## 10.2 LARGE HOLES AND CUTOUTS

Some designs may occur in which it is necessary or desirable to have relatively large holes or cutouts in a plate, such as lightening holes in the web of a beam or cutouts in a plate structure. A limited amount of data is available for problems of this type; however, available solutions will be discussed in this section.

### 10.2.1 Bending of Plates with Circular Holes

Solutions have been obtained in Ref. 18 for a uniformly loaded square plate either simply supported or clamped along the outer boundary with a central circular hole as shown in Fig. B10-28. Results for deflections and bending moments for each boundary condition are given in Tables B10-2 and -3.

### 10.2.2 Holes in Beam Webs

Holes are frequently cut in the webs of beams to provide for passage of pipes and ducts, for access to the inside of a box beam, or for weight saving. Little information is available on the stress distribution around holes in beam webs.

An analytical method for calculating stresses around holes in the web of wide flange beams shown in Fig. B10-29 is presented in Ref. 19. The applicability of the analysis depends on the size of the hole and on the magnitude of the moment-shear ratio at the hole. The analysis is primarily applicable to circular holes; as for elliptic holes, limits of applicability of the analysis technique were not established.

An empirical technique for the analysis of webs with round lightening holes having formed 45 deg flanges is presented in Ref. 20.

Table B10-1. Stress Concentration in a Plate Due to Uniformly Spaced Circular Holes

$$\frac{\rho}{p} = 0.92$$

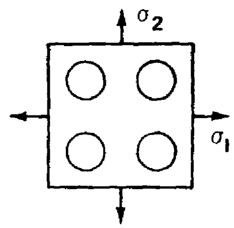
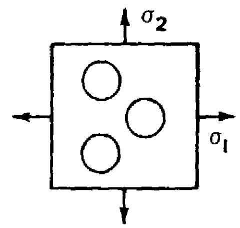
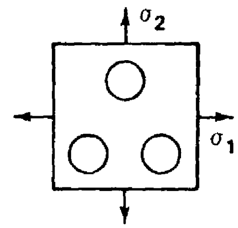
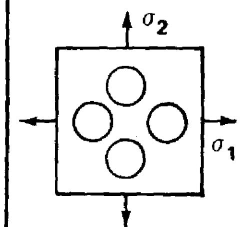
| Configuration / Biaxial loads |  |  |  |  |
|---|---|---|---|---|
| $\sigma_1 \neq 0,\ \sigma_2 = 0$ Uniaxial Tension | 12.5 | 19.4 | 23.0 | 37.0 |
| $\sigma_2 = 0.5\,\sigma_1$ | 12.6 | 14.0 | 17.4 | 23.4 |
| $\sigma_2 = \sigma_1$ hydrostatic tension | 12.6 | 13.5 | 13.5 | 12.6 |
| $\sigma_2 = -\sigma_1$ pure shear | 12.6 | 39.0 | 39.0 | 64.4 |

Table B10-2. Maximum Deflections and Moments in Simply Supported Square Plate With a Circular Hole Subjected to Uniform Load

| R/b | $W_{max}$ | Max $M_\theta$ |
|---|---|---|
| | $\frac{qb^4}{D}$ | $qb^2$ |
| 0 | 0.649 | 0.192 |
| 1/6 | 0.0719 | 0.344 |
| 1/3 | 0.0697 | 0.276 |
| 1/2 | 0.0530 | 0.207 |
| 2/3 | 0.0303 | 0.143 |
| 5/6 | 0.0119 | 0.085 |
| 1 | 0.00268 | 0.036 |

Table B10-3. Maximum Deflections and Moments in a Clamped Square Plate With a Circular Hole Subjected to Uniform Load

| R/b | $W_{max}$ | Max $M_\theta$ along the hole | Max $M_n$ along the edge |
|---|---|---|---|
| | $\frac{qb^4}{D}$ | $qb^2$ | $qb^2$ |
| 0 | 0.02025 | 0.0916 | -0.2055 |
| 1/6 | 0.02148 | 0.1451 | -0.2032 |
| 1/3 | 0.01648 | 0.0907 | -0.1837 |
| 1/2 | 0.00858 | 0.0522 | -0.1374 |
| 2/3 | 0.00307 | 0.0310 | -0.0780 |
| 5/6 | 0.00081 | 0.0176 | -0.0410 |
| 1 | 0.00025 | 0.0067 | -0.0215 |

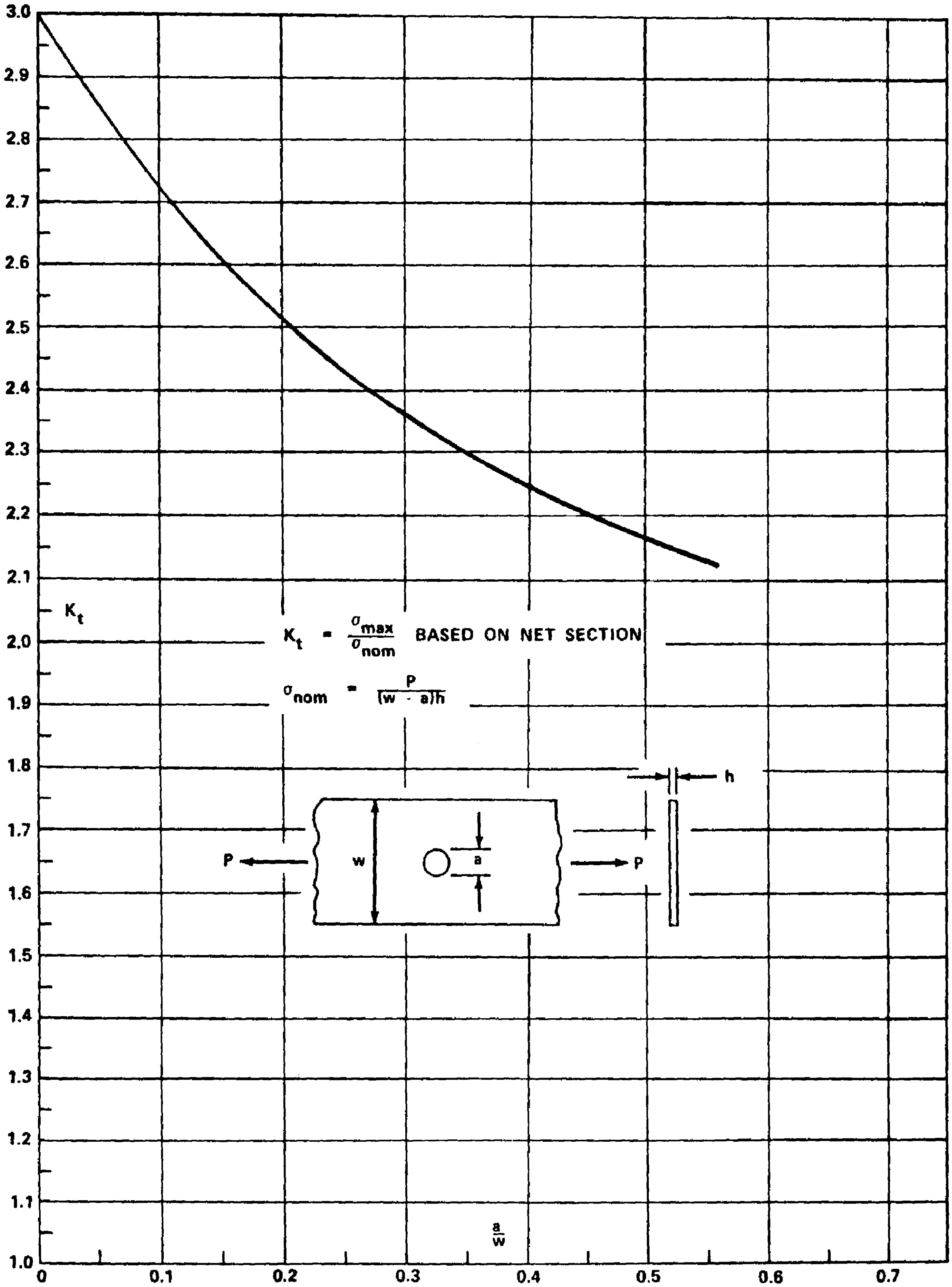



FIGURE B10-1. STRESS CONCENTRATION FACTOR, $K_t$, FOR AXIAL LOADING CASE OF A FINITE-WIDTH PLATE WITH A TRANSVERSE HOLE.

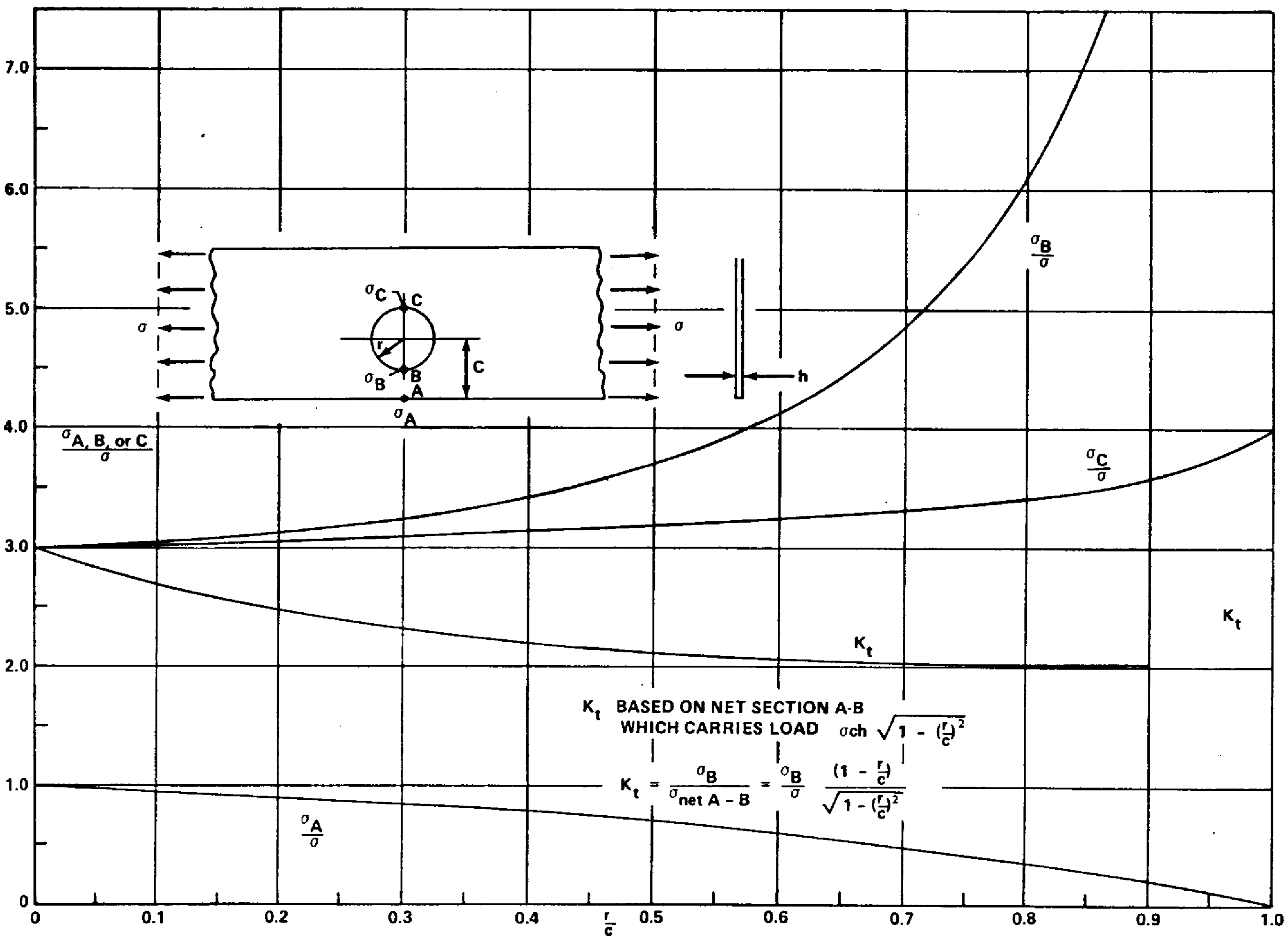



FIGURE B10-2. STRESS CONCENTRATION FACTOR, $K_t$, FOR THE TENSION CASE OF A SEMI-INFINITE PLATE WITH A CIRCULAR HOLE NEAR THE EDGE.

