

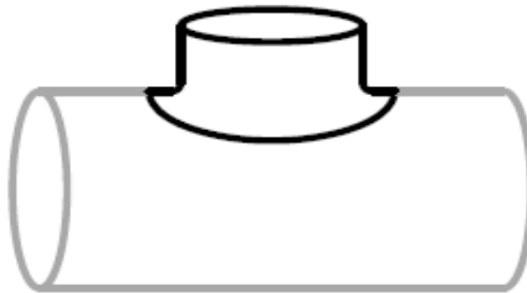


Spiral Duct Manufacturers Association

## White Paper

Volume 2011-1

### Loss Coefficients of Pressed Saddle Tee Taps



The pressed saddle tee fitting has become commonly used in round duct systems, replacing previous types of tee fittings such as straight tees and conical tees. They are available from several manufacturers and dimensions are very similar. Two prominent features are the radiused entrance and the wide mounting saddle. They are formed to fit both on flat surfaces and with a contoured base for installation on a round trunk.

Though common and presumed to be superior in performance to many shop fabricated 90-degree branches, there was no test data to support that belief and the fitting performance did not appear in any of the traditional industry publications. In 2010 SPIDA initiated a research project with Dr. Steve Idem of Tennessee Tech University to determine the loss coefficients for this fitting. It was found that the pressed saddle tees performed comparable to conical tees with small variances relative to area and volume ratios. It is important to note that these pressed saddle tee taps are commonly available only in the range of smaller diameters (up to 12" diameter) so they are not a replacement for conical and lo-loss branches throughout the system design. Instead, they should be used as an effective cost-saving alternative within their size range. The resulting data has been offered to ASHRAE for inclusion in their Duct Fitting Database where it will be available to all designers and users. The following is a White Paper produced from that research, summarizing the results and offering loss coefficient graphs and an example of use.

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## LABORATORY TESTING OF SADDLE TAP TEES TO DETERMINE LOSS COEFFICIENTS

This report describes pressure loss tests that were conducted on diverging and converging flow saddle tap tees per ASHRAE Standard 120-2008; complete details are provided in Idem and Nalla (2011). Consider the saddle tap tees illustrated in Figure 1. These junctions can be employed in diverging or converging flow applications. For diverging flow, a fraction of the air that enters the common section flows out from the main (straight) section, and remainder exits through the branch section. For converging flow, separate air streams enter the junction through the main and branch sections and exit through the common section. Pressure losses occur in fittings when air streams are forced to change flow directions, or are required to mix. The pressure loss is increased when the flow streams are highly turbulent. Fitting pressure loss is difficult to predict using a theoretical analysis. Instead, the pressure loss is characterized by an experimentally determined loss coefficient. The loss coefficient represents the ratio of the total pressure drop across the fitting to the velocity pressure at a reference location in the fitting. In general the loss coefficient is defined as:

$$C = \frac{\Delta p_t}{\rho V^2 / 2} = \frac{\Delta p_t}{p_v} \quad (1 \text{ SI})$$

$$C = \frac{\Delta p_t}{\rho (V/1097)^2} = \frac{\Delta p_t}{p_v} \quad (1 \text{ IP})$$

where:

- C = loss coefficient, dimensionless
- $\Delta p_t$  = total pressure loss, Pa (in. wg)
- $\rho$  = density, kg/m<sup>3</sup> (lbm/ft<sup>3</sup>)
- V = air velocity, m/s (ft/min)
- $p_v$  = velocity pressure, Pa (in. wg)

At any section of the fitting the air velocity is related to the volume flow rate as follows:

$$V = \frac{Q}{A} \quad (2)$$

where:

- A = cross section, m<sup>2</sup> (ft<sup>2</sup>)
- Q = volume flow rate, m<sup>3</sup>/s (ft<sup>3</sup>/min)

For converging and diverging flow junctions, the total pressure loss through the branch section is given by

$$\Delta p_{t,b} = C_b \cdot p_{v,b} \quad (3)$$

Similarly the total pressure loss through the main (straight) section is calculated by

$$\Delta p_{t,s} = C_s \cdot p_{v,s} \quad (4)$$

In Equations 3 and 4, the quantities  $p_{v,b}$  and  $p_{v,s}$  are the velocity pressures at the main and branch cross sections, respectively. Likewise  $C_b$  and  $C_s$  are the local loss coefficients for the branch and straight (main) flow paths, respectively, referenced to the velocity pressure at sections 'b' and 's'.

