Designing Multiple-Diameter Relief Piping

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Most design methods consider a single pipe diameter. Here's how to evaluate multiple-diameter systems and to calculate conservative single-pipe representations.

Design engineers face the complex task of protecting reactors and other vessels from excess pressures due to runaway reactions and fire engulfment. The Design Institute for Emergency Relief Systems (DIERS) methodology for emergency relief system (ERS) design *(1)* takes a conservative approach to this important engineering task.

The great majority of design methods deal explicitly with relief piping systems with a single pipe diameter for compressible flows, including two-phase flashing flow. Methods are available ranging from direct numerical calculation *(1)* to manual/graphical techniques based on the Omega method *(1–3)*. The computation of these flows for systems with multiple diameters, while also discussed in the literature *(1–6),* is not covered as frequently.

This article presents design methods that address several important issues for multiple-diameter systems:

• the logic that should be followed to identify where choke flow occurs and how to compute the maximum flow capacity and pressure profile of such systems (this has direct application to the development of software solutions to multiple-pipe analysis)

• how to apply a simple single-pipe representation of a multiple-pipe vent system that gives a conservative estimate of the system flow capacity with minimum design effort, and how to improve this estimate

• how to account for the effect of elevation change on the system's estimated flow capacity.

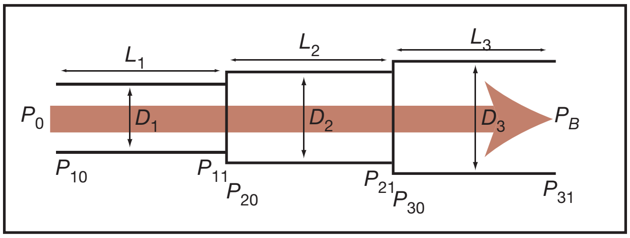
Computational approach for three sections of piping

Consider a system (Figure 1) consisting of three sections of piping in series with diameters and equivalent lengths of (D_1, L_1), (D_2, L_2) and (D_3, L_3). The fluid pressures at the beginning and end of each section are (P_{10}, P_{11}), (P_{20}, P_{21}) and (P_{30}, P_{31}), respectively. (In this analysis, pressure recovery on transition from a smaller to a larger pipe is neglected). Each equivalent length L_1, L_2 and L_3 is the sum of the actual lengths and the equivalent lengths of all fittings (including entrances and exits) in each section of pipe. (See Ref. 1 for details.)

The fixed upstream pressure is P_0, the fixed downstream backpressure is P_B, and the following relationships exist:

$$P_0 = P_{10}$$
$$P_{11} \geq P_{20}$$
$$P_{21} \geq P_{30}$$
$$P_{31} \geq P_B$$

If no choke exists in the piping system, the equalities in



■ Figure 1. Relief-vent piping with multiple diameters.

the above expressions apply. If a choke occurs in a section, then the inequality may pertain. When a choke occurs, it is assumed to occur at the end of the section.

The calculation of pressure drop due to a specified mass flowrate can be carried out in either of two ways:

- forward calculation from a known upstream pressure
- backward calculation from a known downstream pressure.

Starting with a low value, the flowrate is increased in steps, and forward calculation from the known upstream pressure P_0 is carried out until choked flow occurs in one of the piping sections. The exact choking value is found by iteration, until the flow in the section exactly chokes at the end of that section. Various iteration methods have been tested, and the simple bisection method gave satisfactory results.

The general flow regime possibilities for the three pipe sections arising from this calculation are denoted CXX, UCX, UUC and UUU, where C indicates choked flow, U indicates unchoked flow and X indicates flow either choked or unchoked. The specific flow regimes represented by CXX are CUU, CCU, CUC and CCC; UCX includes the UCU and UCC regimes. The UUU regime has no choking, in which case the choke flow calculated by forward calculation is less than the maximum unchoked flow determined by backward calculation from the known downstream backpressure.

