Sizing of Discharge Piping for Relief Devices

The purpose of this Technical Bulletin is to provide a method for sizing discharge piping for relief devices discharging to atmosphere.

This bulletin has been revised to reflect BSEN13136:2001 Refrigerating Systems and Heat Pumps – Pressure relief devices and their associated piping – Methods for calculation – Section 7.4.1 which limits the pressure loss in the downstream line of a back pressure dependent relief valve to 10% of the actual relieving pressure and to refer to the sizing equation given in the IIAR Ammonia Refrigeration Piping Handbook.

In addition the issue record is now based on a letter sequence.

Refrigerant pressure relief devices are sized to allow refrigerant release at a controlled rate while maintaining a safe pressure in the vessel and system. While the relief device is discharging, back pressure will build up in the discharge piping. This back pressure must be taken into account to allow the device to perform properly and discharge its rated capacity. For relief devices with fixed openings, such as fusible plugs and bursting discs, the back pressure can build up to approximately 50% of the pressure upstream of the device without affecting the capacity of the relief device. This is due to the phenomenon known as “critical flow” through a fixed orifice, whereby a decrease in outlet pressure below 50% of the inlet pressure is not accompanied by an increase in flow. This condition does not necessarily apply to pressure relief valves since the effective opening through a relief valve depends on both the orifice diameter and the lift of the valve seat, which in turn depends on the pressure difference across the valve. The amount of back pressure permitted without loss of capacity through a pressure relief valve will vary depending on the design. In most cases it is less than 50% of the inlet pressure. However, for both back pressure dependant relief valves and bursting discs the opening pressure is dependant on the differential between inlet and outlet so the back pressure in a common discharge header must not exceed 10% of the lowest set pressure of any relief device connected to that header.

To reflect the acceptable pressure losses specified in BSEN13136:2001 Star’s policy for both bursting discs and relief valves is to size the discharge piping to limit the back pressure to a maximum value equal to 10% of the inlet pressure while the device is discharging at the rated capacity.

The tables in this Technical Bulletin are not refrigerant specific and are based on discharge capacity rates in kg/s **of air.**
Star’s Standard Specification No 105 gives guidance on the sizing of individual relief valves. The sizing procedure is that given in BS EN378:2000 which gives a discharge capacity in kg/s for a specific refrigerant.
Suppliers produce tables showing the discharge capacities for their devices at different settings for various refrigerants and **for air**. Engineers must use the figures for discharge capacities **for air** when using the tables in this Technical Bulletin.

Knowing the set pressure and capacity of the relief device, the length of discharge piping for each pipe size can be calculated from the formula given in the International Institute of Ammonia Refrigeration (IIAR) Ammonia Refrigeration Piping Handbook Section 6.

Equation 6.3 converted into SI units gives:

$$L = \frac{7.437 d^5 (P_0^2 - P_2^2)}{10^{11} f C_r^2} - \frac{d \ln P_0/P_2}{500 f}$$

where	L	=	Length of the discharge piping in metres
	P_0	=	Maximum allowable back pressure in Bar A
		=	0.1 [set pressure in Bar G] + 1.0
	P_2	=	Atmospheric pressure in Bar A
	d	=	Internal diameter of piping in mm
	C_r	=	Rated required discharge capacity in kg/s **of air**
	f	=	Darcy friction factor for fully turbulent flow

Table 1 gives some maximum total equivalent lengths of discharge piping for the Herl T19 dual safety valve assembly.

Maximum Equivalent Length of Discharge Piping in metres for Herl T19 Relief Valve Assembly					
Setting (Bar G)	**Discharge Capacity (kg/s of air)**	**NB Schedule 40 Pipe**			
		25	**32**	**40**	**50**
12.0	0.075	36	146	322	1130
17.0	0.104	27	113	251	883
25.5	0.153	20	89	199	703

Table 1

Tables 2a to 2c give the percentage of allowable pressure drop for different numbers of Herl T19 Dual Safety Valves. In this case, where pipe sizes are increasing as more relief valves discharge into common headers, the sizing procedure shall keep the overall pressure drop to a value less than the maximum allowed (i.e. less than 10% of the actual relieving pressure). For each combination of "number of relief valves" and "pipe size", Table 2a to 2c give a value for pressure drop for a 1 metre run of pipe expressed as a percentage of that allowed.

