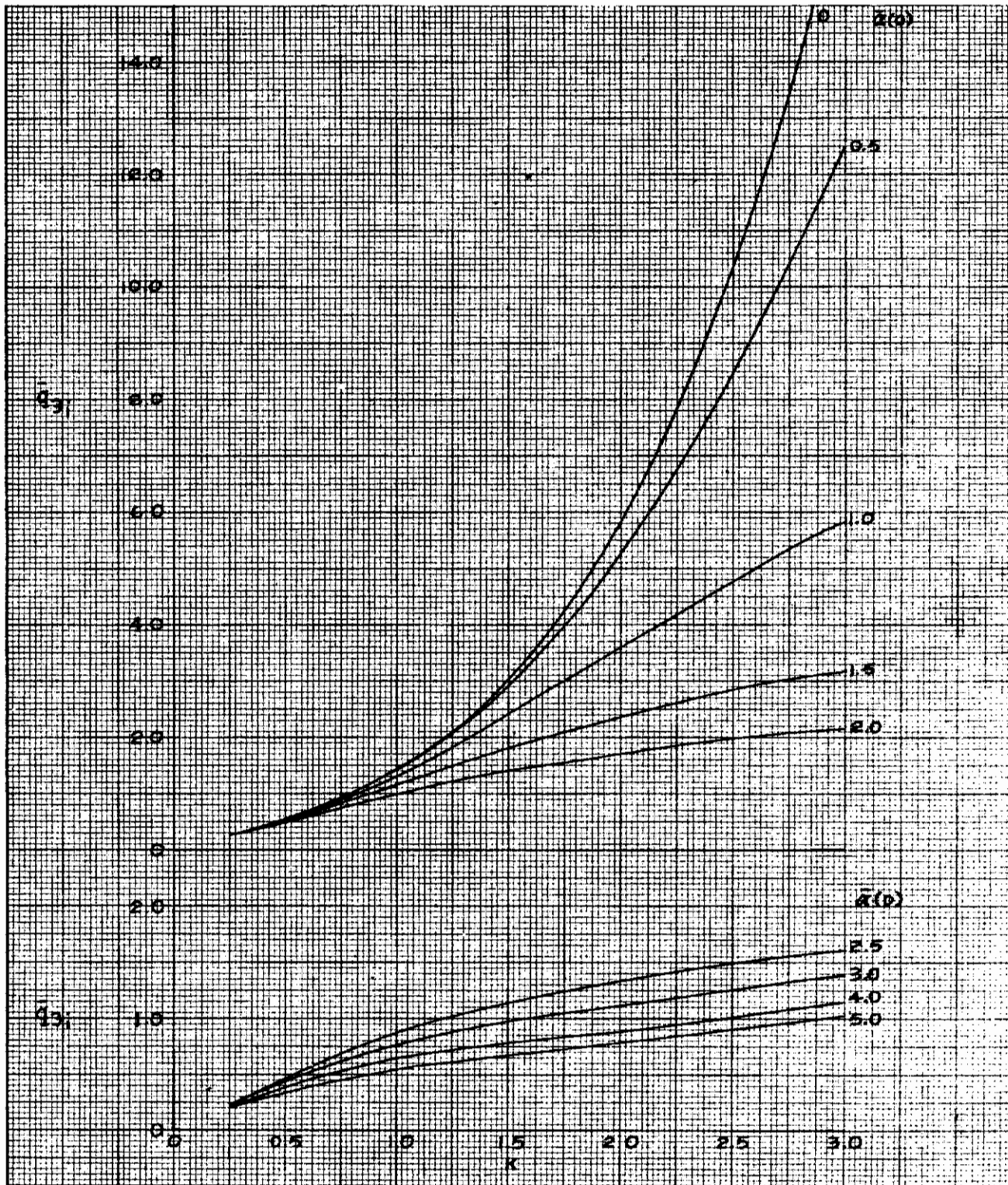


Figure 70. Single Wedge, $0 \leq \xi_i \leq 1.00$

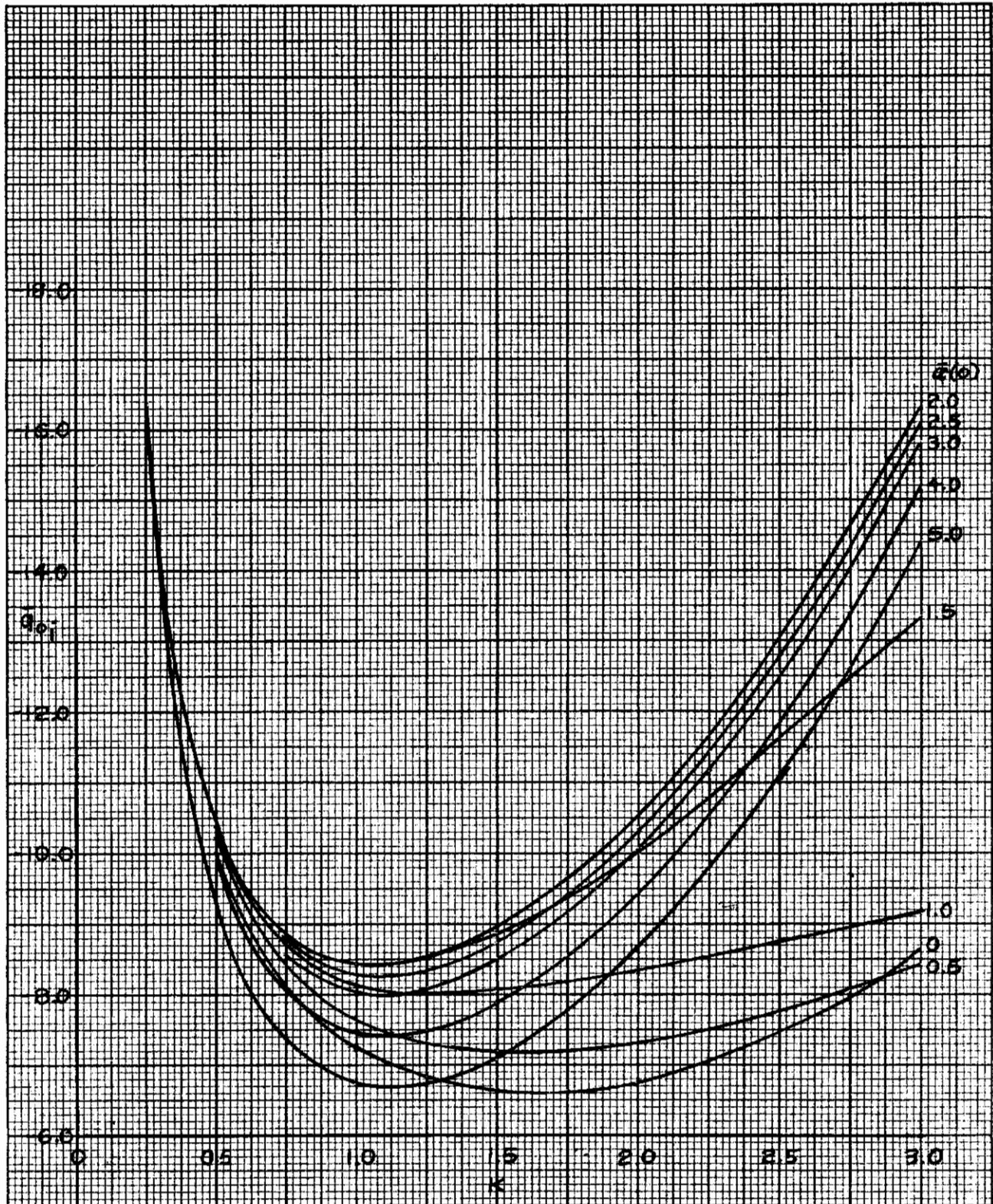


Figure 71. Single Parabolic B.T.E., $\xi_i = 0.20$

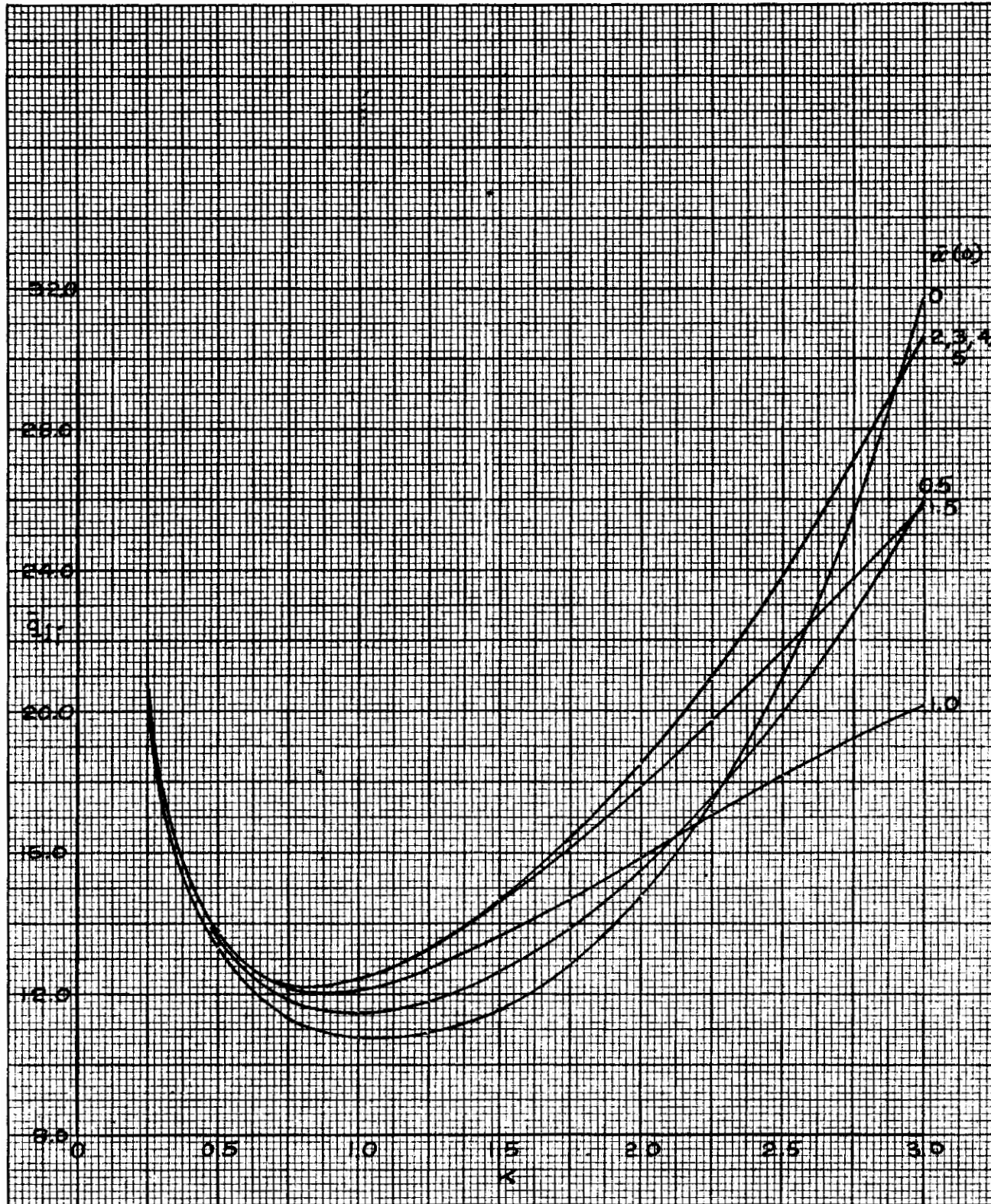


Figure 72. Single Parabolic B.T.E., $\xi_1 = 0.20$.

