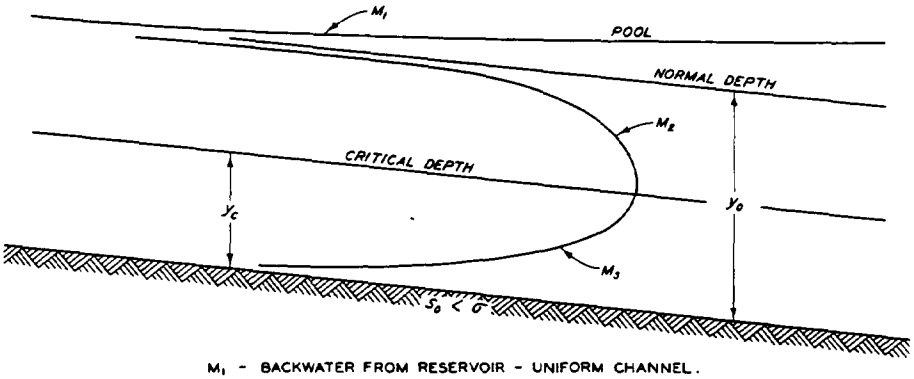
APPENDIX C

PLATES

Plate No.	Title	Paragraphs in Which Plate Is Mentioned
C-1	Open-Channel Flow Classifications	2-3,4-16
C-2	Pressure Flow Definition Sketch	2-6,2-9,3-7
C-3	Exit Portal Pressure	2-7,5-2d(2),Table D-4, F-3e(1)
C-4	Resistance Coefficients, Concrete Conduits	2-12a,c,d,e,g,g(1)(b), g(1)(c),g(2)(b),5-2c, Table D-4
C-5	Hydraulic Elements, Conduit Sections	2-12f,4-2c
C-6	Flow Characteristics, Horseshoe Conduits	2-12f
C-7	Resistance Coefficient, Corrugated Metal Pipe	2-12g(3)
C-8	Head Loss Coefficients, Abrupt Transitions	2-13b,c
C-9	Loss Coefficients, Conical Transitions	2-13d
C-10	Bend Loss Coefficients, Circular Conduits	2-13e(2)(a)
C-11	Loss Coefficients, Circular Conduits, Multiple Miter Bends	2-13e(2)(a)
C-12	Loss Coefficients, Rectangular Conduits, 90° Circular Bends	2-13e(2)(b)
C-13	Relative Loss Coefficients, Rectangular Conduits, Circular Bends	2-13e(2)(b)
C-14	Loss Coefficients, Rectangular Conduits, Triple Bend	2-13e(2)(b)
C-15	Examples of Cavitation Hydraulics	2-14
C-16	Air Demand, Primary and Secondary Maxima	2-19
C-17	Air Demand	2-19

Plate No.	Title	Paragraphs in Which Plate Is Mentioned
C-18	Sluice Location, Monolith Center Line	3-1,3-3a
C-19	Typical Off-Monolith Center Line Sluice Location	3-1
C-20	Conduits, Circular Bends, Minimum Pressure	3-3b
C-21	Sluice Intakes	3-4,4-21
C-22	Pressure Drop Coefficients, Sluice Entrances	3-6c,4-12,4-21
C-23	Vertical-Lift Gate, Gate Slot Details	3-9a,3-13,3-17f,4-15, 4-16
C-24	Discharge Coefficients, Conduit Tainter Gates, Free Flow	3-9b
C-25	Discharge Coefficients, Fixed-Cone Valves	3-10d
C-26	Pressure Coefficients, Gate Slot	3-13
C-27	Incipient Cavitation Coefficients for Slots	3-13
C-28	Sluice Exit Portal, Roof Constrictions	3-19
C-29	Exit Portal Deflector, Allegheny Dam Model	3-19
C-30	Sluice Exit Portal, Sidewall Flare with Roof Constriction, Red Rock Dam Model	3-19
C-31	Sluice Eyebrow Deflector, Folsom Dam Model	3-20
C-32	Intake Loss Coefficients, All Gates Fully Open	4-3a,4-21,D-8,Table D-4
C-33	Intake Loss Coefficients, All or Fewer Gates Open	4-3a,4-21
C-34	Concrete Conduits, Intake Losses, Drop Inlets	4-3a
C-35	Vortex Formation	4-3c

Plate No.	Title	Paragraphs in Which Plate Is Mentioned
C-36	Types of Conduit Gates	4-9,4-14
C-37	Pressure Drop Coefficients, Entrance with Roof Curve Only	4-12,4-21
C-38	Conduit Entrances with Roof Curve and Side Flare	4-13,4-21
C-39	Discharge Coefficients, Vertical-Lift Gate	4-16
C-40	Definition Sketch, Low-Level Outlets	5-2b
C-41	Stilling Basin Layout, Single Outlet	5-2d(1),5-2h,5-2i
* C-41A	Stilling Basin Trajectory Modification to Reduce Low Flow Eddies	5-2d(3) *
C-42	Outlet Channel	5-2k,5-6
C-43	Preformed Scour Hole	5-4
C-44	Water Quality Intake Types	6-1
C-45	Water Quality Outlet, Concrete Gravity Dam, Rowlesburg Dam	6-2b(4),6-4a
C-46	Water Quality Outlet, Earth Dam, Beltzville	6-2b(4),6-4b
C-47	Intake Structure, Multilevel Detail, Taylorsville Dam	6-2b(4),6-4b
C-48	Intake Structure, Multilevel Detail, New Hope Dam	6-2b(4),6-4b
C-49	Temperature Control Weirs	6-2b(5)
C-50	Multiple Penstock Intake Structure, Dickey Dam	6-4a
C-51	Cylindrical Gate Intake Tower, DeGray Dam	6-4b
C-52	Water Quality Intake, Earth Dam, Beech Fork	6-4b



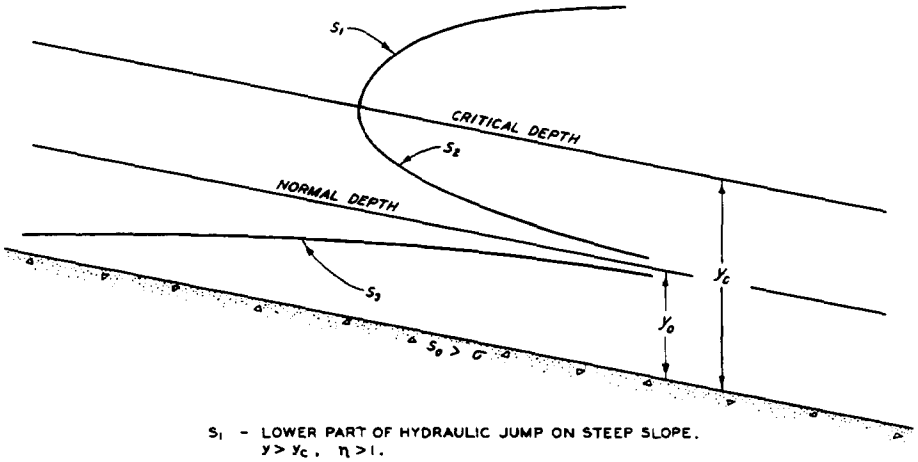
M_1 - BACKWATER FROM RESERVOIR - UNIFORM CHANNEL.
$y > y_0$, $\eta > 1$.

M_2 - DRAWDOWN TO SPILLWAY WITH SHALLOW APPROACH.
$y_0 > y > y_c$, $\eta < 1$.

M_3 - FLOW UNDER GATE ON MILD SLOPE.
$y < y_c$, $\eta < 1$.

MILD SLOPE

$y_0 > y_c$



S_1 - LOWER PART OF HYDRAULIC JUMP ON STEEP SLOPE.
$y > y_c$, $\eta > 1$.

S_2 - CHUTE FLOW FROM LOW OGEE CREST.
$y_c > y > y_0$, $\eta > 1$.

S_3 - CHUTE FLOW FROM HIGH OGEE CREST. FLOW UNDER GATE ON STEEP SLOPE.
$y < y_0$, $\eta < 1$.

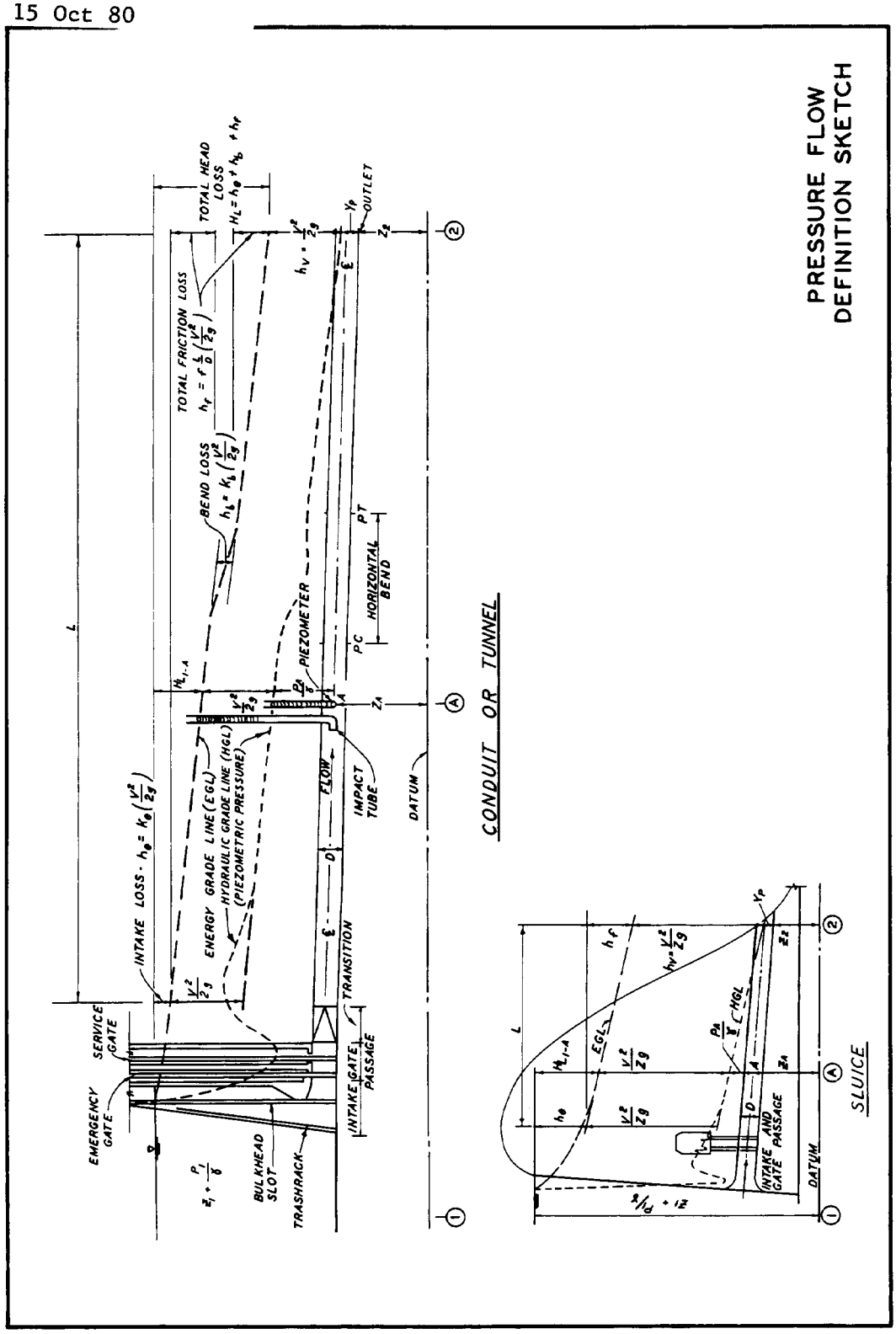
STEEP SLOPE

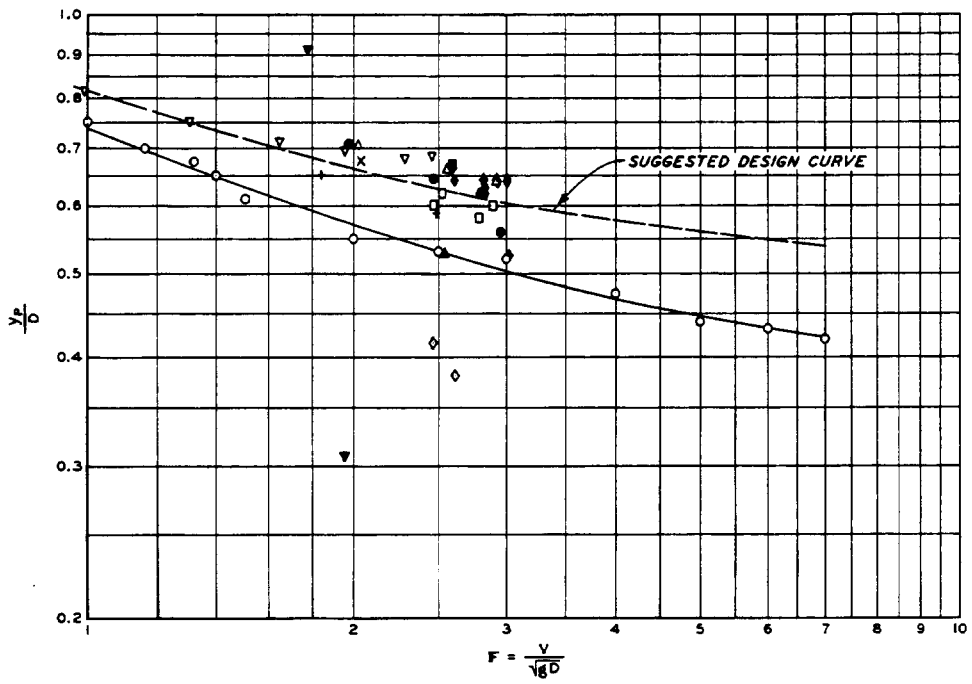
$y_0 < y_c$

$$\eta = \frac{y}{y_0}$$

OPEN-CHANNEL FLOW
CLASSIFICATIONS

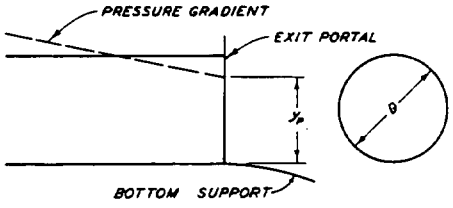
FROM HDC 010-1


PRESSURE FLOW
DEFINITION SKETCH
CONDUIT OR TUNNEL
SLUICE
TOTAL HEAD LOSS
$H_L = h_e + h_b + h_f$
TOTAL FRICTION LOSS
$h_f = f \frac{L}{D} \left(\frac{V^2}{2g}\right)$
BEND LOSS
$h_b = K_b \left(\frac{V^2}{2g}\right)$
INTAKE LOSS - $h_e = K_e \left(\frac{V^2}{2g}\right)$
ENERGY GRADE LINE (EGL)
HYDRAULIC GRADE LINE (HGL)
(PIEZOMETRIC PRESSURE)
PIEZOMETER
IMPACT TUBE
FLOW
DATUM
OUTLET
HORIZONTAL BEND
PC
PT
TRANSITION
INTAKE GATE PASSAGE
SERVICE GATE
EMERGENCY GATE
BULKHEAD SLOT
TRASHRACK
$z_1 + \frac{P_1}{\gamma}$
$h_v = \frac{V^2}{2g}$
h_{L1-A}
$\frac{V^2}{2g}$
$\frac{P_A}{\gamma}$
z_A
z_2
y_p
L
D
A
EGL
HGL
h_e
h_f
$h_v = \frac{V^2}{2g}$
INTAKE AND GATE PASSAGE
$z_1 + \frac{P_1}{\gamma}$



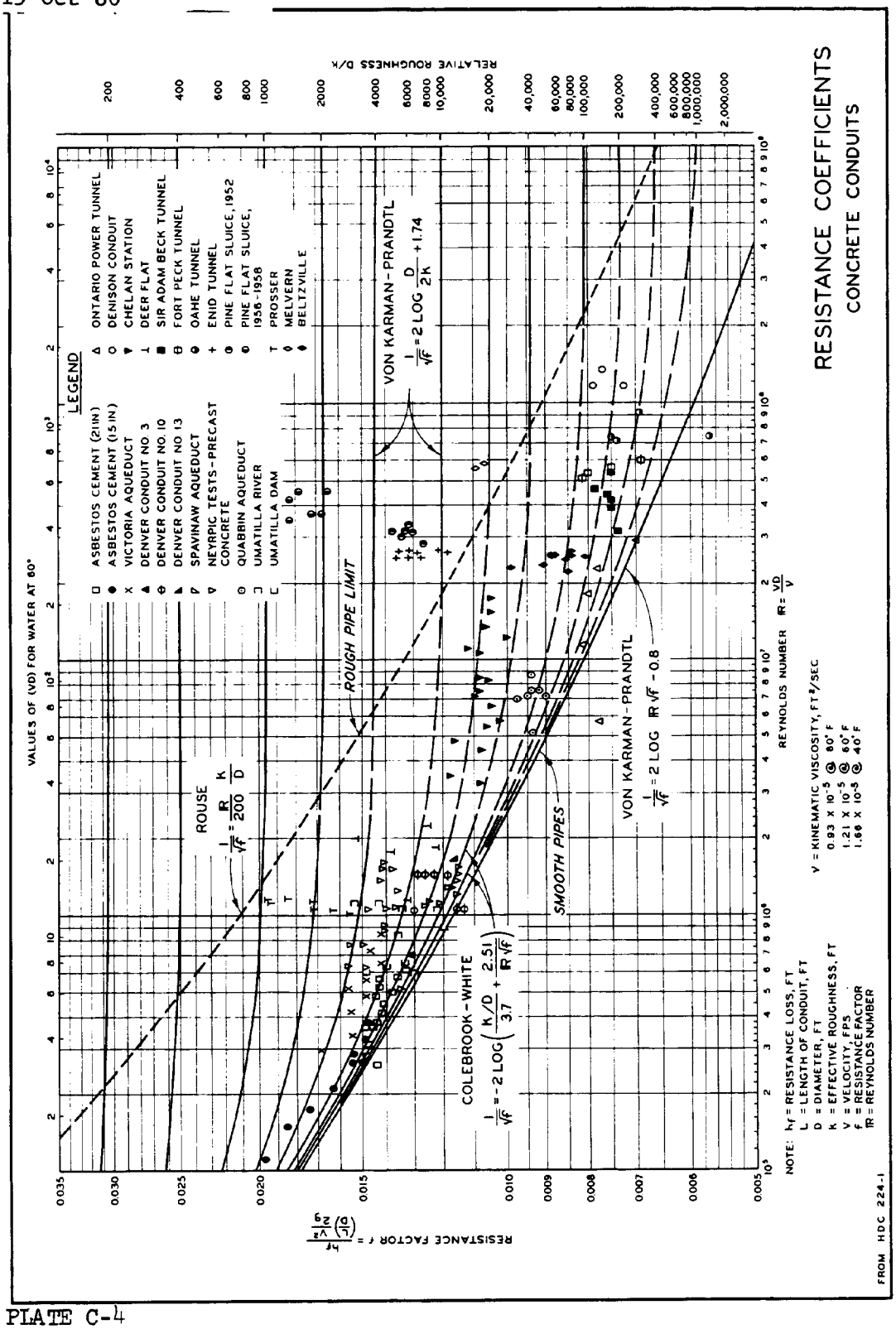
LEGEND

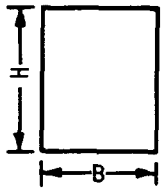
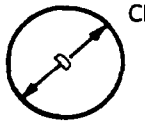
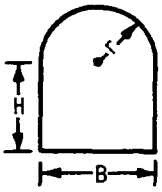
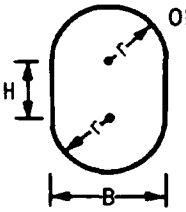
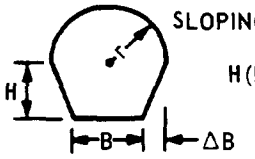
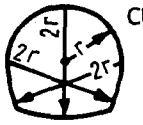
SYMBOL	DATA SOURCE	BOTTOM SUPPORT	CONDUIT SHAPE
—o—	STATE UNIVERSITY OF IOWA	NONE	CIRCULAR
□	DENISON MODEL	LEVEL	CIRCULAR
■	DENISON PROTOTYPE	LEVEL	CIRCULAR
●	GARRISON MODEL	PARABOLIC	CIRCULAR
▽	YOUGHIOGHENY MODEL	1 ON 20	CIRCULAR
X	ENID PROTOTYPE	PARABOLIC	CIRCULAR
△	FORT RANDALL MODEL	LEVEL	CIRCULAR
▲	FORT RANDALL PROTOTYPE	LEVEL	CIRCULAR
+	OAHE PROTOTYPE	PARABOLIC	CIRCULAR
♦	BELTZVILLE	PARABOLIC	CIRCULAR
▼	TUTTLE CREEK PROTOTYPE	PARABOLIC	HORSESHOE
◇	MELVERN PROTOTYPE	PARABOLIC	HORSESHOE



EXIT PORTAL PRESSURE

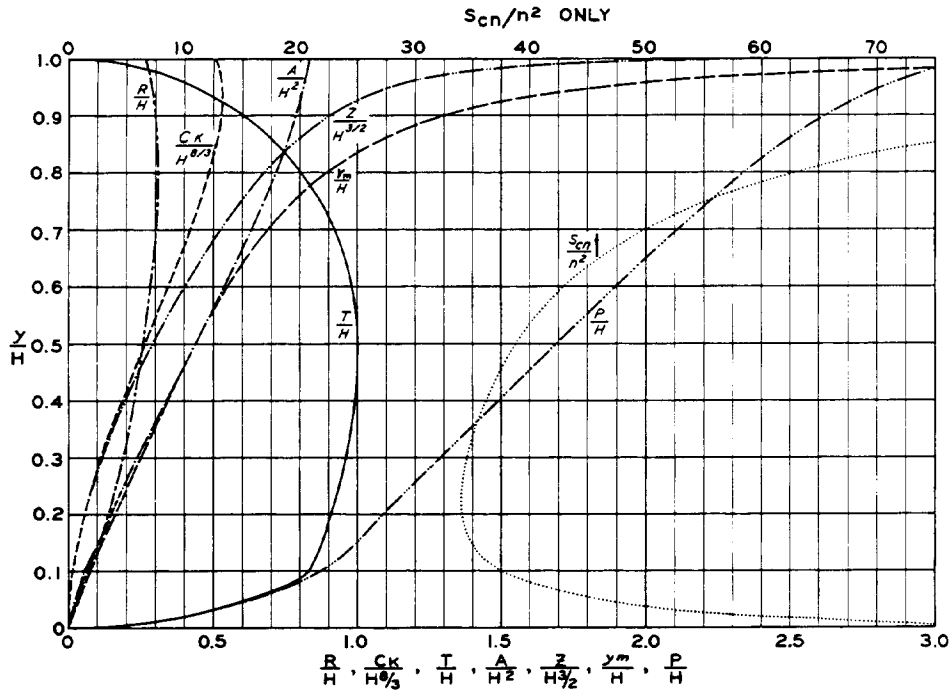
FROM HDC 225-1


RESISTANCE COEFFICIENTS
CONCRETE CONDUITS
LEGEND
ASBESTOS CEMENT (21 IN)
ASBESTOS CEMENT (15 IN)
VICTORIA AQUEDUCT
DENVER CONDUIT NO 3
DENVER CONDUIT NO. 10
DENVER CONDUIT NO 13
SPAVINAW AQUEDUCT
NEYRPIC TESTS-PRECAST CONCRETE
QUABBIN AQUEDUCT
UMATILLA RIVER
UMATILLA DAM
ONTARIO POWER TUNNEL
DENISON CONDUIT
CHELAN STATION
DEER FLAT
SIR ADAM BECK TUNNEL
FORT PECK TUNNEL
OAHE TUNNEL
ENID TUNNEL
PINE FLAT SLUICE, 1952
PINE FLAT SLUICE, 1956-1958
PROSSER
MELVERN
BELTZVILLE
VALUES OF (VD) FOR WATER AT 60°
RELATIVE ROUGHNESS D/k
REYNOLDS NUMBER R = VD/ν
RESISTANCE FACTOR f = hf/(L/D)(V²/2g)
ROUGH PIPE LIMIT
SMOOTH PIPES
ROUSE
1/√f = R/200 k/D
VON KARMAN-PRANDTL
1/√f = 2 LOG D/2k + 1.74
VON KARMAN-PRANDTL
1/√f = 2 LOG R√f - 0.8
COLEBROOK-WHITE
1/√f = -2 LOG (k/D / 3.7 + 2.51 / R√f)
NOTE: hf = RESISTANCE LOSS, FT
L = LENGTH OF CONDUIT, FT
D = DIAMETER, FT
k = EFFECTIVE ROUGHNESS, FT
V = VELOCITY, FPS
f = RESISTANCE FACTOR
R = REYNOLDS NUMBER
ν = KINEMATIC VISCOSITY, FT²/SEC
0.93 X 10⁻⁵ @ 80° F
1.21 X 10⁻⁵ @ 60° F
1.66 X 10⁻⁵ @ 40° F
FROM HDC 224-1

