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Tech Talk 0074
AVV Flow Rates

This tech talk has three aims:

1. Set out how to calculate flow rates for LIQUIP AVV's, based upon the relevant Australian Standards
2. To summarise past tests that have been performed on vapour vent flow rates
3. Look at the complete vapour recovery system, and investigate other causes of compartment pressure rises during loading

1. Theoretical Flow Rates

It is important to realise that a flow rating cannot be given directly for vents etc. For any given configuration, the flow rate will depend on both the fluid used and the pressure across the vent.*

According to AS 1940-2004 (p.165), the venting capacity of a free orifice type vent may be given by:

$$\text{Venting capacity } (m^3/h)^{\dagger} = 0.0575 d^2 \sqrt{(\Delta P)}$$

Where d = orifice diameter (mm)

ΔP = pressure difference between inside and outside tank (kPa)

Although the Liquip vapour vents contain a bend in the flow path, this may be ignored, as the formula above is conservative, and the flow rates involved are quite low. Hence under this assumption the AVV075 vapour vent provides a clear opened passage equivalent to a 75mm diameter orifice.

It should also be noted that flow rates for fuel vapour differ from those for free air by a factor of 0.59. That is, vapour flow is 0.59 times that of free air for the same pressure difference across the valve. Hence in order to simulate a normal loading flow rate of 2500 L/min, the free air rate required would be

$$F_r = 2500/0.59$$
$$\simeq 4200 \text{ L/min}$$
$$\simeq 252 \text{ m}^3/\text{hr}$$

* For further discussion please see Tech Talk 0019 – 'Venting Capacities'
† To convert from m^3/hr to L/min, multiply by a factor of 1000/60 [16.67]

The graphs below were derived from AS 1940-2004 with an orifice diameter of 75mm.

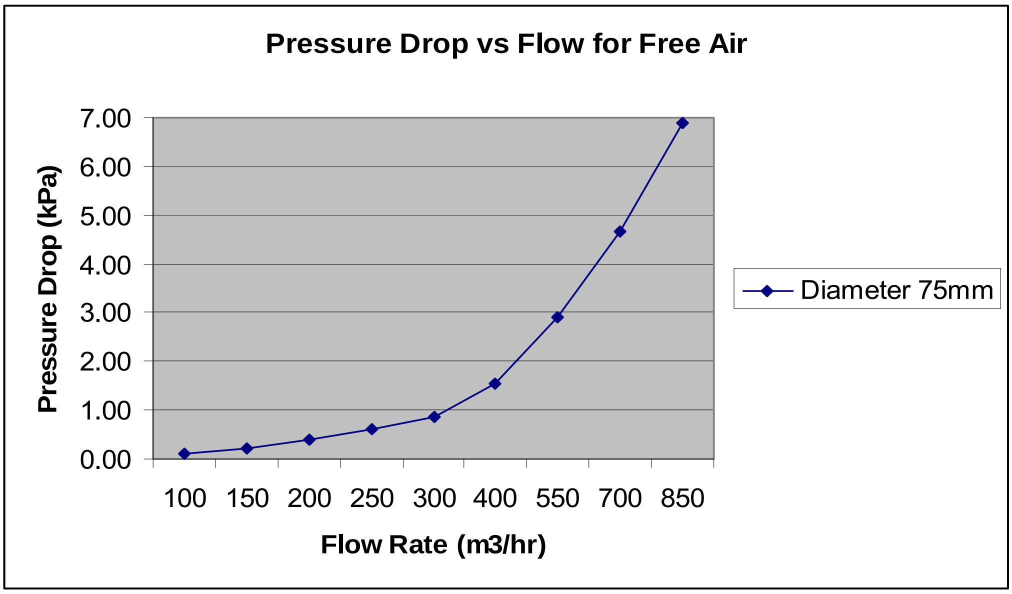

Figure 1.1 – Flow rates for free air through a 75mm orifice, as derived from AS 1940-2004

As the graph shows, the pressure difference during normal loading (equivalent to 250m^3/hr free air) is approximately 0.5kPa. At a pressure difference of 7kPa the vent flow capacity is approximately

