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Soil Conservation Service

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TECHNICAL RELEASE NO. 70
210-VI

SUBJECT: ENG - HYDRAULIC PROPORTIONING OF TWO-WAY COVERED BAFFLE INLET RISER

Purpose. To distribute Technical Release No. 70 - Hydraulic Proportioning of Two-Way Covered Baffle Inlet Riser

Effective Date. Effective when received.

Explanation. The information contained in Technical Release No. 70 was initially developed and presented as a paper at the 19th Winter Meeting of the American Society of Agricultural Engineers in Chicago, Illinois. The paper was subsequently modified to provide the documentation for proportioning of the two-way covered baffle inlet to risers. The national standard detail drawings for construction of spillway inlet risers, based upon these proportions, were designed using the criteria shown on ES-232. The index to the available drawings is in ES-231. Both of the ES drawings are contained in Design Note No. 18.

Guidance is included for special inlet designs when spillway conduit discharge velocities exceed 30 feet per second. These guides have been developed based upon laboratory model testing. The development of the weir proportions is contained in the appendix.

Distribution. Sufficient copies are being distributed to the States and NTC's so that each practicing professional engineer may receive one. Additional copies may be obtained from Central Supply by ordering TR-70.

Filing. A copy should be filed with other technical releases.

Paul M. Howard

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DIST: See reverse

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REMARKS

TECHNICAL RELEASE

NUMBER 70

HYDRAULIC PROPORTIONING OF TWO-WAY COVERED BAFFLE INLET RISER

SEPTEMBER 1983

U.S. DEPARTMENT OF AGRICULTURE

SOIL CONSERVATION SERVICE

ENGINEERING

PREFACE

This Technical Release presents the structural layout proportioning for the two-way baffle inlet on a covered riser. The hydraulic performance, based on model studies that were used as a basis for the proportioning, are reported by Wendell R. Gwinn in the Transactions of the American Society of Agricultural Engineering, Volume 19, No. 1, pages 97-104 and 107, 1976.

The idea of the baffle inlet was conceived by M. M. Culp, former head design engineer, Soil Conservation Service, Washington, D.C. The baffle inlet was developed to overcome the limitation of the standard two-way covered riser described in Technical Release No. 29 that does not permit encroachment of the ground surface, embankment or sediment pool, into the area of the trashrack below the weir crest elevation. Numerous variations of the original concept have been tested at the SEA-AR Hydraulic Laboratory at Stillwater, Oklahoma. Results of the initial model testing are contained in the 1970 Annual Report for the Water Conservation Structures Laboratory, Stillwater, Oklahoma, authored by W. R. Gwinn, G. G. Hebaus, and W. O. Ree.

The inlet of drop inlet spillways for reservoir outlets can be designed with a high degree of confidence that performance will be satisfactory. This is a result of experience gained through exhaustive model studies and field performance by using procedures contained in this Technical Release and in Technical Release No. 29.

This Technical Release was prepared by Robert A. Fronk, Head of the Engineering Staff, South National Technical Center, Fort Worth, Texas. The appendix was developed by Quinton K. Milhollin, design engineer, at the same location.

NOMENCLATURE

A = net area (projection on a horizontal plane) through both sides of inlet, in square feet.

B = number of baffles on one side of inlet.

C = weir discharge coefficient where $Q = C L_w H^{1.5}$.

D = inside width of riser (equal to the conduit diameter for pipe or width for a rectangular box), in feet.

d = depth of baffles, in inches.

f = vertical overlap between baffles, in inches.

H = stage of water surface over weir crest, in feet.

K_e = entrance loss coefficient.

L = inside length of the baffle inlet in the upstream-downstream direction, in feet.

L_o = length of cover slab overhang, measured from outside of riser to outside edge of cover slab, in feet.

L_w = weir length of one side of the riser, in feet.

m = number of interior walls.

N = distance between the weir crest and the underside of the cover slab, in feet.

Q = discharge, in cubic feet per second.

Q_p = priming discharge, in cubic feet per second.

Q_5 = discharge when water surface is 5 ft. above the top of the cover slab, in cubic feet per second.

s = clear horizontal distance between baffles, in inches.

t = width of the interior walls, in inches.

u = clear vertical distance between cover slab and first baffle, in inches.

V = average velocity, in feet per second.

w = width of baffle, in inches.

INTRODUCTION

This technical release presents criteria for the design of baffle inlets and discusses their use.

The basic purpose of any spillway inlet and its associated trashrack is to intercept debris that could plug the spillway after passing through the inlet. Ideally, the trashrack should pass all debris small enough to pass through all other elements of the spillway and intercept anything that could become lodged. Also, ideally, it should function with a minimum effect on the discharge capacity of the spillway.