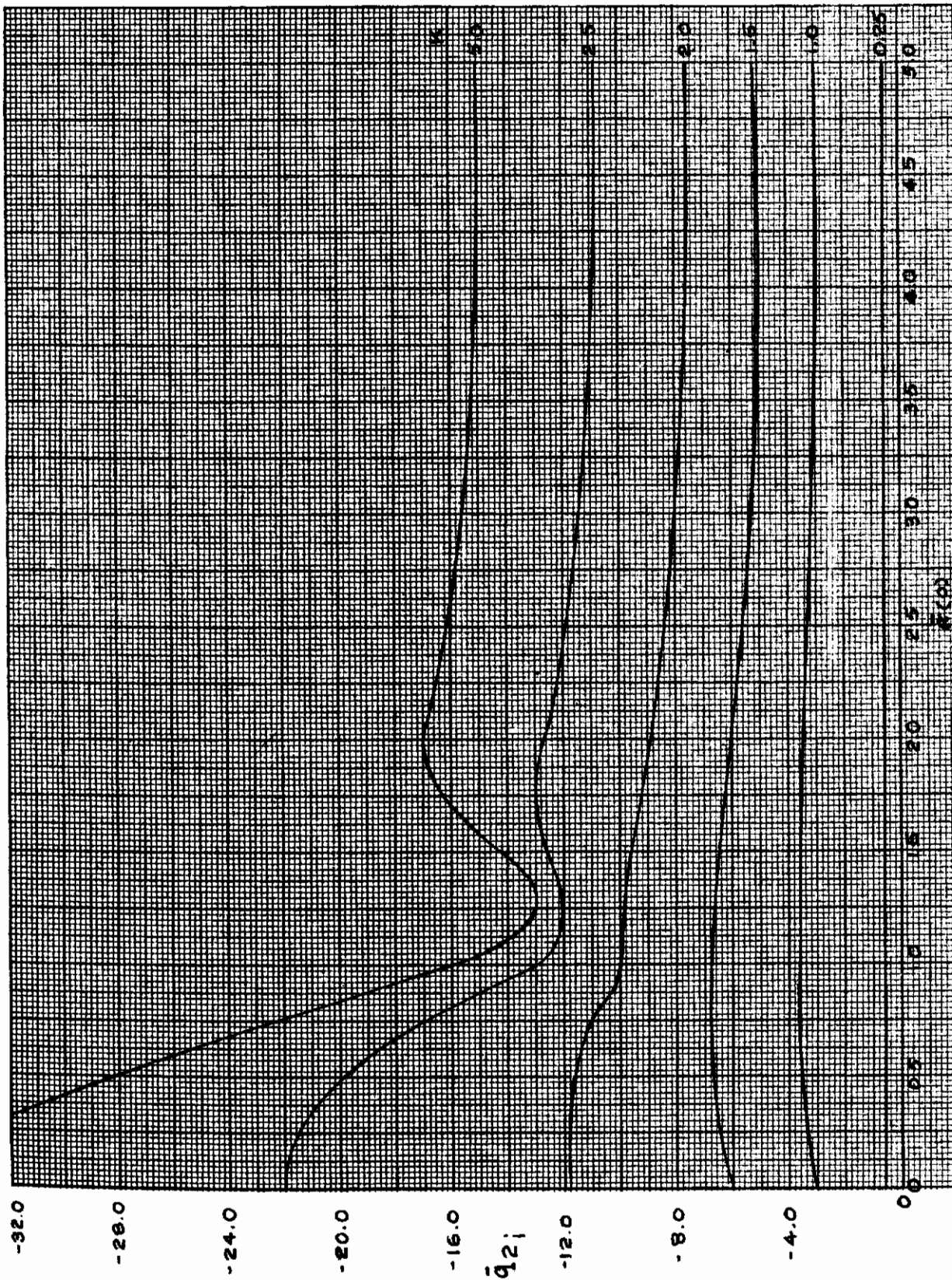


Figure 73. Single Parabolic B.T.E., $\zeta_i = 0.20$

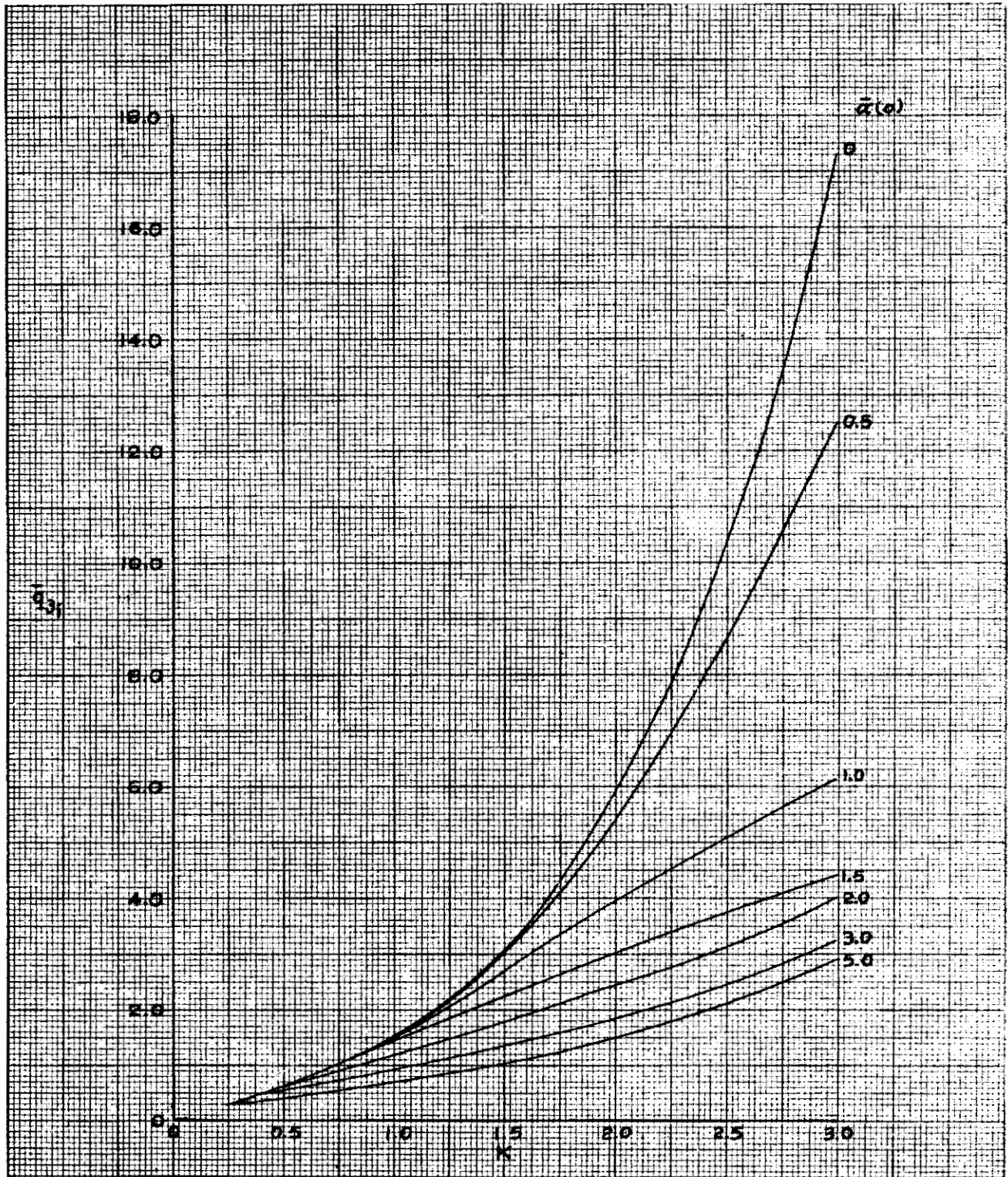


Figure 74.. Single Parabolic B.T.E., $\xi_i = 0.20$

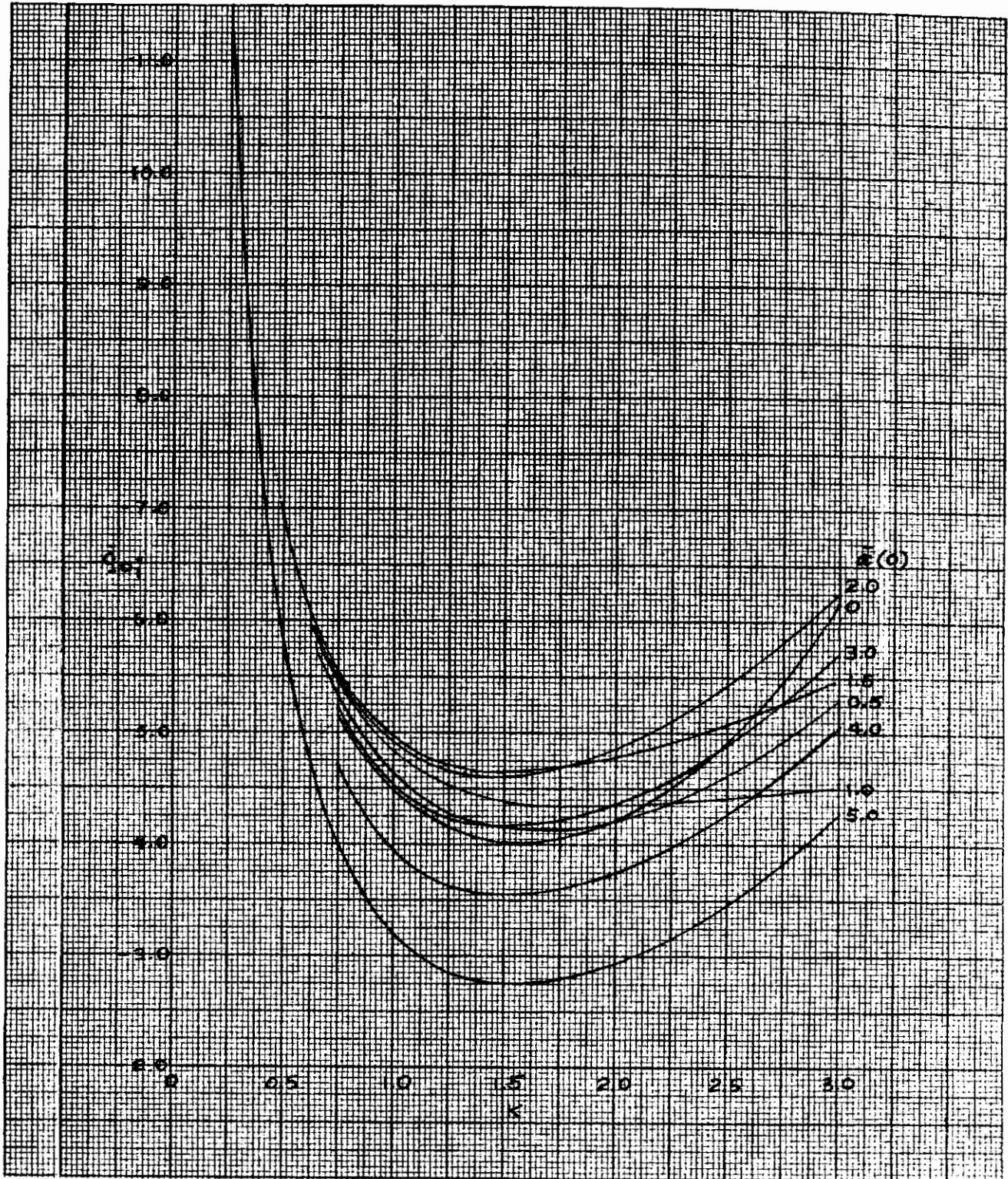


Figure 75. Single Parabolic B.T.E., $\xi_1 = 0.40$

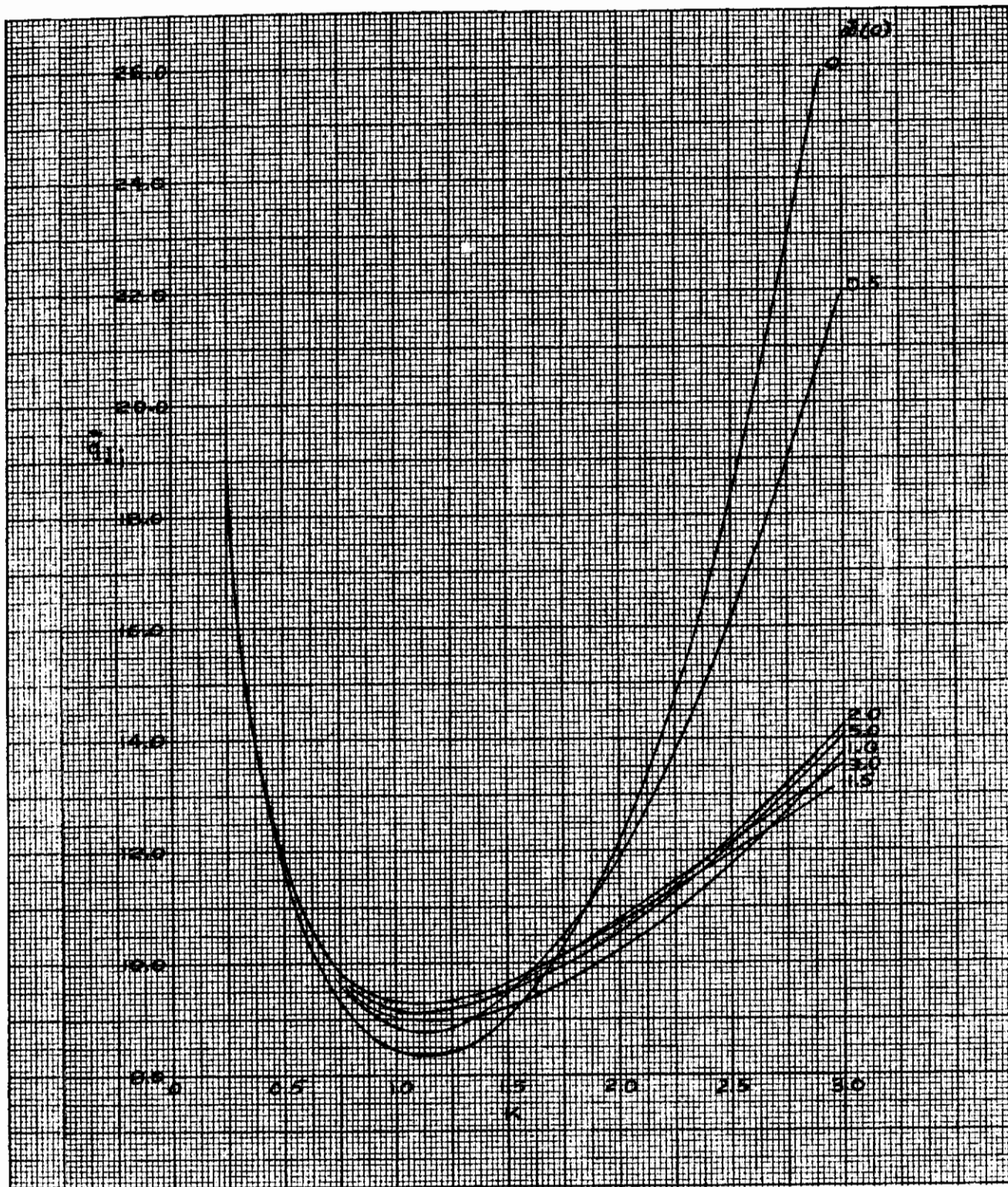


Figure 76. Single Parabolic B.T.E., $\xi_i = 0.40$

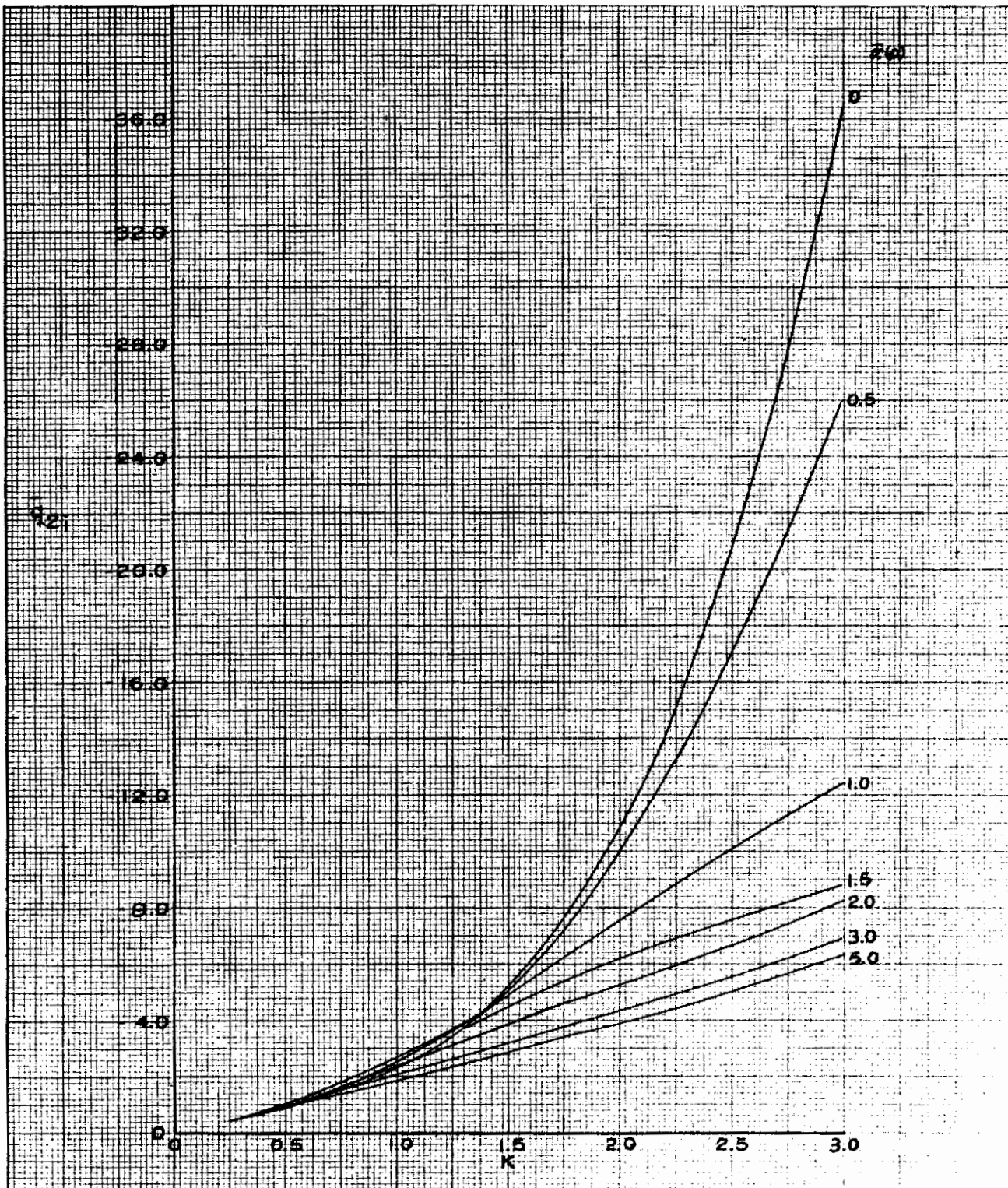


Figure 77. Single Parabolic B.T.E., $\xi_i = 0.40$

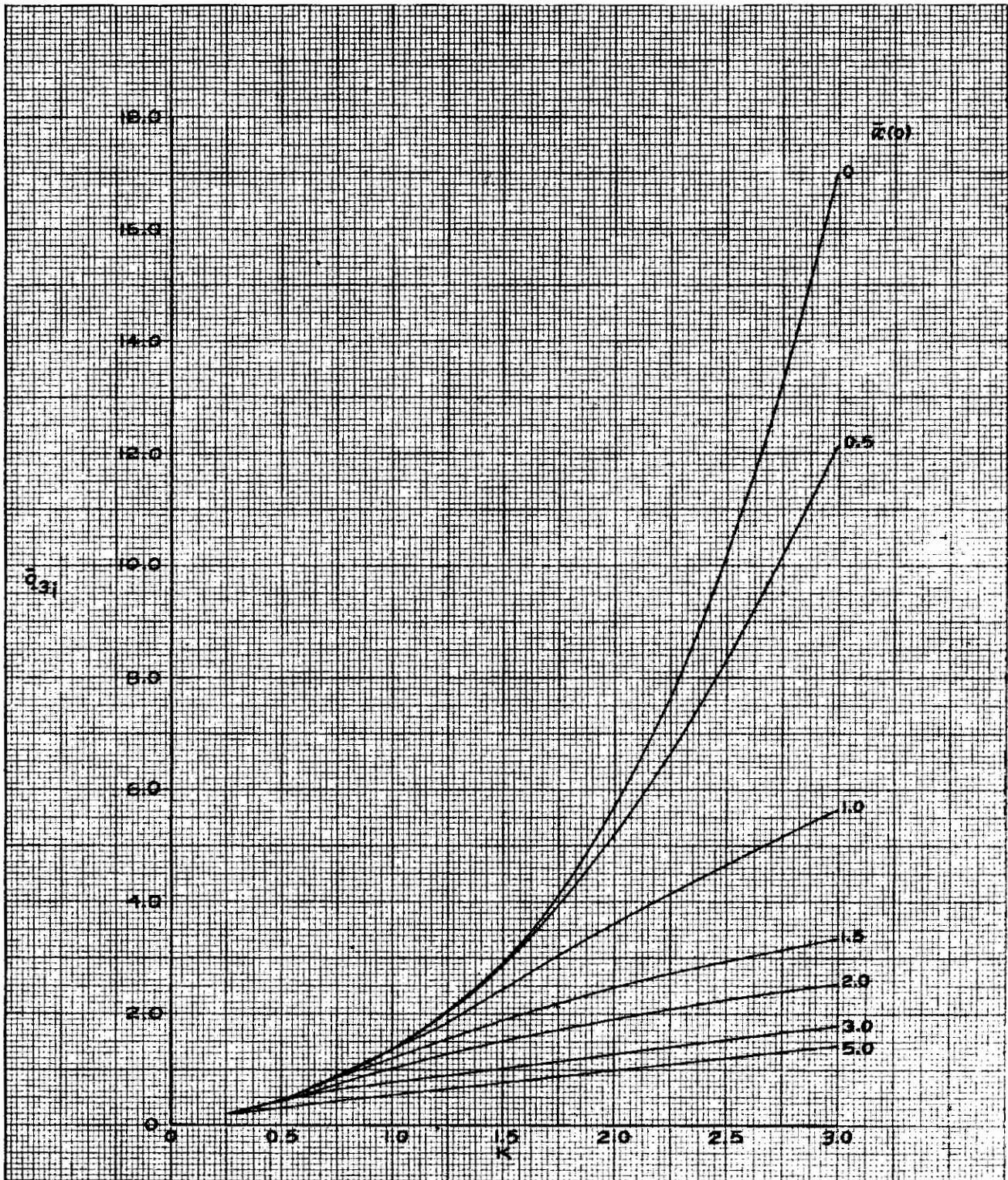


Figure 78. Single Parabolic B.T.E., $\xi_1 = 0.40$

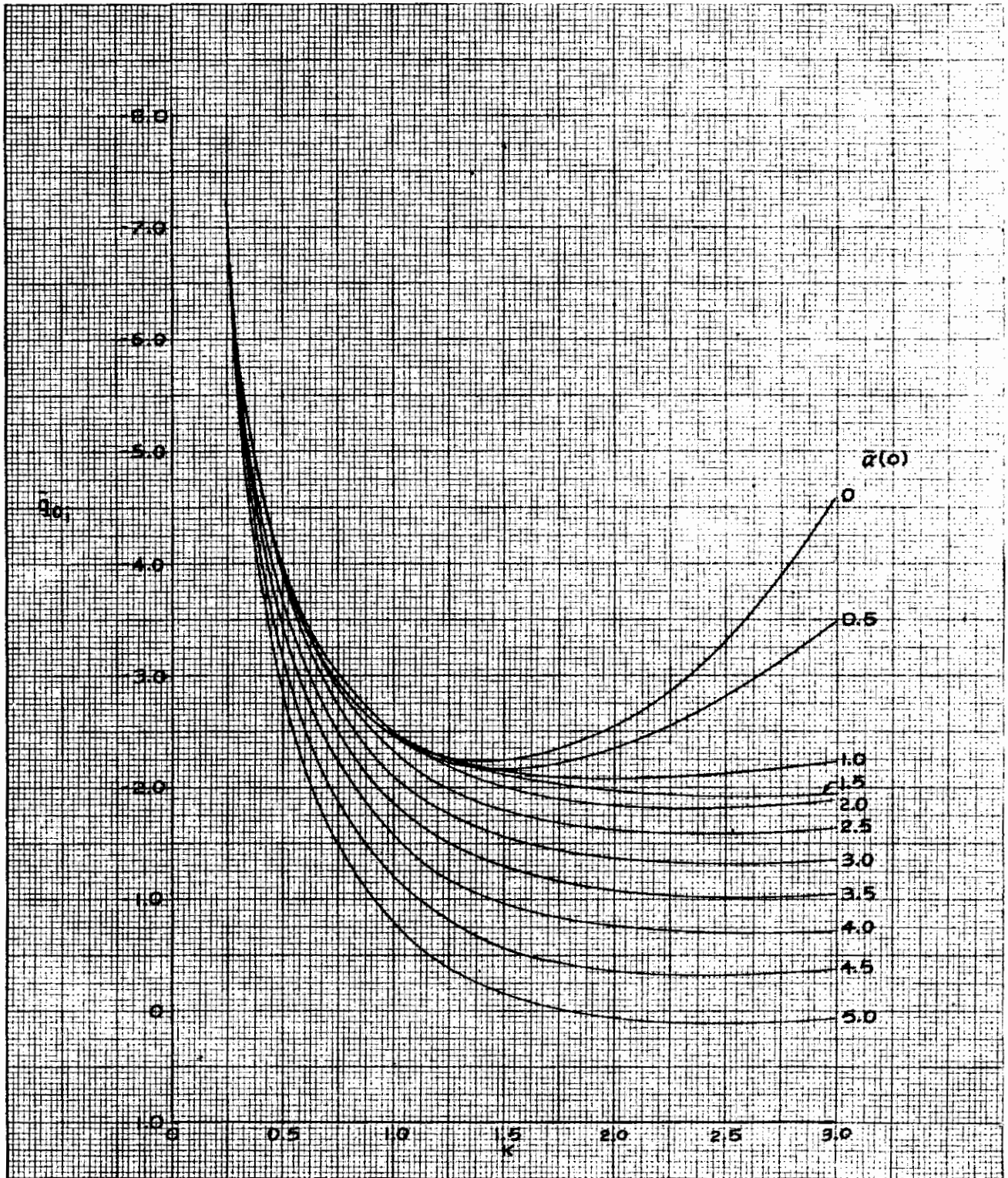


Figure 79. Single Parabolic B.T.E., $\xi_i = 0.60$

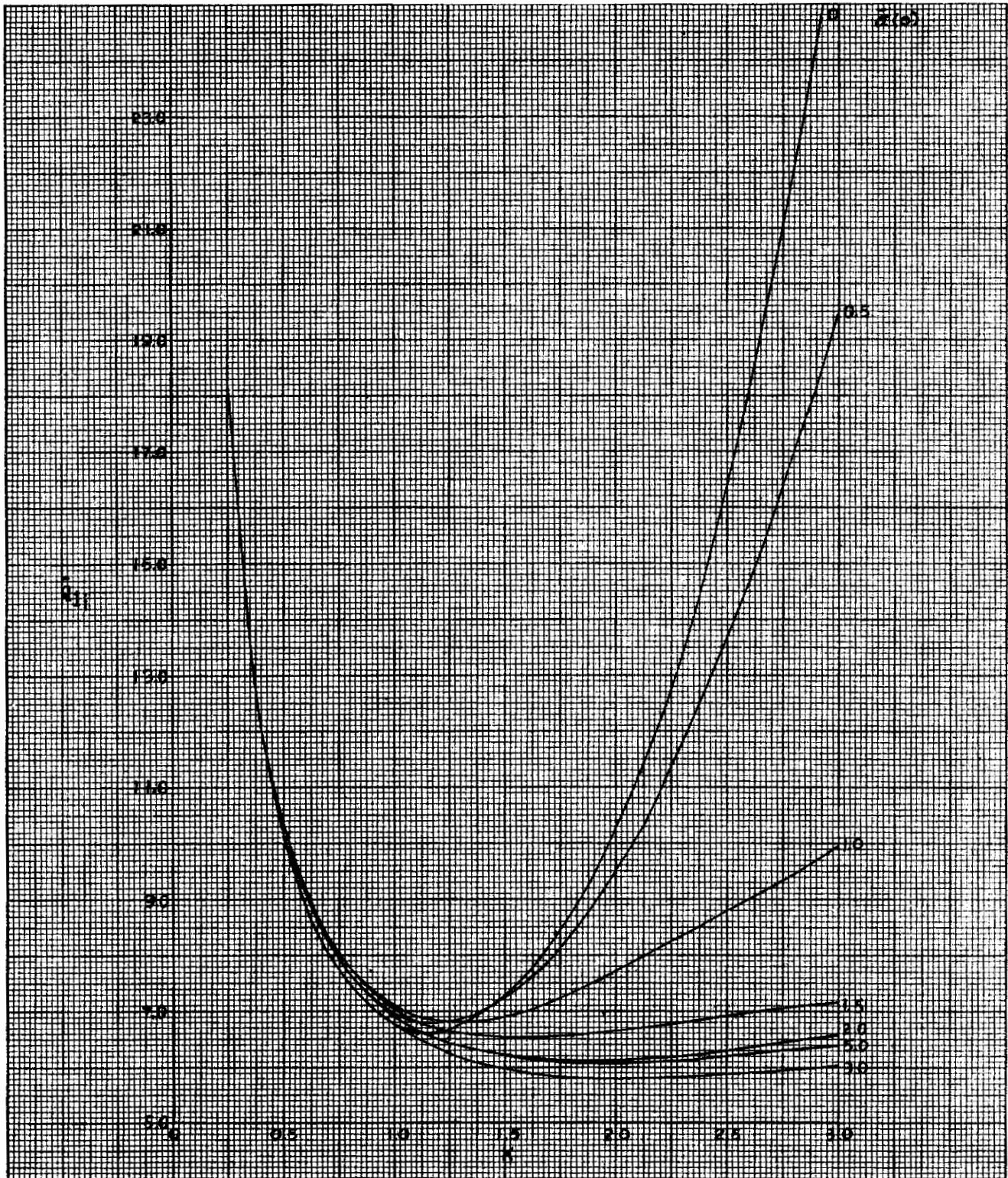


Figure 80. Single Parabolic B.T.E., $\xi_1 = 0.60$

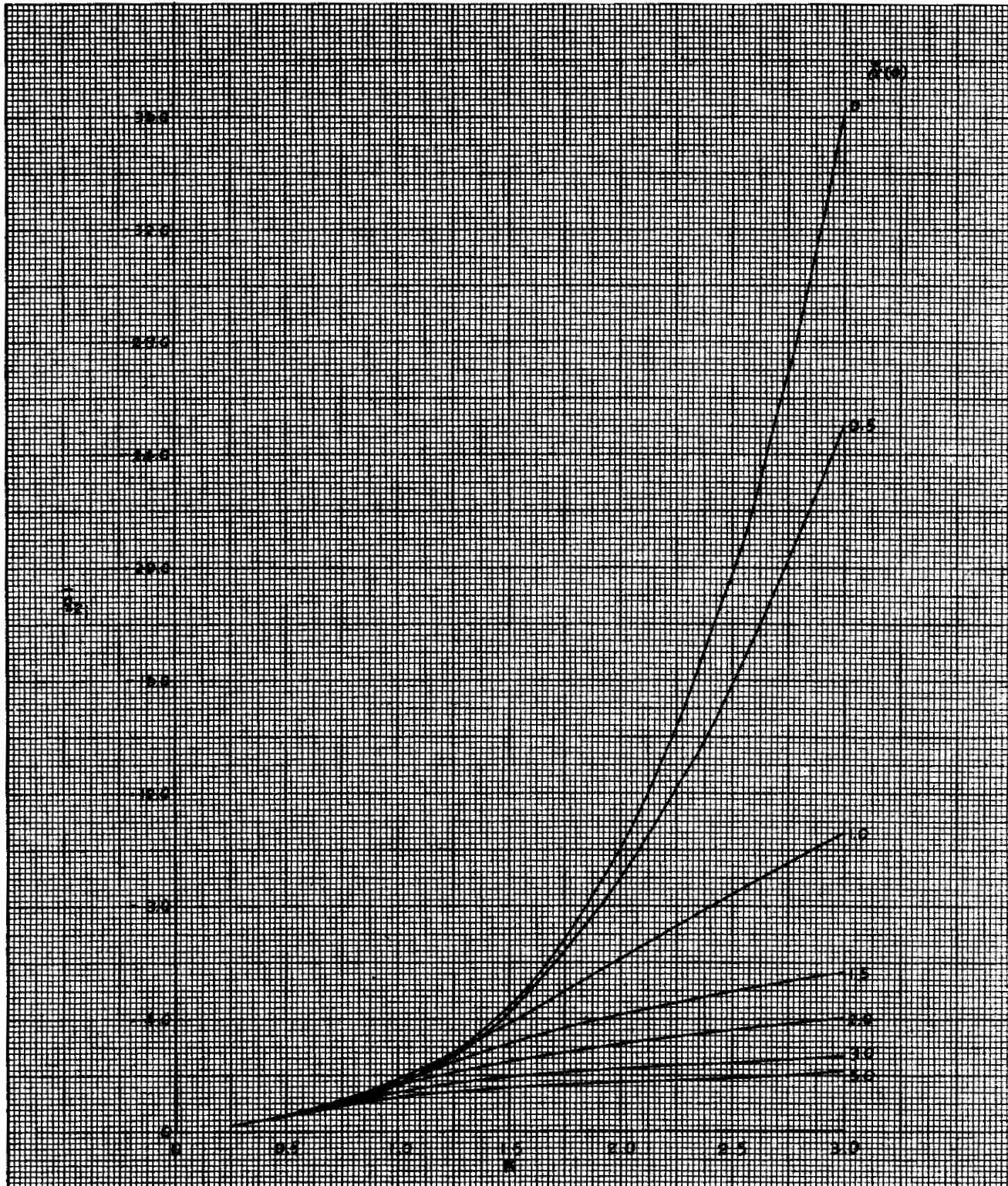


Figure 81. Single Parabolic B.T.E., $\xi_i = 0.60$

