INTRODUCTION

Head losses across junctions are often referred to as “minor losses”, implying that they are small compared to other losses in the system, eg pipe friction, major equipment items and static head. This is not always the case. For instance, head losses on the suction side of a pump may need to be precisely modeled to determine NPSH available, but on the delivery side such precision may not be needed (or may not be achievable because other data might be imprecise, eg roughness of pipes). So when designing a system, the relative importance of the various losses in the system should be kept in mind. With long pipes and large static heads, the head loss across a junction might be quite insignificant; with the sort of pipe systems found in petrochemical plants total junction losses may be far greater than pipe friction losses.

Junction losses can be included in a model by selecting the junction tab from the Component Palette and selecting the appropriate icon, viz bend, tee or wye.

A common method of calculating the head loss across a junction has been to use data from the Crane publication.

- Crane: “Flow of Fluids Through Valves, Fitting and. Pipes" Publication 410M.

The Crane method is really an equivalent length method, sometimes referred to as K_f

FluidFlow3 allows this method but it does have some shortcomings. For instance, it does not allow the simulation of unequal tees, ie a tee with pipes of different diameter joining, nor does it allow tees with an angle other than 90 deg. (To simulate an unequal tee, a reducer could be added to a Crane tee with a negligible length of joining pipe). Crane does not account for the occurrence of pressure *rise* across tees and wyes; a phenomenon arising from pressure recovery as a joining stream slows.

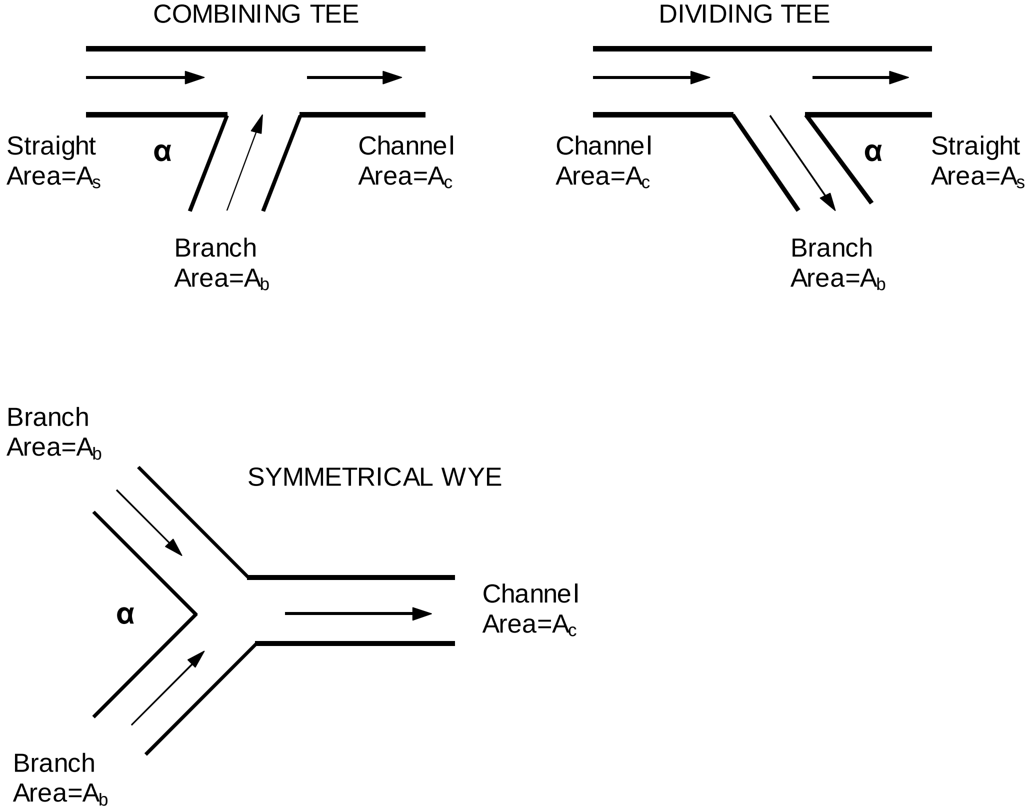
Three other methods of estimating head loss across tees and wyes are available in FluidFlow3. These are:

- Idelchick: ”Handbook of Hydraulic Resistance”, 3rd Edition, IE Idlechick,
  Pub Begelll House ISBN 1-56700-074-6
- Miller: “Internal Flow Systems”, 2nd Edition, DS Miller,
  Pub BHRA Information Services. ISBN 0-947711-77-5
- SAE International: http://www.sae.org

This note only deals with Idelchik and Miller.

Idelchik and Miller resolve the shortcomings of Crane by providing extensive nomographs and equations dealing with tees and wyes with pipes of different pipe diameters adjoining at various angles. Both will determine pressure *rise* where it occurs. The data is heavily qualified in that it applies to very precise conditions. For example, for Miller diverging tees, the straight and channel must be the same diameter.

