MO650.0305 Pipe Flow, State Supplement

HYDRAULIC DESIGN CRITERIA FOR CANOPY, HOOD AND DROP INLET SPILLWAYS

Nomenclature used in formulas.

α = Deflection angle in the barrel in degrees.
a = Cross-sectional area of barrel, in square feet.
D = Inside diameter of barrel, in feet.
D_R = Inside diameter of riser or box inlet, in feet.
g = Acceleration of gravity, 32.2 feet per second per second.
h = Inlet stage for weir and slug flow for canopy or hood inlet spillways, in feet
H_c = Effective head of water acting on conduit in feet. [1/]
H_n = Head loss due to friction in barrel when it is flowing full, in feet.
H_o = Head of water over centerline of orifice at inlet of barrel, in feet.
H_w = Head of water over crest of weir, in feet.
K_e = Head loss coefficient due to entrance conditions.
K_m = Head loss coefficient due to miter-bend.
K_p = Head loss coefficient for Manning's coefficient of roughness "n" for circular pipe flowing full. See ES-42 or EFM pg. 3-75.
L = Length of barrel in feet.
L_w = Length of weir measured along the perimeter, in feet.
n = Manning's coefficient of roughness.
Q = Discharge for weir and slug flow for canopy or hood inlet spillway, in cubic feet per second.
Q_c = Conduit discharge, in cubic feet per second.
Q_o = Orifice discharge, in cubic feet per second.
Q_w = Weir discharge, in cubic feet per second.
S_n = Normal slope of the barrel, in feet/foot.
V = Velocity of flow in barrel, in feet per second.
Z = Height of riser, in feet.

[1/] To compute H_c, when free outlets exists, the tailwater is considered to be 0.6 D above the invert of the outlet end of the barrel. When tailwater is above this point, the tailwater surface is used.

Formulas.

Weir flow for box inlets or drop inlets.

$Q_w = 3.1\,(\pi D_R - \text{obstructions}) H_w^{3/2}$ (Round)

$Q_w = 3.1\,(L_w - \text{obstructions})\, H_w^{3/2}$ (Square or rectangular)

Orifice flow at conduit entrance for drop inlet.

$Q_o = 0.71\, a\, (2\, g\, H_o)^{1/2}$ (Sharp edge entrance)

Conduit flow.

$Q_c = a\,[(2\,g\,H_c) \div (1 + K_e + k_m + k_p\,L)]^{1/2}$

$K_m = n\,\alpha \div 3$ for α equal to or less than 30°

K_p = See ES-42 or EFM page 3-75

Table MO-3-1. Recommended Coefficient Values.

ENTRANCE LOSS COEFFICIENTS, k_e (Full Conduit Flow)	
Canopy and Hood Inlets[1/]	
Thin wall conduits (wall thickness ÷ D < 0.04)	1.1
Thick wall conduits	0.9
Drop Inlet Spillways[2/]	
Round conduit and standard rectangular open top riser with flat bottom and square-edged entrance to conduit (D x 3D Riser).	0.9
Round conduit and standard rectangular open top riser with round bottom and square-edged entrance to conduit (D x 3D Riser).	0.6
Round conduit and round riser (metal or concrete) with flat bottom and square-edged entrance to conduit.	1.0
MISCELLANEOUS COEFFICIENTS	
Weir coefficient (box or drop inlets).	3.1
Orifice coefficient (sharp edge entrance).	0.71

[1/] Same for canopy or hood with box culvert.

[2/] k_e includes all head loss through the riser and conduit entrance.

Table MO-3-2. Recommended Manning's n Values.

RECOMMENDED MANNING'S *n* VALUES		
Smooth PVC		0.011
Welded Steel Pipe and Concrete		0.013
Helical Corrugated Metal	Pitch x Depth	
	1 ½ x ¼	0.017
	2 $^2/_3$ x ½	0.021
Annular Corrugated Metal	2 $^2/_3$ x ½	0.025
	3 x 1	0.030

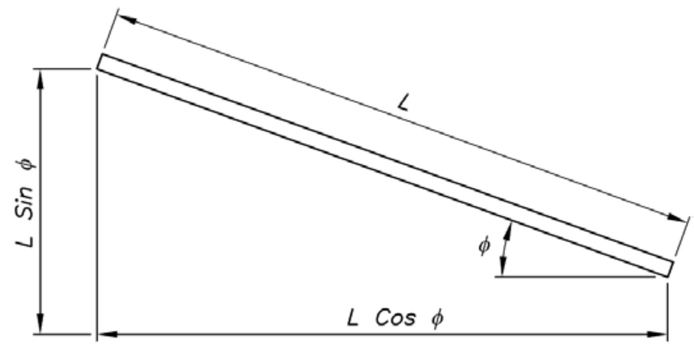
NORMAL SLOPE

Normal slope (sometimes referred to as friction or neutral slope) is defined as that slope of the conduit at which the friction loss is equal to the slope of the conduit, example: when conduit is parallel to the hydraulic gradient.