Figures 2, 3 and 4 present the steps involved in analyzing the various regime alternatives. This approach can be extended by analogy to piping systems with more than three diameters. It becomes significantly more complex when there are more than about four diameters, but the great majority of vent relief systems can be satisfactorily and accurately modeled using this logic.

Multiple chokes

The initial choke determined by this procedure will be the first choke downstream. This will be the controlling choke, in that the flow determined at this point will be a maximum for the rest of the computation.

In the pipe section immediately after a choke, there will be a discontinuity in the pressure profile. The pressure profile in the downstream section (*e.g.,* Pipe 2) will start at a value less than or equal to the final choke pressure in the upstream section (Pipe 1). If the downstream section (Pipe 2) also develops a choke, the value of this secondary choke pressure at the end of Pipe 2 will be greater than or equal to the downstream backpressure in Pipe 3. This means that there is, in principle, a pressure range over which the choke in Pipe 2 can lie. The higher the initial pressure in Pipe 2 (*i.e.,* the closer to P_{11}), the higher the flowrate in Pipe 2 will be due to higher vapor densities; the lower the initial pressure in Pipe 2, the lower the flowrate in Pipe 2 will be. The actual values of the initial and choke pressures in Pipe 2 will be determined by the value of the flowrate already determined for Pipe 1.

These relationships can be expressed as (for a controlling choke in Pipe 1 and a secondary choke in Pipe 2):

$$P_{11} \geq P_{20} > P_{21} \geq P_{30} \quad (1)$$

The maximum flow condition for a choke in Pipe 2 is:

$$P_{11} = P_{20} > P_{21} > P_{30} \quad (2)$$

and the minimum flow condition for a choke in Pipe 2 is:

$$P_{11} > P_{20} > P_{21} = P_{30} \quad (3)$$

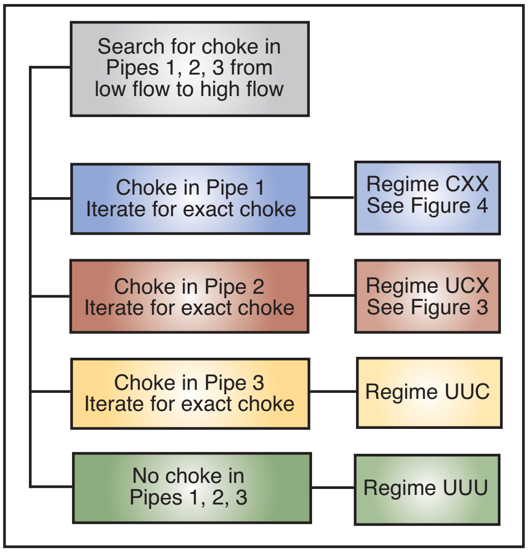


Figure 2. Procedure to identify the controlling choke.

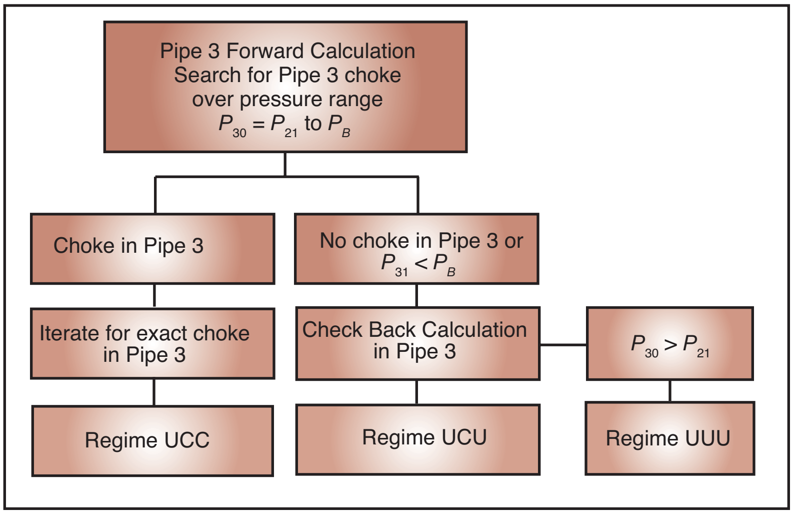


Figure 3. Procedure for evaluating the UCX regime alternatives.