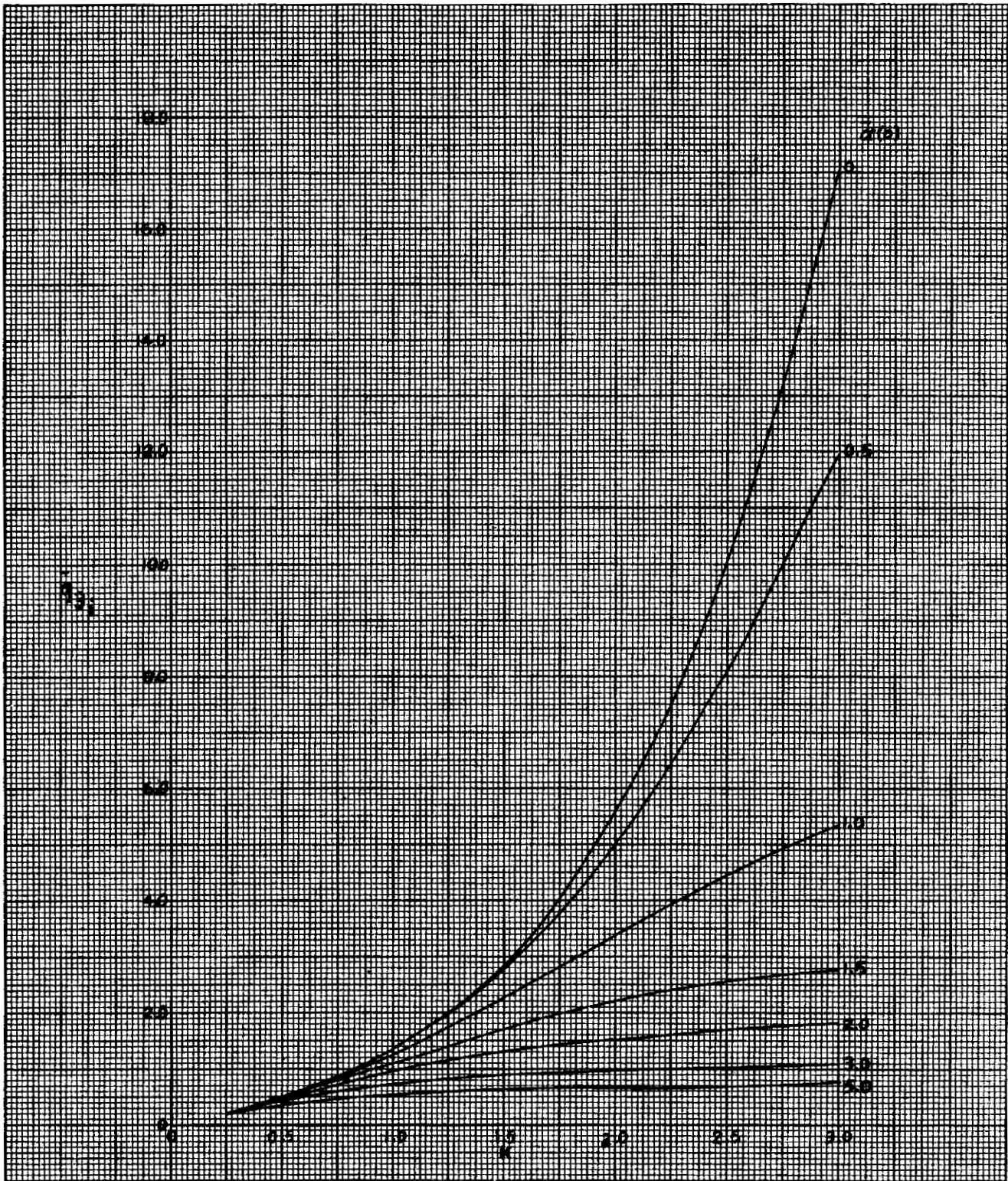


Figure 82. Single Parabolic B.T.E., $\xi_1 = 0.60$

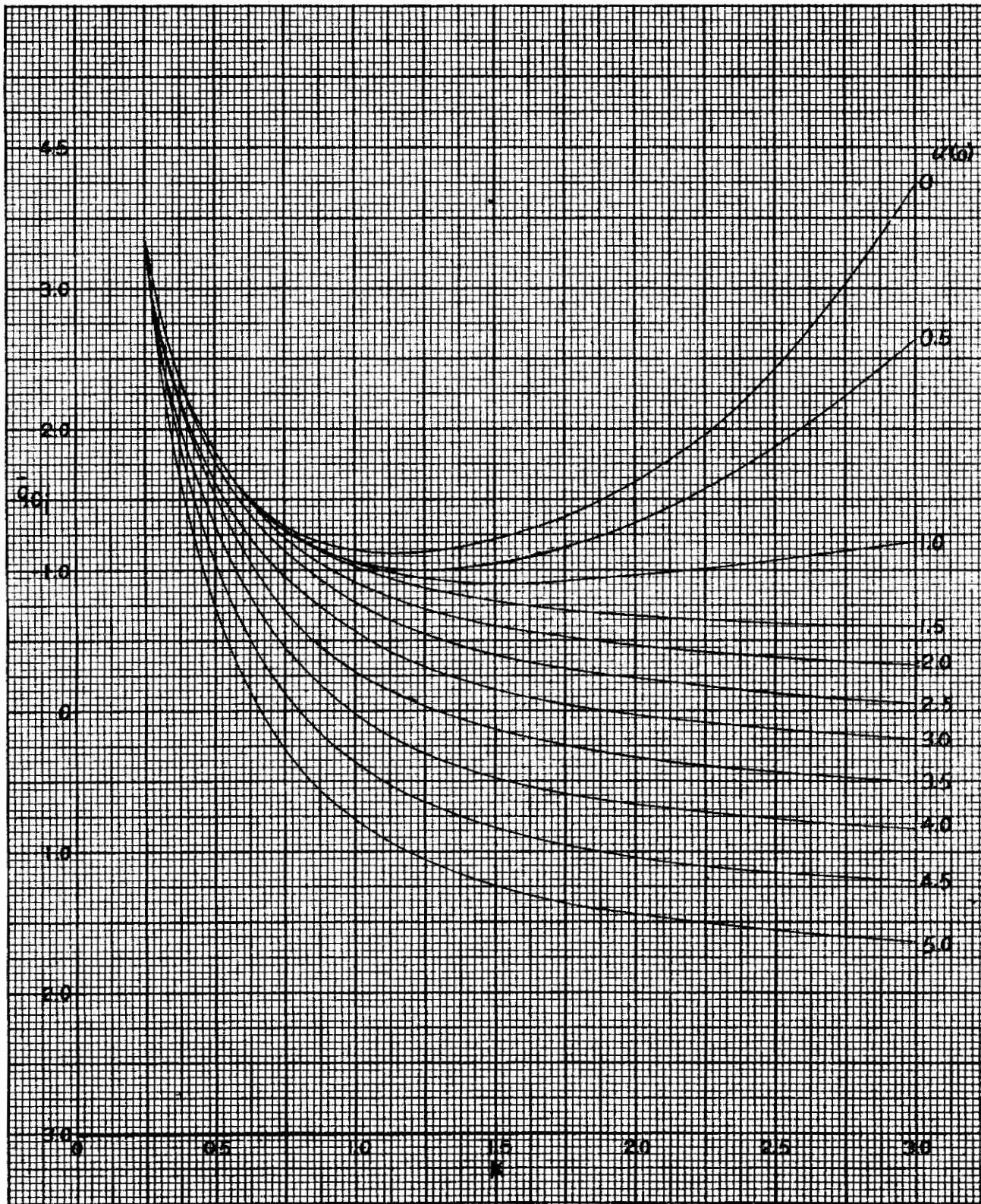


Figure 83. Single Parabolic B.T.E., $\xi_i = 0.80$

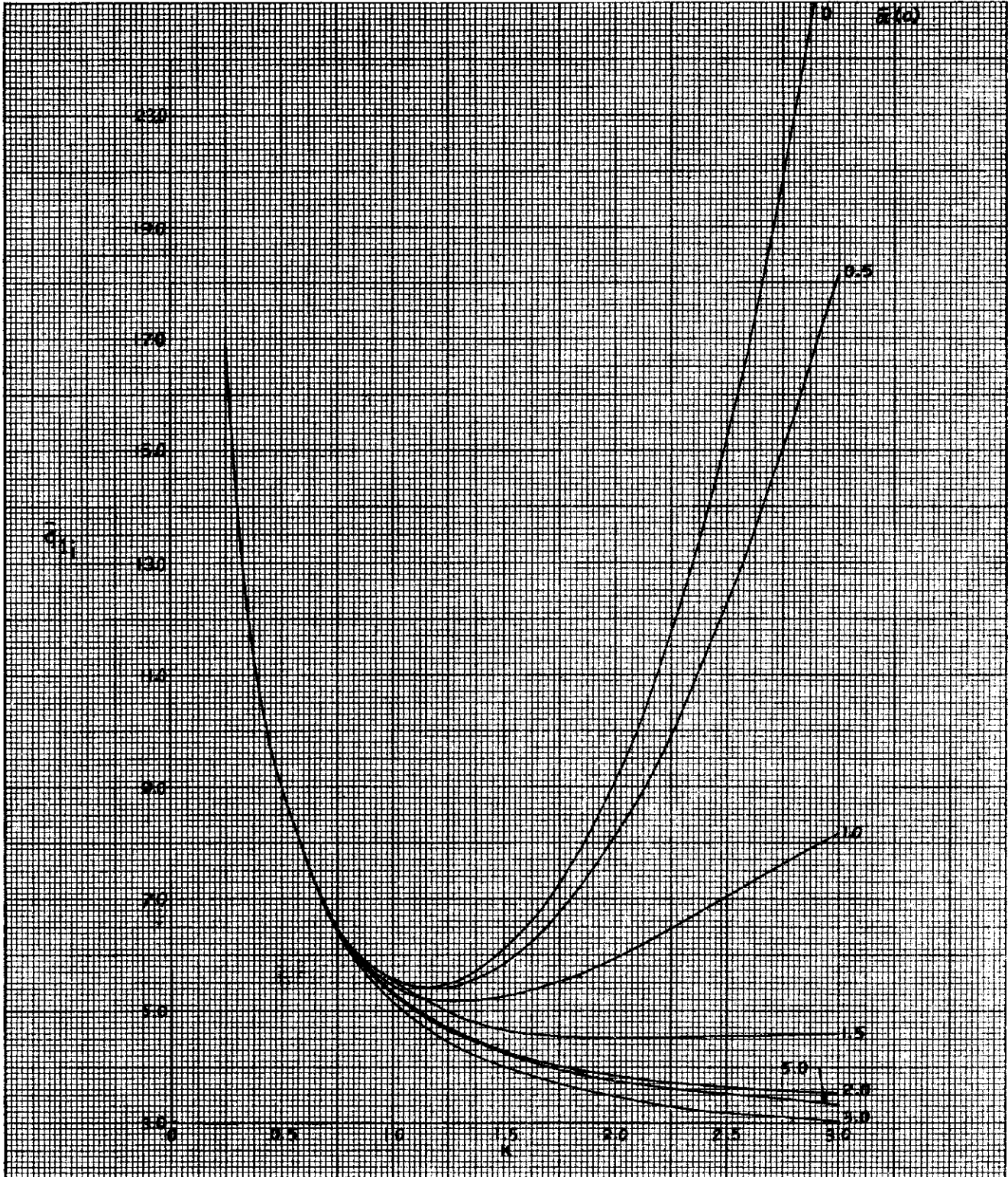


Figure 84. Single Parabolic B.T.E., $\xi_i = 0.80$

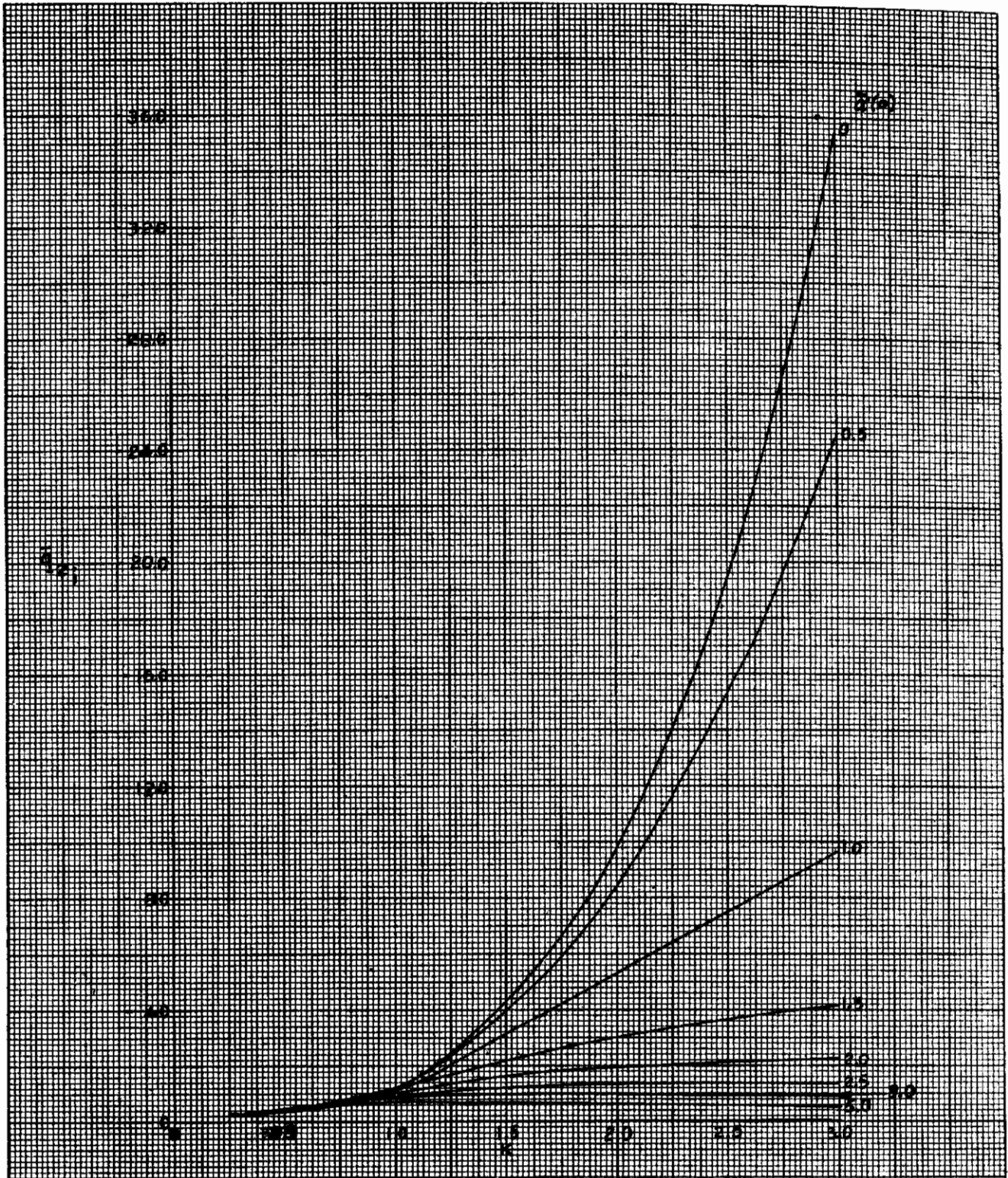


Figure 85. Single Parabolic B.T.E., $\xi_1 = 0.80$

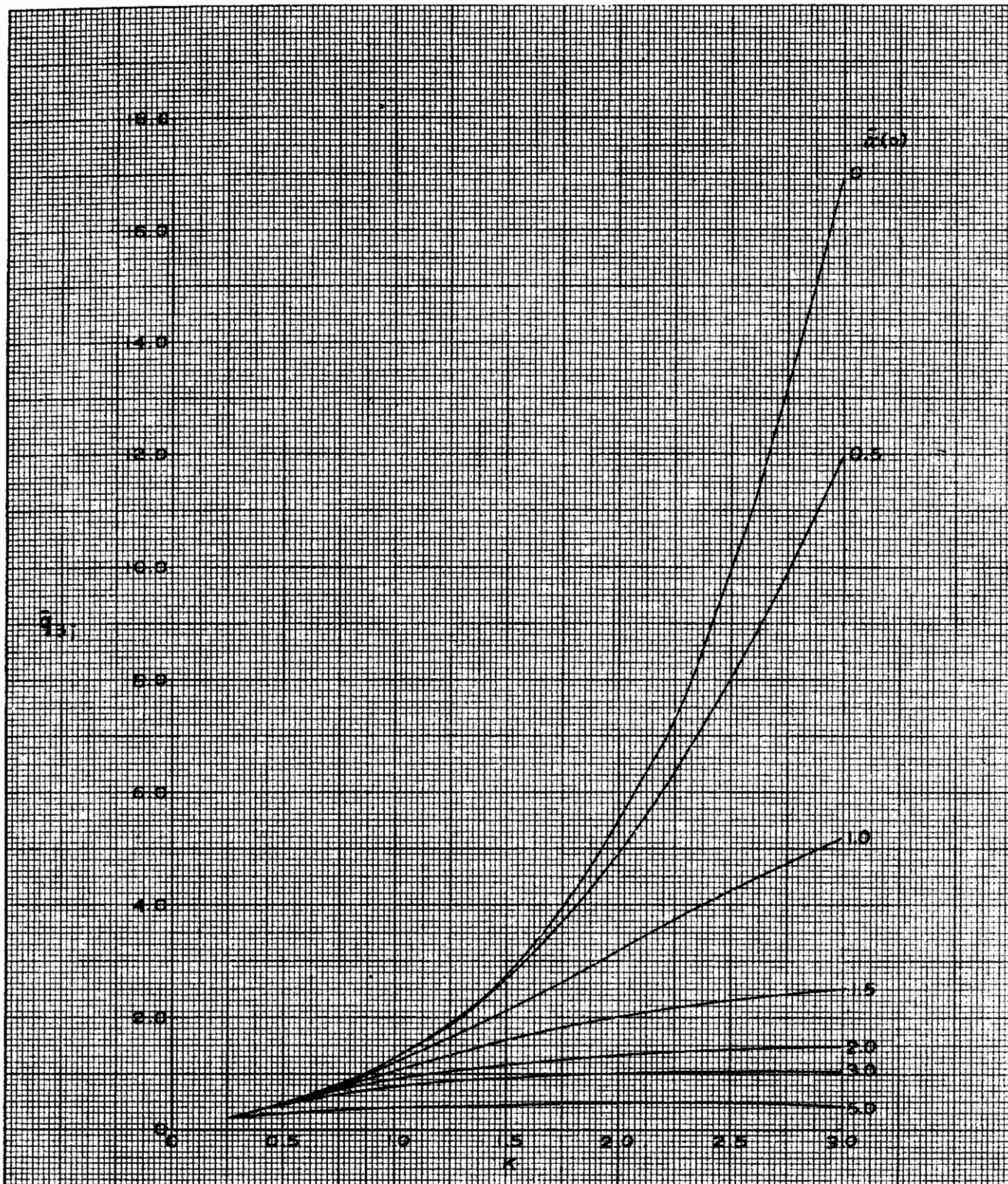


Figure 86. Single Parabolic B.T.E., $\xi_1 = 0.80$ and 1.00

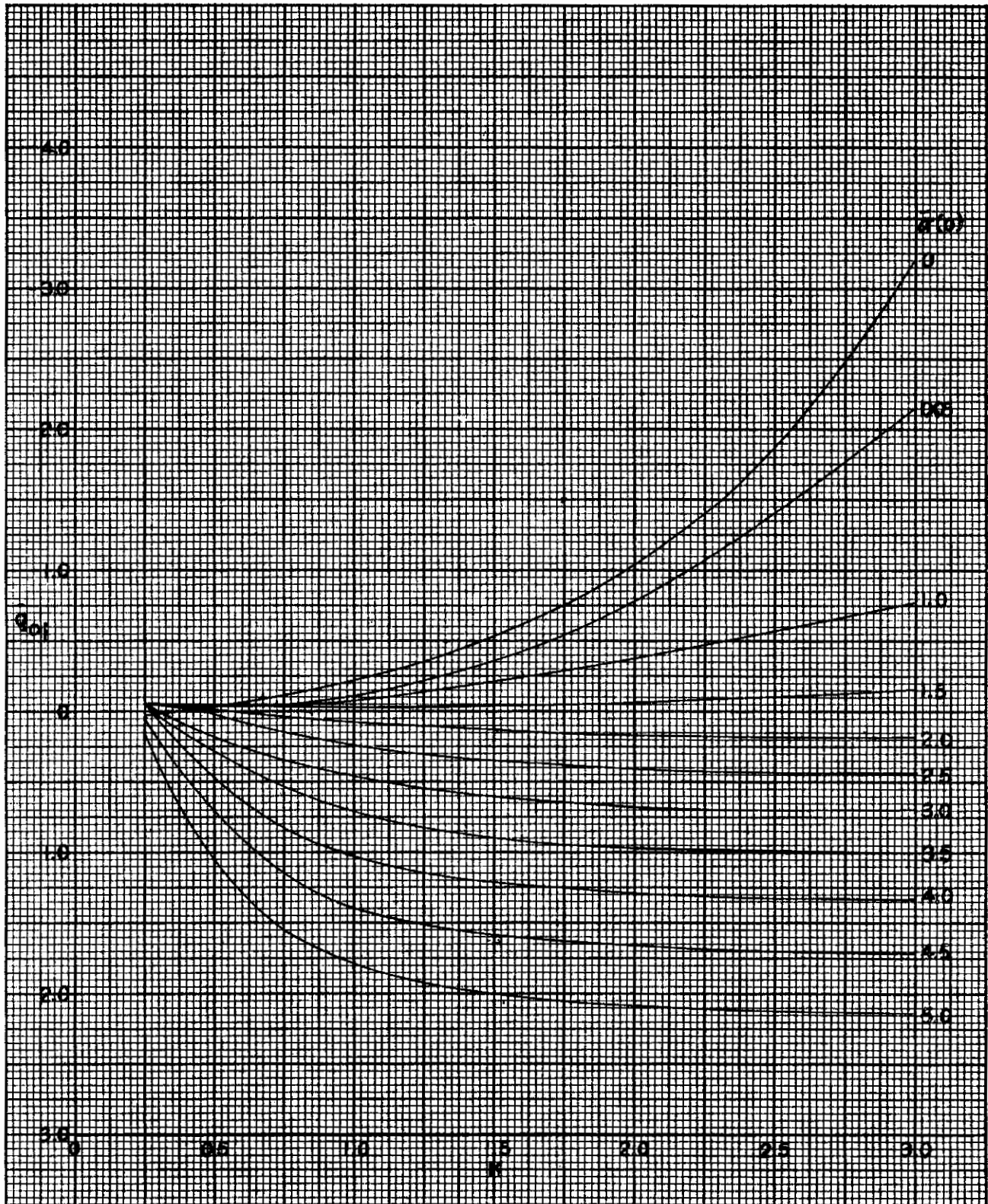


Figure 87. Single Parabolic B.T.E., $\xi_i = 1.00$

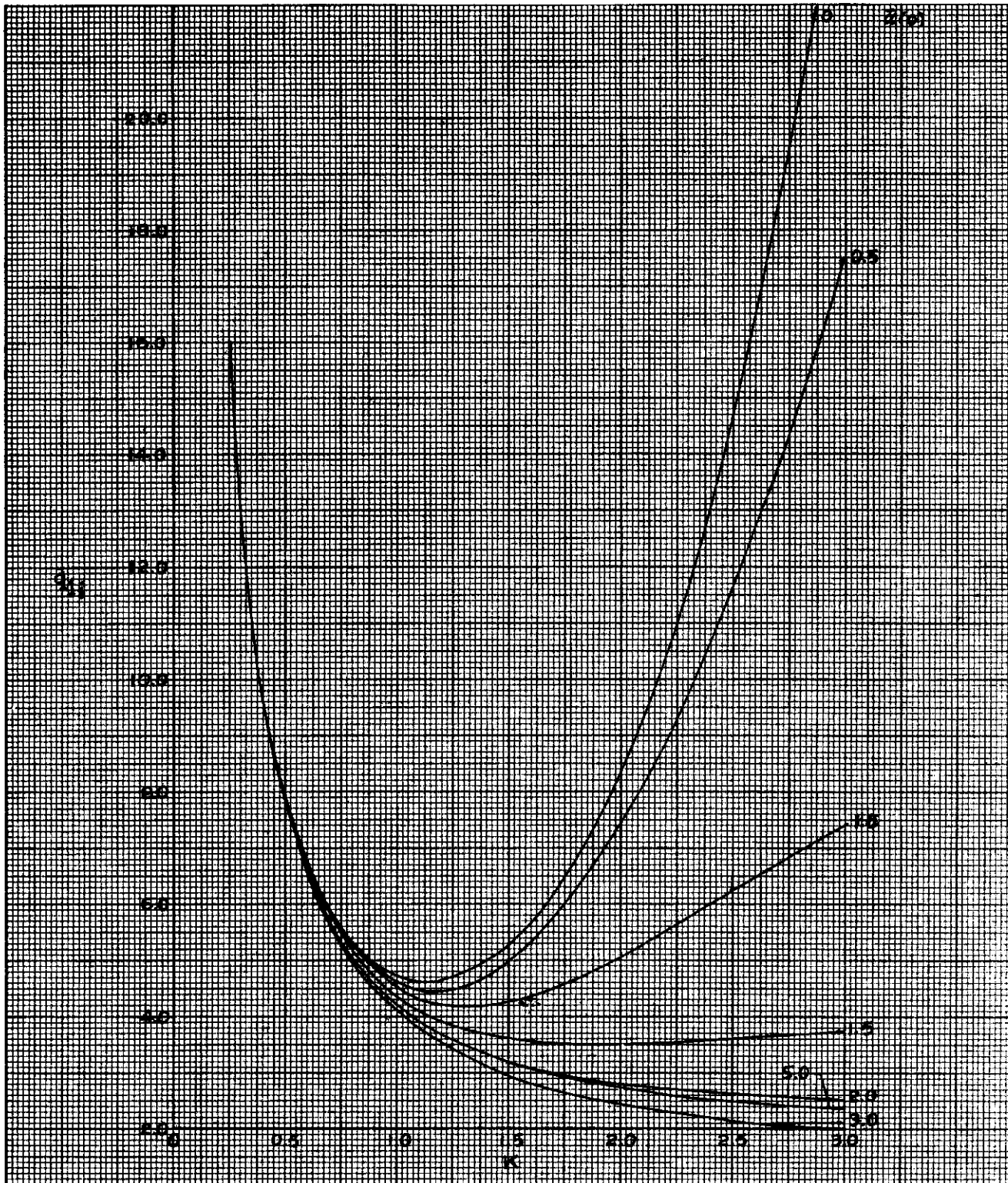


Figure 88. Single Parabolic B.T.E., $\xi_1 = 1.00$

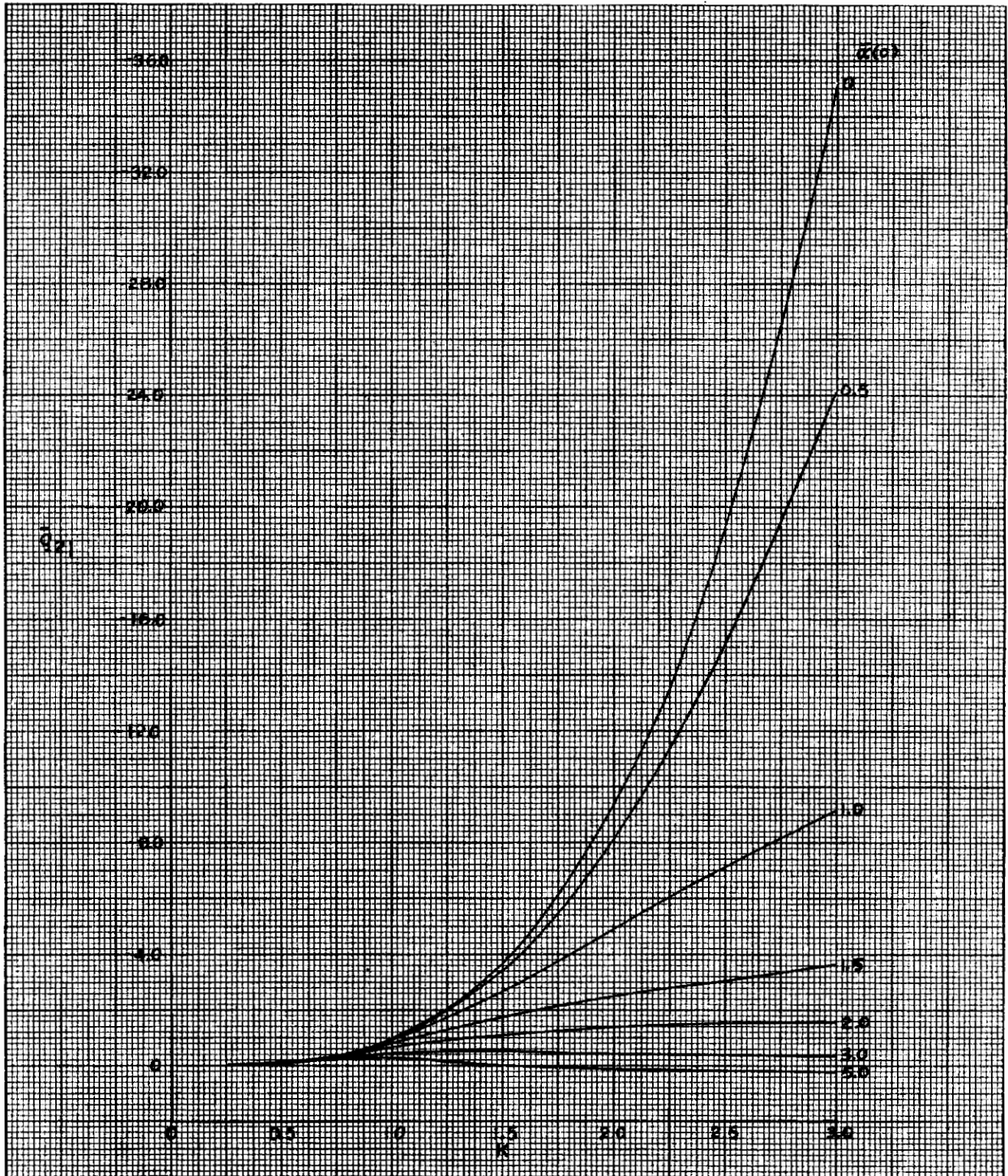


Figure 89. Single Parabolic B.T.E., $\xi_1 = 1.00$

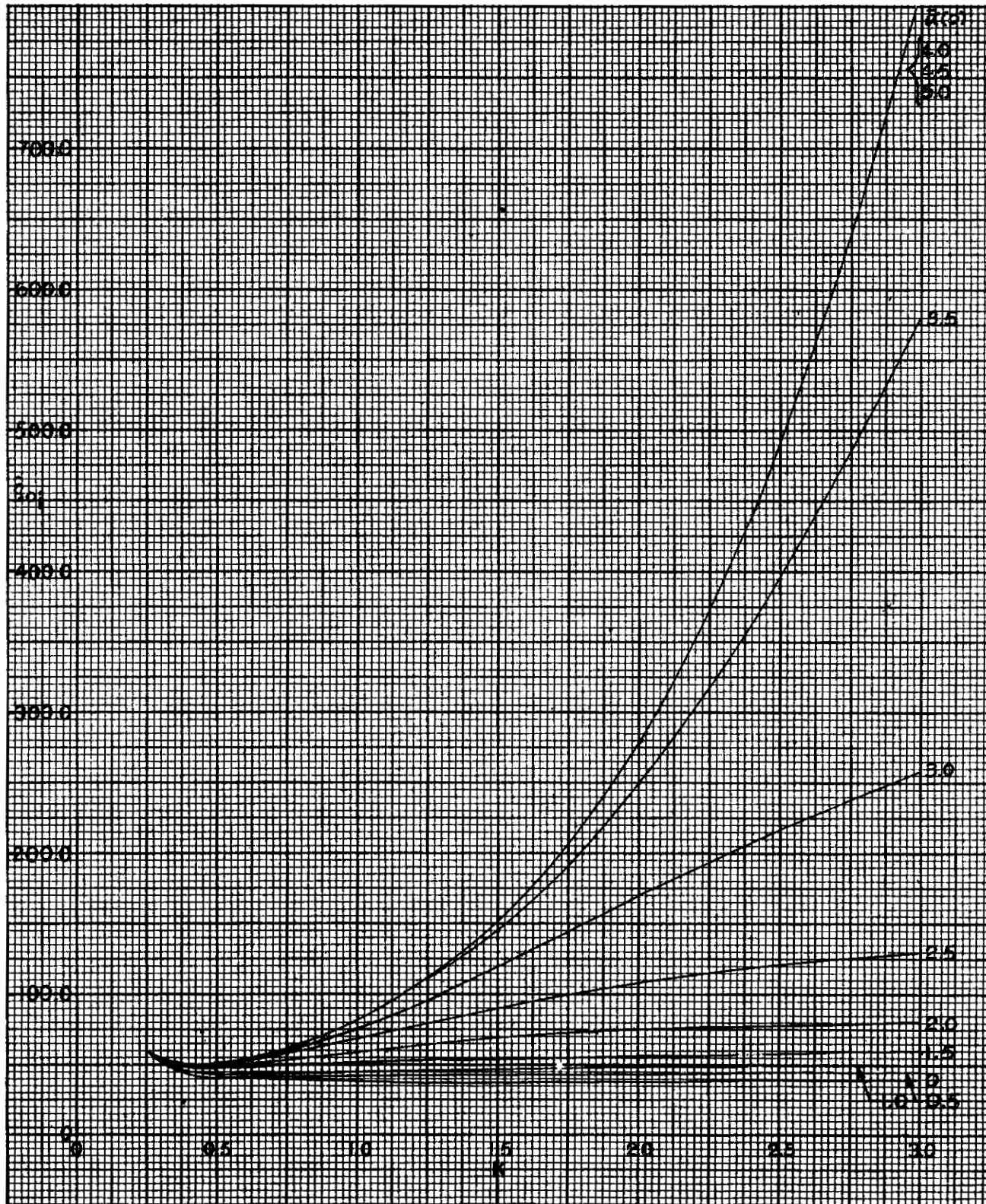


Figure 90. Single Wedge Plate, $0 \leq \xi_i \leq 0.25$

