TRAPEZOIDAL FLUME

User's Manual

TABLE OF CONTENTS

INTRODUCTION TO THE TRAPEZOIDAL FLUME

The Trapezoidal flume is a fixed hydraulic structure used to measure the flow of sub-critical waters in open channels. Although originally developed to measure natural streams, irrigation canals, and small furrows, the use of the flume has been expanded and now includes:

- *Cooling water discharge*
- *Dam seepage*
- *Industrial effluent*
- *Irrigation / water rights*
- *Landfill leachate*
- *Mine discharge / dewatering*
- *Surface waters*
- *Storm water*

DEVELOPMENT

Unlike Parshall flumes which were the work on one man, Trapezoidal flumes have been investigated by a number governmental and academic institutions, including: the U.S. Bureau of Reclamation, the U.S. Department of Agriculture, Colorado State University, Utah State University, Washington State University, Israel Institute of Technology, and others.

FUNCTION

Sub-critical flumes like the Trapezoidal flume operate by accelerating slow, sub-critical flow (Fr<1) to a supercritical state (Fr>1) by restricting the flow as it passes through the flume. The Trapezoidal flume accomplishes this restriction by contracting the side walls of the flume.

DESIGN

The defining characteristics of the Trapezoidal flume are its Trapezoidal shaped cross-section and flat floor.

From above, the floor of the flume is wasp-waisted with the narrowest part the throat section of the flume.

The outward opening sidewalls mean that the Trapezoidal flume is easier to adapter to ditches and earthen channels. They also mean that the flume can accommodate a large range of flows since an incremental increase in flow produces a relatively small increase in depth.

The flat bottom of the Trapezoidal flume means that it is easier to install in existing channels, passes trash quite readily, and reduces the problem of silt build-up upstream of the flume.

STANDARDS

There are no national / international standards for Trapezoidal flumes. In general only one or two flumes are described in each academic paper on them, however, Robinson and Chamberlain's Trapezoidal Flumes for Open-Channel Flow Measurement, Transactions of the American Society of Agricultural Engineers, Vol. 3, No. 2 (1960), presents a number of different styles and sizes of Trapezoidal flumes.

ACCURACY

Like other flow measurement flumes, Trapezoidal flumes should be expected to have free-flow accuracy within +/- 5% when installed correctly and taking into account practical considerations such as approach flow, installation, and dimensional tolerance accounted for.

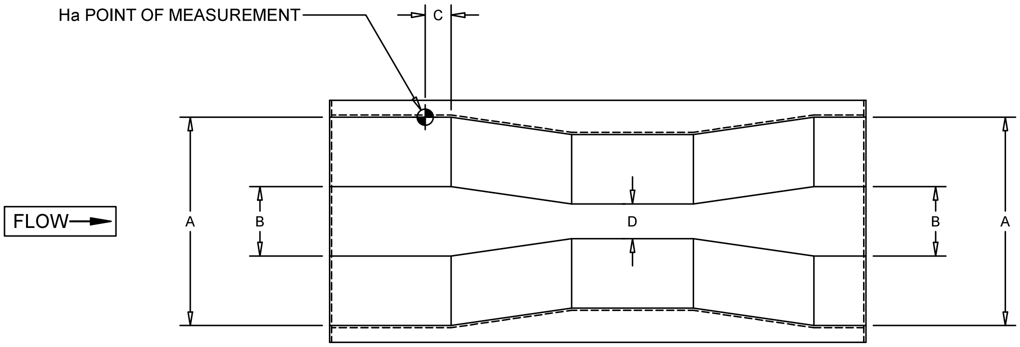
DIMENSIONS

The master dimensions for many common Trapezoidal flumes are found in Figure 1.

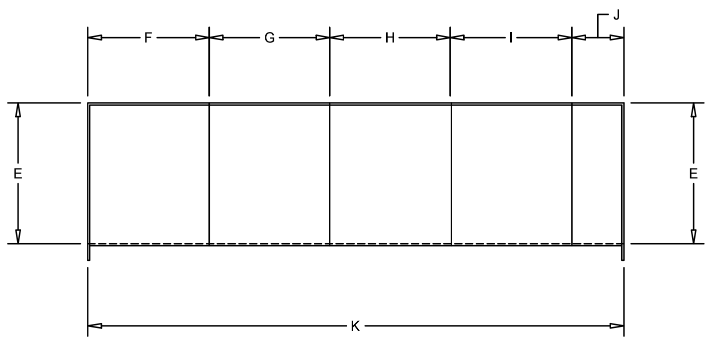
DIMENSIONAL TOLERANCES

To date, there has been no published information on the dimensional tolerances required for Trapezoidal flumes. As such, the recommendation of +/-2% for Parshall flumes (per ASTM D1941) should be followed.