For either diverging or converging junctions, branch loss coefficients are a function of the branch-to-common area ratio  $A_b/A_c$ , and the flow rate ratio  $Q_b/Q_c$ . If the main and common section cross sections are equal, the main loss coefficient  $C_s$  is a function of the straight-to-common flow rate ratio  $Q_s/Q_c$ .

A power law curve-fit was used to correlate branch loss coefficients as a function of branch-to-common flow rate and area ratios for diverging flow tees. That yielded the following expression for diverging flow branch loss coefficients:

$$C_b = 0.809 \left( \frac{Q_b}{Q_c} \right)^{-2.044} \left( \frac{A_b}{A_c} \right)^{2.147} \quad (5)$$

Equation 5 is plotted in Figure 2. A logarithmic curve-fit model was used to correlate branch loss coefficients for converging flow tees as a function of branch-to-common flow rate ratio. The argument of the logarithmic function was corrected to account for the area ratio of the fitting. This resulted in the following correlation for converging flow branch loss coefficients:

$$C_b = 0.530 \ln \left[ \left( \frac{Q_b}{Q_c} \right) - 0.323 \left( \frac{A_b}{A_c} \right)^{0.718} \right] + 1.539 \quad (6)$$

A graph of Equation 6 is presented in Figure 3. For both diverging and converging flows, main loss coefficients were correlated in terms of an inverse linear relationship with the straight-to-common flow rate ratio. Main loss coefficient data were largely independent of branch-to-common area ratio. For diverging flows this led to the following relationship for the main loss coefficient:

$$C_s = \frac{0.802}{(Q_s/Q_c)} - 1.048 \quad (7)$$

Similarly for converging flows the main loss coefficients were correlated as follows:

$$C_s = \frac{1.056}{(Q_s/Q_c)} - 1.128 \quad (8)$$

A main loss coefficient chart based on Equations 7 and 8 is presented in Figure 4.

### EXAMPLE

As an example of the use of these correlations, consider a diverging flow saddle tap tee. The air density  $\rho = 0.075 \text{ lbm/ft}^3$ . Assume the branch and straight section diameters are 6 in. and 12 in., respectively. In that case the branch-to-common area ratio is given by:

$$\frac{A_b}{A_c} = \left( \frac{6 \text{ in.}}{12 \text{ in.}} \right)^2 = 0.250$$

Further suppose the volume flow rate entering the common section equals  $2000 \text{ ft}^3/\text{min}$ , and that the flow is split evenly between the branch and main sections, such that:

$$\frac{Q_b}{Q_c} = \frac{Q_s}{Q_c} = 0.5$$

In that case by Equation 2 the air velocity in the branch and main sections, respectively, is:

$$V_b = \frac{1000 \text{ ft}^3 / \text{min}}{\left(\frac{\pi}{4}\right)(0.5)^2 \text{ ft}^2} = 5090 \text{ ft} / \text{min}$$

and:

$$V_s = \frac{1000 \text{ ft}^3 / \text{min}}{\left(\frac{\pi}{4}\right)(1)^2 \text{ ft}^2} = 1270 \text{ ft} / \text{min}$$

Referring to Equation 1 the velocity pressure in the branch and main sections, respectively, is given by:

$$p_{v,b} = (0.075 \text{ lbm} / \text{ft}^3) \left( \frac{5090 \text{ ft} / \text{min}}{1097} \right)^2 = 1.615 \text{ in. wg}$$

and:

$$p_{v,s} = (0.075 \text{ lbm} / \text{ft}^3) \left( \frac{1270}{1097} \right)^2 = 0.101 \text{ in. wg}$$