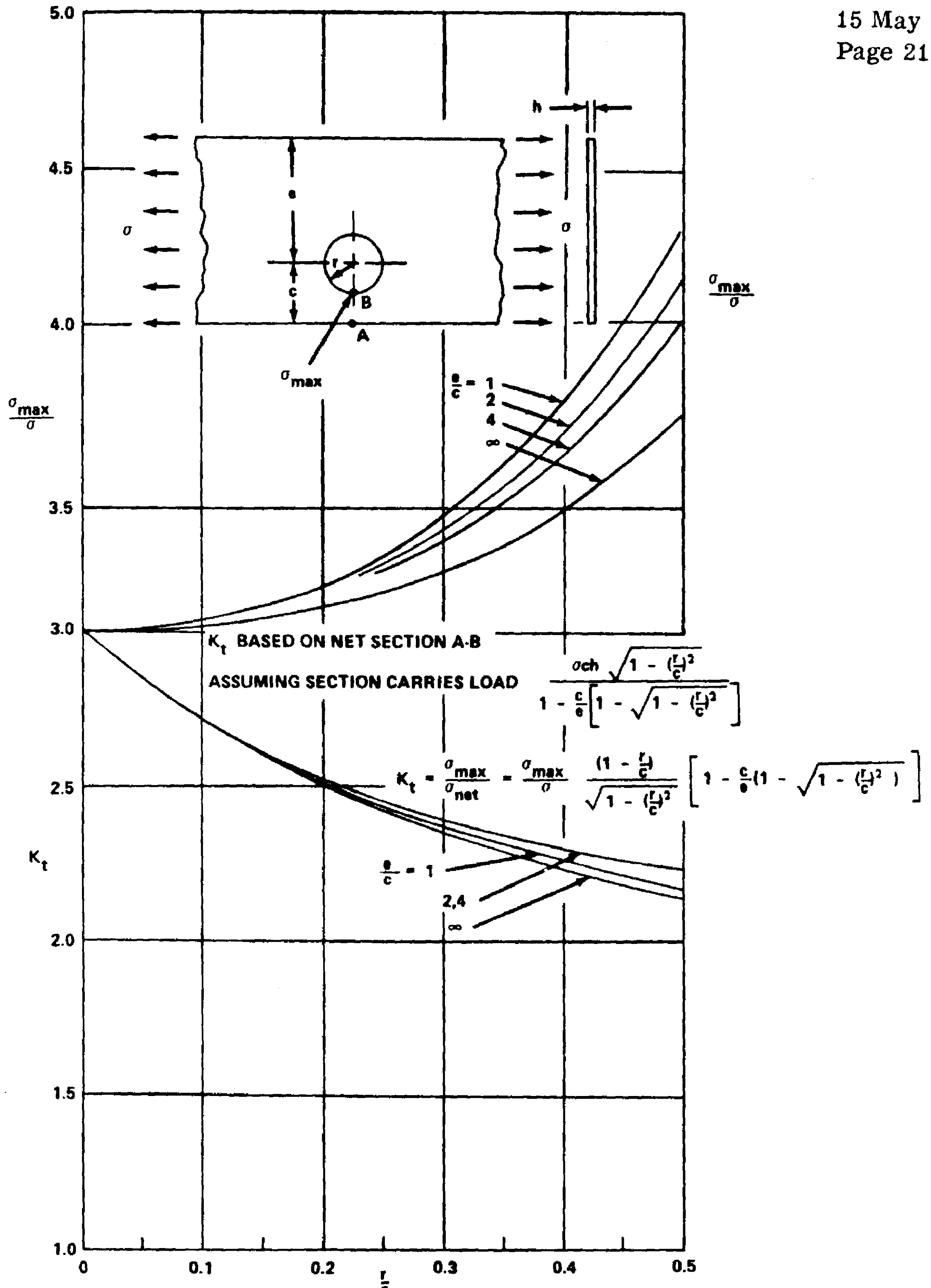



FIGURE B10-3. STRESS CONCENTRATION FACTOR, $K_t$, FOR TENSION CASE OF A FLAT BAR WITH A CIRCULAR HOLE DISPLACED FROM CENTER LINE.

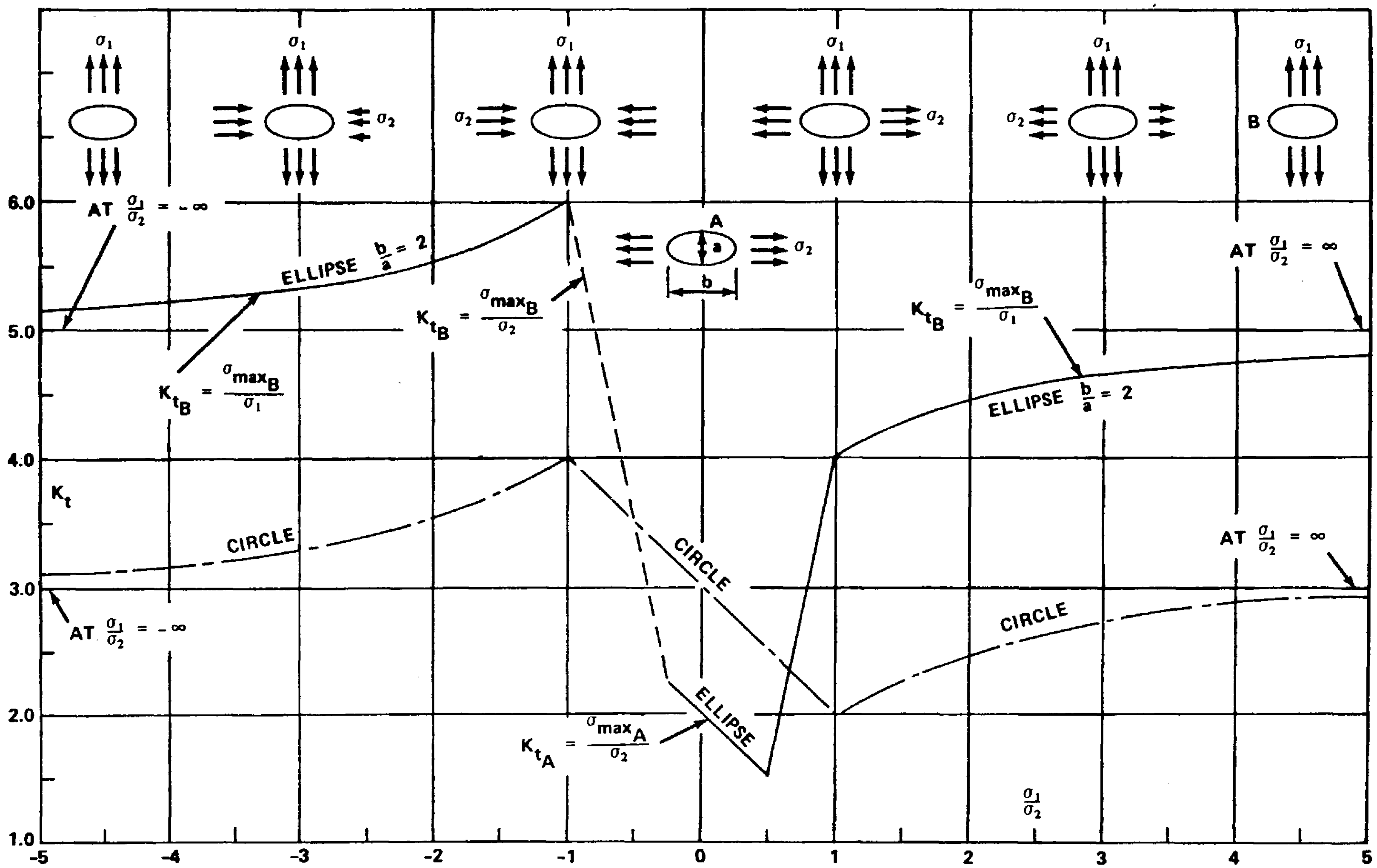



FIGURE B10-4. STRESS CONCENTRATION FACTOR, $K_t$, FOR AN ELLIPTICAL HOLE $\frac{b}{a} = 2$ AND FOR A CIRCULAR HOLE IN A PLATE SUBJECTED TO BIAXIAL STRESS.

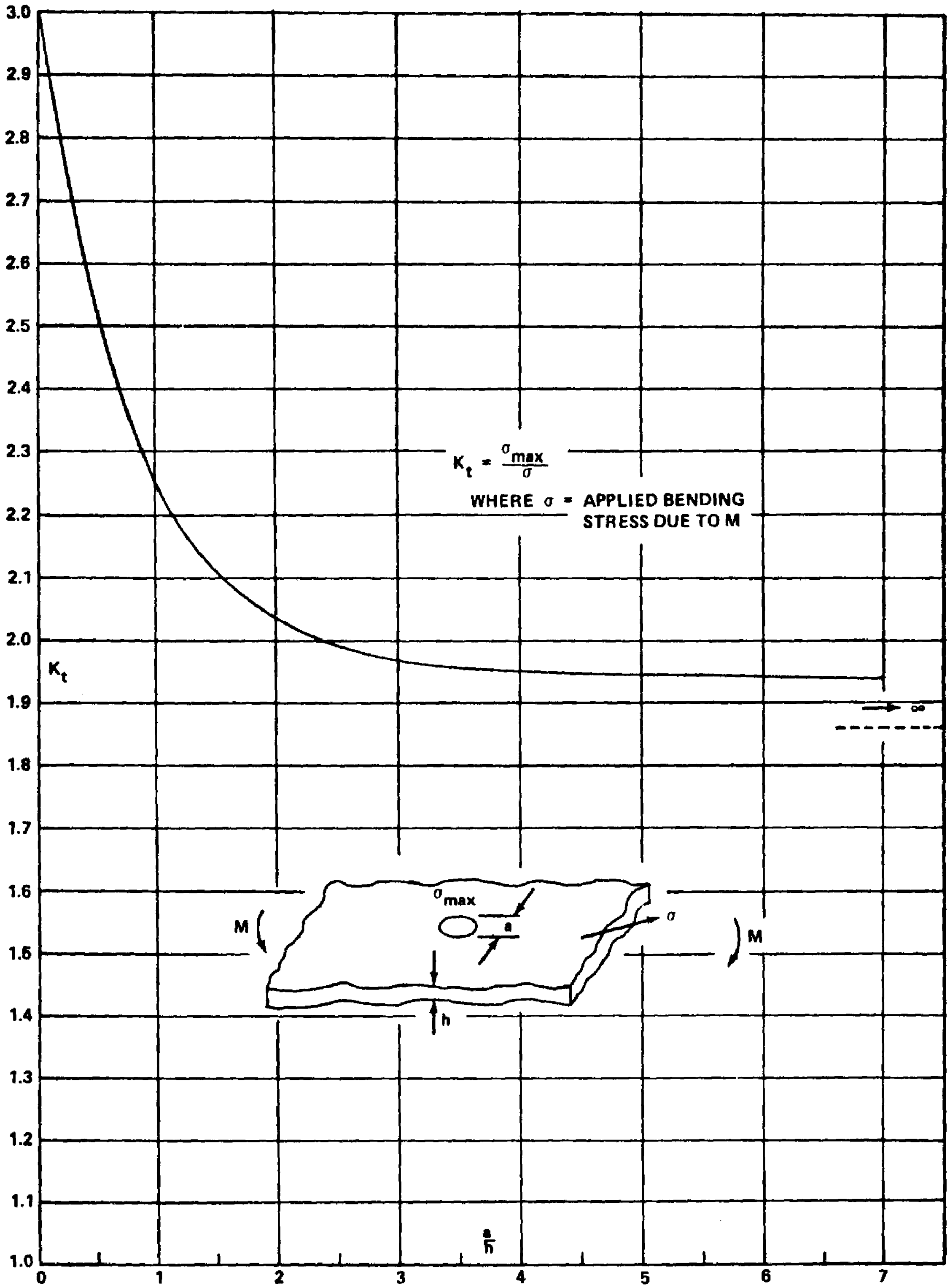



FIGURE B10-5. STRESS CONCENTRATION FACTOR, $K_t$, FOR BENDING CASE OF AN INFINITELY WIDE PLATE WITH A TRANSVERSE HOLE.

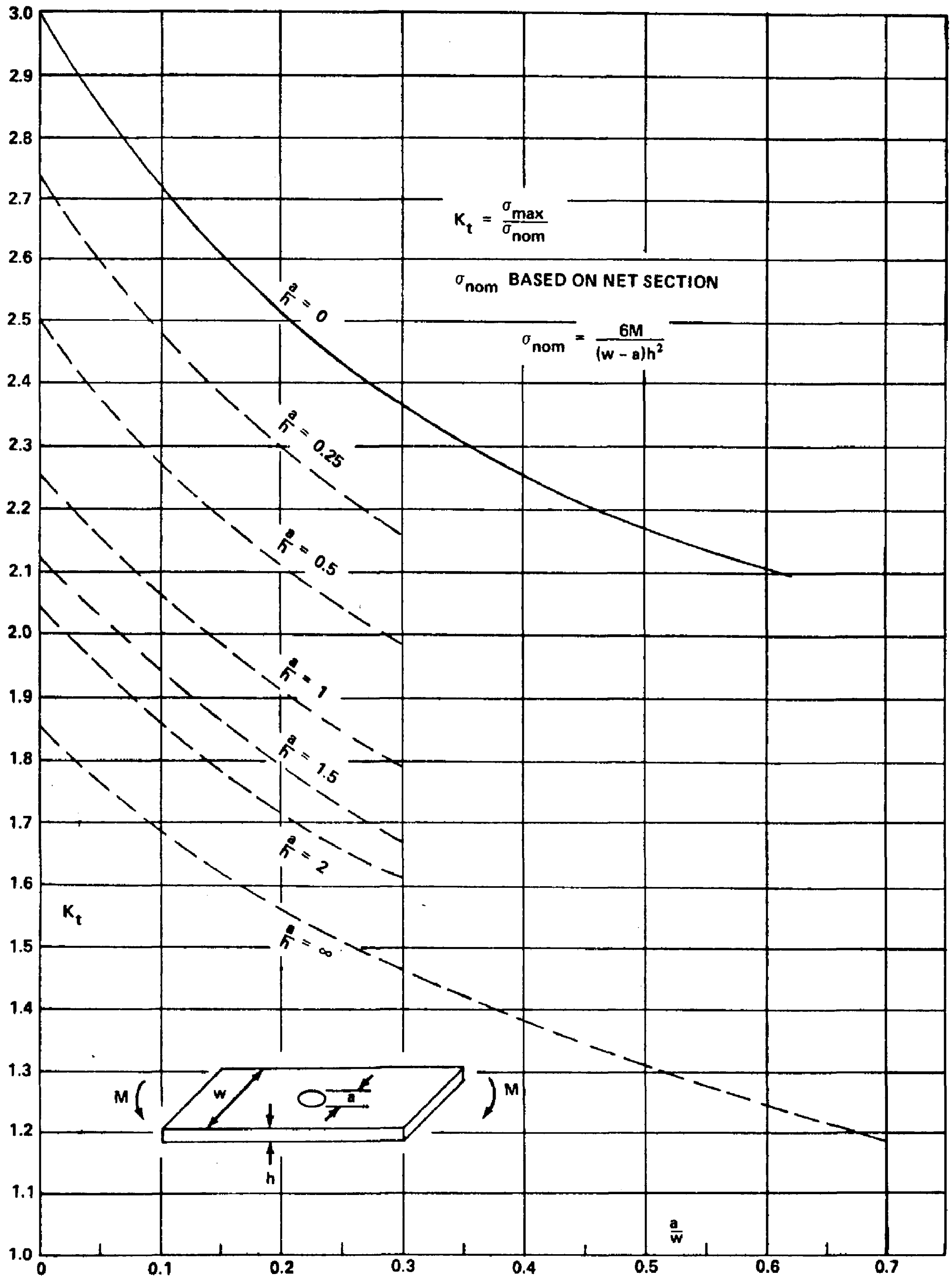



FIGURE B10-6. STRESS CONCENTRATION FACTOR, $K_t$, FOR BENDING CASE OF FINITE-WIDTH PLATE WITH A TRANSVERSE HOLE.