Trapezoidal flumes with dimensions outside of these ranges should be considered to be non-conforming and should be either replaced or field rated.



PLAN VIEW



ELEVATION VIEW

SIZE	A	B	C	D	E	F	G	H	I	J	K
SMALL 60° V	6 3/4" [17.14 CM]	2" [5.08 CM]	1" [2.54 CM]	0" [0 CM]	4" [10.16 CM]	5" [12.70 CM]	4 3/64" [10.258 CM]	5" [12.70 CM]	4 3/64" [10.28 CM]	2" [5.08 CM]	1'-8 3/32" [51.04 CM]
LARGE 60° V	10" [25.40 CM]	2" [5.08 CM]	1 1/2" [3.82 CM]	0" [0 CM]	6 3/4" [17.14 CM]	7" [17.78 CM]	6 15/16" [17.62 CM]	7" [17.78 CM]	6 15/16" [17.62 CM]	3" [7.62 CM]	2'-6 7/8" [78.42 CM]
EXTRA LARGE 60°	1' 6 3/8" [46.67 CM]	4 1/2" [11.43 CM]	1 1/2" [3.82 CM]	0" [0 CM]	1' [30.48 CM]	7" [17.78 CM]	6 15/16" [17.62 CM]	1' 6" [45.72 CM]	6 15/16" [17.62 CM]	3" [7.62 CM]	3' 5 7/8" [106.4 CM]
12" 45° SRCRC (NO. 1)	3'-8" [111.8 CM]	1' [30.48 CM]	1 3/4" [4.46 CM]	4 13/16" [12.22 CM]	1'-4" [40.64 CM]	1'-3" [38.10 CM]	1'-5 1/16" [43.34 CM]	1' [30.48 CM]	1'-5 1/16" [43.34 CM]	6" [15.24 CM]	5'-7 1/8" [170.5 CM]
24" 38° SRCRC (NO. 2)	9'-6" [289.6 CM]	2' [60.96 CM]	6" [15.24 CM]	1' [30.48 CM]	3' [91.44 CM]	2' [60.96 CM]	3' [91.44 CM]	2'-6" [76.2 CM]	2' [60.96 CM]	1' [30.48 CM]	10'-6" [320.0 CM]
2" 60° WSC (NO. 3)	1'-4 7/8" [42.86 CM]	4 7/8" [12.38 CM]	1 1/2" [3.82 CM]	2" [5.08 CM]	10 3/8" [26.35 CM]	8' [20.32 CM]	8 13/32" [21.35 CM]	8 1/2" [21.59 CM]	8 13/32" [21.35 CM]	3" [7.62 CM]	3'-0 5/16" [92.23 CM]
2" 45° WSC (NO. 4)	2'-2 1/16" [66.20 CM]	4 7/8" [12.38 CM]	1 1/2" [3.82 CM]	2" [5.08 CM]	10 19/32" [26.91 CM]	8" [20.32 CM]	8 3/8" [21.27 CM]	8 1/2" [21.59 CM]	8 3/8" [21.27 CM]	3" [7.62 CM]	3'-0 1/4" [92.08 CM]
2" 30° WSC (NO. 5)	3'-3 33/64" [100.4 CM]	4 7/8" [12.38 CM]	1 1/2" [3.82 CM]	2" [5.08 CM]	10" [25.4 CM]	8" [20.32 CM]	8 3/8" [21.27 CM]	8 1/2" [21.59 CM]	8 3/8" [21.27 CM]	3" [7.62 CM]	3'-0 1/4" [92.08 CM]
2" 30° CSU (NO. 7)	3'-7 1/2" [110.5 CM]	10" [25.4 CM]	1 1/2" [3.82 CM]	2" [5.08 CM]	9 21/32" [24.53 CM]	10" [25.4 CM]	10" [25.4 CM]	10" [25.4 CM]	10" [25.4 CM]	3" [7.62 CM]	3'-7" [109.2 CM]
8" 60°	4' [121.9 CM]	1'-4" [40.64 CM]	3" [7.62 CM]	8" [20.32 CM]	2'-3 23/32" [70.39 CM]	1'-6" [45.72 CM]	1'-7 19/32" [49.77 CM]	1'-8" [50.8 CM]	1'-7 19/32" [49.77 CM]	6" [15.24 CM]	6'-11 3/16" [211.3 CM]

Figure 1 – Trapezoidal Flume Master Dimensions

POINTS OF MEASUREMENT

The primary, free-flow, point of measurement, Ha, is located upstream of the throat in the straight approach section of the flume.