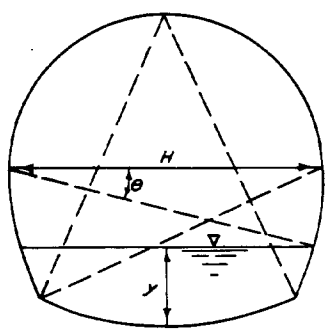
SECTION	AREA (A)	WETTED PERIMETER (P)	HYDRAULIC RADIUS (R)
 RECTANGULAR SHAPE	BH	$2(B+H)$	$\frac{BH}{2(B+H)}$
 CIRCULAR SHAPE	$\frac{\pi D^2}{4}$	πD	$\frac{D}{4}$
 VERTICAL-SIDE HORSESHOE SHAPE	$BH + \frac{\pi r^2}{2}$	$B + 2H + \pi r$	$\frac{BH + \frac{\pi r^2}{2}}{B + 2H + \pi r}$
 OBLONG SHAPE	$BH + \pi r^2$	$2(H + \pi r)$	$\frac{BH + \pi r^2}{2(H + \pi r)}$
 SLOPING-SIDE HORSESHOE SHAPE	$H(B + \Delta B) + \frac{\pi r^2}{2}$	$B + 2(H^2 + (\Delta B)^2)^{1/2} + \pi r$	$\frac{H(B + \Delta B) + \frac{\pi r^2}{2}}{B + 2(H^2 + (\Delta B)^2)^{1/2} + \pi r}$
 CURVED-SIDE HORSESHOE SHAPE (USBR)	$3.3172\ r^2$	$6.5338\ r$	$0.5077\ r$

HYDRAULIC ELEMENTS
CONDUIT SECTIONS

FROM HDC 224-2



a. FLOW CHARACTERISTICS OF USBR STANDARD HORSESHOE TUNNEL SECTION



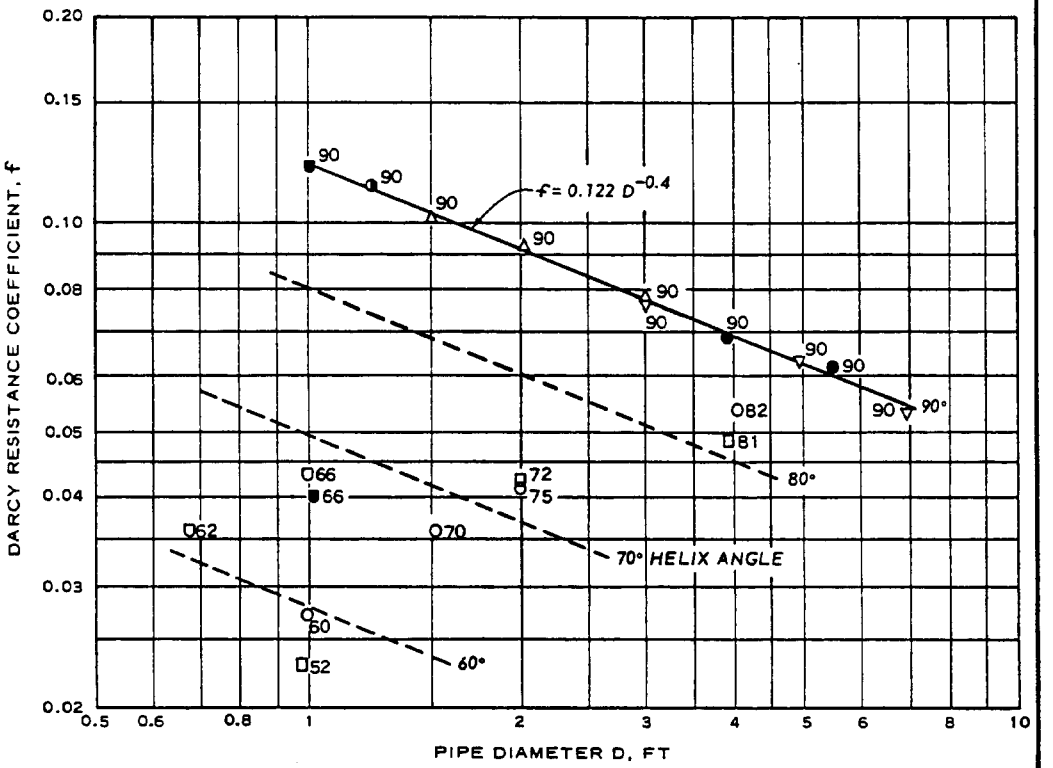
b. GEOMETRY OF CROSS SECTION OF USBR STANDARD HORSESHOE TUNNEL

LEGEND

A	AREA OF FLOW CROSS SECTION
y_m	HYDRAULIC DEPTH OF SECTION = A/T
H	CENTRAL HEIGHT OF TUNNEL AND MAXIMUM WIDTH OF TUNNEL
C_K	CONVEYANCE FACTOR OF MANNING FORMULA = 1.486 $AR^{2/3}$
P	WETTED PERIMETER
R	HYDRAULIC RADIUS = A/P
S_{cn}	CRITICAL SLOPE FOR NORMAL DEPTH
T	WIDTH OF WATER SURFACE
y	CENTRAL FLOW DEPTH
Z	SECTION FACTOR = $A\sqrt{y_m}$
θ	ANGLE OF HORIZONTAL DIAMETER WITH WATER SURFACE ON OPPOSITE SIDE
H/2	CROWN RADIUS
n	MANNING ROUGHNESS FACTORS

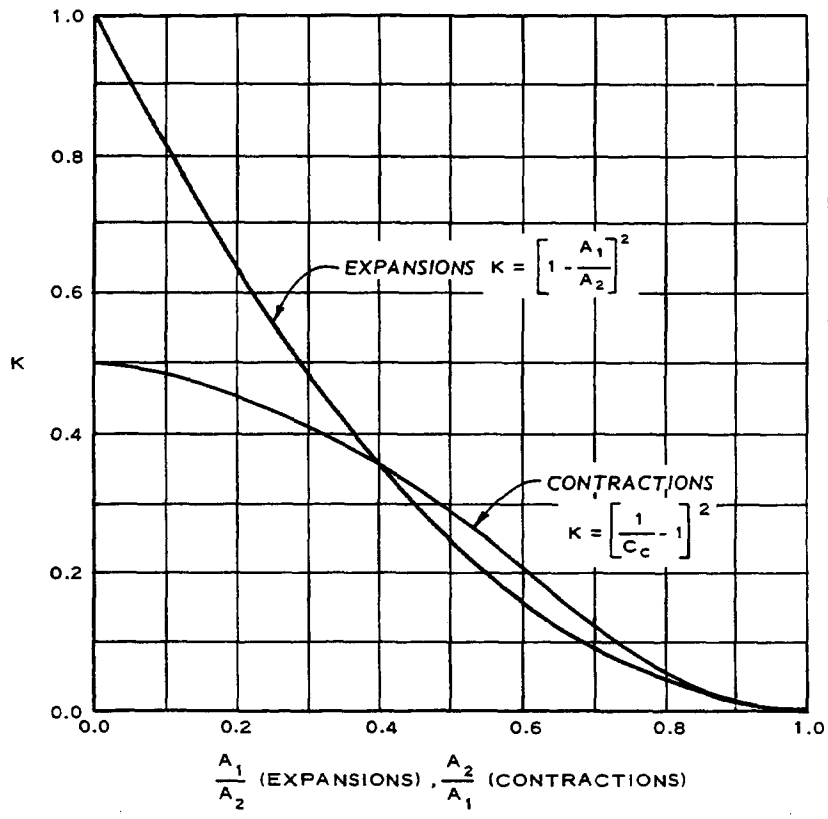
FROM HDC 224-10

FLOW CHARACTERISTICS
HORSESHOE CONDUITS

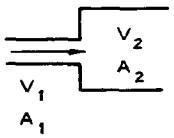


RESISTANCE COEFFICIENT
CORRUGATED METAL PIPE

(From SAFHL, item 112)

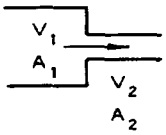


EXPANSIONS



$h_\ell = K \frac{V_1^2}{2g}$

CONTRACTIONS



$h_\ell = K \frac{V_2^2}{2g}$

WHERE

h_ℓ = HEAD LOSS, FT

K = LOSS COEFFICIENT

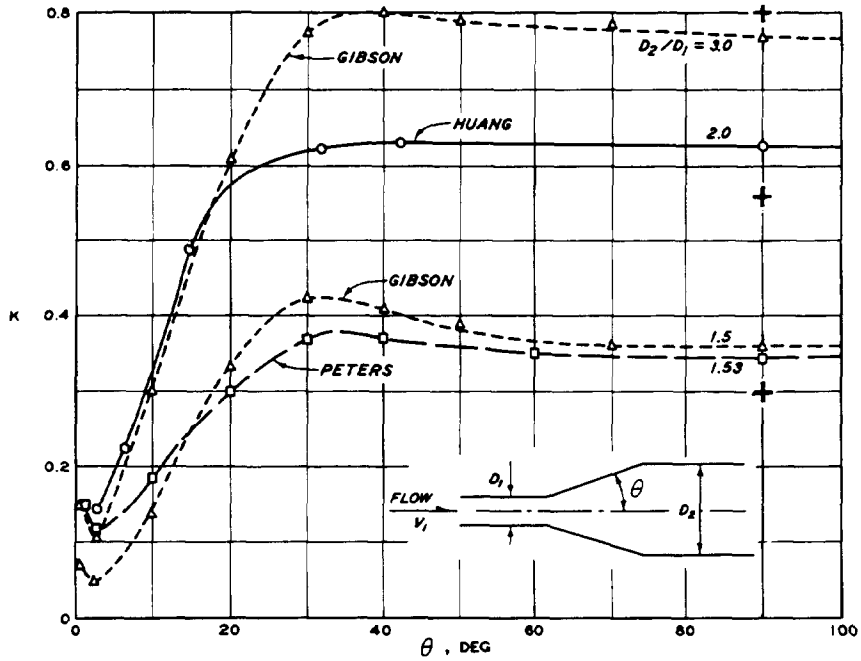
V = REFERENCE CONDUIT VELOCITY, FPS

A = CROSS-SECTION AREA, FT^2

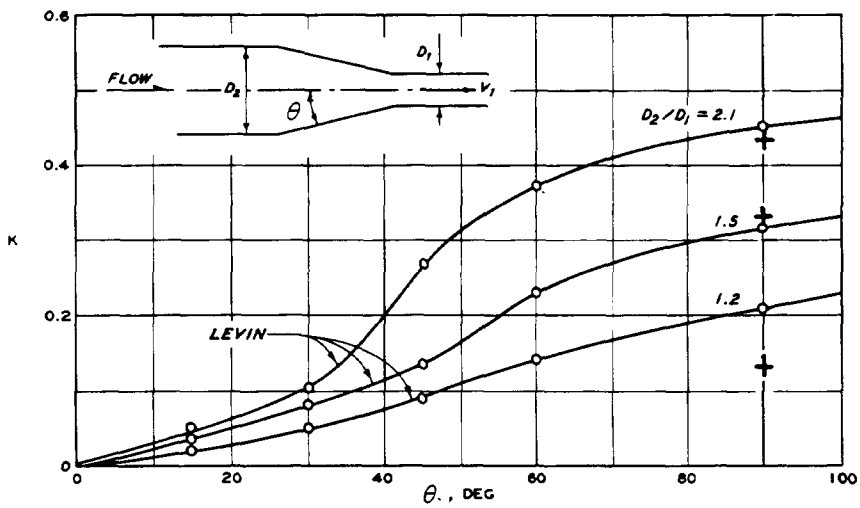
g = ACCELERATION OF GRAVITY, FT/SEC^2

C_c = CONTRACTION COEFFICIENT (FROM WEISBACH)

HEAD LOSS COEFFICIENTS
ABRUPT TRANSITIONS



a. EXPANSIONS



b. CONTRACTIONS

✚ FROM PLATE C-8 FOR θ = 90°.

BASIC EQUATION

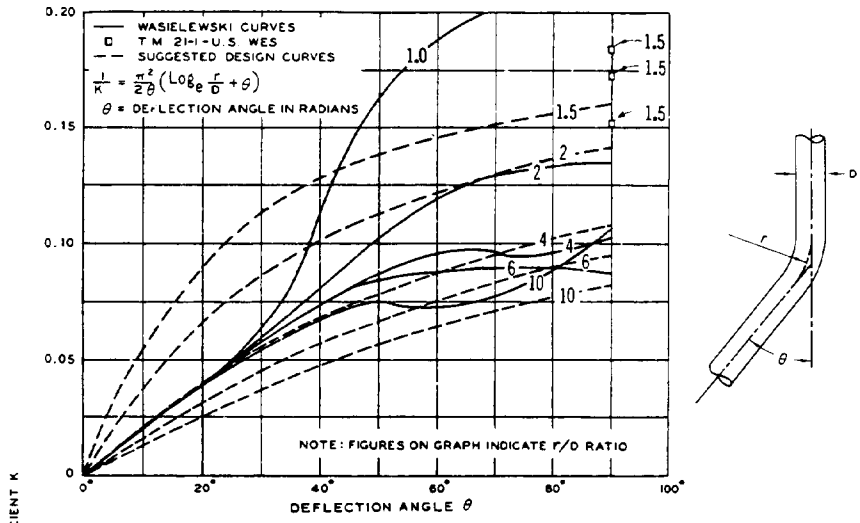
$$K = \frac{h_\ell}{V^2/2g}$$

WHERE:

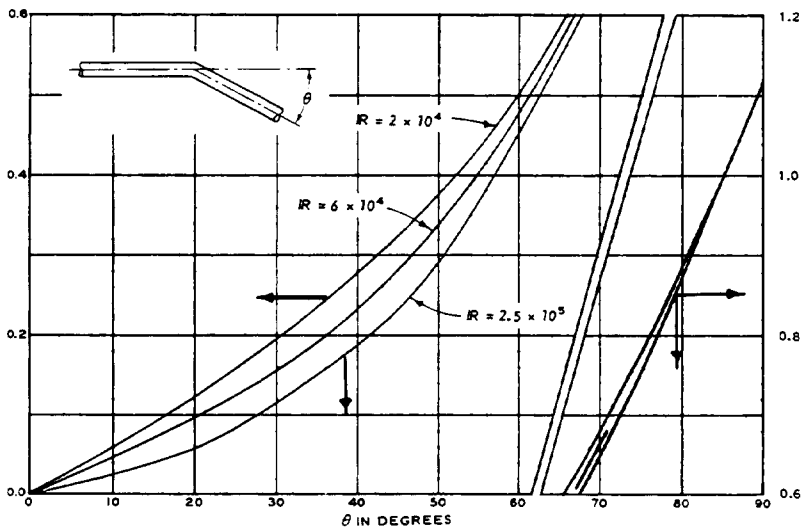
h_ℓ = HEAD LOSS, FT
g = ACCELERATION OF GRAVITY, FT/SEC^2
V_1 = AVERAGE VELOCITY IN THE SMALLER CONDUIT, FPS

FROM HDC 228-4

LOSS COEFFICIENTS
CONICAL TRANSITIONS



a. CIRCULAR BENDS



b. SINGLE MITER BENDS

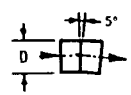
BASIC EQUATION

$$K = \frac{h_L}{V^2/2g}$$

WHERE K = BEND LOSS COEFFICIENT
h_L = HEAD LOSS DUE TO BEND

BEND LOSS COEFFICIENTS
CIRCULAR CONDUITS

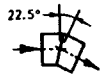
FROM HDC 228-1 AND 228-2/1



$K_s = 0.015$
$K_f = 0.024$

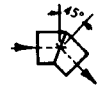
$K_s = 0.034$
$K_f = 0.044$

$K_s = 0.042$
$K_f = 0.082$

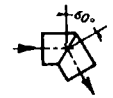


$K_s = 0.066$
$K_f = 0.154$

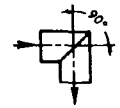
$K_s = 0.130$
$K_f = 0.185$



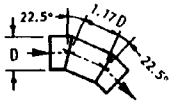
$K_s = 0.236$
$K_f = 0.320$



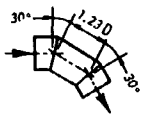
$K_s = 0.471$
$K_f = 0.624$



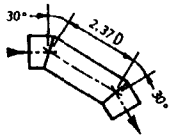
$K_s = 1.129$
$K_f = 1.265$



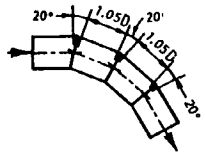
$K_s = 0.112$
$K_f = 0.284$



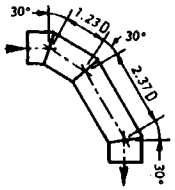
$K_s = 0.150$
$K_f = 0.268$



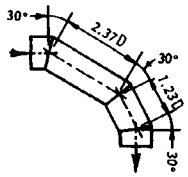
$K_s = 0.143$
$K_f = 0.227$



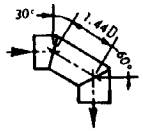
$K_s = 0.108$
$K_f = 0.236$



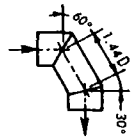
$K_s = 0.188$
$K_f = 0.320$



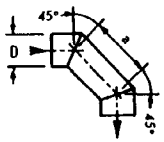
$K_s = 0.202$
$K_f = 0.323$



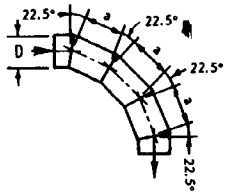
$K_s = 0.400$
$K_f = 0.534$



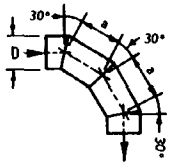
$K_s = 0.400$
$K_f = 0.601$



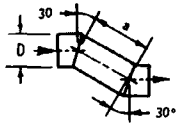
a/D	K_s	K_f
0.71	0.507	0.510
0.94	0.350	0.475
1.17	0.333	0.384
1.42	0.261	0.377
1.50	0.280	0.376
1.85	0.285	0.390
2.56	0.356	0.429
3.14	0.346	0.426
3.72	0.356	0.450
4.89	0.389	0.455
5.59	0.392	0.444
6.28	0.399	0.444



a/D	K_s	K_f
1.19	0.120	0.294
1.40	0.125	0.252
1.50	-	0.250
1.63	0.124	0.256
1.86	0.117	0.272
2.32	0.095	0.317
2.40	0.095	-
2.91	0.108	0.317
3.49	0.130	0.318
4.55	0.148	0.310
6.05	0.142	0.313



a/D	K_s	K_f
1.23	0.195	0.347
1.44	0.195	0.320
1.67	0.150	0.300
1.70	0.149	0.299
1.91	0.154	0.312
2.37	0.167	0.337
2.96	0.172	0.342
4.11	0.190	0.354
4.70	0.192	0.360
6.10	0.201	0.350



a/D	K_s	K_f
1.23	0.157	0.300
1.67	0.156	0.378
2.37	0.143	0.264
3.77	0.160	0.242

BASIC EQUATION

$$h_b = K\frac{V^2}{2g}$$

WHERE:

h_b = HEAD LOSS DUE TO BEND, FT

K = BEND LOSS COEFFICIENT
K_s FOR SMOOTH PIPE, K_f FOR ROUGH PIPE

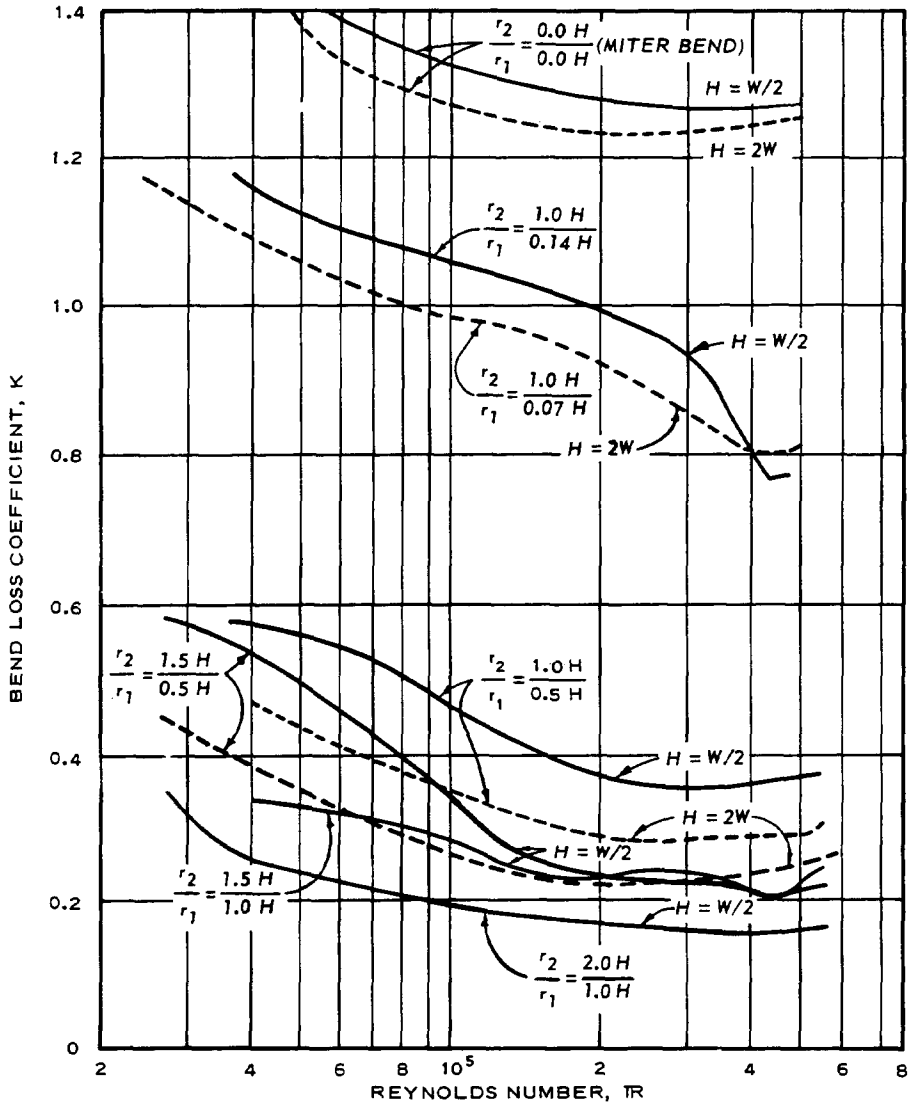
V = FLOW VELOCITY, FPS

g = ACCELERATION OF GRAVITY, FT/SEC^2

REYNOLDS NUMBER ABOUT 225,000

(From SAFHL for U. S. Navy, item 4)