Early experiments on trashracks for drop inlet spillways for reservoir outlets demonstrated that, in the weir flow range, open inlets resulted in a drawdown of the surface of the approaching flow, attracting floating debris. Floating debris has consistently been the major cause for plugging of drop inlet spillways. When a solid wall or skirt, extending above and below the weir crest level (Fig. 1), was placed around the inlet at a reasonable distance from the weir crest, surface flow and drawdown outside the skirt was eliminated, and trash accumulation on the rack was reduced. The skirt, therefore, is a desirable feature for a trashrack. Based on this thinking, the Soil Conservation Service (SCS) standard covered top inlet [1/] has evolved in which flow into the spillway must enter through this trashrack below the skirt.

Nonfloating debris, such as sediment and similar stream bedload material, must also be considered because it can plug the inlet and

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1/ The standard covered top inlet is described in Technical Release No. 29, Hydraulics of Two-Way Covered Risers.

spillway by encroachment upon the flow area below the crest of the inlet. Therefore, in a reservoir that is expected to fill to the spillway weir crest with sediment, the space between the inlet endwalls below the weir crest can become filled with trash and sediment. The baffle inlet was developed to accommodate this situation by permitting flow to enter the spillway above the level of the weir crest and still retain the advantages of the skirt. In this inlet, the trashrack members themselves are segments of a skirt (fig. 2), arranged in stair-step fashion, which can exclude floating trash. Model and prototype tests and field observations of actual installations of baffle inlets have demonstrated that they function well.