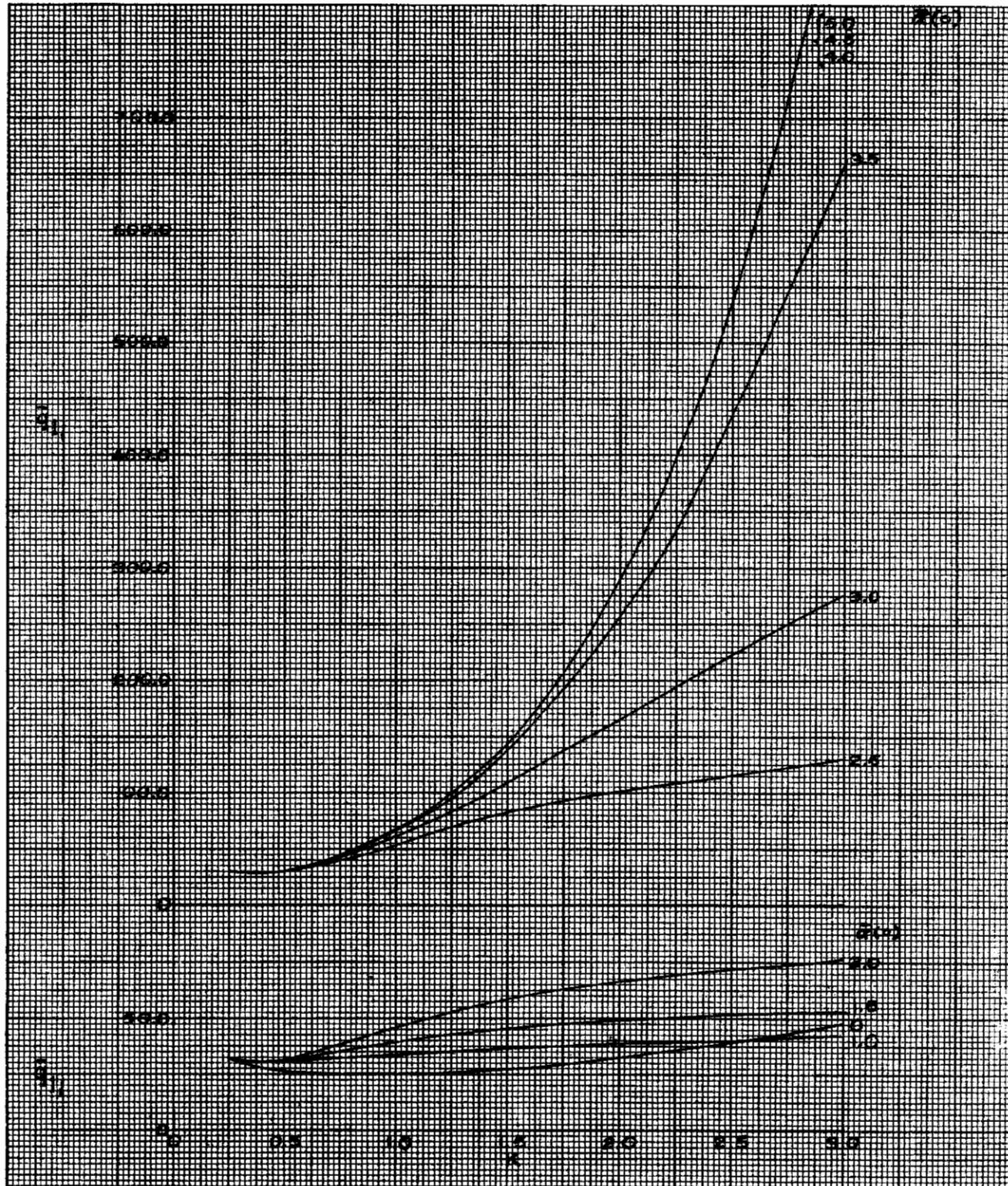


Figure 91. Single Wedge Plate, $0 \leq \xi_1 \leq 0.25$

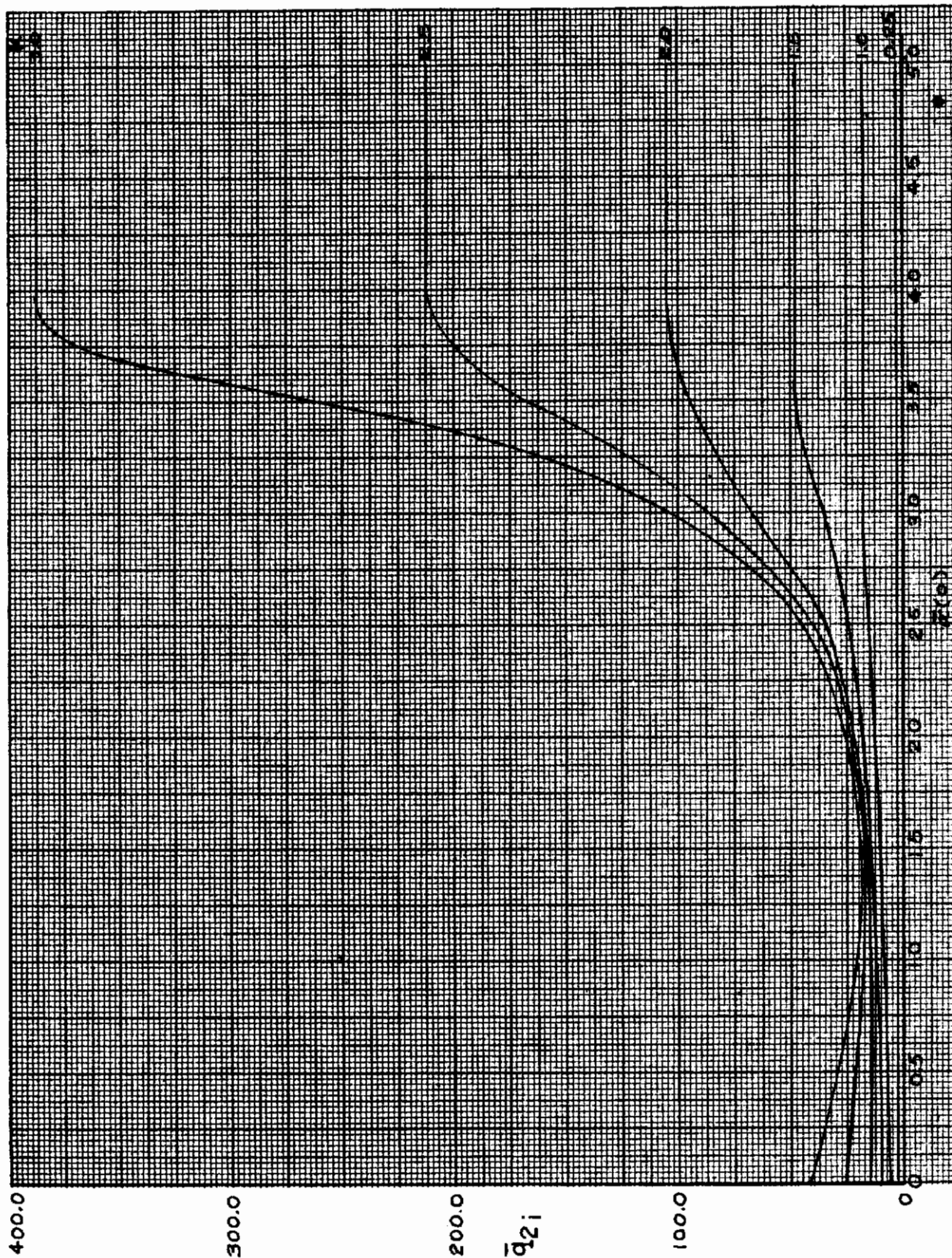


Figure 92. Single Wedge Plate, $0 \leq \alpha_i \leq 0.25$

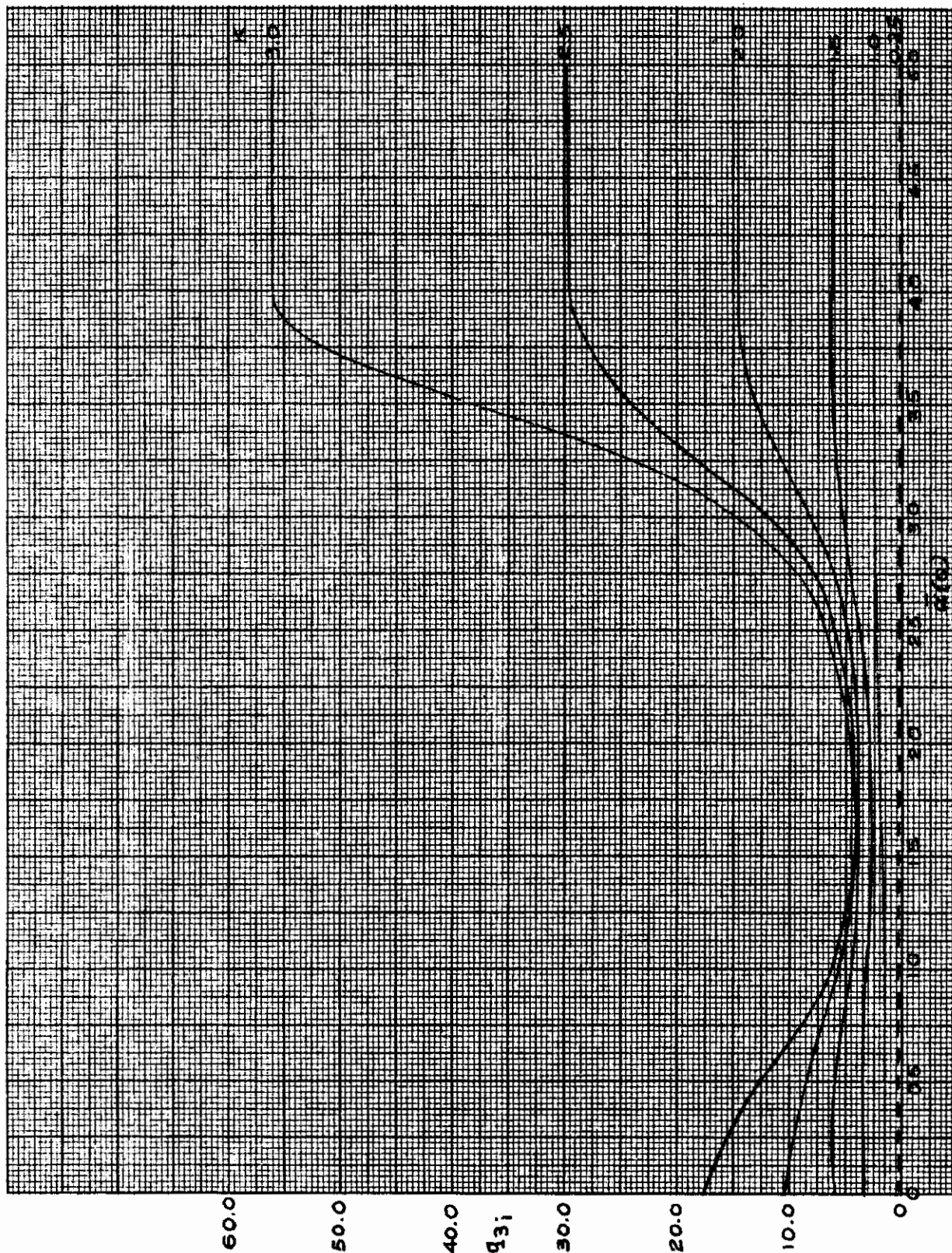


Figure 93. Single Wedge Plate, $0 \leq \xi_i \leq 0.25$

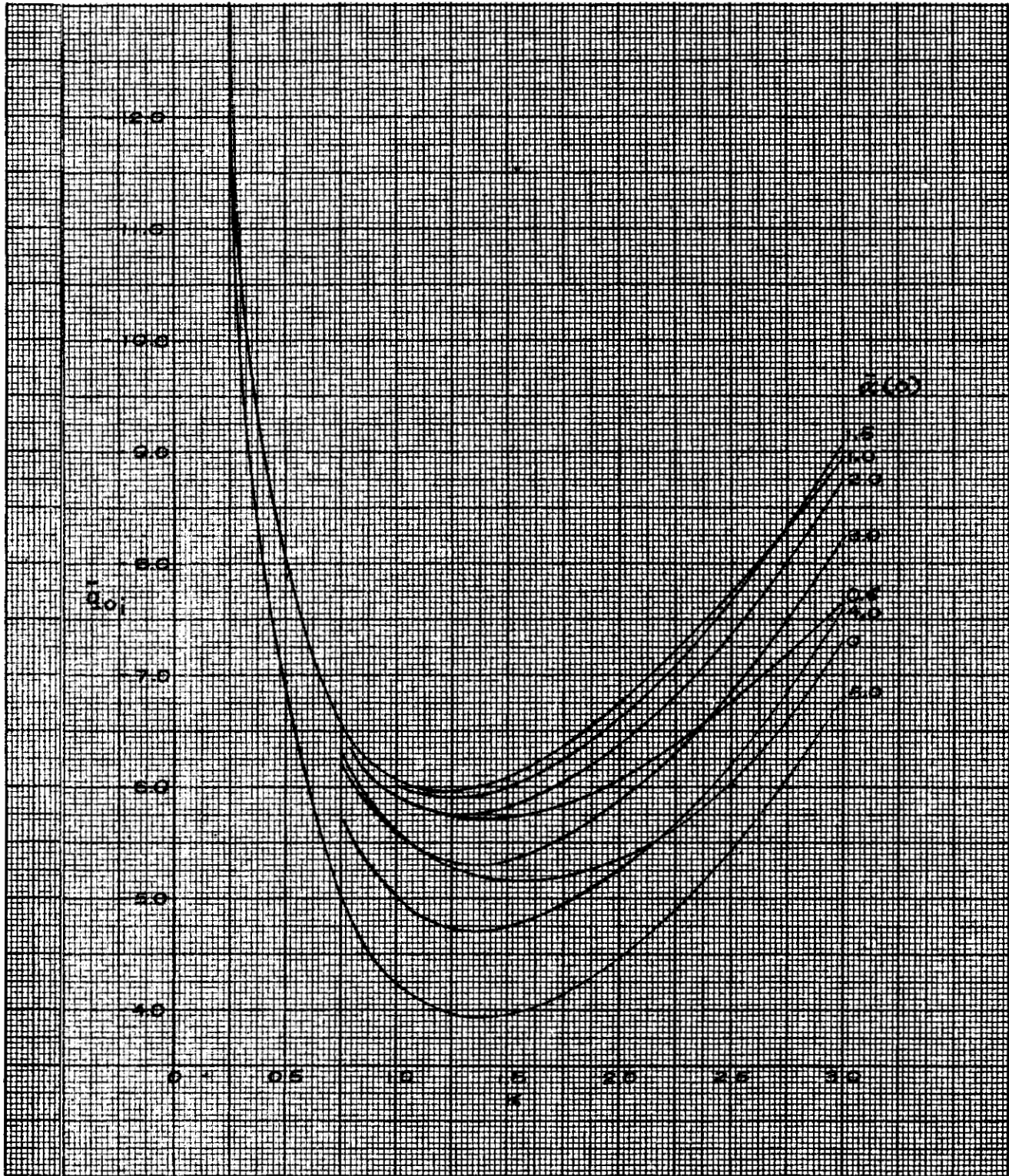


Figure 94. Single Wedge Plate, $0 \leq \xi_i \leq 0.75$

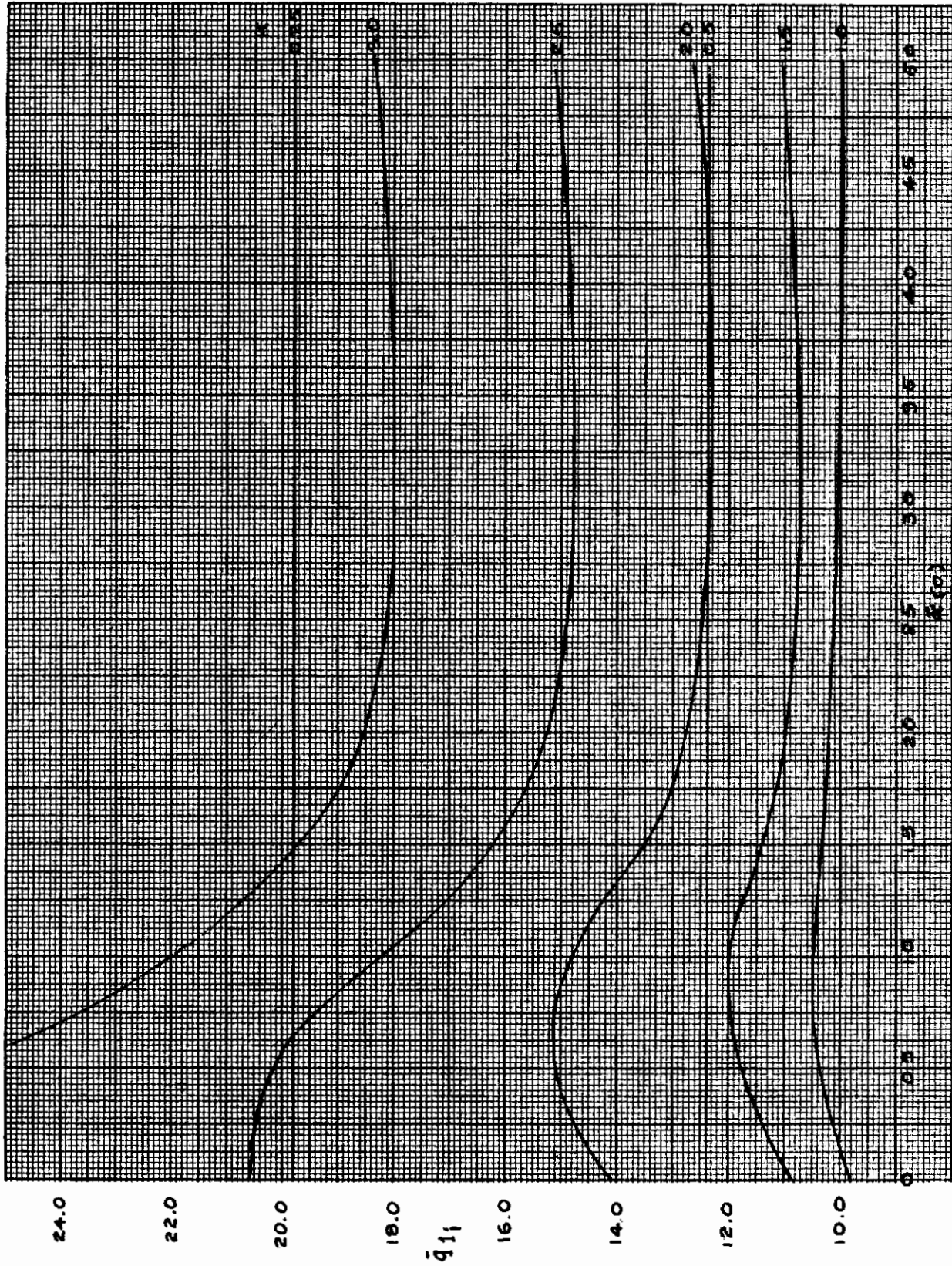


Figure 95. Single Wedge Plate, $0 \leq \xi_i \leq 0.75$

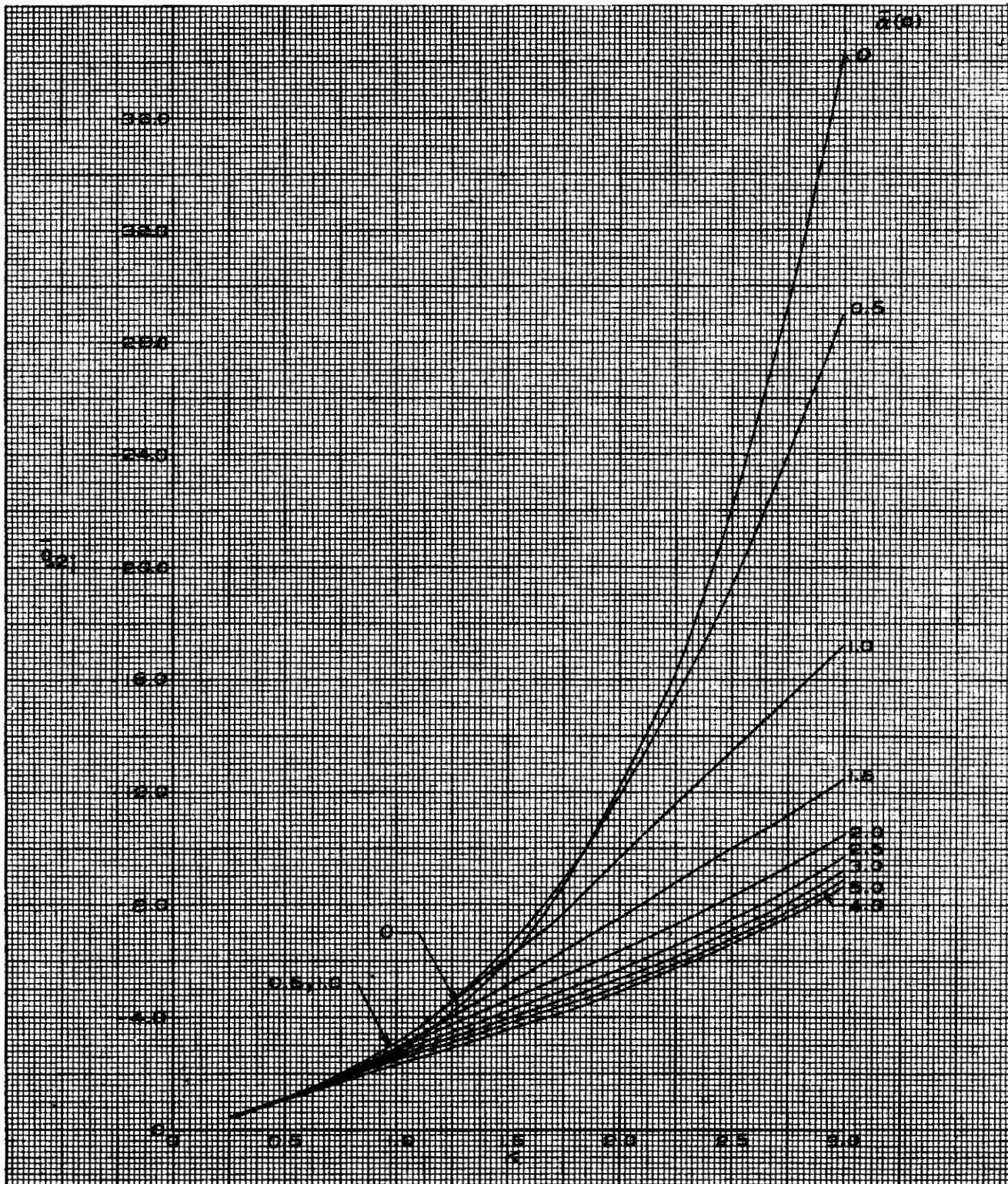


Figure 96. Single Wedge Plate, $0 \leq \xi_i \leq 0.75$

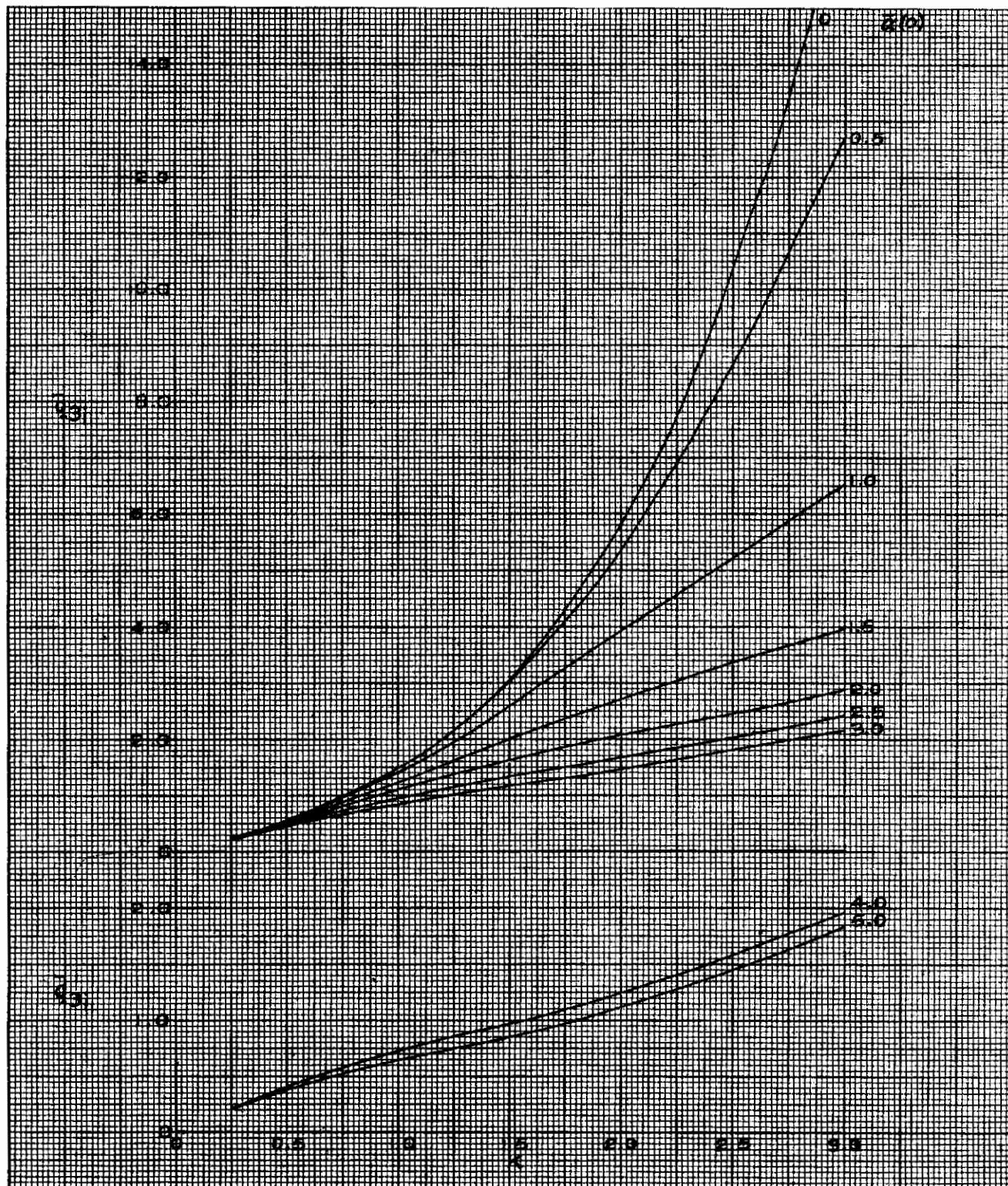


Figure 97. Single Wedge Plate, $0 \leq \xi_i \leq 0.75$

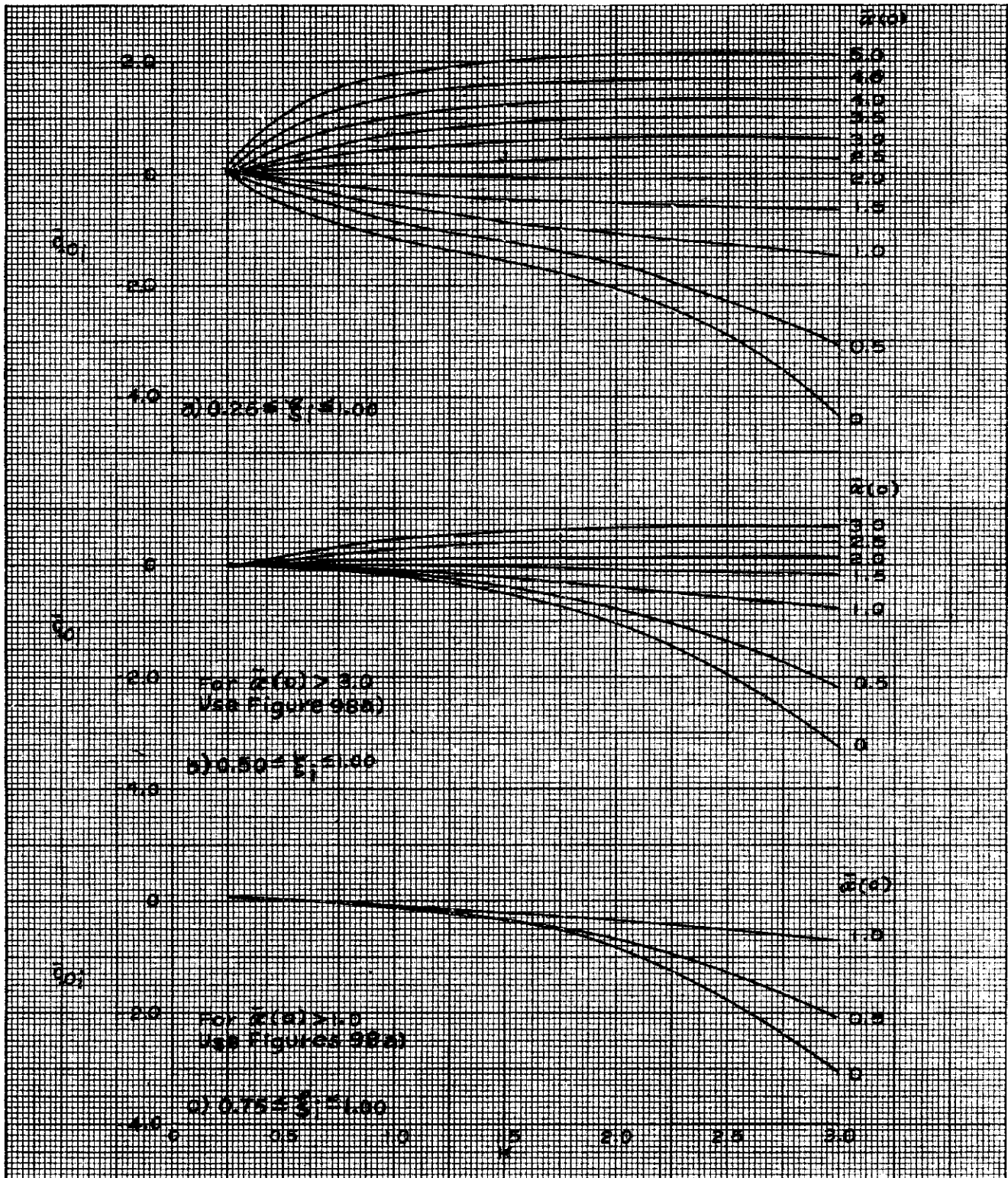


Figure 98. Single Wedge Plate

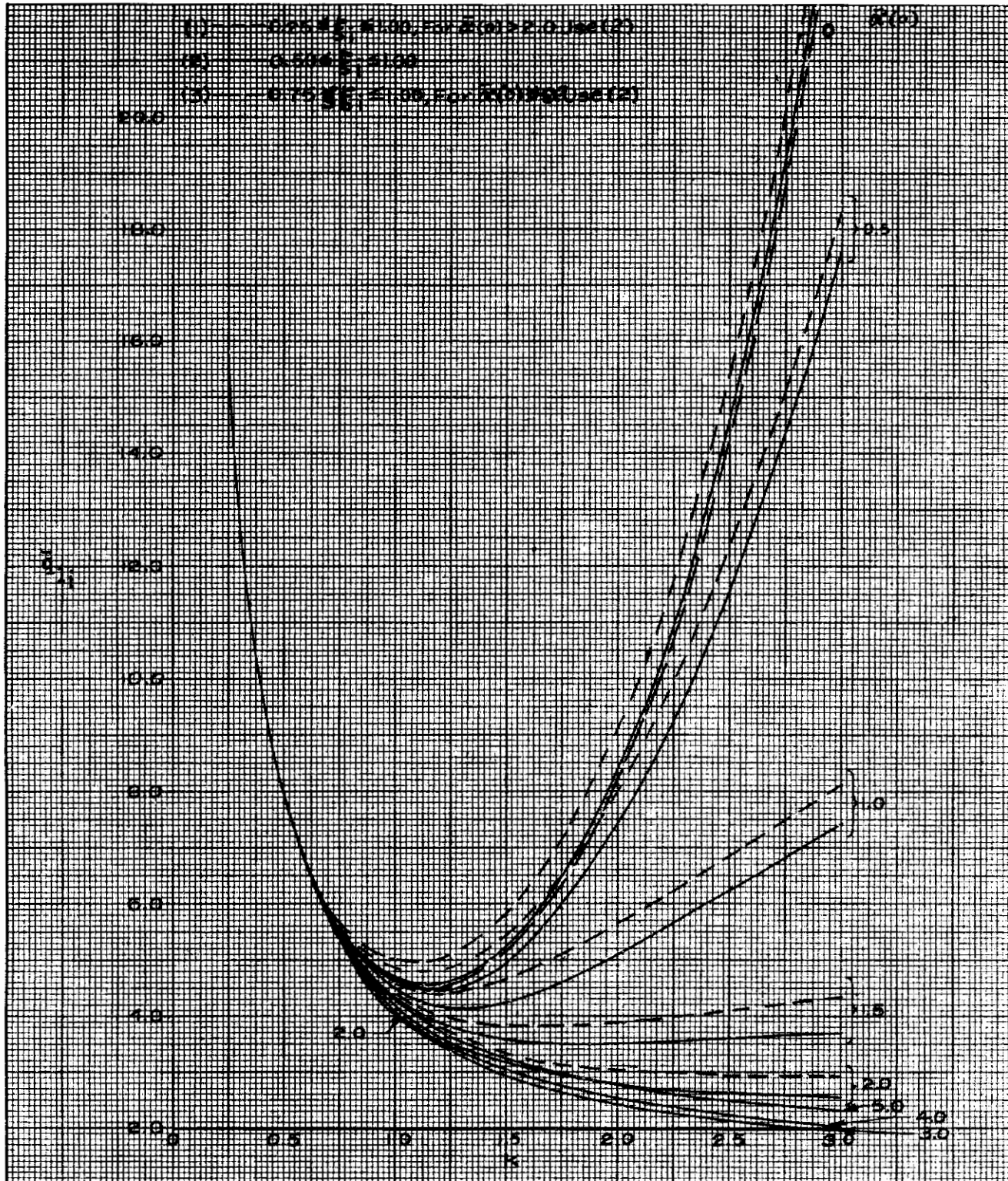