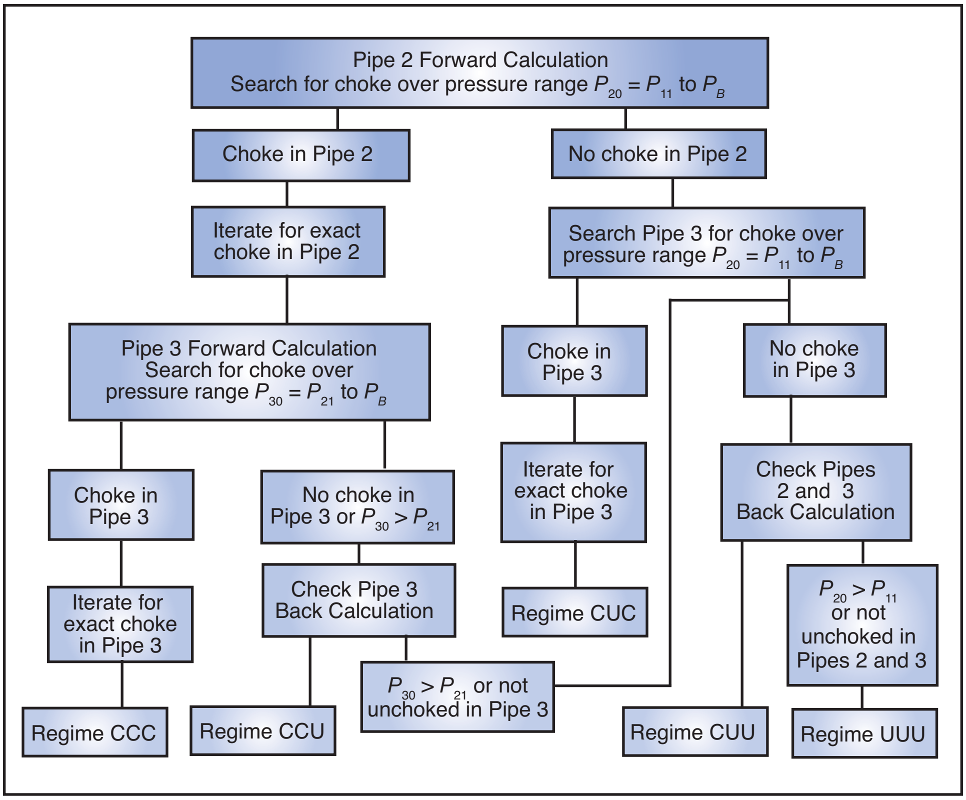


Figure 4. Procedure for evaluating the CXX regime alternatives.

Downstream piping configurations can only reduce the maximum flow by moving the first choke point to another downstream location or by eliminating all chokes in the system (for example by greatly increasing overall pipe length).

Modeling of two-phase flashing flow

While the computation methods discussed here are, in principle, applicable to all kinds of compressible flows, the main application is to two-phase flashing flows typically encountered in the analysis of reactor relief-vent sizing. The fundamental difference equation governing two-phase flashing flow in a pipe with friction and elevation changes is adapted from Eq. II-47 in the DIERS manual *(1):*

$$\Delta L = \frac{\Delta P - G^2 \Delta v}{\left[\frac{\Delta P}{\Delta L} + \frac{g\left(\Delta H / \Delta L\right)}{v}\right]_{ave}} \quad (4)$$

This equation is integrated to give the equivalent length, L_E. The approach taken is to assume isentropic or isenthalpic expansion along the pipe. The adiabatic (constant energy) case can also be handled. Details of the model are presented for the isenthalpic case; the isentropic case is similar. The isentropic case gives the maximum possible flow. The isenthalpic case is somewhat more conservative and is used generally in the CCPS Guidelines *(7)* and the DIERS manual *(1)*. The adiabatic case lies between the isenthalpic and isentropic cases. For many practical situations, the difference between the three design cases is small (see Ref. 7 and example calculations).