Percentage of Allowable Pressure Drop (% per m) for Herl T19 Relief Valve Assembly set at 12.0 Bar G										
No of Valves	**Valve Setting (Bar G)**	**Allowable Back Pressure (Bar G)**	**Discharge Capacity (kg/s of air)**	**Schedule 40 Pipe Size**						
				25 NB %	**32 NB %**	**40 NB %**	**50 NB %**	**65 NB %**	**80 NB %**	**100 NB %**
1	12.0	1.2	0.075	**2.7**	**0.6**	**0.27**	**0.09**	**0.04**	**0.01**	
2	12.0	1.2	0.150	**13.1**	**2.8**	**1.10**	**0.36**	**0.15**	**0.05**	**0.01**
3	12.0	1.2	0.225	**42.6**	**7.0**	**2.60**	**0.82**	**0.30**	**0.10**	**0.03**
4	12.0	1.2	0.300		**14.5**	**5.0**	**1.40**	**0.60**	**0.20**	**0.05**
5	12.0	1.2	0.375		**28.3**	**8.5**	**2.40**	**0.90**	**0.30**	**0.08**
6	12.0	1.2	0.450			**13.7**	**3.50**	**1.40**	**0.40**	**0.10**
7	12.0	1.2	0.525			**21.9**	**5.10**	**1.90**	**0.60**	**0.16**
8	12.0	1.2	0.600			**35.6**	**7.10**	**2.60**	**0.80**	**0.20**
9	12.0	1.2	0.675				**9.60**	**3.40**	**1.05**	**0.26**
10	12.0	1.2	0.750				**13.00**	**4.30**	**1.30**	**0.32**
11	12.0	1.2	0.825				**17.50**	**5.40**	**1.60**	**0.39**
12	12.0	1.2	0.900				**23.80**	**6.80**	**1.90**	**0.47**

Table 2a

Percentage of Allowable Pressure Drop (% per m)
for Herl T19 Relief Valve Assembly set at 17.0 Bar G

No of Valves	Valve Setting (Bar G)	Allowable Back Pressure (Bar G)	Discharge Capacity (kg/s of air)	Schedule 40 Pipe Size						
				25 NB %	32 NB %	40 NB %	50 NB %	65 NB %	80 NB %	100 NB %
1	17.0	1.7	0.104	**3.6**	**0.88**	**0.35**	**0.11**	**0.05**	**0.016**	
2	17.0	1.7	0.208	**19.7**	**3.82**	**1.40**	**0.46**	**0.19**	**0.06**	**0.016**
3	17.0	1.7	0.312		**10.00**	**3.50**	**1.06**	**0.43**	**0.14**	**0.04**
4	17.0	1.7	0.416		**23.60**	**7.00**	**1.96**	**0.78**	**0.25**	**0.06**
5	17.0	1.7	0.520			**12.80**	**3.20**	**1.25**	**0.42**	**0.10**
6	17.0	1.7	0.624			**23.30**	**4.90**	**1.80**	**0.59**	**0.15**
7	17.0	1.7	0.728				**7.40**	**2.60**	**0.80**	**0.20**
8	17.0	1.7	0.832				**10.80**	**3.50**	**1.08**	**0.26**
9	17.0	1.7	0.936				**15.70**	**4.70**	**1.30**	**0.30**
10	17.0	1.7	1.040				**23.50**	**6.20**	**1.70**	**0.40**
11	17.0	1.7	1.144				**36.90**	**8.20**	**2.10**	**0.50**
12	17.0	1.7	1.248				**65.10**	**10.7**	**2.67**	**0.60**