Figure 99. Single Wedge Plate

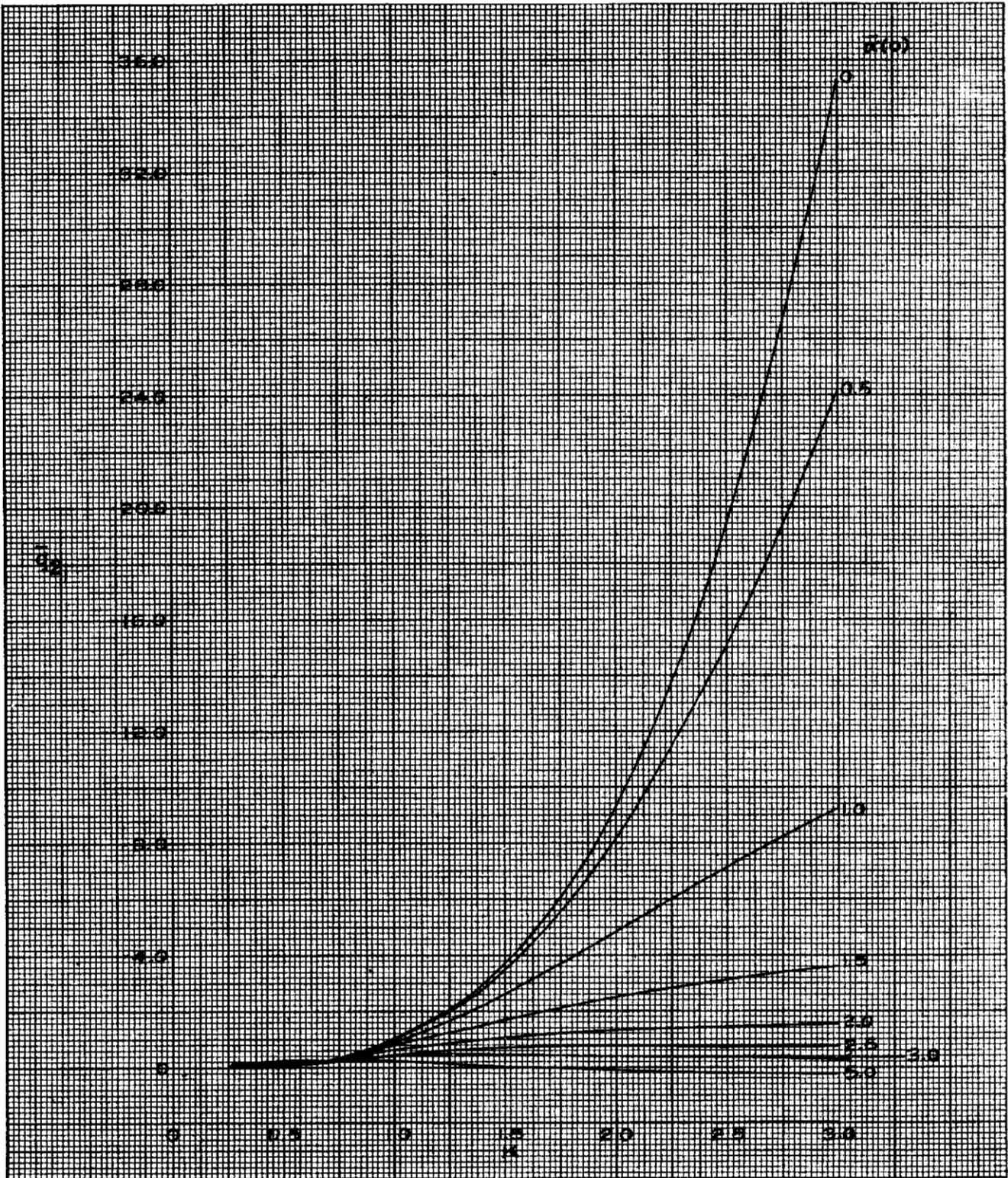


Figure 100. Single Wedge Plate $0.25, 0.50, 0.75 \leq \xi_i \leq 1.00$

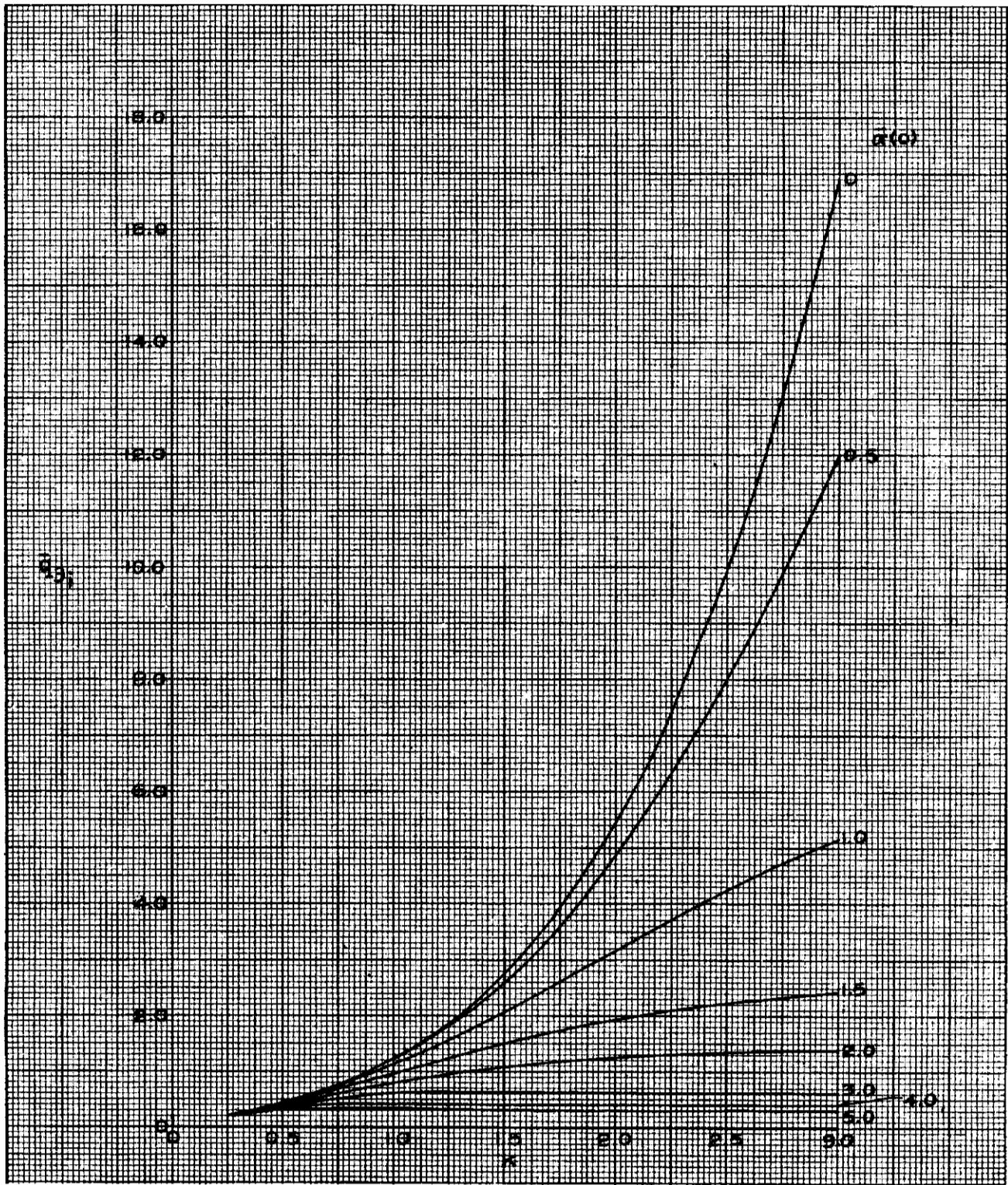


Figure 101. Single Wedge Plate $0.25, 0.50, 0.75 \leq \xi_1 \leq 1.00$

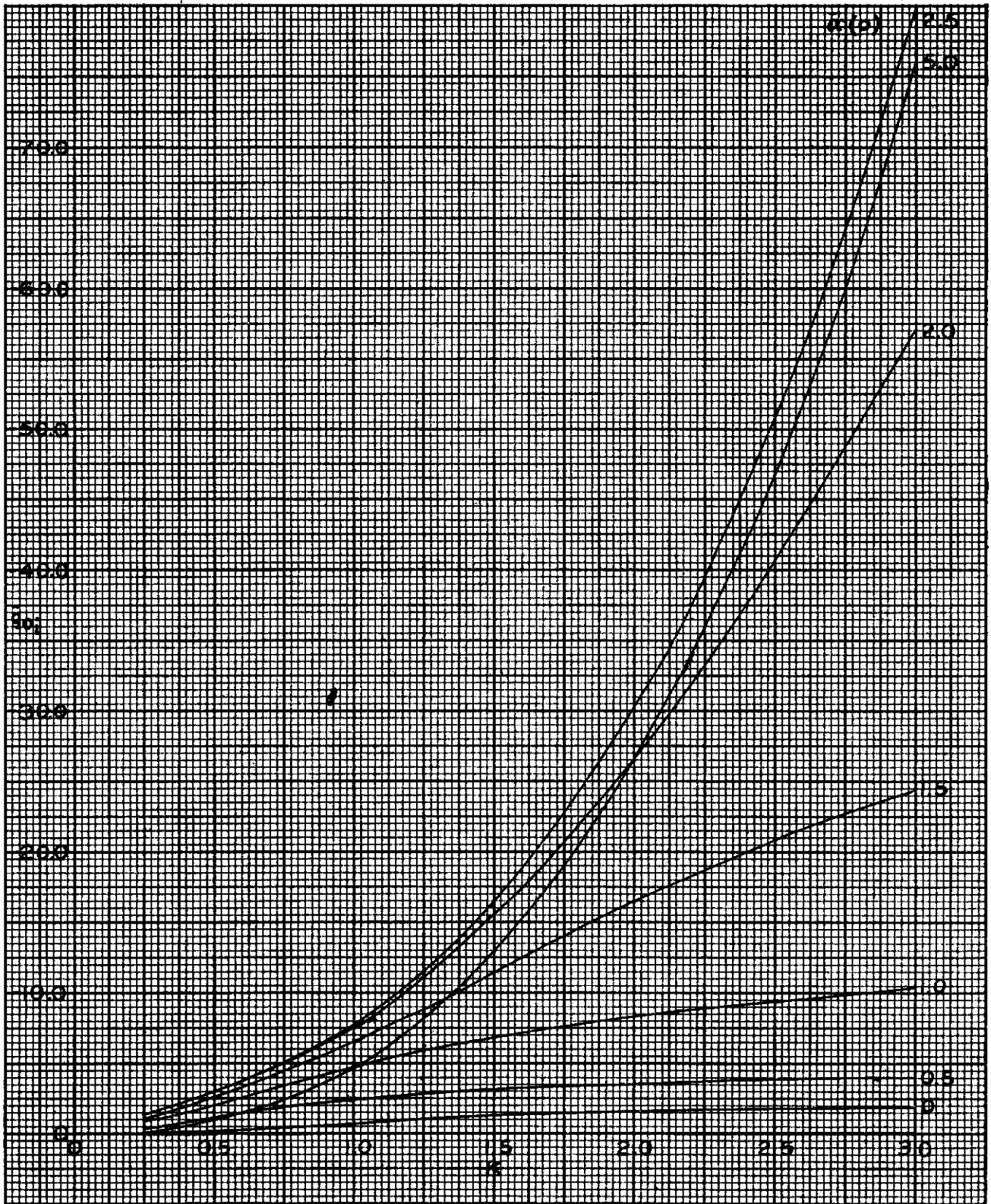


Figure 102. Modified Double Wedge $0 \leq \xi_i \leq 0.20$

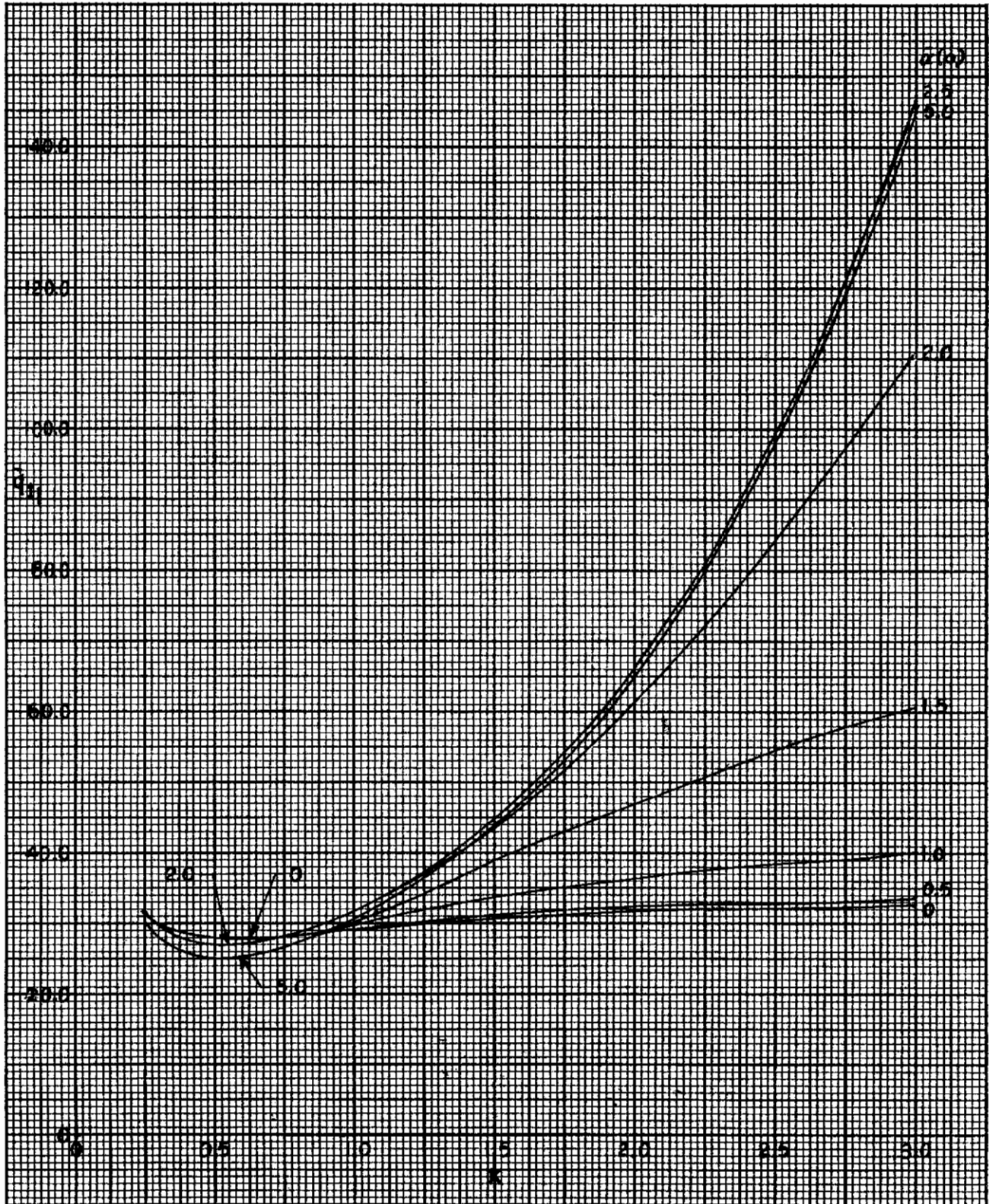


Figure 103. Modified Double Wedge, $0 \leq \xi_i \leq 0.20$

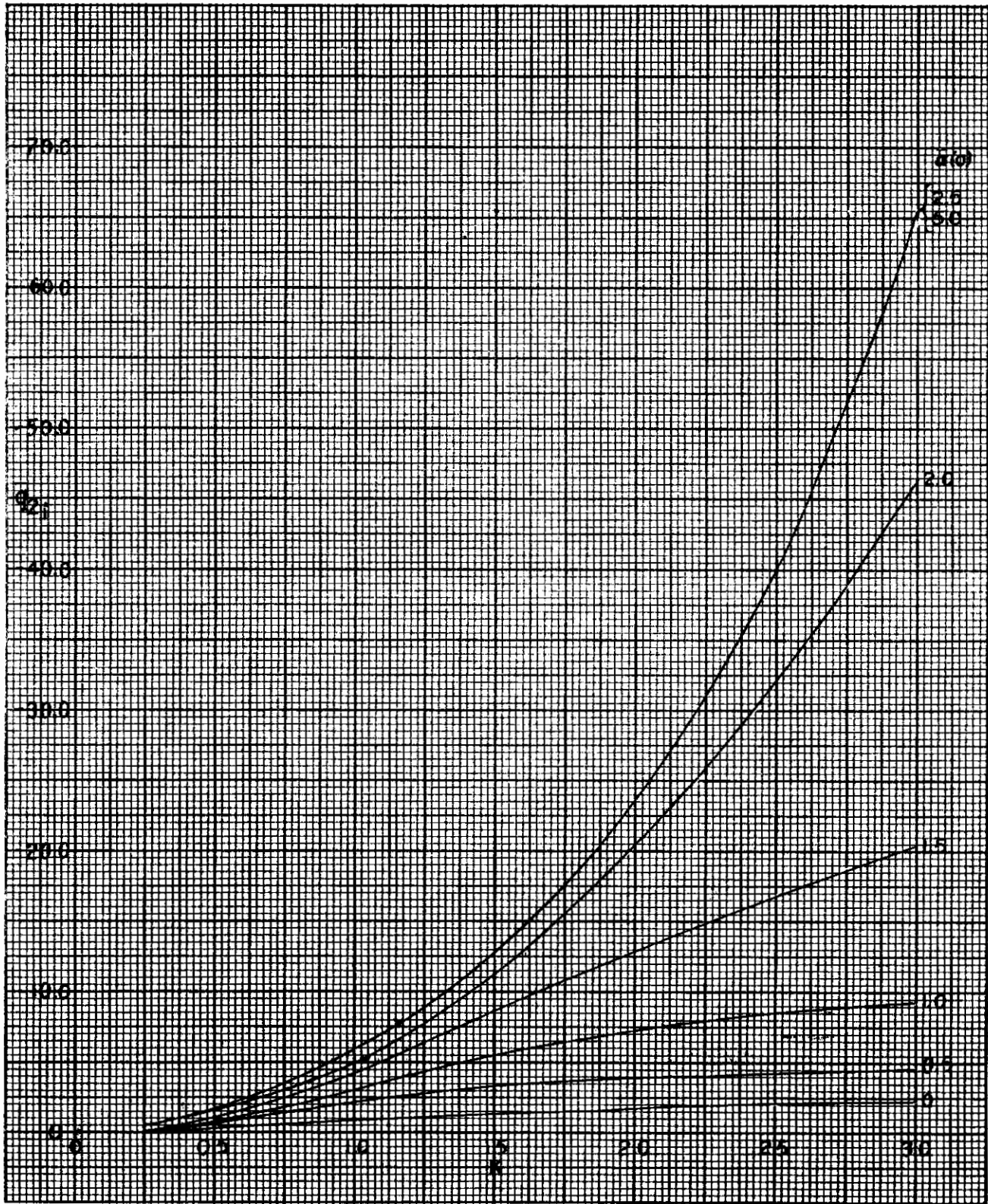


Figure 104. Modified Double Wedge $0 \leq \xi_1 \leq 0.20$

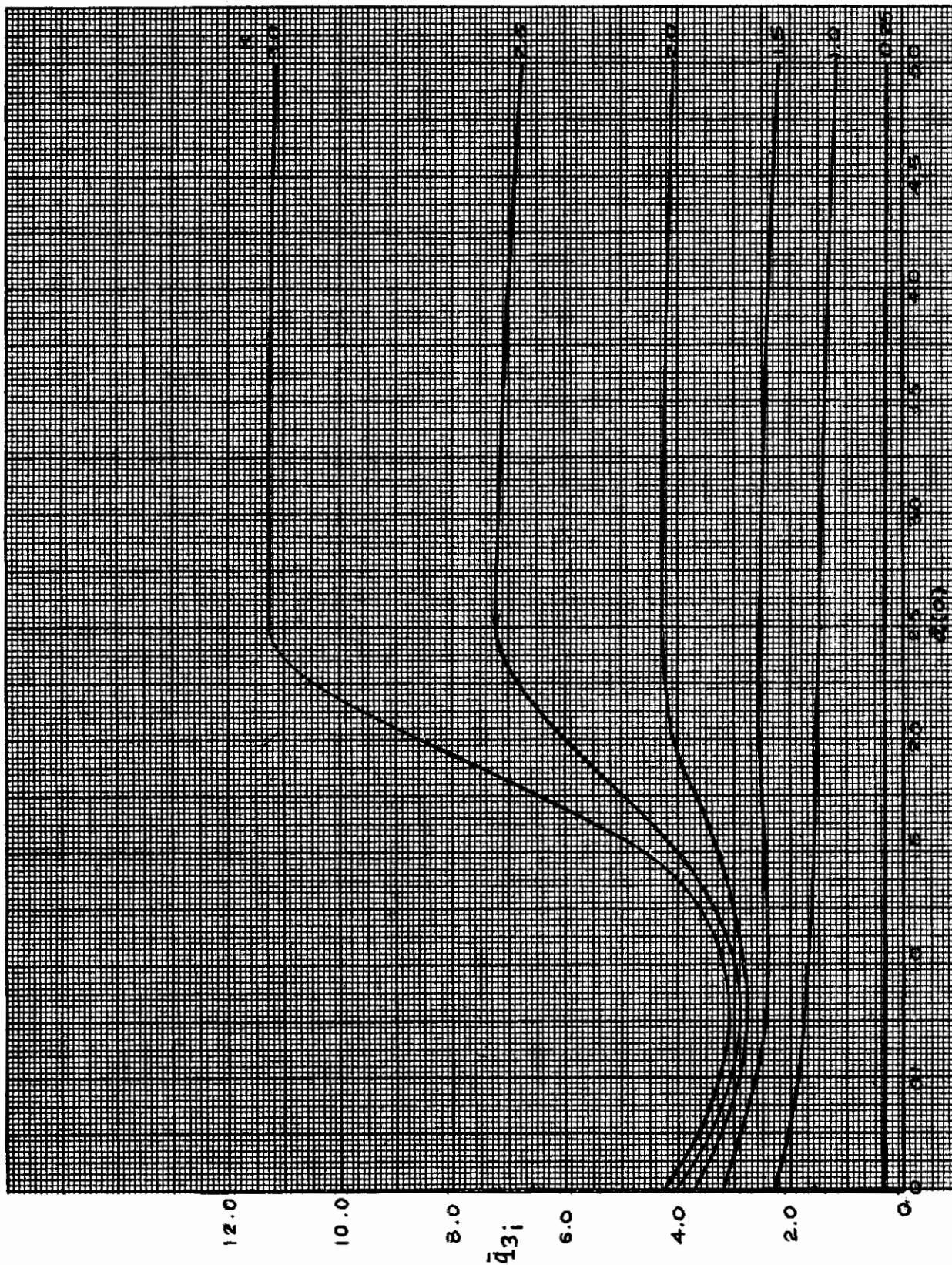


Figure 105. Modified Double Wedge $0 \leq \xi_1 \leq 0.20$

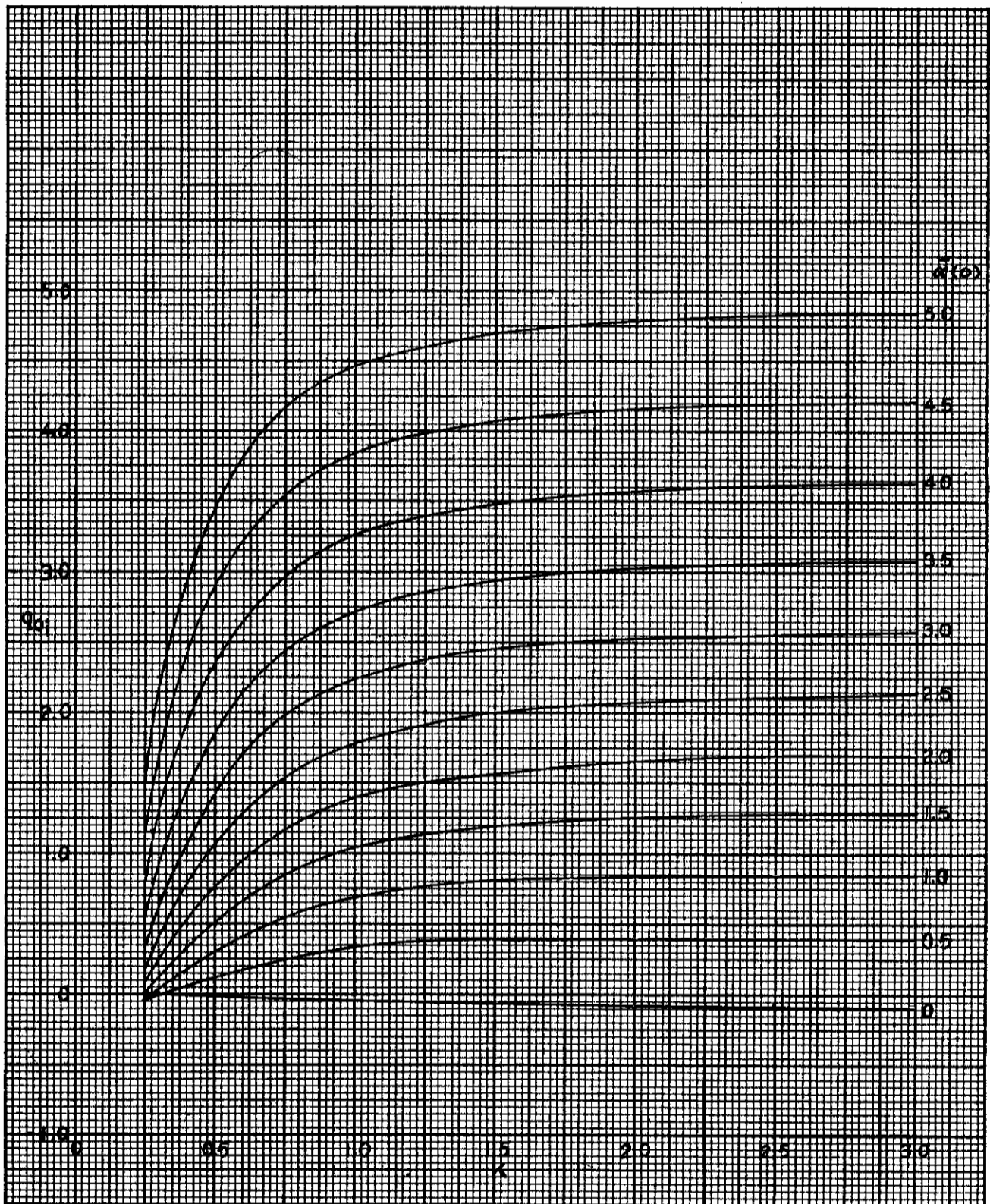


Figure 106. Modified Double Wedge $0.20 \leq \xi_i \leq 0.80$

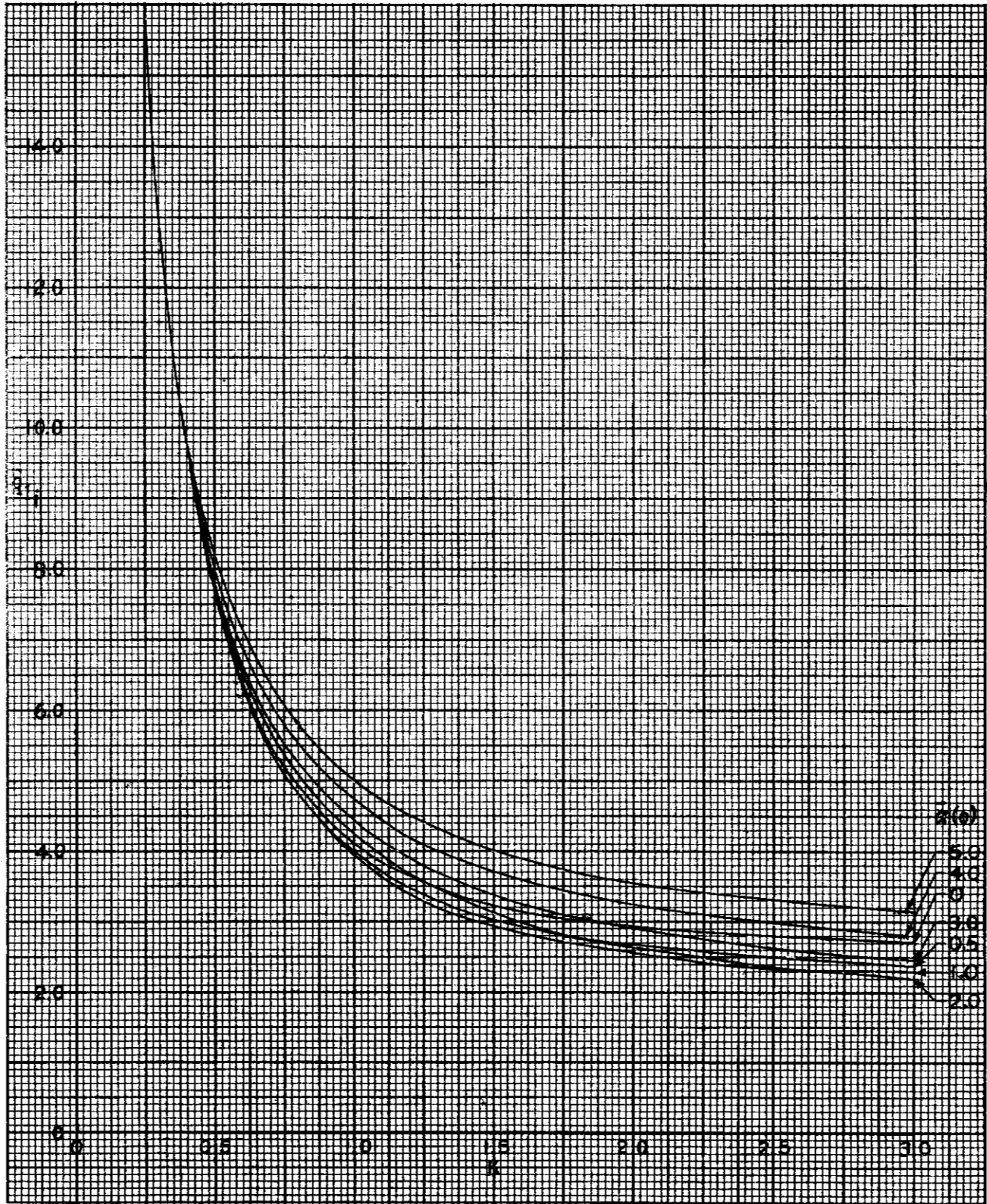


Figure 107. Modified Double Wedge $0.20 \leq \xi_i \leq 0.80$