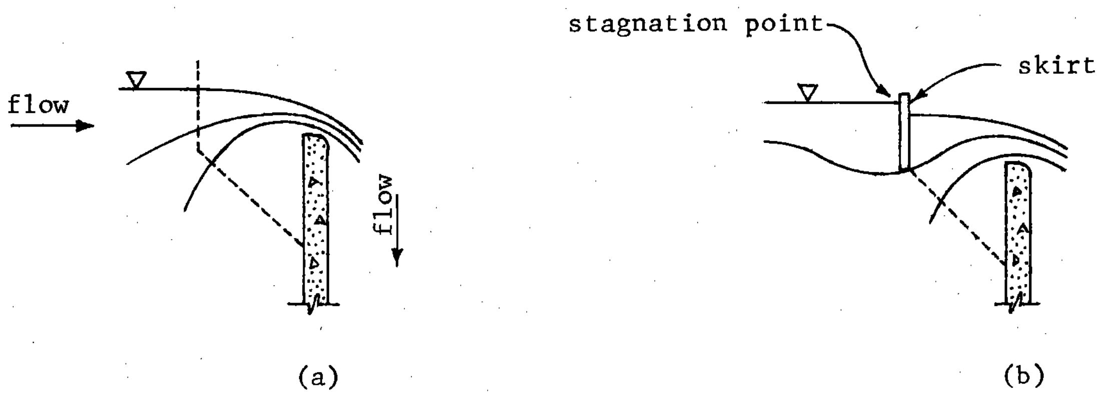

Figure 1--Water surface for flow without (a) and with (b) a solid skirt

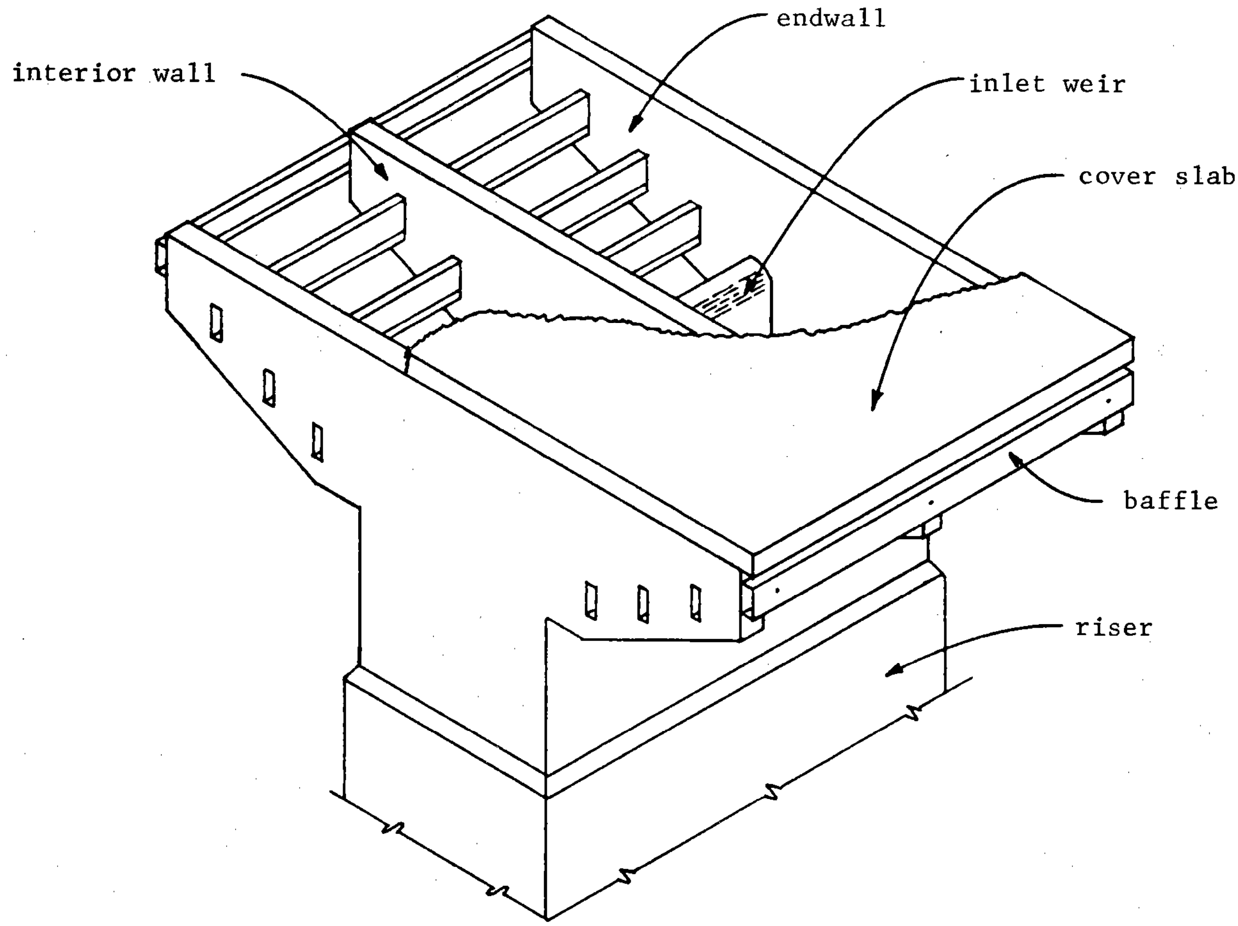

Figure 2--Isometric view from top of a baffle inlet

APPLICATION

The baffle inlet was developed to overcome the sediment-related limitations of the standard covered riser. This inlet is usable on risers where the maximum sediment or backfill elevation is anticipated to be at or near the weir crest, or where the riser is to be located in an embankment with its weir crest elevation at or near the embankment berm elevation. Reservoir model studies indicate that a scour hole develops around the baffle inlet if it is backfilled to the weir crest. The inlet's performance is better if backfill adjacent to the inlet is kept to at least one-half of the riser width, D, below the weir crest (fig. 3). The baffle inlet is easily adapted to box-type low-stage inlets.

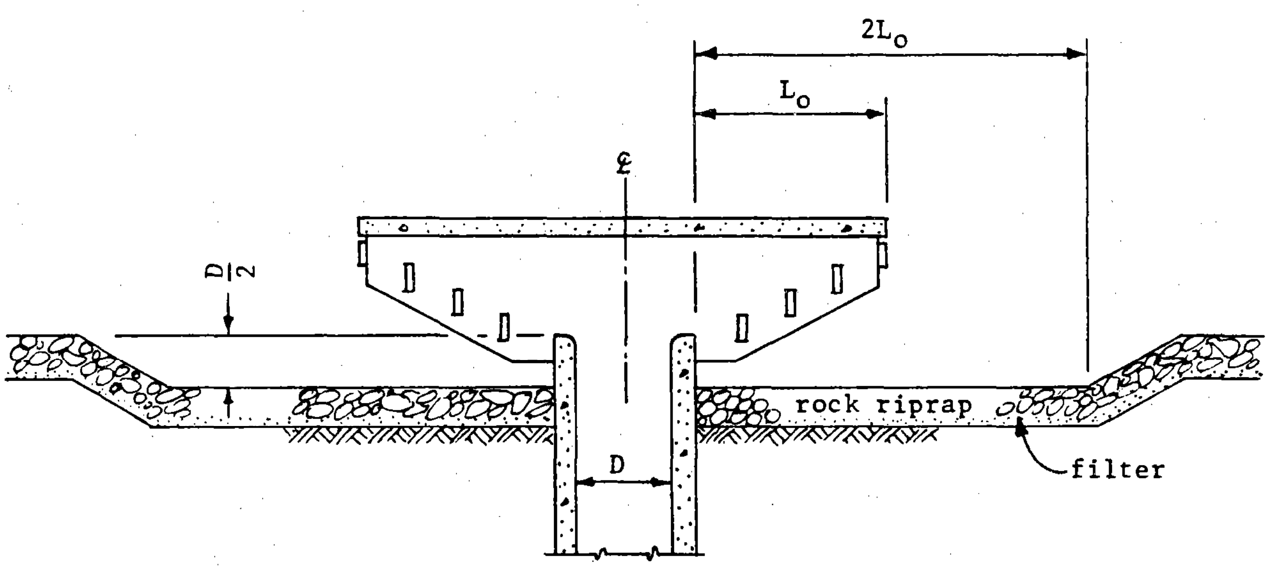

Figure 3--Longitudinal section along an embankment berm containing a baffle inlet riser

