Accounting for sound power level reduction at fittings in AIV Calcs (DRAFT)

Piping head loss is normally calculated as follows

$$\Delta h_L = K\frac{v^2}{2g_n}$$

where

$$K = f\frac{L}{d}$$

d is internal diameter, f is the friction factor, L is length of pipe.

The reduction in sound power level with distance from an acoustic vibration source is given in various sources as (using consistent units):

$$\Delta PWL = 0.06\frac{L}{d}$$

If it is assumed that a fitting has the same equivalent length 'L/d' for both sound power level reduction and head loss, the reduction in sound power at a fitting is

$$\Delta PWL = 0.06\frac{K}{f}$$

And the fitting causes the same reduction as a linear length of

$$L = d\frac{K}{f}$$

For completely turbulent flow, the friction factor f is referred to as f_T

Sound Power Reduction at Fittings

Bends

The Salad script calculates K based on the bend radius and a curve fit of the table from Crane p A-29. Eg. for r/d=1.5, K=14 f_T, therefore

$$\Delta PWL = 0.06\frac{14f_T}{f_T} = 0.84\ dB$$

Bends with angle less than or greater than 90 degrees are catered for using the formula beneath the table.

Miter bends are currently treated in the same manner as given above for normal bends.

Tees

Flow through branch:

$$\Delta PWL = 0.06.60 = 3.6\ dB$$

Flow through run (equal size branch):

$$\Delta PWL = 0.06.20 = 1.2\ dB$$

Flow through run (any size branch):

This formula came from a company standard, origin unknown..

$$K = 40 f_T \frac{d_{side}}{d_{run} + d_{side}}$$

$$\Delta PWL = 2.4\ \frac{d_{side}}{d_{run} + d_{side}}$$

Note: for conservatism the sound power level of all sources going into a branch are summed and checked (using the header D/t properties), prior to applying attenuation. This shows up in the output of the D/t method as an additional element listed as 'nodeT-node', eg for a branch at node 50 this would be '50T-50'. The same approach is applied for EI guidelines method but no special designation is shown at the branch location.

Reducers / Expanders

The formulae from Crane pA-26 are used, except that the β^4 denominators in the formulae are omitted. The 4^{th} power of Beta (diameter ratio) is a correction factor for head loss, which is proportional to velocity squared. If our previous assumptions are correct then sound power reduction is proportional only to K/f, which should be the same when 'looking from' either side of the fitting. Thus no correction factor is required, except perhaps for the change of friction factor with diameter (as the friction factor is not included in the formula unlike other fittings, it can make a difference). The script always uses the turbulent friction factor corresponding to the smaller diameter. This value is taken from a curve fit of the 'commercial steel' figures from Crane page A-23.

The angle of the reducer/expander is assumed to be 45°. Currently CAESAR II does not export information about reducers to the XML file. Only the diameter of the 'from' node is known for a reducer (like any other element). Depending on the direction of modelling (from upstream to downstream or vice versa) this can have a minor impact on results. The script assigns the PWL reduction at the point of diameter change.

Formulae ($\beta = d_{small}/d_{large}$)

Expansion (θ is assumed to be ≥45°):

$$\Delta PWL = 0.06\ \frac{(1-\beta^2)^2}{f_{T(1)}}$$

Eg. β=0.5, f =0.015: $\Delta PWL = 2.25dB$

Reduction (θ is assumed to be 45°):

$$\Delta PWL = 0.048 \frac{\sin\frac{45}{2}(1-\beta^2)}{f_{T(1)}}$$

Eg. β=0.5, f =0.015: $\Delta PWL = 0.93 dB$

Valves

These are currently ignored by the script.