The enthalpy at the start of the pipe is:

$$h_0 = x_0 h_{g0} + (1 - x_0) h_{f0} \quad (5)$$

where x_0 is the vapor quality, h_{g0} is the initial vapor enthalpy and h_{f0} is the initial liquid enthalpy. The final enthalpy is set equal to the initial value of enthalpy (h_0).

Pressure is then computed in a stepwise manner:

$$\Delta P = (P_0 - P_1)/N \quad (6)$$

where P_0 is the initial pressure, P_1 is the final pressure at the end-of-pipe conditions and N is the total number of steps.

At each computation step n ($n = 1 \ldots N$):

$$x_n = (h_0 - h_f)/(h_g - h_f) \quad (7)$$
$$y_n = xv_g/(xv_g + (1 - x)v_f) \quad (8)$$
$$v_n = xv_g + (1 - x)v_f \quad (9)$$
$$\Delta v_n = v_n - v_{n-1} \quad (10)$$
$$G = W/A \quad (11)$$
$$\mu = y_n\mu_g + (1 - y_n)\mu_f \quad (12)$$
$$Re = DG/\mu \quad (13)$$
$$f^{1/2} = -0.5757/\ln(e/3.7D + 1.255/f^{1/2}Re) \quad (14)$$
$$\Delta P/\Delta L = 2fG^2v_n/D \quad (15)$$
$$B_n = \Delta P/\Delta L + 9.81(\Delta H/L)/v_n \quad (16)$$
$$B_{mean} = (B_n + B_{n-1})/2 \quad (17)$$
$$C_n = \Delta P - G^2\Delta v_n \quad (18)$$
$$\Delta L = C_n/B_{mean} \quad (19)$$
$$L_E = \Sigma L \quad (20)$$
$$P_n = P_1 + \Sigma\Delta P \text{ for back-calculation from } P_1 \quad (21)$$
$$P_n = P_0 - \Sigma\Delta P \text{ for forward-calculation from } P_0 \quad (22)$$

where x is the vapor mass fraction, y is the vapor volume fraction, v is the specific volume, G is the mass flux, W is the mass flowrate, A is the area, μ is the viscosity, Re is the Reynolds number, f is the Fanning friction factor given by the Colebrook equation *(8),* H is the elevation and L_E is the pipe equivalent length.

If any ΔL value is negative, the flow is choked in the vent system.

This model has been satisfactorily validated against the Adair/Fisher benchmarks *(9)* for horizontal flashing flow (Benchmark 2), vertical/horizontal flashing flow (Benchmark 3) and horizontal/vertical flashing flow (Benchmark 3) for both isenthalpic and isentropic cases.

Equivalent single-pipe representation — no elevation change

The logic system depicted in Figures 2, 3 and 4, together with numerical solutions of vapor-only and two-phase flashing flows plus a suitable physical properties database, have been implemented in software by the authors. Inlet pressures, diameters and lengths of pipes, choke conditions and capacity flowrates have been evaluated for both two-phase and vapor-only flows for a wide range of fluids. Unusual configurations (for example, cases where D_2 is smaller than D_1, or where L_2 is very large) have been included to test the robustness of the methodology.

The equivalent single-pipe representation of the multiple-pipe system (which will be identical for incompressible flows with a constant friction factor and zero elevation change) has been calculated for each case:

$$L_E \text{ (at } D_{min}) = \Sigma_i \Delta L_i (D_{min}/D_i)^5 \qquad (23)$$

where D_{min} is the minimum of the D_i.

