DIERS Users Group Pipe Flow Calculations – A Round-Robin Exercise

As part of the DIERS UG Design / Testing committee activity, a round-robin exercise is proposed in connection with pipe discharge flow calculations for three fluid mixtures:

(I) cyclohexane (c-C6) at 10 bar abs (single component)

(II) 20% mole ethane in heptane (C2/n-C7) at 10 bar abs (two component)

(III) 2.5% mole nitrogen in cyclohexane (N2/c-C6) at 33 bar abs (two component)

Recently a round-robin exercise based on nozzle discharge for these fluids has been completed. The proposed activity extends the nozzle case to a pipe discharge configuration. Again the classical homogeneous equilibrium model (HEM) – thermodynamic equilibrium and no slip between phases - should be followed. By fixing the flow regime, this allows us to check the variability of the calculations and the results. The proposed discharge flow inlet (stagnation) conditions are identical to the earlier nozzle case:

Proposed inlet conditions

Case	**Liquid Composition (mole)**	**P_o (bar)**	**T_o (°C)**	**x_o (vapor mass frac.)**
Ia	100% c-C6	10	182.3	0.0001 (bubble pt)
Ib	100% c-C6	10	182.3	0.01
Ic	100% c-C6	10	182.3	0.1
IIa	20% C2/n-C7	10	51.9	0.0001 (bubble pt)
IIb	20% C2/n-C7	10	51.9	0.01
IIc	20% C2/n-C7	10	51.9	0.1
IIIa	2.5% N_2/c-C6	33	25	0.0001 (bubble pt)
IIIb	2.5% N_2/c-C6	33	25	0.01
IIIc	2.5% N_2/c-C6	33	25	0.1

See the Peng-Robinson VLE model and the associated k_{ij} parameter discussions in the nozzle flow benchmark result presentation at the San Antonio DIERS UG meeting for more details (DUG 42-850-1).

Two horizontal straight pipe configurations are proposed for each case listed above:

Pipe I with total piping resistance N = 1.5.
Pipe II with total piping resistance N = 5.

Taking a pipe diameter (i.d.) of 2.067" or 52.5 mm, a Fanning two-phase friction factor f_{TP} of 0.005 and an entrance loss K_{en} of 0.5, the corresponding L/D and pipe length would be

Pipe I	L/D = 50, L = 8.61 ft (2.63 m)
Pipe II	L/D = 225, L = 38.8 ft (11.8 m)

For those who use Reynolds number-dependent f_{TP}, i.e.

$$f_{TP} = \text{function}\left(\frac{GD}{\mu_{TP}}\right)$$

where μ_{TP} is the mean two-phase viscosity in the normal friction factor relationships (such as Blasius equation), an average $\bar{f}_{TP}$ value along the pipe should be used to "determine" the required pipe length L to achieve the same piping resistance, i.e.,

$$N = K_{en} + 4\,\bar{f}_{TP}\,\frac{L}{D}$$

such that the appropriate N values would agree with the problem specification. As for the two-phase viscosity, a common practice is based on the McAdam's formula,

$$\frac{1}{\mu_{TP}} = \frac{x}{\mu_g} + \frac{(1-x)}{\mu_f}$$

where μ_g and μ_f are the vapor viscosity and liquid viscosity, respectively.

Data Submission should include a summary sheet listing methods or calculational steps and the assumed f_{TP} or model used. Also provide the pressure, temperature and quality (vapor mass fraction) profiles in the pipe (if available), pipe exit pressure (if choking occurs), mass flux G (kg/m^2s) and discharge rate W (kg/s) corresponding to the pipe flow area of 3.355 in^2 (2165 mm^2).

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NO LATER THAN March 13, 2009

Presentation of the results will be made at the next DIERS UG meeting in Orlando.

Thank you in advance of your participation !