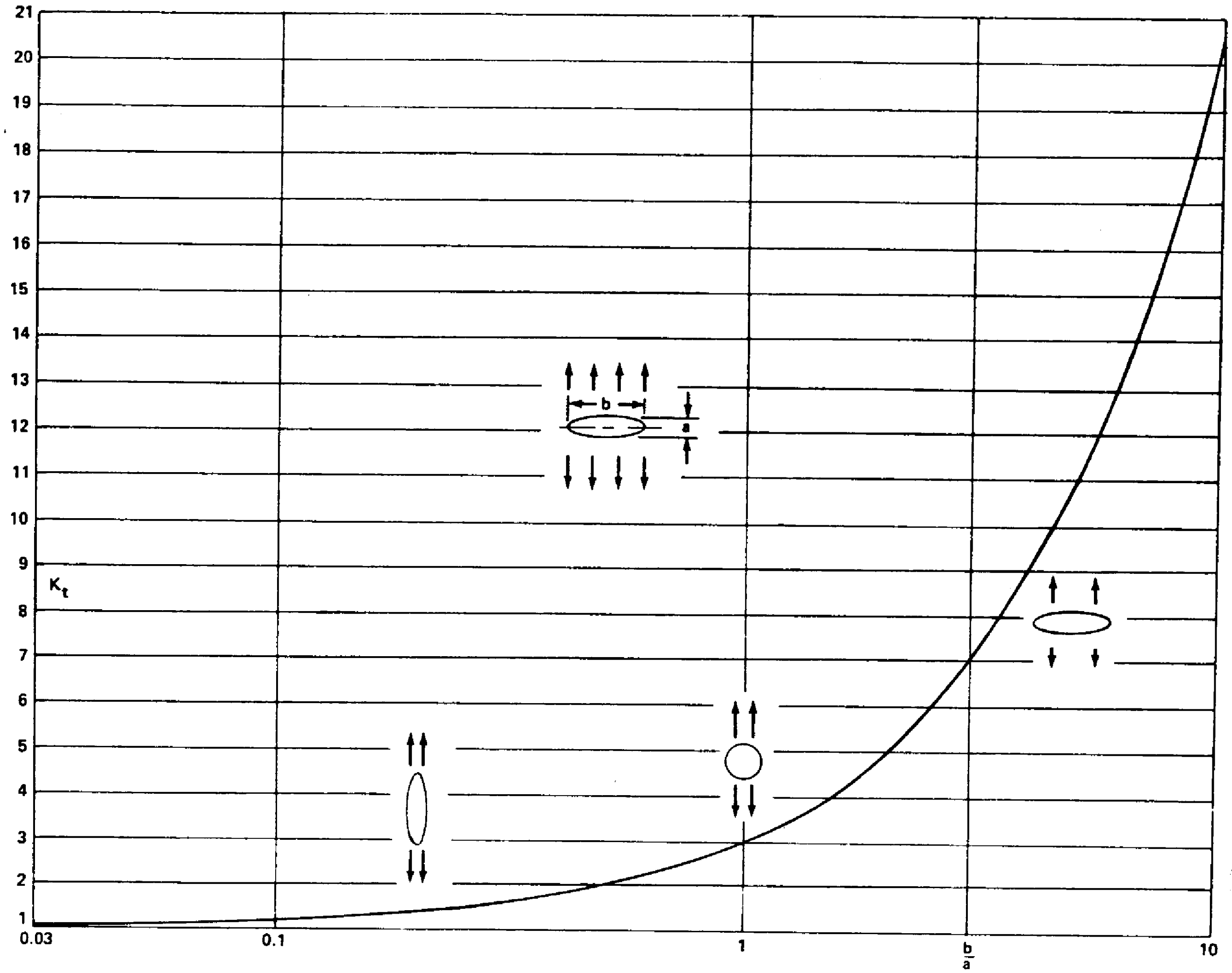



FIGURE B10-7. STRESS CONCENTRATION FACTOR, $K_t$, FOR AN ELLIPTICAL HOLE IN AN INFINITE PLATE IN TENSION.

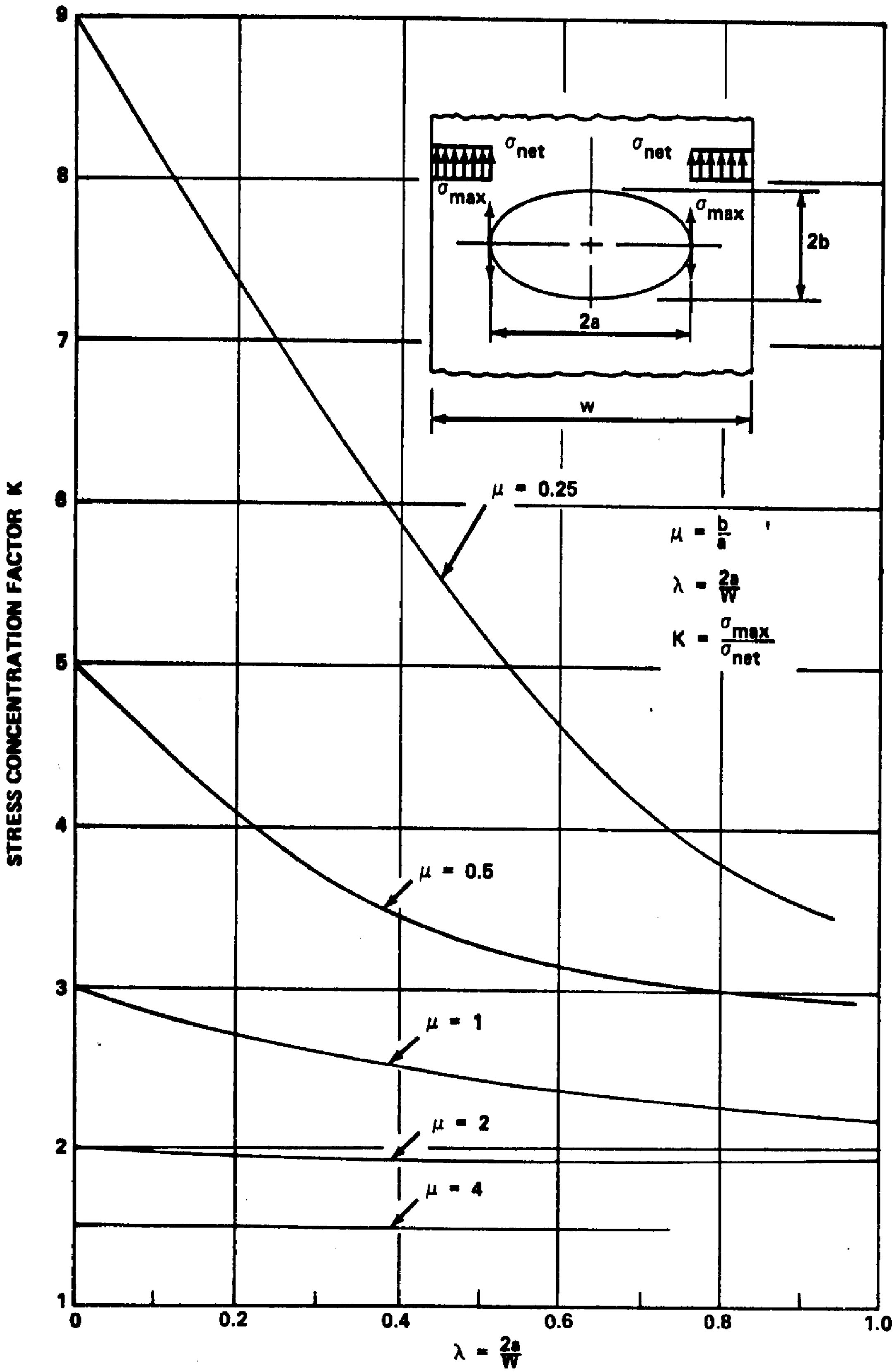



FIGURE B10-8. STRESS CONCENTRATION FACTOR FOR POINTS UNDER MAXIMUM TENSION IN A FINITE PLATE WITH AN ELLIPTICAL HOLE.

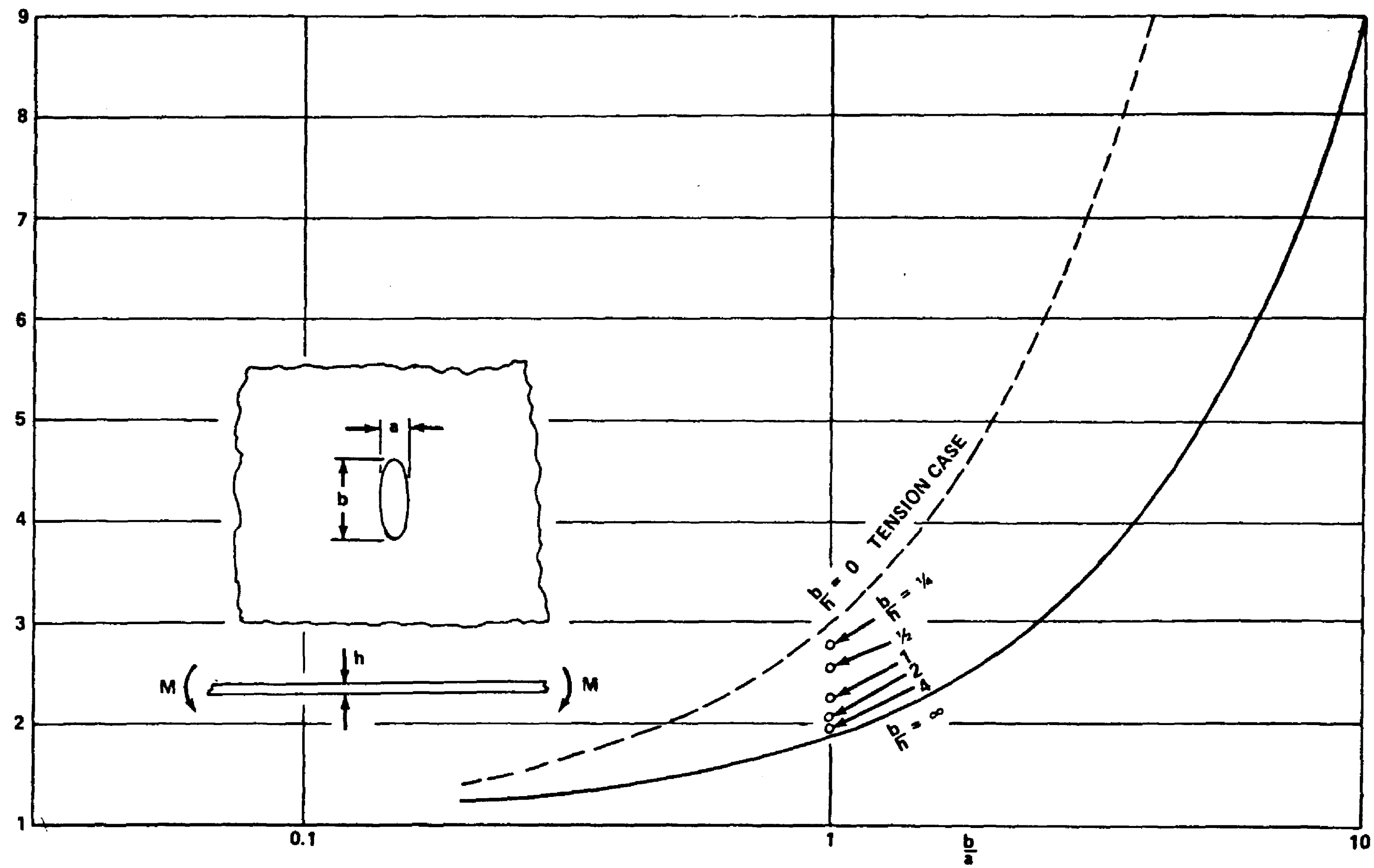



FIGURE B10-9. STRESS CONCENTRATION FACTOR, $K_t$, FOR THE TRANSVERSE BENDING CASE OF AN INFINITELY WIDE SHEET CONTAINING AN ELLIPTICAL HOLE.