LOSS COEFFICIENTS
CIRCULAR CONDUITS
MULTIPLE MITER BENDS

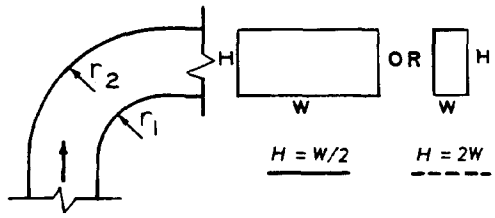


BASIC EQUATION

$$h_b = K\frac{V^2}{2g}$$

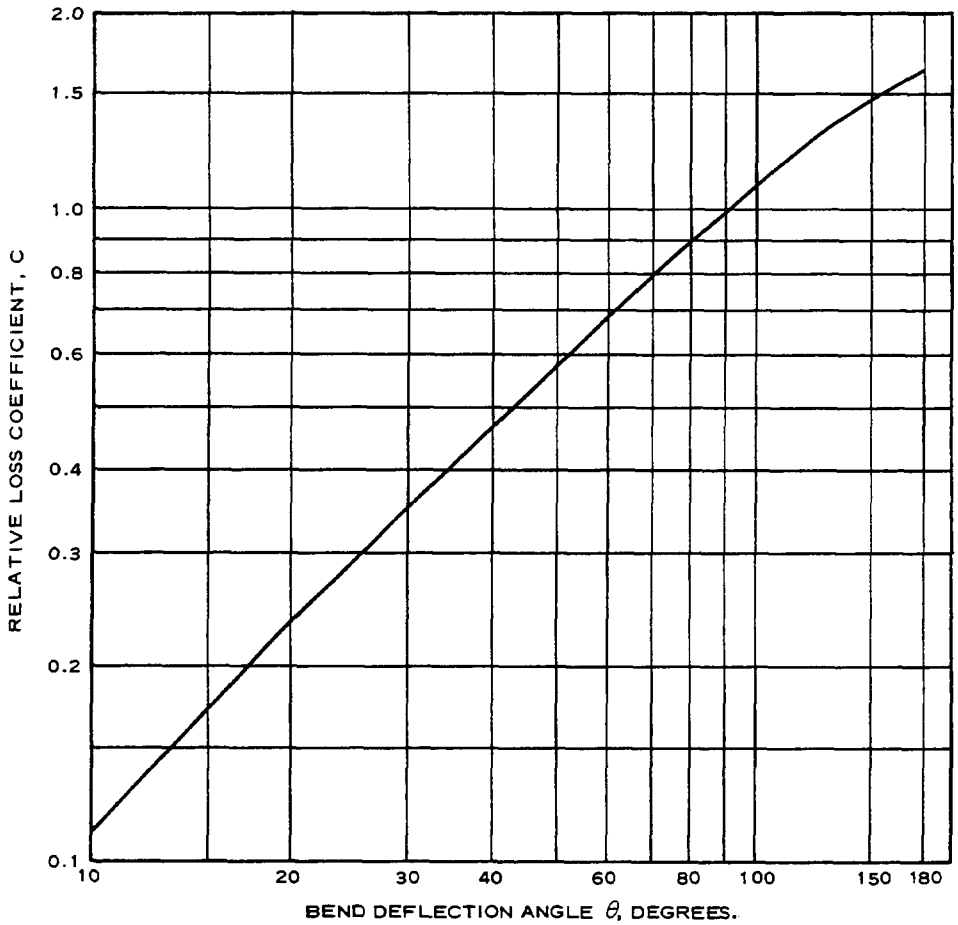
WHERE:

h_b = BEND HEAD LOSS, FT
K = BEND LOSS COEFFICIENT
V = FLOW VELOCITY, FPS
g = ACCELERATION OF GRAVITY, FT/SEC^2



LOSS COEFFICIENTS
RECTANGULAR CONDUITS
90° CIRCULAR BENDS

(From ASME, item 64, and WES Trans., item 116)



BASIC EQUATION

$$h_b = CK \frac{V^2}{2g}$$

WHERE

h_b = BEND HEAD LOSS, FT

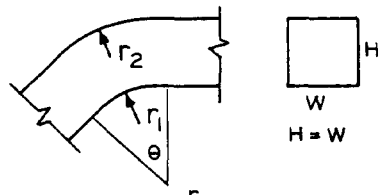
C = RELATIVE LOSS COEFFICIENT

K = 90° BEND LOSS COEFFICIENT (PLATE 12)

V = CONDUIT VELOCITY, FPS

g = ACCELERATION OF GRAVITY, FT/SEC^2

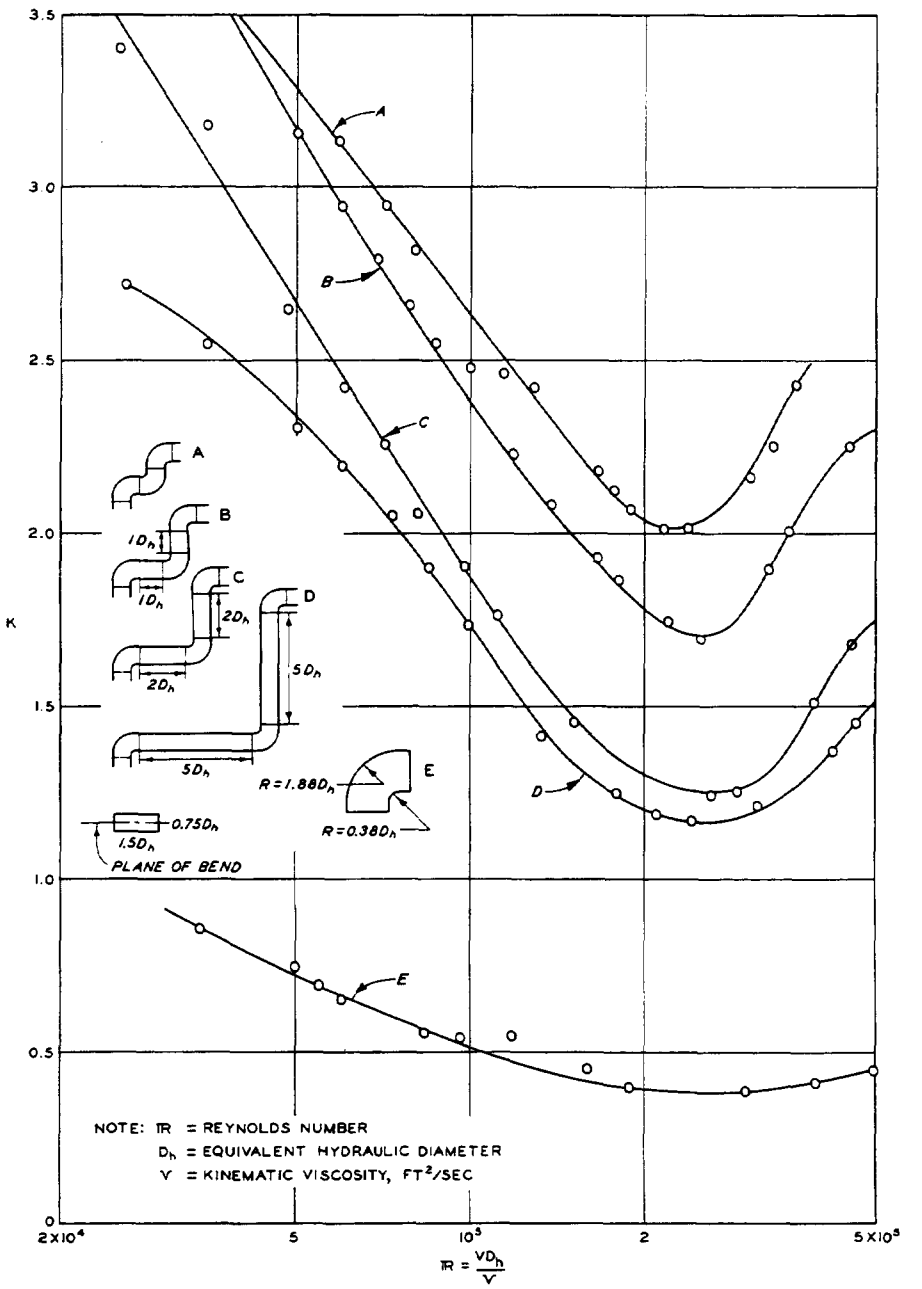
REYNOLDS NUMBER ABOUT 200,000



$$\frac{r_2}{r_1} = \frac{1.5H}{0.5H}$$

RELATIVE LOSS COEFFICIENTS
RECTANGULAR CONDUITS
CIRCULAR BENDS

(From ASME, item 64)



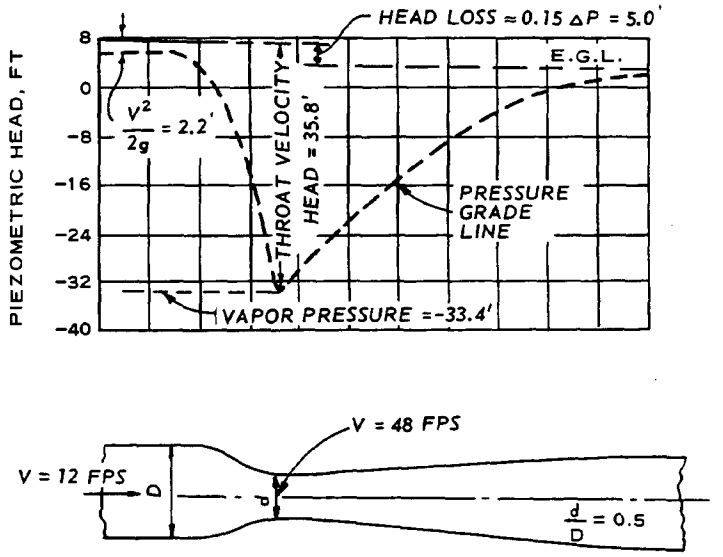
BASIC EQUATION

$h_b = KV^2/2g$

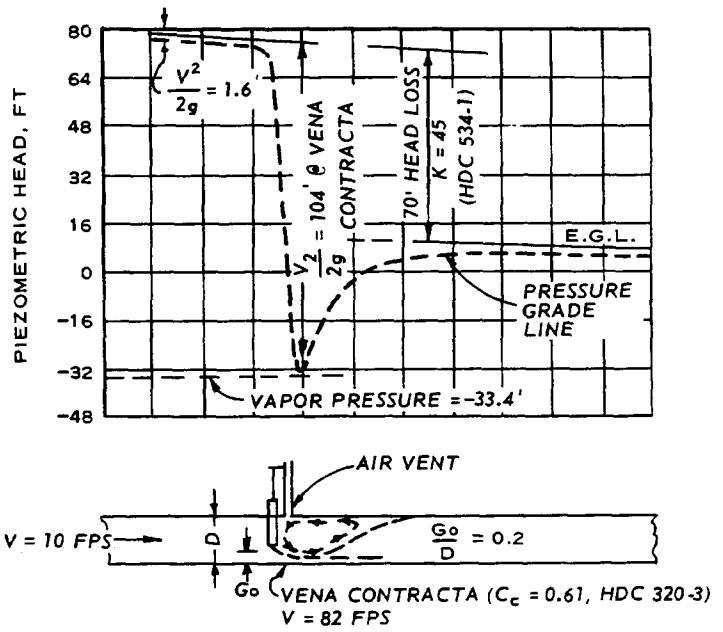
WHERE:
h_b = HEAD LOSS, FT
V = CONDUIT VELOCITY, FPS
K = LOSS COEFFICIENT
g = ACCELERATION OF GRAVITY, FT/SEC²

FROM HDC 228-6

LOSS COEFFICIENTS
RECTANGULAR CONDUITS
TRIPLE BEND



a. VENTURI METER



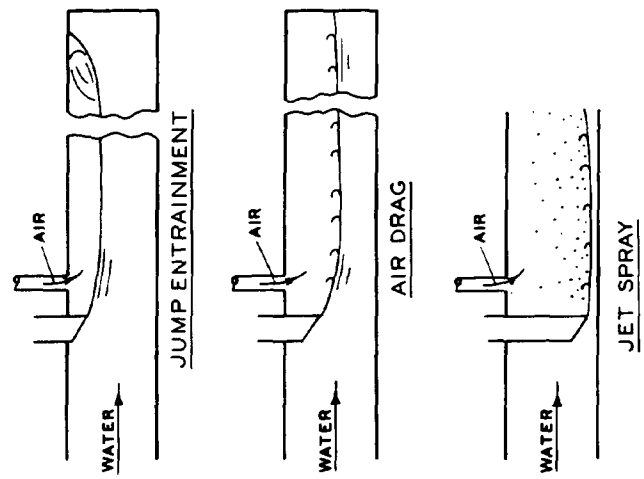
b. IN-LINE GATE

PHYSICAL CONDITIONS:

ATMOSPHERIC PRESSURE = 33.8 FT
AT 50°F AT SEA LEVEL (HDC 000-2)

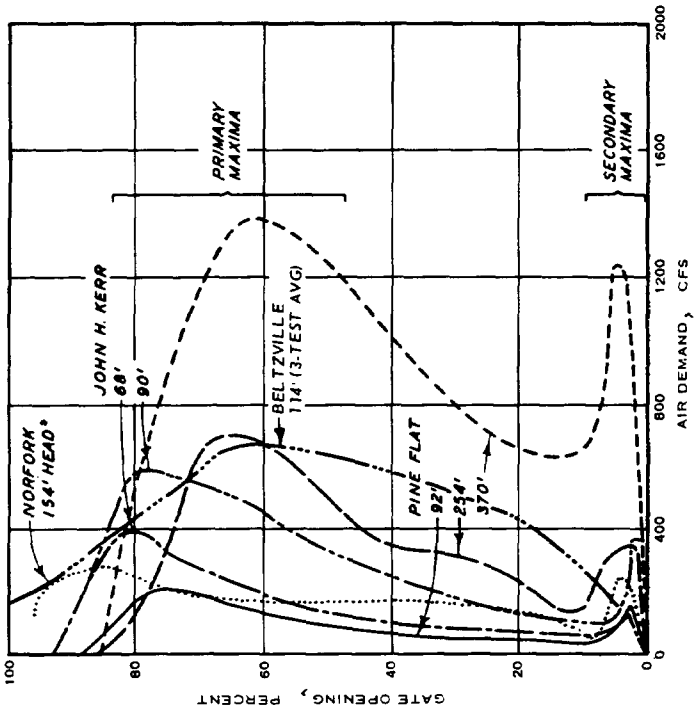
VAPOR PRESSURE = 0.17 PSIA = 0.4 FT
AT 50°F (HDC 001-2)

EXAMPLES OF
CAVITATION HYDRAULICS



AIR DEMAND

PRIMARY AND SECONDARY MAXIMA

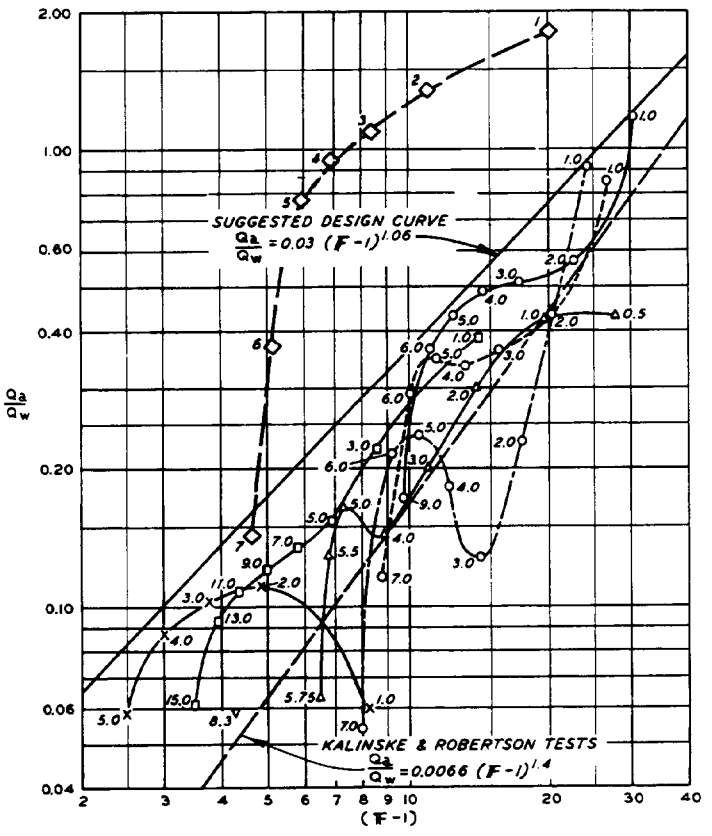


	CONDUIT		AIR VENT	
	LENGTH, FT	SIZE, FT	LENGTH, FT	DIAMETER, FT
JOHN H. KERR	117	5.67 × 10	90	2.50
NORFORK	195	4 × 6	188	1.67
PINE FLAT	334	5 × 9	320	2.50
BELTZVILLE	63†	2.83 × 7.33†	150	2.50

NOTE: * HEADS ARE MEASURED FROM POOL TO CENTER LINE OF CONDUIT.

† ONE OF TWO GATE PASSAGES DISCHARGING INTO 9-FT-DIAM × 1161-FT-LONG CONDUIT.

FROM HDC 050-1/1



NOTE: $F = V/\sqrt{gy}$ (FROUDE NUMBER)
V = WATER VELOCITY AT VENA CONTRACTA, FPS:
y = WATER DEPTH AT VENA CONTRACTA, FT
Q_a = AIR DEMAND, CFS
Q_w = WATER DISCHARGE, CFS

LEGEND

- PINE FLAT - H = 370 FT
- PINE FLAT - H = 304 FT
- PINE FLAT - H = 254 FT
- DENISON - H = 84 FT
- HULAH - H = 24 FT
- NORFORK - H = 154 FT
- TYGART - H = 92 FT
- BELTZVILLE H = 114 FT (3-TEST AVG)*

H = HEAD, POOL TO CONDUIT CENTER LINE
FIGURES ON GRAPH SHOW GATE OPENING IN FEET.

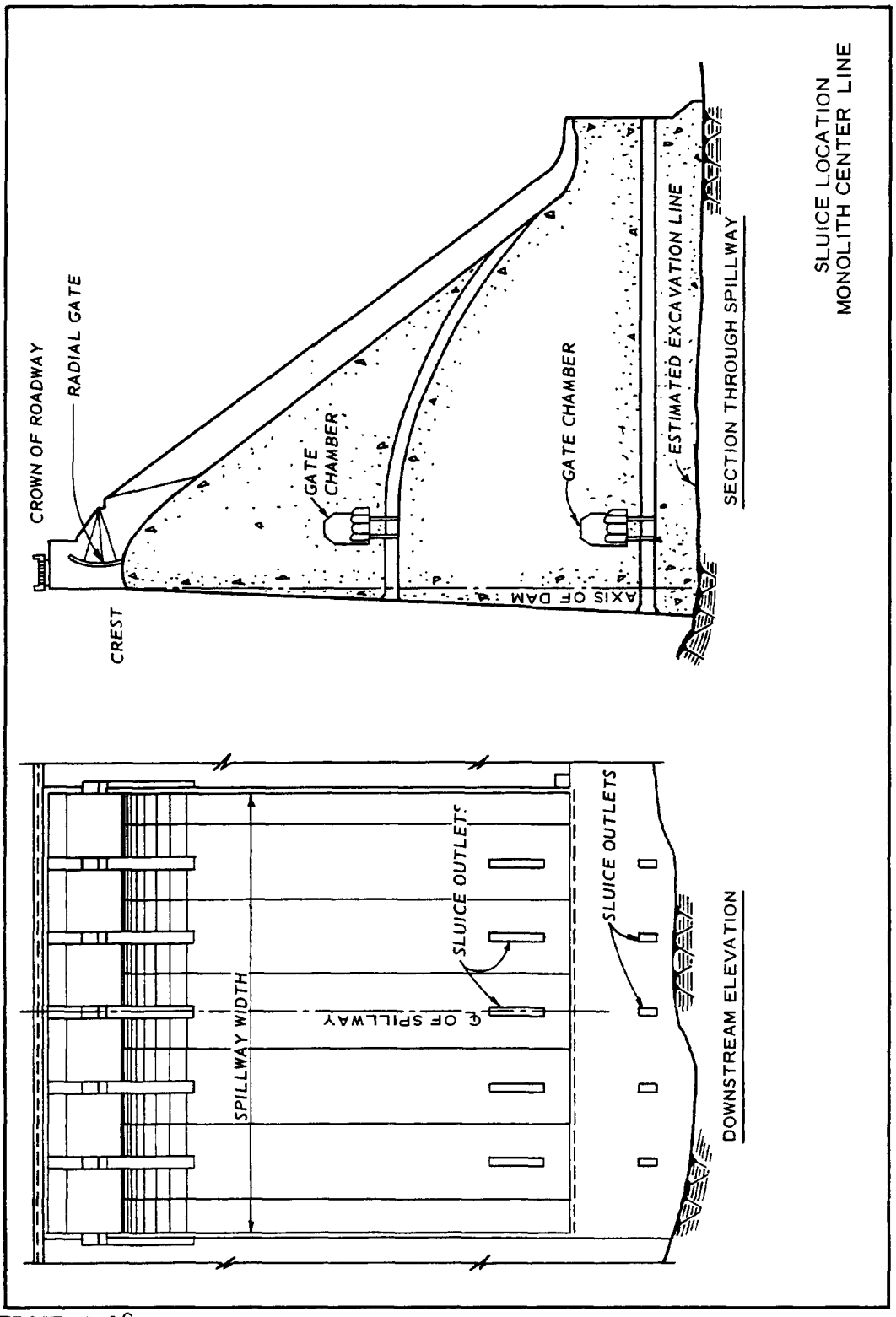
* PROBABLY FREE FLOW CONDITION

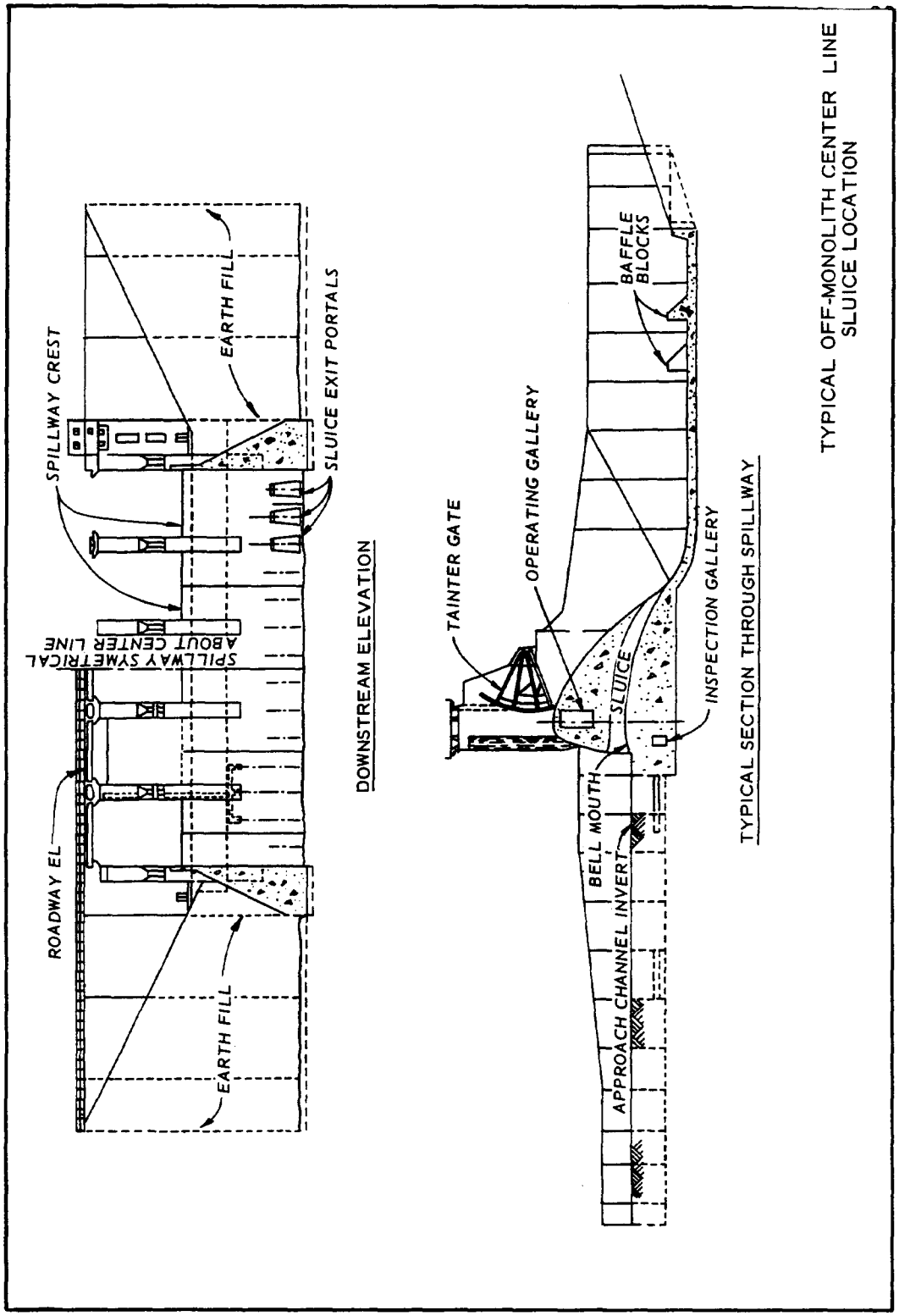
AIR PROPERTIES
AT SEA LEVEL ATMOSPHERIC PRESSURE

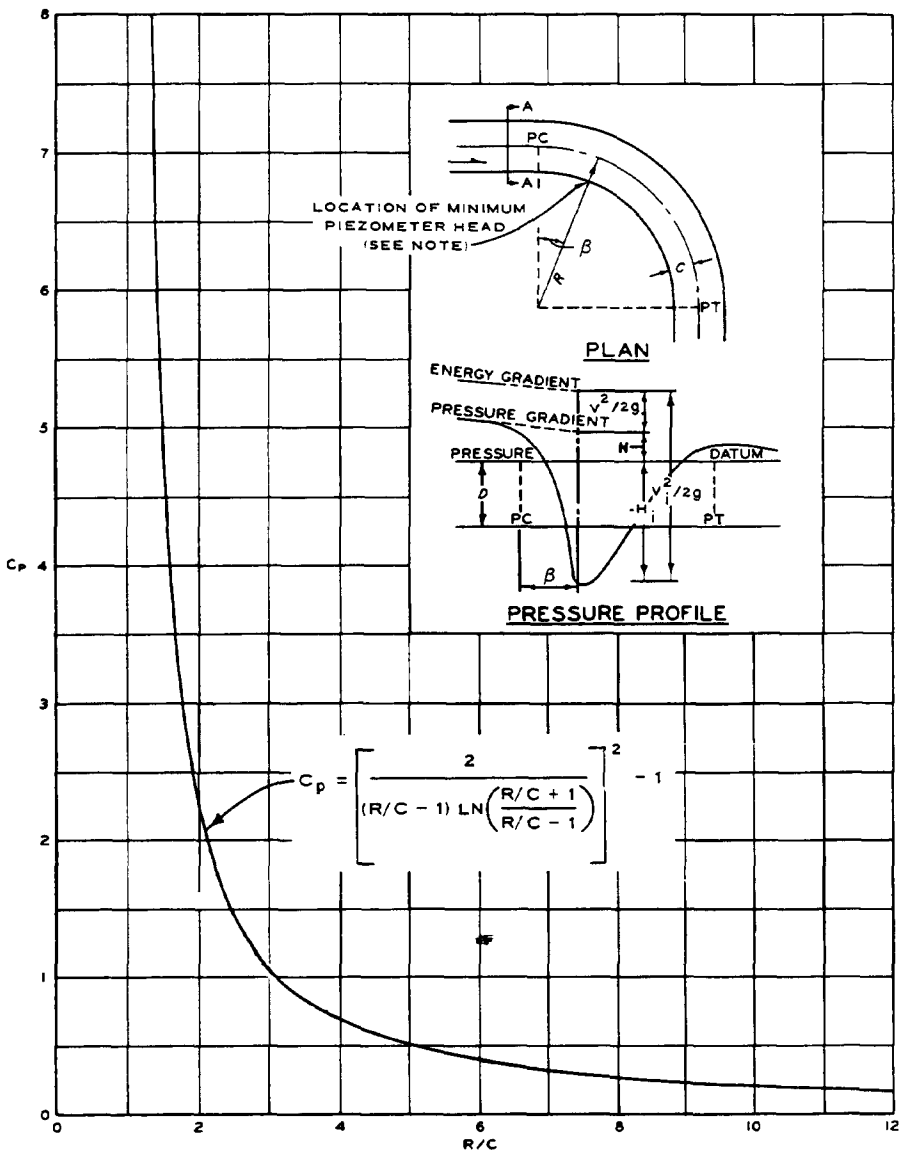
TEMP °F	KINEMATIC VISCOSITY FT^2/SEC	DENSITY $SLUG/FT^3$	SPECIFIC WEIGHT LB/FT^3
80	1.69×10^{-4}	2.28×10^{-3}	7.35×10^{-2}
60	1.58×10^{-4}	2.37×10^{-3}	7.63×10^{-2}
40	1.46×10^{-4}	2.47×10^{-3}	7.94×10^{-2}