The diagram below shows the nomenclature used in the software.



It is important to understand that for converging junctions, losses are calculated only for the **'straight to channel'** path (coefficient K_s) and the **'branch to channel'** path (coefficient K_b); there is no loss allocated to the channel itself. (This is the convention used in both Idelchik and Miller). For diverging junctions the losses are **'channel to straight'** and **'channel to branch'**. For symmetrical wyes the loss is **'branch to channel'**.

Also note that "channel" flow is the largest of the three values, ie the sum of the converging flows or the total flow prior to diverging. The software nomenclature is as follows:

- Converging and diverging tees: the red dot is the branch
- Converging wyes: the red dot is the channel.

Both Idelchik and Miller are based on extensive testing, so the data is subject to experimental error. Also, the head loss graphs have had to be converted into equation form. As a consequence, there will be differences between a head loss calculated with Idlechick to the same head loss calculated with Miller (and with Crane and SAE).

Therefore, if head loss across junctions is vital to the simulation of a flow system, other methods of calculation such as direct reference to the above methods may be needed. Always review the K values calculated with FluidFlow3. Do they look sensible? If not, perhaps your arrangement is outside the scope of the equations currently used. Re-solve the junction with a Crane junction and reducers or even replace it with a zero head loss connector and use Crane or Miller to estimate individual K values for the straight and branch and add these as General Resistances to the database.

NON-CONVERGENCE OF A MODEL OR UNREASONABLE K VALUES FOR A TEE

FluidFlow3's head loss calculations for tees (and elbows and crosses) are based, as described above, on experimental data. Essentially, FluidFlow3 needs to resolve at convergence the following ratios:

- Straight to branch pipe diameters
- Straight to branch pipe flows

If these fall within the experimental ranges used to determine the K values then the head loss value calculated is likely to be in accordance with the underlying theory. (Calculation of tees is quite resource intensive and can add many iterations to the solution process).

If the above ratios fall outside the experimental range then the following may occur:

1. A model may fail to converge.
2. The model may solve but FluidFlow3 will enunciate a warning for the non-complying tees.
3. Fluidflow3 may calculate unreasonable value of K.

If a model fails to converge, there are three immediate possibilities:

1. Tees outside range as described above.
2. Pump curves not entered into the database with an estimated coordinate of Head = 0 and Flow = maximum.
3. Flow in a pipe calculated to be zero or extremely low.

To eliminate the tee problem, use the List Inspector to select all tees and replace them with Connectors. Usually it's only one or two tees that wont converge and these will probably have the following characteristics:

- Zero of very low flow in one leg.
- Symmetrical converging flow.
- Ratio of diameter well outside the experimental range.

If flow in a pipe is extremely low, simply close the pipe.

In summary then, we have a number of sources of information about the head loss across tees. All are based on experiment data and all operate within a specified range of application. Outside these ranges there is no available data on which to base the calculation, so an engineering judgement needs to be made, viz:

- Ignore the head loss across some or all of the tees
- Estimate a head loss by some other method such as a fixed pressure drop or an equal tee combined with a reducer.

FLOW STABILITY (This section is copied from Miller)

Combining flow is a relatively stable process. Velocities increase through the junction in many combining junctions. This aids flow stability reducing the tendency for transient movement, growth and decay of flow separation regions.

Dividing flows can lead to large flow instabilities that have caused structural failures of large dividing tee junctions. These instabilities are associated with changes if flow patterns within junctions with the size and location of flow separation regions changing as the incoming flow is biased first towards one outlet leg and then the other. Instabilities can be at a maximum at or close to typical design operating conditions, such as a 50/50 split in a symmetrical dividing tee junction. Under conditions of violently unsteady flow, head loses across a junction may be several times the predicted values.

It is recommended that when head losses after a symmetrical tee junction do not exceed the junction loss by factor of 10 and flow distribution is important a symmetrical 180 deg tee junction should not be used. Symmetrical tee junctions are best avoided in large systems, systems with high velocities and systems with flexible pipework.

Although Miller uses the term tee in this comment, he later also refers to instabilities in symmetrical wye junctions so it is assumed the comments apply to both.

GUIDANCE ON THE SIMULATION OF TEES, WYES AND BENDS

The solution of tees and wyes according to Idelchik and Miller is processor intensive and will increase the number of iterations to closure considerably. Any increase in the precision of the solution achieved by using Idelchik or Miller junctions may not justify the increased solution time.

To determine just what contribution junctions make to the overall simulation they can either be temporarily removed from the calculation changing them to Connectors with No Resistance or set to *"Ignore Pressure Loss"* in the Input Inspector. FluidFlow3 will then solve the model as if the head loss across the junctions were zero. A judgment can then be made as to whether junctions should be included in the simulation.