The equivalent single-pipe representation yielded a maximum capacity flowrate, W_{SP}, less than that obtained by the full multiple-diameter analysis, W_{MP}, for every case analyzed. This is a very general result. It can be shown analytically that the equivalent single-pipe representation (based on the minimum diameter or less) always produces a maximum mass-flow capacity less than or equal to that produced by the full multiple-diameter analysis for compressible flow at constant elevation (including vapor-only and two-phase), as discussed later in the article (p. 47).

In most cases examined, W_{SP} was reasonably close to W_{MP}. Based on a detailed analysis of more than 430 data points, both two-phase and vapor-only flows of dichloromethane, methanol and hexane, with 20-bar and 5-bar upstream pressures, the following expressions relating W_{MP} to W_{SP} were developed. These equations can be used to derive error estimates for W_{SP} or to derive improved estimates of W_{MP} from W_{SP}.

For $1 < L_E/L_{min} < (L_E/L_{min})^*$:

$$W_{MP}/W_{SP} = \ln[2.93(L_E/L_{min} - 0.5)^{0.108}] \qquad (24a)$$

$(L_E/L_{min})^*$ represents the value of L_E/L_{min} at which W_{MP}/W_{SP} reaches a maximum value (as discussed below). The value of $(L_E/L_{min})^*$ is between 3 and 10. Note that when $L_E/L_{min} = 1$, then $W_{MP} = W_{SP}$.

The average absolute error of Eq. 24a is 1.5%. In the region $L_E/L_{min} < (L_E/L_{min})^*$, the controlling choke typically occurs in the upstream section of pipe.

For $L_E/L_{min} > (L_E/L_{min})^*$, the controlling choke usually occurs in the final or downstream section of pipe and W_{MP}/W_{SP} falls with increasing values of L_E/L_{min}. This is consistent with the observation (discussed later) that as pipe length tends to infinity, W_{SP} approaches W_{MP}. For $L_E/L_{min} > (L_E/L_{min})^*$:

$$W_{MP}/W_{SP} = 1.551(L_E/D_{min})^{-0.0495} \qquad (24b)$$

The average absolute error associated with Eq. 24b is

Nomenclature

A	= area, m^2
B, C	= simplifying variables
D	= diameter, m
e	= absolute roughness, m; e = 0.0000457 m for steel pipe
f	= Fanning friction factor
g	= acceleration due to gravity; g = 9.81 m/s^2
G	= mass flux, kg/s-m^2
h	= enthalpy, J/kg
H	= elevation, m
L_E	= eqivalent length, m
L_{min}	= length of minimum-diameter section, m; note that this is not the minimum section length
N	= number of computation steps
P	= pressure, Pa abs
Re	= Reynolds number; $Re = DG/\mu$
v	= specific volume, m^3/kg
W	= mass flowrate, kg/s
x	= vapor mass fraction
y	= vapor volume fraction

Greek Letters

μ	= viscosity, kg/m-s
ρ	= density, kg/m^3

Subscripts

0	= initial value
ave	= average between successive computation steps
A	= above (upstream of) first choke
B	= below (downstream of) first choke
CS	= constant-slope configuration
E	= equivalent
f	= liquid (fluid)
g	= vapor (gas)
HV	= horizontal-vertical configuration
MP	= exact multiple-pipe value
SP	= equivalent single-pipe value
tp	= two-phase
VH	= vertical-horizontal configuration

about 1.6%. Equation 24b will give reasonable values up to about L_E/D_{min} = 2,000.

An interesting implication of the behavior of W_{MP}/W_{SP} as represented by Eqs. 24a and 24b is that W_{MP}/W_{SP} reaches a maximum of about 1.20 to 1.25 at $L_E/L_{min} = (L_E/L_{min})^*$. This result establishes an overall maximum limit to the error associated with the use of the equivalent single-pipe value, W_{SP}.