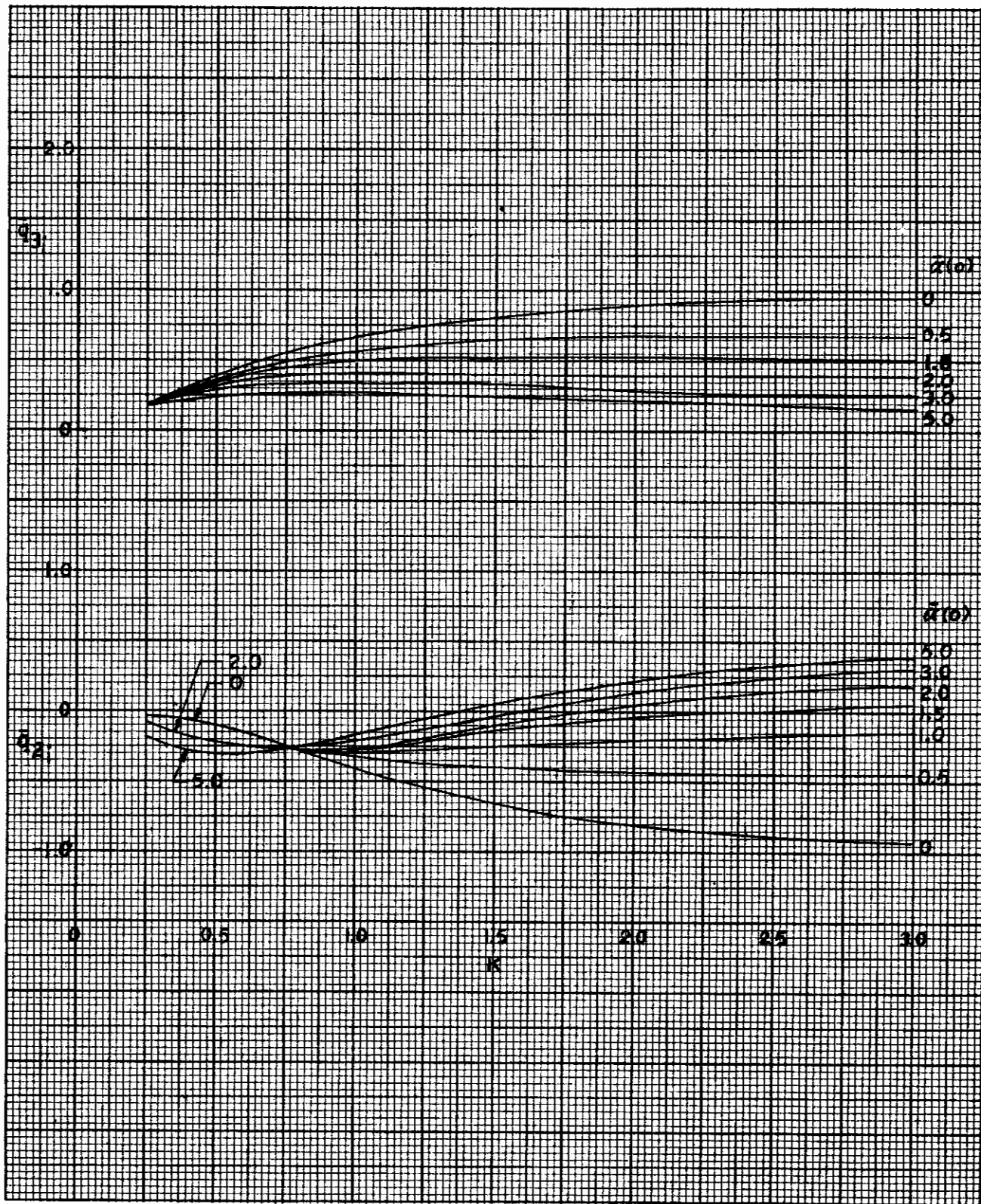


Figure 108. Modified Double Wedge $0.20 \leq \xi_1 \leq 0.80$

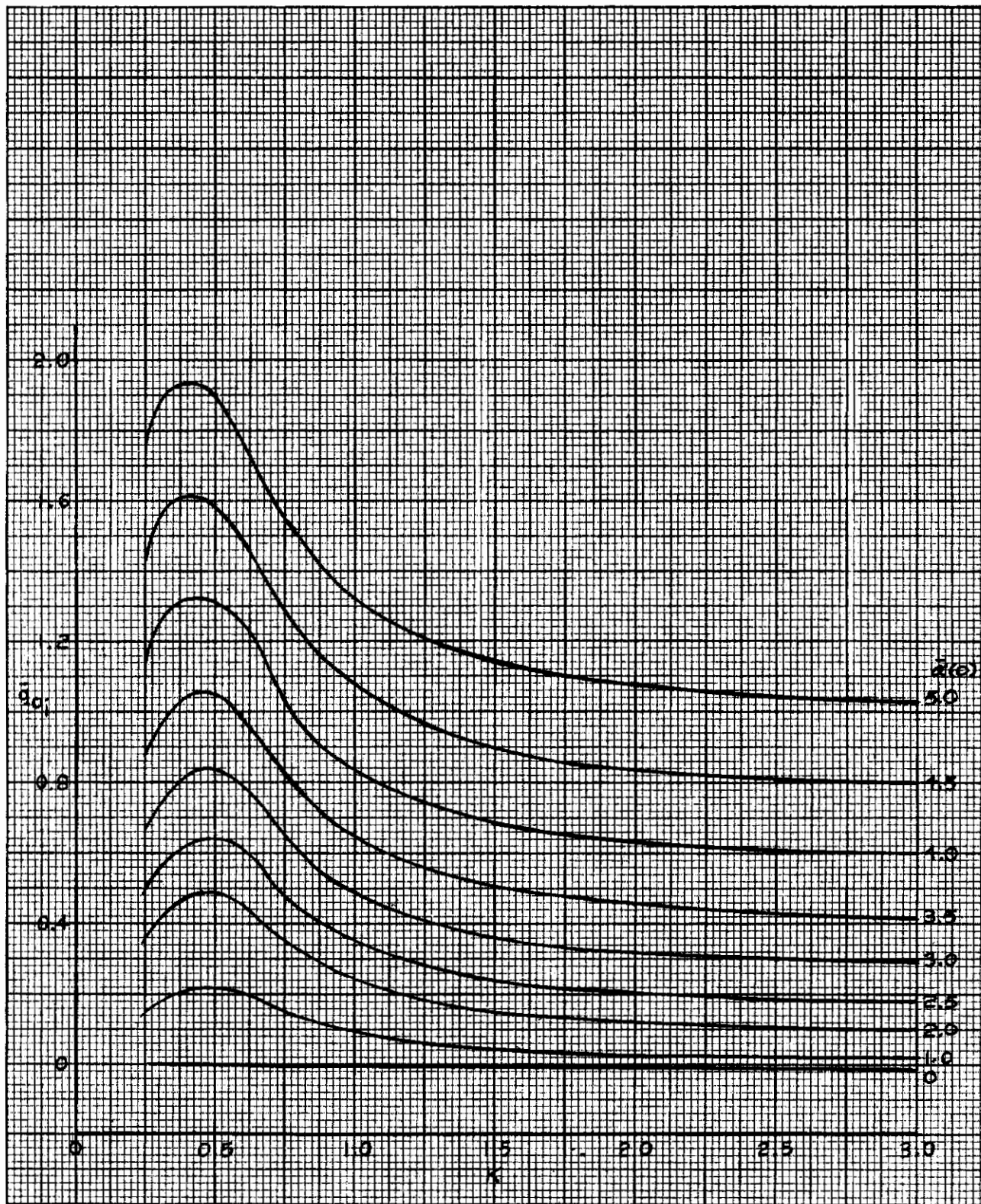


Figure 109. Modified Double Wedge $0.80 \leq \xi_i \leq 1.00$

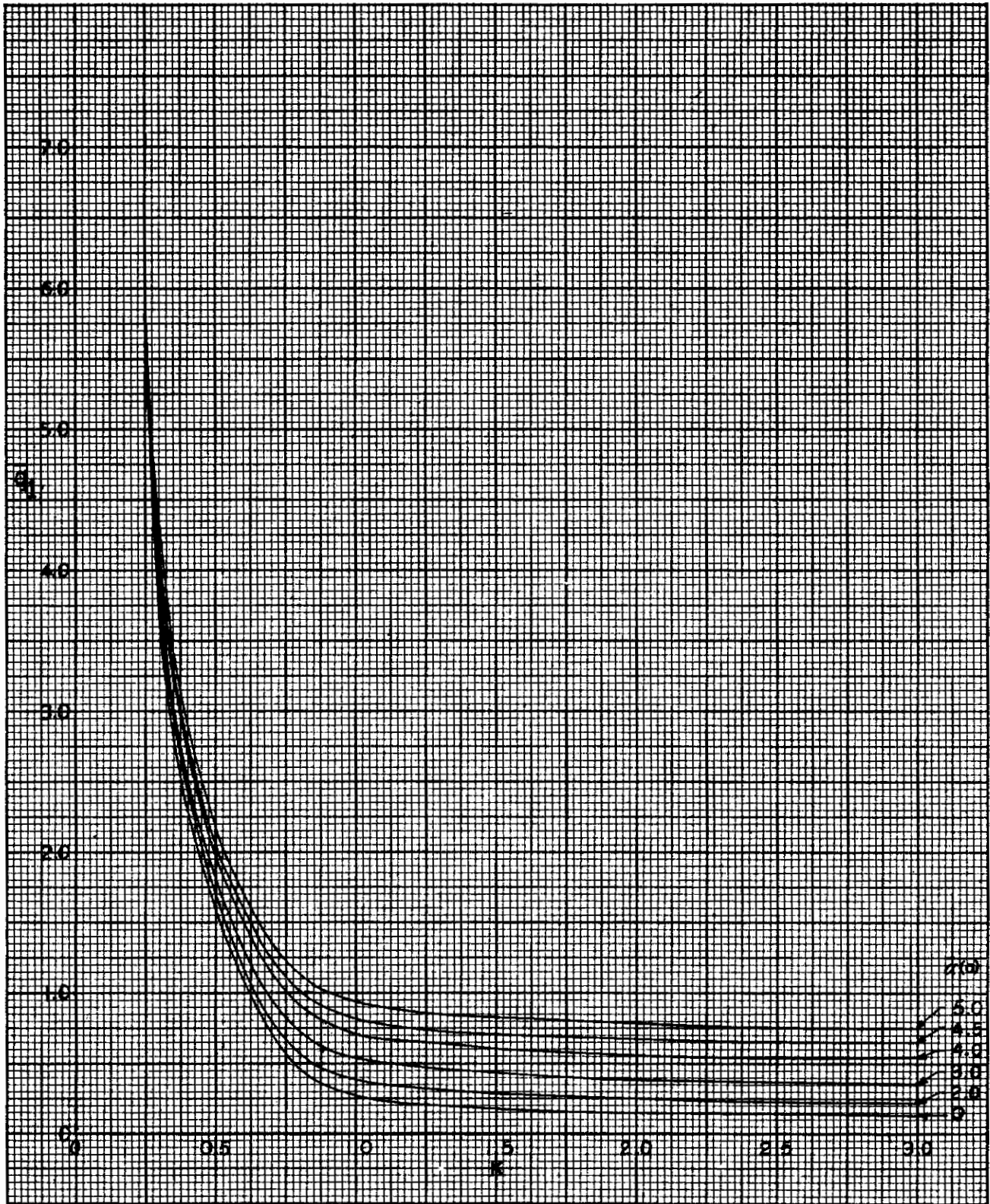


Figure 110. Modified Double Wedge $0.80 \leq \xi_1 \leq 1.00$

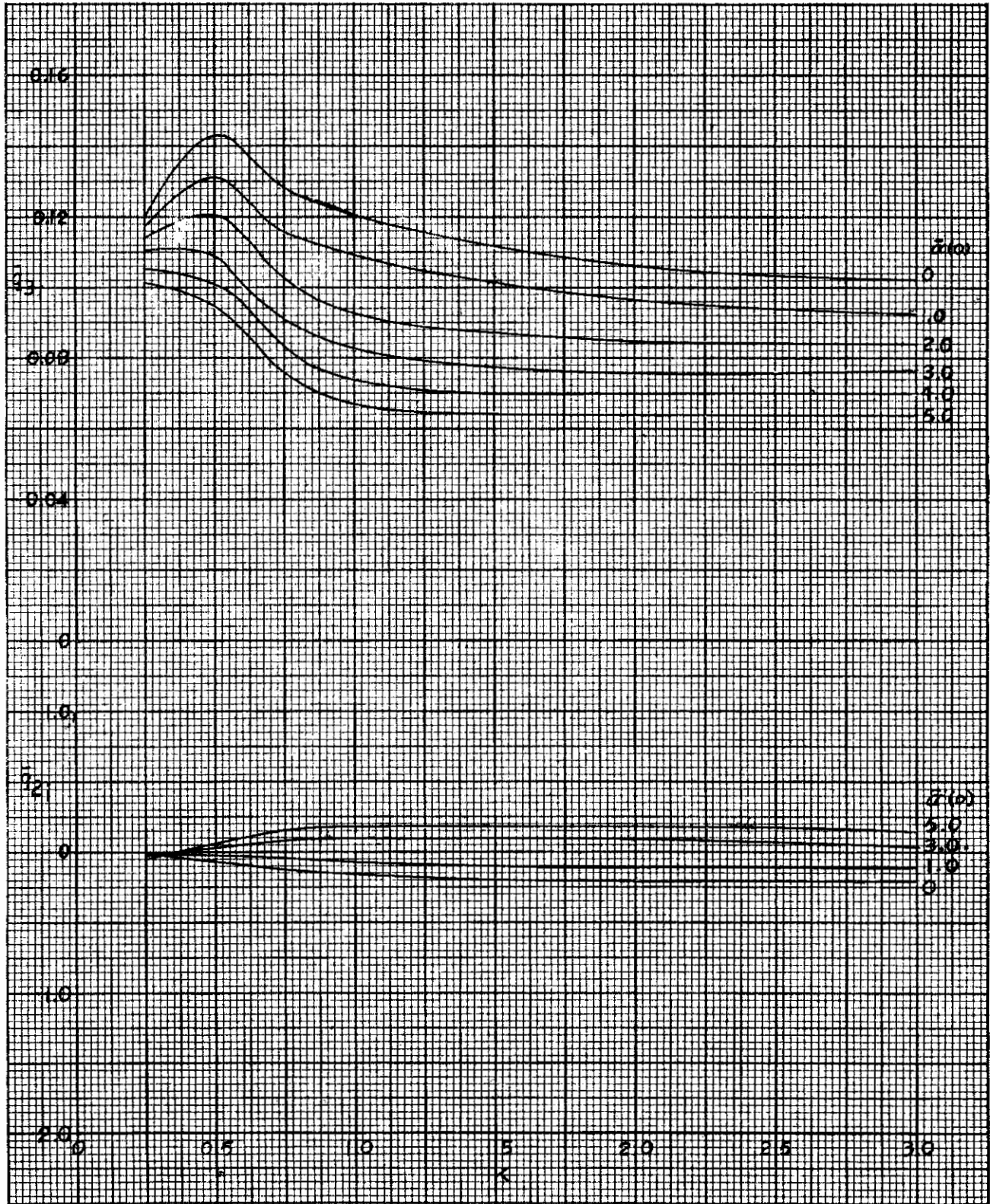


Figure 111. Modified Double Wedge $0.80 \leq \xi_1 \leq 1.00$

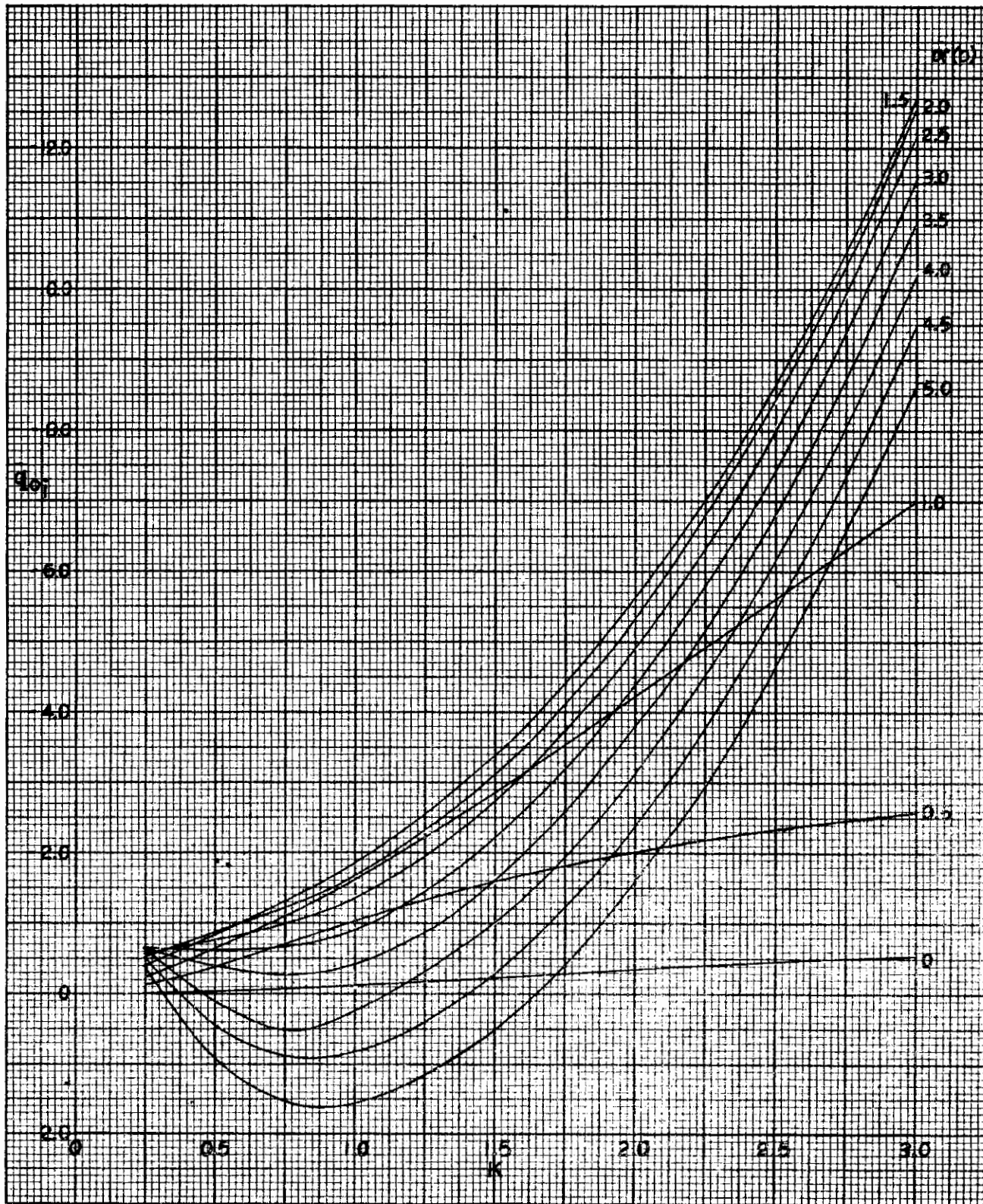


Figure 112. Modified Double Wedge $0 \leq \xi_i \leq 0.30$

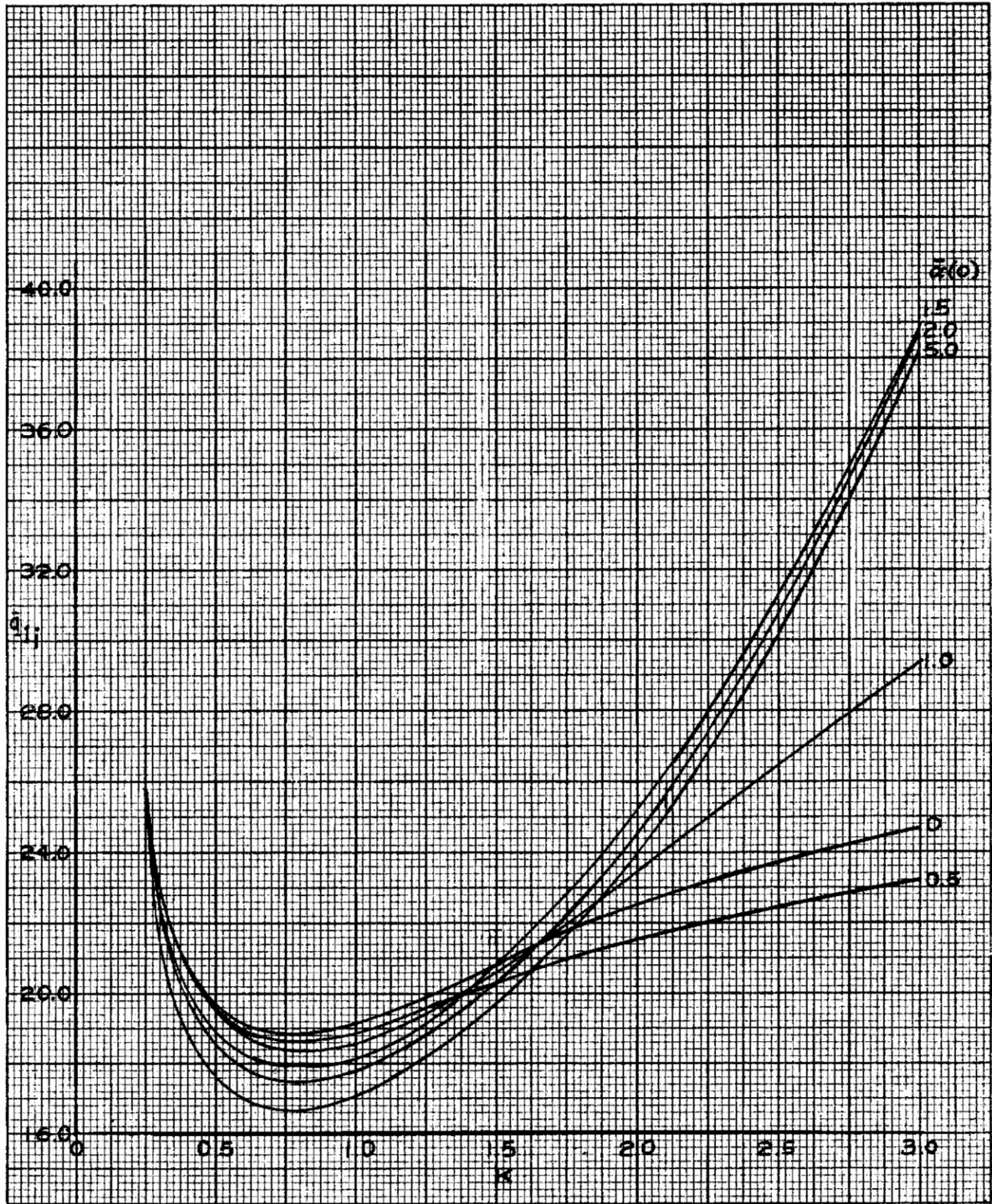


Figure 113. Modified Double Wedge $0 \leq \xi_i \leq 0.30$

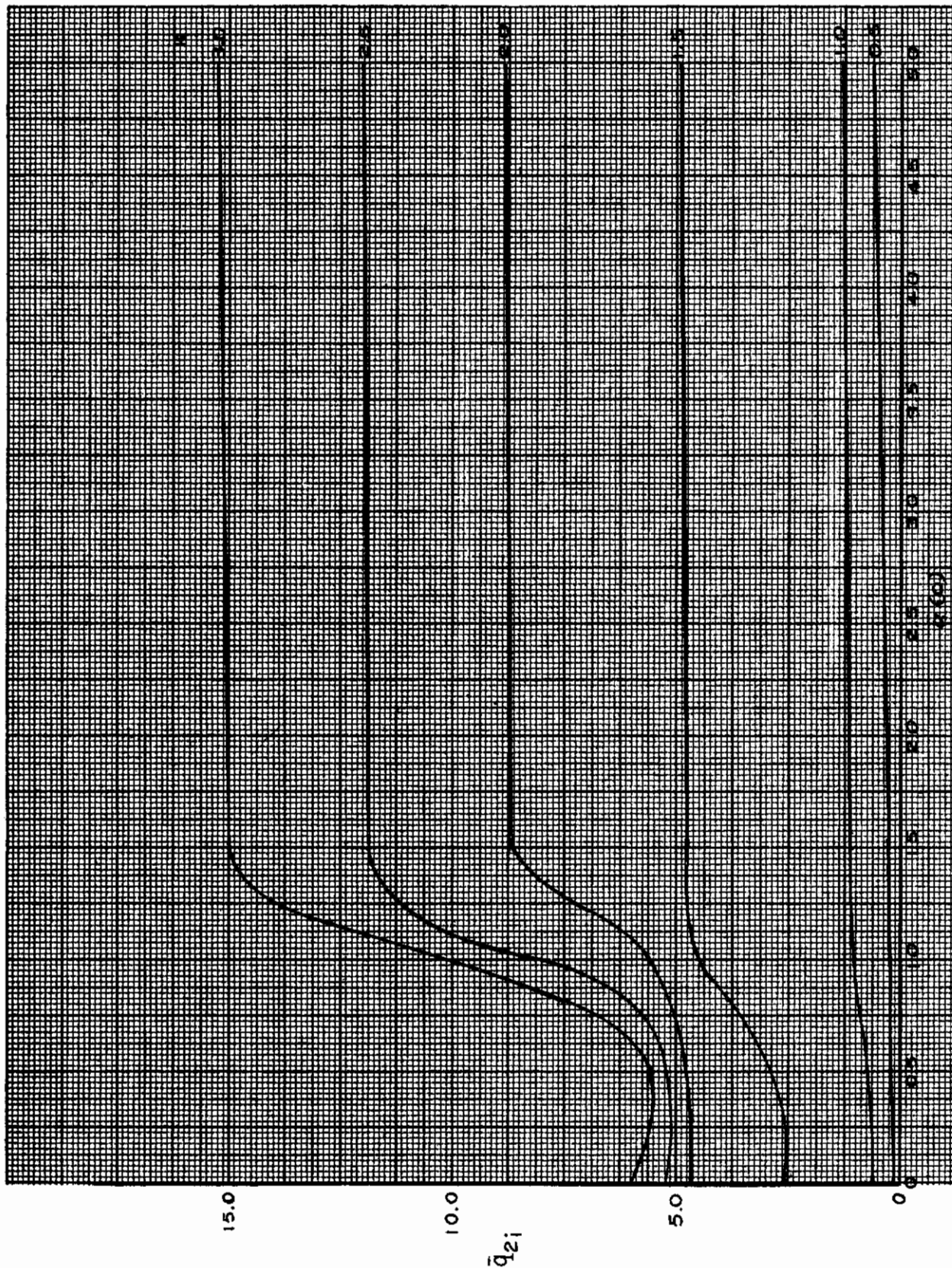


Figure 114. Modified Double Wedge, $0 \leq \xi_i \leq 0.30$

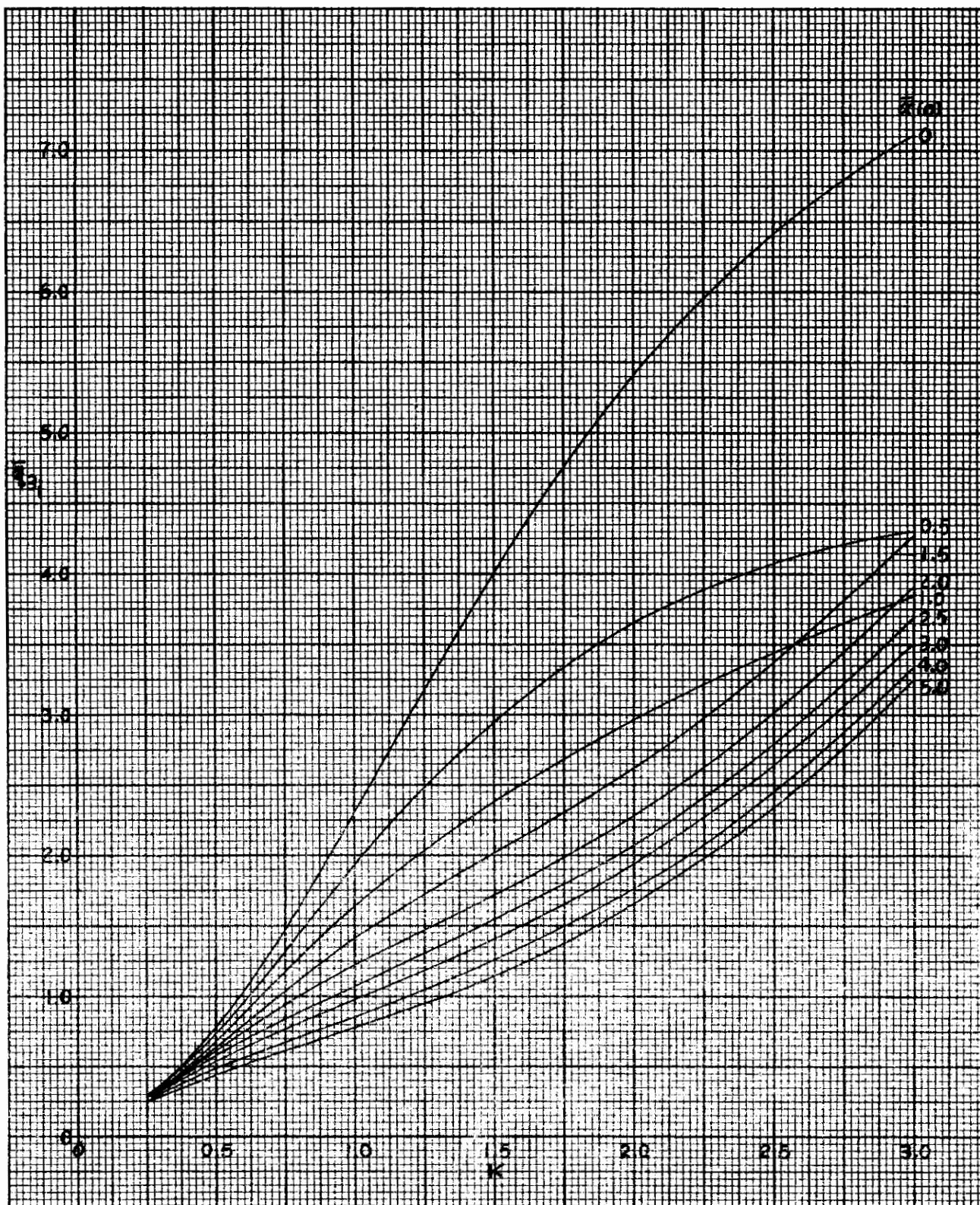


Figure 115. Modified Double Wedge, $0 \leq \xi_i \leq 0.30$