Table 2b

Percentage of Allowable Pressure Drop (% per m)
for Herl T19 Relief Valve Assembly set at 25.5 Bar G

No of Valves	Valve Setting (Bar G)	Allowable Back Pressure (Bar G)	Discharge Capacity (kg/s of air)	Schedule 40 Pipe Size						
				25 NB %	32 NB %	40 NB %	50 NB %	65 NB %	80 NB %	100 NB %
1	25.5	2.55	0.15	**4.8**	**1.1**	**0.4**	**0.1**	**0.06**	**0.02**	**0.01**
2	25.5	2.55	0.31	**34.0**	**5.1**	**1.9**	**0.5**	**0.20**	**0.08**	**0.02**
3	25.5	2.55	0.46		**15.5**	**4.8**	**1.3**	**0.50**	**0.10**	**0.05**
4	25.5	2.55	0.61			**10.3**	**2.6**	**1.0**	**0.30**	**0.08**
5	25.5	2.55	0.77			**22.3**	**4.4**	**1.6**	**0.50**	**0.13**
6	25.5	2.55	0.92				**7.2**	**2.4**	**0.70**	**0.18**
7	25.5	2.55	1.07				**11.6**	**3.5**	**1.0**	**0.25**
8	25.5	2.55	1.22				**19.3**	**5.0**	**1.4**	**0.33**
9	25.5	2.55	1.38				**35.0**	**7.1**	**1.8**	**0.43**
10	25.5	2.55	1.53					**9.9**	**2.3**	**0.53**
11	25.5	2.55	1.68					**14.0**	**3.0**	**0.65**
12	25.5	2.55	1.84					**20.9**	**3.7**	**0.80**

Table 2c

Table 3 gives some maximum total equivalent lengths of discharge piping for the Herl T19F and T24V dual safety valve assemblies.

Maximum Equivalent Length of Discharge Piping in metres for Herl T19F and T24V Relief Valve Assemblies							
Setting (Bar G)	Discharge Capacity (kg/s of air)	NB Schedule 40 Pipe					
		32	40	50	65	80	100
12.0	0.326	5.4	14.3	56.3	140.0	426.0	1679
17.0	0.451	3.0	9.9	42.6	108.0	332.0	1318.0
25.5	0.667	1.0	6.1	31.4	82.0	259.0	1037.0

Table 3

Tables 4a to 4c give the percentage of allowable pressure drop for different numbers of Herl T19F and T24V Dual Safety Valves. In this case, where pipe sizes are increasing as more relief valves discharge into common headers, the sizing procedure shall keep the overall pressure drop to a value less than the maximum allowed (i.e. less than 10% of the actual relieving pressure). For each combination of "number of relief valves" and "pipe size", Tables 4a to 4c give a value for pressure drop for a 1 metre run of pipe expressed as a percentage of that allowed.

Percentage of Allowable Pressure Drop (% per m) for Herl T19F and T24V Relief Valve Assemblies set at 12.0 Bar G											
No of Valves	Valve Setting (Bar G)	Allowable Back Pressure (Bar G)	Discharge Capacity (kg/s of air)	Schedule 40 Pipe Size							
				32 NB %	40 NB %	50 NB %	65 NB %	80 NB %	100 NB %	125 NB %	150 NB %
1	12.0	1.2	0.326	**18.3**	**6.0**	**1.77**	**0.70**	**0.23**	**0.06**	**0.019**	**0.008**
2	12.0	1.2	0.652			**8.80**	**3.10**	**0.90**	**0.24**	**0.08**	**0.03**
3	12.0	1.2	0.978			**33.4**	**8.50**	**2.30**	**0.50**	**0.18**	**0.07**
4	12.0	1.2	1.304				**21.40**	**4.60**	**1.00**	**0.30**	**0.12**
5	12.0	1.2	1.630					**6.10**	**1.66**	**0.50**	**0.20**
6	12.0	1.2	1.956					**15.3**	**2.50**	**0.74**	**0.28**
7	12.0	1.2	2.282					**29.8**	**3.60**	**1.00**	**0.39**
8	12.0	1.2	2.608						**5.20**	**1.30**	**0.50**
9	12.0	1.2	2.934						**7.30**	**1.80**	**0.60**
10	12.0	1.2	3.260						**10.30**	**2.30**	**0.80**
11	12.0	1.2	3.586						**14.70**	**2.90**	**1.00**
12	12.0	1.2	3.912						**22.00**	**3.60**	**1.25**