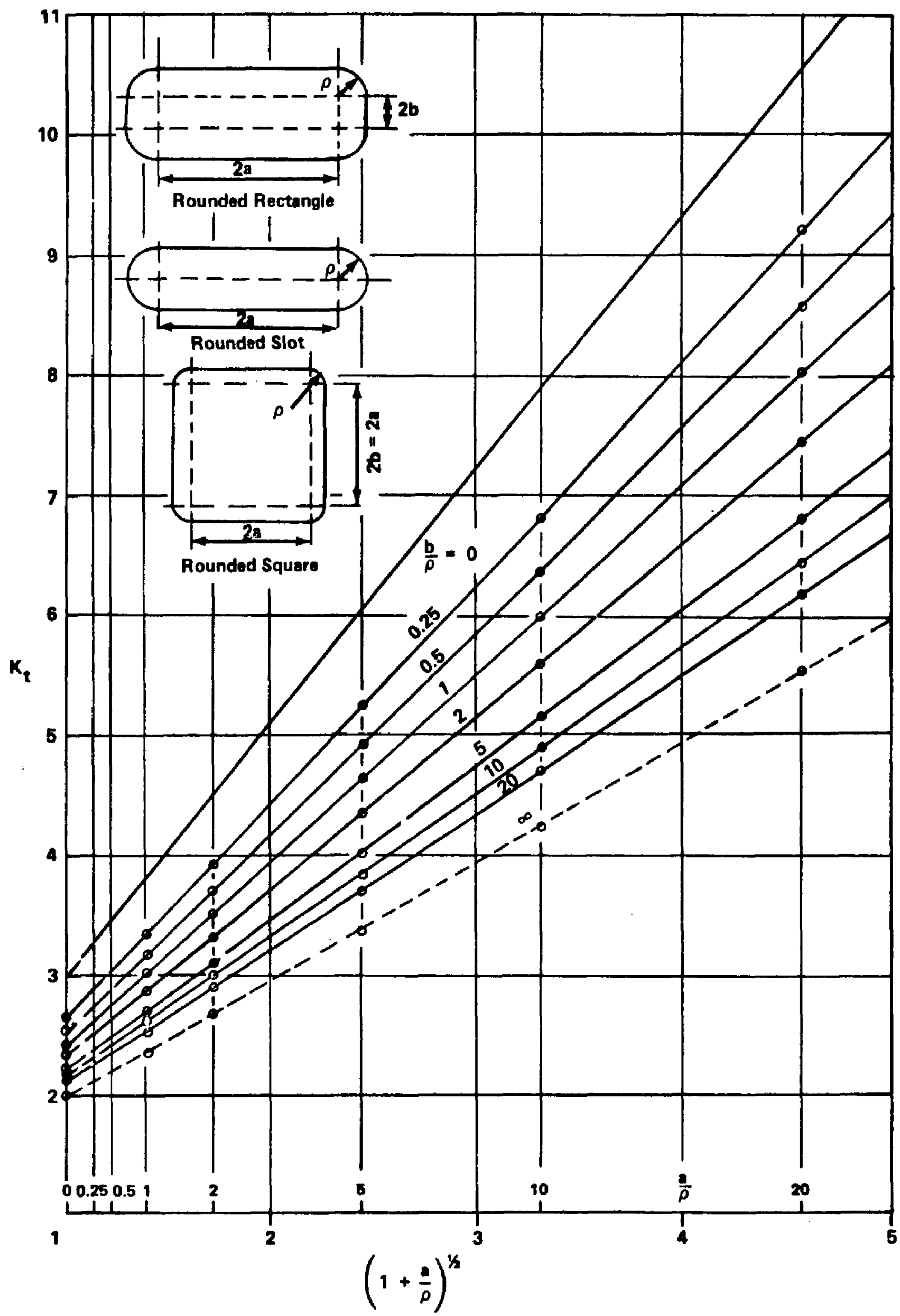



FIGURE B10-10. VARIATION OF $K_t$ WITH $\frac{a}{\rho}$ FOR CONSTANT $\frac{b}{\rho}$ WITH TENSILE LOADING TENDING TO OPEN THE SLOT.

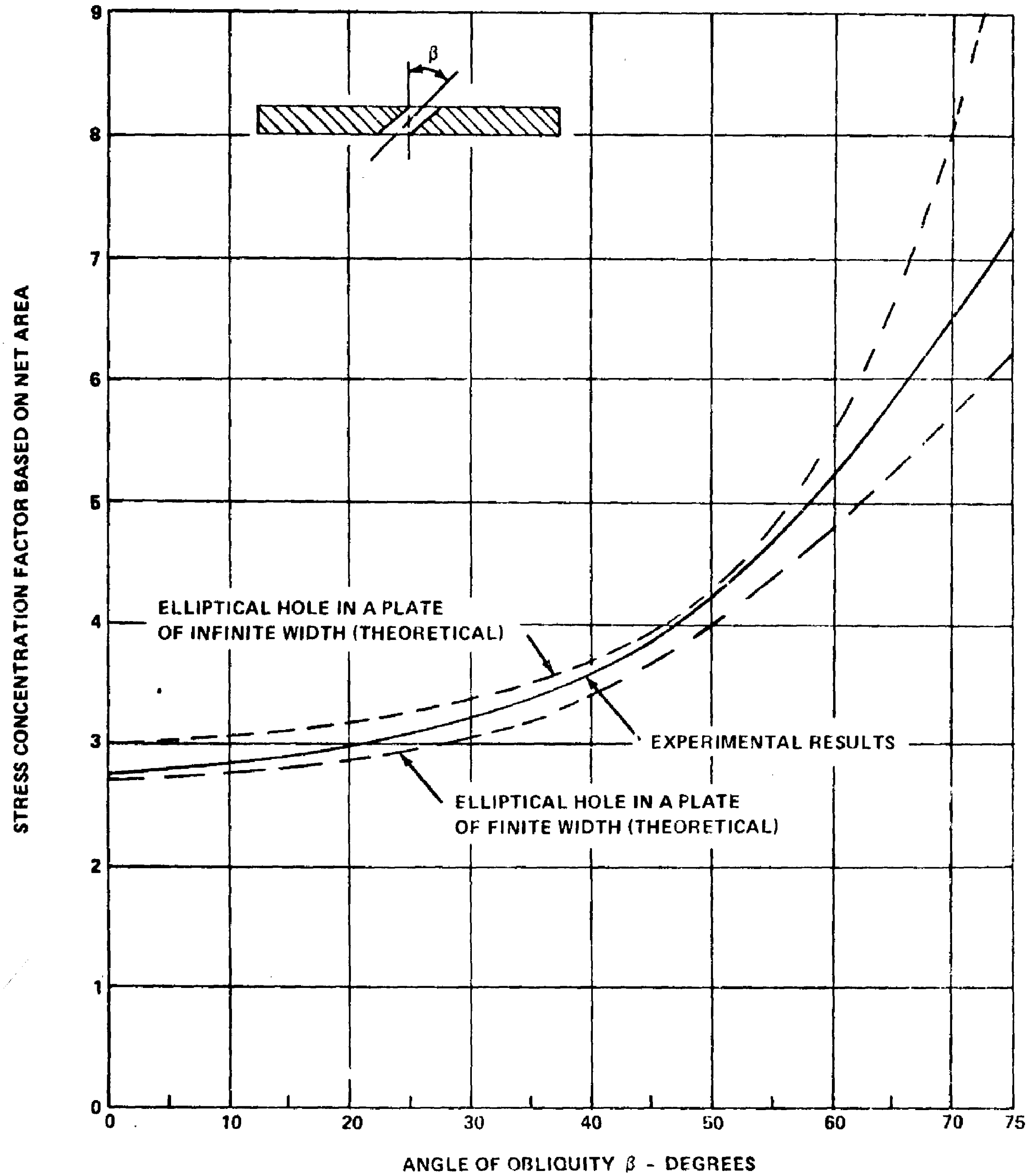



FIGURE B10-11. STRESS CONCENTRATION FACTOR BASED ON NET AREA AS A FUNCTION OF ANGLE OF OBLIQUITY $\beta$ .

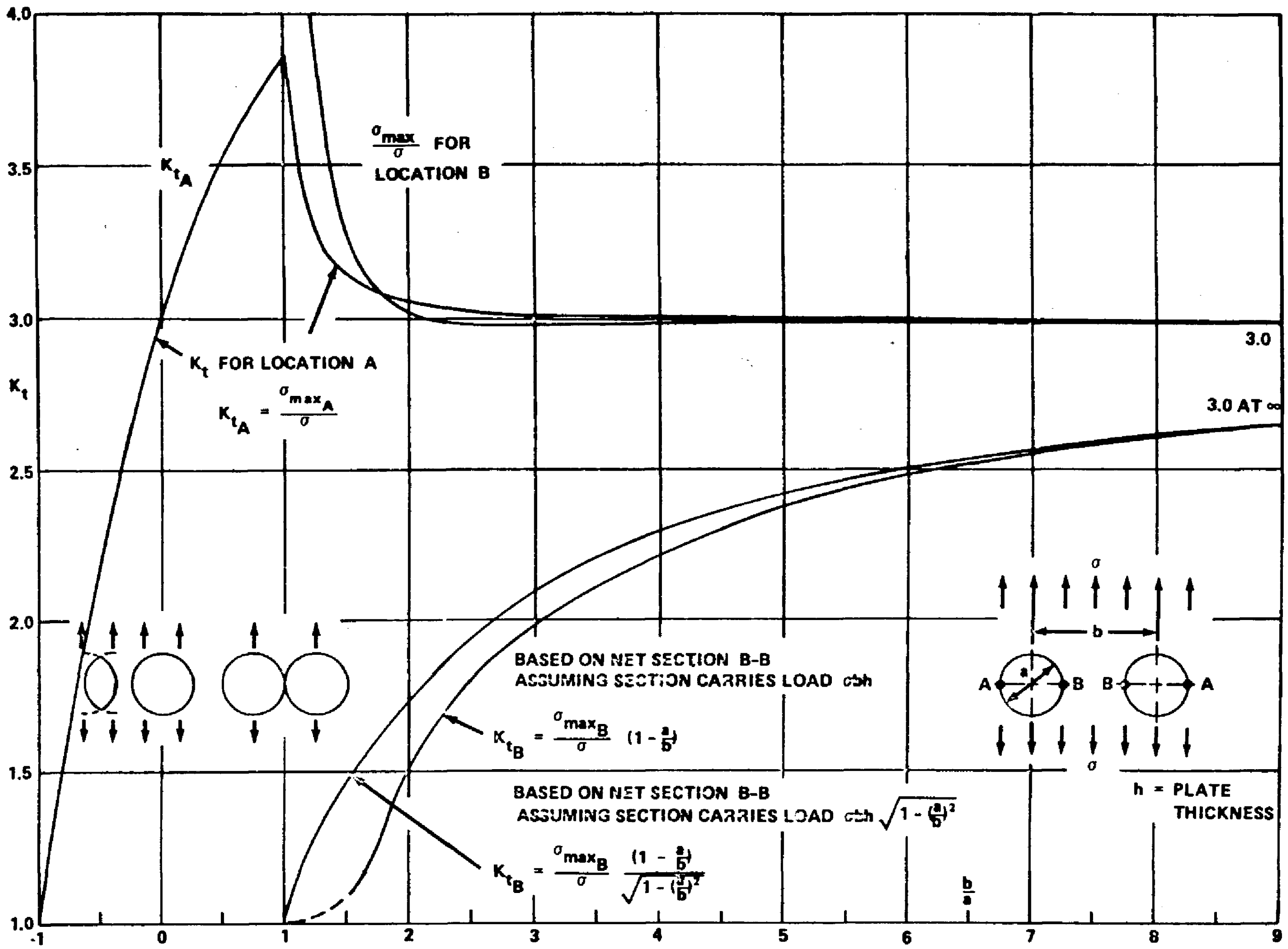



FIGURE B10-12. STRESS CONCENTRATION FACTOR, $K_t$, FOR TENSION CASE OF AN INFINITE PLATE WITH TWO CIRCULAR HOLES (TENSION PERPENDICULAR TO LINE OF HOLES).

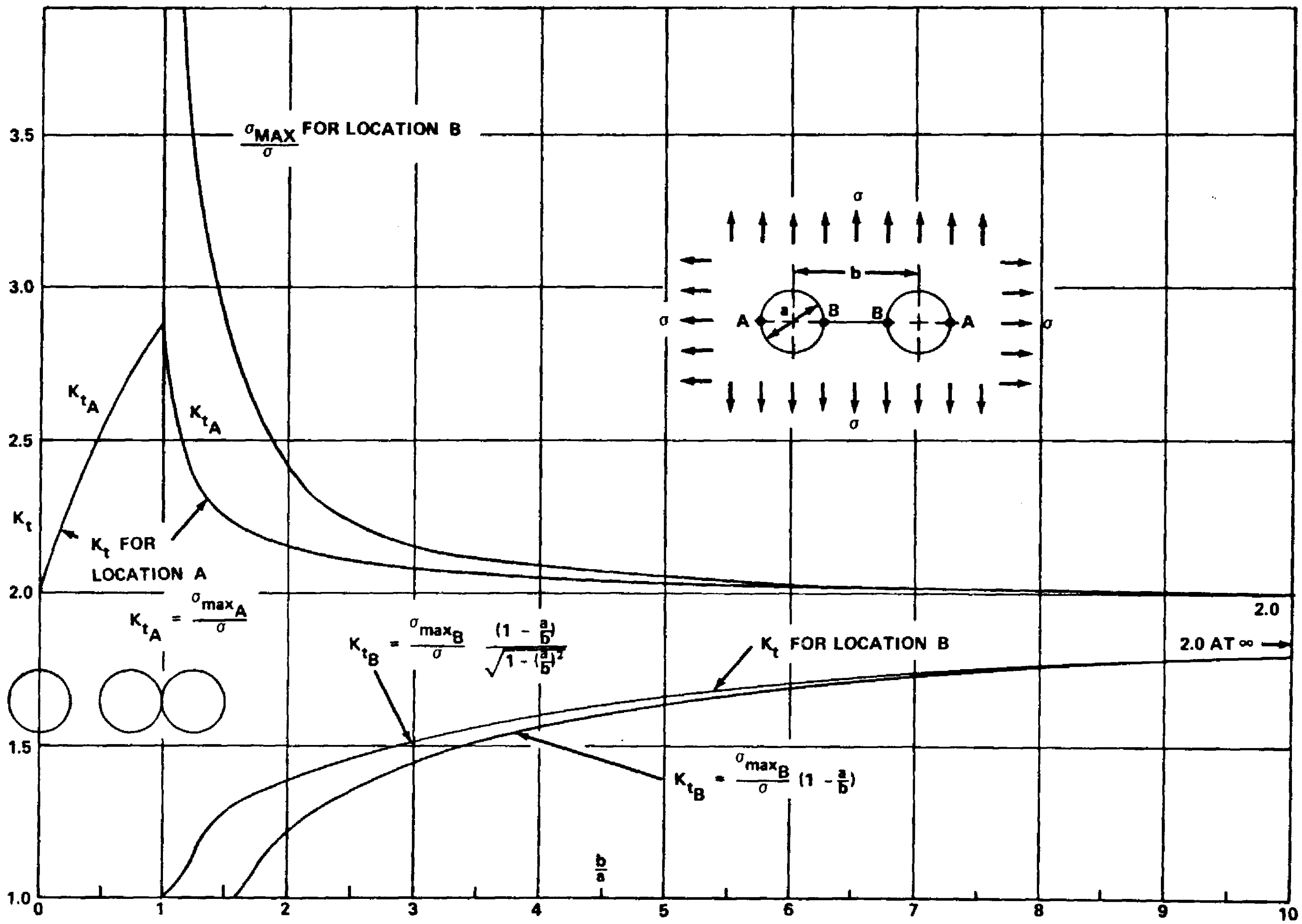



FIGURE B10-13. STRESS CONCENTRATION FACTOR, $K_t$, FOR BIAXIAL TENSION CASE OF AN INFINITE PLATE WITH TWO CIRCULAR HOLES.