The secondary point of measurement, Hb, used to determine the submergence of a Trapezoidal flume is located in the exit section of the flume.

FLOW EQUATIONS

Depending upon the flume, the free-flow discharge equations for Trapezoidal flumes can be quite simple or quite complex. In general, the equations are usually reduced to the simplified form below unless the investigators have published the equation.

SUBMERGED FLOW

As a Trapezoidal flume becomes submerged – where downstream conditions reduce the flow out of the flume – corrections must be made to the flow equation.

In order to determine when these corrections should be made (and the degree to which the flume is submerged), the submergence ratio must be calculated.

The submergence ratio is the ratio of the downstream depth at the secondary point of measurement, Hb, to the depth at the primary point of measurement, Ha.

$$S = \frac{H_b}{H_a}$$

Equation 2 – Submergence Ratio Equation

SUBMERGENCE TRANSITION

The transition from free, unrestricted flow to submerged to one of backwater / slowed velocity discharge is known as the submergence transition (St). Trapezoidal flumes have relatively high submergence transitions (75-85%).

Small 60º Trapezoidal	$Q = 1.55\ H_a{}^{2.58}$
Large 60º Trapezoidal	$Q = 1.55\ H_a{}^{2.58}$
Extra Large 60º Trapezoidal	$Q = 1.55\ H_a{}^{2.63}$
8-inch 60º Trapezoidal	$Q = 2.22\ H_a{}^{1.53} + 1.467\ H_a{}^{2.5}$
12-Inch 45º SRCRC (No. 1) Trapezoidal	$Q = 0.05 + 0.063\ H_a{}^{1.5} + 3.23\ H_a{}^{2.5}$
24-Inch 38º SRCRC (No. 2) Trapezoidal	$Q = 0.19 + 1.67\ H_a{}^{1.5} + 4.27\ H_a{}^{2.5}$
2-Inch 60º WSC	$Q = 1.99\ H_a{}^{2.04}$
2-Inch 45º WSC	$Q = 3.32\ H_a{}^{2.18}$
2-Inch 30º WSC	$Q = 5.92\ H_a{}^{2.28}$
4-Inch 60º WSC	$Q = 2.63\ H_a{}^{1.83}$
2-Inch 30º CSU	$Q = 4.80\ H_a{}^{2.26}$

Equation 1 –Trapezoidal Flume Free-Flow Equations

SUBMERGED FLOW EQUATIONS

Submerged flow equations have not been published for Trapezoidal flumes. As a result, if submergence is suspected, the flume must be raised in the channel or the downstream conditions must be modified so that the flume is no longer submerged.

WHERE TO INSTALL A TRAPEZOIDAL FLUME

When selecting a site in which to install a Trapezoidal flume, there are several points to consider:

UPSTREAM OF THE FLUME

- *Flow entering the Trapezoidal flume MUST be sub-critical.*
- *The Froude number (Fr) for flow entering a flume should not exceed 0.5 and should never exceed 0.99.*
    - *Surface turbulence may be encountered for Froude numbers above 0.5.*
    - *For a flume to accurately measure flow, that flow must be sub-critical (Fr<0.99).*
- *If the approaching flow is critical (Fr = 1.0) or supercritical (Fr > 1.0), then a hydraulic jump must be formed at least 30 times the maximum anticipated head upstream of the entrance to the flume or upstream energy absorbers must be used to slow the flow.*
- *The flow entering the flume should be smooth, tranquil, and well distributed across the channel.*
- *The approaching channel should be straight so that the velocity profile is uniform. Surging, turbulent, or unbalanced flows must be conditioned before the flow enters the flume.*
- *Any bends, dips, elbows, or flow junctions upstream of the flume must be sufficiently far upstream so that the flow has is well distributed and non-turbulent.*
- *The upstream channel should be straight for 10 to 20 times the throat width.*
- *Trapezoidal flumes have been successfully used in applications where the flow rises up a uniform vertical column and then enters the flume.*
- *Where the channel is wider than the inlet of the Trapezoidal flume, wing walls should be formed to smoothly direct the flow into the flume.*
- *When connecting to inlet piping, observations have shown that the pipe should be straight and without bends for at least 15 pipe diameters.*
- *The upstream channel should be clear of vegetative growth.*
- *Open channel (non-full pipe) flow must be present under all flow conditions.*