$$Q = 875 \ m^3/hr$$

$$\simeq 14500 \ L/min$$

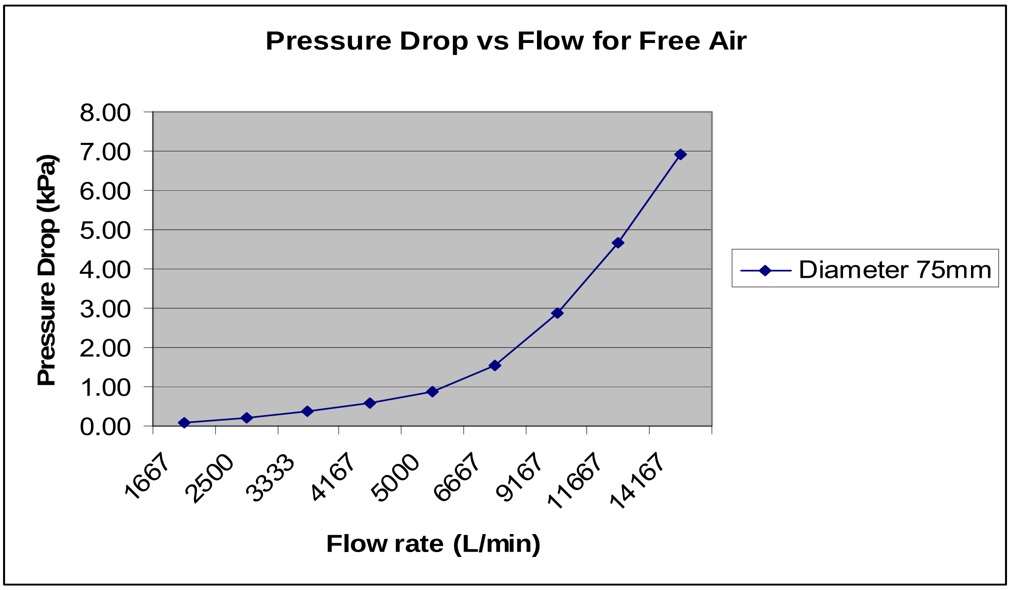

Figure 1.2 – The graph from 1.1 with flow rates in litres per minute

2. Physical Flow Tests

Physical tests were performed by Liquip/Shell in 1989 and by Shell in Fremantle in 2000 to investigate the flow performance of vapour recovery systems. For each test, the vapour pressures were measured at various locations to check if they were within allowable limits during normal loading operations.

During the former test, three compartments were loaded simultaneously while pressures were monitored at compartment dip points, on the rollover coaming, and at the vapour coupler. It was found that compartment pressures remained at an acceptable 10kPa when subjected to combined loading flow rates of 4100 L/min. The test was repeated with both vapour couplings still attached, but with the vapour recovery line open to the atmosphere, and with total flow (across all three compartments) increased to 6537 L/min. Compartment pressures remained at 2 kPa, suggesting that vapour recovery systems place a much greater restriction on the flow than the AVV's themselves.

Further tests were carried out by Shell at Fremantle in 2000. A sample of the test data is shown below. Of the five samples, three involved 3 loading arms in use at once, while the others used 4 loading arms. The total system pressure drops equal the pressures in the compartments during loading. For both trials using 4 arms, the pressures are higher than 15kPa, the minimum opening pressure for Pressure Vacuum Vents.

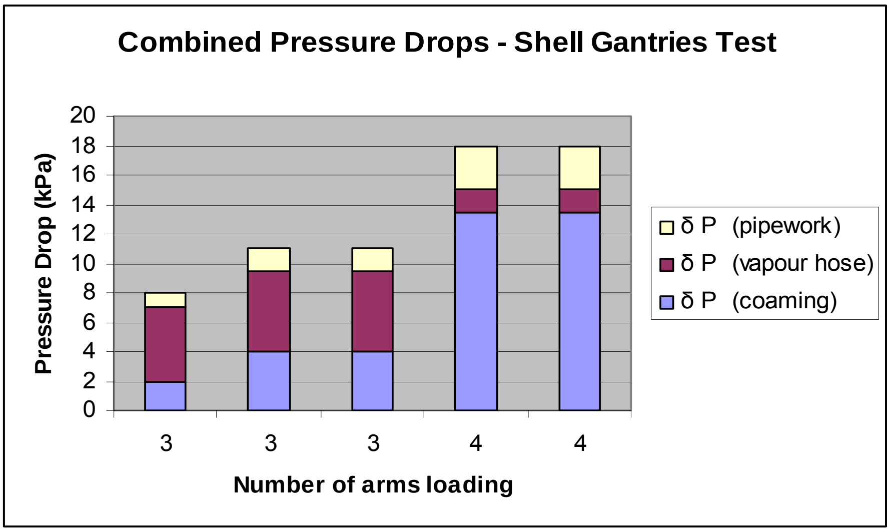

Figure 2.1 – Sample of data from Shell Fremantle tests

The Shell report concluded that compartment pressures can be kept within acceptable limits by;

a) Restricting loading rates to 2500 L/min

b) Limiting loading to three compartments at once.

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3. Vapour Couplings and other Flow Restrictions

As demonstrated by both theory and physical tests, the AVV's themselves present little restriction to vapour flow at normal loading rates (in the order of 2500 L/min). Also, when properly maintained, the gantry-side vapour recovery systems don't generally contribute greatly to flow restriction (i.e. if filters and spark arresters are kept clean). Another reason exists for pressure rises during loading, and hence the limitation on loading rates.

As shown, the Air Actuated Vapour Vents provide a free orifice of 75mm, and one is present on each compartment. On a typical five compartment tanker, there will then be up to five AVV's discharging into the truck-side vapour hose (or up to 9 in Europe!). Although they are nominally 75mm in diameter, typical 3" vapour couplers, such as the VCF075 and VCM3F contain poppets which disrupt the vapour flow. Keeping in mind that vapour from every compartment being loaded at any time must flow through a single coupler, it is clear that the Vapour Coupler & hose assembly, and not the Vapour Vents, is the limiting factor in vapour flow.

The problem becomes worse when the Vapour Coupler and Vapour Adaptor come from different manufacturers. Unlike API type valves, which are strictly governed by standards to ensure compatibility between brands, there is no guarantee that different brand vapour couplers will work correctly together (and may not open fully!). Given that vapour couplers present a major restriction to flow, even when fully open, loading with the vapour coupler only part open could be disastrous.

4. Conclusions

Both the theoretical calculations and test data confirm that the flow resistance through the AVV's contributes little to the overall pressure rise within a compartment. That is, other parts of the vapour recovery system, such as the hoses and vapour couplings are the major contributors to system backpressure during loading, and hence are the main determinants of maximum vapour recovery and loading rates.

Please note that the content of this tech talk is taken from Australian regulations. Some details, such as PVV pressure settings, can vary from country to country due to local regulations.

5. Further Reading

AS 2809.2 – Road Tank Vehicles for Dangerous Goods [Part 2: Tankers for Flammable Liquids]

AS 1940 – The Storage and Handling of Flammable and Combustible Liquids

Liquip Tech Talk 0019 – 'Venting Capacities'