HYDRAULIC DESIGN CRITERIA

SHEETS 311-1 TO 311-5

TAINTER GATES ON SPILLWAY CRESTS

DISCHARGE COEFFICIENTS

1. Discharge through a partially open tainter gate mounted on a spillway crest can be computed using the basic orifice equation:

$$Q = CA\sqrt{2gH}$$

where,

Q = discharge in cfs

C = discharge coefficient

A = area of orifice opening in ft^2

H = head to the center of the orifice in ft.

The coefficient (C) in the above equation is primarily dependent upon the characteristics of the flow lines approaching and leaving the orifice. In turn, these flow lines are dependent upon the shape of the crest, the radius of the gate, and the location of the trunnion.

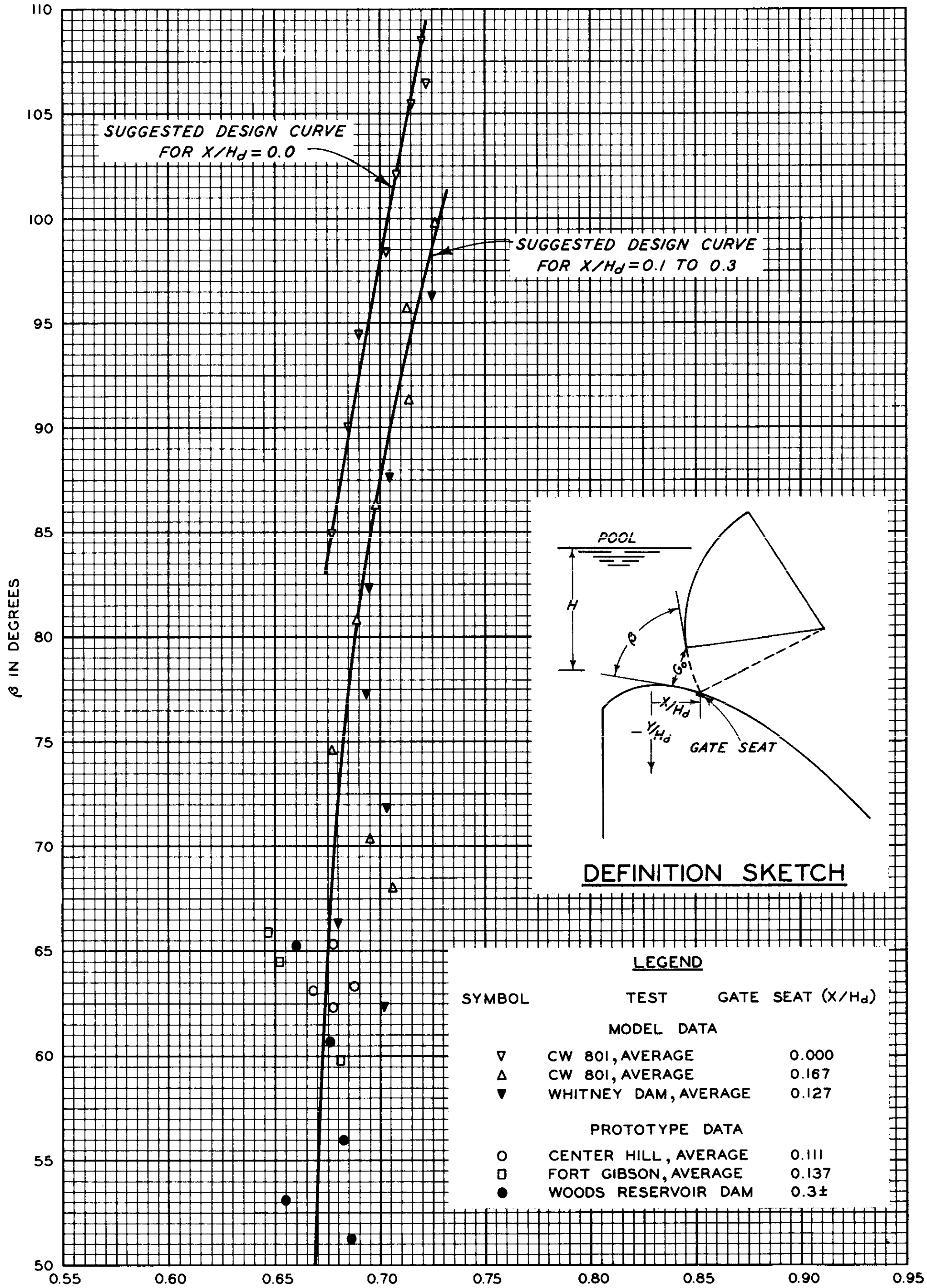
2. Discharge Coefficients. Chart 311-1 shows a plot of average discharge coefficients computed from model and prototype data for several crest shapes and tainter gate designs for nonsubmerged flow. Data shown are based principally on tests with three or more bays in operation. Discharge coefficients for a single bay would be lower because of side contractions although data are not presently available to evaluate this factor. On this chart, the discharge coefficient (C) is plotted as a function of the angle (β) formed by the tangent to the gate lip and the tangent to the crest curve at the nearest point of the crest curve. The net gate opening is considered to be the shortest distance from the gate lip to the crest curve. The angle is a function of the major geometric factors affecting the flow lines of the orifice discharge. One suggested design curve applies to tainter gates having gate seats located downstream from the crest axis. The other suggested design curve is based on tests with the gate seat located on the axis and indicates the effects of the masonry shape upstream from the crest axis.