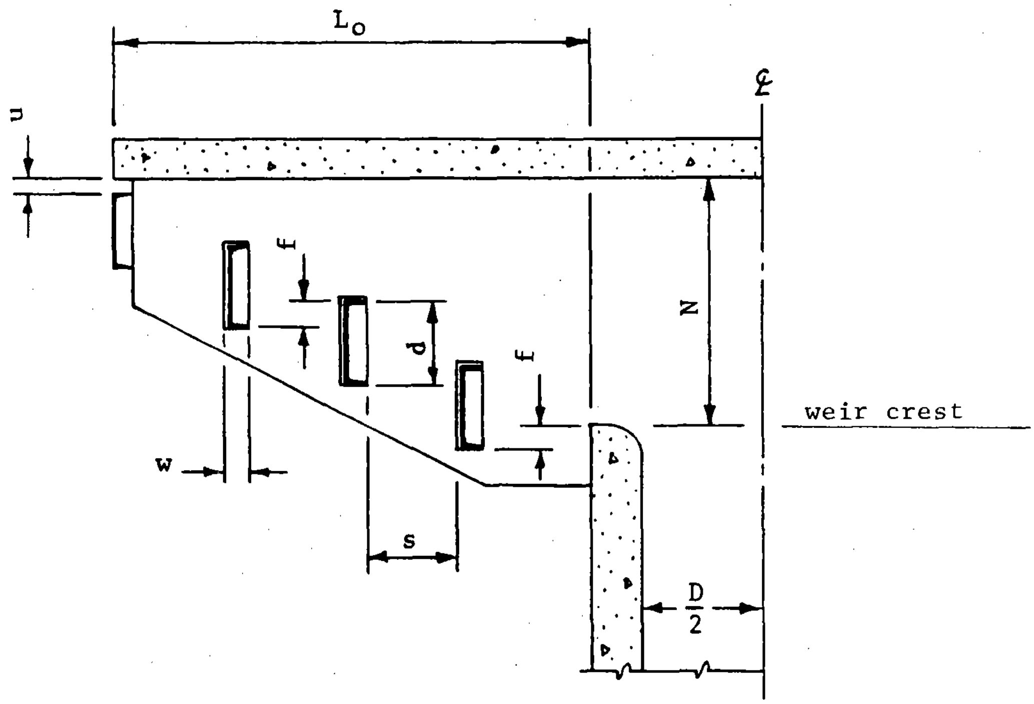

Figure 4--Half section of a standard baffle inlet

DESIGN

The design of the standard baffle inlet is dictated by the following criteria (See fig. 4 for dimensions):

1. The average velocity (V) through the net trashrack area is not to exceed 2.5 ft/s when the water surface in the reservoir is 5 ft above the top of the cover slab.

2. The clear horizontal distance between baffles (s) is to be no more than one-half and no less than one-third the riser width (D).

3. The baffle inlet is to be symmetrical about the longitudinal centerline of the riser.

4. The inside length of the baffle inlet (L) in the upstream-downstream direction is to be equal to or greater than 3D.

5. The vertical overlap (f) between baffles is to be equal to or greater than 3 in.

6. The clearance (u) between the cover slab and the first baffle is to be no less than 2 in and no more than 3 in.

7. The weir discharge coefficient (C) is 3.1 for clear water (no trash) and 2.0 for trash-laden flow.

8. The entrance loss coefficient (K_e) based on the velocity head in the conduit for full-conduit flow is 0.70 for clear water and 0.75 for flow with trash. These losses are applicable to a pipe conduit riser inlet with a half-round bottom of width D and length 3D or greater, or a rectangular box conduit riser inlet of width D and length equal to or greater than 3 times the box conduit height.

9. The distance (N) between the weir crest and the underside of the cover slab is to be equal to or greater than the head over the weir crest when the conduit primes full flow for "with trash" conditions; i.e., $K_e = 0.75$ and $C = 2.0$.

10. An interior transverse wall may be used to limit the size of rigid trash that can enter the spillway. Inlets on risers with a D of 36 in and greater include an interior transverse wall.

11. Baffle inlets on risers installed in the embankment should be located within a depressed section of the berm (fig. 3). The depression should be D/2 below the weir crest and extend level for a distance $2L_o$ out from the riser. The depression should be lined with rock riprap, having a mean diameter (D_{50}) not less than 6 in.

The following are equations derived from the design criteria for the component parts of the baffle inlet.

1. Determine the weir length (L_w), for one side of the riser, in feet,

$$L_w = L - \frac{mt}{12} \qquad \text{Eq. 1}$$

where L = inside length of riser, in feet,
m = number of interior walls, and
t = width of interior walls, in inches.

2. Determine the height of cover slab above weir crest (N), in feet,

$$Q_p = C\,(2L_w)\,N^{3/2}$$

where Q_p = priming discharge for an inlet with flow entering on two sides, in cubic feet per second.

When C = 2.0, for a single barrel conduit spillway having flow entering a riser inlet from two sides,

$$N = \left(\frac{Q_p}{4L_w}\right)^{2/3} \qquad \text{Eq. 2}$$

3. Determine the number of baffles (B) on one side of inlet,

$$A = 2B\left(\frac{s}{12}\right)L_w = \frac{B\,s\,L_w}{6}$$

where A = net inlet area (including both sides) projected on a horizontal plane through which flow passes, in square feet and

s = spacing between baffles, in inches.