$$L \sin \phi = H_n$$

$$H_n = \frac{K_p L V^2}{2g}$$

$$S_n = \frac{2.8752\, n^2 V^2}{D^{4/3} \cos \phi}$$



CANOPY AND HOOD INLET PIPE SPILLWAYS

For the conduit to charge and flow according to the conduit formula, the following conditions must exist:

- The barrel must be on a slope less than 35%.
- The canopy or hood inlet and anti-vortex device must be designed and installed as shown under inlet dimensions.

Canopy and Hood inlet spillways progress through weir flow and slug flow before achieving full pipe flow. Weir flow does not follow normal weir flow formulas. Slug flow is a condition where the conduit operates alternately under weir flow and full pipe flow. Slug flow as shown is an average of these flow conditions. The discharge-stage curve for different sizes and kinds of pipe is shown on the following page with the numerical values for the plotting points in the following table.

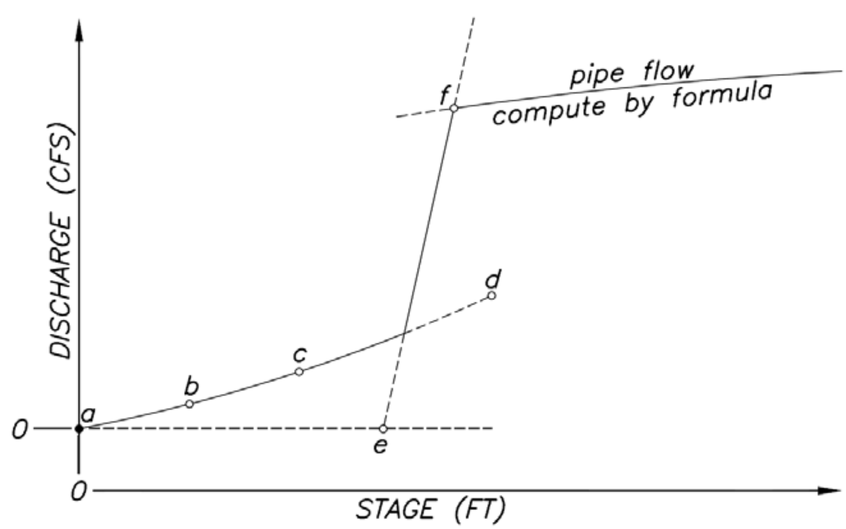


Table MO-3-3. Canopy or Hood Inlet Discharge.