3. Computation. Computation of discharge through a tainter gate mounted on a spillway crest is considerably complicated by the geometry involved in determining the net gate opening to be used in the orifice formula. The problem is simplified by fitting circular arcs to the crest

curve used in the design of spillways. Chart 311-2 illustrates the necessary computations to obtain the net gate opening and the angle β described in paragraph 2, for tainter gates mounted on spillway crests shaped to $X^{1.85} = -2\ H_d^{0.85}Y$. All factors are expressed in terms of the design head (H_d). The method shown is applicable to other crest shapes. However, the accompanying design aids, Charts 311-3 and 311-4, apply only to standard crests.

4. To initiate the computations, Y_L/H_d values of the gate lip are assumed and corresponding values of X_L/H_d are computed (columns 1 to 6, Chart 311-2). These coordinates are then located on Chart 311-3 to determine the characteristics of a substitute arc. The substitute arc is then used to compute the net gate opening (columns 7 to 14). The point of intersection of the masonry line by the gate opening is determined by similar triangles (columns 14, 15, and 16). Design aid Chart 311-4 can be used to determine the Y_c/H_d coordinate of the gate opening and masonry line intersection (column 17), and also the slope of the masonry line (columns 18 and 19) which in turn combines with the slope of the gate lip tangent to form the angle β (column 20). If graphical methods are preferred to analytical methods, a large-scale layout will enable the head, net gate opening, and the angle β to be scaled so that the discharge can be computed with fair accuracy.

5. Chart 311-5 is a sample computation of the steps involved in the development of a rating curve for a partially open tainter gate. The final computations are dimensional and are believed accurate to within ± 2 per cent, for gate opening-head ratios (G_o/H) less than 0.6.



FORMULA

$$Q = CG_oB\sqrt{2gH}$$

WHERE:

G_o = NET GATE OPENING
B = GATE WIDTH
H = HEAD TO CENTER OF GATE OPENING

TAINTER GATES ON SPILLWAY CRESTS

DISCHARGE COEFFICIENTS

HYDRAULIC DESIGN CHART 311-1

WES 3-56

COMPUTATION SHEET

GATE OPENINGS AND ANGLE β

JOB CW804 PROJECT JOHN DOE DAM
SUBJECT SPILLWAY DISCHARGE
COMPUTED BY AAM^{c} DATE 8-24-54
CHECKED BY HAB DATE 8-26-54

GIVEN

DESIGN HEAD (H_d) = 37.0 FT.
RADIUS OF GATE (R_G) = 0.831 H_d.
TRUNNION COORDINATES (X_T, Y_T).
$X_T = 0.907 H_d$, $Y_T = 0.324 H_d$.

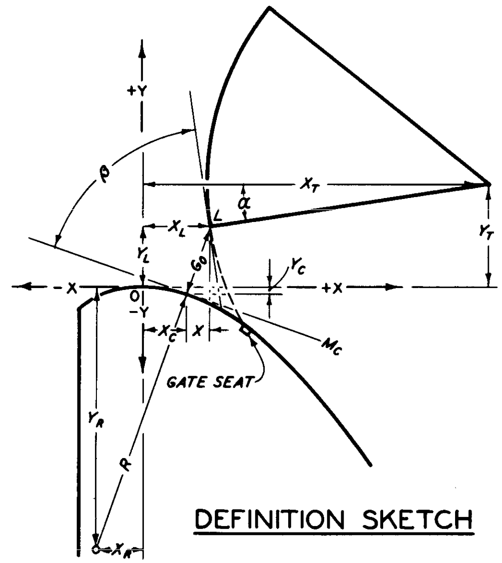
DEFINITIONS

GATE LIP COORDINATES (X_L, Y_L).
SPILLWAY CREST COORDINATES (X_C, Y_C).
SLOPE OF TANGENT TO CREST (M_C), NEGATIVE WHEN DOWNSTREAM FROM CREST.
SHORTEST DISTANCE FROM GATE LIP TO CREST (G_0).