There is no simple way to determine the value of $(L_E/L_{min})^*$ for a particular application: equating Eqs. 24a and 24b and solving for L_E/L_{min} requires an iterative solution. When applying Eqs. 24a or 24b, the correct value of W_{MP}/W_{SP} will always be found by taking the minimum of the W_{MP}/W_{SP} values calculated from both equations.

This analysis demonstrates that the equivalent single-pipe representation (Eq. 23) gives a conservative design for two-phase flashing or vapor-only flow in multiple-diameter vent piping systems at constant elevation, with minimum effort and a known error range. In addition, Eqs. 24a and 24b give improved estimates of the true capacity flowrate.

Equivalent single-pipe representation — with elevation change

The impact of elevation changes on the capacity flowrate of pipes with two-phase flashing flow was studied for three basic cases:

- constant slope (CS) — the elevation changes at a constant rate over the length of the pipe
- vertical/horizontal (VH) — a vertical elevation change occurs in the first section of pipe, and the remainder of the pipe is horizontal
- horizontal/vertical (HV) — the pipe run starts horizontal, then changes elevation in the last section of pipe.

The elevation changes can be either positive or negative in the direction of flow.

The only cases of interest here are those in which the elevation changes tend to lower the flow capacity of the piping system. Flow capacity is reduced by upflow and increased by downflow. It can easily be shown that in upflow, the flow capacity is reduced most in the VH configuration, followed by the CS configuration and then the HV configuration. Thus, the primary cases of interest are the VH and CS upflow configurations.

Elevation changes in the first section of pipe have a far greater impact on flow capacity than elevation changes in other downstream sections, particularly downstream of the first choke. With this in mind, it is recommended that corrections for elevation change be made only for elevation changes in the first section.

Analysis of CS upflow was carried out for the following conditions:

- hexane, methanol and dichloromethane
- diameters of 50, 100 and 150 mm
- lengths of 6, 10 and 20 m
- elevation changes ranging up to the pipe length
- initial qualities of 0.1%, 5% and 10%
- initial pressures of 5 and 20 bar(g)

The rate of change of flow capacity with respect to elevation change ($\Delta W/\Delta H$) was effectively constant for all CS configurations. The following dimensionless expression was fitted to the computed data (162 data points) with a normalized standard deviation (standard deviation divided by mean) of 12%:

$$(1/W)(\Delta W/\Delta H)(L_E/D)^{1/3}(v_{tp0}P_0/g) = -6.33 \qquad (25)$$

where W = two-phase capacity flowrate (kg/s), H = elevation (m), L_E = pipe equivalent length (m), D = pipe diameter (m), v_{tp0} = two-phase specific volume at the start of the pipe (m^3/kg), g = acceleration due to gravity (9.81 m/s^2) and P_0 = pressure at the start of the pipe (Pa abs).

From Eq. 25, it can be seen that relative flow deviations ($\Delta W/W$) are maximized in short, large-diameter pipes with large elevation changes operating at low pressure and low vapor content, and minimized for long, small-diameter pipes with small elevation changes operating at high pressure and high vapor content.

As noted earlier, the VH configuration reduces the flow capacity more than the CS configuration. The VH effect can be closely related to the CS effect as follows:

$$\left(\frac{\Delta W}{\Delta H}\right)_{VH} = \frac{\left(\Delta W/\Delta H\right)_{CS}}{0.6\,\Delta H/L_E + 0.4} \qquad (26)$$

Equations 25 and 26 can be combined to estimate flow capacities for VH configurations:

$$\frac{\Delta W_{VH}}{W} = \frac{-6.33\Delta H\left(D/L_E\right)^{1/3}\left(g/v_{tp0}P_0\right)}{0.6\,\Delta H/L_E + 0.4} \qquad (27)$$

where W is obtained from Eq. 24a or 24b ($W_{MP(Eq24)}$).

The final estimated value of W_{MP} is:

$$W_{MP(Corrected)} = W_{MP(Eq24)} + \Delta W_{VH} \qquad (28)$$

Equation 28 can be used directly to determine the region within which elevation changes can be neglected (subject to a predetermined acceptable error level). It can also be used to determine those regions where an explicit calculation of the effects of elevation change must be taken into account.