FLUME LOCATION

- *The flume must be able to be set so that the floor is level from front-to-back and from side-to-side.*
- *When Trapezoidal flumes are installed in earthen channels and furrows, care should be taken to ensure that a stable bottom elevation is present and that the elevation does not change during dry / wet seasons or low-flow periods.*
- *The flume must be centered in the flow stream.*
- *Where a Trapezoidal flume must be set above the floor of a channel, a 1:4 (rise:run) slope should be formed into the flume. Slopes greater than this should be avoided as they can cause turbulence as the flow separates at the junction of the ramp and the inlet of the flume.*
- *All of the flow must go through the flume – there should be no bypass.*

DOWNSTREAM OF THE FLUME

- *For a Trapezoidal flume to operate under free-flow conditions, the downstream channel must be of a sufficient size / configuration so that flow does not back up into the flume – slowing discharge out of the flume.*
- *When flow out of the Trapezoidal flume is returning to a channel or pipe, the channel should be straight and unobstructed for 5-20 throat widths – although flow spilling freely off the end of the flume can eliminate this requirement.*
- *To transition the flow out of a Trapezoidal flume, wing walls should be used. These walls can be flat or perpendicular to the flume (to save space or money) or they can extend from the flume's discharge at some angle or radius sufficient to transition the flow as desired. Transitions to earthen or natural channels should be as gradual as practical to minimize downstream scour.*
- *The downstream channel should be armored (riprap) or otherwise protected so that scour does not occur.*
- *The downstream channel must be clear of vegetative growth or the collection of debris so that flow does not back up in to the flume.*

HOW TO INSTALL A TRAPEZOIDAL FLUME

Once a site has been selected, the flume must then be installed correctly:

- *The flume should be set so that it is centered in the flow stream.*
- *The floor of the flume should be set high enough so that the flume does not operate under submerged flow conditions.*
- *The outlet of the flume should be set at or above (ideally) the invert of the outlet channel / pipe to help transition solids out of the flume.*
- *The point of measurement must be set upstream.*
- *The floor of the flume must be level from front-to-back and from side-to-side (using a level on the floor - not the top - of the flume)*
- *The flume must be braced internally (plywood and lumber are typically used) during installation to ensure that distortion does not occur.*
- *The flume must not float out of its intended final position during installation.*

BRACING THE FLUME

Most Trapezoidal flumes ship with dimensional bracing (angle or tube) at the top of the flume. The bracing should be left on the flume until the installation has been completed.

If the flume is set in concrete, the bracing may be removed once the installation has been completed.

For installations where the flume is free-standing or otherwise not set in concrete, the bracing should be left in place.

If the bracing is removed, verify the dimensional accuracy of the flume after the removal.

CONNECTION JOINTS

Trapezoidal flumes supplied with bulkheads, or transition sections must remain sealed between the joints.

While these joints may be sealed initially at the factory, a final visual inspection of all joints should be done before installation. Where required, apply one or two continuous beads of silicone on all seating surfaces before proceeding with the installation.

HOW TO MAINTAIN A TRAPEZOIDAL FLUME

For a Trapezoidal flume to accurately measure flow, it must be periodically inspected and maintained. This inspection should be done six (6) months after installation and each following year.

The inspection should include the channel in which the flume is installed, the flow entering / exiting the flume, and the flume itself.

CHANNEL INSPECTION

- The upstream channel banks should be clear of vegetation or debris that could affect the flow profile entering the flume (upstream) or restrict flow out of the flume (downstream).
- Inspect the upstream channel to make sure that flow is not bypassing the flume.
- Inspect the downstream channel to make sure that scouring is not occurring.
- Any hydraulic jump should be at least 30 times the maximum head (Hmax) upstream of the flume.

FLOW INSPECTION

- *Flow entering the flume should be tranquil and well distributed.*
- *Turbulence, poor velocity profile, or surging should not be present.*
- *The Froude (Fr) number should, ideally, be 0.5.*
- *As the Froude number increases so does surface turbulence.*
- *Flumes accelerate sub-critical flow (Fr < 1) to a supercritical state (Fr 1>) .*
- *Flumes experiencing flows greater than unit (Fr = 1) will not accurately measure flow.*

FLUME INSPECTION

- *Flumes must be level from front-to-back and from side-to-side.*
- *Earthen installations are particularly susceptible to settling due to wet / dry and freeze / thaw cycles.*
- *Flow surfaces are to be kept clean of surface buildup or algal growth. Scrubbing or a mild detergent can be used.*
- *Galvanized flumes should be checked for corrosion.*
- *Any corrosion should be removed and then cold galvanization applied to the area.*