By equating the discharge to the net flow area times the allowable velocity, a relationship for the number of baffles can be developed,

$$Q = VA = \frac{V\ B\ s\ L_w}{6}$$

where Q = discharge, in cubic feet per second and
V = velocity through the baffles, in feet per second.

When the velocity (V) is equal to the maximum allowable of 2.5 ft/s and

$Q = Q_5$ = discharge when water surface is 5 ft above top of cover slab,

determine the minimum number of baffles,

$$B_{min} = \frac{6Q_5}{2.5sL_w} \qquad \text{Eq. 3}$$

where B_{min} = minimum number of baffles on one side of the inlet.

Determine the minimum number of baffles (B_{min}) for the maximum allowable spacing (s).

At $s = 0.5D$ and by substitution in Eq. 3, then,

$$B_{min} = \frac{4.8Q_5}{DL_w}$$

Since B must be a positive integer, use the next larger whole number above B_{min} for B. Use this value of B and solve for the spacing (s) corresponding to a velocity of 2.5 ft/s through the inlet.

$$s = \frac{6Q_5}{2.5BL_w} \qquad \text{Eq. 3a}$$

Use this value of the spacing if s is greater than D/3. If the value of s is less than D/3, use D/3 as the spacing.

4. Determine the depth (d) of baffles, in inches,

$$N = B\,\frac{d-f}{12} + \frac{u}{12}$$

where N = height of cover slab above weir crest, in feet,
B = number of baffles on one side of the inlet,
f = baffle overlap, in inches, and
u = clearance between first baffle and cover slab, in inches.

From this relationship, the baffle depth can be determined by

$$d = \frac{12N - u}{B} + f \qquad \text{Eq. 4}$$

The application of equation 4 may require some trial and error to match d to the depth of a standard structural member. Varying the values of f, u, and N may be necessary to give a practical combination of these variables. The overlap (f) of 3 in is a minimum and may be increased; the clearance (u) may be varied between the values of 2 and 3 in and N may be increased if a satisfactory layout cannot be accomplished by varying f and u.

5. Determine the length of cover slab overhang (L_o) by the relationship

$$L_o = \frac{B\ (s + w)}{12} \qquad \text{Eq. 5}$$

where s = baffle spacing, in inches and
w = baffle width, in inches.

FABRICATION OF THE BAFFLES

American Standard and miscellaneous channels, structural tubing, or reinforced concrete beams can be used for baffles in the inlet. Both the American Standard (C) and the miscellaneous (MC) channels have a narrow application because of the limited selection of member depths. When a channel shape is selected, the minimum web thickness should be not less than 0.375 in. The flanges in a channel baffle should be oriented toward the riser.

Structural tubing (TS) is the most versatile structural shape for baffles. A particular tubing size may be used by itself or in combination with other tubing sizes. Thus, if a baffle depth of 14 in is required, it can be obtained by fastening a 6 x 3-in piece of tubing to an 8- x 3-in piece. The wall thickness of structural steel tubing members should not be less than 0.375 in.

Baffles also can be made of cast-in-place or precast reinforced concrete.

SPECIAL DESIGNS

Riser inlet spillways with hydraulic flow conditions creating pressures less than atmospheric will result in cavitation and possible erosion of the spillway structure. These types of spillways can also develop flow conditions that cause flow separation and nappe flutter at the weir crest and sloshing, gulping, and vibrations in the riser. To eliminate these problems, special design sizes and shapes are recommended when the velocity in the conduit exceeds 30 ft/s. Criteria previously presented are applicable, and the following additional requirements should be met.

1. The weir crest is rounded or streamlined, as shown in figure 5, to prevent weir flow separation and nappe flutter. Refer to the Appendix for the special crest development.