> *Hint: Build your model first with Ik with tees. Set the orientations correctly. Save. Then globally change all your tees to connectors with zero resistance or ignore head loss. Does this make a significant difference? Globally change to Crane etc.*

JUNCTION CALCULATIONS: QUALIFICATIONS: Legend: Q = flowrate; V = velocity

Tee Junctions:

Idelchik Combining Tee

QUALIFICATIONS		SENSIBLE RANGE OF K_b FOR $Q_b/Q_c = 0.5$	SENSIBLE RANGE OF K_s FOR $Q_b/Q_c = 0.5$	NOTES
Area Ratios	**Angles α (deg)**			
$A_s + A_b > A_c$ $A_s = A_c$	30 - 90	6.75 to 0.77 for values of A_b/A_c = 0.2 and 1.0	-1.43 to 0.50 for values of A_b/A_c = 0.2 and 1.0	• High positive K_b values occur with $A_b / A_c < 0.2$ and $Q_s / Q_c > 0.6$. • High negative Ks values occur with Ab / Ac < 0.2 and Qs / Qc > 0.6. • As α approaches 90 deg, Ks approaches a relatively constant value of 0 to 0.5.
$A_s + A_b = A_c$	15-90	6.7 to -0.3 for values of A_b/A_c = 0.2 and 0.5	-1.6 to 1.10 for values of A_b/A_c = 0.2 and 0.5	

Idelchik Diverging Tee

QUALIFICATIONS		SENSIBLE RANGE OF K_b FOR Vb/Vc = 2.0	SENSIBLE RANGE OF K_s FOR Vb/Vc = 2.0	NOTES
Area Ratios	**Angles α (deg)**			
$A_s + A_b > A_c$ $A_s = A_c$	15 - 90	1.1 to 3	See Miller	
		Vb/Vc = 1.0	**Vb/Vc = 1.0**	
$A_s + A_b = A_c$	15-90	0.06 to 1.0	See Miller	

Miller Combining Tee

QUALIFICATIONS		SENSIBLE RANGE OF K_b FOR $Q_b/Q_c = 0.5$	SENSIBLE RANGE OF K_s FOR $Q_b/Q_c = 0.5$	NOTES
Area Ratios	**Angles α (deg)**			
$A_s = A_c$	45	5.00 to 0.10 for values of A_b/A_c = 0.2 to 1.0	-0.6 to 0.15 for values of A_b/A_c = 0.2 to 1.0	
$A_s = A_c$	90	5.5 to 0.45 for values of A_b/A_c = 0.2 to 1.0	0.7 to 0.5 for values of A_b/A_c = 0.2 to 1.0	

Miller Diverging Tee

QUALIFICATIONS		SENSIBLE RANGE OF K_b $Q_b/Q_c = 0.5$	SENSIBLE RANGE OF K_s FOR $Q_b/Q_c = 0.5$	NOTES
Area Ratios	**Angles α (deg)**			
$A_s = A_c$	45	0.25 to 0.44 for values of A_b/A_c = 0.2 to 1.0	0.00 – 0.10	
$A_s = A_c$	90	4.0 to 0.85 for values of A_b/A_c = 0.2 to 1.0	0.00 – 0.10	

Symmetrical Wye Junctions
Legend: Q = flowrate; V = velocity

*** IMPORTANT NOTE ***

FluidFlow3 allows only Idelchik symmetrical wyes at this moment. However, this component is still under development (January 2006, Version 3.06, Build 01) and we recommend that you do not use this component within this release.

The table below indicates that K values for combining symmetrical wyes may be relatively low. In fact the two Miller nomographs describing this show between them, ranges of values of K of between –2.0 to 2.0.

Miller Combining Symmetrical Wye

QUALIFICATIONS		SENSIBLE RANGE OF K_b FOR $Q_b/Q_c = 0.5$		NOTES
Area Ratios	Angles α (deg)			
$A_{b1} + A_{b2} = A_c$	30 -120	0.10 – 0.80		Negative values likely for $Q_b/Q_c < 0.4$ and angles less than 90deg
$A_{b1} = A_{b2} = A_c$	60 -180	0.06 – 0.62		Negative values likely for $Q_b/Q_c < 0.3$ and angles less than 90deg

VARIATIONS

Both references provide a wide range of variations on the above data. For instance:

- Differentiating between welded and screwed fittings
- Effect of Reynolds number
- Effect of proximity of other fittings and line equipment
- Radii of pipe joins
- Flow instability for dividing junctions

This note and the calculations performed by FluidFlow3 can only provide an approximation of the actual head loss across a junction. The actual effects of the on-site workmanship of the pipe fabrication, the proximity of other line equipment items, pipe roughness and internal flow conditions etc cannot be predicted by FluidFlow3. It is the responsibility of the engineer to …

1. Ensure that the FluidFlow3 can simulate the junction arrangement modeled.
2. Ensure that the calculated values of K are realistic.
3. To provide a cross-check by some other method.

NOTE: This Software Application Note is intended only as a guide as to the determination of head loss across junctions. It is the responsibility of the software user to ensure that values generated by FluidFlow3 are correct by checking against other methods.

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