The branch loss coefficient calculated by means of Equation 5 is:

$$C_b = 0.809(0.5^{-2.044})(0.250)^{2.147} = 0.170$$

Likewise the main loss coefficient determined using Equation 7 is:

$$C_s = \frac{0.802}{(0.5)} - 1.048 = 0.556$$

Therefore the total pressure loss through the branch section is calculated using Equation 3 as follows:

$$\Delta p_{t,b} = (0.170)(1.615 \text{ in. wg}) = 0.275 \text{ in. wg}$$

The main section total pressure loss is evaluated by means of Equation 4 such that:

$$\Delta p_{t,s} = (0.556)(0.101 \text{ in. wg}) = 0.056 \text{ in. wg.}$$

#### AUTHOR

Dr. Stephen Idem is a professor in the Department of Mechanical Engineering at Tennessee Tech University. He received his Ph.D. in Mechanical Engineering from Purdue University. He has more than 24 years of experience in the areas of scale model testing, fluid flow measurement, and thermal modeling.

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Idem, S. and A. Nalla. 2011. "Laboratory Testing of Saddle Tap Tees to Determine Loss Coefficients," SPIDA Final Report, Spiral Duct Manufacturers Association.

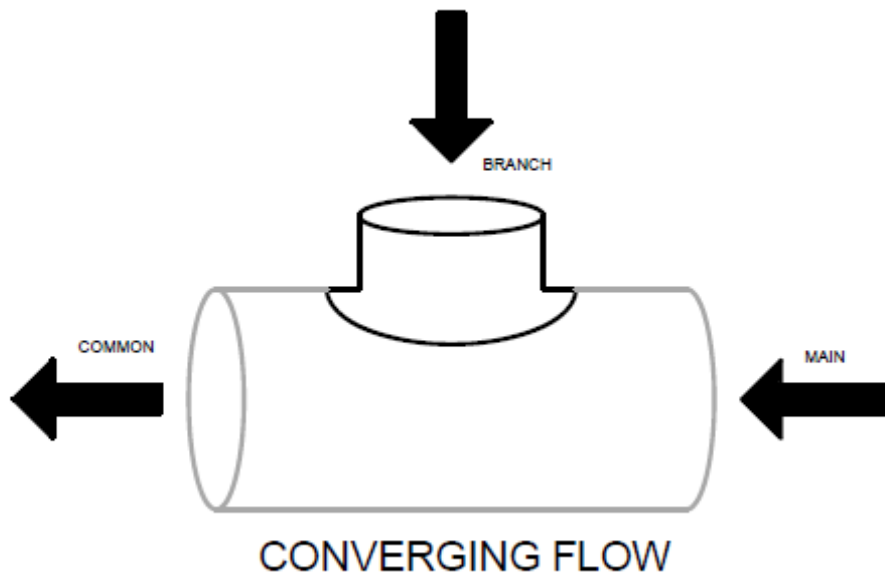
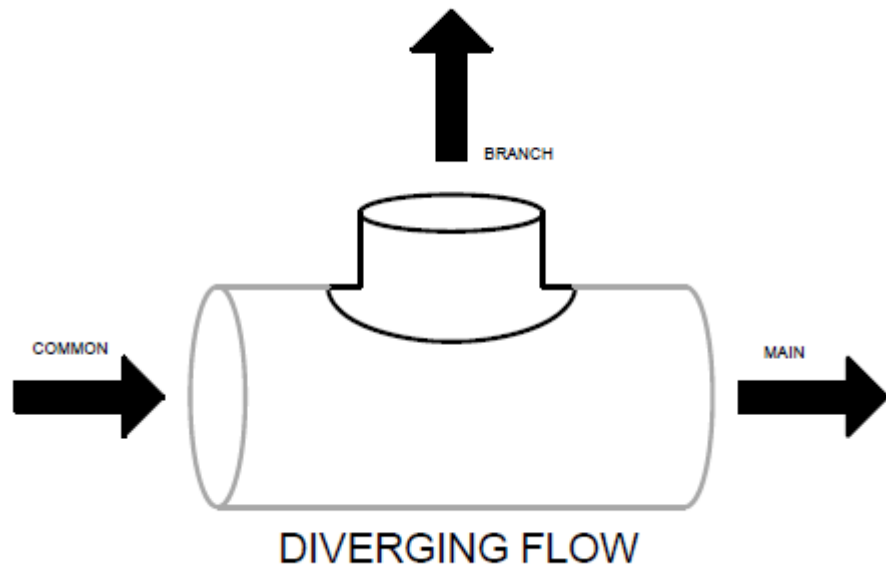