Table 1. Characteristics of the multiple-diameter relief piping system in Example 1.

Section	1	2
Diameter (D), mm	54.8	108.2
Equivalent Length (L_E), m	8	100
Elevation Change (ΔH), m	5	0

Example 1

Table 1 lists the dimensions of a multiple-diameter relief piping system. Saturated hexane with a quality of 5% is released into Section 1 at 5 bar(g). The backpressure at the end of the piping system is 0 bar(g). Assume isenthalpic conditions.

1. Estimate the flow capacity of the piping system using Eqs. 23–28, and compare the equivalent single-pipe value with the calculated exact value.

1a. Calculate the equivalent single-pipe capacity. The equivalent length is $L_E = 8 + 100(54.8/108.2)^5 = 11.33$ m at $D = 54.8$ mm. The flow capacity for a single horizontal pipe with these dimensions is $W_{SP} = 6.28$ kg/s.

1b. Calculate the improved estimate. From Eq. 24a: $W_{MP(Est)} = 6.28 \ln[2.93(11.33/8 - 0.5)^{0.108}] = 6.69$ kg/s.

1c. Calculate the impact of elevation change. The properties of saturated hexane at 5 bar(g) and $x = 0.05$ are: $v_g = 0.05492$ m^3/kg; $v_f = 0.001869$ m^3/kg; and $v_{tp0} = 0.00452$ m^3/kg. Using $W = 6.69$ kg/s from Step 1c, the effect of elevation change is calculated from Eq. 27:

$$\Delta W = \frac{(6.69)(-6.33)(5)\left(\frac{0.0548}{11.33}\right)^{1/3}\left[\frac{9.81}{(0.00452)(601,325)}\right]}{0.6(5/11.33)+0.4}$$

$$= -0.086 \text{ kg/s}$$

The estimate of W after correcting for the elevation change is $W = 6.69 - 0.086 = 6.60$ kg/s. The exact value computed for this multiple-pipe system in isenthalpic flow is 6.63 kg/s. The computed values for isentropic and adiabatic flow are 6.71 kg/s and 6.69 kg/s, respectively.

2. What elevation change (VH configuration) will result in a 2% correction in flow capacity?

Known values are inserted into Eq. 27 to give:

$$0.02 = \frac{(-6.33)(\Delta H)\left(\frac{0.0548}{11.33}\right)^{1/3}\left[\frac{9.81}{(0.00452)(601,325)}\right]}{0.6(\Delta H/11.33)+0.4}$$

which is solved for $\Delta H = 2.85$ m.

Single-pipe representation of multiple-pipe systems for compressible flows

Consider a multiple-pipe system with individual section diameters and lengths of (D_1, L_1), (D_2, L_2) … (D_n, L_n). For constant friction factor and incompressible flow, an equivalent length for the piping system can be defined as follows:

$$L_E = L_{E1} + L_{E2} + \ldots + L_{En} \quad (29)$$

$$L_{Ei} = L_i(D_E/D_i)^5 \quad (30)$$

where D_E is the equivalent single-pipe diameter corresponding to the equivalent length L_E.

The total pressure drop in this system is:

$$\Delta P = 2fL_E\rho V^2/D_E = (32/\pi^2)fL_E W^2/\rho D_E^5 \quad (31)$$

For compressible flow in a uniform pipe of diameter D, length L and small elevation changes, the mechanical energy balance for adiabatic flow is:

$$dP/\rho + udu + 2fu^2dL/D = 0 \quad (32)$$

where $u = G/\rho$. Integrating Eq. 32 and substituting $G = W/A$ and $A = (\pi/4)D^2$ gives:

$$\int_{P_0}^{P_1}\rho dP - \frac{(16/\pi^2)W^2\ln(\rho_1/\rho_0)}{D^4} + \frac{(16/\pi^2)2fW^2L}{D^5} = 0 \quad (33)$$

and a flowrate in the pipe of:

$$W^2 = \frac{\pi^2\int_{P_0}^{P_1}\rho dP}{16\ln(\rho_1/\rho_0)/D^4 - 32fL/D^5} \quad (34)$$