AIR DEMAND

FROM HDC 050-1


CROWN OF ROADWAY
RADIAL GATE
CREST
GATE CHAMBER
GATE CHAMBER
AXIS OF DAM
ESTIMATED EXCAVATION LINE
SECTION THROUGH SPILLWAY
SLUICE LOCATION
MONOLITH CENTER LINE
SPILLWAY WIDTH
SLUICE OUTLETS
℄ OF SPILLWAY
SLUICE OUTLETS
DOWNSTREAM ELEVATION


SPILLWAY CREST
EARTH FILL
SLUICE EXIT PORTALS
SPILLWAY SYMETRICAL ABOUT CENTER LINE
ROADWAY EL
EARTH FILL
DOWNSTREAM ELEVATION
TAINTER GATE
OPERATING GALLERY
BAFFLE BLOCKS
SLUICE
INSPECTION GALLERY
BELL MOUTH
APPROACH CHANNEL INVERT
TYPICAL SECTION THROUGH SPILLWAY
TYPICAL OFF-MONOLITH CENTER LINE SLUICE LOCATION



$$C_p = \left[\frac{2}{(R/C - 1)\,\mathrm{LN}\left(\frac{R/C + 1}{R/C - 1}\right)}\right]^2 - 1$$

EQUATIONS

$$H + \frac{V^2}{2g} = H_1 + \frac{V_1^2}{2g}, \qquad \frac{H - H_1}{\frac{V^2}{2g}} = C_p$$

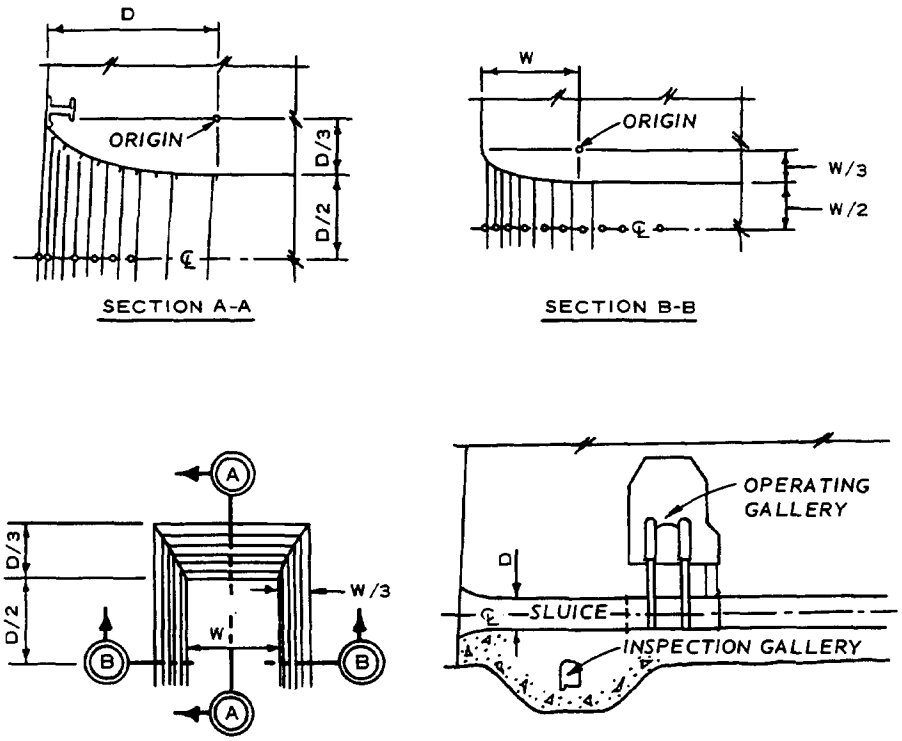
NOTE: β = 22.5° FOR CIRCULAR CONDUITS AND 45° FOR RECTANGULAR CONDUITS.

WHERE:

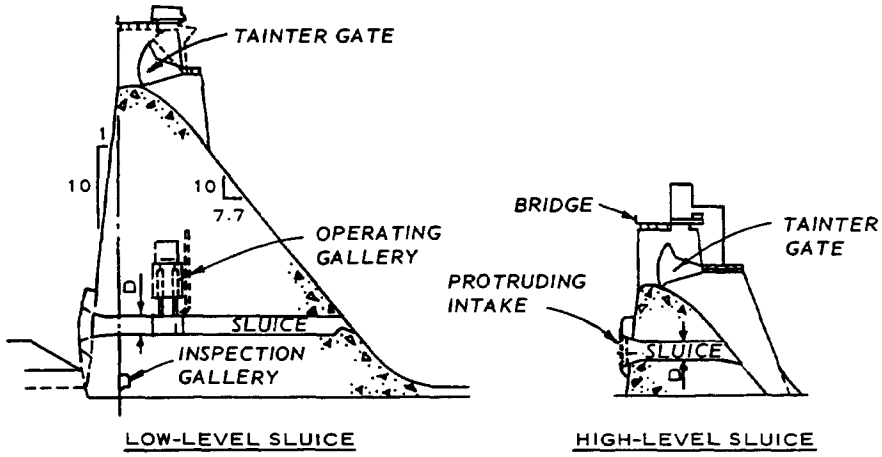
- H = PIEZOMETRIC HEAD FROM PRESSURE GRADIENT EXTENSION, FT
- V = AVERAGE VELOCITY, FPS
- g = ACCELERATION OF GRAVITY, FT/SEC²
- H_1 = MINIMUM PIEZOMETRIC HEAD, FT
- V_1 = VELOCITY AT LOCATION OF H_1, FPS
- C_p = PRESSURE DROP PARAMETER
- C = CONDUIT HALF WIDTH

CONDUITS
CIRCULAR BENDS
MINIMUM PRESSURE

FROM HCD 228-3

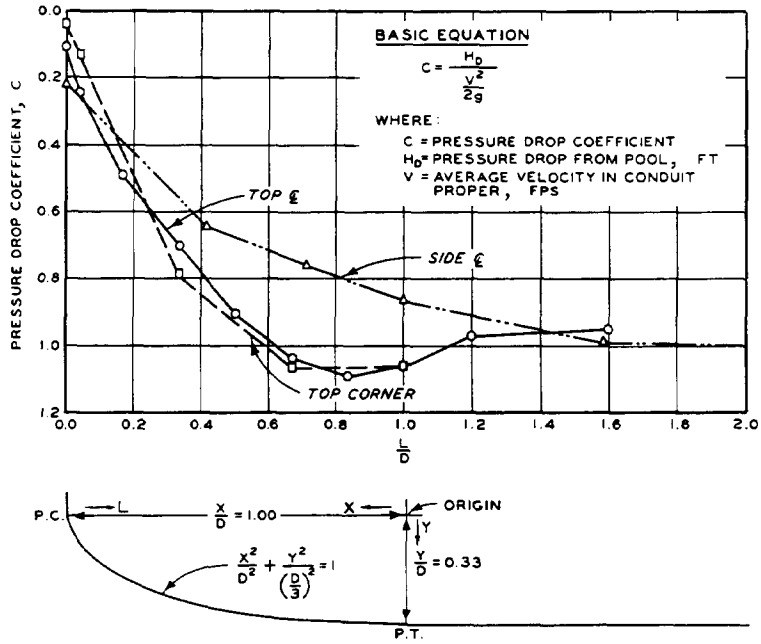


a. FLUSH INTAKE

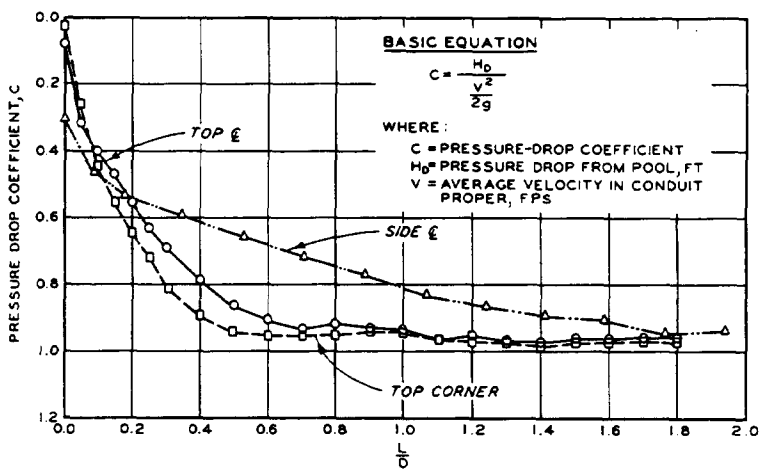


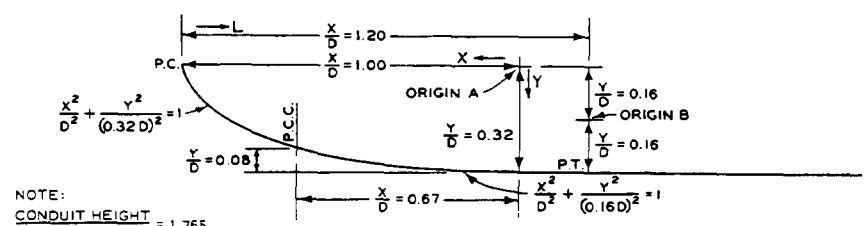
b. PROTRUDING INTAKES

SLUICE INTAKES



a. SIMPLE CURVES



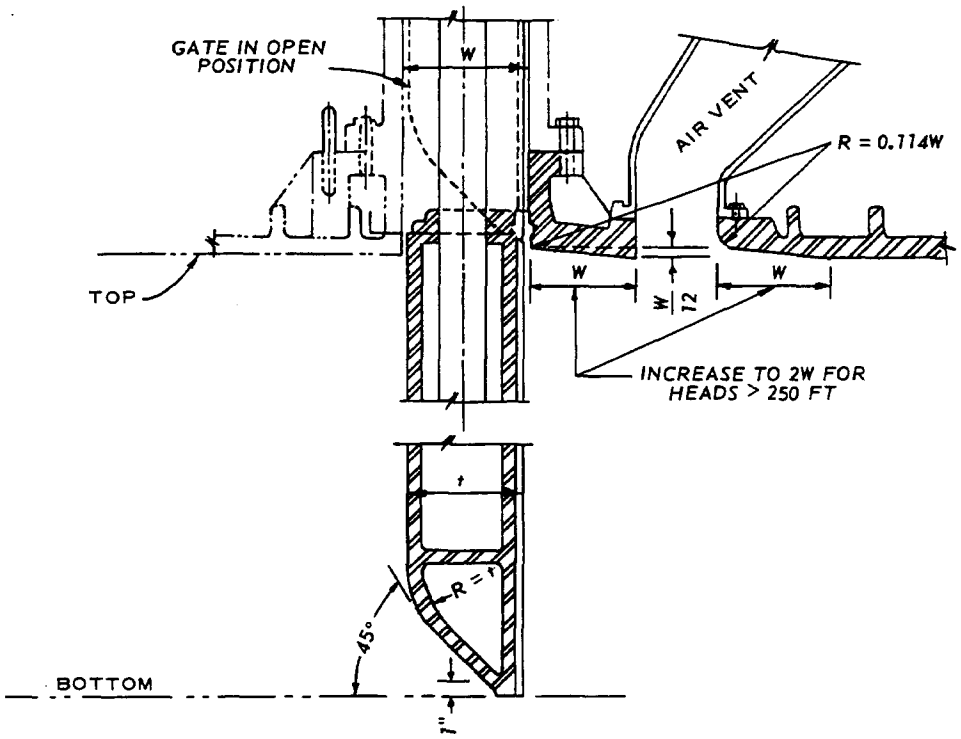


b. COMPOUND CURVES

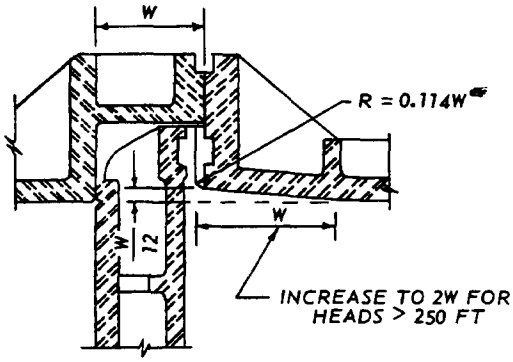
NOTE:
$\frac{\text{CONDUIT HEIGHT}}{\text{CONDUIT WIDTH}} = 1.765$
D = DIMENSION OF CONDUIT IN DIRECTION CONCERNED, FT
L = DISTANCE ALONG CONDUIT, FT

PRESSURE DROP COEFFICIENTS
SLUICE ENTRANCES

FROM HDC 211-1, 1/1



DETAIL OF ROOF SLOT

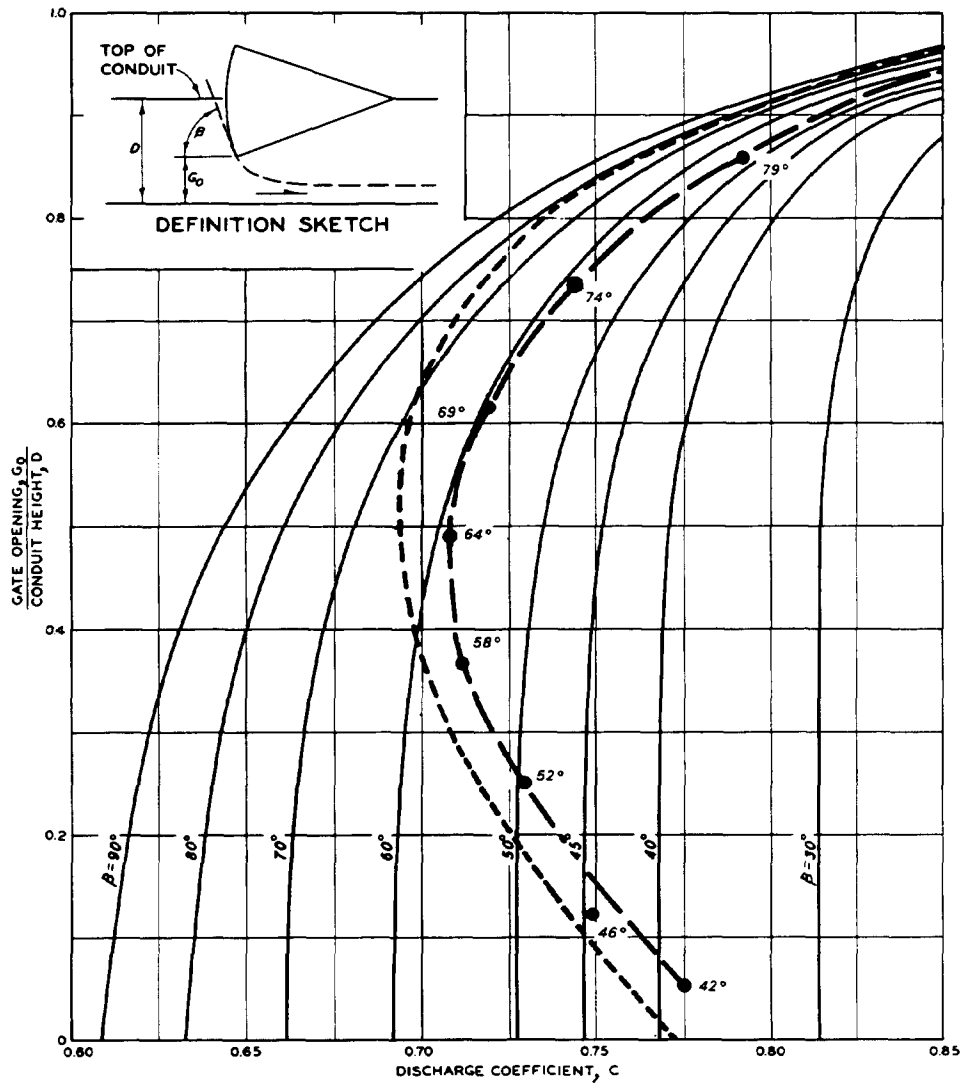


DETAIL OF SIDEWALL SLOT

NOTE: GATE LEAF, FRAME, AND LINER MAY BE OF CAST OR WELDED CONSTRUCTION.

VERTICAL-LIFT GATE

GATE SLOT DETAILS



BASIC EQUATION:

$$Q = C\,G_0 B\sqrt{2gH}$$

WHERE:

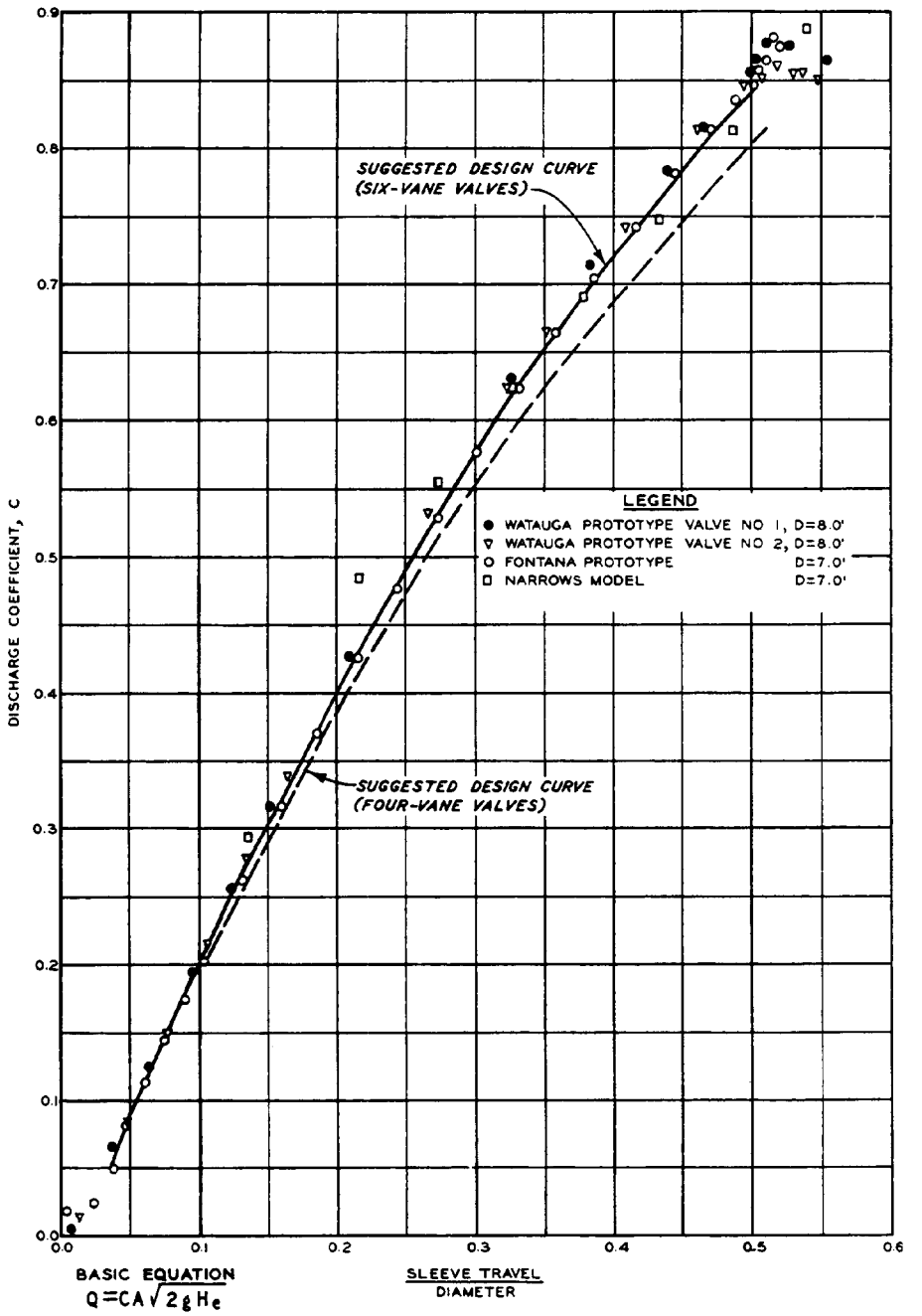
Q = DISCHARGE, CFS
C = DISCHARGE COEFFICIENT
G_0 = GATE OPENING, FT
B = WIDTH OF GATE OPENING, FT
H = ENERGY GRAD. EL. MINUS (INVERT EL. + CG_0), FT

LEGEND

VON MISES
GARRISON MODEL (H MEASURED TO LIP)
GARRISON (THEORETICAL, FROM VON MISES)