Table 4a

Percentage of Allowable Pressure Drop (% per m) for Herl T19F and T24V Relief Valve Assemblies set at 17.0 Bar G											
No of Valves	Valve Setting (Bar G)	Allowable Back Pressure (Bar G)	Discharge Capacity (kg/s of air)	Schedule 40 Pipe Size							
				32 NB %	40 NB %	50 NB %	65 NB %	80 NB %	100 NB %	125 NB %	150 NB %
1	17.0	1.7	0.451	**31.9**	**8.62**	**2.35**	**0.92**	**0.30**	**0.08**	**0.024**	**0.01**
2	17.0	1.7	0.902			**13.90**	**4.30**	**1.28**	**0.30**	**0.10**	**0.04**
3	17.0	1.7	1.353				**14.0**	**3.24**	**0.70**	**0.23**	**0.09**
4	17.0	1.7	1.804					**6.90**	**1.30**	**0.40**	**0.16**
5	17.0	1.7	2.255					**7.80**	**2.20**	**0.60**	**0.25**
6	17.0	1.7	2.706					**39.0**	**3.50**	**0.90**	**0.37**
7	17.0	1.7	3.157						**5.50**	**1.30**	**0.51**
8	17.0	1.7	3.608						**8.50**	**1.90**	**0.68**
9	17.0	1.7	4.059						**13.6**	**2.50**	**0.88**
10	17.0	1.7	4.510						**23.5**	**3.30**	**1.12**
11	17.0	1.7	4.961							**4.40**	**1.40**
12	17.0	1.7	5.412							**5.80**	**1.70**

Table 4b

Percentage of Allowable Pressure Drop (% per m) for Herl T19F and T24V Relief Valve Assemblies set at 25.5 Bar G										
No of Valves	Valve Setting (Bar G)	Allowable Back Pressure (Bar G)	Discharge Capacity (kg/s of air)	Schedule 40 Pipe Size						
				40 NB %	50 NB %	65 NB %	80 NB %	100 NB %	125 NB %	150 NB %
1	25.5	2.55	0.667	**13.56**	**3.18**	**1.21**	**0.38**	**0.10**	**0.032**	**0.012**
2	25.5	2.55	1.334		**29.20**	**6.47**	**1.70**	**0.40**	**0.13**	**0.05**
3	25.5	2.55	2.001			**33.8**	**4.70**	**0.95**	**0.29**	**0.11**
4	25.5	2.55	2.668				**12.4**	**1.80**	**0.53**	**0.20**
5	25.5	2.55	3.335					**3.20**	**0.87**	**0.32**
6	25.5	2.55	4.002					**5.60**	**1.33**	**0.48**
7	25.5	2.55	4.669					**10.1**	**1.90**	**0.67**
8	25.5	2.55	5.336					**20.5**	**2.70**	**0.91**
9	25.5	2.55	6.003						**3.90**	**1.20**
10	25.5	2.55	6.670						**5.60**	**1.56**
11	25.5	2.55	7.337						**8.10**	**2.00**
12	25.5	2.55	8.004						**12.50**	**2.50**

Table 4c

Table 5 gives pressure drops for various pipe fittings by applying an L/d factor to give an “equivalent length”.