Figure 1. Diagram of Diverging and Converging Flow Saddle Tap Tees

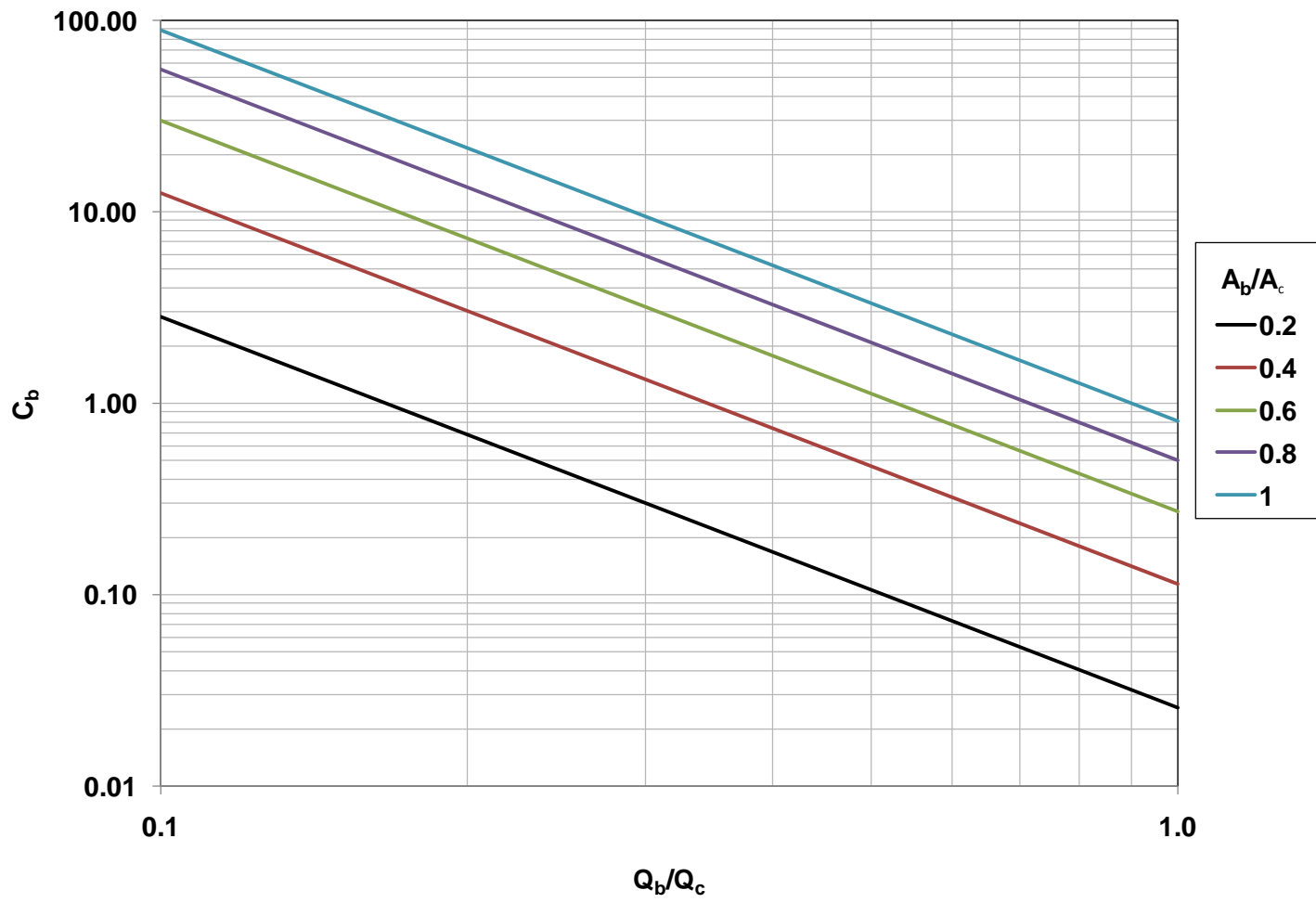