CANOPY OR HOOD INLET STAGE vs DISCHARGE PLOTTING COORDINATES
WEIR AND SLUG FLOW

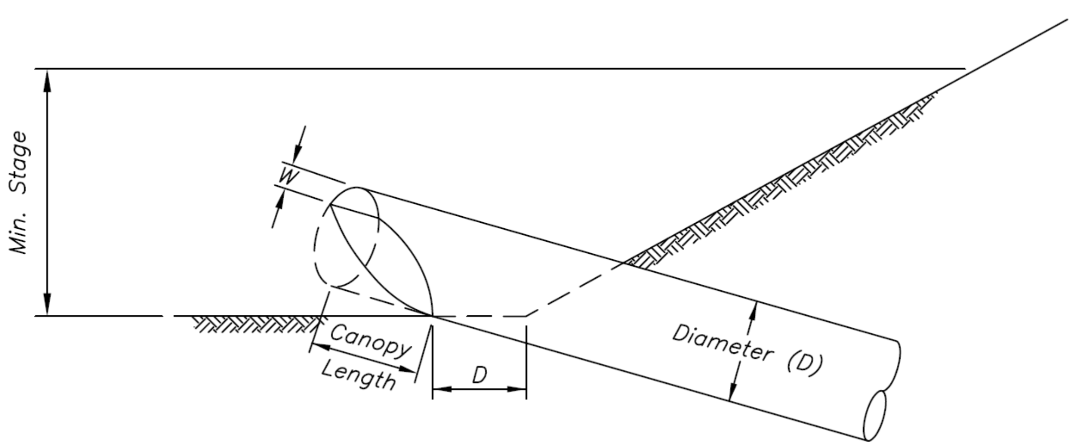
Pipe Diam.	b		c		d		e		f		
in inches	h Feet	Q cfs	h Feet	Q cfs	h Feet	Q cfs	h Feet	Q cfs	h 1/ Feet	h 2/ Feet	Q cfs
6	0.25	0.1	0.50	0.4	0.75	0.7	0.53	0	0.65	--	Value determined by conduit flow formula
8	0.33	0.2	0.67	0.8	1.00	1.3	0.70	0	0.87	1.20	
10	0.42	0.4	0.83	1.4	1.25	2.3	0.87	0	1.08	1.47	
12	0.50	0.7	1.00	2.2	1.50	3.6	1.05	0	1.30	1.80	
14	0.58	1.0	1.17	3.3	1.76	5.4	1.23	0	1.52	--	
15	0.63	1.1	1.25	3.8	1.88	6.3	1.31	0	1.62	2.25	
16	0.67	1.3	1.33	4.5	2.00	7.4	1.40	0	1.73	--	
18	0.75	1.8	1.50	6.1	2.25	10.0	1.58	0	1.95	2.70	
20	0.83	2.3	1.67	7.9	2.50	13.0	1.75	0	2.16	--	
21	0.87	2.7	1.75	8.9	2.62	14.7	1.84	0	2.27	3.15	
22	0.92	2.9	1.83	10.0	2.75	16.4	1.92	0	2.38	--	
24	1.00	3.7	2.00	12.4	3.00	20.5	2.10	0	2.60	3.60	
26	1.08	4.5	2.17	15.2	3.26	25.1	2.28	0	2.82	--	
27	1.13	4.9	2.25	16.7	3.38	27.4	2.36	0	2.92	4.05	
28	1.17	5.4	2.33	18.2	3.50	30.0	2.45	0	3.03	--	
30	1.25	6.4	2.50	21.7	3.75	35.8	2.62	0	3.25	4.50	
36	1.50	10.1	3.00	34.3	4.50	56.3	3.15	0	3.90	5.40	
42	1.75	14.9	3.50	50.4	5.25	83.0	3.68	0	4.55	6.30	
48	2.00	20.8	4.00	70.4	6.00	115.8	4.20	0	5.20	7.20	

1/ For smooth pipe (n = 0.010 to 0.013).
2/ For corrugated pipe (n = 0.017 to 0.025).

MINIMUM INLET DIMENSIONS FOR CANOPY INLET

Conduit Slope %	W 1/	Canopy Length	Min 2/ Stage
0–5	.2D	.6D	1.3D
6–15	.2D	.8D	1.4D
16–25	.3D	1.1D	1.5D
26–35	.35D	1.3D	1.6D

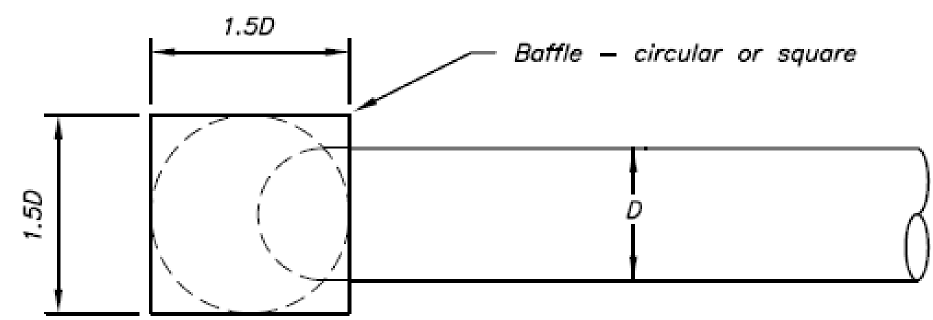
1/ Measured from valley on CMP and inside surface of smooth pipe.
2/ Minimum stage for full pipe flow.