Fitting	L/d
45º Elbow	16
90° Elbow Short Radius	30
90° Elbow Long Radius	20
Tee with flow through run	20
Tee with flow through branch	60
Unequal Tee	100

Table 5

For example, the size and length of the discharge piping will be such that the sum of the “fitting equivalent” lengths and “straight piping” lengths will be less than the maximum equivalent length allowed for in Tables 1 and 3. So, an 8 metre long 32NB pipe (with internal diameter d = 35mm) with 2-off 90° standard long radius elbows would have an equivalent length of:

$$\text{Equivalent Length} = \text{Straight Length} + \left(\text{No of Fittings x } {}^{L}\!/_{d} \text{ x Internal Diameter}\right)$$

$$= 8 + \left(2 \text{ x } 20 \text{ x } \frac{35}{1000}\right)$$

$$= 9.4 \text{ metres}$$

Notes:

1. The tables are not refrigerant specific and can be used for all refrigerants, provided the discharge capacities relate to the equivalent air flow rate.

2. The allowable lengths given by the IIAR equation 6.3 are found to be more conservative than other current design codes and standards. Even so designers, when sizing relief valve discharge piping at an early stage in a job where perhaps exact pipe routes have still to be established, should introduce a further safety factor by designing the system to limit the pressure drop to say 80% of the maximum allowable pressure drop.

3. It is stressed that the total equivalent lengths given in Tables 1 and 3 are maximum values. It is good practice to keep the length of discharge piping well within that permitted. This is particularly important for relief valves since excessive lengths may not only reduce capacity but can cause piston chatter and valve damage while discharging.

4. The discharge capacity figures given in the tables are the maximum actual relief valve capacities, i.e. the rated capacities (and not the minimum required discharge capacities based on the vessels and equipment they are protecting).

5. In order to facilitate inspection under the Pressure Systems Safety Regulations, it is Star’s policy to fit dual relief valves (even for cases where the gross internal volume is small enough to allow a single relief valve). Where dual relief valves with a changeover valve combination are fitted, only one valve shall be open to the system at any one time. The common outlet pipe shall be sized on the basis of one single valve.

6. The following is an example of how Table 4c can be applied to check pressure drops in a large system. Consider an ammonia plant with five Herl T19F dual safety valve assemblies set at 25.5 Bar G discharging to atmosphere through common headers routed round a building, as shown in Figure 1.

   For this arrangement relief valve V1 will be the worst case.

Figure 1 Section No	No of Valves	Proposed Pipe		Fittings		Pipe Length (m)	Total Equivalent Length (L eq m)	% per m from Table 4c	Total Pressure Drop Calculation (% per m x L eq)
		NB	id (mm)	L/d	Equivalent Length L(m)				
1	1	50	52.5	20	1.1	4	5.1	3.18	16.2
2	2	80	77.9			1	1	1.7	1.7
3	3	80	77.9			1	1	4.7	4.7
4	4	100	102.3	20	2.1	7	9.1	1.8	16.4
5	5	100	102.3	2 x 20	4.1	16	20.1	3.2	64.3
									103.3%

The proposed pipe sizes result in a total pressure drop which exceeds 100% of the maximum allowable pressure drop, so the pipe sizes are not acceptable. It will be necessary to increase the diameter of at least one of the pipes. For example, to reduce the total pressure we could consider increasing the 16m run in Section 5 from 100NB to 125NB. This would change the last full line to

5	5	125	128.1	2 x 20	5.1	16	21.1	0.87	18.3

giving a total pressure drop of 57.3% of the maximum allowable. This would be acceptable.

6. Ammonia relief lines shall vent at a high level and be fitted with either a "swan neck" with the outlet pointing down, or some other means to prevent water ingress.

7. In the cases of HFC refrigerants such as R404A and R507 which are prone to leaking past the seat of the relief valve, we prefer to use a combination of bursting disc in series with a pressure relief valve. The bursting disc will be located on the **inlet** side of the pressure relief valve. The bursting disc need not be larger but shall not be smaller than the inlet of the pressure relief valve.