Thus, the flowrate in a pipe with an equivalent length L_E and diameter D_E is:

$$W_E^2 = \frac{\pi^2\int_{P_0}^{P_1}\rho dP}{16\ln(\rho_1/\rho_0)/D_E^4 - 32fL_E/D_E^5} \quad (35)$$

The ratio of W_E to W is determined by:

$$\frac{W_E^2}{W^2} = \frac{\ln(\rho_1/\rho_0)/D^4 - 2fL/D^5}{\ln(\rho_1/\rho_0)/D_E^4 - 2fL_E/D_E^5} \quad (36)$$

Using $L_E/D_E^5 = L/D^5$:

$$\frac{W_E^2}{W^2} = \frac{\ln(\rho_1/\rho_0)/D^4 - 2fL/D^5}{\ln(\rho_1/\rho_0)/D^4 - 2fL_E/D^5} \quad (37)$$

Then, by inspection, for $D_E \leq D$ and $\rho_1 \leq \rho_0$:

$$W_E/W \leq 1 \quad (38)$$

This assumes that the friction factors in the original and equivalent piping systems differ by only small amounts.

Equation 38, known as the inequality relationship, has

Table 2. Equivalent single-pipe representation of the two-segment pipe system in Example 2.

	Multiple-Pipe System	Equivalent Single-Pipe System
Pressures		
Upstream	P_0	P_0
Intermediate	P_1	P_{SP1}
Downstream	P_2	P_2
Segment 1		
Diameter	D_1	D_1
Length	L_1	L_1
Capacity	W_{MP1}	W_{SP1}
Segment 2		
Diameter	D_2	$D_{SP2} = D_1$
Length	L_2	$L_{SP2} = L_2(D_1/D_2)^5$
Capacity	W_{MP2}	W_{SP2}

been shown to hold under general conditions of compressibility. The only necessary requirement in this respect is that the final density is less than or equal to the initial density. This density condition is sufficiently general to cover both vapor-only and two-phase vapor/liquid pipe flows. Note that at the incompressible limit of $\rho_0 = \rho_1$, $W_E = W$ for all values of D_E. In addition, from Eq. 27, for long pipes (L approaching infinity), W_E approaches W.

Equation 38 can be applied directly to multiple-pipe systems. The two-segment piping system described in the second column of Table 2 can be represented by the equivalent single-pipe system, with the designations as shown in the third column. The intermediate pressures are defined at the junction of Segment 1 and Segment 2. Note that the intermediate pressure for the equivalent single-pipe system (P_{SP1}) is not assumed to be equal to the intermediate pressure for the multiple-pipe system (P_1).

Continuity requires that $W_{MP1} = W_{MP2}$ and $W_{SP1} = W_{SP2}$. Equation 38 applied to Segment 2 gives $W_{SP2} \le W_{MP2}$ calculated between equal pressures. In addition, $W_{SP1} = W_{MP1}$ calculated between equal pressures (all dimensional details are the same). These conditions imply the following inequalities:

If $P_{SP1} \le P_1$ then $W_{SP2} \le W_{MP2}$
If $P_{SP1} > P_1$ then $W_{SP1} < W_{MP1}$

Therefore, for all possible values of P_{SP1}:

$$W_{SP1} = W_{SP2} \le W_{MP2} = W_{MP1}$$

Closing thoughts

The methods presented here will allow the design engineer to tackle multiple-pipe relief systems with confidence using simple spreadsheet-based techniques or the Omega method, without the complications detailed in Ref. 2. The authors feel strongly that there is an important role for well-validated approximations that can offer insight and clarity to an otherwise complex process. CEP

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