DISCHARGE COEFFICIENTS
CONDUIT TAINTER GATES
FREE FLOW

FROM HDC 320-3



BASIC EQUATION

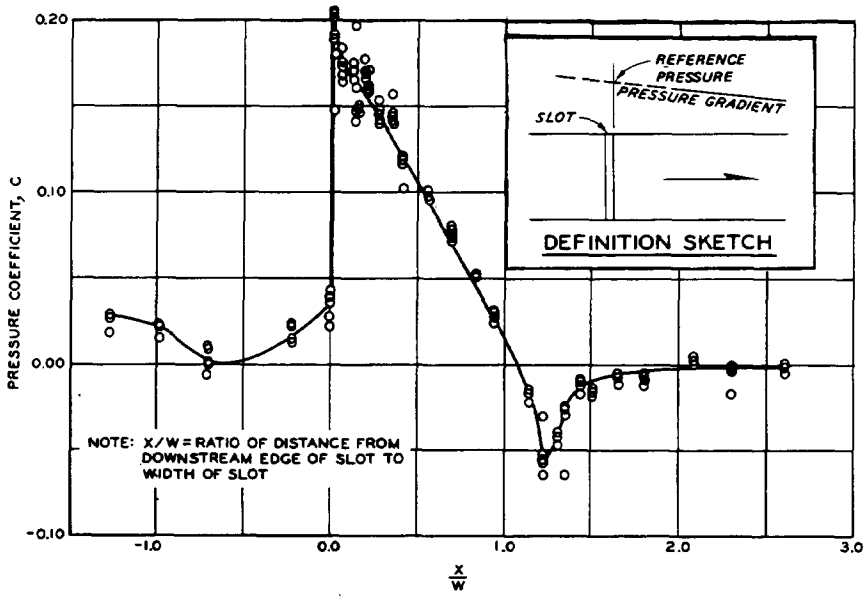
$$Q = CA\sqrt{2gH_e}$$

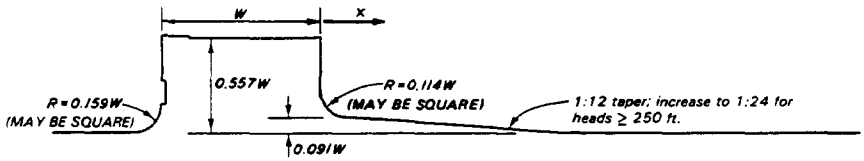
WHERE:

C = DISCHARGE COEFFICIENT
A = AREA OF CONDUIT IMMEDIATELY UPSTREAM FROM VALVE, FT^2
H_e = ENERGY HEAD MEASURED TO CENTER LINE OF CONDUIT IMMEDIATELY UPSTREAM FROM VALVE, FT

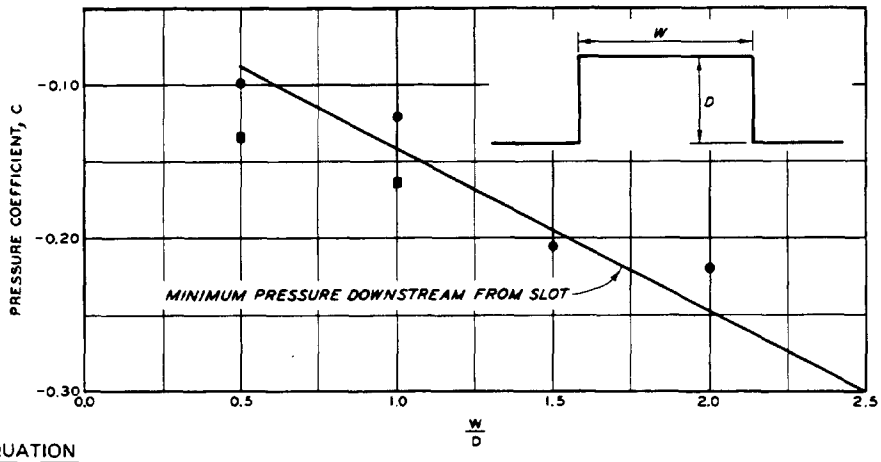
FROM HDC 332-1, 1/1

DISCHARGE COEFFICIENTS
FIXED-CONE VALVES





a. PRESSURE DETAILS



b. MINIMUM PRESSURE

EQUATION

$H_d = CH_v$

WHERE:

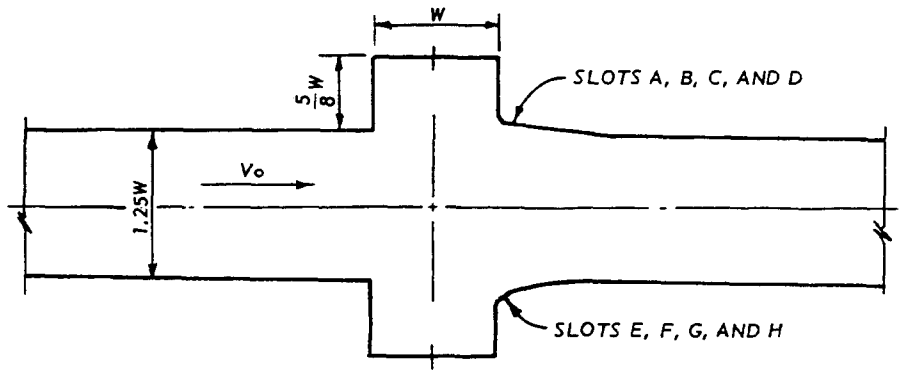
H_d = PRESSURE DIFFERENCE FROM REFERENCE PRESSURE, FT

C = PRESSURE COEFFICIENT

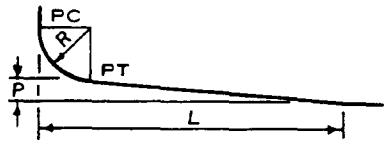
H_v = CONDUIT VELOCITY HEAD AT REFERENCE PRESSURE STATION, FT

FROM HDC 212-1/1, 1/2

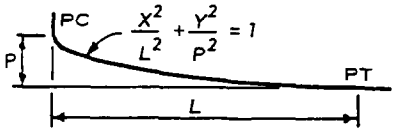
PRESSURE COEFFICIENTS
GATE SLOT



PLAN



SLOTS A, B, C, AND D



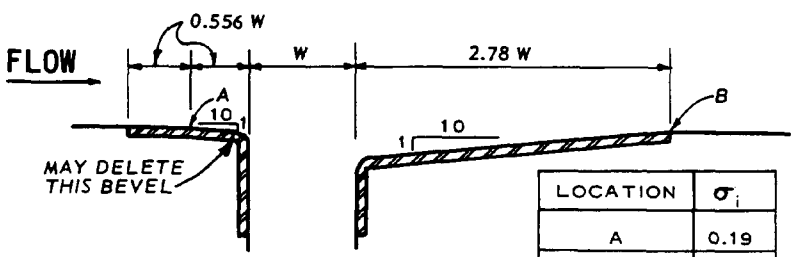
SLOTS E, F, G, AND H

DOWNSTREAM PLAN OF GATE SLOTS

DIMENSIONS RELATIVE TO W				σ_i
SLOT TYPE	R	P	L	
A	0.425	0.200	2.50	0.36
B	0.425	0.425	5.00	0.29
C	0.725	0.625	7.50	0.28
D	1.025	0.825	10.00	0.22
E	--	0.425	2.50	0.36
F	--	0.825	5.00	0.29
G	--	1.250	7.50	0.24
H	--	1.675	10.00	0.27

NOTE: CONDUIT HEIGHT = 0.708W

a. GATE SLOTS



LOCATION	σ_i
A	0.19
B	0.18

b. AIR VENT AND DRAIN INLET PROFILE

BASIC EQUATION:

$$\sigma = \frac{h_o - h_v}{\frac{V_o^2}{2g}}$$; IF $\sigma > \sigma_i$, CAVITATION WILL NOT OCCUR

WHERE:

V_o = CONDUIT VELOCITY, FPS

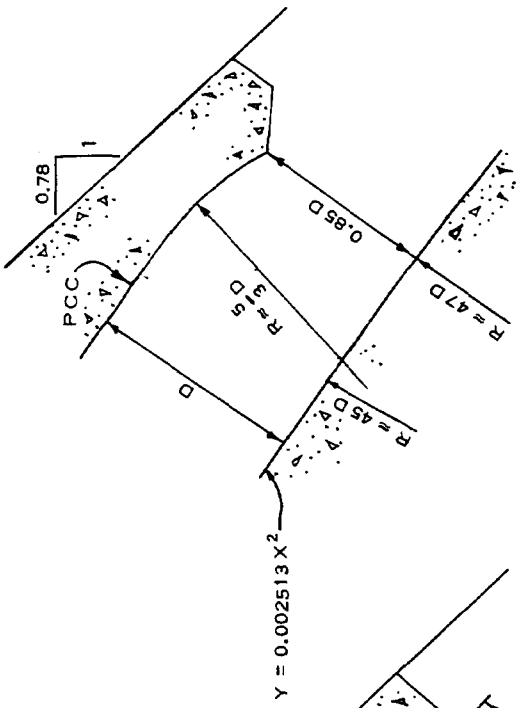
h_o = PRESSURE HEAD IN UNDISTURBED FLOW, FT

h_v = VAPOR PRESSURE OF WATER, FT

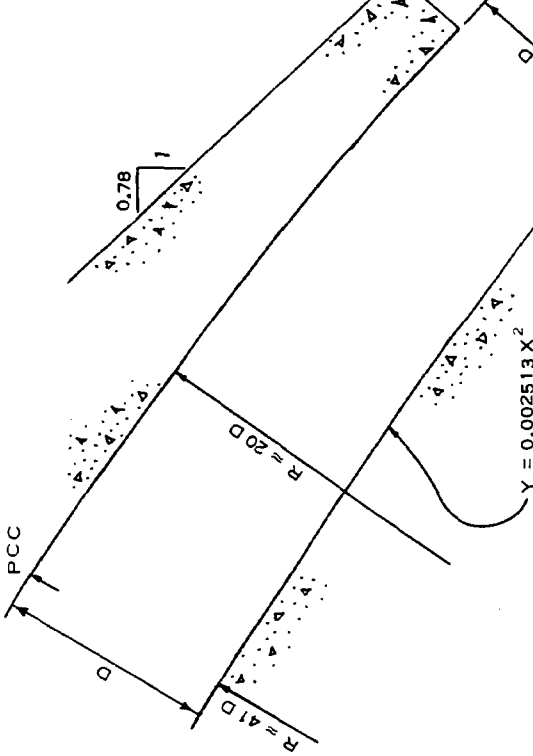
σ = CAVITATION INDEX COEFFICIENT

g = ACCELERATION OF GRAVITY, FT/SEC^2

INCIPIENT CAVITATION COEFFICIENTS FOR SLOTS

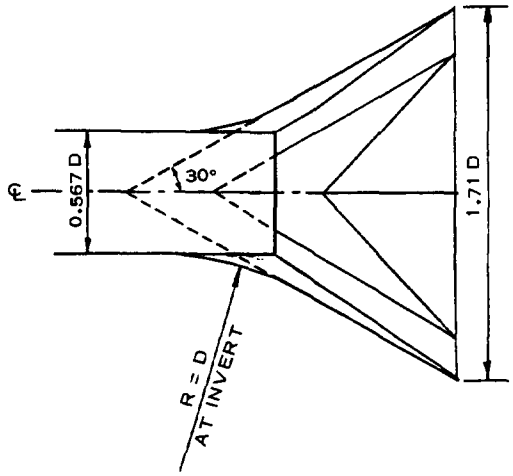


ELONGATED 1.5% CONSTRICTION
PINE FLAT DAM MODEL

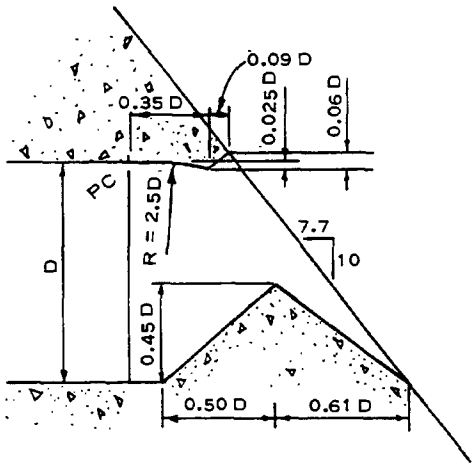


ABRUPT 1.5% CONSTRICTION
PINE FLAT DAM MODEL

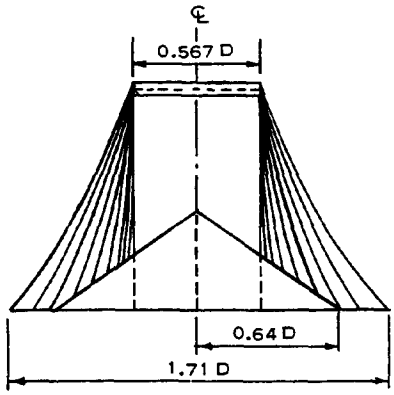
SLUICE EXIT PORTAL
ROOF CONSTRICTIONS



PLAN

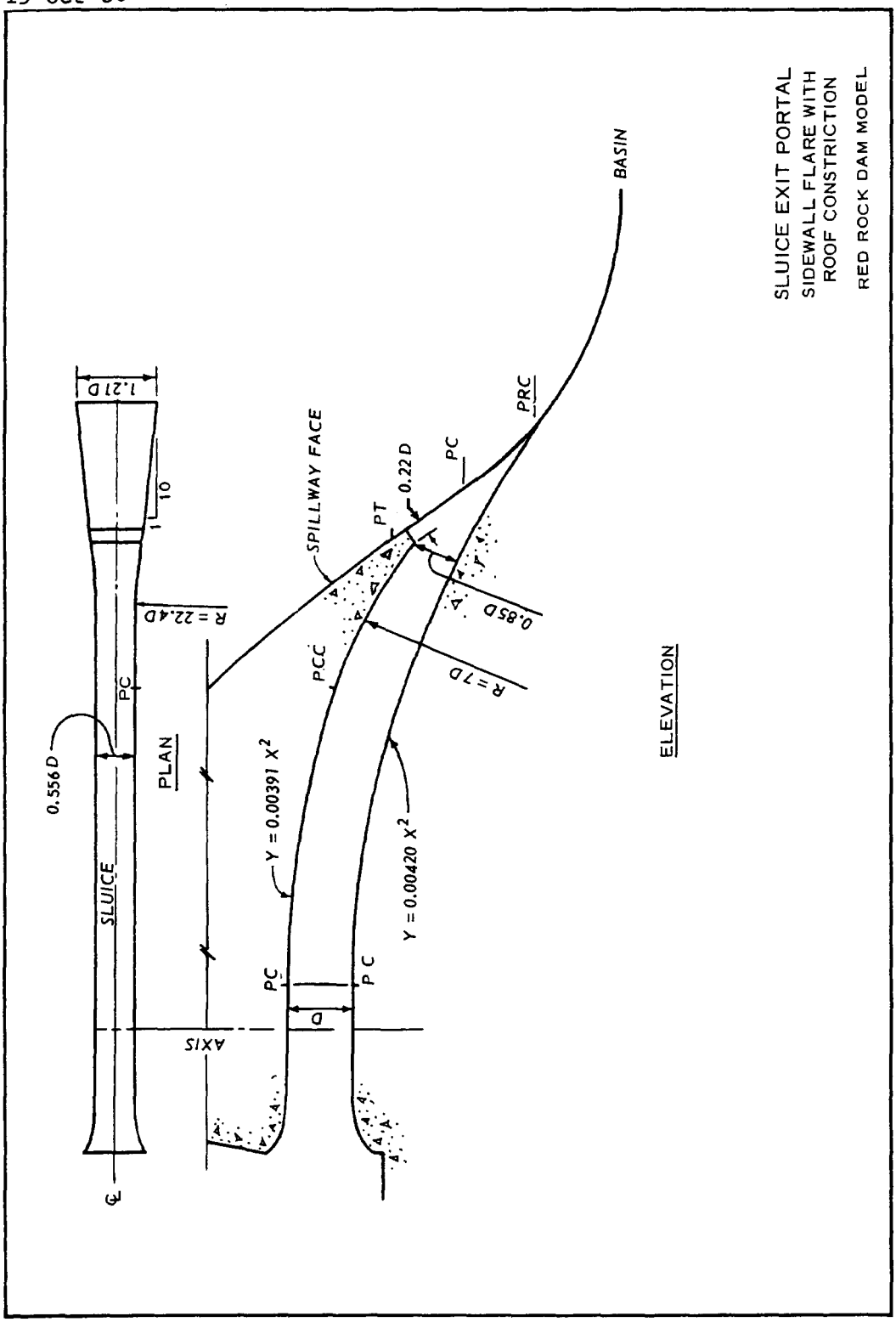


℄ SECTION

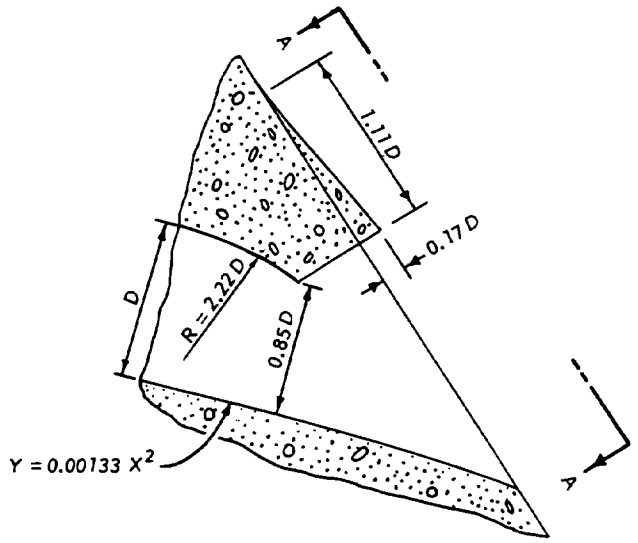


DOWNSTREAM ELEVATION

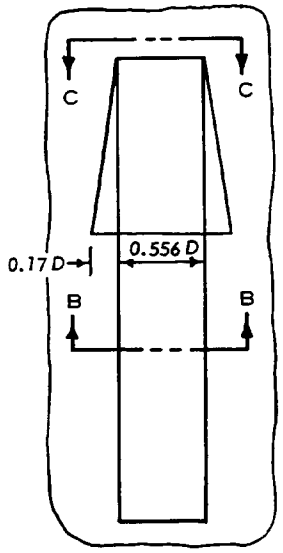
EXIT PORTAL DEFLECTOR
ALLEGHENY DAM MODEL



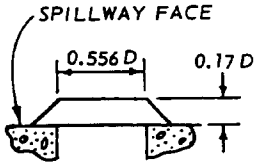
SLUICE EXIT PORTAL
SIDEWALL FLARE WITH
ROOF CONSTRICTION
RED ROCK DAM MODEL



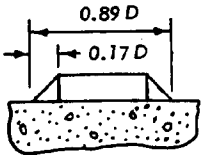
ELEVATION



VIEW A – A

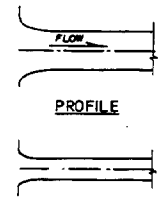


VIEW B – B



VIEW C – C

SLUICE EYEBROW DEFLECTOR
FOLSOM DAM MODEL

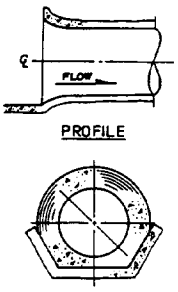


PROFILE

PLAN

K = 0.07 M; 0.16 P

(WES; PINE FLAT)

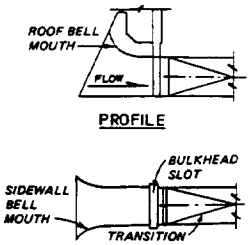


PROFILE

UPSTREAM ELEVATION

K = 0.05 M

(OROVILLE)

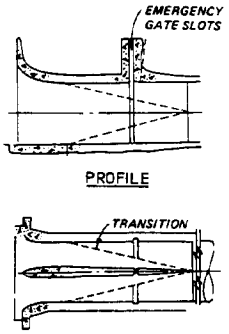


PROFILE

PLAN

K = 0.06 M

(OAHE)

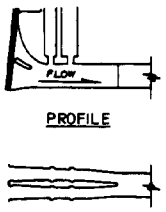


PROFILE

PLAN

K = 0.10 M

(OROVILLE)

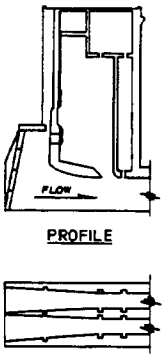


PROFILE

PLAN

K = 0.12 M; 0.16 M
K = 0.19 P; 0.25 P

(DENISON; FT. RANDALL)

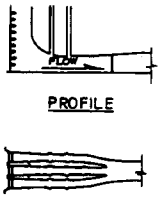


PROFILE

PLAN

K = 0.13 M

(NEW HOPE)

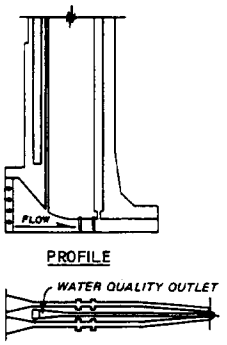


PROFILE

PLAN

K = 0.33 M

(TIONESTA)

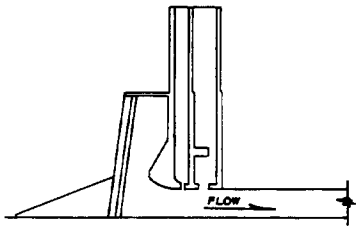


PROFILE

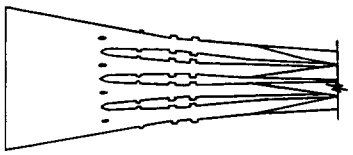
PLAN

K = 1.21 M; 0.57 P

(BELTZVILLE)



PROFILE



PLAN

K = 0.12 M; 0.11 P

(TUTTLE CREEK)

BASIC EQUATION:

$$h_\ell = K\frac{V^2}{2g}$$

WHERE:

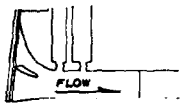
h_ℓ = HEAD LOSS, FT
K = LOSS COEFFICIENT
V = VELOCITY IN CONDUIT PROPER, FPS
g = ACCELERATION OF GRAVITY, FT/SEC^2

NOTE:

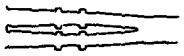
M = MODEL DATA
P = PROTOTYPE DATA
SEE ALSO PLATE C-33.

FROM HDC 221-1, 1/1

INTAKE LOSS COEFFICIENTS
ALL GATES FULLY OPEN



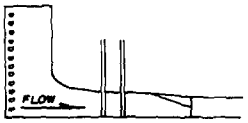
PROFILE



PLAN

K (TWO GATES) = 0.16 M
K (ONE GATE) = 3.10 M
A_G/A_C = 0.666

(FT. RANDALL)

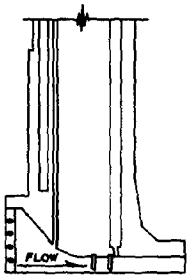


PROFILE

PLAN

K (TWO GATES) = 0.22 M
K (ONE GATE) = 1.80 M
A_G/A_C = 0.509

(EAST BRANCH)



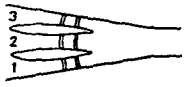
PROFILE

PLAN

K (TWO GATES) = 0.57 P
K (ONE GATE) = 2.62 P
A_G/A_C = 0.539

(BELTZVILLE)

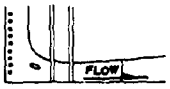
PROFILE



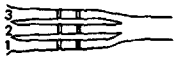
PLAN

K (THREE GATES) = 0.08 M
K (GATES 1 & 3) = 0.29 M
K (GATE 2) = 3.22 M
A_G/A_C = 0.527

(WAPPAPELLO)



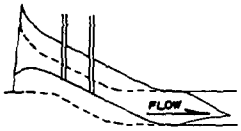
PROFILE



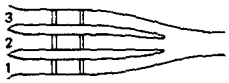
PLAN

K (THREE GATES) = 0.33 M
K (GATE 2) = 5.65 M
A_G/A_C = 0.423

(TIONESTA)



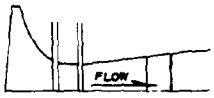
PROFILE



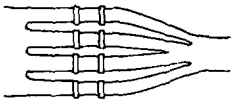
PLAN

K (THREE GATES) = 0.20 M
K (GATES 1 & 3) = 0.40 M
A_G/A_C = 0.631

(ARKABUTLA)



PROFILE



PLAN

K (FOUR GATES) = 0.20 M
K (THREE GATES) = 0.39 M
K (TWO GATES) = 2.07 M
A_G/A_C = 0.317

(SARDIS)

BASIC EQUATION:

$$h_\ell = K\frac{V^2}{2g}$$

WHERE:

h_ℓ = HEAD LOSS, FT
K = LOSS COEFFICIENT
V = VELOCITY IN CONDUIT PROPER, FPS
g = ACCELERATION OF GRAVITY, FT/SEC^2

NOTE:

NOTATIONS INDICATE GATES OPEN.