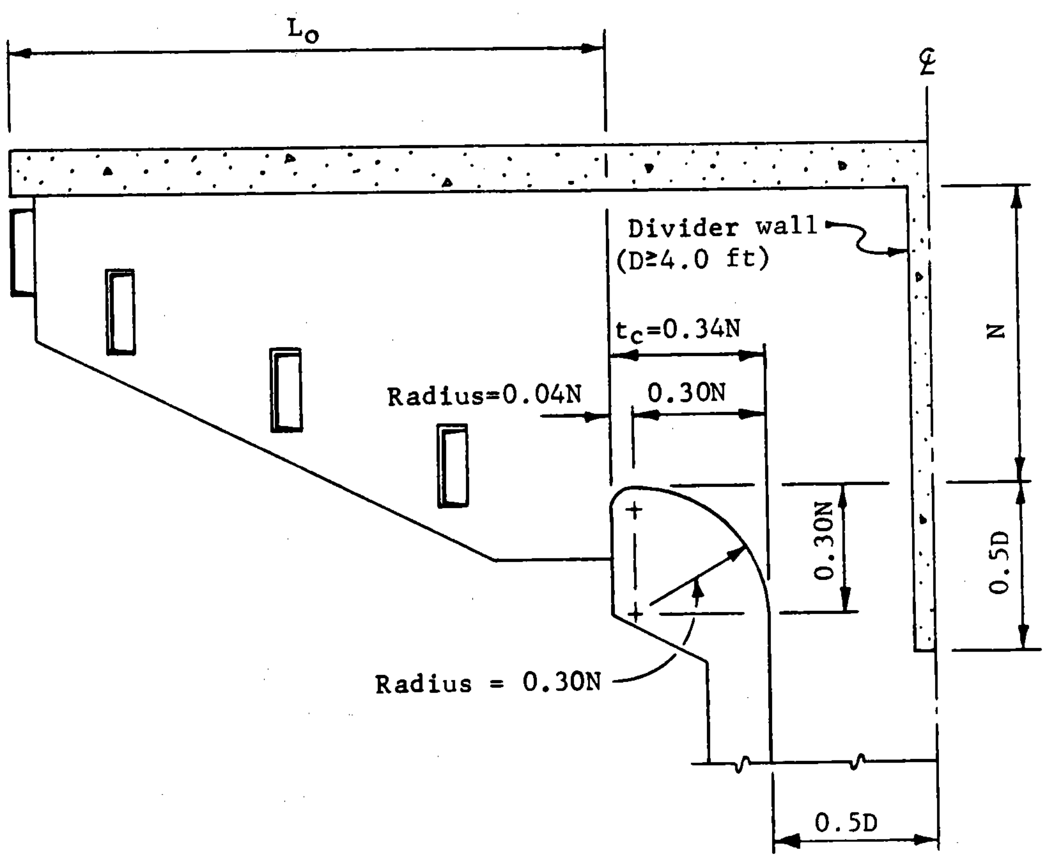

Figure 5--Special weir crest

2. A longitudinal divider wall is to be placed in the inlet as shown in figure 5 to prevent sloshing at crest during priming of riser. Because of riser access limitations, the divider wall should only be placed in risers that are at least 4.0 ft wide.