DEFINITIONS (CONT)

α IS THE ANGLE BETWEEN A LINE CONNECTING THE GATE LIP AND THE TRUNNION CENTER, AND A HORIZONTAL LINE THROUGH THE TRUNNION, CONSIDERED POSITIVE AND NEGATIVE WHEN THE GATE LIP IS ABOVE AND BELOW THE TRUNNION, RESPECTIVELY.

NOTE: ALL DIMENSIONS USED IN COMPUTATIONS ARE IN TERMS OF DESIGN HEAD (H_d).



DEFINITION SKETCH

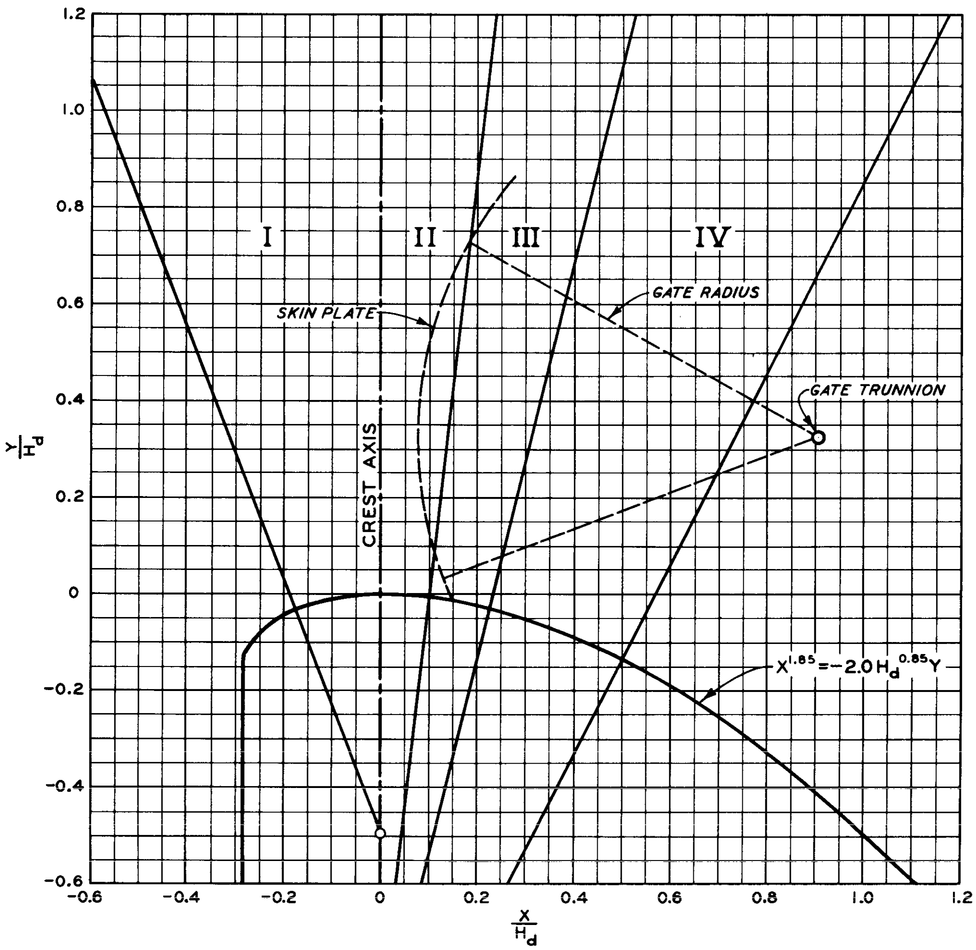
(1) Y_L	(2) Y_T-Y_L	(3) SIN α (2) ÷ R_G	(4) α DEGREES	(5) R_G COS α 0.831 COS α	(6) X_L X_T−(5)	(7) FROM CHART 311-3 CLASS	(8) FROM CHART 311-3 X_R	(9) FROM CHART 311-3 Y_R	(10) FROM CHART 311-3 R	(11) X_L-X_R (6)−(8)	(12) Y_L-Y_R (1)−(9)	(13) $R+G_0$ $[(11)^2+(12)^2]^{1/2}$	(14) G_0 (13)−(10)	(15) X $\frac{(11)\times(14)}{(13)}$	(16) X_C (6)−(15)	(17) FROM CHART 311-4 Y_C	(18) FROM CHART 311-4 M_C	(19) $TAN^{-1} M_C$ DEGREES	(20) β $90°+TAN^{-1}M_C+\alpha$ 90°+(19)+(4) DEGREES
0.100	0.224	0.270	-15.67	0.800	0.107	II	-0.050	-1.329	1.330	0.157	1.429	1.437	0.107	0.012	0.095	-0.0065	-0.125	-7.13	67.20
0.200	0.124	0.149	-8.57	0.821	0.086	II	-0.050	-1.329	1.330	0.136	1.529	1.535	0.205	0.018	0.068	-0.0035	-0.094	-5.35	76.06
0.300	0.024	0.029	-1.66	0.830	0.077	II	-0.050	-1.329	1.330	0.127	1.629	1.634	0.304	0.024	0.053	-0.0022	-0.076	-4.36	83.98
0.400	-0.076	-0.091	+5.22	0.829	0.078	II	-0.050	-1.329	1.330	0.128	1.729	1.733	0.403	0.030	0.048	-0.0018	-0.070	-4.02	91.20