   In order to check that the bursting disc is intact, a pressure gauge valve shall be located on the pipe between the bursting disc and the pressure relief valve.

8. Where a relief valve other than Herl is specified, the selection should be referred to the Technical Department.

Date	Issue No	Originator	Detail
02.07.99	1	DJH	
27.06.00	2	DJH	
18.10.00	3	DJH/PAS	
04.06.01	4	DJH	
15/04/04	E	DJH	
06/10/05	F	DJH	Formula for L corrected at page 1

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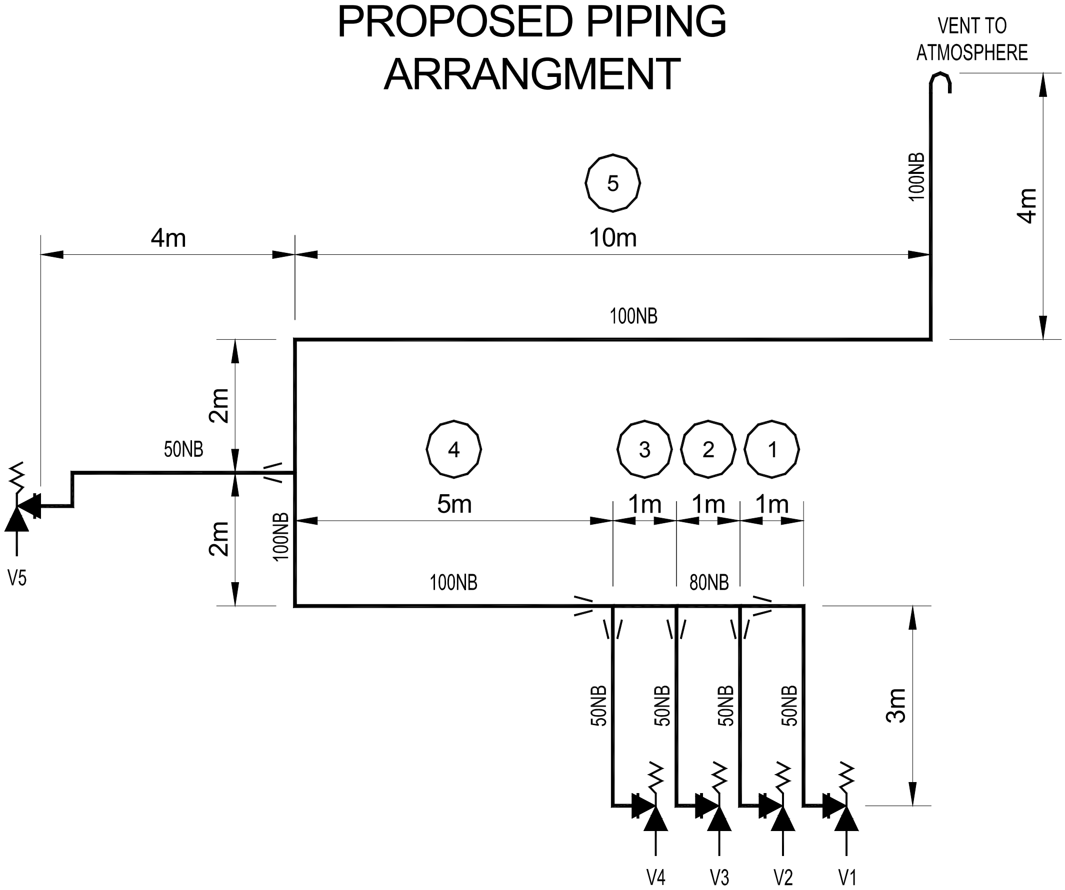
PROPOSED PIPING ARRANGMENT



V1 is the worst case.

T.B.120 FIGURE 1

Example of pressure drop in the discharge piping of a multiple relief valve system.