3. The transition from the riser to the conduit should be designed as shown in figure 6.

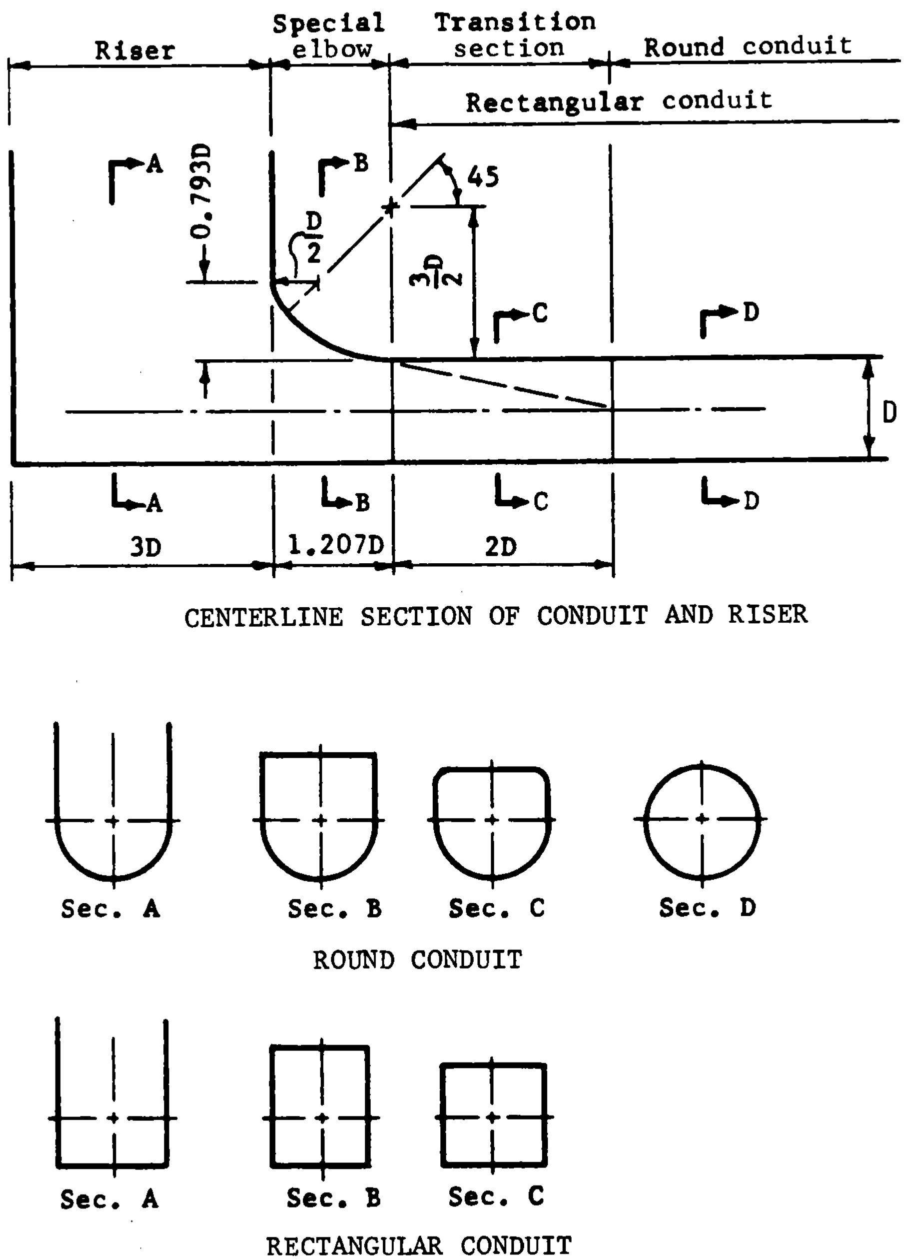

Figure 6--Special elbow and transition section

Example No. 1

Design a baffle inlet with flow entering from two sides for a drop inlet spillway with a single 4 ft 6 in square conduit and a Dx3D riser. The inlet is to have one 10-in transverse wall. The maximum discharge (Q_{max}) through the inlet is 700 ft^3/s; the priming discharge (Q_p) is 600 ft^3/s; and the discharge (Q_5) where the water surface is 5 ft above the top of the cover is 630 ft^3/s.

Maximum average velocity in the conduit is

$$\frac{700}{(4.5)^2} = 34.57 \text{ ft/s} > 30 \text{ ft/s}$$ (Provide for special design considerations.)

Determine the baffle inlet layout.

1. Determine the weir length (L_w).

$$L_w = L - \frac{mt}{12} \qquad \text{Eq. 1}$$

When $L = 3D = 13.5$ ft
$m = 1$
$t = 10$ in.

Then,

$$L_w = 13.5 - \frac{10}{12} = 12.67 \text{ ft.}$$

2. Determine the height of the cover slab (N).

$$N = \left(\frac{Q_p}{4L_w}\right)^{2/3} \qquad \text{Eq. 2}$$

$$N = \left[\frac{600}{4(12.67)}\right]^{2/3} = 5.20 \text{ ft.} \qquad \text{(Use 5 ft 3 in.)}$$

3. Determine the minimum number of baffles (B).

$$B_{min} = \frac{6(Q_5)}{2.5sL_w} \qquad \text{Eq. 3}$$

Let s = 0.5D = 27 in.

Then,

$$B_{min} = \frac{(6)(630)}{(2.5)(27)(12.67)} = 4.42 \qquad \text{(Use 5.)}$$

Adjust the baffle spacing.

$$s = \frac{6(Q_5)}{2.5\ BL_w} \qquad \text{Eq. 3a}$$

At B = 5,

$$s = \frac{(6)(630)}{(2.5)(5)(12.67)} = 23.9 \text{ in} \qquad \text{(Use 24 in.)}$$

A check shows this is valid, since

$$D/3 < 24 \text{ in} < D/2$$
(18 in) (27 in) (OK)

4. Determine the depth of baffles (d).

$$d = \frac{12N - u}{B} + f$$

Try u = 2 in and f = 3 in.

$$d = \frac{12(5.25) - 2}{5} + 3 = 15.2 \text{ in}$$

Try u = 3 in and f = 3 in.

$$d = \frac{12(5.5) - 3}{5} + 3 = 15 \text{ in}$$ (Use 15 in.)

Baffle Member Selection.

a. Structural Steel Tubing.

Fasten a TS 7 x 3 x 0.375 on top of a TS 8 x 3 x 0.375. Then, combined depth = 15 in, width = 3 in, and member wall thickness = 0.375 in.

Then,

$$L_o = \frac{B\ (s + w)}{12}$$

$$L_o = \frac{5(24 + 3)}{12} = 11.25 \text{ ft.}$$ (Use 11 ft 3 in.)

b. American Standard Channel

Use (C15 x 33.9). Then, depth = 15 in; width = 3.4 in.

$$L_o = \frac{B\ (s + w)}{12}$$

$$L_o = \frac{5(24 + 3.4)}{12} = 11.417 \text{ ft.}$$ (Use 11 ft 5 in.)

Weir crest thickness -

Use the special weir crest shown in figure 5.

Riser transition to the box conduit -

Use the special elbow shown in figure 6.

In summary, the drop inlet spillway and standard baffle inlet layout parameters are:

Q_{max} = 700 ft^3/s
Q_5 = 630 ft^3/s
Q_p = 600 ft^3/s
L = 13.5 ft
L_w = 12.67 (with one 10-in interior wall)
N = 5 ft 3 in
B = 5
S = 24 in
Maximum conduit velocity = 34.6 ft/s.

Baffle dimension & layout	Baffle shape and size	
	Structural steel tubing	Structural channel
	a TS7 x 3 x 0.375 with TS8 x 3 x 0.375	C15 x 33.9
d	15 in	15 in
w	3 in	3.4 in
u	3 in	3 in
f	3 in	3 in
L_o	11 ft 3 in	11 ft 5 in

Riser: Special weir crest and special elbow.