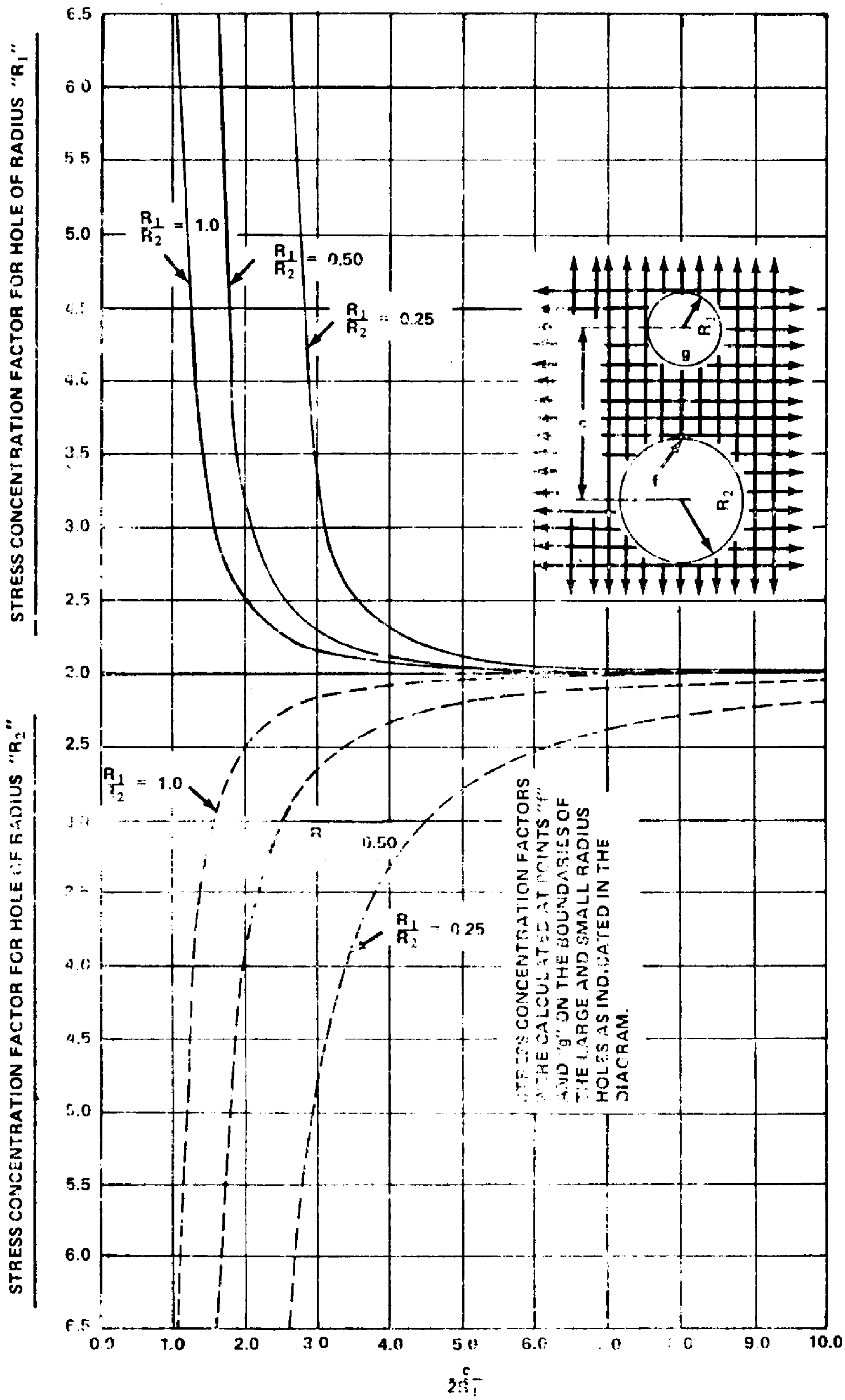



FIGURE B10-14. STRESS CONCENTRATION FACTORS FOR TWO UNEQUAL-SIZED HOLES IN BIAXIAL FIELD OF STRESS.

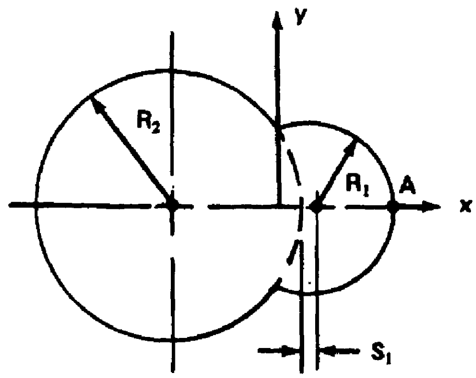



FIGURE B10-15. HOLE WITH CIRCULAR NOTCH.

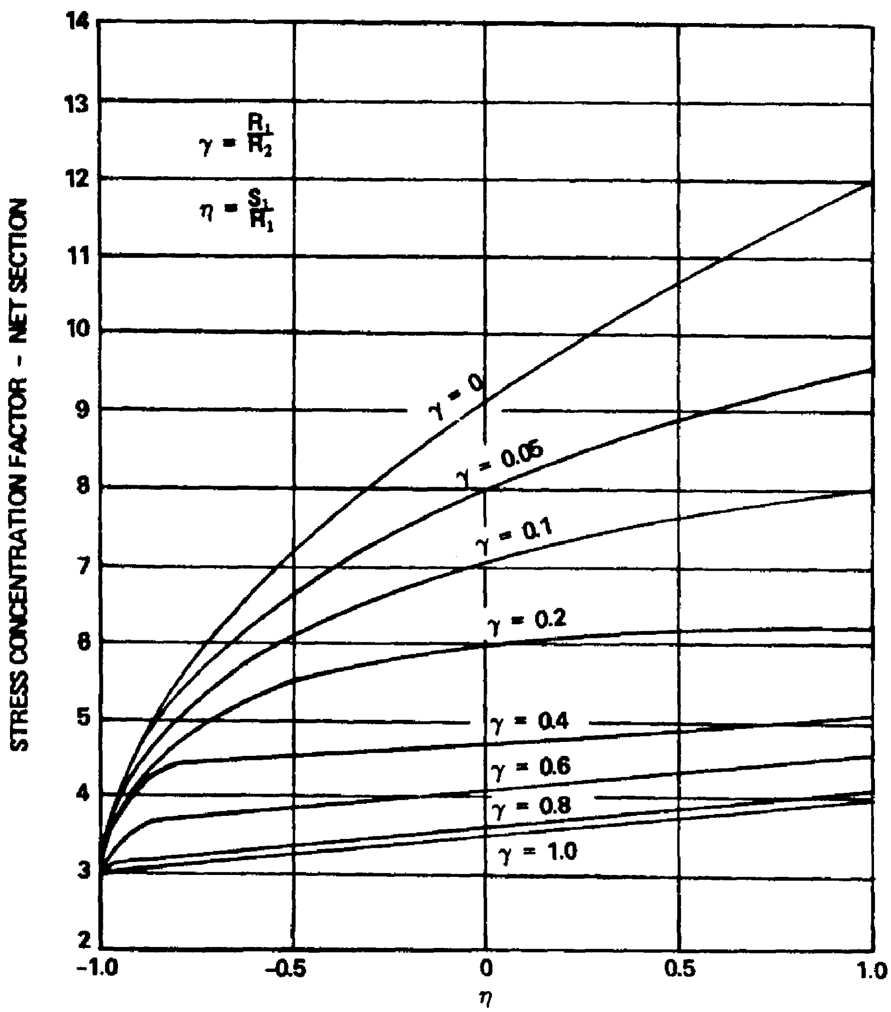



FIGURE B10-16. STRESS CONCENTRATION FACTOR AT POINT A UNDER TENSION IN Y-DIRECTION.

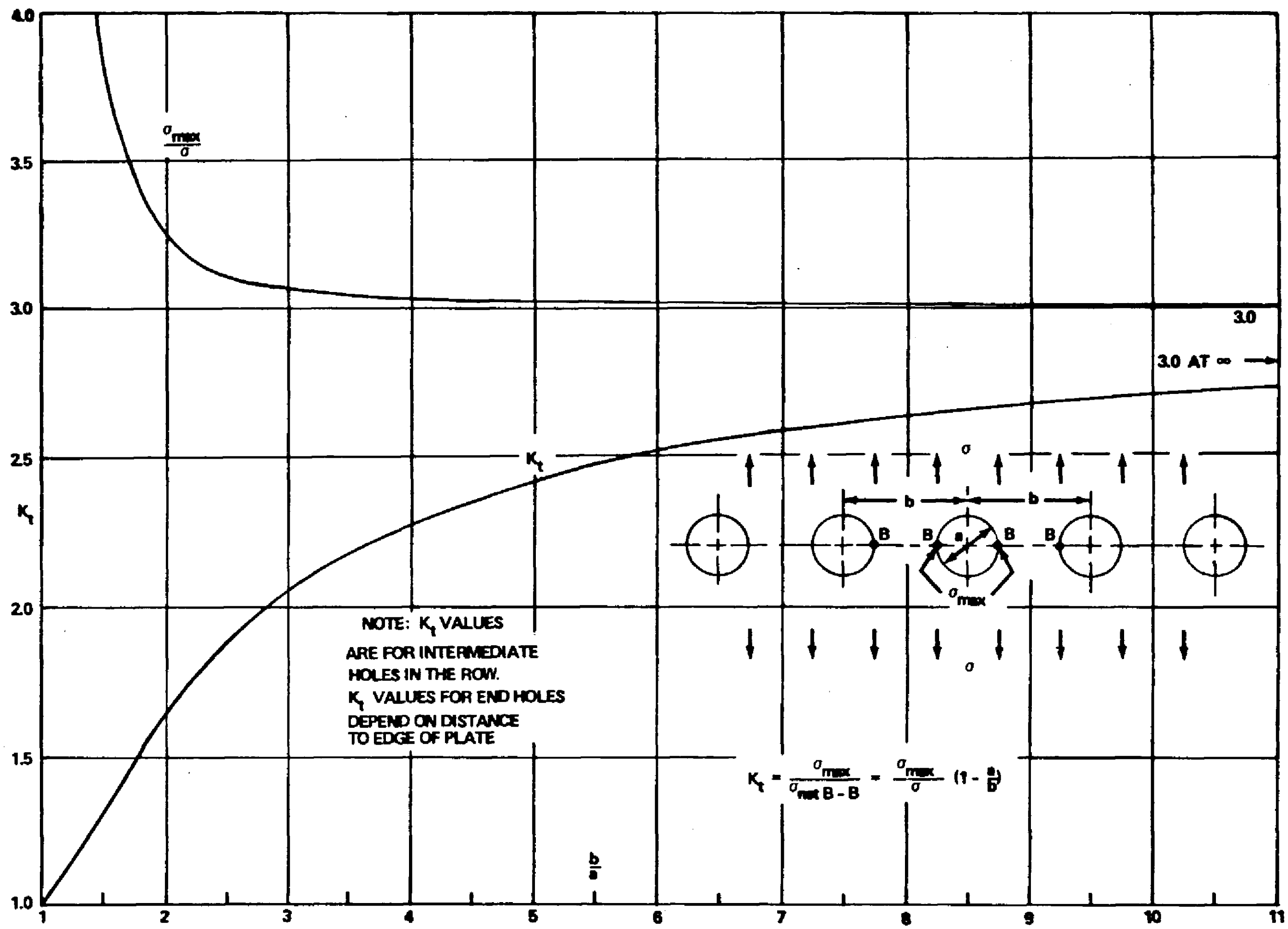



FIGURE B10-17. STRESS CONCENTRATION FACTOR, $K_t$, FOR TENSION CASE OF A SHEET WITH A SINGLE ROW OF HOLES. (TENSION PERPENDICULAR TO LINE OF HOLES.) $K_t$ BASED ON NET SECTION.

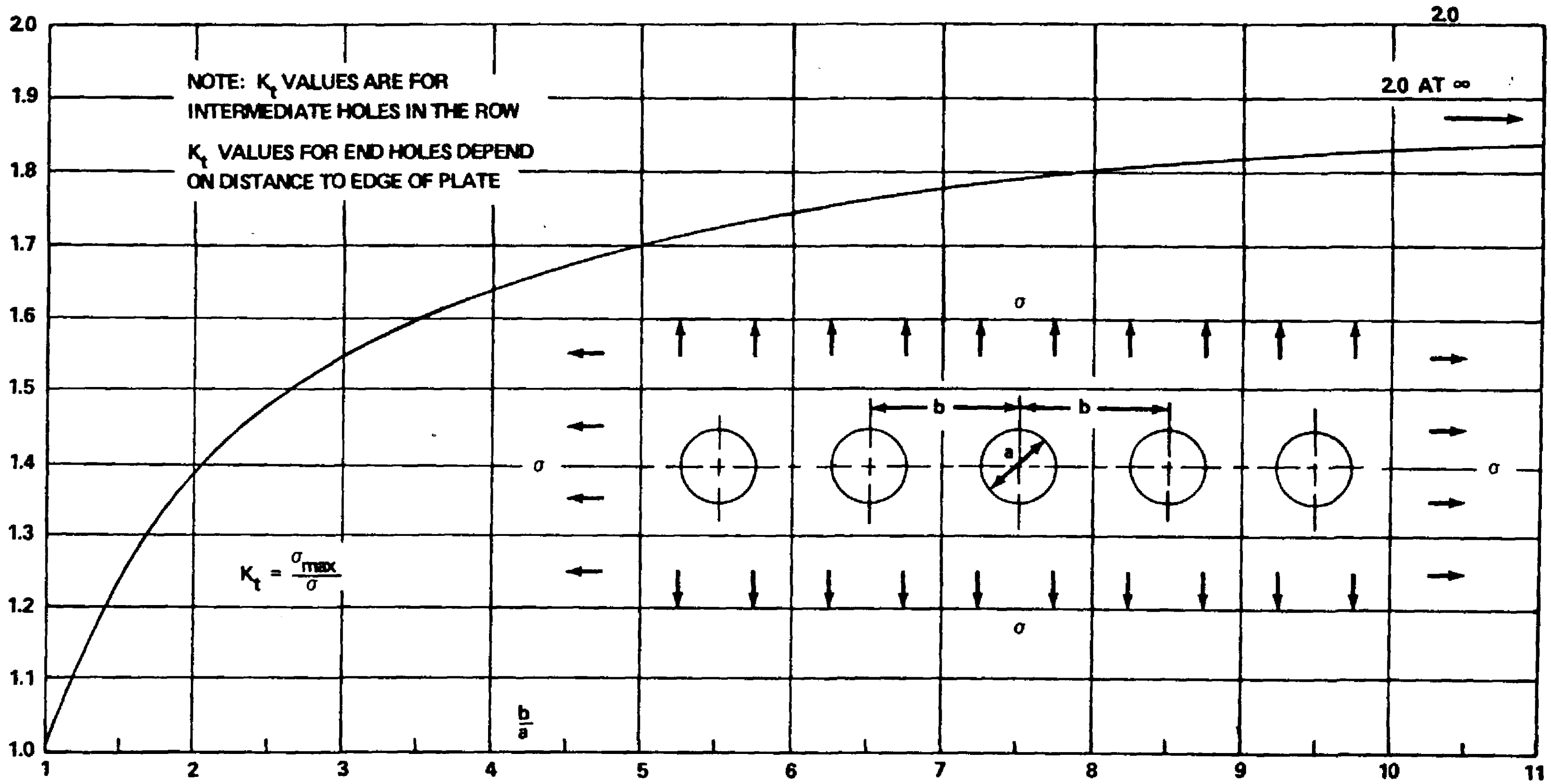



FIGURE B10-18. STRESS CONCENTRATION FACTOR, $K_t$, FOR A BIAXIALLY STRESSED INFINITELY WIDE PLATE CONTAINING A ROW OF HOLES.