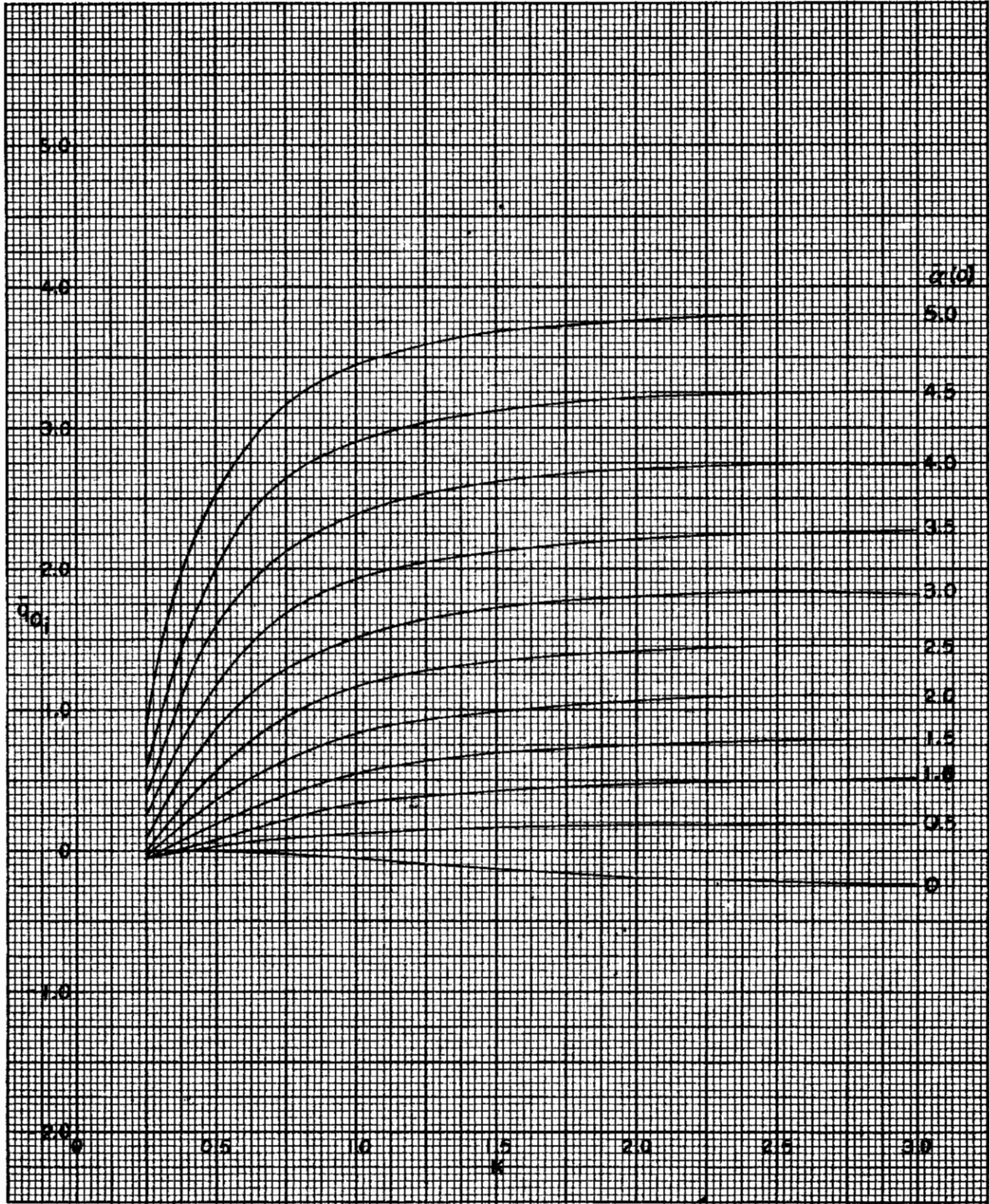


Figure 116. Modified Double Wedge, $0.30 \leq \xi_1 \leq 0.70$

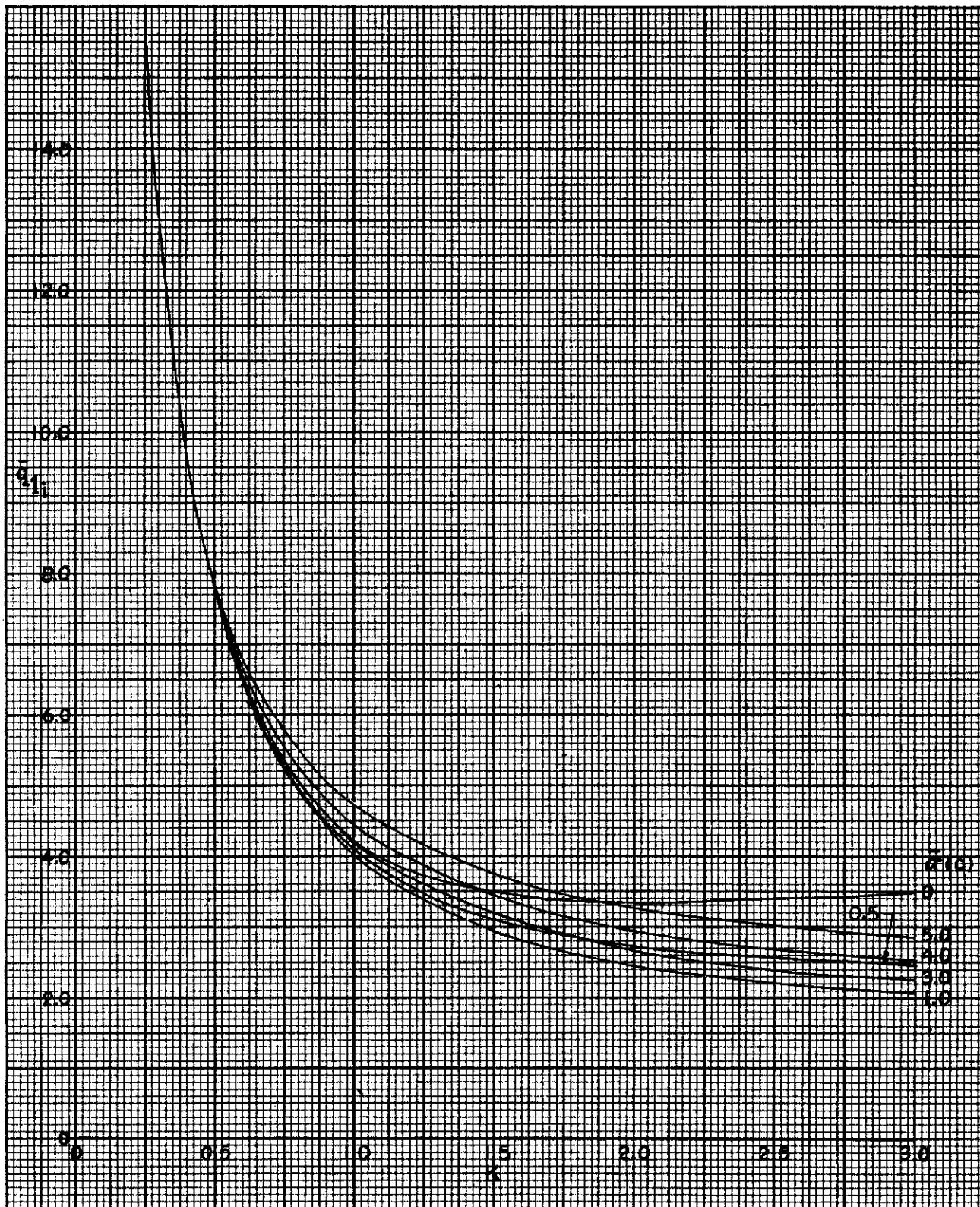


Figure 117. Modified Double Wedge, $0.30 \leq \xi_i \leq 0.70$

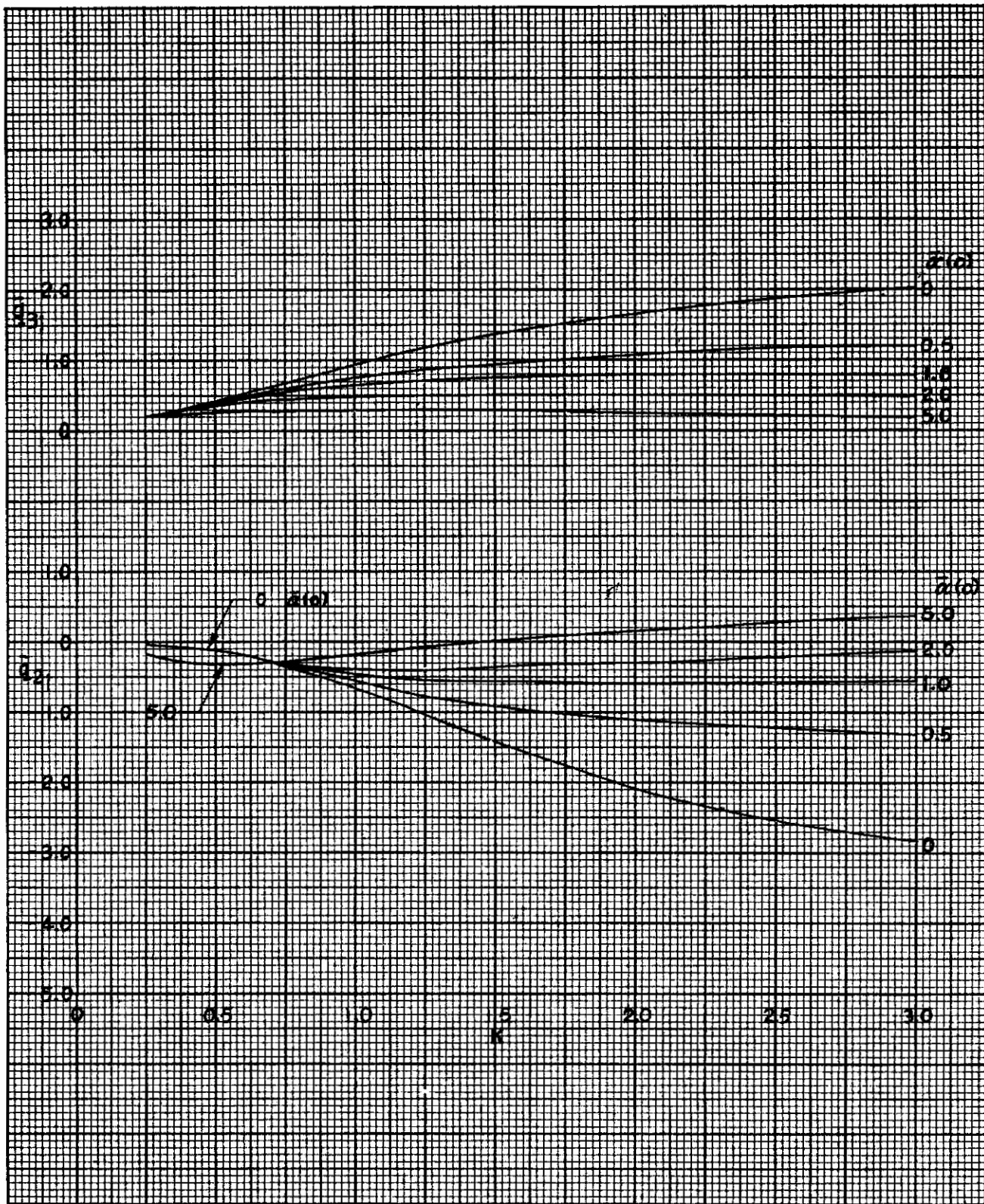


Figure 118. Modified Double Wedge $0.30 \leq \xi_1 \leq 0.70$

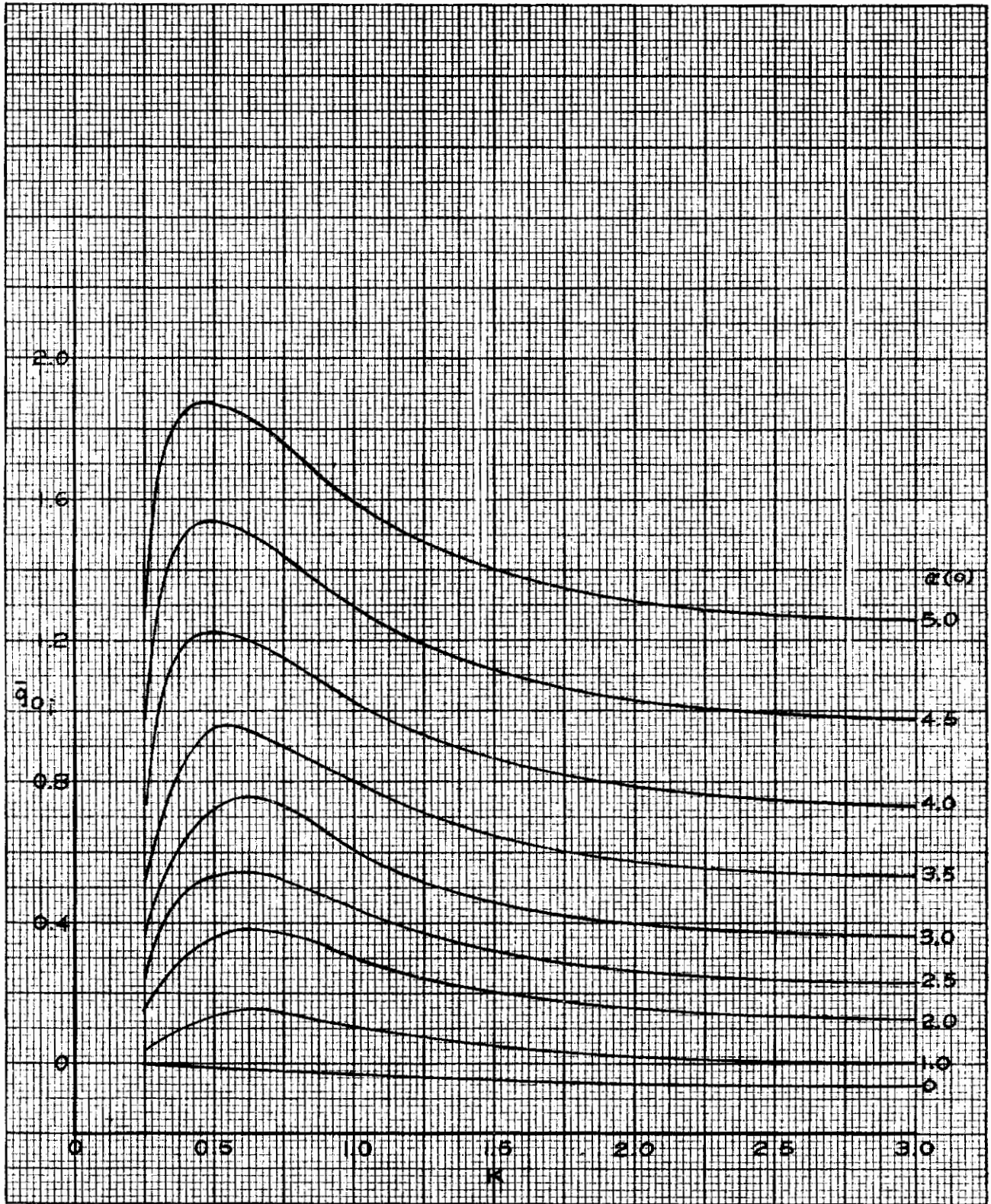


Figure 119. Modified Double Wedge $0.70 \leq \xi_1 \leq 1.00$

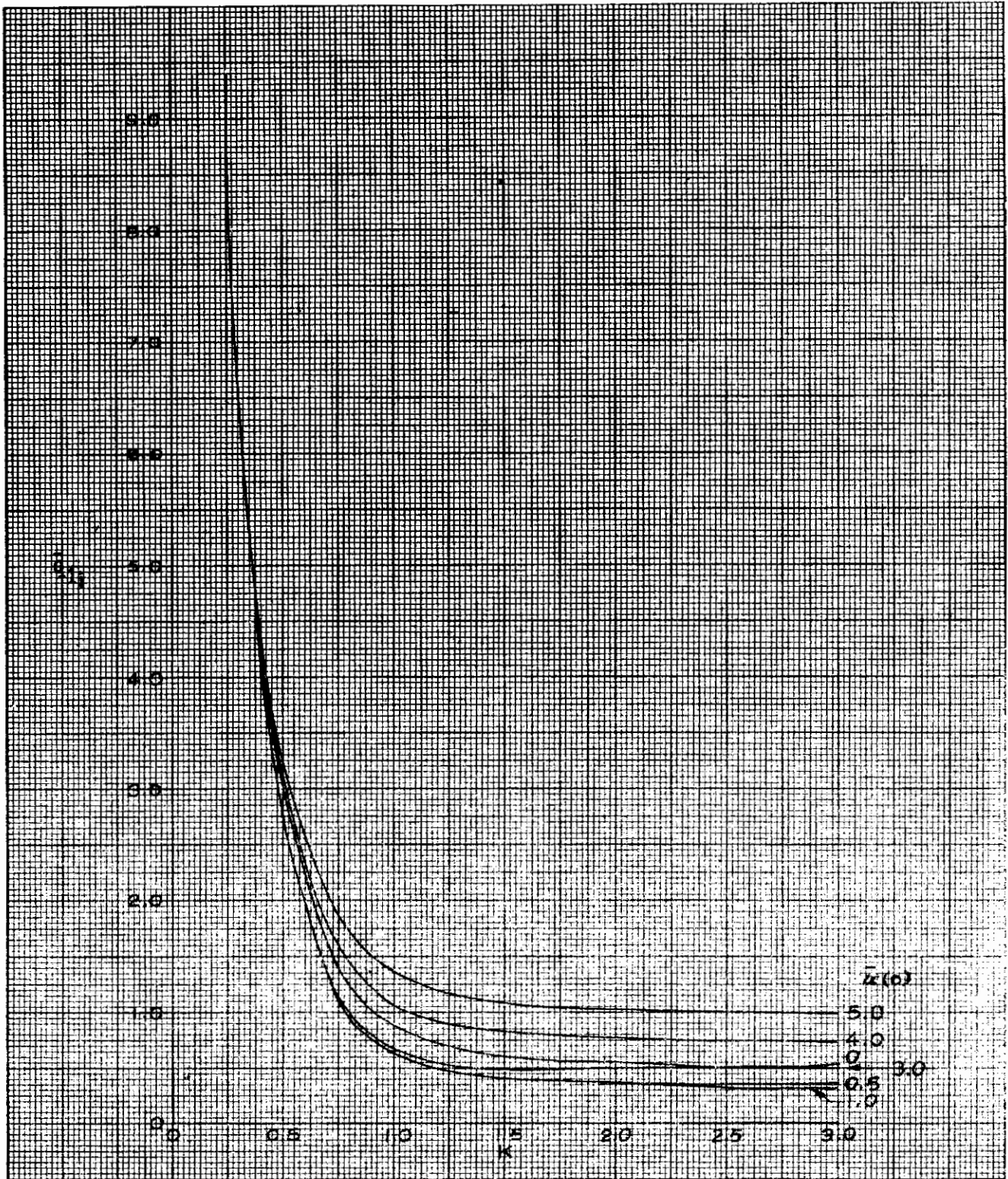


Figure 120. Modified Double Wedge $0.70 \leq \xi_1 \leq 1.00$

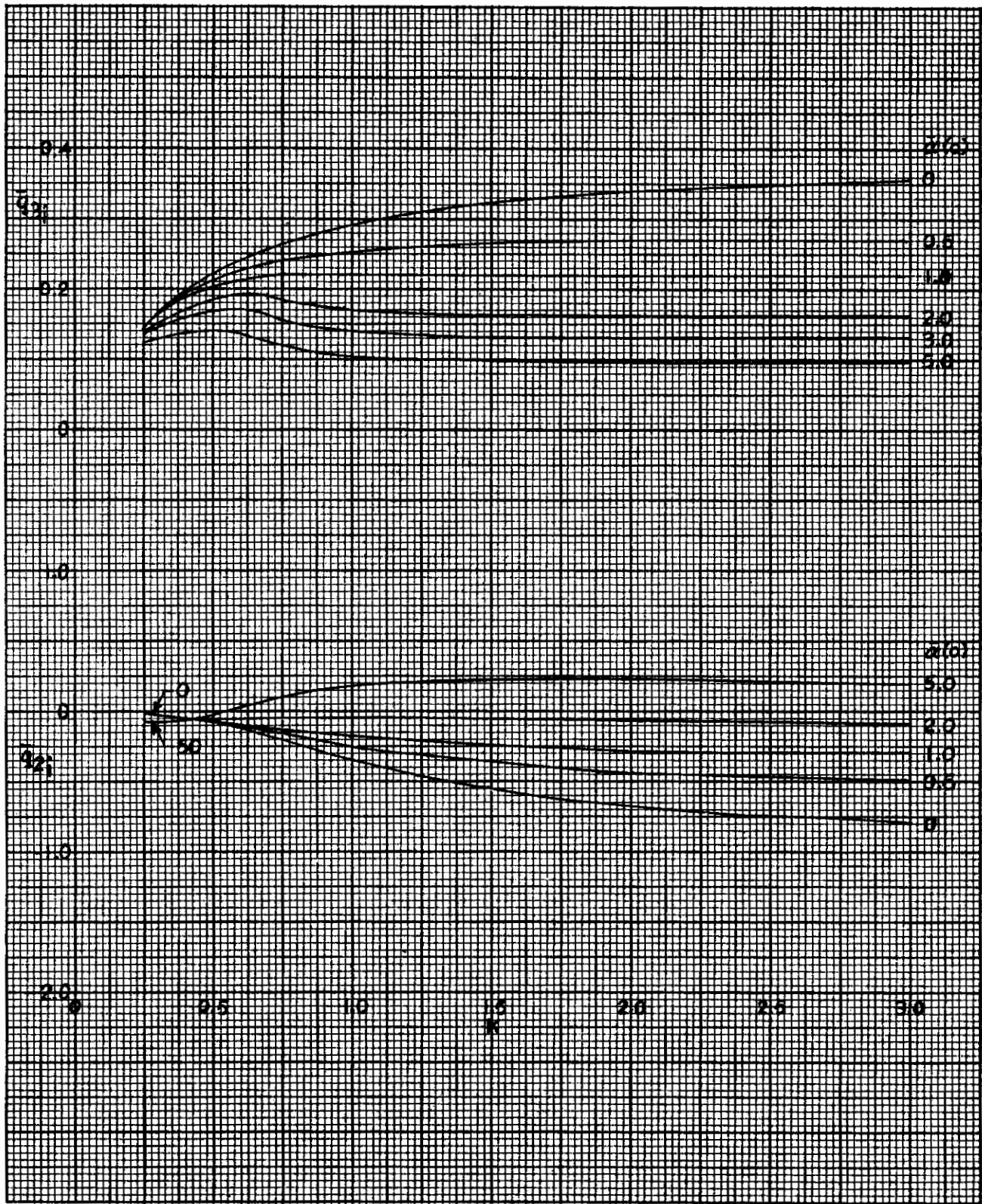


Figure 121. Modified Double Wedge, $0.70 \leq \xi_1 \leq 1.00$

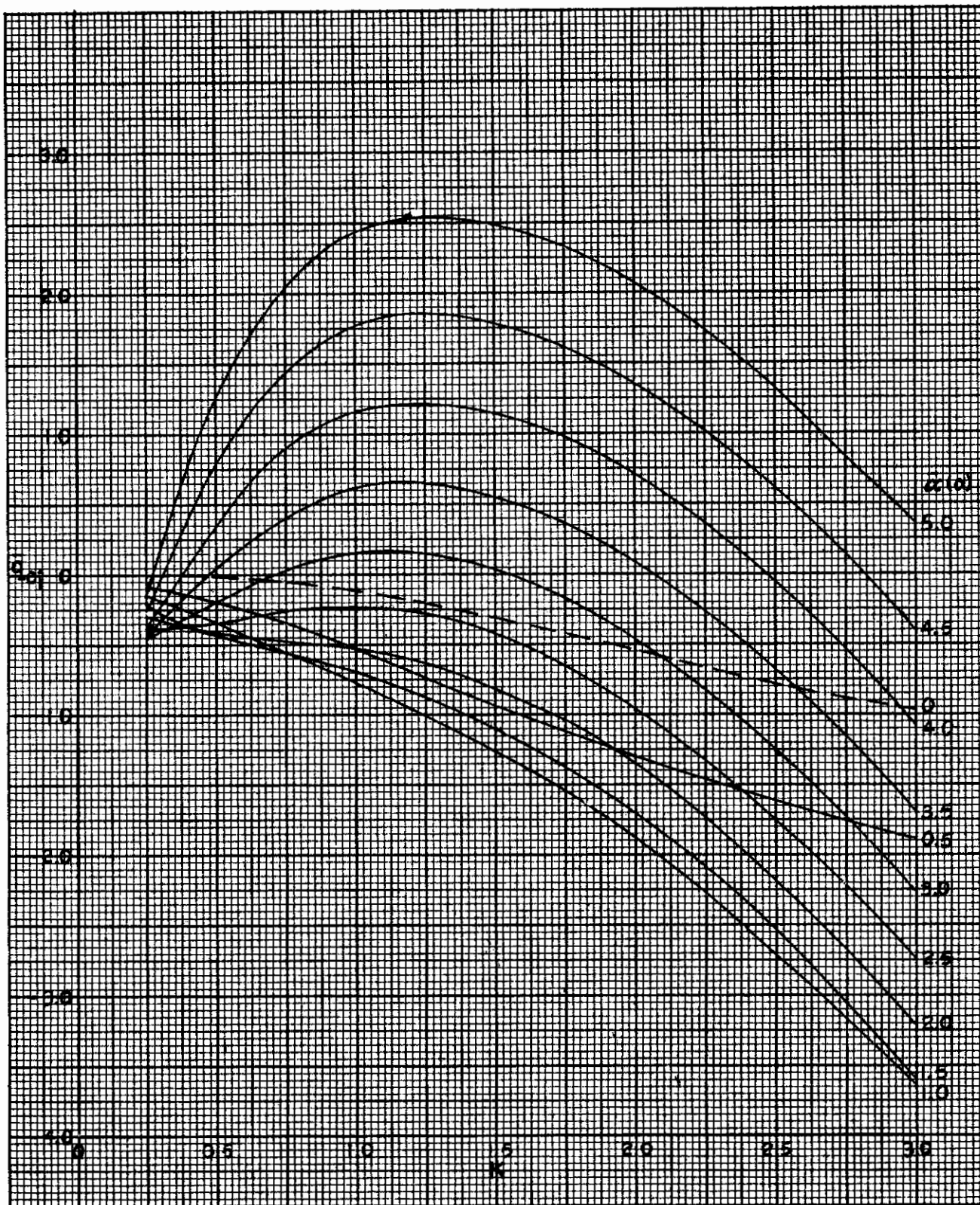


Figure 122. Modified Double Wedge, $0 \leq \xi_i \leq 0.40$

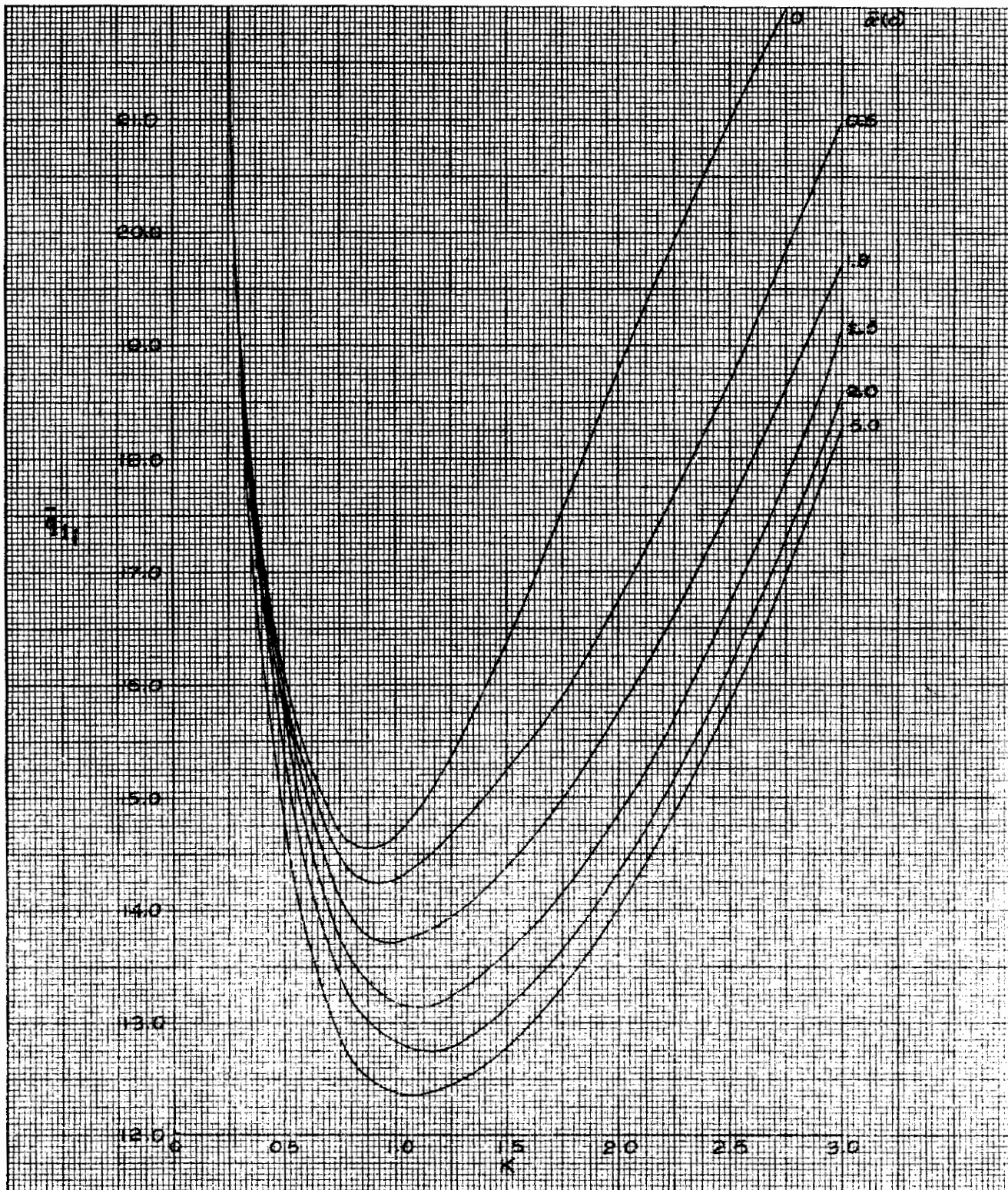


Figure 123. Modified Double Wedge, $0 \leq \xi_1 \leq 0.40$