APPENDIX

DEVELOPMENT OF THE SPECIAL WEIR CREST

Background Material

The U. S. Army Corps of Engineers tested several types of weir crests for the outlet works for Branched Oak Creek, Nebraska, and Cottonwood Springs Creek, South Dakota. The results of these tests reported in Technical Report H-72-1 furnished the idea for designing a curved weir crest for drop inlet risers to eliminate the periodic nappe flutter observed during flow over a square or sharp-edged weir. Later, during the testing of the stepped baffled trashrack by the Agricultural Research Service (ARS), it was observed that the nappe would cling to the weir crest during a rising stage up to a ratio of the head above the crest (H) to the crest thickness (t_c), equaling 1.9. Above this point, the nappe would separate from the crest. The weir crest used in the trashrack tests had a square upstream corner and a one-quarter round on the inside or downstream face of the weir. The rounding had a radius equal to $t_c/2$. This one-quarter round weir was also one of the weirs tested by the Corps of Engineers.

Determination of Crest Thickness

Flow separation and the accompanying undesirable flow conditions may be avoided by proportioning the weir crest so that full pipe or conduit flow will occur before exceeding the H/t_c limit of 1.9. Using a weir coefficient of 3.8, as determined from the inlet hydraulics of the trashrack tests, one can determine the minimum required value for t_c by setting the equation for weir flow equal to the priming discharge (Q_p) of the spillway conduit.

$$Q_p = C(2L_w)H^{3/2}$$

By substitution of C = 3.8 and H = 1.9 t_c and by rearranging results in the equation:

$$t_c = \left(\frac{Q_p}{19.9L_w}\right)^{2/3} = 0.136\left(\frac{Q_p}{L_w}\right)^{2/3}$$

L_w is the length of weir on one side of a Dx3D inlet.

Comparison using Cottonwood Springs Test Data

The weir coefficient developed by the U. S. Army Corps of Engineers is not compatible with the results of the ARS tests since no trashrack was used in the Corps tests; however, the two tests for the one-quarter round weir may be compared since the discharges for each are known. The most critical test in the Cottonwood Springs tests in terms of head over the crest (the largest H/t_c ratio) was on a 2DxD riser with a priming discharge equal to 435 ft^3/s and a pipe diameter of 4.0 ft. The weir flow equation at conduit priming discharge is:

$$Q_p = C(2L_w)H^{3/2}$$

By substituting Q_p = 435 ft^3/s and L_w = 2D = 8.0 ft and using C = 3.8 and H = 1.9t_c, the required value of t_c is 1.95 ft. This is approximately equal to the tested t_c value of 2.0 ft, which had satisfactory test performance.

A second check can also be made by examining of the centripetal force for flow over the weir, tending to break the nappe free from the crest. To test for dynamic equilibrium, the centripetal force (F) at critical velocity (V_c) divided by the mass (M) should be equal to the critical velocity squared divided by the radius of curvature (R):

$$F/M = V_c^2/R = (gq)^{2/3}/R \quad \underline{1/}$$

By substituting $q = Q_p/2L_w$ and using test values as before, F/M was 91.5 ft/s^2 which is approximately equal to the limit of 93.7 ft/s^2 computed using $q = CH^{3/2}$ and $R = t_c/2$ with C = 3.8 and H = 1.9 t_c.

1/ The approximate centrifugal pressure over the weir crest is:

$$P = \frac{\gamma d}{g}\,\frac{V_c^2}{R} \quad \text{or} \quad \frac{F}{M} = \frac{Pg}{\gamma_d} = \frac{V_c^2}{R}$$

[Ven Te Chow, Open-Channel Hydraulics, (New York: McGraw, Hill, 1959), p. 31].

The critical depth over a rectangular weir is:

$$d_c = \left(\frac{q^2}{g}\right)^{1/3}$$

(NEH-5, Eq. 5.4-12)

The unit discharge $q = V_c d_c$; therefore,

$$V_c = \frac{q}{d_c} = \frac{q}{\left(\frac{q^2}{g}\right)^{1/3}} \quad \text{and} \quad V_c = (gq)^{1/3}.$$

Since the performance of the Corps outlet was satisfactory in all respects, using the limiting ratio of weir head to crest thickness (H/t_c) as equal to 1.9 for the stepped baffled trashrack weir appears to be valid.

Proportioning of the Weir Crest

The Corps model investigations did show that a compound curve crest shape was less likely to permit separation other than the crest shapes tested; therefore, a similarly shaped crest with an upstream curve radius equal to 0.125 t_c and a downstream curve radius of 0.875 t_c is recommended for use on all inlets requiring a special weir crest. Since the Corps tests did not determine the particular H/t_c ratio where nappe separation occurred, the value of H/t_c equal to 1.9 determined by ARS for the one-quarter round weir crest should be used to size the compound curve.

The relationship of t_c to the height of the cover slab (N) may be determined by equating the discharge for trash-laden flow to the weir formula used to determine the crest thickness

$$\frac{Q_p}{2L_w} = 2N^{3/2} = 3.8H^{3/2}.$$

With H = 1.9 t_c, the required minimum value for t_c is 0.34N.

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