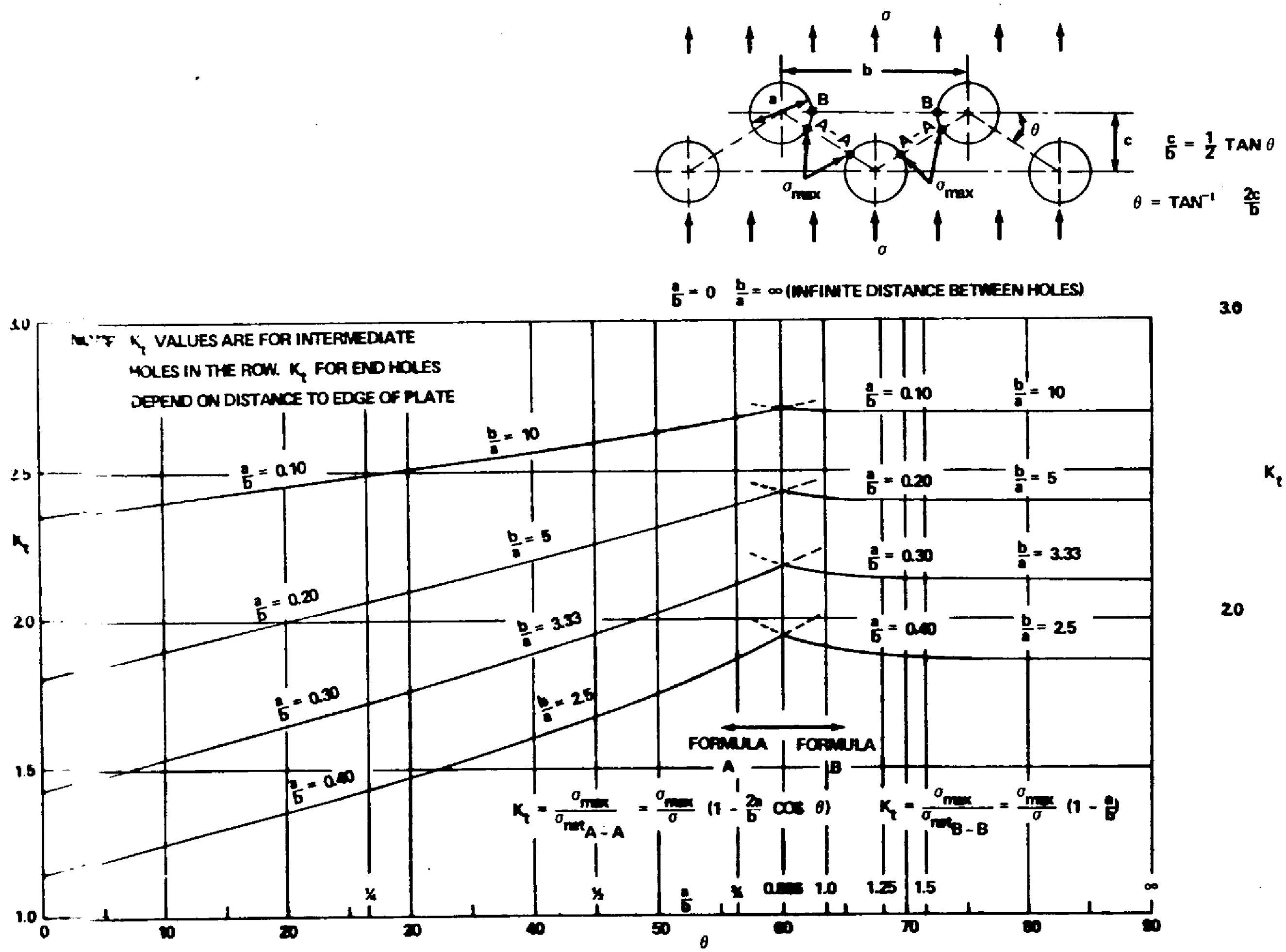



FIGURE B10-19. STRESS CONCENTRATION FACTOR, $K_t$, FOR TENSION CASE OF A SHEET WITH DOUBLE ROW OF HOLES. $K_t$ BASED ON MINIMUM NET SECTION.

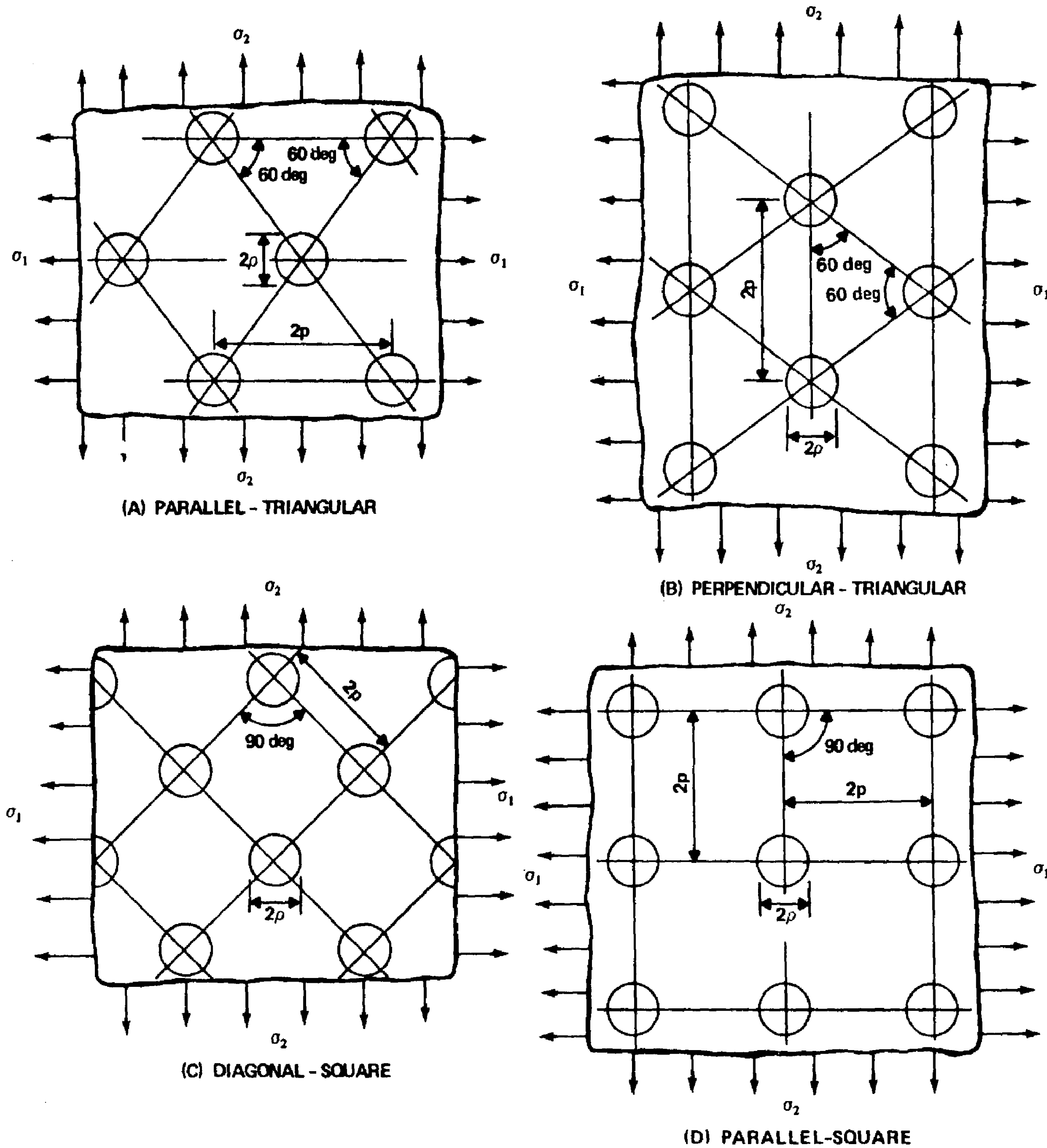



FIGURE B10-20. HOLE CONFIGURATIONS.

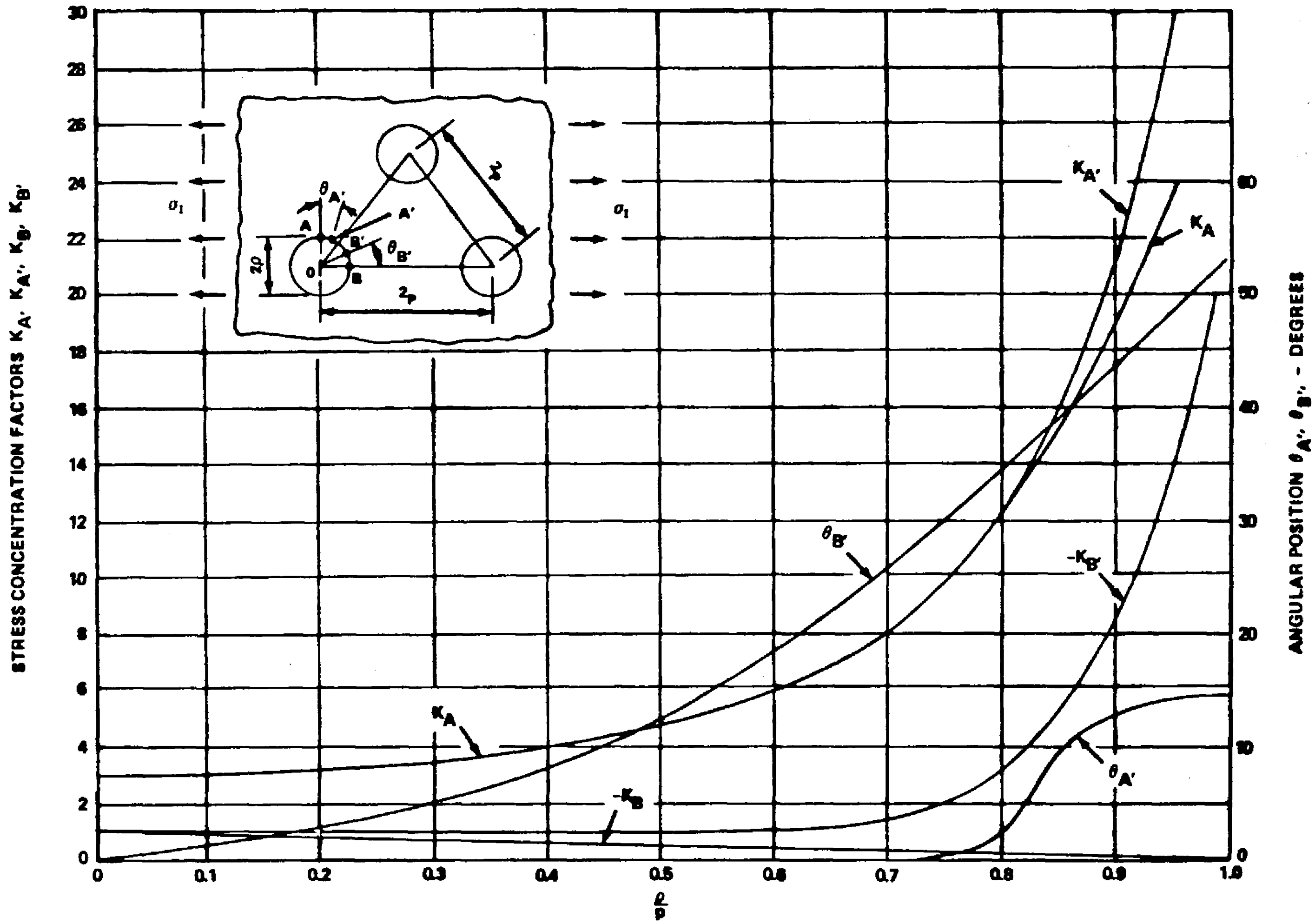



FIGURE B10-21. STRESS CONCENTRATION FACTORS FOR UNIAXIAL TENSION AND PARALLEL-TRIANGULAR HOLE CONFIGURATION.