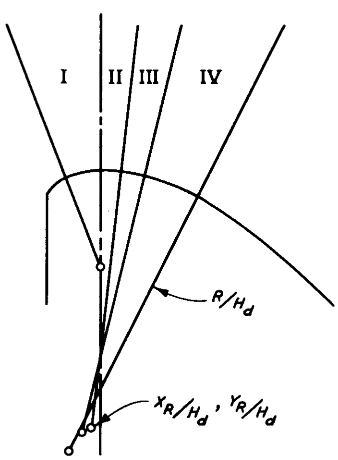
TAINTER GATES ON SPILLWAY CRESTS

SAMPLE GEOMETRIC COMPUTATION

HYDRAULIC DESIGN CHART 311-2

WES 3-56





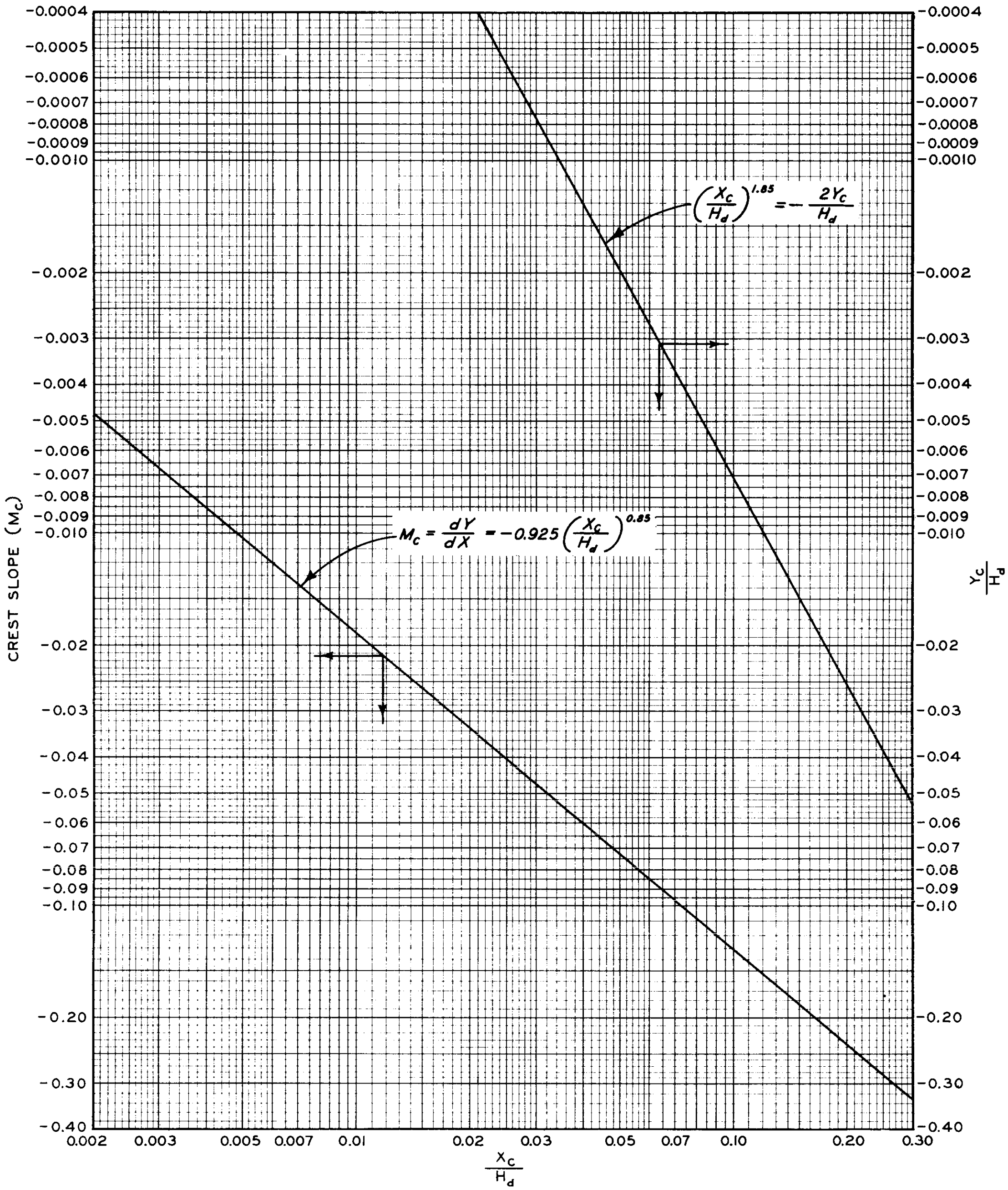
DEFINITION SKETCH

CLASS	R/H_d	X_R/H_d	Y_R/H_d
I	0.500	0.000	-0.500
II	1.330	-0.050	-1.329
III	1.359	-0.100	-1.351
IV	1.472	-0.164	-1.452

TAINTER GATES ON SPILLWAY CRESTS

GEOMETRIC FACTORS

HYDRAULIC DESIGN CHART 311-3



TAINTER GATES ON SPILLWAY CRESTS

CREST COORDINATES AND SLOPE FUNCTION

HYDRAULIC DESIGN CHART 311-4

WES 3-56

WATERWAYS EXPERIMENT STATION

COMPUTATION SHEET

JOB CW804 PROJECT JOHN DOE DAM SUBJECT SPILLWAY DISCHARGE

COMPUTATIONS COORDINATES FOR RATING CURVE (POOL VS DISCHARGE FOR VARIOUS GATE OPENINGS)

COMPUTED BY AAMc DATE 8-25-54 CHECKED BY RRW DATE 8-27-54

GIVEN

DESIGN HEAD (H_d) = 37.0 FT
GATE WIDTH (B) = 42.0 FT
CREST ELEV = 288.0 FT

FORMULAS

$Q = CG_0B\sqrt{2gH}$

$H = \text{POOL ELEV} - 0.5\left[\text{ELEV } Y_L + \text{ELEV } Y_C\right]$