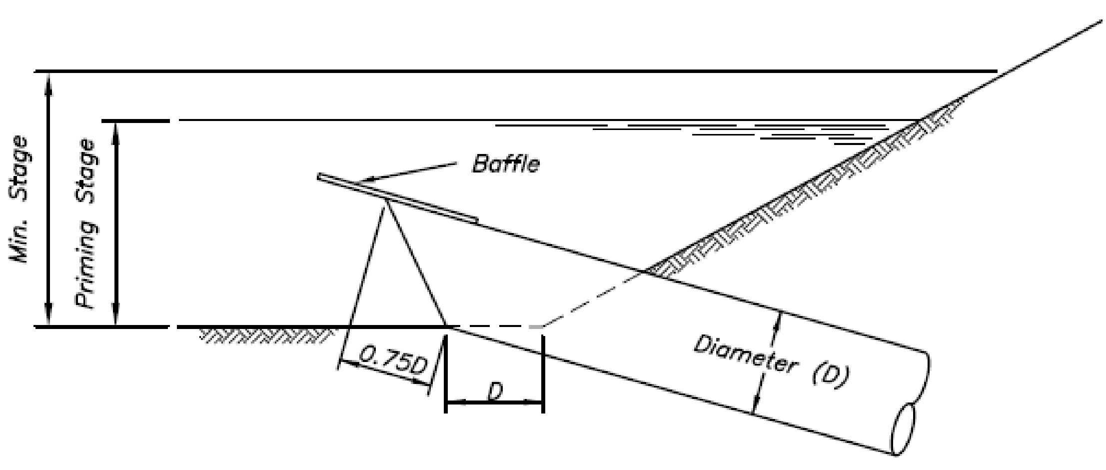


MINIMUM INLET DIMENSIONS FOR HOOD INLET

Conduit Slope %	Min. 1/ Stage
0–5	1.5D
6–15	1.6D
16–25	1.7D
26–35	1.8D

1/ Minimum stage for full pipe flow.

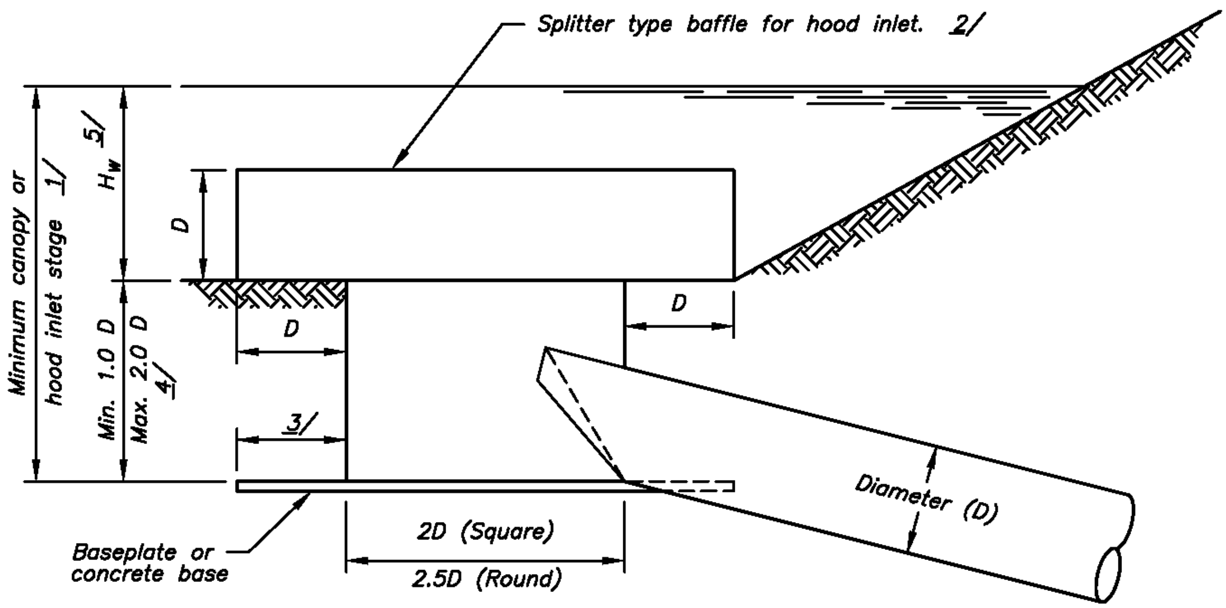




BOX INLET FOR CANOPY OR HOOD INLET

A box may be added to the Canopy or Hood inlet to prime the pipe with a lower stage in the pool. The dimensions of the box must be hydraulically sound. It may be either round or square.

Minimum Box Dimensions



1/ Minimum stage for efficient use of pipe capacity. (Shall not be less than shown on MO–3–3 or MO–3–4)

2/ The splitter type baffle is not required for Canopy Inlet.

3/ Dimension of base plate or concrete base shall be as required to provide a safety factor of 1.5 against flotation.

Weight of Materials
Water = 62.4 lbs/ft^3
Submerged soil = 55.0 lbs/ft^3
Reinforced concrete = 150 lbs/ft^3
Steel = 490 lbs/ft^3

4/ This dimension does not need to be less than 1.5 feet for small diameter pipe.

5/ Check H_W by weir equation to ensure full pipe flow.