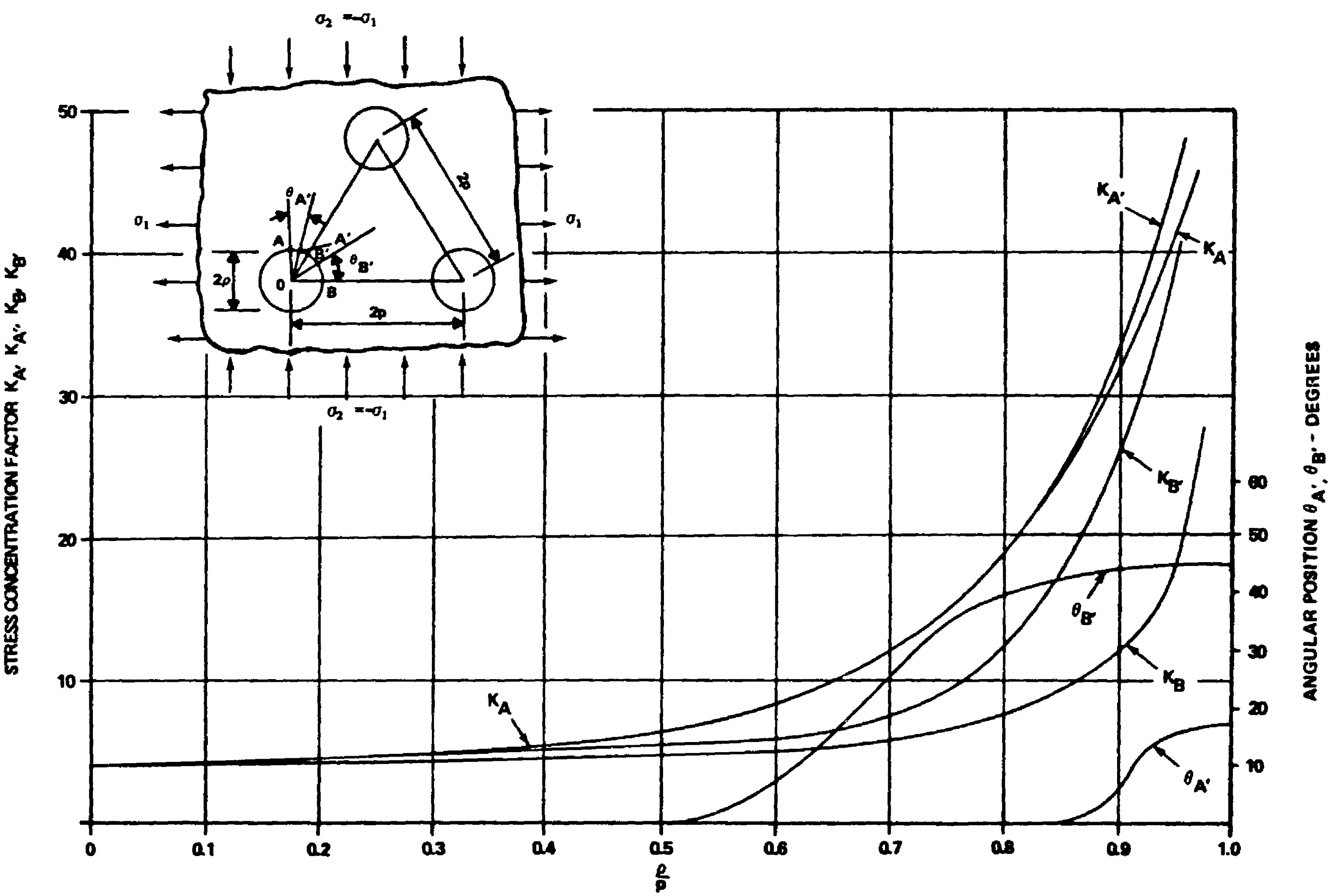



FIGURE B10-22. STRESS CONCENTRATION FACTORS FOR PURE SHEAR AND PARALLEL-TRIANGULAR HOLE CONFIGURATION.

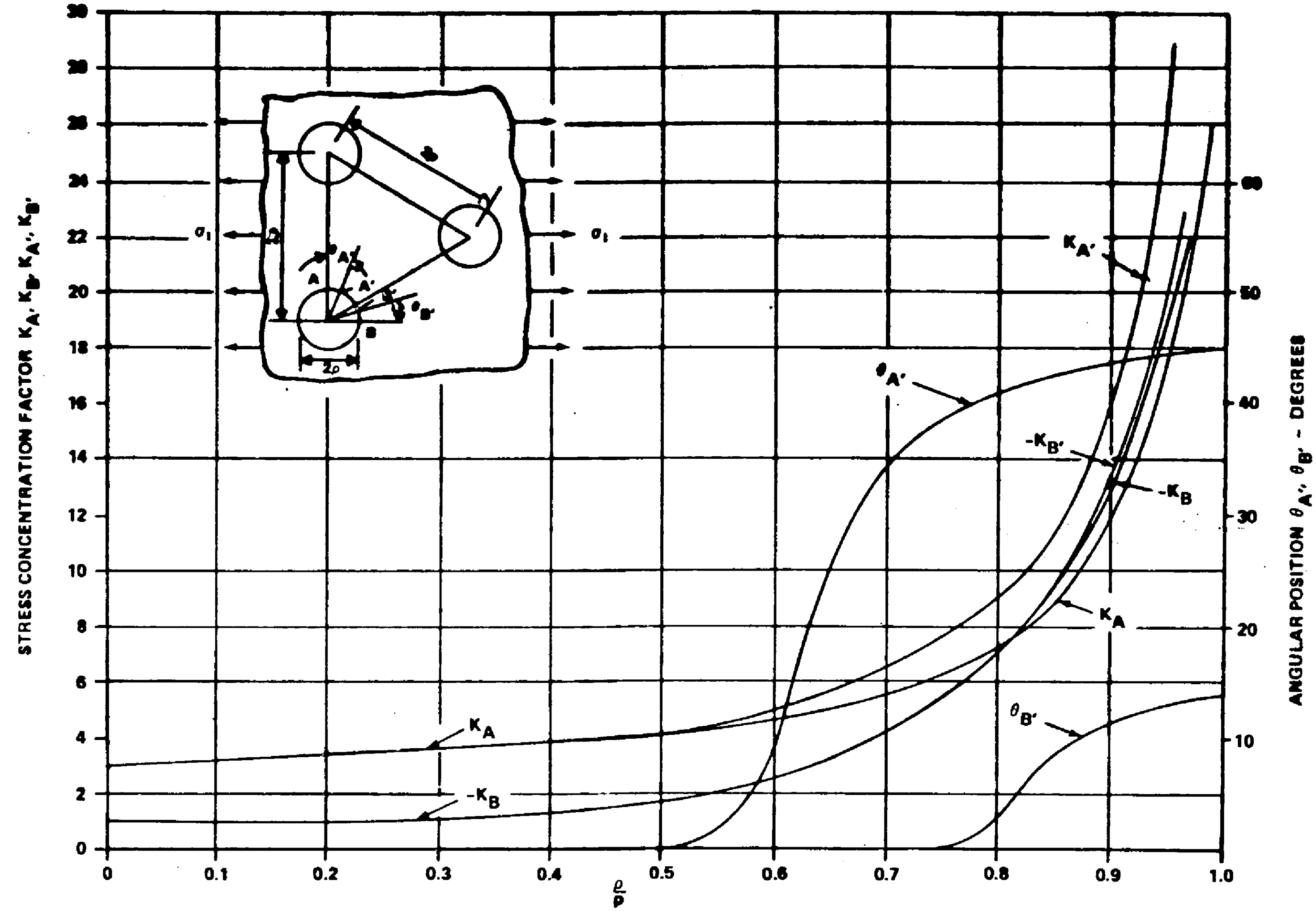



FIGURE B10-23. STRESS CONCENTRATION FACTORS FOR UNIAXIAL TENSION AND PERPENDICULAR-TRIANGULAR HOLE CONFIGURATION.

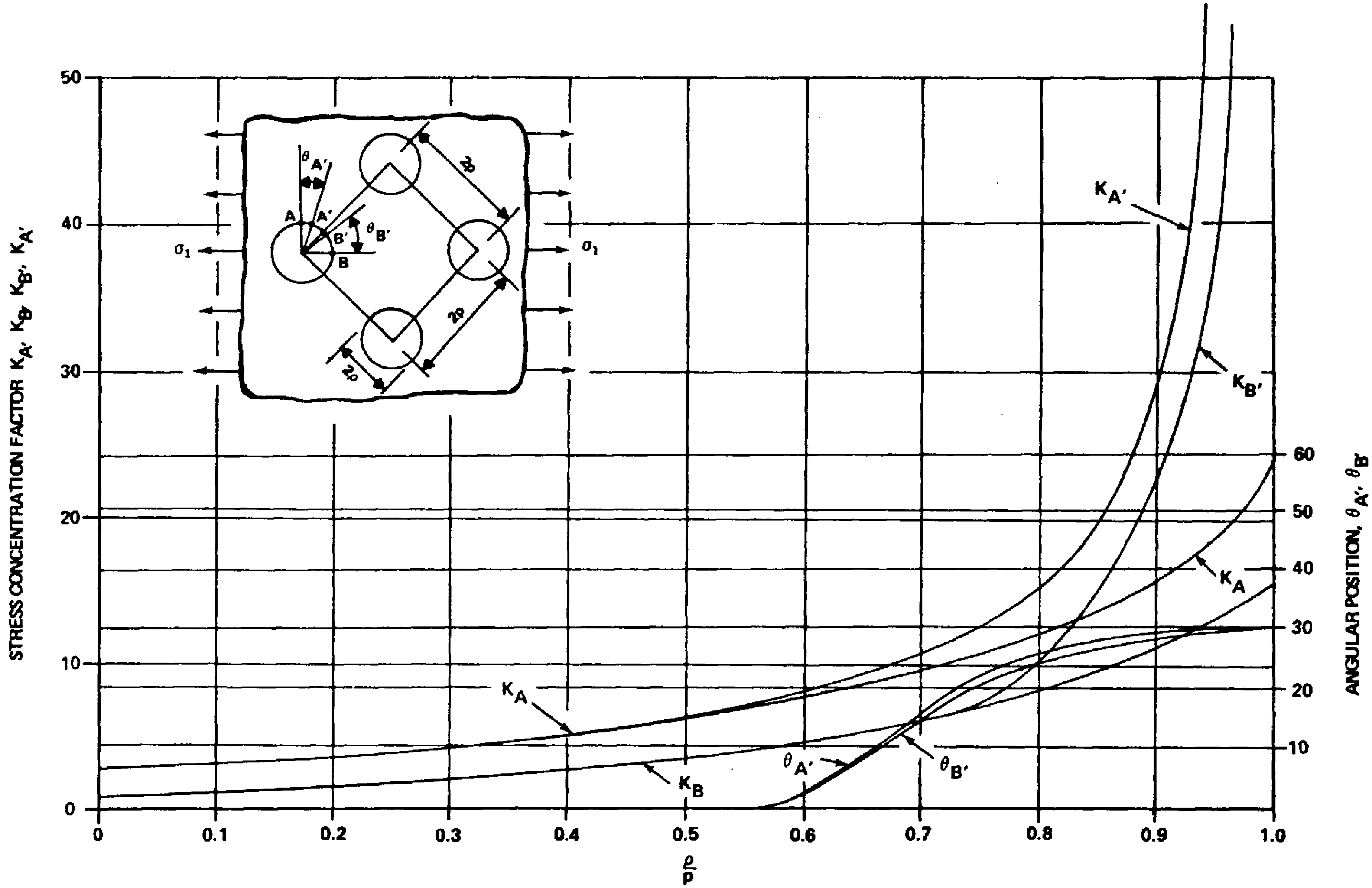



FIGURE B10-24. STRESS CONCENTRATION FACTORS FOR UNIAXIAL TENSION AND DIAGONAL-SQUARE HOLE CONFIGURATION.

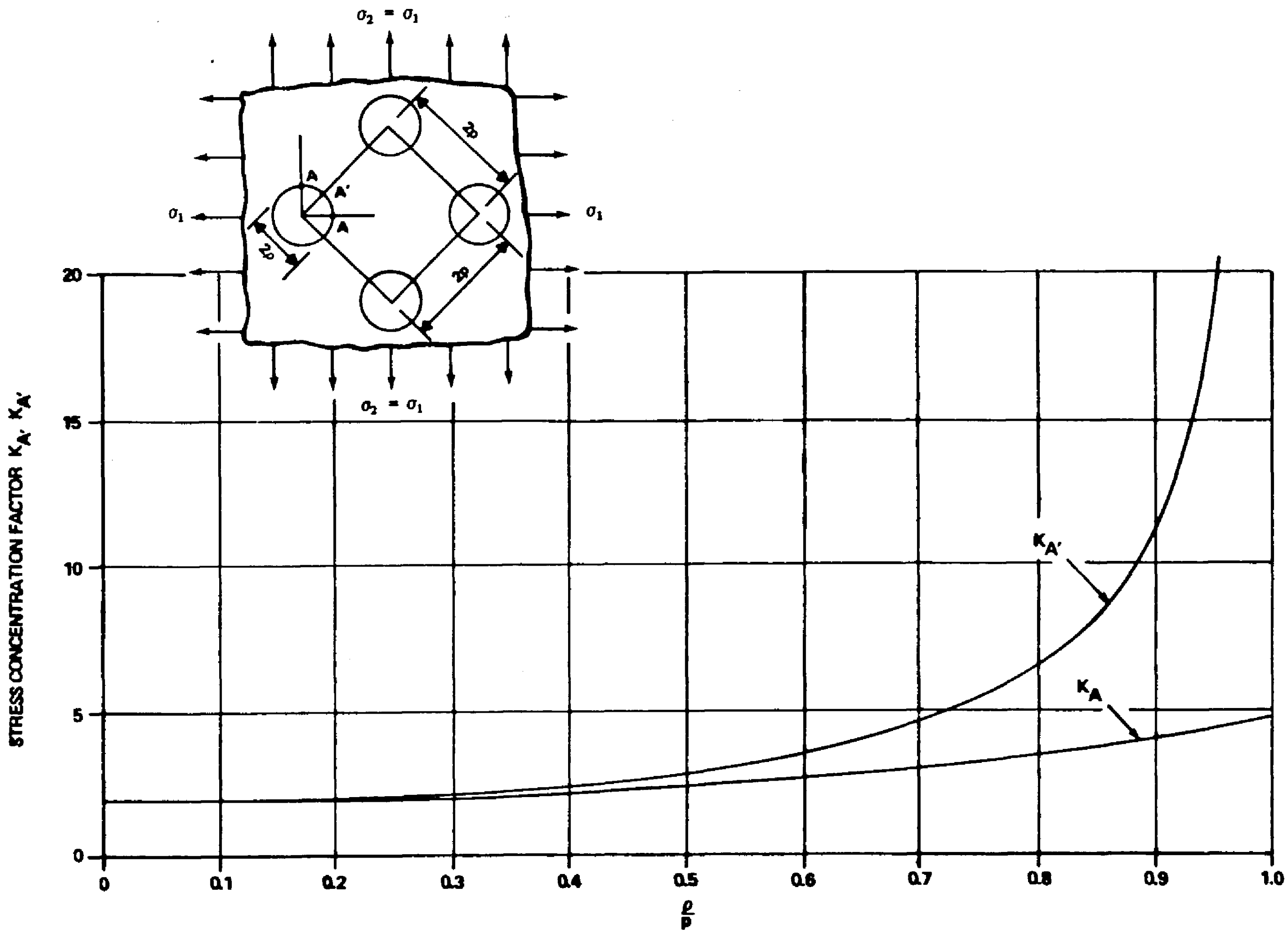



FIGURE B10-25. STRESS CONCENTRATION FACTORS FOR HYDROSTATIC TENSION FOR DIAGONAL-SQUARE HOLE CONFIGURATION.