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
β * DEGREES	C**	G_0/H_d *	G_0 FT	Y_L/H_d *	Y_L FT	Y_C/H_d *	Y_C FT	ELEV Y_L = 288 + Y_L FT	ELEV Y_C = 288 + Y_C FT	$\frac{(9)+(10)}{2}$	POOL FT	H (12) − (11) FT	$H^{1/2}$	Q CFS
67.20	0.676	0.107	3.96	0.100	3.70	-0.0065	-0.24	291.70	287.76	289.73	300 315 325	10.27 25.27 35.27	3.20 5.03 5.94	2,900 4,500 5,400
76.06	0.683	0.205	7.59	0.200	7.40	-0.0035	-0.13	295.40	287.87	291.64	310 315 325	18.36 23.36 33.36	4.28 4.83 5.78	7,500 8,400 10,100
83.98	0.694	0.304	11.25	0.300	11.10	-0.0022	-0.08	299.10	287.92	293.51	310 315 325	16.49 21.49 31.49	4.06 4.64 5.61	10,700 12,200 14,800
91.20	0.707	0.403	14.91	0.400	14.80	-0.0018	-0.07	302.80	287.93	295.37	315 320 325	19.63 24.63 29.63	4.43 4.96 5.44	15,800 17,600 19,300

* FROM HYDRAULIC DESIGN CHART 311-2
** FROM HYDRAULIC DESIGN CHART 311-1

TAINTER GATES ON SPILLWAY CRESTS
SAMPLE DISCHARGE COMPUTATIONS

HYDRAULIC DESIGN CHART 311-5