Figure 2. Diverging Flow Tee Branch Loss Coefficients

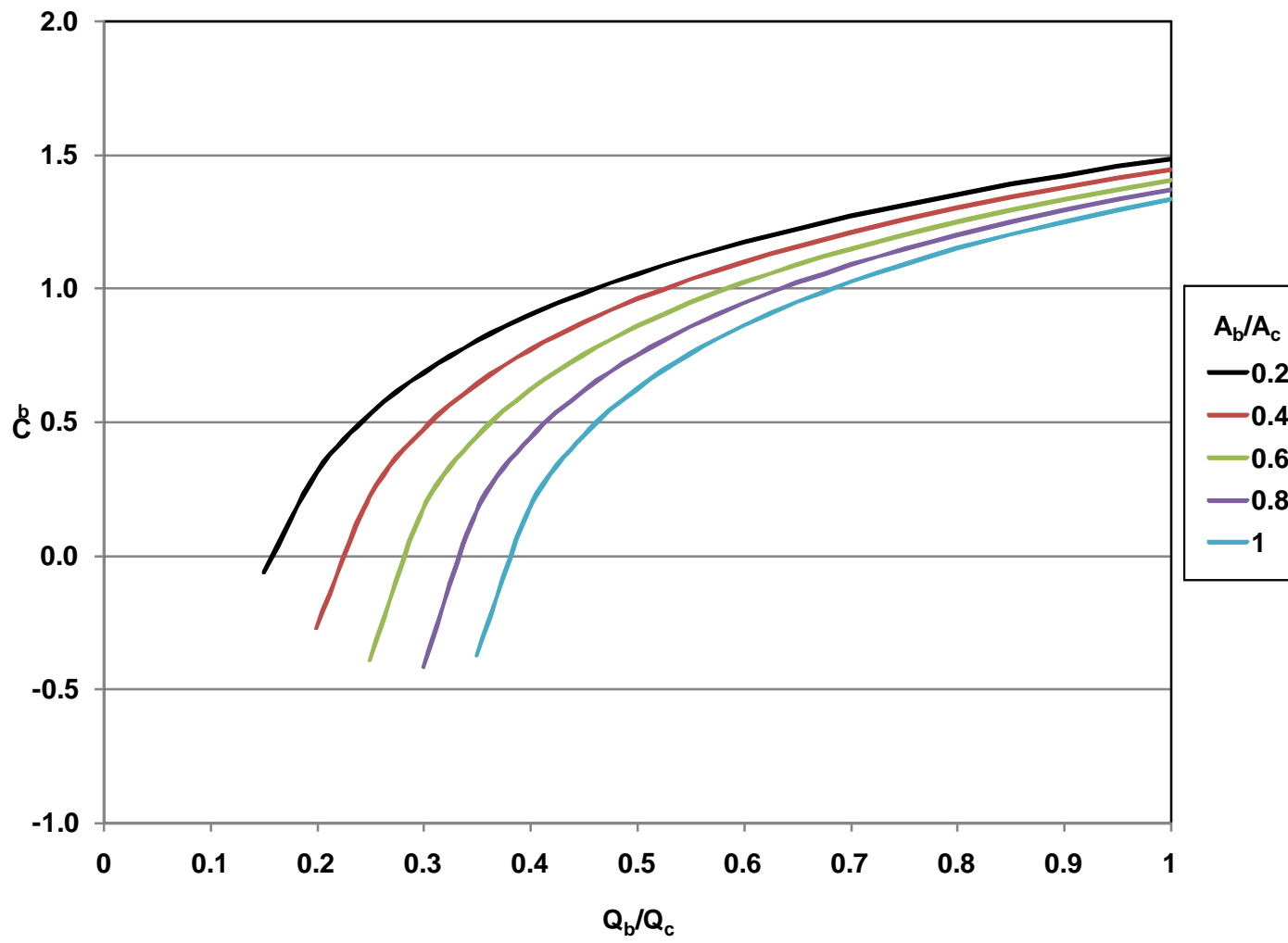


Figure 3. Converging Flow Tee Branch Loss Coefficients