M = MODEL DATA
P = PROTOTYPE DATA

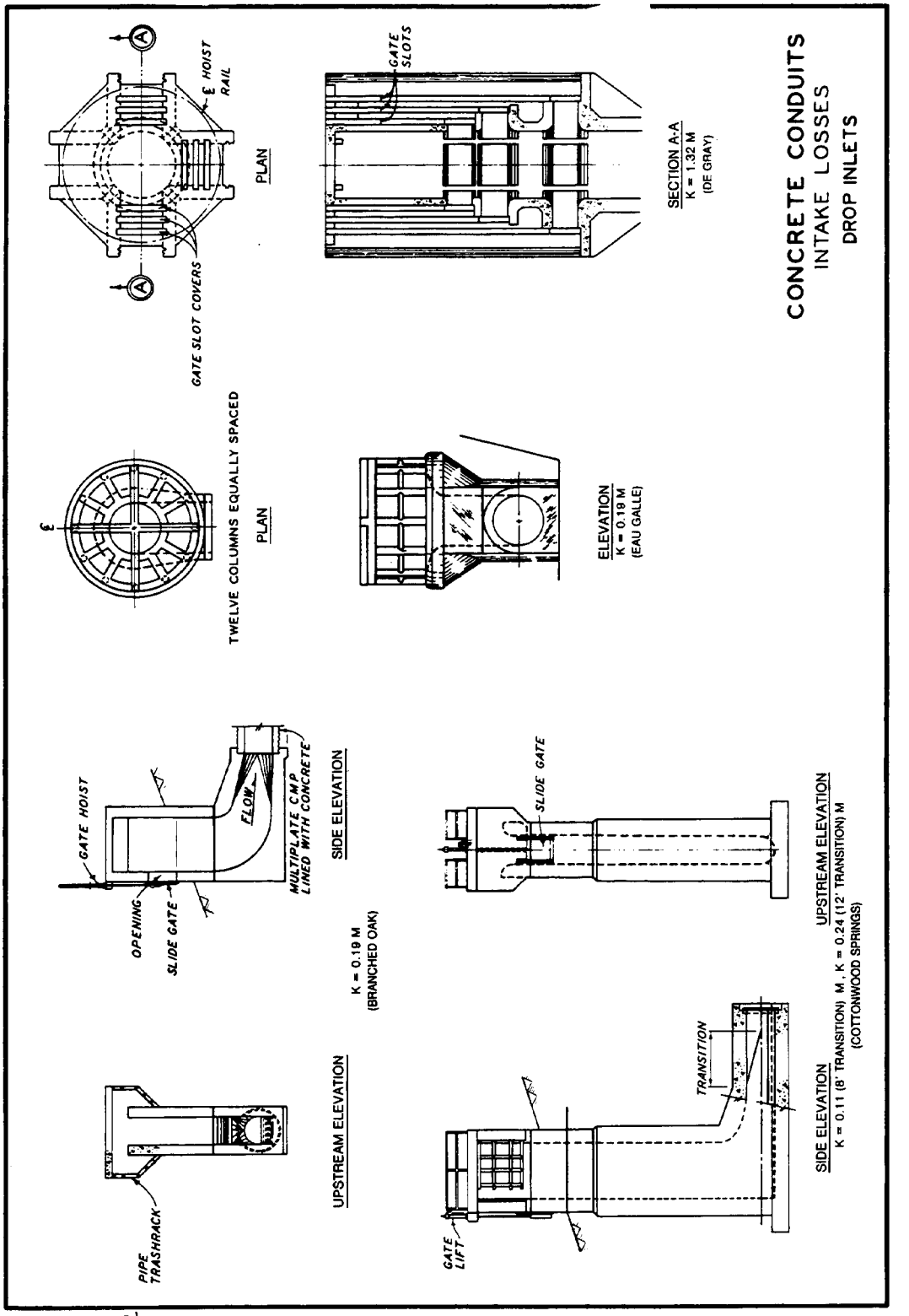
SEE ALSO PLATE C-32.

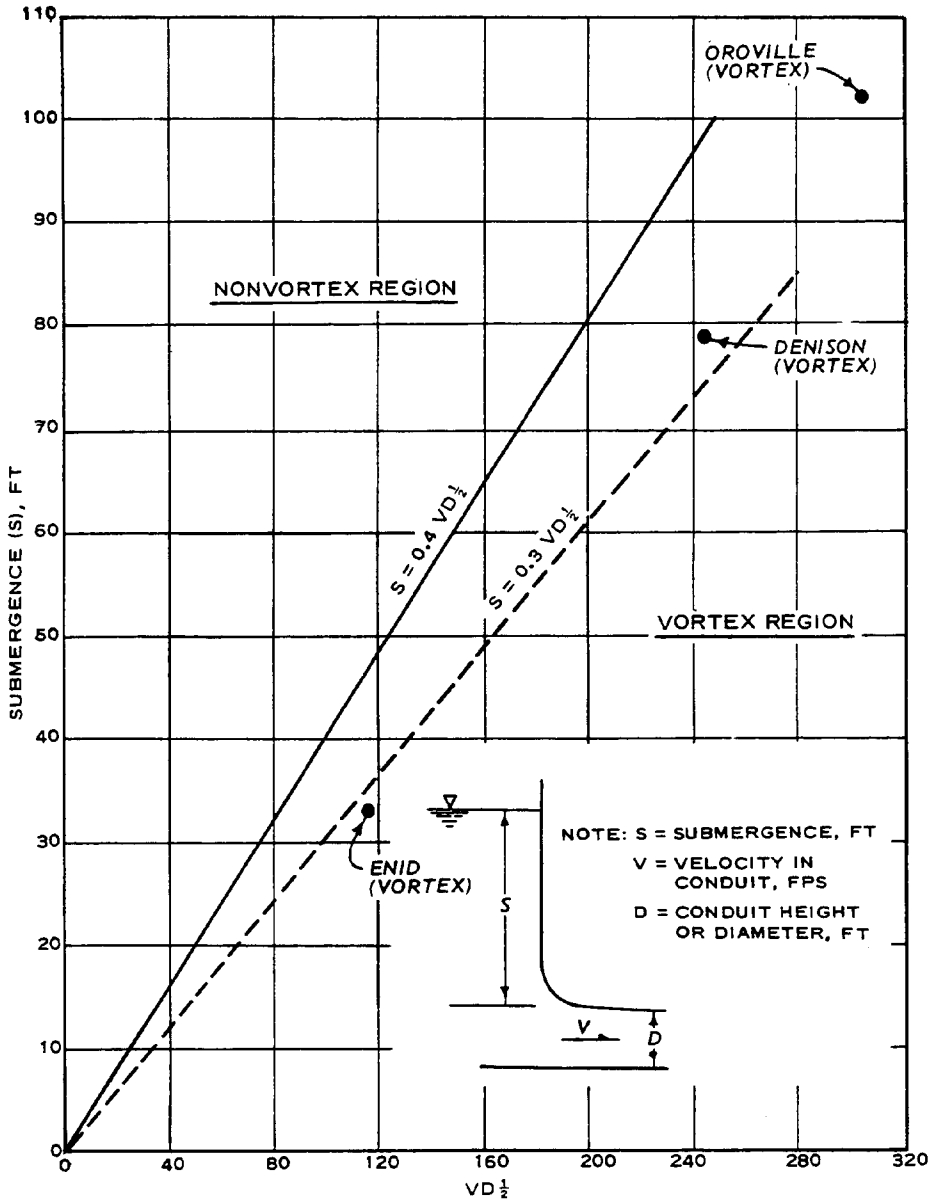
A_G/A_C = RATIO OF ONE GATE PASSAGE FLOW AREA TO THE CONDUIT AREA.

TO CONVERT LOSS COEFFICIENTS INTO TERMS OF GATE PASSAGE VELOCITY HEAD, MULTIPLY K BY THE SQUARE OF THE RATIO OF THE OPERATIVE GATE PASSAGE(S) FLOW AREA TO THE CONDUIT AREA.

INTAKE LOSS COEFFICIENTS
ALL OR FEWER GATES OPEN

FROM HDC 221-1/1, 1/2

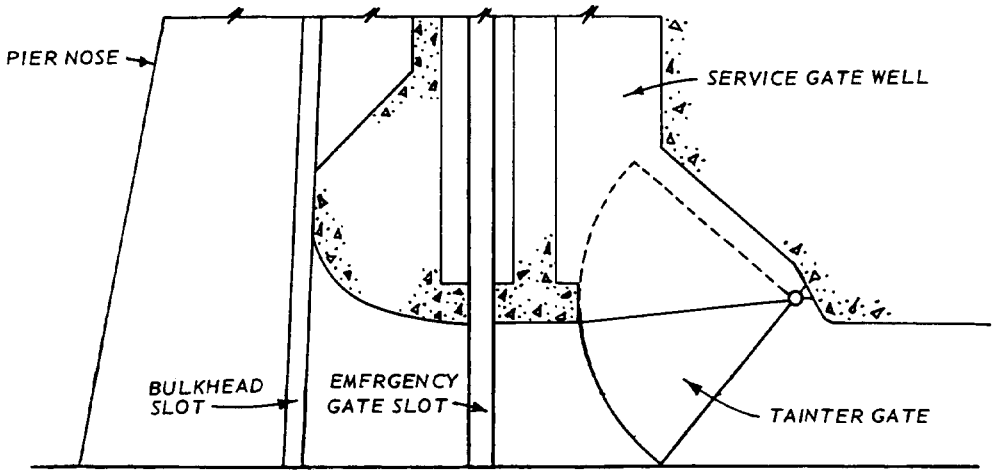

PLAN
℄ HOIST RAIL
GATE SLOT COVERS
GATE SLOTS
SECTION A-A
K = 1.32 M
(DE GRAY)
CONCRETE CONDUITS
INTAKE LOSSES
DROP INLETS
TWELVE COLUMNS EQUALLY SPACED
PLAN
ELEVATION
K = 0.19 M
(EAU GALLE)
GATE HOIST
FLOW
MULTIPLATE CMP LINED WITH CONCRETE
SIDE ELEVATION
OPENING
SLIDE GATE
K = 0.19 M
(BRANCHED OAK)
SLIDE GATE
UPSTREAM ELEVATION
PIPE TRASHRACK
UPSTREAM ELEVATION
TRANSITION
SIDE ELEVATION
K = 0.11 (8' TRANSITION) M, K = 0.24 (12' TRANSITION) M
(COTTONWOOD SPRINGS)
GATE LIFT



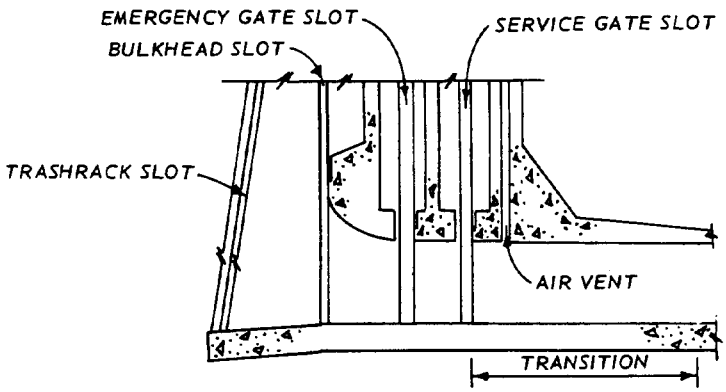
LEGEND

OROVILLE	MODEL
DENISON	PROTOTYPE
ENID	PROTOTYPE
- - - - -	GORDON (SYMMETRICAL APPROACH)
———	GORDON (UNSYMMETRICAL APPROACH)

VORTEX FORMATION

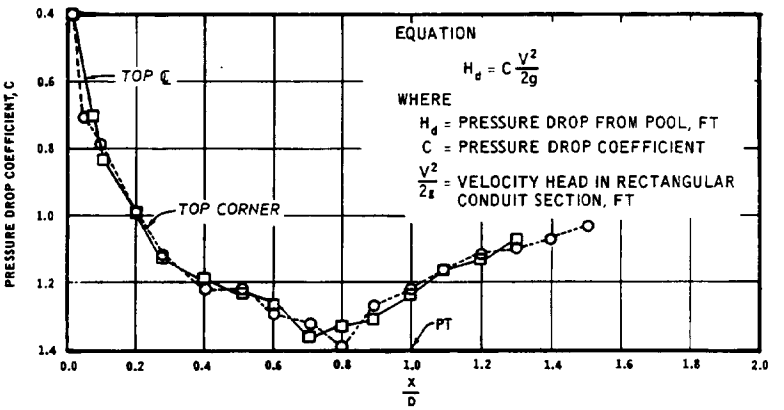


TAINTER GATE
GARRISON DAM

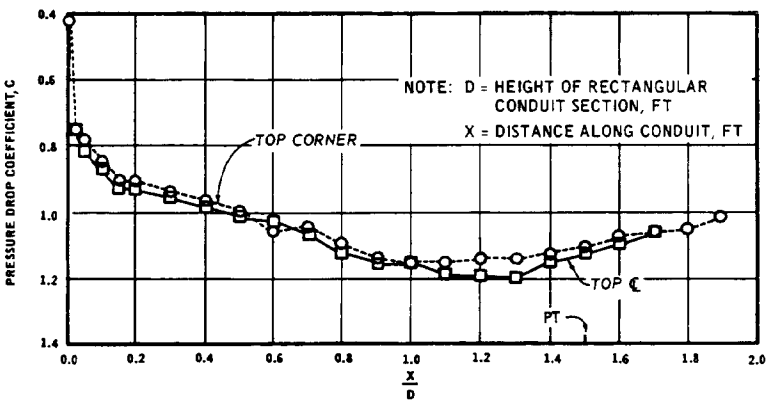


VERTICAL-LIFT GATE
FORT RANDALL DAM

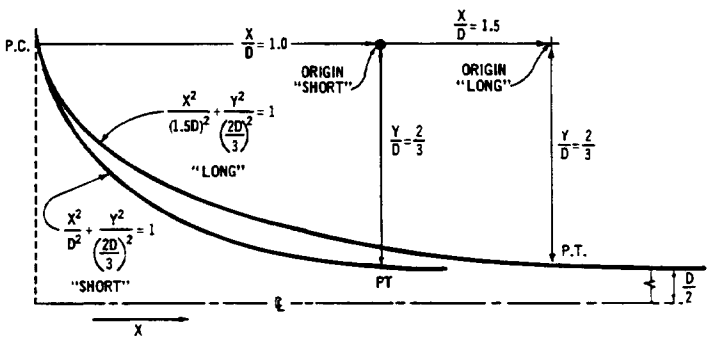
TYPES OF
CONDUIT GATES



a. "SHORT" CURVE



b. "LONG" CURVE

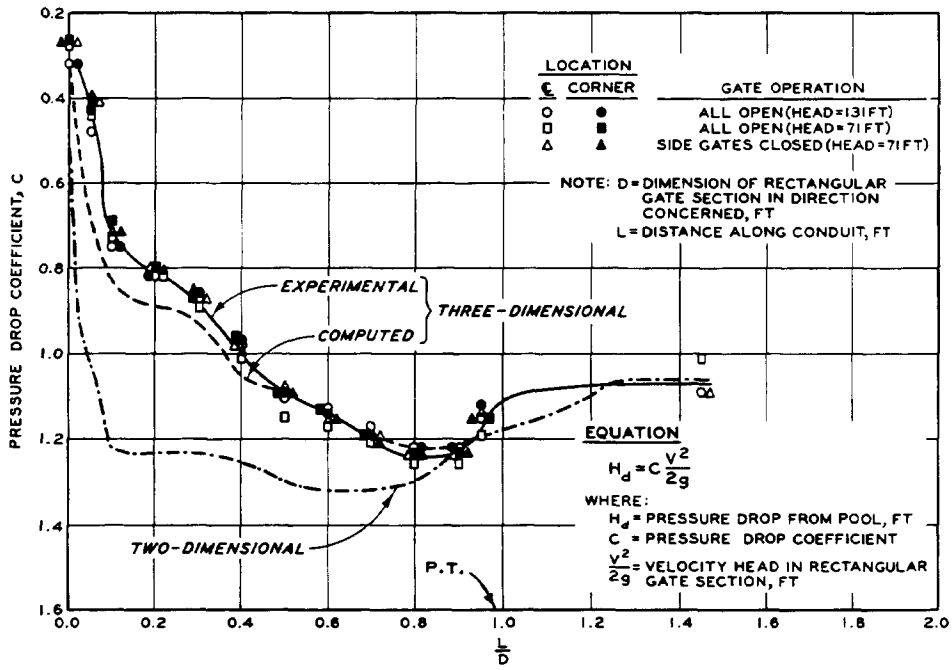


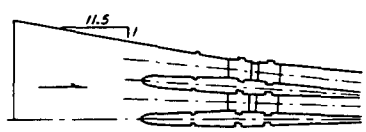
DEFINITION SKETCH

CONDUIT HEIGHT-WIDTH RATIO = 1.785

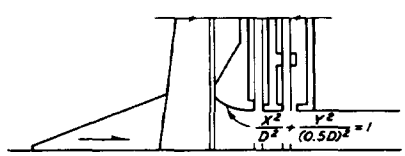
FROM HDC 221-2, 2/1

PRESSURE DROP COEFFICIENTS
ENTRANCE WITH ROOF CURVE ONLY





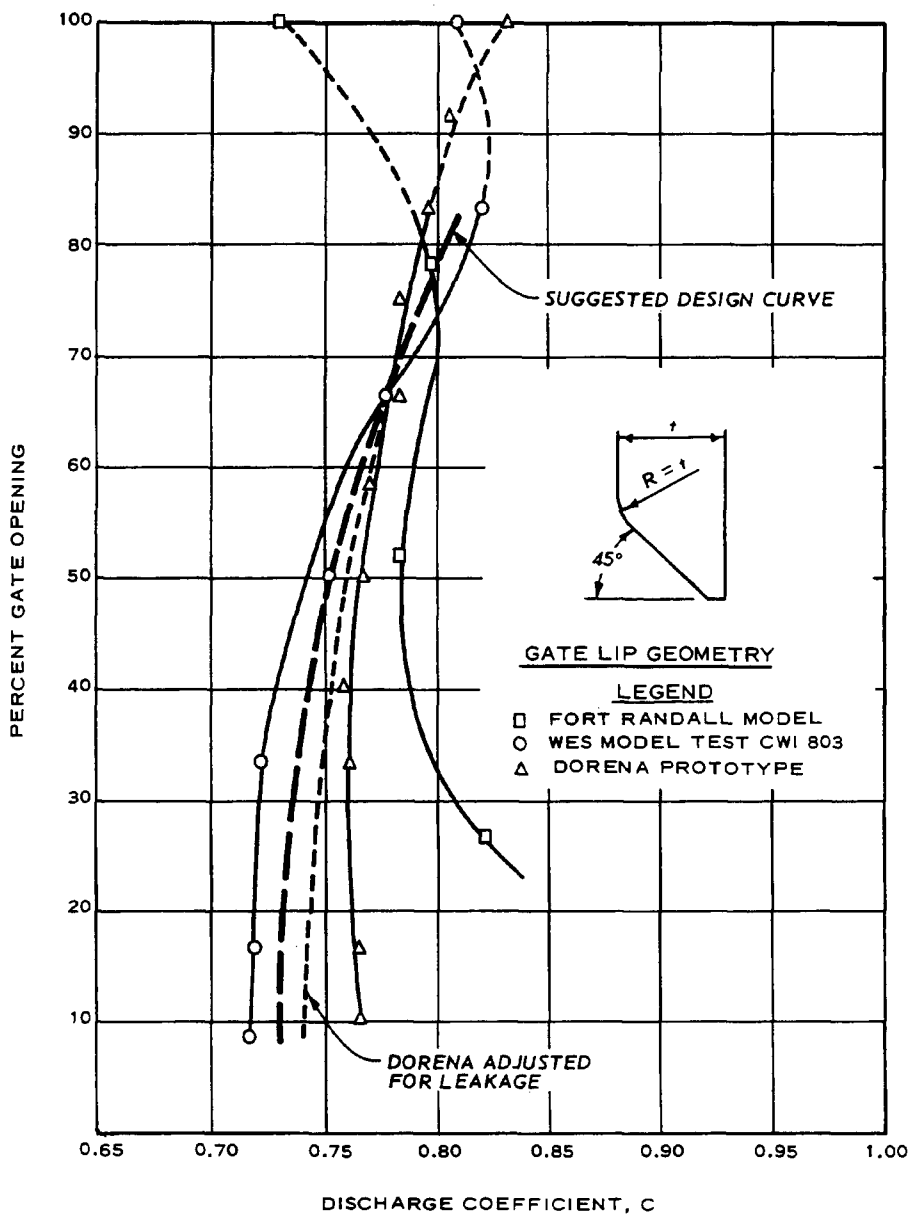
PLAN



ELEVATION

FROM HDC 221-3

CONDUIT ENTRANCES WITH ROOF CURVE AND SIDE FLARE



BASIC EQUATION

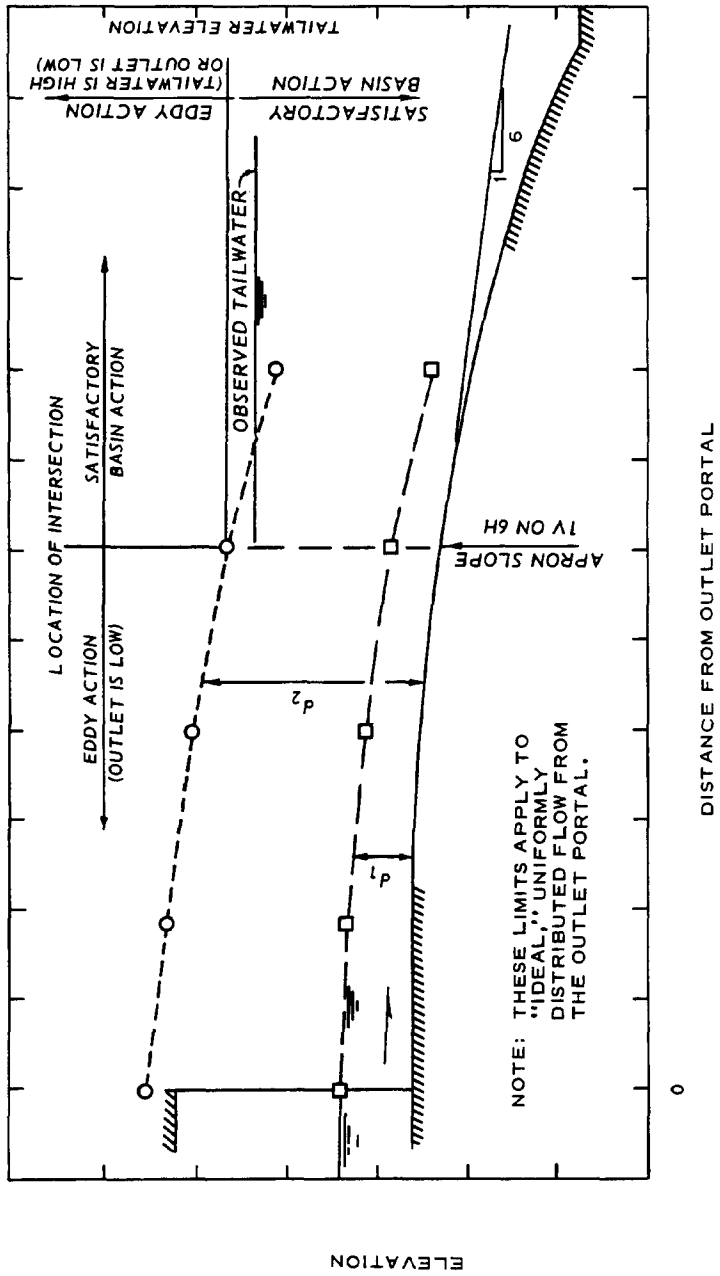
$Q = CG_oB\sqrt{2gH}$

WHERE:

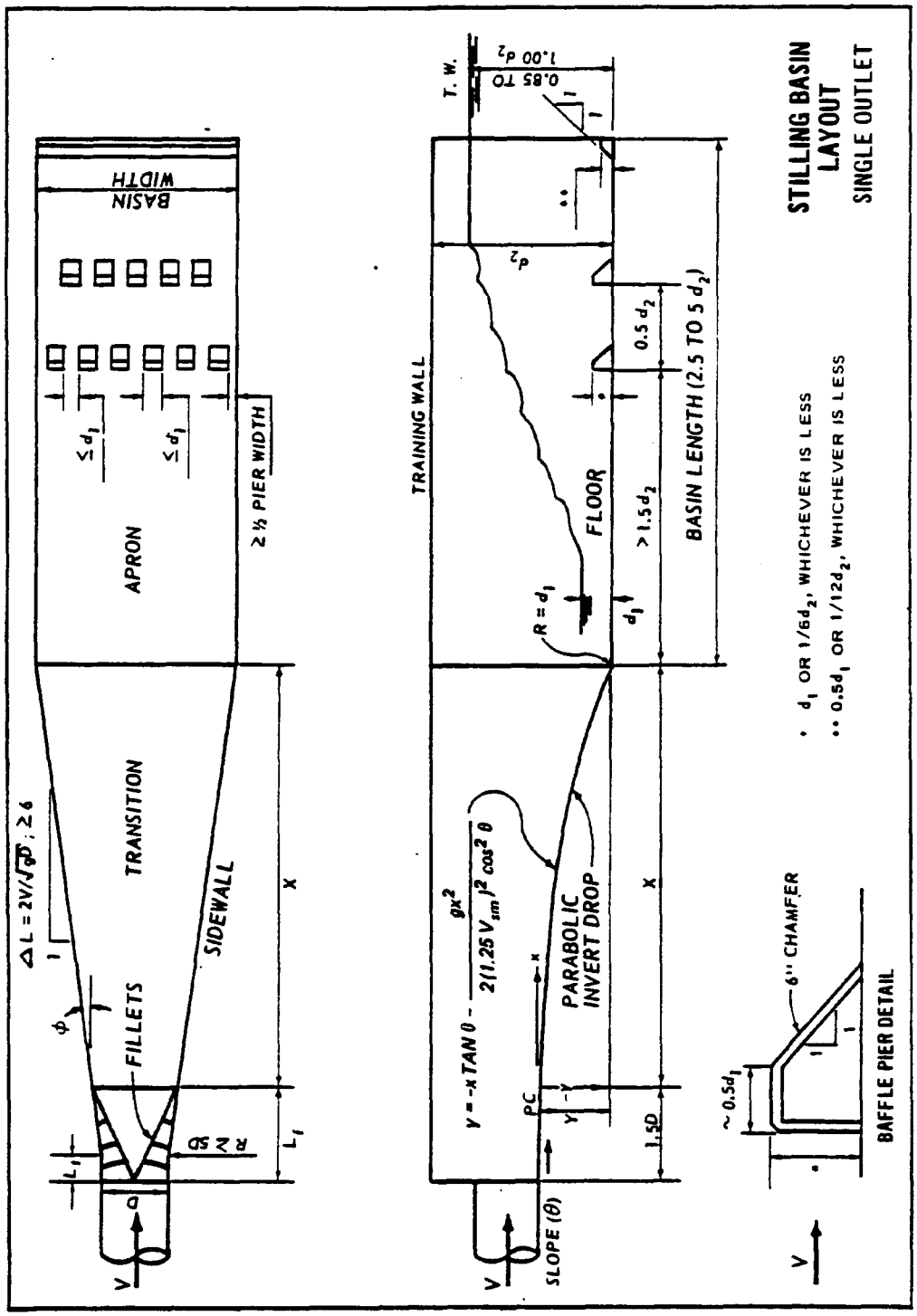
Q = DISCHARGE, CFS
C = DISCHARGE COEFFICIENT
G_o = GATE OPENING, FT
B = GATE WIDTH, FT
H = HEAD, FT: ENERGY GRADE LINE TO ℄ OF GATE OPENING

DISCHARGE COEFFICIENTS
VERTICAL-LIFT GATE

FROM HDC 320-1



DEFINITION SKETCH
LOW-LEVEL OUTLETS


STILLING BASIN
LAYOUT
SINGLE OUTLET
BASIN WIDTH
APRON
≤ d_1
≤ d_1
≥ ½ PIER WIDTH
TRANSITION
SIDEWALL
FILLETS
$\Delta L = 2V/\sqrt{gD}$; ≥ 6
ϕ
L_1
R ≥ 5D
X
L_1
V
TRAINING WALL
T. W.
0.85 TO 1.00 d_2
d_2
0.5 d_2
FLOOR
> 1.5 d_2
BASIN LENGTH (2.5 TO 5 d_2)
R = d_1
d_1
$y = -x \tan\theta - \frac{gx^2}{2(1.25 V_{sm})^2 \cos^2\theta}$
PARABOLIC
INVERT DROP
PC
Y
X
1.5D
SLOPE (θ)
V
• d_1 OR 1/6d_2, WHICHEVER IS LESS
•• 0.5d_1 OR 1/12d_2, WHICHEVER IS LESS
6" CHAMFER
~ 0.5d_1
BAFFLE PIER DETAIL
V

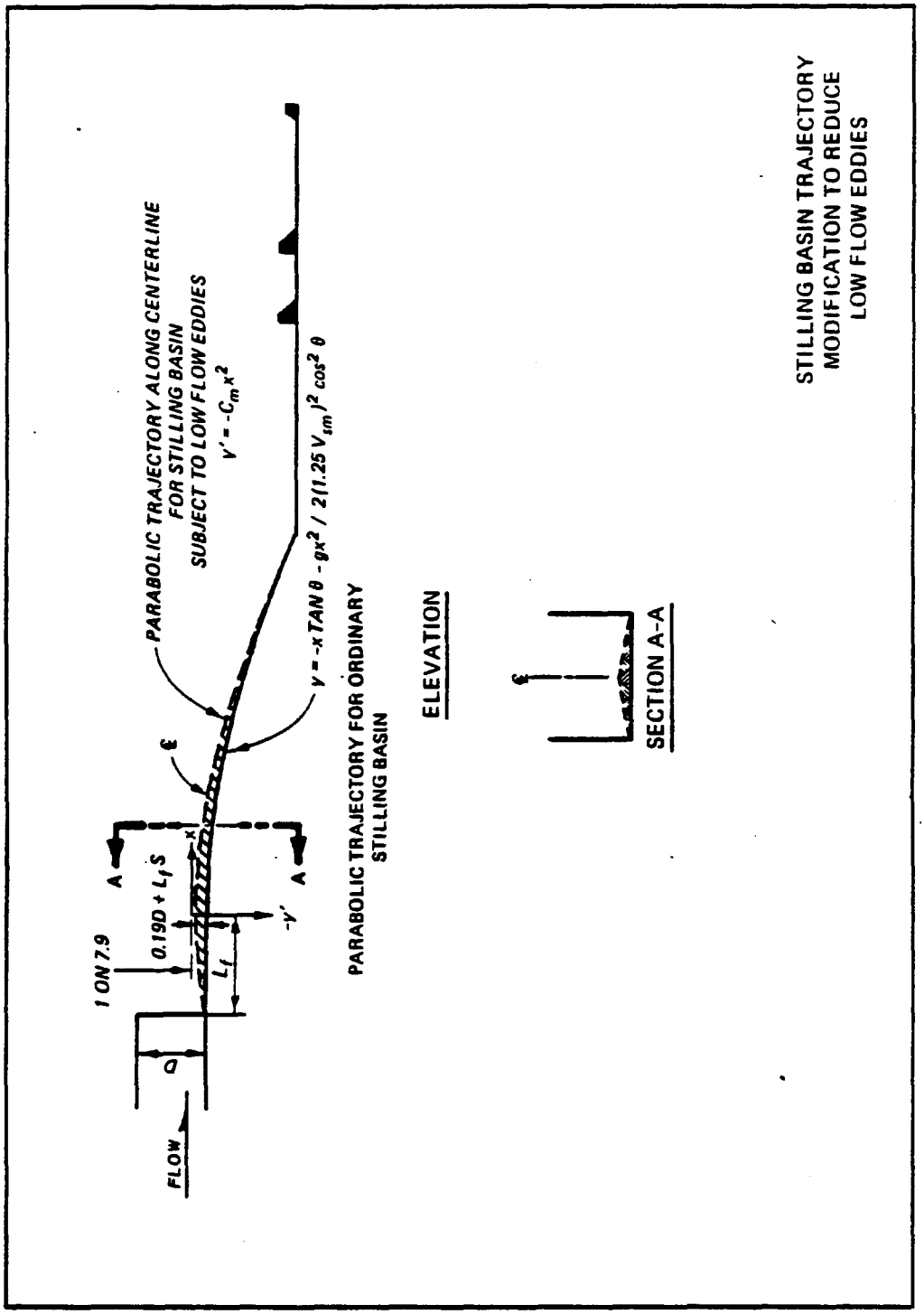
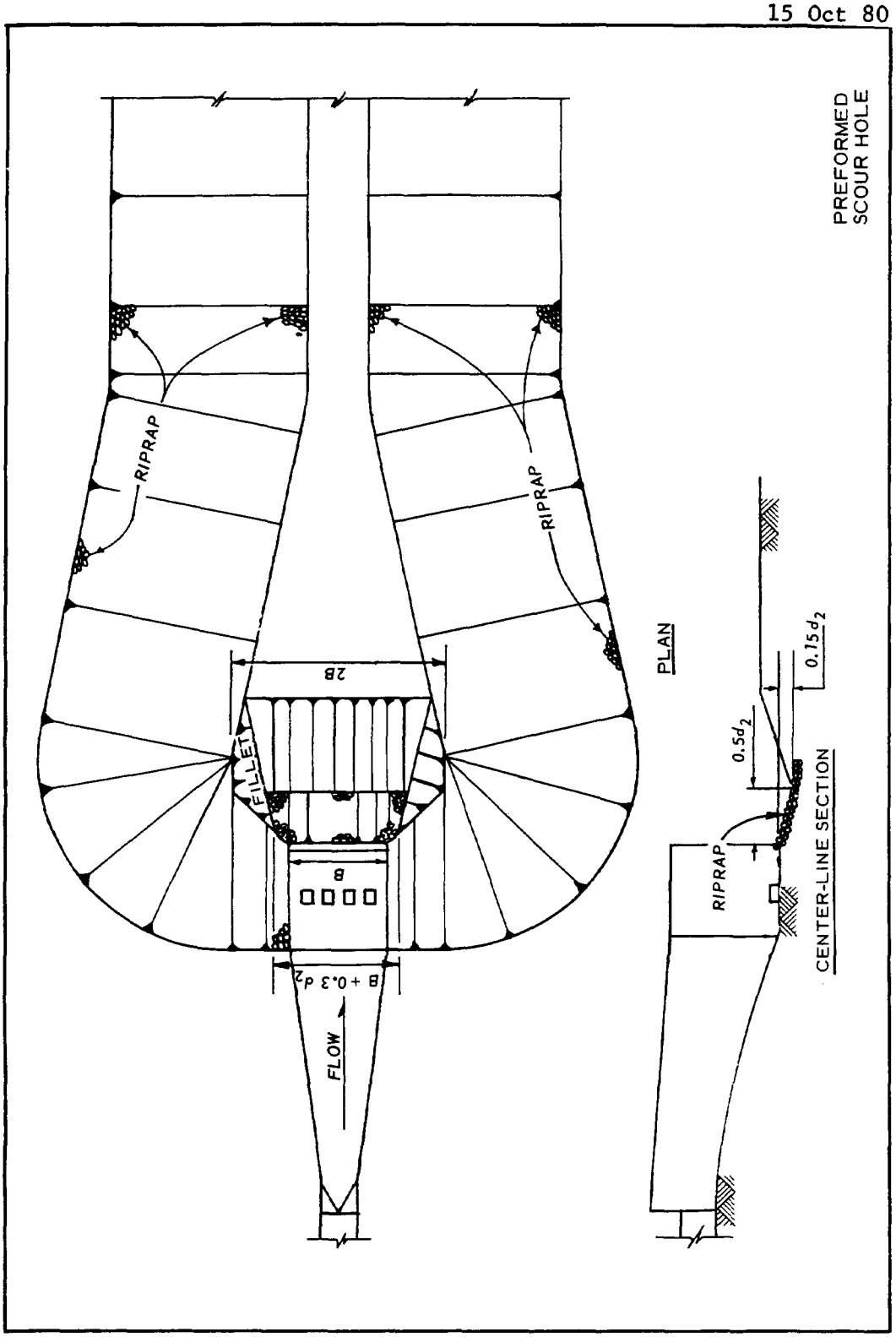
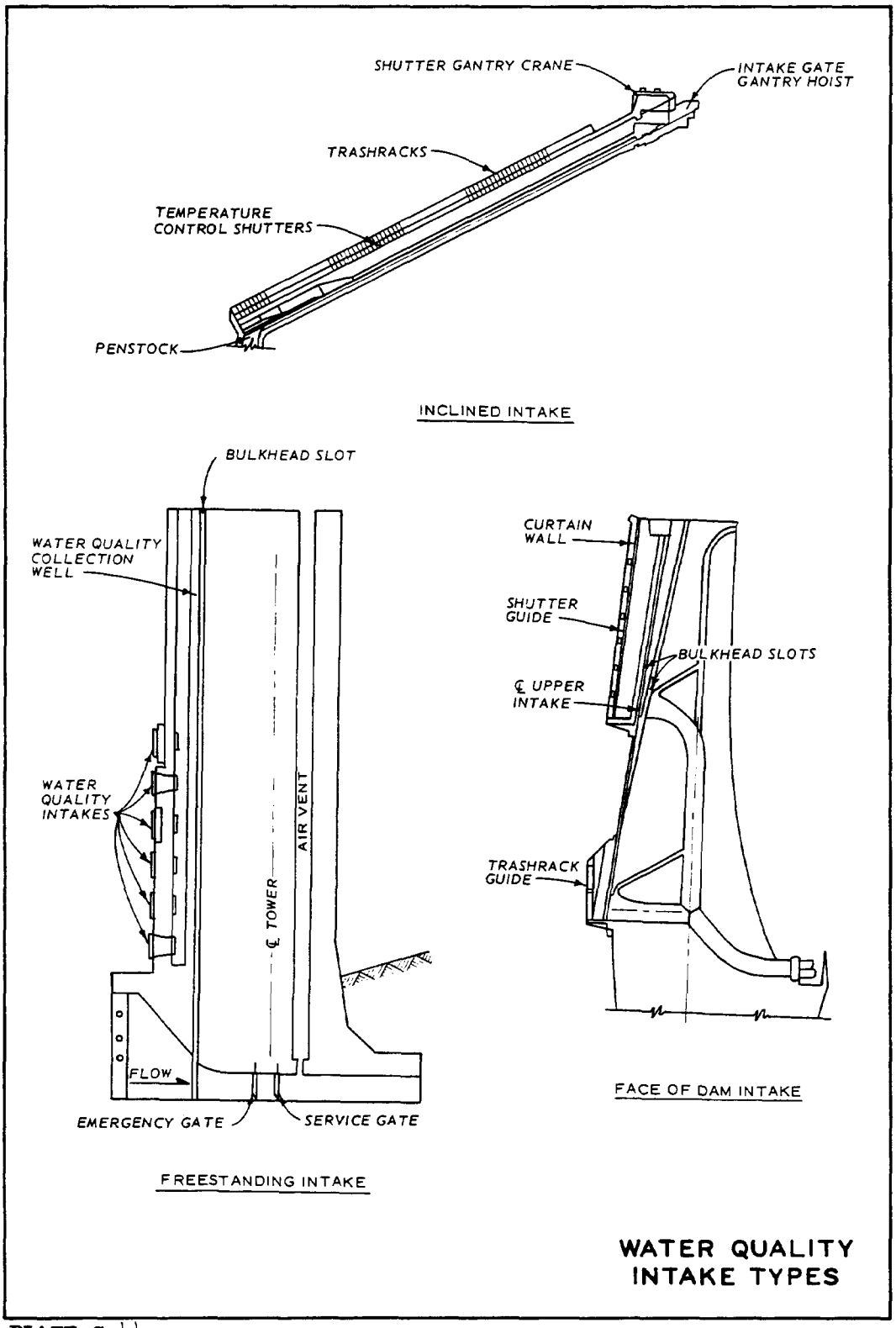
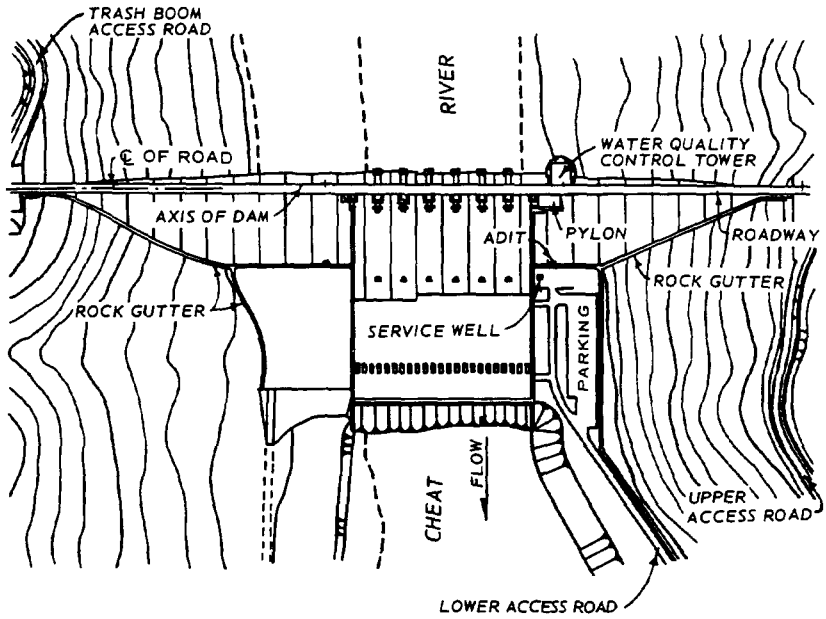

PARABOLIC TRAJECTORY ALONG CENTERLINE
FOR STILLING BASIN
SUBJECT TO LOW FLOW EDDIES
$y' = -C_m x^2$
$y = -x \tan\theta - gx^2 / 2(1.25 V_{sm})^2 \cos^2\theta$
PARABOLIC TRAJECTORY FOR ORDINARY
STILLING BASIN
ELEVATION
SECTION A-A
STILLING BASIN TRAJECTORY
MODIFICATION TO REDUCE
LOW FLOW EDDIES
1 ON 7.9
$0.19D + L_f S$
L_f
$-y'$
A
A
a
FLOW