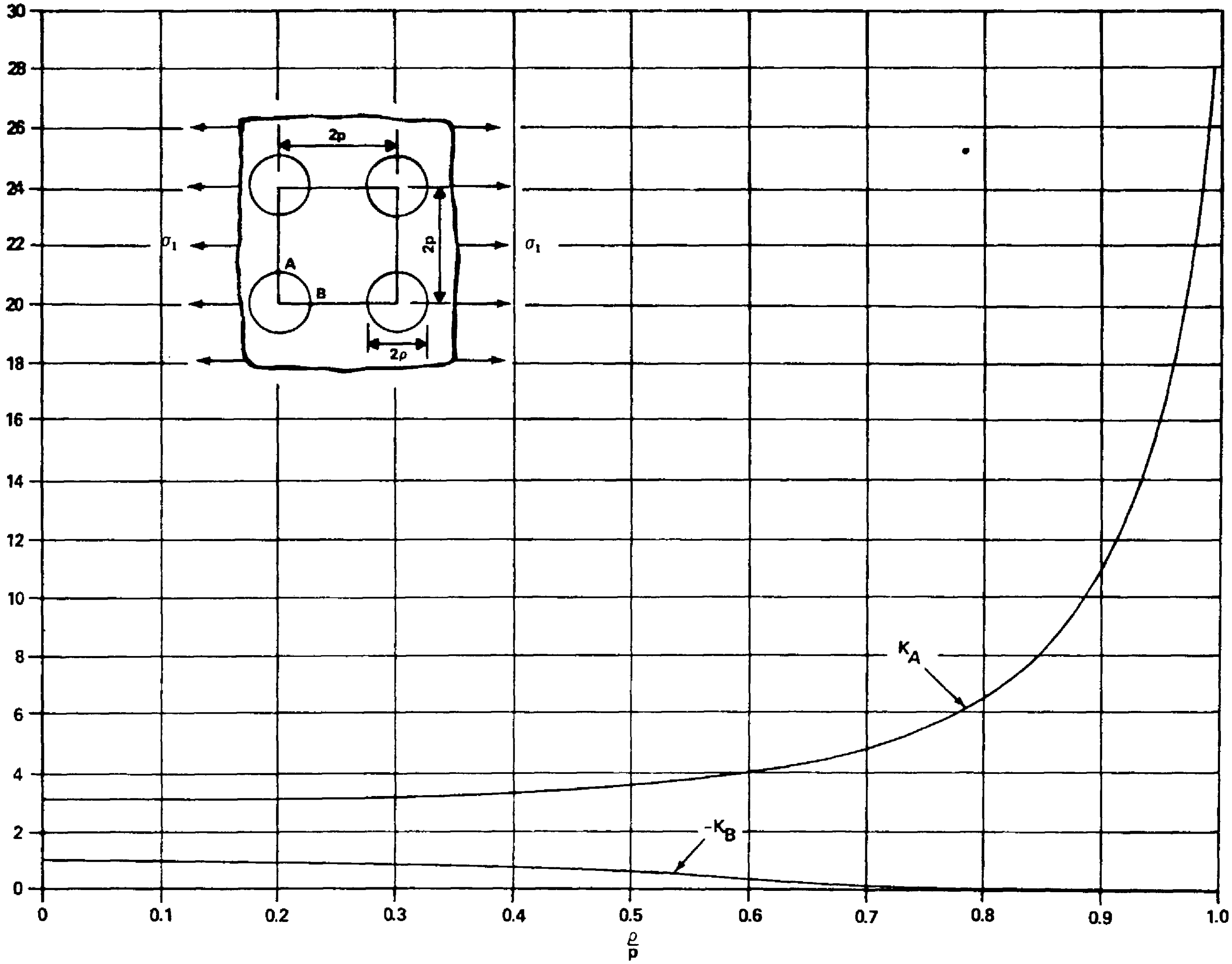



FIGURE B10-26. STRESS CONCENTRATION FACTORS FOR UNIAXIAL TENSION FOR PARALLEL-SQUARE HOLE CONFIGURATION.

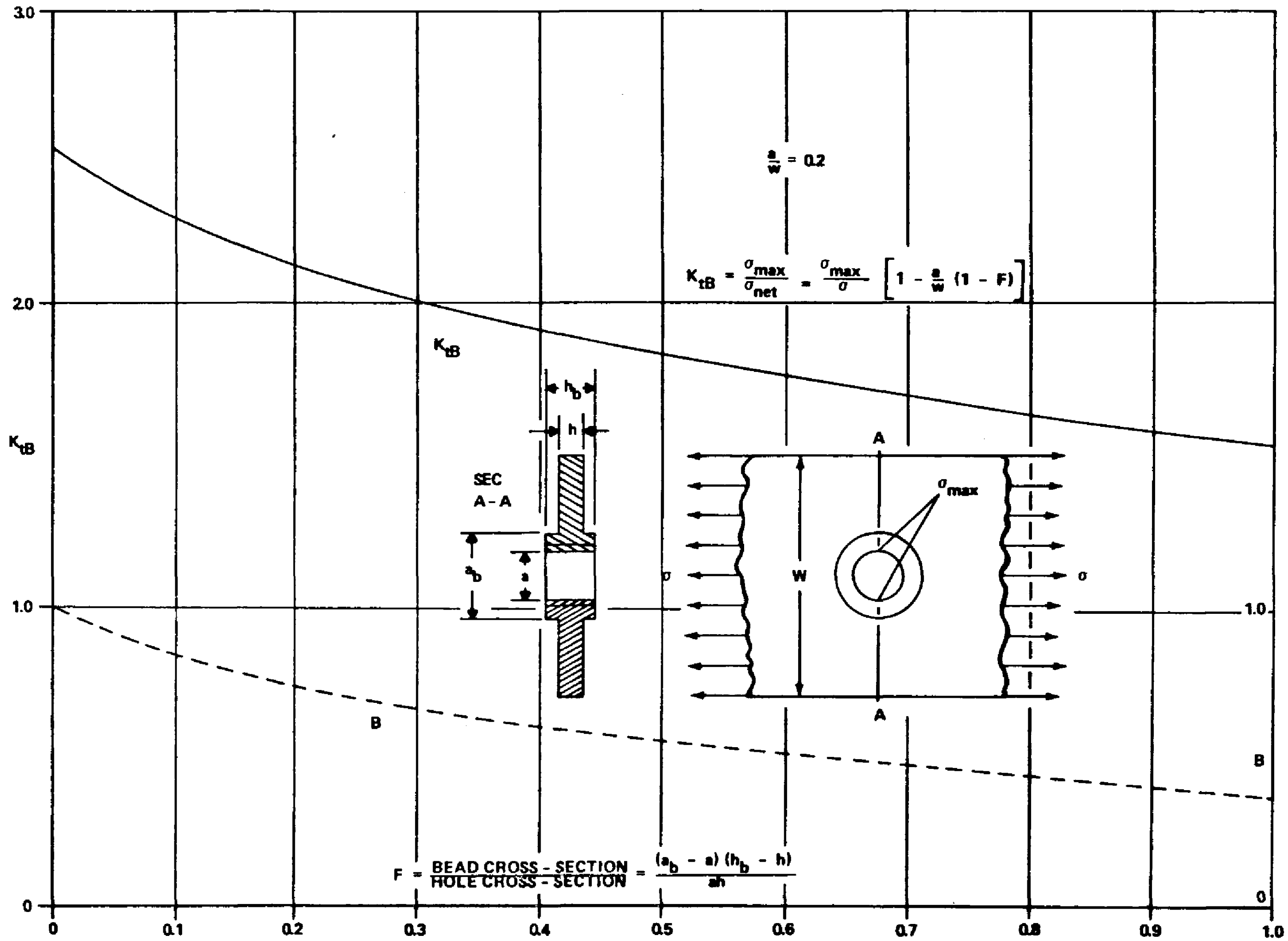



FIGURE B10-27. STRESS CONCENTRATION FACTOR, $K_{tB}$, FOR A TENSION PLATE WITH A BEADED HOLE.

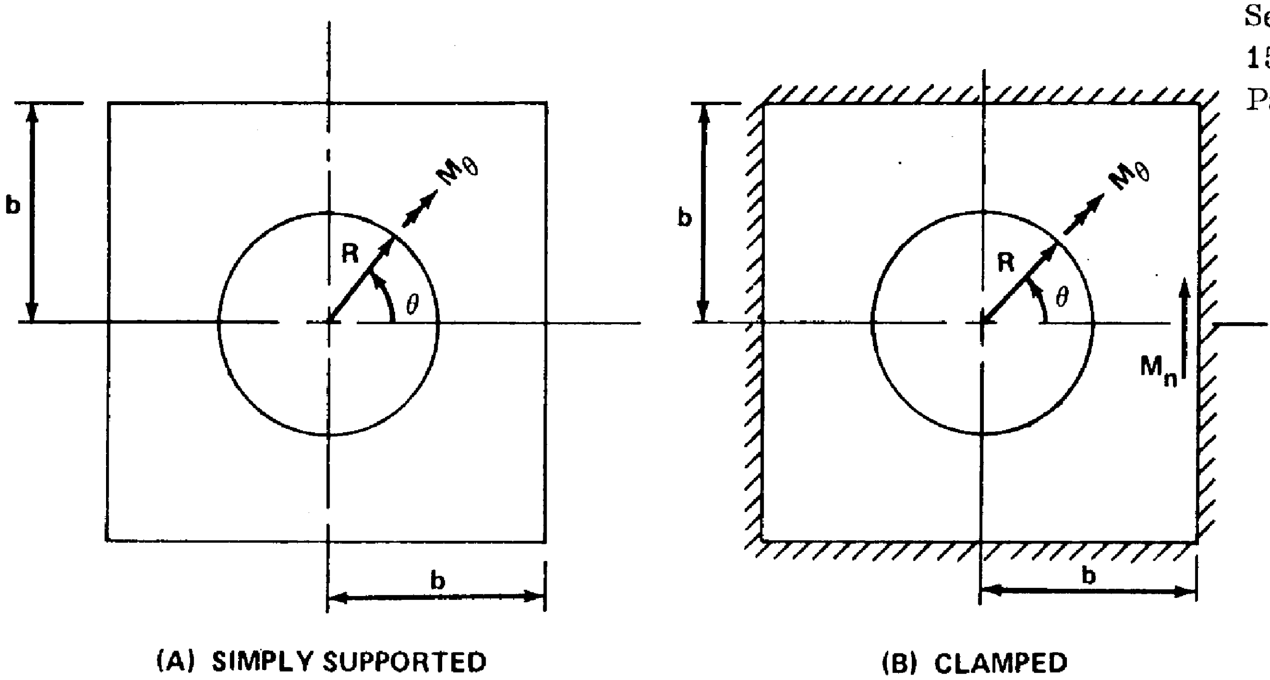



FIGURE B10-28. SQUARE PLATE WITH A CIRCULAR HOLE.

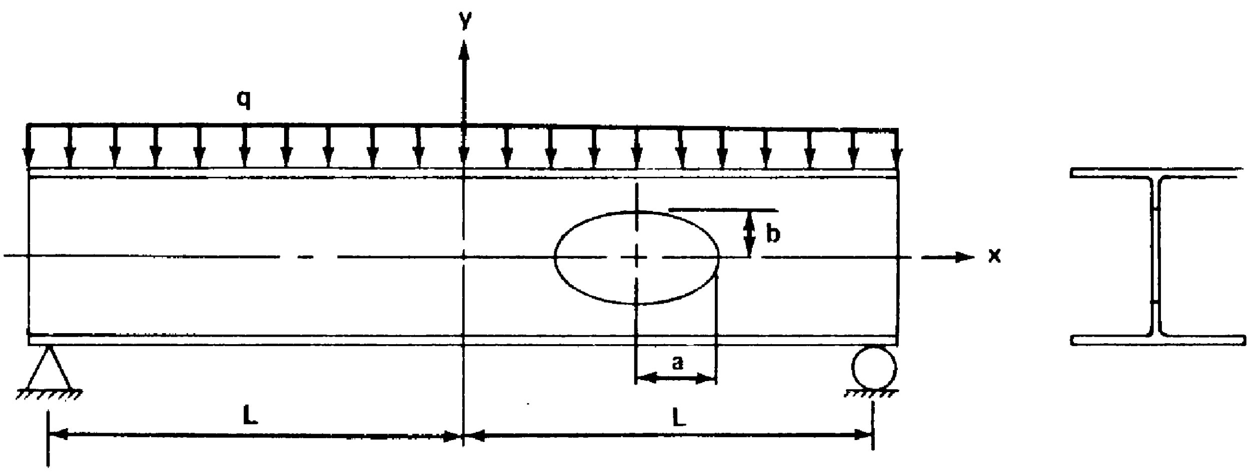



FIGURE B10-29. WIDE-FLANGE BEAM WITH A WEB HOLE.

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