DROP INLET SPILLWAYS

For the conduit to charge and flow full according to the conduit formula, the flowing conditions must exist: (1) the area of the drop inlet is at least 1.5a: (2) flow over drop inlet weir is sufficient to provide full conduit flow; (3) an anti-vortex device is designed and installed as shown under inlet dimensions; and (4) one of the following conditions exists:

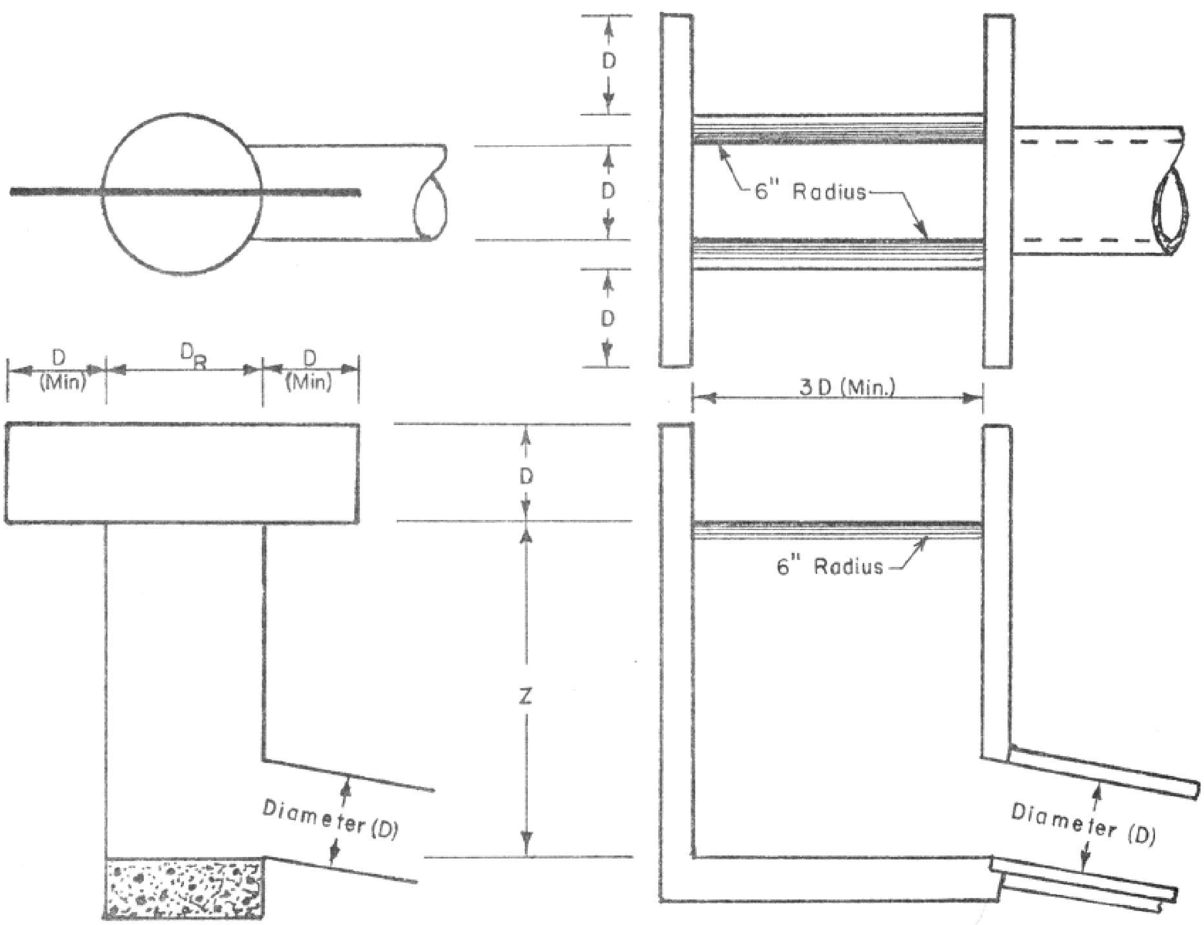
a) Z is equal or greater than 5D and conduit slope is less than 30% or outlet has 20 foot section on a mild slope.

b) Z is less than 5D but equal to or greater than 2D and conduit slope is less than normal slope.

c) Z is less than 2D and slope of conduit is less than normal slope, provided orifice flow does not control.

d) Z is less than 2D and outlet is submerged or outlet has 20 foot section on a mild slope, provided orifice flow does not control.

<u>CAUTION</u>! Shallow drop inlets are more likely to have slug flow if air is admitted at the inlet.



Round Drop Inlet
Concrete or Metal

Rectangular Drop Inlet
Concrete