PLATE C-41A

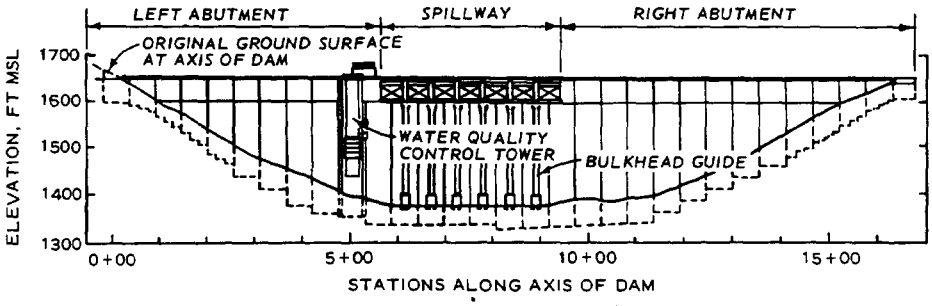

PREFORMED
SCOUR HOLE
RIPRAP
RIPRAP
2B
FILLET
B
B + 0.3 d_2
FLOW
PLAN
$0.15 d_2$
$0.5 d_2$
RIPRAP
CENTER-LINE SECTION



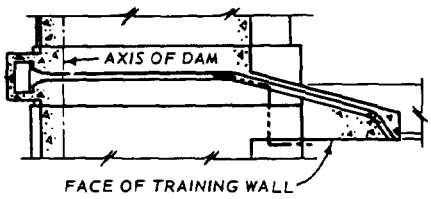
WATER QUALITY INTAKE TYPES



PLAN

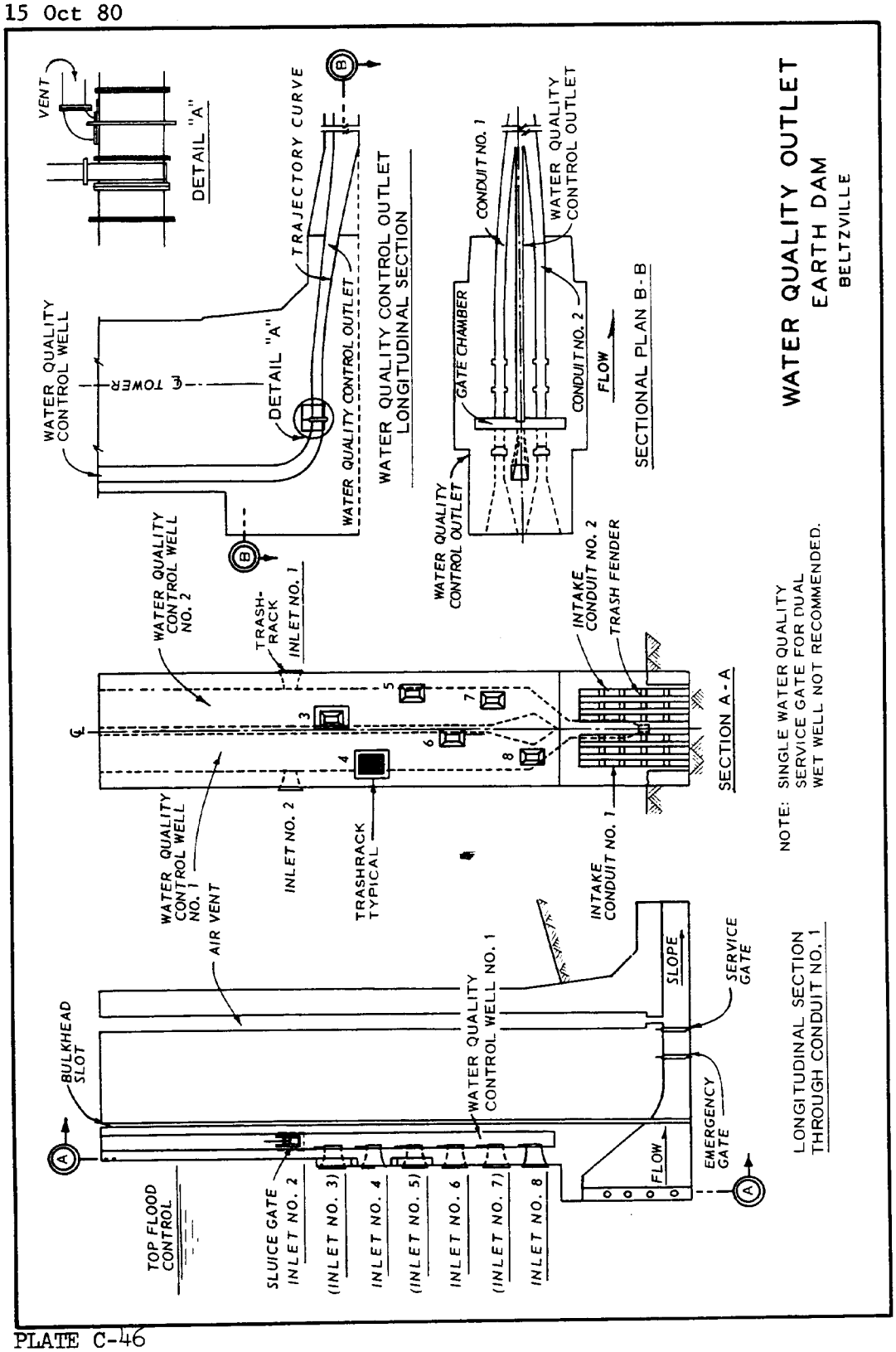


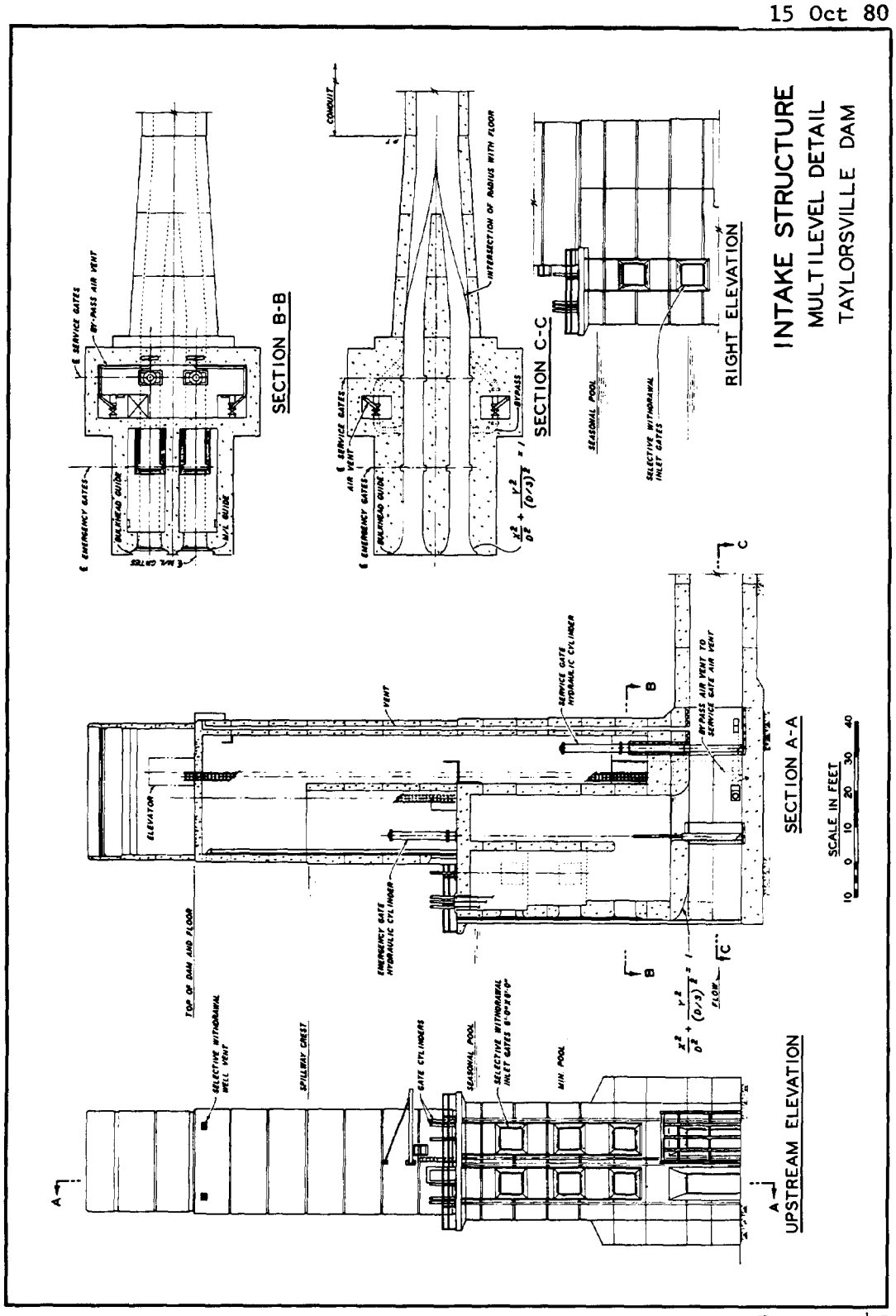
ELEVATION LOOKING DOWNSTREAM

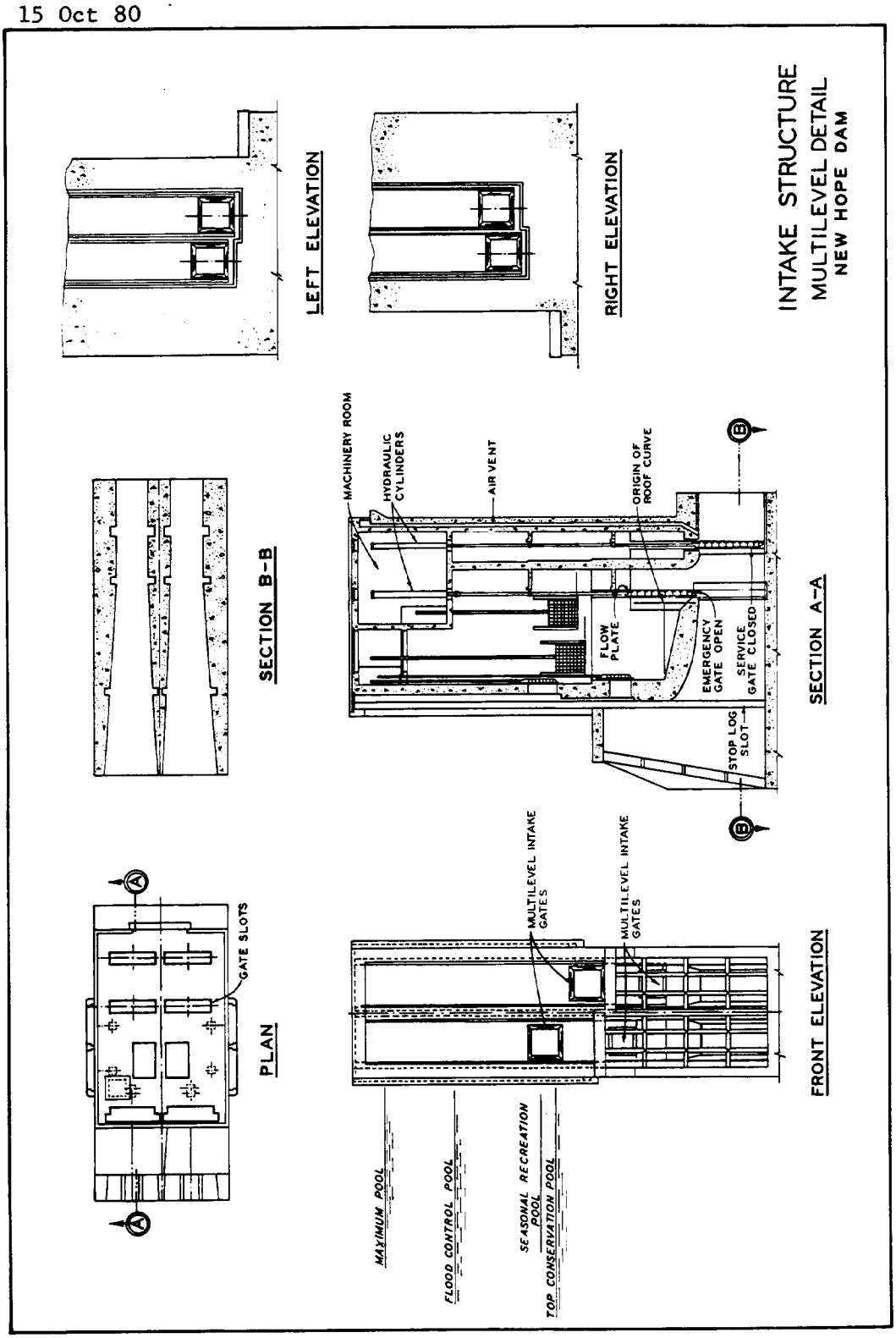


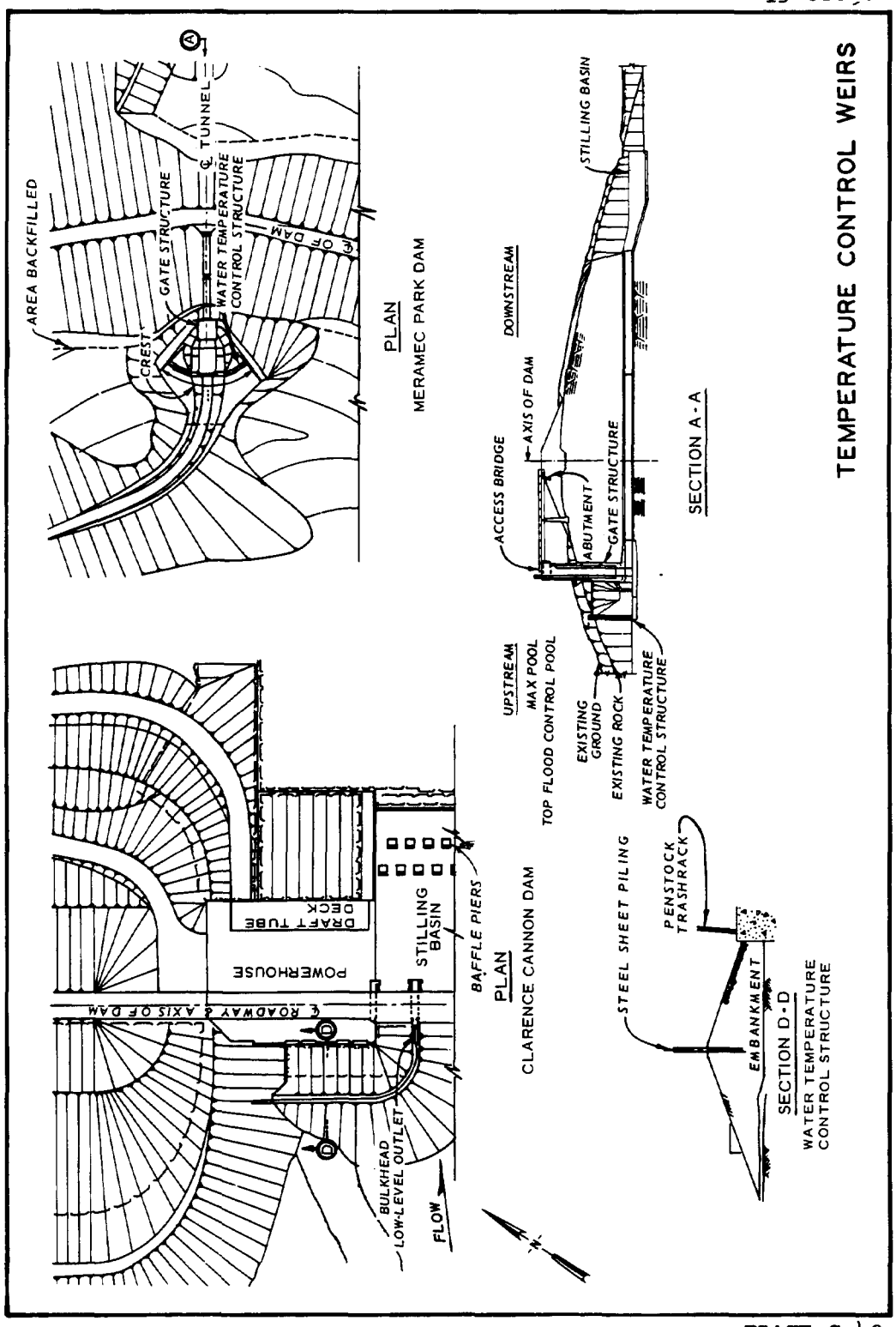
SECTIONAL PLAN OF CONTROL TOWER AND SLUICE

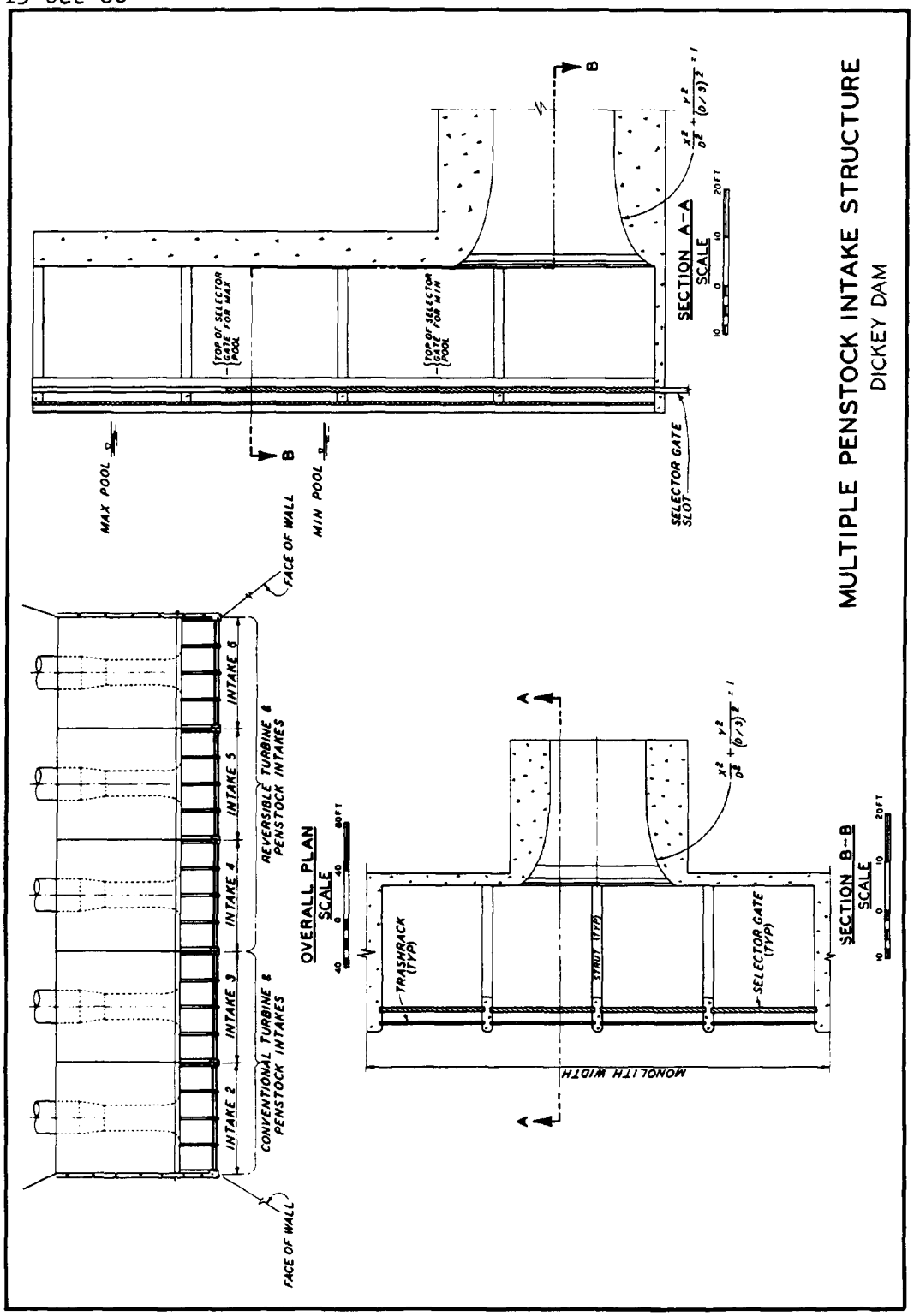
WATER QUALITY OUTLET
CONCRETE GRAVITY DAM
ROWLESBURG DAM

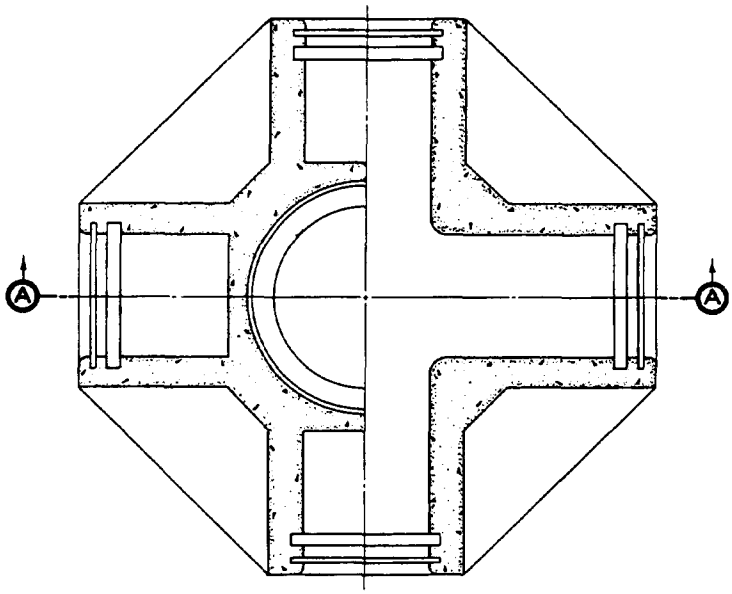

WATER QUALITY OUTLET
EARTH DAM
BELTZVILLE
DETAIL "A"
VENT
WATER QUALITY CONTROL WELL
℄ TOWER
DETAIL "A"
TRAJECTORY CURVE
WATER QUALITY CONTROL OUTLET
WATER QUALITY CONTROL OUTLET LONGITUDINAL SECTION
CONDUIT NO. 1
WATER QUALITY CONTROL OUTLET
GATE CHAMBER
CONDUIT NO. 2
FLOW
SECTIONAL PLAN B-B
WATER QUALITY CONTROL OUTLET
WATER QUALITY CONTROL WELL NO. 2
TRASH-RACK
INLET NO. 1
INTAKE CONDUIT NO. 2
TRASH FENDER
SECTION A-A
NOTE: SINGLE WATER QUALITY SERVICE GATE FOR DUAL WET WELL NOT RECOMMENDED.
WATER QUALITY CONTROL WELL NO. 1
INLET NO. 2
TRASHRACK TYPICAL
INTAKE CONDUIT NO. 1
AIR VENT
WATER QUALITY CONTROL WELL NO. 1
SLOPE
SERVICE GATE
BULKHEAD SLOT
EMERGENCY GATE
FLOW
LONGITUDINAL SECTION THROUGH CONDUIT NO. 1
TOP FLOOD CONTROL
SLUICE GATE
INLET NO. 2
(INLET NO. 3)
INLET NO. 4
(INLET NO. 5)
INLET NO. 6
(INLET NO. 7)
INLET NO. 8


SECTION B-B
SECTION C-C
RIGHT ELEVATION
INTAKE STRUCTURE
MULTILEVEL DETAIL
TAYLORSVILLE DAM
SECTION A-A
UPSTREAM ELEVATION
SCALE IN FEET
ELEVATOR
VENT
SERVICE GATE HYDRAULIC CYLINDER
EMERGENCY GATE HYDRAULIC CYLINDER
TOP OF DAM AND FLOOR
SELECTIVE WITHDRAWAL WELL VENT
SPILLWAY CREST
GATE CYLINDERS
SEASONAL POOL
MIN. POOL
SELECTIVE WITHDRAWAL INLET GATES
BYPASS AIR VENT TO SERVICE GATE AIR VENT
FLOW
CONDUIT
INTERSECTION OF RADIUS WITH FLOOR
BULKHEAD GUIDE
W/L GUIDE
EMERGENCY GATES
SERVICE GATES
BYPASS
AIR VENT

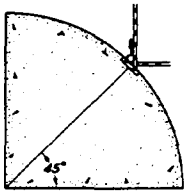

LEFT ELEVATION
RIGHT ELEVATION
INTAKE STRUCTURE
MULTILEVEL DETAIL
NEW HOPE DAM
SECTION B-B
MACHINERY ROOM
HYDRAULIC CYLINDERS
AIR VENT
ORIGIN OF ROOF CURVE
FLOW PLATE
EMERGENCY GATE OPEN
SERVICE GATE CLOSED
STOP LOG SLOT
SECTION A-A
GATE SLOTS
PLAN
MULTILEVEL INTAKE GATES
MULTILEVEL INTAKE GATES
FRONT ELEVATION
MAXIMUM POOL
FLOOD CONTROL POOL
SEASONAL RECREATION POOL
TOP CONSERVATION POOL


TEMPERATURE CONTROL WEIRS
AREA BACKFILLED
CREST
GATE STRUCTURE
WATER TEMPERATURE CONTROL STRUCTURE
℄ OF DAM
℄ TUNNEL
PLAN
MERAMEC PARK DAM
STILLING BASIN
DOWNSTREAM
AXIS OF DAM
ACCESS BRIDGE
ABUTMENT
GATE STRUCTURE
SECTION A-A
UPSTREAM
MAX POOL
TOP FLOOD CONTROL POOL
EXISTING GROUND
EXISTING ROCK
WATER TEMPERATURE CONTROL STRUCTURE
POWERHOUSE
DRAFT TUBE DECK
STILLING BASIN
BAFFLE PIERS
℄ ROADWAY & AXIS OF DAM
BULKHEAD
LOW-LEVEL OUTLET
FLOW
PLAN
CLARENCE CANNON DAM
STEEL SHEET PILING
PENSTOCK TRASHRACK
EMBANKMENT
SECTION D-D
WATER TEMPERATURE CONTROL STRUCTURE


MULTIPLE PENSTOCK INTAKE STRUCTURE
DICKEY DAM
SECTION A-A
SCALE
0 10 20 FT
TOP OF SELECTOR GATE FOR MAX POOL
TOP OF SELECTOR GATE FOR MIN POOL
MAX POOL
MIN POOL
B
B
SELECTOR GATE SLOT
FACE OF WALL
OVERALL PLAN
SCALE
0 40 80 FT
INTAKE 2
INTAKE 3
INTAKE 4
INTAKE 5
INTAKE 6
CONVENTIONAL TURBINE & PENSTOCK INTAKES
REVERSIBLE TURBINE & PENSTOCK INTAKES
FACE OF WALL
SECTION B-B
SCALE
0 10 20 FT
TRASHRACK (TYP)
STRUT (TYP)
SELECTOR GATE (TYP)
MONOLITH WIDTH
A
A

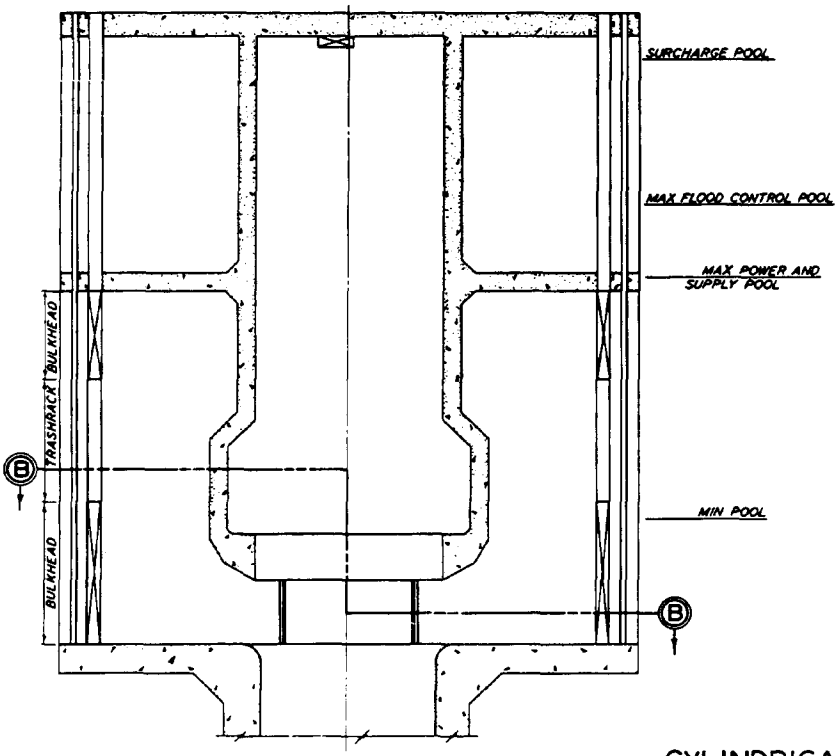


SECTIONAL PLAN B-B



GATE SEAL AT WATER PASSAGE

NOT TO SCALE



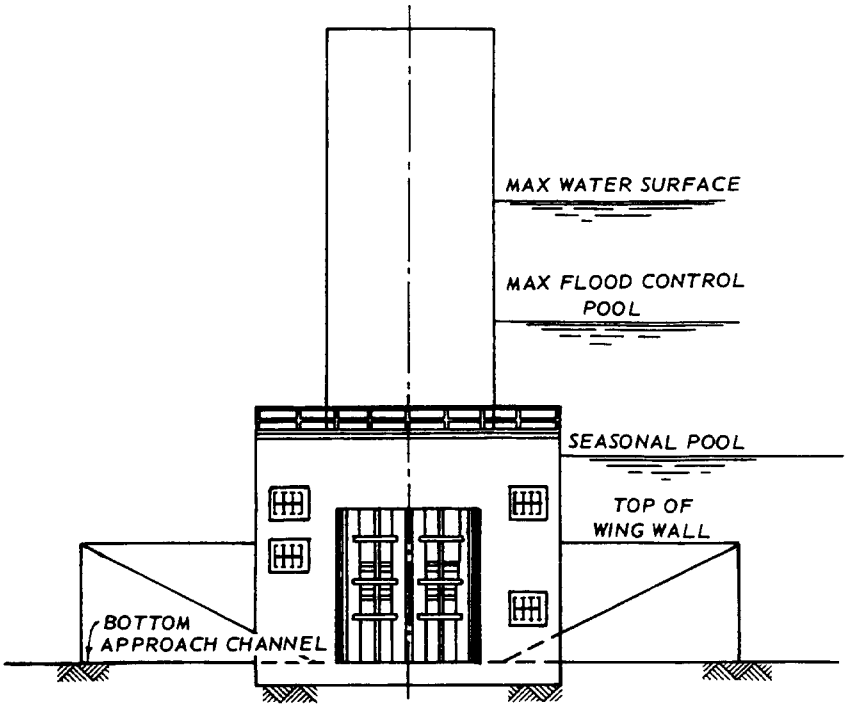
SECTION A-A

SCALE IN FEET

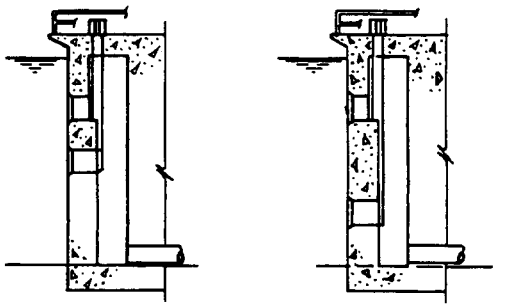
10 0 10 20 30 40

CYLINDRICAL GATE INTAKE TOWER

DE GRAY DAM



UPSTREAM ELEVATION



LEFT SELECTIVE WITHDRAWAL WELL

RIGHT SELECTIVE WITHDRAWAL WELL

WATER QUALITY INTAKE
EARTH DAM
BEECH FORK