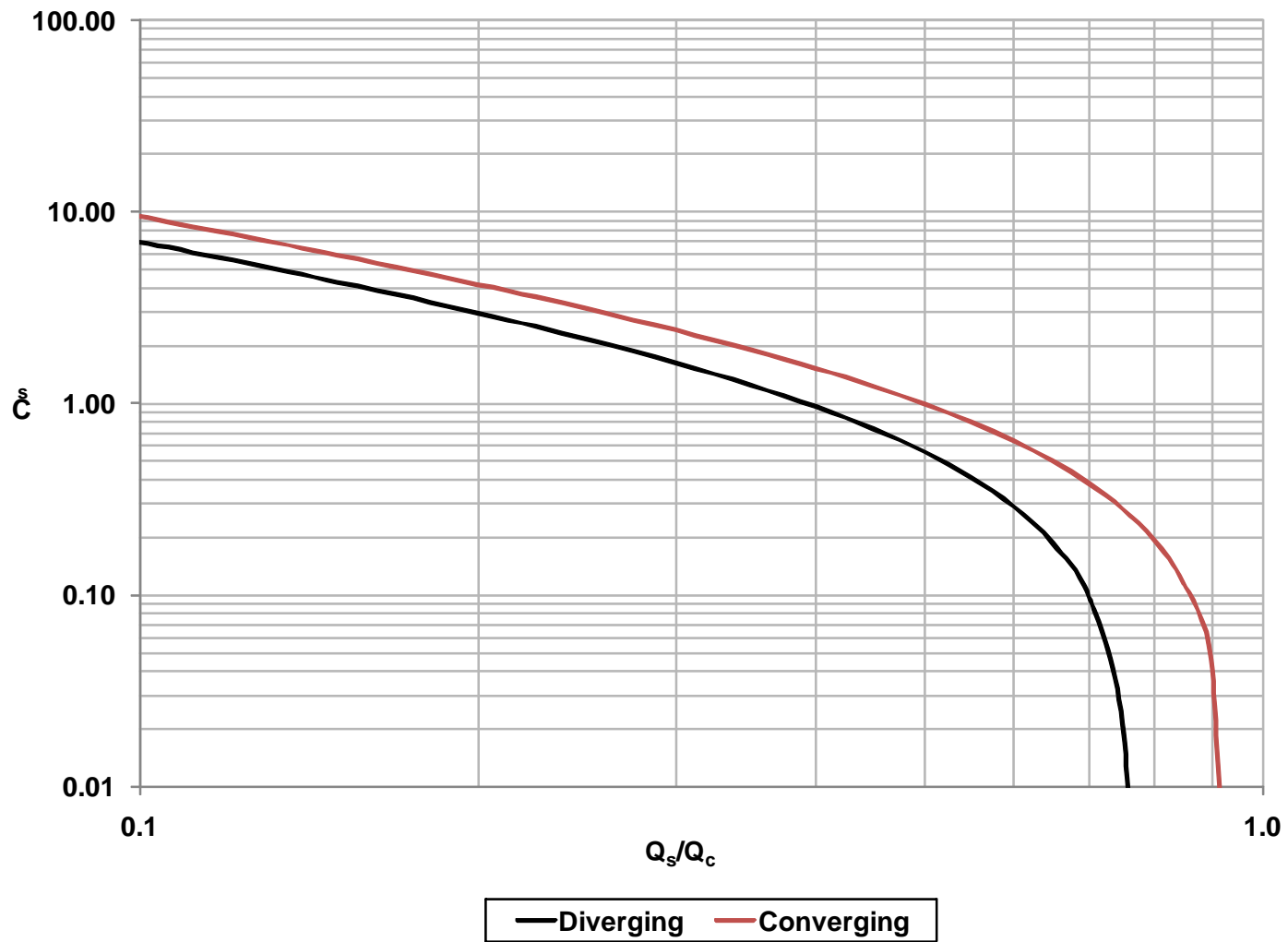


Figure 4. Diverging and Converging Flow Tee Main Loss Coefficients