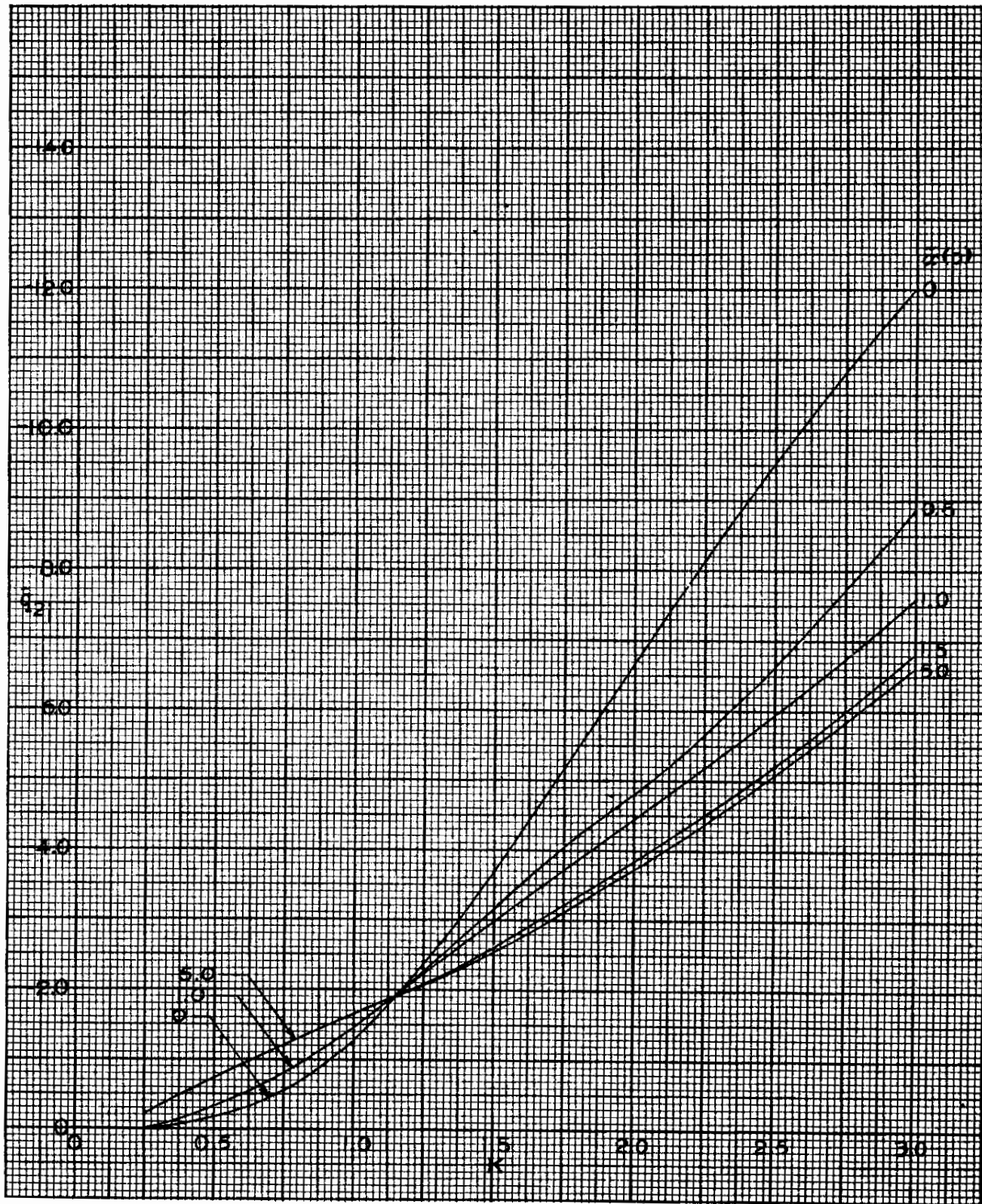


Figure 124. Modified Double Wedge, $0 \leq \xi_1 \leq 0.40$

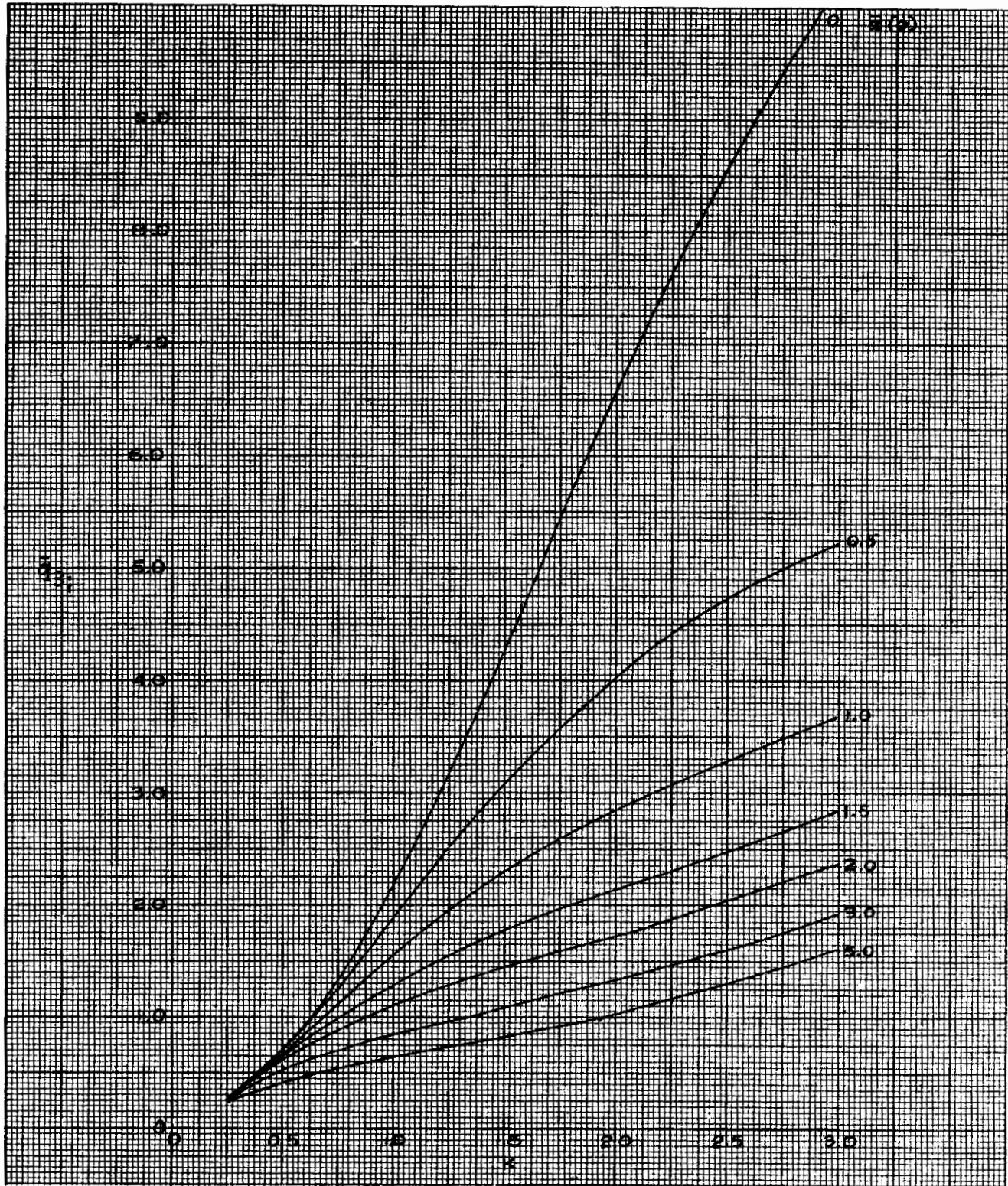


Figure 125. Modified Double Wedge, $0 \leq \xi_1 \leq 0.40$

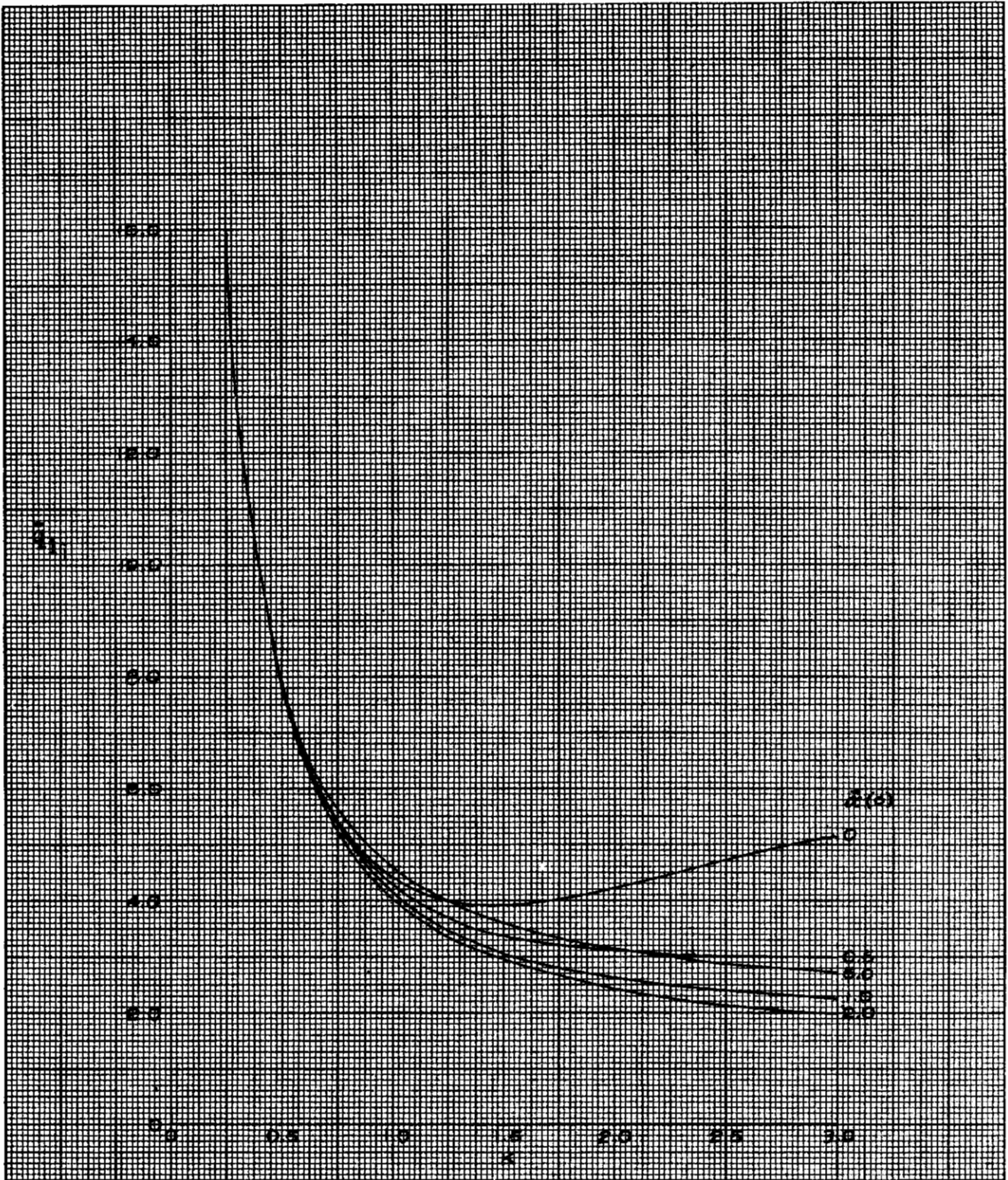


Figure 126. Modified Double Wedge, $0.40 \leq \xi_1 \leq 0.60$

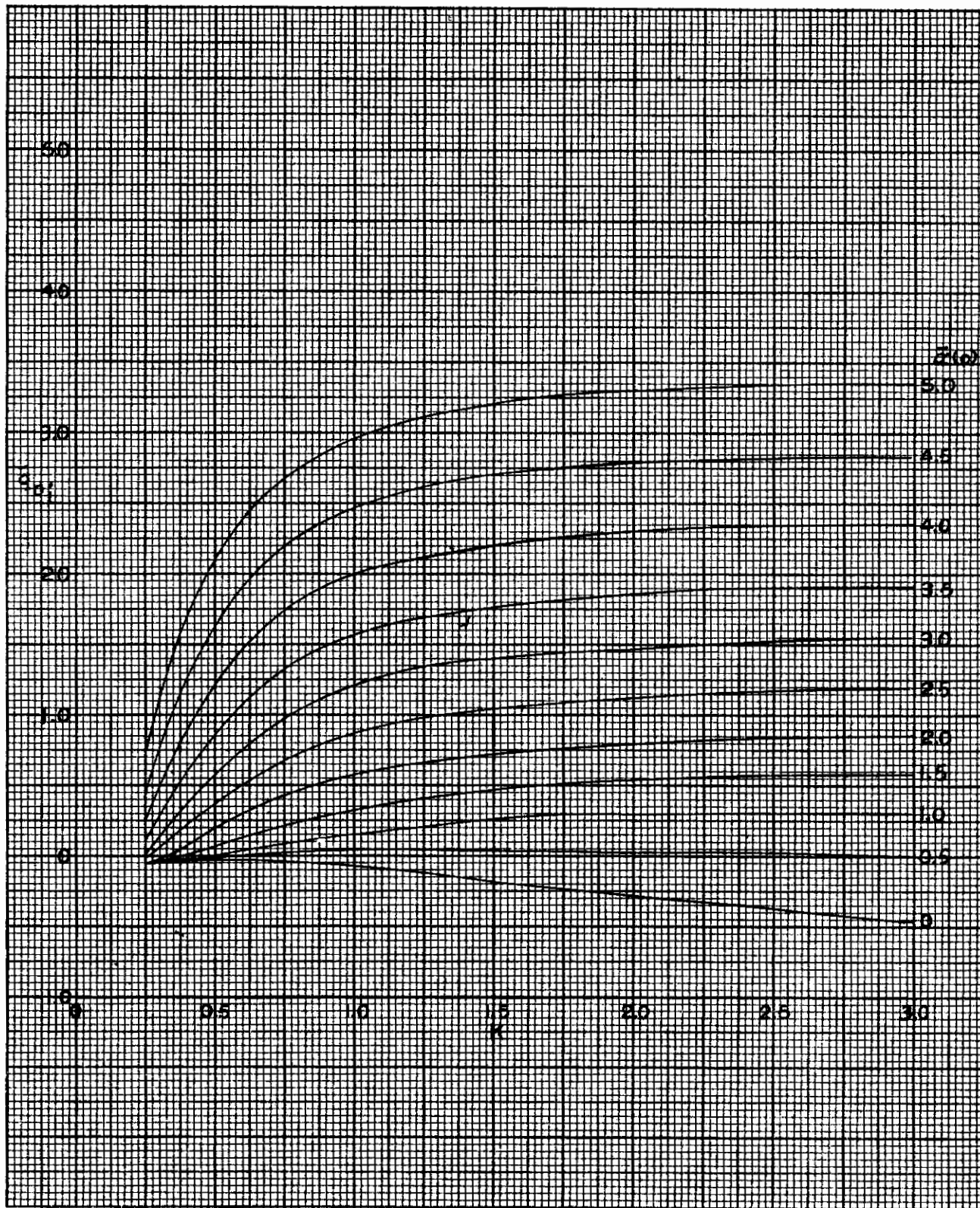


Figure 127. Modified Double Wedge, $0.40 \leq \xi_1 \leq 0.60$

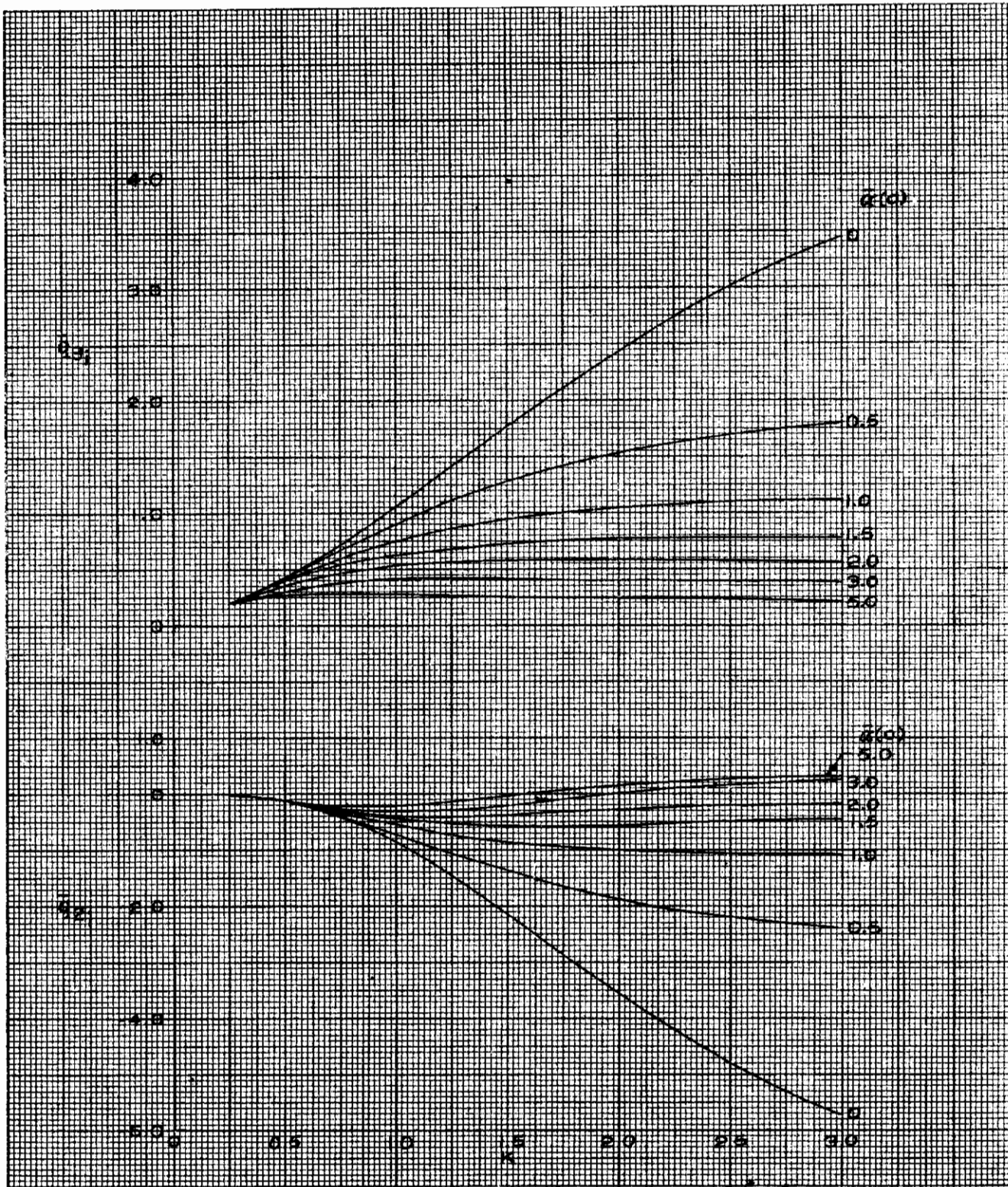


Figure 128. Modified Double Wedge, $0.40 \leq \zeta_i \leq 0.60$

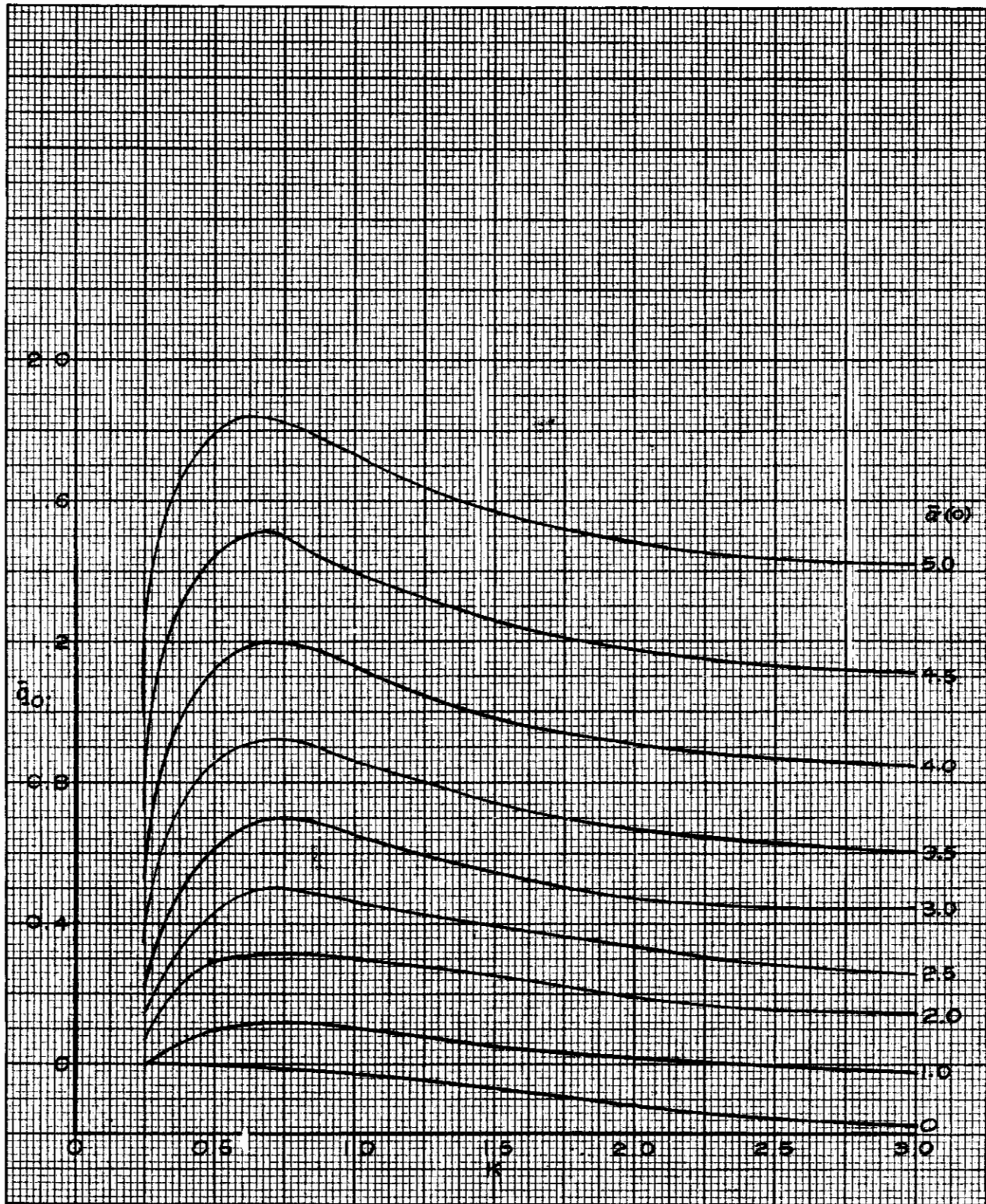


Figure 129. Modified Double Wedge, $0.60 \leq \xi_i \leq 1.00$

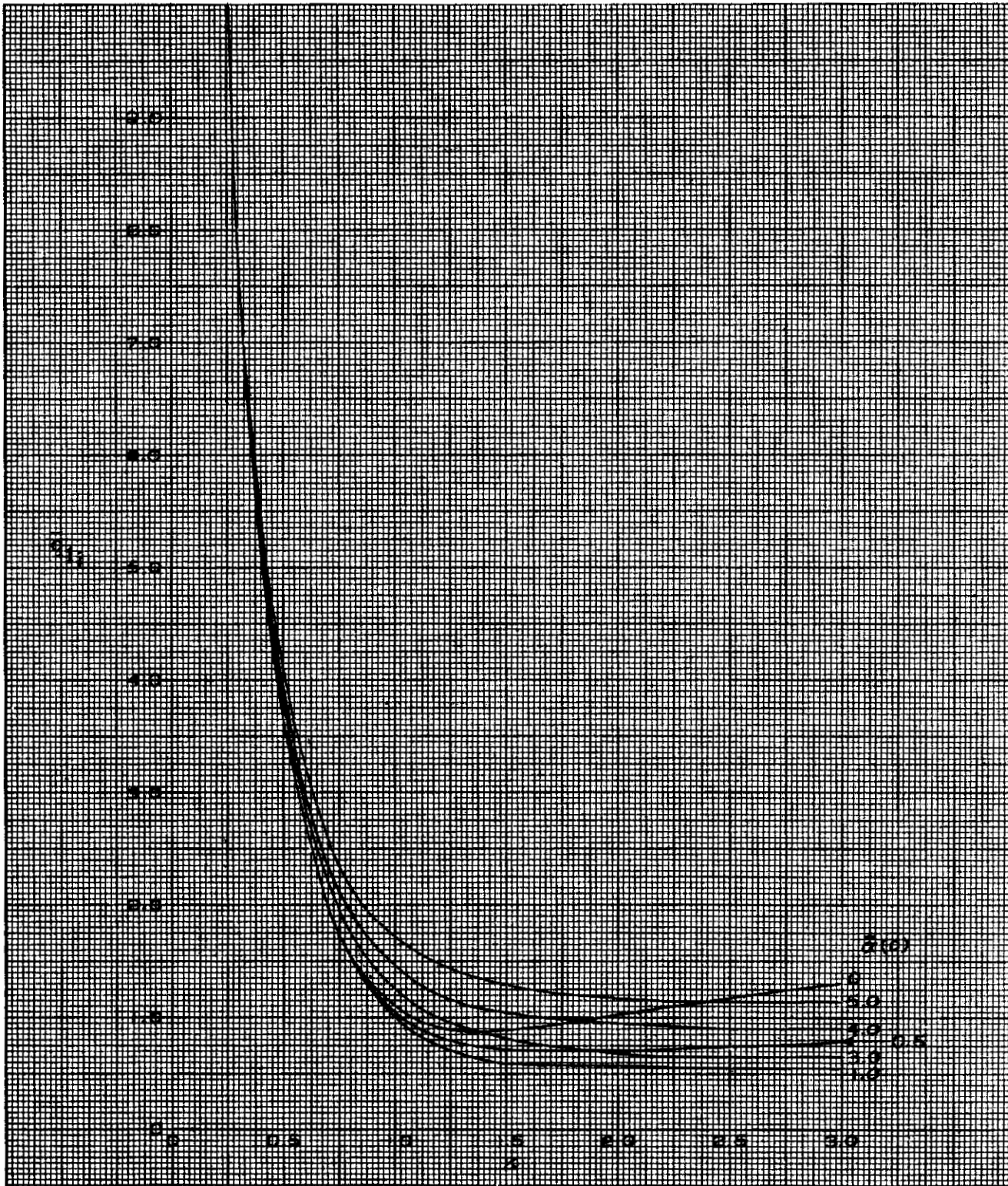


Figure 130. Modified Double Wedge, $0.60 \leq \xi_i \leq 1.00$

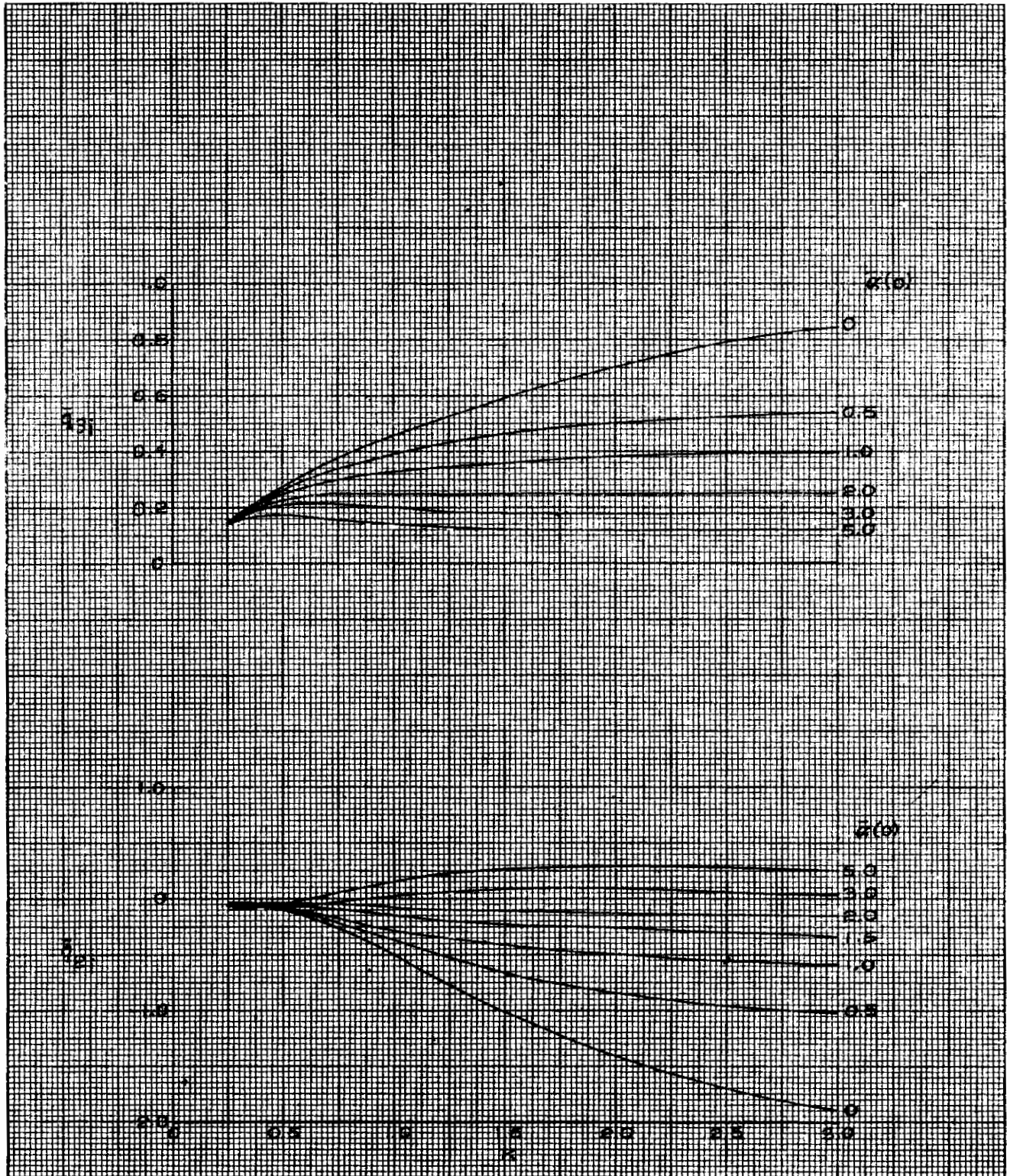


Figure 131. Modified Double Wedge, $0.60 \leq \xi_1 \leq 1.00$